Table of contents

Table of contents

1 Get Started
  1.1 Introduction ................................................................. 3
  1.2 What You Need ............................................................. 3
  1.3 Development Board Overviews ........................................... 4
    1.3.1 ESP32-DevKitC V4 Getting Started Guide .......................... 4
    1.3.2 ESP-WROVER-KIT V4.1 Getting Started Guide .................... 10
    1.3.3 ESP32-PICO-KIT V4 / V4.1 Getting Started Guide ................ 33
    1.3.4 ESP32-Ethernet-Kit V1.2 Getting Started Guide .................. 43
    1.3.5 ESP32-DevKitS(-R) .................................................. 71
    1.3.6 ESP32-PICO-KIT-1 .................................................. 77
    1.3.7 ESP32-PICO-DevKitM-2 .............................................. 83
    1.3.8 ESP32-DevKitM-1 .................................................... 88
  1.4 Installation Step by Step ............................................... 93
    1.4.1 Setting up Development Environment .................................. 93
    1.4.2 Creating Your First Project ....................................... 93
  1.5 Step 1. Install prerequisites ........................................... 93
    1.5.1 Standard Setup of Toolchain for Windows .......................... 93
    1.5.2 Standard Setup of Toolchain for Linux ............................ 98
    1.5.3 Standard Setup of Toolchain for Mac OS ........................... 99
  1.6 Step 2. Get ESP-IDF ..................................................... 100
    1.6.1 Linux and macOS .................................................... 100
    1.6.2 Windows .............................................................. 100
  1.7 Step 3. Set up the tools ................................................. 100
    1.7.1 Windows .............................................................. 101
    1.7.2 Linux and macOS .................................................... 101
    1.7.3 Alternative File Downloads ........................................ 101
    1.7.4 Customizing the tools installation path ........................... 102
  1.8 Step 4. Set up the environment variables .............................. 102
    1.8.1 Windows .............................................................. 102
    1.8.2 Linux and macOS .................................................... 102
  1.9 Step 5. Start a Project .................................................. 103
    1.9.1 Linux and macOS .................................................... 103
    1.9.2 Windows .............................................................. 103
  1.10 Step 6. Connect Your Device ............................................ 103
  1.11 Step 7. Configure ........................................................ 103
    1.11.1 Linux and macOS .................................................... 103
    1.11.2 Windows .............................................................. 104
  1.12 Step 8. Build the Project ............................................... 104
  1.13 Step 9. Flash onto the Device .......................................... 105
    1.13.1 Encountered Issues While Flashing? ............................... 105
    1.13.2 Normal Operation .................................................. 106
  1.14 Step 10. Monitor .......................................................... 107
  1.15 Updating ESP-IDF .......................................................... 108
  1.16 Related Documents ........................................................ 108
## API Reference

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.16.1</td>
<td>Establish Serial Connection with ESP32</td>
<td>108</td>
</tr>
<tr>
<td>1.16.2</td>
<td>Build and Flash with Eclipse IDE</td>
<td>114</td>
</tr>
<tr>
<td>1.16.3</td>
<td>Getting Started with VS Code IDE</td>
<td>115</td>
</tr>
<tr>
<td>1.16.4</td>
<td>IDF Monitor</td>
<td>115</td>
</tr>
<tr>
<td>1.16.5</td>
<td>Customized Setup of Toolchain</td>
<td>119</td>
</tr>
</tbody>
</table>

### 2 API Reference

#### 2.1 Bluetooth API

- 2.1.1 Controller && VHCI | 125 |
- 2.1.2 BT COMMON | 125 |
- 2.1.3 BT LE | 132 |
- 2.1.4 CLASSIC BT | 137 |
- 2.1.5 NimBLE-based host APIs | 229 |
- 2.1.6 ESP-BLE-MESH | 305 |

#### 2.2 Networking APIs

- 2.2.1 Wi-Fi | 602 |
- 2.2.2 Ethernet | 627 |
- 2.2.3 Thread | 632 |
- 2.2.4 ESP-NETIF | 649 |
- 2.2.5 IP Network Layer | 652 |
- 2.2.6 Application Layer | 652 |

#### 2.3 Peripherals API

- 2.3.1 Analog to Digital Converter (ADC) | 653 |
- 2.3.2 Digital To Analog Converter (DAC) | 672 |
- 2.3.3 GPIO & RTC GPIO | 675 |
- 2.3.4 General Purpose Timer (GPTimer) | 693 |
- 2.3.5 Inter-Integrated Circuit (I2C) | 701 |
- 2.3.6 Inter-IC Sound (I2S) | 717 |
- 2.3.7 LCD | 732 |
- 2.3.8 LED Control (LED C) | 741 |
- 2.3.9 Motor Control Pulse Width Modulator (MCPWM) | 755 |
- 2.3.10 Pulse Counter (PCNT) | 779 |
- 2.3.11 Remote Control (RMT) | 788 |
- 2.3.12 SD Pull-up Requirements | 807 |
- 2.3.13 SDMMC Host Driver | 810 |
- 2.3.14 SD SPI Host Driver | 815 |
- 2.3.15 SDIO Card Slave Driver | 820 |
- 2.3.16 Sigma-delta Modulation | 829 |
- 2.3.17 SPI Master Driver | 832 |
- 2.3.18 SPI Slave Driver | 853 |
- 2.3.19 ESP32-WROOM-32SE (Secure Element) | 860 |
- 2.3.20 Touch Sensor | 860 |
- 2.3.21 Two-Wire Automotive Interface (TWAI) | 874 |
- 2.3.22 Universal Asynchronous Receiver/Transmitter (UART) | 889 |

#### 2.4 Application Protocols

- 2.4.1 ASIO port | 912 |
- 2.4.2 ESP-MQTT | 913 |
- 2.4.3 ESP-TLS | 924 |
- 2.4.4 OpenSSL-APIs | 935 |
- 2.4.5 ESP HTTP Client | 962 |
- 2.4.6 HTTP Server | 975 |
- 2.4.7 HTTPS server | 997 |
- 2.4.8 ICMP Echo | 999 |
- 2.4.9 ESP Local Control | 1004 |
- 2.4.10 mDNS Service | 1012 |
- 2.4.11 ESP-Modbus | 1026 |
- 2.4.12 ESP WebSocket Client | 1048 |
- 2.4.13 ESP Serial Slave Link | 1055 |
2.14 ESP x509 Certificate Bundle ........................................ 1070
2.15 IP Network Layer ......................................................... 1072
2.5 Provisioning API .......................................................... 1072
  2.5.1 Protocol Communication ............................................... 1072
  2.5.2 Unified Provisioning .................................................. 1082
  2.5.3 Wi-Fi Provisioning .................................................... 1086
2.6 Storage API ............................................................... 1103
  2.6.1 FAT Filesystem Support .............................................. 1103
  2.6.2 Manufacturing Utility ............................................... 1109
  2.6.3 Non-volatile storage library ....................................... 1113
  2.6.4 NVS Partition Generator Utility ................................... 1132
  2.6.5 SD/SDIO/MMC Driver ............................................... 1139
  2.6.6 SPI Flash API ....................................................... 1148
  2.6.7 SPIFFS Filesystem .................................................. 1173
  2.6.8 Virtual filesystem component ..................................... 1176
  2.6.9 Wear Levelling API ................................................ 1189
2.7 System API ............................................................... 1193
  2.7.1 App Image Format .................................................. 1193
  2.7.2 Application Level Tracing ......................................... 1198
  2.7.3 Console ............................................................. 1202
  2.7.4 eFuse Manager ..................................................... 1210
  2.7.5 Error Codes and Helper Functions ................................ 1226
  2.7.6 ESP HTTPS OTA .................................................... 1228
  2.7.7 POSIX Threads Support ............................................. 1232
  2.7.8 Event Loop Library ................................................. 1236
  2.7.9 FreeRTOS ............................................................ 1252
  2.7.10 FreeRTOS Additions ............................................... 1356
  2.7.11 Heap Memory Allocation ......................................... 1373
  2.7.12 Heap Memory Debugging ......................................... 1384
  2.7.13 High Resolution Timer ............................................ 1395
  2.7.14 The himem allocation API ........................................ 1400
  2.7.15 Inter-Processor Call .............................................. 1403
  2.7.16 Call function with external stack ............................... 1407
  2.7.17 Interrupt allocation .............................................. 1409
  2.7.18 Logging library ..................................................... 1414
  2.7.19 Miscellaneous System APIs ...................................... 1420
  2.7.20 Over The Air Updates (OTA) ...................................... 1426
  2.7.21 Performance Monitor .............................................. 1436
  2.7.22 Power Management ................................................ 1440
  2.7.23 Random Number Generation ..................................... 1446
  2.7.24 Sleep Modes ........................................................ 1447
  2.7.25 Watchdogs .......................................................... 1457
  2.7.26 System Time ........................................................ 1460
  2.7.27 Internal and Unstable APIs ...................................... 1464
2.8 API Conventions ........................................................ 1465
  2.8.1 Error handling ..................................................... 1465
  2.8.2 Configuration structures .......................................... 1465
  2.8.3 Private APIs ....................................................... 1466
  2.8.4 Components in example projects .................................. 1466
  2.8.5 API Stability ....................................................... 1466
2.9 Project Configuration .................................................. 1467
  2.9.1 Introduction ........................................................ 1467
  2.9.2 Project Configuration Menu ...................................... 1468
  2.9.3 Using sdkconfig.defaults ........................................ 1468
  2.9.4 Kconfig Formatting Rules ........................................ 1468
  2.9.5 Backward Compatibility of Kconfig Options ................. 1468
  2.9.6 Configuration Options Reference ................................ 1469
2.10 Error Codes Reference ............................................... 1720
3 ESP32 Hardware Reference

3.1 Chip Series Comparison .................................................. 1727
3.1.1 Related Documents ................................................... 1729

4 API Guides

4.1 Application Level Tracing library ..................................... 1731
4.1.1 Overview ............................................................ 1731
4.1.2 Modes of Operation .................................................. 1731
4.1.3 Configuration Options and Dependencies ....................... 1732
4.1.4 How to use this library ............................................. 1733

4.2 Application Startup Flow ................................................. 1741
4.2.1 First stage bootloader ............................................... 1741
4.2.2 Second stage bootloader ............................................ 1742
4.2.3 Application startup .................................................. 1742

4.3 BluFi ........................................................................... 1744
4.3.1 Overview ............................................................ 1744
4.3.2 The BluFi Flow ...................................................... 1744
4.3.3 The Flow Chart of BluFi ............................................ 1745
4.3.4 The Frame Formats Defined in BluFi ......................... 1745
4.3.5 The Security Implementation of ESP32 ....................... 1751
4.3.6 GATT Related Instructions ......................................... 1752

4.4 Bootloader ................................................................. 1752
4.4.1 Bootloader compatibility .......................................... 1753
4.4.2 Log Level ............................................................ 1753
4.4.3 Factory reset ........................................................ 1754
4.4.4 Boot from Test Firmware ......................................... 1754
4.4.5 Rollback ............................................................. 1755
4.4.6 Watchdog ............................................................ 1755
4.4.7 Bootloader Size ...................................................... 1755
4.4.8 Fast boot from Deep Sleep ....................................... 1755
4.4.9 Custom bootloader .................................................. 1755

4.5 Build System ............................................................... 1756
4.5.1 Overview ............................................................ 1756
4.5.2 Using the Build System .......................................... 1757
4.5.3 Example Project .................................................... 1760
4.5.4 Project CMakeLists File ........................................ 1761
4.5.5 Component CMakeLists Files .................................. 1762
4.5.6 Component Configuration ......................................... 1765
4.5.7 Preprocessor Definitions ......................................... 1765
4.5.8 Component Requirements ........................................ 1765
4.5.9 Overriding Parts of the Project ................................ 1769
4.5.10 Configuration-Only Components ............................... 1769
4.5.11 Debugging CMake ................................................ 1770
4.5.12 Example Component CMakeLists .............................. 1770
4.5.13 Custom sdkconfig defaults ...................................... 1774
4.5.14 Flash arguments ................................................... 1774
4.5.15 Building the Bootloader ......................................... 1775
4.5.16 Selecting the Target .............................................. 1775
4.5.17 Writing Pure CMake Components .............................. 1776
4.5.18 Using Third-Party CMake Projects with Components .... 1776
4.5.19 Using Prebuilt Libraries with Components .................. 1777
4.5.20 Using ESP-IDF in Custom CMake Projects ................. 1777
4.5.21 ESP-IDF CMake Build System API ............................ 1778
4.5.22 File Globbing & Incremental Builds ......................... 1782
4.5.23 Build System Metadata .......................................... 1782
4.5.24 Build System Internals ........................................... 1783
4.5.25 Migrating from ESP-IDF GNU Make System ............... 1784

4.6 Deep Sleep Wake Stubs .................................................. 1786
4.13.5  Guru Meditation Errors .................................................. 1863
4.13.6  Other Fatal Errors ......................................................... 1865
4.14  Flash Encryption ............................................................. 1867
  4.14.1  Introduction .............................................................. 1867
  4.14.2  Relevant eFuses ......................................................... 1868
  4.14.3  Flash Encryption Process ................................................ 1868
  4.14.4  Flash Encryption Configuration ......................................... 1869
  4.14.5  Possible Failures ........................................................ 1875
  4.14.6  ESP32 Flash Encryption Status ........................................ 1876
  4.14.7  Reading and Writing Data in Encrypted Flash .......................... 1876
  4.14.8  Updating Encrypted Flash ............................................... 1877
  4.14.9  Disabling Flash Encryption ............................................ 1878
  4.14.10  Key Points About Flash Encryption .................................. 1878
  4.14.11  Limitations of Flash Encryption ....................................... 1879
  4.14.12  Flash Encryption and Secure Boot .................................... 1879
  4.14.13  Advanced Features ..................................................... 1879
  4.14.14  Technical Details ...................................................... 1881
4.15  ESP-IDF FreeRTOS (SMP) .................................................... 1882
  4.15.1  Overview ................................................................. 1882
  4.15.2  Symmetric Multiprocessing ............................................. 1883
  4.15.3  Tasks ................................................................. 1883
  4.15.4  SMP Scheduler ......................................................... 1885
  4.15.5  Critical Sections ....................................................... 1888
  4.15.6  Misc ................................................................. 1889
4.16  Hardware Abstraction .................................................... 1890
  4.16.1  Architecture ............................................................ 1891
  4.16.2  LL (Low Level) Layer .................................................. 1892
  4.16.3  HAL (Hardware Abstraction Layer) .................................... 1893
4.17  High-Level Interrupts ................................................... 1894
  4.17.1  Interrupt Levels ...................................................... 1894
  4.17.2  Notes ................................................................. 1895
4.18  JTAG Debugging ............................................................ 1895
  4.18.1  Introduction ............................................................ 1895
  4.18.2  How it Works? ........................................................... 1896
  4.18.3  Selecting JTAG Adapter ................................................ 1897
  4.18.4  Setup of OpenOCD ..................................................... 1897
  4.18.5  Configuring ESP32 Target ............................................... 1897
  4.18.6  Launching Debugger .................................................... 1903
  4.18.7  Debugging Examples ................................................... 1903
  4.18.8  Building OpenOCD from Sources ....................................... 1903
  4.18.9  Tips and Quirks ....................................................... 1907
  4.18.10  Related Documents ................................................... 1912
4.19  Linker Script Generation ................................................ 1937
  4.19.1  Overview ............................................................... 1937
  4.19.2  Quick Start ............................................................ 1937
  4.19.3  Linker Script Generation Internals .................................... 1940
4.20  Memory Types .............................................................. 1947
  4.20.1  DRAM (Data RAM) ...................................................... 1947
  4.20.2  IRAM (Instruction RAM) ............................................... 1947
  4.20.3  IROM (code executed from Flash) ..................................... 1948
  4.20.4  RTC fast memory ....................................................... 1948
  4.20.5  DROM (data stored in Flash) ........................................ 1949
  4.20.6  RTC slow memory ........................................................ 1949
  4.20.7  DMA Capable Requirement .............................................. 1949
  4.20.8  DMA Buffer in the stack ............................................... 1950
4.21  lwIP ........................................................................... 1950
  4.21.1  Supported APIs ........................................................ 1950
  4.21.2  BSD Sockets API ....................................................... 1950
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.21.3</td>
<td>Netconn API</td>
</tr>
<tr>
<td>4.21.4</td>
<td>lwIP FreeRTOS Task</td>
</tr>
<tr>
<td>4.21.5</td>
<td>IPv6 Support</td>
</tr>
<tr>
<td>4.21.6</td>
<td>esp-lwip custom modifications</td>
</tr>
<tr>
<td>4.21.7</td>
<td>Performance Optimization</td>
</tr>
<tr>
<td>4.22</td>
<td>OpenThread</td>
</tr>
<tr>
<td>4.22.1</td>
<td>Mode of the OpenThread stack</td>
</tr>
<tr>
<td>4.22.2</td>
<td>How To Write an OpenThread Application</td>
</tr>
<tr>
<td>4.22.3</td>
<td>The OpenThread border router</td>
</tr>
<tr>
<td>4.23</td>
<td>Partition Tables</td>
</tr>
<tr>
<td>4.23.1</td>
<td>Overview</td>
</tr>
<tr>
<td>4.23.2</td>
<td>Built-in Partition Tables</td>
</tr>
<tr>
<td>4.23.3</td>
<td>Creating Custom Tables</td>
</tr>
<tr>
<td>4.23.4</td>
<td>Generating Binary Partition Table</td>
</tr>
<tr>
<td>4.23.5</td>
<td>Partition Size Checks</td>
</tr>
<tr>
<td>4.23.6</td>
<td>Flashing the partition table</td>
</tr>
<tr>
<td>4.23.7</td>
<td>Partition Tool (parttool.py)</td>
</tr>
<tr>
<td>4.24</td>
<td>Performance</td>
</tr>
<tr>
<td>4.24.1</td>
<td>How to Optimize Performance</td>
</tr>
<tr>
<td>4.24.2</td>
<td>Guides</td>
</tr>
<tr>
<td>4.25</td>
<td>RF calibration</td>
</tr>
<tr>
<td>4.25.1</td>
<td>Partial calibration</td>
</tr>
<tr>
<td>4.25.2</td>
<td>Full calibration</td>
</tr>
<tr>
<td>4.25.3</td>
<td>No calibration</td>
</tr>
<tr>
<td>4.25.4</td>
<td>PHY initialization data</td>
</tr>
<tr>
<td>4.26</td>
<td>Secure Boot</td>
</tr>
<tr>
<td>4.26.1</td>
<td>Background</td>
</tr>
<tr>
<td>4.26.2</td>
<td>Secure Boot Process Overview</td>
</tr>
<tr>
<td>4.26.3</td>
<td>Keys</td>
</tr>
<tr>
<td>4.26.4</td>
<td>Bootloader Size</td>
</tr>
<tr>
<td>4.26.5</td>
<td>How To Enable Secure Boot</td>
</tr>
<tr>
<td>4.26.6</td>
<td>Re-Flashable Software Bootloader</td>
</tr>
<tr>
<td>4.26.7</td>
<td>Generating Secure Boot Signing Key</td>
</tr>
<tr>
<td>4.26.8</td>
<td>Remote Signing of Images</td>
</tr>
<tr>
<td>4.26.9</td>
<td>Secure Boot Best Practices</td>
</tr>
<tr>
<td>4.26.10</td>
<td>Technical Details</td>
</tr>
<tr>
<td>4.26.11</td>
<td>Secure Boot &amp; Flash Encryption</td>
</tr>
<tr>
<td>4.26.12</td>
<td>Signed App Verification Without Hardware Secure Boot</td>
</tr>
<tr>
<td>4.26.13</td>
<td>Advanced Features</td>
</tr>
<tr>
<td>4.27</td>
<td>Secure Boot V2</td>
</tr>
<tr>
<td>4.27.1</td>
<td>Background</td>
</tr>
<tr>
<td>4.27.2</td>
<td>Advantages</td>
</tr>
<tr>
<td>4.27.3</td>
<td>Secure Boot V2 Process</td>
</tr>
<tr>
<td>4.27.4</td>
<td>Signature Block Format</td>
</tr>
<tr>
<td>4.27.5</td>
<td>Verifying a Signature Block</td>
</tr>
<tr>
<td>4.27.6</td>
<td>Verifying an Image</td>
</tr>
<tr>
<td>4.27.7</td>
<td>Bootloader Size</td>
</tr>
<tr>
<td>4.27.8</td>
<td>eFuse usage</td>
</tr>
<tr>
<td>4.27.9</td>
<td>How To Enable Secure Boot V2</td>
</tr>
<tr>
<td>4.27.10</td>
<td>Restrictions after Secure Boot is enabled</td>
</tr>
<tr>
<td>4.27.11</td>
<td>Generating Secure Boot Signing Key</td>
</tr>
<tr>
<td>4.27.12</td>
<td>Remote Signing of Images</td>
</tr>
<tr>
<td>4.27.13</td>
<td>Secure Boot Best Practices</td>
</tr>
<tr>
<td>4.27.14</td>
<td>Technical Details</td>
</tr>
<tr>
<td>4.27.15</td>
<td>Secure Boot &amp; Flash Encryption</td>
</tr>
<tr>
<td>4.27.16</td>
<td>Signed App Verification Without Hardware Secure Boot</td>
</tr>
<tr>
<td>4.27.17</td>
<td>Advanced Features</td>
</tr>
<tr>
<td>4.28</td>
<td>Thread Local Storage</td>
</tr>
</tbody>
</table>

vii
4.28.1 Overview .................................................................................................................. 1995
4.28.2 FreeRTOS Native API ............................................................................................ 1995
4.28.3 Pthread API ........................................................................................................... 1996
4.28.4 C11 Standard ......................................................................................................... 1996
4.29 Tools .......................................................................................................................... 1996
4.29.1 Downlodable Tools ............................................................................................... 1996
4.29.2 IDF Docker Image ................................................................................................. 2004
4.29.3 IDF Windows Installer ........................................................................................... 2006
4.29.4 IDF Component Manager ...................................................................................... 2007
4.29.5 IDF Clang Tidy ...................................................................................................... 2008
4.30 ULP Coprocessor programming ................................................................................. 2009
4.30.1 ESP32 ULP coprocessor instruction set .................................................................. 2009
4.30.2 Programming ULP coprocessor using C macros (legacy) ..................................... 2022
4.30.3 Installing the Toolchain ......................................................................................... 2027
4.30.4 Compiling the ULP Code ....................................................................................... 2027
4.30.5 Accessing the ULP Program Variables ................................................................. 2028
4.30.6 Starting the ULP Program ..................................................................................... 2028
4.30.7 ESP32 ULP program flow ...................................................................................... 2030
4.31 Unit Testing in ESP32 ............................................................................................... 2030
4.31.1 Normal Test Cases ............................................................................................... 2031
4.31.2 Multi-device Test Cases ....................................................................................... 2031
4.31.3 Multi-stage Test Cases ......................................................................................... 2032
4.31.4 Tests For Different Targets .................................................................................. 2033
4.31.5 Building Unit Test App ......................................................................................... 2033
4.31.6 Running Unit Tests ............................................................................................... 2034
4.31.7 Timing Code with Cache Compensated Timer ..................................................... 2035
4.31.8 Mocks .................................................................................................................... 2036
4.32 Unit Testing on Linux ............................................................................................... 2037
4.32.1 Embedded Software Tests ..................................................................................... 2038
4.32.2 IDF Unit Tests on Linux Host ................................................................................. 2038
4.33 Wi-Fi Driver ............................................................................................................... 2039
4.33.1 ESP32 Wi-Fi Feature List ...................................................................................... 2039
4.33.2 How To Write a Wi-Fi Application ....................................................................... 2039
4.33.3 ESP32 Wi-Fi API Error Code ............................................................................... 2040
4.33.4 ESP32 Wi-Fi API Parameter Initialization ............................................................. 2040
4.33.5 ESP32 Wi-Fi Programming Model ....................................................................... 2040
4.33.6 ESP32 Wi-Fi Event Description .......................................................................... 2041
4.33.7 ESP32 Wi-Fi Station General Scenario ............................................................... 2044
4.33.8 ESP32 Wi-Fi AP General Scenario ....................................................................... 2046
4.33.9 ESP32 Wi-Fi Scan .................................................................................................. 2048
4.33.10 ESP32 Wi-Fi Station Connecting Scenario ....................................................... 2054
4.33.11 ESP32 Wi-Fi Station Connecting When Multiple APs Are Found ....................... 2058
4.33.12 Wi-Fi Reconnect .................................................................................................. 2058
4.33.13 Wi-Fi Beacon Timeout ....................................................................................... 2058
4.33.14 ESP32 Wi-Fi Configuration ............................................................................... 2058
4.33.15 Wi-Fi Easy Connect™ (DPP) .............................................................................. 2063
4.33.16 Wireless Network Management ........................................................................... 2064
4.33.17 Radio Resource Measurement .......................................................................... 2064
4.33.18 ESP32 Wi-Fi Power-saving Mode ....................................................................... 2064
4.33.19 ESP32 Wi-Fi Throughput .................................................................................... 2065
4.33.20 Wi-Fi 80211 Packet Send ................................................................................... 2065
4.33.21 Wi-Fi Sniffer Mode ............................................................................................. 2067
4.33.22 Wi-Fi Multiple Antennas .................................................................................... 2068
4.33.23 Wi-Fi Channel State Information ....................................................................... 2069
4.33.24 Wi-Fi Channel State Information Configure ....................................................... 2070
4.33.25 Wi-Fi HT20/40 ..................................................................................................... 2071
4.33.26 Wi-Fi QoS ............................................................................................................ 2071
4.33.27 Wi-Fi AMSDU ..................................................................................................... 2072
6 Libraries and Frameworks

6.1 Cloud Frameworks
6.1.1 ESP RainMaker
6.1.2 AWS IoT
6.1.3 Azure IoT
6.1.4 Google IoT Core
6.1.5 Aliyun IoT
6.1.6 Joylink IoT
6.1.7 Tencent IoT
6.1.8 Tencentyun IoT
6.1.9 Baidu IoT

6.2 Espressif’s Frameworks
6.2.1 Espressif Audio Development Framework
6.2.2 ESP-CVI
6.2.3 Espressif DSP Library
6.2.4 ESP-WIFI-MESH Development Framework
6.2.5 ESP-WHO
6.2.6 ESP RainMaker
6.2.7 ESP-IoT-Solution

5 ESP-IDF 5.0 Migration Guides

5.1 Migrate Windows Environment to ESP-IDF 5.0
5.2 Migrate Peripherals to ESP-IDF 5.0
5.2.1 Peripheral Clock Gating
5.2.2 SPI Flash Interface
5.2.3 ADC
5.2.4 GPIO
5.2.5 Timer Group Driver
5.3 Migrate Build System to ESP-IDF 5.0
5.4 Migrate System to ESP-IDF 5.0
5.4.1 Inter-Processor Call
5.4.2 ESP Clock
5.4.3 Cache Error Interrupt
5.4.4 Brownout
5.4.5 Trax
5.4.6 ROM
5.4.7 ESP HW Support
5.4.8 SOC dependency
5.4.9 APP Trace
5.5 Migrate FreeRTOS to ESP-IDF 5.0
5.5.1 Tasks Snapshot
5.5.2 FreeRTOS Asserts
5.6 Migrate Ethernet Drivers to ESP-IDF 5.0
5.6.1 esp_eth_ioctl() API
5.6.2 KSZ8041/81 and LAN8720 Driver Update
5.6.3 ESP NETIF Glue Event Handlers
5.7 Removed or deprecated components
# Contributions Guide

7.1 How to Contribute ............................................. 2097
7.2 Before Contributing ........................................... 2097
7.3 Pull Request Process .......................................... 2097
7.4 Legal Part ...................................................... 2097
7.5 Related Documents ............................................ 2098
  7.5.1 Espressif IoT Development Framework Style Guide ............. 2098
  7.5.2 Install pre-commit Hook for ESP-IDF Project ................... 2105
  7.5.3 Documenting Code ........................................ 2106
  7.5.4 Creating Examples ....................................... 2111
  7.5.5 API Documentation Template ............................... 2112
  7.5.6 Contributor Agreement .................................... 2114
  7.5.7 Copyright Header Guide ................................... 2116

# ESP-IDF Versions

8.1 Releases ..................................................... 2119
8.2 Which Version Should I Start With? ............................ 2119
8.3 Versioning Scheme .......................................... 2119
8.4 Support Periods .............................................. 2120
8.5 Checking the Current Version ................................ 2121
8.6 Git Workflow ................................................ 2122
8.7 Updating ESP-IDF ........................................... 2122
  8.7.1 Updating to Stable Release ................................ 2123
  8.7.2 Updating to a Pre-Release Version ......................... 2123
  8.7.3 Updating to Master Branch ............................... 2123
  8.7.4 Updating to a Release Branch ............................. 2124

# Resources

9.1 PlatformIO .................................................. 2125
  9.1.1 What is PlatformIO? ...................................... 2125
  9.1.2 Installation ............................................. 2125
  9.1.3 Configuration ........................................... 2126
  9.1.4 Tutorials ................................................. 2126
  9.1.5 Project Examples ......................................... 2126
  9.1.6 Next Steps ............................................... 2126
  9.2 Useful Links .............................................. 2126

# Copyrights and Licenses

10.1 Software Copyrights ......................................... 2127
  10.1.1 Firmware Components ................................... 2127
  10.1.2 Build Tools ............................................. 2128
  10.1.3 Documentation ........................................ 2128
  10.2 ROM Source Code Copyrights ................................ 2128
  10.3 Xtensa libhal MIT License ................................ 2129
  10.4 TinyBasic Plus MIT License ................................ 2129
  10.5 TJpgDec License ........................................... 2129

# About

11 About .......................................................... 2131

# Switch Between Languages

12 Switch Between Languages ..................................... 2133

Index .............................................................. 2135

Index .............................................................. 2135
This is the documentation for Espressif IoT Development Framework (esp-idf). ESP-IDF is the official development framework for the ESP32, ESP8684, ESP32-S and ESP32-C Series SoCs.

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

<table>
<thead>
<tr>
<th>Get Started</th>
<th>API Reference</th>
<th>H/W Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>API Guides</th>
<th>Contribute</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>
Chapter 1

Get Started

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

Note: This is documentation for 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 is a system on a chip that integrates the following features:

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

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

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

1.2 What You Need

Hardware:

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

Software:

You have a choice to either download and install the following software manually

- Toolchain to compile code for ESP32
- Build tools - CMake and Ninja to build a full Application for ESP32
- ESP-IDF that essentially contains API (software libraries and source code) for ESP32 and scripts to operate the Toolchain
or get through the onboarding process using the following official plugins for integrated development environments (IDE) described in separate documents

- Eclipse Plugin (installation link)
- VS Code Extension (setup)

Fig. 1: Development of applications for ESP32

1.3 Development Board Overviews

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

1.3.1 ESP32-DevKitC V4 Getting Started Guide

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

What You Need

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

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

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

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

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

For details please refer to ESP Product Selector.

Functional Description

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

![ESP32-DevKitC V4 with ESP32-WROOM-32 module soldered](image)

Fig. 2: ESP32-DevKitC V4 with ESP32-WROOM-32 module soldered
Chapter 1. Get Started

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

**Note:** The pins D0, D1, D2, D3, CMD and CLK are used internally for communication between ESP32 and SPI flash memory. They are grouped on both sides near the USB connector. Avoid using these pins, as it may disrupt access to the SPI flash memory / SPI RAM.

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

**Power Supply Options**

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

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

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

**Header Block**

The two tables below provide the **Name** and **Function** of I/O header pins on both sides of the board, as shown in ESP32-DevKitC V4 with ESP32-WROOM-32 module soldered. The numbering and names are the same as in the ESP32-DevKitC V4 schematics (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>EN</td>
<td>I</td>
<td>CHIP PU, Reset</td>
</tr>
<tr>
<td>3</td>
<td>IO36</td>
<td>I</td>
<td>GPIO36, ADC1.CH0, S_VP</td>
</tr>
<tr>
<td>4</td>
<td>IO39</td>
<td>I</td>
<td>GPIO39, ADC1.CH3, S_VN</td>
</tr>
<tr>
<td>5</td>
<td>IO34</td>
<td>I</td>
<td>GPIO34, ADC1.CH6, VDET_1</td>
</tr>
<tr>
<td>6</td>
<td>IO35</td>
<td>I</td>
<td>GPIO35, ADC1.CH7, VDET_2</td>
</tr>
<tr>
<td>7</td>
<td>IO32</td>
<td>I/O</td>
<td>GPIO32, ADC1.CH4, TOUCH.CH9, XTAL_32K.P</td>
</tr>
<tr>
<td>8</td>
<td>IO33</td>
<td>I/O</td>
<td>GPIO33, ADC1.CH5, TOUCH.CH8, XTAL_32K.N</td>
</tr>
<tr>
<td>9</td>
<td>IO25</td>
<td>I/O</td>
<td>GPIO25, ADC1.CH8, DAC_1</td>
</tr>
<tr>
<td>10</td>
<td>IO26</td>
<td>I/O</td>
<td>GPIO26, ADC2.CH9, DAC_2</td>
</tr>
<tr>
<td>11</td>
<td>IO27</td>
<td>I/O</td>
<td>GPIO27, ADC2.CH7, TOUCH.CH7</td>
</tr>
<tr>
<td>12</td>
<td>IO14</td>
<td>I/O</td>
<td>GPIO14, ADC2.CH6, TOUCH.CH6, MTMS</td>
</tr>
<tr>
<td>13</td>
<td>IO12</td>
<td>I/O</td>
<td>GPIO12, ADC2.CH5, TOUCH.CH5, MTDI</td>
</tr>
<tr>
<td>14</td>
<td>GND</td>
<td>G</td>
<td>Ground</td>
</tr>
<tr>
<td>15</td>
<td>IO13</td>
<td>I/O</td>
<td>GPIO13, ADC2.CH4, TOUCH.CH4, MTCK</td>
</tr>
<tr>
<td>16</td>
<td>IO9</td>
<td>I/O</td>
<td>GPIO9, D2</td>
</tr>
<tr>
<td>17</td>
<td>IO10</td>
<td>I/O</td>
<td>GPIO10, D3</td>
</tr>
<tr>
<td>18</td>
<td>IO11</td>
<td>I/O</td>
<td>GPIO11, CMD</td>
</tr>
<tr>
<td>19</td>
<td>5V0</td>
<td>P</td>
<td>5 V power supply</td>
</tr>
</tbody>
</table>

### J3

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND</td>
<td>G</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>IO23</td>
<td>I/O</td>
<td>GPIO23</td>
</tr>
<tr>
<td>3</td>
<td>IO22</td>
<td>I/O</td>
<td>GPIO22</td>
</tr>
<tr>
<td>4</td>
<td>IO1</td>
<td>I/O</td>
<td>GPIO1, U0TXD</td>
</tr>
<tr>
<td>5</td>
<td>IO3</td>
<td>I/O</td>
<td>GPIO3, U0RXD</td>
</tr>
<tr>
<td>6</td>
<td>IO21</td>
<td>I/O</td>
<td>GPIO21</td>
</tr>
<tr>
<td>7</td>
<td>GND</td>
<td>G</td>
<td>Ground</td>
</tr>
<tr>
<td>8</td>
<td>IO19</td>
<td>I/O</td>
<td>GPIO19</td>
</tr>
<tr>
<td>9</td>
<td>IO18</td>
<td>I/O</td>
<td>GPIO18</td>
</tr>
<tr>
<td>10</td>
<td>IO5</td>
<td>I/O</td>
<td>GPIO5</td>
</tr>
<tr>
<td>11</td>
<td>IO17</td>
<td>I/O</td>
<td>GPIO17</td>
</tr>
<tr>
<td>12</td>
<td>IO16</td>
<td>I/O</td>
<td>GPIO16</td>
</tr>
<tr>
<td>13</td>
<td>IO4</td>
<td>I/O</td>
<td>GPIO4, ADC2.CH0, TOUCH.CH0</td>
</tr>
<tr>
<td>14</td>
<td>IO0</td>
<td>I/O</td>
<td>GPIO0, ADC2.CH1, TOUCH.CH1, Boot</td>
</tr>
<tr>
<td>15</td>
<td>IO2</td>
<td>I/O</td>
<td>GPIO2, ADC2.CH2, TOUCH.CH2</td>
</tr>
<tr>
<td>16</td>
<td>IO15</td>
<td>I/O</td>
<td>GPIO15, ADC2.CH3, TOUCH.CH3, MTD0</td>
</tr>
<tr>
<td>17</td>
<td>IO8</td>
<td>I/O</td>
<td>GPIO8, D1</td>
</tr>
<tr>
<td>18</td>
<td>IO7</td>
<td>I/O</td>
<td>GPIO7, D0</td>
</tr>
<tr>
<td>19</td>
<td>IO6</td>
<td>I/O</td>
<td>GPIO6, SCK</td>
</tr>
</tbody>
</table>

P: Power supply; I: Input; O: Output.

**Pin Layout**

**Note on C15**

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

- The board may boot into Download mode
- If you output clock on GPIO0, C15 may impact the signal
In case these issues occur, please remove the component. The figure below shows the location of C15 highlighted in yellow.

**Start Application Development**

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

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

**Board Dimensions**

**Related Documents**

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

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

**ESP32-DevKitC V2 Getting Started Guide**  This guide shows how to start using the ESP32-DevKitC V2 development board.
What You Need

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

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

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

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

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-WROOM-32</td>
<td>Standard module with ESP32 at its core. For more information, see <a href="#">ESP32-WROOM-32 Datasheet</a>.</td>
</tr>
<tr>
<td>EN</td>
<td>Reset button.</td>
</tr>
<tr>
<td>Boot</td>
<td>Download button. Holding down <strong>Boot</strong> and then pressing <strong>EN</strong> initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>Micro USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and ESP32-WROOM-32.</td>
</tr>
<tr>
<td>I/O</td>
<td>Most of the pins on the ESP module are broken out to the pin headers on the board. You can program ESP32 to enable multiple functions such as PWM, ADC, DAC, I2C, I2S, SPI, etc.</td>
</tr>
</tbody>
</table>
Chapter 1. Get Started

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

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

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

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

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

Related Documents

- ESP32-DevKitC schematics (PDF)
- ESP32 Datasheet (PDF)
- ESP32-WROOM-32 Datasheet (PDF)

1.3.2 ESP-WROOM-KIT V4.1 Getting Started Guide

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

What You Need

- **ESP-WROOM-KIT V4.1 board**
- USB 2.0 cable (A to Micro-B)
You can skip the introduction sections and go directly to Section *Start Application Development.*

**Overview**

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

ESP-WROVER-KIT features the following integrated components:

- ESP32-WROVER-E module
- LCD screen
- MicroSD card slot

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

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

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

**Functionality Overview**

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

![Fig. 7: ESP-WROVER-KIT block diagram](image)

**Functional Description**

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

The table below provides description in the following manner:

- Starting from the first picture’s top right corner and going clockwise
- Then moving on to the second picture
Chapter 1. Get Started

Fig. 8: ESP-WROVER-KIT board layout - front

Fig. 9: ESP-WROVER-KIT board layout - back
<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FT2232</td>
<td>The FT2232 chip serves as a multi-protocol USB-to-serial bridge which can be programmed and controlled via USB to provide communication with ESP32. FT2232 also features USB-to-JTAG interface which is available on channel A of the chip, while USB-to-serial is on channel B. The FT2232 chip enhances user-friendliness in terms of application development and debugging. See ESP-WROVER-KIT V4.1 schematic.</td>
</tr>
<tr>
<td>32.768 kHz</td>
<td>External precision 32.768 kHz crystal oscillator serves as a clock with low-power consumption while the chip is in Deep-sleep mode.</td>
</tr>
<tr>
<td>0Ω</td>
<td>Zero-ohm resistor intended as a placeholder for a current shunt, can be desoldered or replaced with a current shunt to facilitate the measurement of ESP32’s current consumption in different modes.</td>
</tr>
<tr>
<td>ESP32-WROVER-E</td>
<td>This ESP32 module features 64-Mbit PSRAM for flexible extended storage and data processing capabilities.</td>
</tr>
<tr>
<td>Diagnostic LEDs</td>
<td>Four red LEDs connected to the GPIO pins of FT2232. Intended for future use.</td>
</tr>
<tr>
<td>UART</td>
<td>Serial port. The serial TX/RX signals of FT2232 and ESP32 are broken out to the inward and outward sides of JP2 respectively. By default, these pairs of pins are connected with jumpers. To use ESP32’s serial interface, remove the jumpers and connect another external serial device to the respective pins.</td>
</tr>
<tr>
<td>SPI</td>
<td>By default, ESP32 uses its SPI interface to access flash and PSRAM memory inside the module. Use these pins to connect ESP32 to another SPI device. In this case, an extra chip select (CS) signal is needed. Please note that the voltage of this interface is 3.3 V.</td>
</tr>
<tr>
<td>CTS/RTS</td>
<td>Serial port flow control signals: the pins are not connected to the circuitry by default. To enable them, short the respective pins of JP14 with jumpers.</td>
</tr>
<tr>
<td>JTAG</td>
<td>JTAG interface. JTAG signals of FT2232 and ESP32 are broken out to the inward and outward sides of JP2 respectively. By default, these pairs of pins are disconnected. To enable JTAG, short the respective pins with jumpers as shown in Section Setup Options.</td>
</tr>
<tr>
<td>USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the board.</td>
</tr>
<tr>
<td>EN Button</td>
<td>Reset button.</td>
</tr>
<tr>
<td>BOOT Button</td>
<td>Download button. Holding down Boot and then pressing EN initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>Power Switch</td>
<td>Power On/Off Switch. Toggling toward the Boot button powers the board on, toggling away from Boot powers the board off.</td>
</tr>
<tr>
<td>Power Selector</td>
<td>Power supply selector interface. The board can be powered either via USB or via the 5V Input interface. Select the power source with a jumper. For more details, see Section Setup Options, jumper header JP7.</td>
</tr>
<tr>
<td>5V Input</td>
<td>5V power supply interface for a standard coaxial power connector, 5.5 x 2.1 mm, center positive. This interface can be more convenient when the board is operating autonomously (not connected to a computer).</td>
</tr>
<tr>
<td>5V Power On LED</td>
<td>This red LED turns on when power is supplied to the board, either from USB or 5V Input.</td>
</tr>
<tr>
<td>LDO</td>
<td>NCP1117(1A). 5V-to-3.3V LDO. NCP1117 can provide a maximum current of 1A. The LDO on the board has a fixed output voltage. Although, the user can install an LDO with adjustable output voltage. For details, please refer to ESP-WROVER-KIT V4.1 schematic.</td>
</tr>
<tr>
<td>Camera Connector</td>
<td>Camera interface, a standard OV7670 camera module.</td>
</tr>
<tr>
<td>RGB LED</td>
<td>Red, green and blue (RGB) light emitting diodes (LEDs), can be controlled by pulse width modulation (PWM).</td>
</tr>
<tr>
<td>I/O Connector</td>
<td>All the pins on the ESP32 module are broken out to pin headers. You can program ESP32 to enable multiple functions, such as PWM, ADC, DAC, 12C, I2S, SPI, etc.</td>
</tr>
<tr>
<td>MicroSD Card Slot</td>
<td>Useful for developing applications that access MicroSD card for data storage and retrieval.</td>
</tr>
<tr>
<td>LCD</td>
<td>Support for mounting and interfacing a 3.2” SPI (standard 4-wire Serial Peripheral Interface) LCD, as shown on figure ESP-WROVER-KIT board layout - back.</td>
</tr>
</tbody>
</table>
Chapter 1. Get Started

Setup Options

There are three jumper blocks available to set up the board functionality. The most frequently required options are listed in the table below.
<table>
<thead>
<tr>
<th>Header</th>
<th>Jumper Setting</th>
<th>Description of Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JP7</td>
<td>Power ESP-WROVER-KIT via an external power supply</td>
</tr>
<tr>
<td></td>
<td>JP7</td>
<td>Power ESP-WROVER-KIT via USB</td>
</tr>
<tr>
<td></td>
<td>JP2</td>
<td>Enable JTAG functionality</td>
</tr>
<tr>
<td></td>
<td>JP3</td>
<td>Enable UART communication</td>
</tr>
</tbody>
</table>
Chapter 1. Get Started

Allocation of ESP32 Pins

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

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

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

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

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

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

Legend:

- NC/XTAL - 32.768 kHz Oscillator
- JTAG - JTAG / JP2
- Boot - Boot button / SW2
- Camera - Camera / JP4
- LED - RGB LED
- MicroSD - MicroSD Card / J4
- LCD - LCD / U5
- PSRAM - ESP32-WROVER-E’s PSRAM

32.768 kHz Oscillator

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

Note: Since GPIO32 and GPIO33 are connected to the oscillator by default, they are not connected to the JP1 I/O connector to maintain signal integrity. This allocation may be changed from the oscillator to JP1 by desoldering the zero-ohm resistors from positions R11 / R23 and re-soldering them to positions R12 / R24.
**Important:** The module’s flash bus is connected to the jumper block JP2 through zero-ohm resistors R140 ~ R145. If the flash memory needs to operate at the frequency of 80 MHz, for reasons such as improving the integrity of bus signals, you can desolder these resistors to disconnect the module’s flash bus from the pin header JP2.
Chapter 1. Get Started

MicroSD Card

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

LCD / U5

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

Start Application Development

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

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

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

Do not install any other jumpers.

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

Now to Development   Please proceed to Get Started, where Section Installation Step by Step will quickly help you set up the development environment and then flash an example project onto your board.
Chapter 1. Get Started

The application examples that use some hardware specific to your ESP-WROVER-KIT can be found below.

- On-board LCD example: peripherals/spi_master/lcd
- SD card slot example: storage/sd_card
- Camera connector example: https://github.com/espressif/sp32-camera

Related Documents

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

ESP-WROVER-KIT V3 Getting Started Guide This guide shows how to get started with the ESP-WROVER-KIT V3 development board and also provides information about its functionality and configuration options. For the description of other ESP-WROVER-KIT versions, please check ESP32 Hardware Reference.

What You Need

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

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

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

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

- ESP32-WROOM-32
- ESP32-WROVER series

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

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

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

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

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

The table below provides description in the following manner:

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

**Fig. 10: ESP-WROVER-KIT block diagram**
Fig. 11: ESP-WROVER-KIT board layout - front
Fig. 12: ESP-WROVER-KIT board layout - back
**Setup Options** There are five jumper blocks available to set up the board functionality. The most frequently required options are listed in the table below.
<table>
<thead>
<tr>
<th>Header</th>
<th>Jumper Setting</th>
<th>Description of Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JP7</td>
<td>Power ESP-WROVER-KIT via an external power supply</td>
</tr>
<tr>
<td></td>
<td>JP7</td>
<td>Power ESP-WROVER-KIT via USB</td>
</tr>
<tr>
<td></td>
<td>JP8</td>
<td>Enable JTAG functionality</td>
</tr>
<tr>
<td></td>
<td>JP11</td>
<td>Enable UART communication</td>
</tr>
</tbody>
</table>
**Allocation of ESP32 Pins**  
Some pins / terminals of ESP32 are allocated for use with the onboard or external hardware. If that hardware is not used, e.g., nothing is plugged into the Camera (JP4) header, then these GPIOs can be used for other purposes.

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

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

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

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

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

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

**32.768 kHz Oscillator**

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

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

**SPI Flash / JP13**

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

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

**JTAG / JP8**

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

**Camera / JP4**

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

- Signals D0 .. D7 denote camera data bus

**RGB LED**

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>RGB LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 GPIO0</td>
<td>Red</td>
</tr>
<tr>
<td>2 GPIO2</td>
<td>Green</td>
</tr>
<tr>
<td>3 GPIO4</td>
<td>Blue</td>
</tr>
</tbody>
</table>
Chapter 1. Get Started

MicroSD Card

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

LCD / U5

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

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

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

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

Do not install any other jumpers.

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

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

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

ESP-WROVER-KIT V2 Getting Started Guide

This guide shows how to get started with the ESP-WROVER-KIT V2 development board and also provides information about its functionality and configuration options. For the description of other ESP-WROVER-KIT versions, please check ESP32 Hardware Reference.

What You Need

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

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

Overview

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

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

- ESP32-WROOM-32
- ESP32-WROVER series

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

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

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

Functionality Overview

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

Functional Description

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

The table below provides description in the following manner:

- Starting from the first picture’s top right corner and going clockwise
- Then moving on to the second picture
Chapter 1. Get Started

Fig. 13: ESP-WROVER-KIT block diagram

Fig. 14: ESP-WROVER-KIT board layout - front
Fig. 15: ESP-WROVER-KIT board layout - back
### Chapter 1. Get Started

#### Key Component | Description
--- | ---
32.768 kHz | External precision 32.768 kHz crystal oscillator serves as a clock with low-power consumption while the chip is in Deep-sleep mode.
ESP32 Module | Either ESP32-WROOM-32 or ESP32-WROVER with an integrated ESP32. The ESP32-WROVER module features all the functions of ESP32-WROOM-32 and integrates an external 32-MBit PSRAM for flexible extended storage and data processing capabilities.
CTS/RTS Serial port flow control signals: the pins are not connected to the circuitry by default. To enable them, short the respective pins of JP14 with jumpers.
UART | Serial port. The serial TX/RX signals of FT2232 and ESP32 are broken out to the inward and outward sides of JP11 respectively. By default, these pairs of pins are connected with jumpers. To use ESP32’s serial interface, remove the jumpers and connect another external serial device to the respective pins.
SPI | By default, ESP32 uses its SPI interface to access flash and PSRAM memory inside the module. Use these pins to connect ESP32 to another SPI device. In this case, an extra chip select (CS) signal is needed. Please note that the interface voltage for the version with ESP32-WROVER is 1.8V, while that for the version with ESP32-WROOM-32 is 3.3V.
JTAG | JTAG interface. JTAG signals of FT2232 and ESP32 are broken out to the inward and outward sides of JP8 respectively. By default, these pairs of pins are disconnected. To enable JTAG, short the respective pins with jumpers as shown in Section Setup Options.
FT2232 | The FT2232 chip serves as a multi-protocol USB-to-serial bridge which can be programmed and controlled via USB to provide communication with ESP32. FT2232 features USB-to-UART and USB-to-JTAG functionalities.
EN | Reset button.
Boot | Download button. Holding down Boot and then pressing EN initiates Firmware Download mode for downloading firmware through the serial port.
USB | USB interface. Power supply for the board as well as the communication interface between a computer and the board.
Power Select | Power supply selector interface. The board can be powered either via USB or via the 5V Input interface. Select the power source with a jumper. For more details, see Section Setup Options, jumper header JP7.
Power Key | Power On/Off Switch. Toggling toward USB powers the board on, toggling away from USB powers the board off.
5V Input | The 5V power supply interface can be more convenient when the board is operating autonomously (not connected to a computer).
LDO | NCP1117(1A). 5V-to-3.3V LDO. NCP1117 can provide a maximum current of 1A. The LDO on the board has a fixed output voltage. Although, the user can install an LDO with adjustable output voltage. For details, please refer to ESP-WROVER-KIT V2 schematic.
Camera | Camera interface, a standard OV7670 camera module.
RGB | Red, green and blue (RGB) light emitting diodes (LEDs), can be controlled by pulse width modulation (PWM).
I/O | All the pins on the ESP32 module are broken out to pin headers. You can program ESP32 to enable multiple functions, such as PWM, ADC, DAC, 12C, 12S, SPI, etc.
MicroSD Card | MicroSD card slot for data storage: when ESP32 enters the download mode, GPIO2 cannot be held high. However, a pull-up resistor is required on GPIO2 to enable the MicroSD Card. By default, GPIO2 and the pull-up resistor R153 are disconnected. To enable the SD Card, use jumpers on JP1 as shown in Section Setup Options.
LCD | Support for mounting and interfacing a 3.2” SPI (standard 4-wire Serial Peripheral Interface) LCD, as shown on figure ESP-WROVER-KIT board layout - back.

**Setup Options** There are five jumper blocks available to set up the board functionality. The most frequently required options are listed in the table below.
<table>
<thead>
<tr>
<th>Header</th>
<th>Jumper Setting</th>
<th>Description of Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter 1. Get Started</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>JP1</strong></td>
<td>Enable pull up for the MicroSD Card</td>
<td></td>
</tr>
<tr>
<td><strong>JP1</strong></td>
<td>Assert GPIO2 low during each download (by jumping it to GPIO0)</td>
<td></td>
</tr>
<tr>
<td><strong>JP7</strong></td>
<td>Power ESP-WROVER-KIT via an external power supply</td>
<td></td>
</tr>
<tr>
<td><strong>JP7</strong></td>
<td>Power ESP-WROVER-KIT via USB</td>
<td></td>
</tr>
<tr>
<td>Espressif Systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Release v5.0-dev-1077-g397639d</td>
</tr>
</tbody>
</table>
**Start Application Development**  Before powering up your ESP-WROVER-KIT, please make sure that the board is in good condition with no obvious signs of damage.

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

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

Do not install any other jumpers.

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

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

**Related Documents**

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

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

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

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

**What You Need**

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

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

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

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

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

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

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

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

Note:

1. The 2 x 3 pads not populated with pin headers are connected to the flash memory embedded in the ESP32-PICO-D4 SiP module. For more details see module’s datasheet in Related Documents.
2. ESP32-PICO-KIT comes with male headers by default.

Functionality Overview

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

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

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

Fig. 17: ESP32-PICO-KIT board layout
**Key Component** | **Description**
--- | ---
ESP32-PICO-D4 | Standard ESP32-PICO-D4 module soldered to the ESP32-PICO-KIT board. The complete ESP32 system on a chip (ESP32 SoC) has been integrated into the SiP module, requiring only an external antenna with LC matching network, decoupling capacitors, and a pull-up resistor for EN signals to function properly.
LDO | 5V-to-3.3V Low dropout voltage regulator (LDO).
USB-UART bridge | Single-chip USB-UART bridge: CP2102 in V4 provides up to 1 Mbps transfer rates and CP2102N in V4.1 offers up to 3 Mbps transfers rates.
Micro USB Port | USB interface. Power supply for the board as well as the communication interface between a computer and the board.
5V Power On LED | This red LED turns on when power is supplied to the board. For details, see the schematics in Related Documents.
I/O | All the pins on ESP32-PICO-D4 are broken out to pin headers. You can program ESP32 to enable multiple functions, such as PWM, ADC, DAC, I2C, I2S, SPI, etc. For details, please see Section Pin Descriptions.
BOOT Button | Download button. Holding down Boot and then pressing EN initiates Firmware Download mode for downloading firmware through the serial port.
EN Button | Reset button.

**Power Supply Options**

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

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

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

**Pin Descriptions**

The two tables below provide the **Name** and **Function** of I/O header pins on both sides of the board, see ESP32-PICO-KIT board layout. The pin numbering and header names are the same as in the schematic given in Related Documents.
## Header J2

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

*Espressif Systems*
### Header J3

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FLASH_CS (FCS)</td>
<td>I/O</td>
<td>GPIO16, HS1_DATA4, U2RXD, EMAC_CLK_OUT</td>
</tr>
<tr>
<td>2</td>
<td>FLASH_SD0 (FSD0)</td>
<td>I/O</td>
<td>GPIO17, HS1_DATA5, U2TXD, EMAC_CLK_OUT_180</td>
</tr>
<tr>
<td>3</td>
<td>FLASH_SD2 (FSD2)</td>
<td>I/O</td>
<td>GPIO11, SD_CMD, SPICS0, HS1_CMD, U1RTS</td>
</tr>
<tr>
<td>4</td>
<td>SENSOR_VP (FSVP)</td>
<td>I</td>
<td>GPIO36, ADC1_CH0, RTC_GPIO0</td>
</tr>
<tr>
<td>5</td>
<td>SENSOR_VN (FSVN)</td>
<td>I</td>
<td>GPIO39, ADC1_CH3, RTC_GPIO3</td>
</tr>
<tr>
<td>6</td>
<td>IO25</td>
<td>I/O</td>
<td>GPIO25, DAC_1, ADC2_CH8, RTC_GPIO0, EMAC_RXD0</td>
</tr>
<tr>
<td>7</td>
<td>IO26</td>
<td>I/O</td>
<td>GPIO26, DAC_2, ADC2_CH9, RTC_GPIO7, EMAC_RXD1</td>
</tr>
<tr>
<td>8</td>
<td>IO32</td>
<td>I/O</td>
<td>32K_XP, ADC1_CH4, TOUCH9, RTC_GPIO9</td>
</tr>
<tr>
<td>9</td>
<td>IO33</td>
<td>I/O</td>
<td>32K_XN, ADC1_CH5, TOUCH8, RTC_GPIO8</td>
</tr>
<tr>
<td>10</td>
<td>IO27</td>
<td>I/O</td>
<td>GPIO27, ADC2_CH7, TOUCH7, RTC_GPIO17, EMAC_RX_DV</td>
</tr>
<tr>
<td></td>
<td>IO14</td>
<td>I/O</td>
<td></td>
</tr>
</tbody>
</table>

*Note: (See 1), (See 2a), (See 2b)*

---

*Espressif Systems* 39/5.0

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Chapter 1. Get Started

The following notes give more information about the items in the tables above.

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

Start Application Development

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

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

Board Dimensions

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

![ESP32-PICO-KIT dimensions](image)

Fig. 18: ESP32-PICO-KIT dimensions - back

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

Related Documents

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

ESP32-PICO-KIT V3 Getting Started Guide  This guide shows how to get started with the ESP32-PICO-KIT V3 mini development board. For the description of other ESP32-PICO-KIT versions, please check ESP32 Hardware Reference.
Chapter 1. Get Started

Fig. 19: ESP32-PICO-KIT dimensions - side

What You Need

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

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

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

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

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

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

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

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

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

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

### 1.3.4 ESP32-Ethernet-Kit V1.2 Getting Started Guide

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

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

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

You can skip the introduction sections and go directly to Section **Start Application Development**.
Fig. 21: ESP32-Ethernet-Kit V1.2 Overview (click to enlarge)
Overview

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

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

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

Functionality Overview

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

Functional Description

The following figures and tables describe the key components, interfaces, and controls of the ESP32-Ethernet-Kit.
Chapter 1. Get Started

Fig. 23: ESP32-Ethernet-Kit block diagram (click to enlarge)

Fig. 24: ESP32-Ethernet-Kit - Ethernet board (A) layout (click to enlarge)
Chapter 1. Get Started

**Ethernet Board (A)** The table below provides description starting from the picture’s top right corner and going clockwise.
<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-WROVER</td>
<td>This ESP32 module features 64-Mbit PSRAM for flexible extended storage and data processing capabilities.</td>
</tr>
<tr>
<td>GPIO Header 2</td>
<td>Five unpopulated through-hole solder pads to provide access to selected GPIOs of ESP32. For details, see GPIO Header 2.</td>
</tr>
<tr>
<td>Function Switch</td>
<td>A 4-bit DIP switch used to configure the functionality of selected GPIOs of ESP32. For details see Function Switch.</td>
</tr>
<tr>
<td>Tx/Rx LEDs</td>
<td>Two LEDs to show the status of UART transmission.</td>
</tr>
<tr>
<td>FT2232H</td>
<td>The FT2232H chip serves as a multi-protocol USB-to-serial bridge which can be programmed and controlled via USB to provide communication with ESP32. FT2232H also features USB-to-JTAG interface which is available on channel A of the chip, while USB-to-seral is on channel B. The FT2232H chip enhances user-friendliness in terms of application development and debugging. See ESP32-Ethernet-Kit V1.2 Ethernet board (A) schematic.</td>
</tr>
<tr>
<td>USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the board.</td>
</tr>
<tr>
<td>Power Switch</td>
<td>Power On/Off Switch. Toggling the switch to 5V0 position powers the board on, toggling to GND position powers the board off.</td>
</tr>
<tr>
<td>5V Input</td>
<td>The 5V power supply interface can be more convenient when the board is operating autonomously (not connected to a computer).</td>
</tr>
<tr>
<td>5V Power On LED</td>
<td>This red LED turns on when power is supplied to the board, either from USB or 5V Input.</td>
</tr>
<tr>
<td>DC/DC Converter</td>
<td>Provided DC 5 V to 3.3 V conversion, output current up to 2 A.</td>
</tr>
<tr>
<td>Board B Connectors</td>
<td>A pair male and female header pins for mounting the PoE board (B).</td>
</tr>
<tr>
<td>IP101GRI (PHY)</td>
<td>The physical layer (PHY) connection to the Ethernet cable is implemented using the IP101GRI chip. The connection between PHY and ESP32 is done through the reduced media-independent interface (RMII), a variant of the media-independent interface (MII) standard. The PHY supports the IEEE 802.3/802.3u standard of 10/100 Mbps.</td>
</tr>
<tr>
<td>RJ45 Port</td>
<td>Ethernet network data transmission port.</td>
</tr>
<tr>
<td>Magnetics Module</td>
<td>The Magnetics are part of the Ethernet specification to protect against faults and transients, including rejection of common mode signals between the transceiver IC and the cable. The magnetics also provide galvanic isolation between the transceiver and the Ethernet device.</td>
</tr>
<tr>
<td>Link/Activity LEDs</td>
<td>Two LEDs (green and red) that respectively indicate the “Link” and “Activity” statuses of the PHY.</td>
</tr>
<tr>
<td>BOOT Button</td>
<td>Download button. Holding down BOOT and then pressing EN initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>EN Button</td>
<td>Reset button.</td>
</tr>
<tr>
<td>GPIO Header 1</td>
<td>This header provides six unpopulated through-hole solder pads connected to spare GPIOs of ESP32. For details, see GPIO Header 1.</td>
</tr>
</tbody>
</table>
Chapter 1. Get Started

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

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

The PoE board (B) has the following features:

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

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

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

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

Setup Options

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

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

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

RMII Clock Selection  The ethernet MAC and PHY under RMII working mode need a common 50 MHz reference clock (i.e. RMII clock) that can be provided either externally, or generated from internal ESP32 APLL (not recommended).
Note: For additional information on the RMII clock selection, please refer to ESP32-Ethernet-Kit V1.2 Ethernet board (A) schematic, sheet 2, location D2.

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

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

Fig. 26: RMII Clock from IP101GRI PHY

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

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

To implement this option, users need to remove or add some RC components on the board. For details please refer to ESP32-Ethernet-Kit V1.2 Ethernet board (A) schematic, sheet 2, location D2. Please note that if the APLL is already used for other purposes (e.g. I2S peripheral), then you have no choice but use an external RMII clock.
Fig. 27: RMII Clock from ESP Internal APLL
Chapter 1. Get Started

GPIO Allocation

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

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

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

**Serial Management Interface**

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

**PHY Reset**

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

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

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

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

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

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

Note:

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

### GPIO Allocation Summary

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

Note:

1. To prevent the power-on state of the GPIO0 from being affected by the clock output on the PHY side, the RESET_N signal to PHY defaults to low, turning the clock output off. After power-on you can control RESET_N with GPIO5 to turn the clock output on. See also RMII Clock Sourced Externally by PHY. For PHYs that cannot turn off the clock output through RESET_N, it is recommended to use a crystal module that can be disabled/enabled externally. Similarly like when using RESET_N, the oscillator module should be disabled by default and turned on by ESP32 after power-up. For a reference design please see ESP32-Ethernet-Kit V1.2 Ethernet board (A) schematic.
2. The ESP32 pins GPIO16 and GPIO17 are not broken out to the ESP32-WROVER-E module and therefore not available for use. If you need to use these pins, please solder a module without PSRAM memory inside, e.g. the ESP32-WROOM-32D or ESP32-SOLO-1.
Start Application Development

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

Initial Setup

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

Now to Development

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

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

Configure and Load the Ethernet Example

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

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

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

Other Versions of ESP32-Ethernet-Kit

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

Related Documents

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

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

ESP32-Ethernet-Kit V1.0 Getting Started Guide

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

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

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

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

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

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

![ESP32-Ethernet-Kit V1.0](image)

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

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

Functional Description The following two figures and tables describe the key components, interfaces, and controls of the ESP32-Ethernet-Kit.
Chapter 1. Get Started

Fig. 29: ESP32-Ethernet-Kit block diagram (click to enlarge)

Fig. 30: ESP32-Ethernet-Kit - Ethernet board (A) layout (click to enlarge)
**Ethernet Board (A)** The table below provides description starting from the picture’s top right corner and going clockwise.
### Key Component | Description
--- | ---
**ESP32-WROVER-B** | This ESP32 module features 64-Mbit PSRAM for flexible extended storage and data processing capabilities.
**GPIO Header 2** | Five unpopulated through-hole solder pads to provide access to selected GPIOs of ESP32. For details, see [GPIO Header 2](#).
**Flow Control** | A jumper header with access to the board signals. For details, see [Flow Control](#).
**Function Switch** | A DIP switch used to configure the functionality of selected GPIOs of ESP32. For details, see [Function Switch](#).
**Tx/Rx LEDs** | Two LEDs to show the status of UART transmission.
**GPIO Header 3** | Provides access to some GPIOs of ESP32 that can be used depending on the position of the [Function Switch](#).
**FT2232H** | The FT2232H chip serves as a multi-protocol USB-to-serial bridge which can be programmed and controlled via USB to provide communication with ESP32. FT2232H also features USB-to-JTAG interface which is available on channel A of the chip, while USB-to-serial is on channel B. The FT2232H chip enhances user-friendliness in terms of application development and debugging. See [ESP32-Ethernet-Kit V1.0 Ethernet board (A) schematic](#).
**USB Port** | USB interface. Power supply for the board as well as the communication interface between a computer and the board.
**Power Switch** | Power On/Off Switch. Toggling toward the Boot button powers the board on, toggling away from Boot powers the board off.
**5V Input** | The 5V power supply interface can be more convenient when the board is operating autonomously (not connected to a computer).
**5V Power On LED** | This red LED turns on when power is supplied to the board, either from USB or 5V Input.
**DC/DC Converter** | Provided DC 5 V to 3.3 V conversion, output current up to 2A.
**Board B Connectors** | A pair male header pins for mounting the PoE board (B).
**IP101GRI (PHY)** | The physical layer (PHY) connection to the Ethernet cable is implemented using the IP101GRI chip. The connection between PHY and ESP32 is done through the reduced media-independent interface (RMII), a variant of the media-independent interface (MII) standard. The PHY supports the IEEE 802.3 / 802.3u standard of 10/100Mbps.
**RJ45 Port** | Ethernet network data transmission port.
**Magnetics Module** | The Magnetics are part of the Ethernet specification to protect against faults and transients, including rejection of common mode signals between the transceiver IC and the cable. The magnetics also provide galvanic isolation between the transceiver and the Ethernet device.
**Link/Activity LEDs** | (green and red) that respectively indicate the “Link” and “Activity” statuses of the PHY.
**BOOT Button** | Download button. Holding down BOOT and then pressing CH_PU initiates Firmware Download mode for downloading firmware through the serial port.
**CH_PU Button** | Reset button.
Chapter 1. Get Started

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

The PoE board (B) has the following features:

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

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

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

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

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

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

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

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

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

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

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

<table>
<thead>
<tr>
<th>ESP32 Pin (MAC)</th>
<th>IP101GRI (PHY)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RMII Interface</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>GPIO21</td>
</tr>
<tr>
<td>2</td>
<td>GPIO19</td>
</tr>
<tr>
<td>3</td>
<td>GPIO22</td>
</tr>
<tr>
<td>4</td>
<td>GPIO25</td>
</tr>
<tr>
<td>5</td>
<td>GPIO26</td>
</tr>
<tr>
<td>6</td>
<td>GPIO27</td>
</tr>
<tr>
<td>7</td>
<td>GPIO0</td>
</tr>
<tr>
<td><strong>Serial Management Interface</strong></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>GPIO23</td>
</tr>
<tr>
<td>9</td>
<td>GPIO18</td>
</tr>
<tr>
<td><strong>PHY Reset</strong></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>GPIO5</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 GPIO32</td>
</tr>
<tr>
<td>2 GPIO33</td>
</tr>
<tr>
<td>3 GPIO34</td>
</tr>
<tr>
<td>4 GPIO35</td>
</tr>
<tr>
<td>5 GPIO36</td>
</tr>
<tr>
<td>6 GPIO39</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>MII Function</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 GPIO17</td>
<td>EMAC_CLK_180</td>
<td>See note 1</td>
</tr>
<tr>
<td>2 GPIO16</td>
<td>EMAC_CLK_OUT</td>
<td>See note 1</td>
</tr>
<tr>
<td>3 GPIO4</td>
<td>EMAC_TX_ER</td>
<td></td>
</tr>
<tr>
<td>4 GPIO2</td>
<td>n/a</td>
<td>See note 2</td>
</tr>
<tr>
<td>5 GPIO5</td>
<td>EMAC_RX_CLK</td>
<td>See note 2</td>
</tr>
</tbody>
</table>

**Note:**

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

**GPIO Header 3**  The functionality of GPIOs connected to this header depends on the settings of the *Function Switch*.

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

**GPIO Allocation Summary**

<table>
<thead>
<tr>
<th>ESP32-WROVER-B</th>
<th>IP101GRI</th>
<th>UART</th>
<th>JTAG</th>
<th>GPIO</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>S_VP</td>
<td></td>
<td></td>
<td></td>
<td>IO36</td>
<td></td>
</tr>
<tr>
<td>S_VN</td>
<td></td>
<td></td>
<td></td>
<td>IO39</td>
<td></td>
</tr>
<tr>
<td>IO34</td>
<td></td>
<td></td>
<td></td>
<td>IO34</td>
<td></td>
</tr>
<tr>
<td>IO35</td>
<td></td>
<td></td>
<td></td>
<td>IO35</td>
<td></td>
</tr>
<tr>
<td>IO32</td>
<td></td>
<td></td>
<td></td>
<td>IO32</td>
<td></td>
</tr>
<tr>
<td>IO33</td>
<td></td>
<td></td>
<td></td>
<td>IO33</td>
<td></td>
</tr>
<tr>
<td>IO25</td>
<td>RXD[0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO26</td>
<td>RXD[1]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO27</td>
<td>CRS_DV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO14</td>
<td></td>
<td></td>
<td></td>
<td>IO14</td>
<td></td>
</tr>
<tr>
<td>IO12</td>
<td></td>
<td></td>
<td></td>
<td>IO12</td>
<td></td>
</tr>
<tr>
<td>IO13</td>
<td></td>
<td></td>
<td></td>
<td>IO13</td>
<td></td>
</tr>
<tr>
<td>IO15</td>
<td></td>
<td></td>
<td></td>
<td>IO15</td>
<td></td>
</tr>
<tr>
<td>IO0</td>
<td></td>
<td></td>
<td></td>
<td>IO2</td>
<td>See notes 1 and 3 below</td>
</tr>
<tr>
<td>IO3</td>
<td></td>
<td></td>
<td></td>
<td>IO1</td>
<td>See notes 2 and 3 below</td>
</tr>
<tr>
<td>IO0</td>
<td></td>
<td></td>
<td></td>
<td>IO4</td>
<td>See notes 2 and 3 below</td>
</tr>
<tr>
<td>IO16</td>
<td></td>
<td></td>
<td></td>
<td>IO16</td>
<td>See note 4 below</td>
</tr>
<tr>
<td>IO17</td>
<td></td>
<td></td>
<td></td>
<td>IO17</td>
<td>See note 4 below</td>
</tr>
<tr>
<td>IO5</td>
<td></td>
<td></td>
<td></td>
<td>IO5</td>
<td></td>
</tr>
<tr>
<td>IO18</td>
<td></td>
<td></td>
<td></td>
<td>IO18</td>
<td>MDIO</td>
</tr>
<tr>
<td>IO19</td>
<td></td>
<td></td>
<td></td>
<td>IO19</td>
<td>TXD[0]</td>
</tr>
<tr>
<td>IO21</td>
<td></td>
<td></td>
<td></td>
<td>IO21</td>
<td>TX_EN</td>
</tr>
<tr>
<td>RXD0</td>
<td></td>
<td></td>
<td></td>
<td>RXD</td>
<td></td>
</tr>
<tr>
<td>TXD0</td>
<td></td>
<td></td>
<td></td>
<td>TXD</td>
<td></td>
</tr>
<tr>
<td>IO22</td>
<td></td>
<td></td>
<td></td>
<td>IO22</td>
<td>TXD[1]</td>
</tr>
<tr>
<td>IO23</td>
<td></td>
<td></td>
<td></td>
<td>IO23</td>
<td>MDC</td>
</tr>
</tbody>
</table>

**Note:**

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

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

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

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

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

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

Related Documents

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

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

ESP32-Ethernet-Kit V1.1 Getting Started Guide  This guide shows how to get started with the ESP32-Ethernet-Kit development board and also provides information about its functionality and configuration options.

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

What You Need

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

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

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

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

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

Functionality Overview  The block diagram below shows the main components of ESP32-Ethernet-Kit and their interconnections.
Chapter 1. Get Started

Fig. 32: ESP32-Ethernet-Kit V1.1

Fig. 33: ESP32-Ethernet-Kit block diagram (click to enlarge)
**Functional Description**  The following figures and tables describe the key components, interfaces, and controls of the ESP32-Ethernet-Kit.

![ES32-Ethernet-Kit Ethernet board (A) layout](image-url)

Fig. 34: ESP32-Ethernet-Kit - Ethernet board (A) layout (click to enlarge)

**Ethernet Board (A)**  The table below provides description starting from the picture’s top right corner and going clockwise.
### Chapter 1. Get Started

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

The PoE board (B) has the following features:

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

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

![PoE Board (B) layout](image)

**Fig. 35: ESP32-Ethernet-Kit - PoE board (B) layout (click to enlarge)**

**Table 2: Table PoE board (B)**

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

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

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

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

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

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

**Note:** For additional information on the RMII clock selection, please refer to ESP32-Ethernet-Kit V1.1 Ethernet board (A) schematic, sheet 2, location D2.
**RMII Clock Sourced Externally by PHY**  By default, the ESP32-Ethernet-Kit is configured to provide RMII clock for the IP101GRI PHY’s 50M_CLKO output. The clock signal is generated by the frequency multiplication of 25 MHz crystal connected to the PHY. For details, please see the figure below.

![Fig. 36: RMII Clock from IP101GRI PHY](image)

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

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

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

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

<table>
<thead>
<tr>
<th>RMII Interface</th>
<th>ESP32 Pin (MAC)</th>
<th>IP101GRI (PHY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO21</td>
<td>TX_EN</td>
</tr>
<tr>
<td>2</td>
<td>GPIO19</td>
<td>TXD[0]</td>
</tr>
<tr>
<td>3</td>
<td>GPIO22</td>
<td>TXD[1]</td>
</tr>
<tr>
<td>4</td>
<td>GPIO25</td>
<td>RXD[0]</td>
</tr>
<tr>
<td>5</td>
<td>GPIO26</td>
<td>RXD[1]</td>
</tr>
<tr>
<td>6</td>
<td>GPIO27</td>
<td>CRS_DV</td>
</tr>
<tr>
<td>7</td>
<td>GPIO0</td>
<td>REF_CLK</td>
</tr>
<tr>
<td>8</td>
<td>GPIO23</td>
<td>MDC</td>
</tr>
<tr>
<td>9</td>
<td>GPIO18</td>
<td>MDIO</td>
</tr>
<tr>
<td>PHY Reset</td>
<td>GPIO5</td>
<td>Reset_N</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>.</th>
<th>ESP32 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO32</td>
</tr>
<tr>
<td>2</td>
<td>GPIO33</td>
</tr>
<tr>
<td>3</td>
<td>GPIO34</td>
</tr>
<tr>
<td>4</td>
<td>GPIO35</td>
</tr>
<tr>
<td>5</td>
<td>GPIO36</td>
</tr>
<tr>
<td>6</td>
<td>GPIO39</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>.</th>
<th>ESP32 Pin</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO17</td>
<td>See note 1</td>
</tr>
<tr>
<td>2</td>
<td>GPIO16</td>
<td>See note 1</td>
</tr>
<tr>
<td>3</td>
<td>GPIO4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>GPIO2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>GPIO13</td>
<td>See note 2</td>
</tr>
<tr>
<td>6</td>
<td>GPIO12</td>
<td>See note 2</td>
</tr>
<tr>
<td>7</td>
<td>GPIO15</td>
<td>See note 2</td>
</tr>
<tr>
<td>8</td>
<td>GPIO14</td>
<td>See note 2</td>
</tr>
<tr>
<td>9</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>10</td>
<td>3V3</td>
<td>3.3 V power supply</td>
</tr>
</tbody>
</table>

**Note:**

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

## GPIO Allocation Summary

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

**Note:**

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

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

---

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

**Initial Setup**

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

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

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

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

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

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

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

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

**Related Documents**

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

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

**1.3.5 ESP32-DevKitS(-R)**

This user guide provides information on ESP32-DevKitS(-R), an ESP32-based flashing board produced by Espressif. ESP32-DevKitS(-R) is a combination of two board names: ESP32-DevKitS and ESP32-DevKitS-R. S stands for springs, and R stands for WROVER.
The document consists of the following major sections:

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

**Getting Started**

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

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

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

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

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

For information about above modules, please refer to ESP32 Series Modules.

**Description of Components**
Fig. 38: ESP32-DevKitS - front

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

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

### How to Flash a Board

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

### Required Hardware

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

### Hardware Setup

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

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

### Software Setup

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

**Alternative Method** As an alternative, Windows users can flash binaries using the Flash Download Tool. Just download it, unzip it, and follow the instructions inside the doc folder.

### Note:

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

### Board Dimensions

### Contents and Packaging
Fig. 40: ESP32-DevKitS board dimensions - back

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


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


**Hardware Reference**

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

---

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

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

It is advised to use the first option: micro USB port.

<table>
<thead>
<tr>
<th>Label</th>
<th>Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>3V3</td>
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<tr>
<td>L2</td>
<td>EN</td>
</tr>
<tr>
<td>L3</td>
<td>VP</td>
</tr>
<tr>
<td>L4</td>
<td>VN</td>
</tr>
<tr>
<td>L5</td>
<td>34</td>
</tr>
<tr>
<td>L6</td>
<td>35</td>
</tr>
<tr>
<td>L7</td>
<td>32</td>
</tr>
<tr>
<td>L8</td>
<td>33</td>
</tr>
<tr>
<td>L9</td>
<td>25</td>
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Continued on next page
### Table 3 - continued from previous page

<table>
<thead>
<tr>
<th>Label</th>
<th>Signal</th>
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</thead>
<tbody>
<tr>
<td>L10</td>
<td>GPIO26</td>
</tr>
<tr>
<td>L11</td>
<td>GPIO27</td>
</tr>
<tr>
<td>L12</td>
<td>GPIO14</td>
</tr>
<tr>
<td>L13</td>
<td>GPIO12</td>
</tr>
<tr>
<td>L14</td>
<td>GND</td>
</tr>
<tr>
<td>L15</td>
<td>GPIO13</td>
</tr>
<tr>
<td>L16</td>
<td>SD_DATA2</td>
</tr>
<tr>
<td>L17</td>
<td>SD_DATA3</td>
</tr>
<tr>
<td>L18</td>
<td>SD_CMD</td>
</tr>
<tr>
<td>L19</td>
<td>External 5V</td>
</tr>
<tr>
<td>R1</td>
<td>GND</td>
</tr>
<tr>
<td>R2</td>
<td>GPIO23</td>
</tr>
<tr>
<td>R3</td>
<td>GPIO22</td>
</tr>
<tr>
<td>R4</td>
<td>U0_TXD</td>
</tr>
<tr>
<td>R5</td>
<td>U0_RXD</td>
</tr>
<tr>
<td>R6</td>
<td>GPIO21</td>
</tr>
<tr>
<td>R7</td>
<td>GND</td>
</tr>
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<td>R8</td>
<td>GPIO19</td>
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<tr>
<td>R9</td>
<td>GPIO18</td>
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<td>R10</td>
<td>GPIO5</td>
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<td>R11</td>
<td>GPIO17</td>
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<td>R12</td>
<td>GPIO16</td>
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<td>GPIO2</td>
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<td>R16</td>
<td>GPIO15</td>
</tr>
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<td>R17</td>
<td>SD_DATA1</td>
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<tr>
<td>R18</td>
<td>SD_DATA0</td>
</tr>
<tr>
<td>R19</td>
<td>SD_CLK</td>
</tr>
</tbody>
</table>

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

**Related Documents**

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

### 1.3.6 ESP32-PICO-KIT-1

**Overview**

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

The core of this board is ESP32-PICO-V3 - a System-in-Package (SiP) module with complete Wi-Fi and Bluetooth functionalities. Compared to other ESP32 modules, ESP32-PICO-V3 integrates the following peripheral components in one single package, which otherwise would need to be installed separately:

- 40 MHz crystal oscillator
Chapter 1. Get Started

- 4 MB flash
- Filter capacitors
- RF matching network

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

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

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

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

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

This guide covers:

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

**Getting Started**

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

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

Below is the description of the items identified in the figure starting from the top left corner and going clockwise.
Fig. 43: ESP32-PICO-KIT-1 Overview (click to enlarge)
### Key Components

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

### Start Application Development

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

### Required Hardware

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

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

**Contents and Packaging**

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


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


**Hardware Reference**

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

![Fig. 45: ESP32-PICO-KIT-1 Block Diagram (click to enlarge)](image)

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

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

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

**Pin Descriptions**  The two tables below provide the **Name** and **Function** of I/O header pins on both sides of the board, see *Description of Components*. The pin numbering and header names are the same as in the schematic given in *Related Documents*. 
## Header J2

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IO20</td>
<td>I/O</td>
<td>GPIO20</td>
</tr>
<tr>
<td>2</td>
<td>IO21</td>
<td>I/O</td>
<td>GPIO21, VSPIHD, EMAC_TX_EN</td>
</tr>
<tr>
<td>3</td>
<td>IO22</td>
<td>I/O</td>
<td>GPIO22, VSPIWP, U0RTS, EMAC_TXD1</td>
</tr>
<tr>
<td>4</td>
<td>IO19</td>
<td>I/O</td>
<td>GPIO19, VSPIQ, U0CTS, EMAC_TXD0</td>
</tr>
<tr>
<td>5</td>
<td>IO8</td>
<td>I/O</td>
<td>GPIO8, SD_DATA1, HS1_DATA1, U2CTS</td>
</tr>
<tr>
<td>6</td>
<td>IO7</td>
<td>I/O</td>
<td>GPIO7, SD_DATA0, HS1_DATA0, U2RTS</td>
</tr>
<tr>
<td>7</td>
<td>IO5</td>
<td>I/O</td>
<td>GPIO5, VSPI0, HS1_DATA6, EMAC_RX_CLK</td>
</tr>
<tr>
<td>8</td>
<td>IO10</td>
<td>I/O</td>
<td>GPIO10, SD_DATA3, SPIWP, HS1_DATA3, U1TXTD</td>
</tr>
<tr>
<td>9</td>
<td>IO9</td>
<td>I/O</td>
<td>GPIO9, SD_DATA2, SPIHD, HS1_DATA2, U1RXD</td>
</tr>
<tr>
<td>10</td>
<td>RXD0</td>
<td>I/O</td>
<td>GPIO3, U0RXD, (See 1), CLK_OUT2</td>
</tr>
<tr>
<td>11</td>
<td>TXD0</td>
<td>I/O</td>
<td>GPIO1, U0TXD, (See 1), CLK_OUT3, EMAC_RXD2</td>
</tr>
<tr>
<td>12</td>
<td>IO35</td>
<td>I</td>
<td>ADC1_CH7, RTC_GPIO7</td>
</tr>
<tr>
<td>13</td>
<td>IO34</td>
<td>I</td>
<td>ADC1_CH6, RTC_GPIO4</td>
</tr>
<tr>
<td>14</td>
<td>IO38</td>
<td>I</td>
<td>GPIO38, ADC1_CH2, RTC_GPIO2</td>
</tr>
<tr>
<td>15</td>
<td>IO37</td>
<td>I</td>
<td>GPIO37, ADC1_CH1, RTC_GPIO1</td>
</tr>
<tr>
<td>16</td>
<td>EN</td>
<td>I</td>
<td>CHIP_PU</td>
</tr>
<tr>
<td>17</td>
<td>GND</td>
<td>P</td>
<td>Ground</td>
</tr>
<tr>
<td>18</td>
<td>VDD33 (3V3)</td>
<td>P</td>
<td>3.3 V power supply</td>
</tr>
</tbody>
</table>

## Header J3

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

The following notes give more information about the items in the tables above.
1. This pin is connected to the pin of the USB bridge chip on the board.

2. 32.768 kHz crystal oscillator: a) input b) output

3. The operating voltage of ESP32-PICO-KIT-1’s embedded SPI flash is 3.3 V. Therefore, the strapping pin MTDI should be pulled down during the module power-on reset. If connected, please make sure that this pin is not held up on reset.

Fig. 46: ESP32-PICO-KIT-1 Pin Layout (click to enlarge)

Pin Layout

Hardware Revision Details

No previous versions available.

Related Documents

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

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

1.3.7 ESP32-PICO-DevKitM-2

Overview

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

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

All the IO signals and system power on ESP32-PICO-MINI-02(02U) are led out to two rows of 18 x 0.1” header pads on both sides of the development board for easy access. For compatibility with Dupont wires, all header pads are populated with two rows of male pin headers.
Note: ESP32-PICO-DevKitM-2 comes with male headers by default.

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

Getting Started

This section describes how to get started with the ESP32-PICO-DevKitM-2. It begins with a few introductory sections about the ESP32-PICO-DevKitM-2, then Section Start Application Development provides instructions on how to flash firmware onto the ESP32-PICO-DevKitM-2.

Description of Components  The following figure and the table below describe the key components, interfaces, and controls of the ESP32-PICO-DevKitM-2 board. We take the board with a ESP32-PICO-MINI-02 module as an example in the following sections.

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

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

**Required Hardware**
- 1 x ESP32-PICO-DevKitM-2
- 1 x USB 2.0 A to Micro B cable
- 1 x Computer running Windows, Linux, or macOS
Chapter 1. Get Started

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

**Contents and Packaging**

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


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


**Hardware Reference**

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

![ESP32-PICO-DevKitM-2 Block Diagram](image)

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

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

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

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

**Pin Descriptions** The two tables below provide the **Name** and **Function** of I/O header pins on both sides of the board, see *Description of Components*. The pin numbering and header names are the same as in the schematic given in *Related Documents*. 
### Header J2

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

### Header J3

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

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

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

Pin Layout

Hardware Revision Details

No previous versions available.

Related Documents

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

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

1.3.8 ESP32-DevKitM-1

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

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

**Getting Started**

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

**Overview**

This is a small and convenient development board that features:

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

**Contents and Packaging**

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


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


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

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

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

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

**Attention:** ESP32-DevKitM-1 is a board with a single core module, please enable single core mode (`CONFIG_FREERTOS_UNICORE`) in `menuconfig` before flashing your applications.

**Hardware Reference**

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

![ESP32-DevKitM-1 Block Diagram](image)

**Fig. 52: ESP32-DevKitM-1**

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

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

**Warning:**

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

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

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND</td>
<td>P</td>
<td>Ground</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>I36</td>
<td>I</td>
<td>GPIO36, ADC1_CH0, RTC_GPIO0</td>
</tr>
<tr>
<td>4</td>
<td>I37</td>
<td>I</td>
<td>GPIO37, ADC1_CH1, RTC_GPIO1</td>
</tr>
</tbody>
</table>

Continued on next page
<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>I38</td>
<td>I</td>
<td>GPIO38, ADC1_CH2, RTC_GPIO2</td>
</tr>
<tr>
<td>6</td>
<td>I39</td>
<td>I</td>
<td>GPIO39, ADC1_CH3, RTC_GPIO3</td>
</tr>
<tr>
<td>7</td>
<td>RST</td>
<td>I</td>
<td>Reset; High: enable; Low: powers off</td>
</tr>
<tr>
<td>8</td>
<td>I34</td>
<td>I</td>
<td>GPIO34, ADC1_CH6, RTC_GPIO4</td>
</tr>
<tr>
<td>9</td>
<td>I35</td>
<td>I</td>
<td>GPIO35, ADC1_CH7, RTC_GPIO5</td>
</tr>
<tr>
<td>10</td>
<td>IO32</td>
<td>I/O</td>
<td>GPIO32, XTAL_32K_P (32.768 kHz crystal oscillator input), ADC1_CH5, TOUCH9, RTC_GPIO9</td>
</tr>
<tr>
<td>11</td>
<td>IO33</td>
<td>I/O</td>
<td>GPIO33, XTAL_32K_N (32.768 kHz crystal oscillator output), ADC1_CH5, TOUCH8, RTC_GPIO8</td>
</tr>
<tr>
<td>12</td>
<td>IO25</td>
<td>I/O</td>
<td>GPIO25, DAC_1, ADC2_CH8, RTC_GPIO6, EMAC_RXD0</td>
</tr>
<tr>
<td>13</td>
<td>IO26</td>
<td>I/O</td>
<td>GPIO26, DAC_2, ADC2_CH9, RTC_GPIO7, EMAC_RXD1</td>
</tr>
<tr>
<td>14</td>
<td>IO27</td>
<td>I/O</td>
<td>GPIO27, ADC2_CH7, TOUCH7, RTC_GPIO17, EMAC_RXDV</td>
</tr>
<tr>
<td>15</td>
<td>IO14</td>
<td>I/O</td>
<td>GPIO14, ADC2_CH6, TOUCH6, RTC_GPIO16, MTMS, HSPICLK, HS2_CLK, SD_CLK, EMAC_TXD2</td>
</tr>
<tr>
<td>16</td>
<td>5V</td>
<td>P</td>
<td>5 V power supply</td>
</tr>
<tr>
<td>17</td>
<td>IO12</td>
<td>I/O</td>
<td>GPIO12, ADC2_CH5, TOUCH5, RTC_GPIO15, MTDI, HSPIQ, HS2_DATA2, SD_DATA2, EMAC_TXD3</td>
</tr>
<tr>
<td>18</td>
<td>IO13</td>
<td>I/O</td>
<td>GPIO13, ADC2_CH4, TOUCH4, RTC_GPIO14, MTCK, HSPID, HS2_DATA3, SD_DATA3, EMAC_RX_ER</td>
</tr>
<tr>
<td>19</td>
<td>IO15</td>
<td>I/O</td>
<td>GPIO15, ADC2_CH3, TOUCH3, RTC_GPIO13, MTDO, HSPICS0, HS2_CMD, SD_CMD, EMAC_RXD3</td>
</tr>
<tr>
<td>20</td>
<td>IO2</td>
<td>I/O</td>
<td>GPIO2, ADC2_CH2, TOUCH2, RTC_GPIO12, HSPIWP, HS2_DATA0, SD_DATA0</td>
</tr>
<tr>
<td>21</td>
<td>IO0</td>
<td>I/O</td>
<td>GPIO0, ADC2_CH1, TOUCH1, RTC_GPIO11, CLK_OUT1, EMAC_TX_CLK</td>
</tr>
<tr>
<td>22</td>
<td>IO4</td>
<td>I/O</td>
<td>GPIO4, ADC2_CH0, TOUCH0, RTC_GPIO10, HSPIHD, HS2_DATA1, SD_DATA1, EMAC_TX_ER</td>
</tr>
<tr>
<td>23</td>
<td>IO9</td>
<td>I/O</td>
<td>GPIO9, HS1_DATA2, U1RXD, SD_DATA2</td>
</tr>
<tr>
<td>24</td>
<td>IO10</td>
<td>I/O</td>
<td>GPIO10, HS1_DATA3, U1TXD, SD_DATA3</td>
</tr>
<tr>
<td>25</td>
<td>IO5</td>
<td>I/O</td>
<td>GPIO5, HS1_DATA6, VSPICS0, EMAC_RX_CLK</td>
</tr>
<tr>
<td>26</td>
<td>IO18</td>
<td>I/O</td>
<td>GPIO18, HS1_DATA7, VSPICLK</td>
</tr>
<tr>
<td>27</td>
<td>IO23</td>
<td>I/O</td>
<td>GPIO23, HS1_STROBE, VSPID</td>
</tr>
<tr>
<td>28</td>
<td>IO19</td>
<td>I/O</td>
<td>GPIO19, VSPIQ, U0CTS, EMAC_TXD0</td>
</tr>
<tr>
<td>29</td>
<td>IO22</td>
<td>I/O</td>
<td>GPIO22, VSPIPQ, U0RTS, EMAC_TXD1</td>
</tr>
<tr>
<td>30</td>
<td>IO21</td>
<td>I/O</td>
<td>GPIO21, VSPIQHD, EMAC_TX_EN</td>
</tr>
<tr>
<td>31</td>
<td>TXD0</td>
<td>I/O</td>
<td>GPIO1, U0TXD, CLK_OUT3, EMAC_RXD2</td>
</tr>
<tr>
<td>32</td>
<td>RXD0</td>
<td>I/O</td>
<td>GPIO3, U0RXD, CLK_OUT2</td>
</tr>
</tbody>
</table>

**Hardware Revision Details**

No previous versions available.

**Related Documents**

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

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

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

1.4.1 Setting up Development Environment

- Step 1. Install prerequisites for Windows, Linux, or macOS
- Step 2. Get ESP-IDF
- Step 3. Set up the tools
- Step 4. Set up the environment variables

1.4.2 Creating Your First Project

- Step 5. Start a Project
- Step 6. Connect Your Device
- Step 7. Configure
- Step 8. Build the Project
- Step 9. Flash onto the Device
- Step 10. Monitor

1.5 Step 1. Install prerequisites

Some tools need to be installed on the computer before proceeding to the next steps. Follow the links below for the instructions for your OS:

1.5.1 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 from this URL: https://dl.espressif.com/dl/esp-idf/?idf=4.4
Chapter 1. Get Started

What is the use case for Online and Offline Installer

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

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

Components of the installation

The installer deploys the following components:

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

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

Launching ESP-IDF Environment

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

Run ESP-IDF PowerShell Environment:

Fig. 53: Completing the ESP-IDF Tools Setup Wizard with Run ESP-IDF PowerShell Environment

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

Fig. 54: ESP-IDF PowerShell

Fig. 55: Completing the ESP-IDF Tools Setup Wizard with Run ESP-IDF Command Prompt (cmd.exe)
Chapter 1. Get Started

Fig. 56: ESP-IDF Command Prompt

Using Python in C:\Users\test\AppData\Local\Programs\Python\Python37\Python 3.7.8
Using Git in C:\Users\test\Git\cmd\git version 2.30.8.windows.1
Setting IDF_PATH: C:\Users\test\esp\esp-idf

Adding ESP-IDF tools to PATH...
C:\Users\test\esp\idf\tools\xtensa-esp32-elf\esp-2020r3-8.4.0\xtensa-esp32-elf\bin
C:\Users\test\esp\idf\tools\xtensa-esp32s2-elf\esp-2020r3-8.4.0\xtensa-esp32s2-elf\bin
C:\Users\test\esp\idf\tools\xtensa-esp32s3-elf\esp-2020r3-8.4.0\xtensa-esp32s3-elf\bin
C:\Users\test\esp\idf\tools\riscv32-esp-elf\1.24.0.123_64eb9ff-8.4.0\riscv32-esp-elf\bin
C:\Users\test\esp\idf\tools\esp32ulp-elf\2.28.51-esp-20191205\esp32ulp-elf\bin
C:\Users\test\esp\idf\tools\esp32ulp-binfmt\bin
C:\Users\test\esp\idf\tools\cmake\3.16.4\bin
C:\Users\test\esp\idf\tools\openocd-esp32\v0.10.0-esp32-20200709\openocd-esp32\bin
C:\Users\test\esp\idf\tools\ninja\1.10.0\nC:\Users\test\esp\idf\tools\idf-exe\1.0.1\nC:\Users\test\esp\idf\tools\ccache\3.7\nC:\Users\test\esp\idf\tools\dfu-util\0.9\dfu-util-0.9-win64
C:\Users\test\esp\idf\tools\python_env\idf4.5_py3.7_env\Scripts\C:\Users\test\esp\idf\tools

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

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

idf.py build

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

Next Steps

If the ESP-IDF Tools Installer has finished successfully, then the development environment setup is complete. Proceed directly to Step 5. Start a Project.

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:

```
install.bat
```

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

```
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:

```
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:
Chapter 1. Get Started

```bash
cd ~/esp/esp-idf
export.ps1
```

When this is done, the tools will be available in this command prompt.

### 1.5.2 Standard Setup of Toolchain for Linux

#### Install Prerequisites

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

- **Ubuntu and Debian:**
  ```bash
  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.
  ```

- **CentOS 7 & 8:**
  ```bash
  sudo yum -y update && sudo yum install git wget flex bison gperf python3 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:**
  ```bash
  sudo pacman -S --needed gcc git make flex bison gperf python-pip cmake ninja-build 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.

#### Additional Tips

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

**Python compatibility**

ESP-IDF supports Python 3.6 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`.

#### Next Steps

To carry on with development environment setup, proceed to *Step 2. Get ESP-IDF*. 

---

This content is from the official ESP-IDF documentation. Espressif Systems 98 Release v5.0-dev-1077-g397639d

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1.5.3 Standard Setup of Toolchain for Mac OS

Install Prerequisites

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

- install pip:
  ```shell
sudo easy_install pip
  ```

- install CMake & Ninja build:
  - If you have HomeBrew, you can run:
    ```shell
    brew install cmake ninja dfu-util
    ```
  - If you have MacPorts, you can run:
    ```shell
    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:

```shell
```

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

## Installing Python 3

Basing 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:

```shell
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:

```shell
python3 --version
```

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

Below is an overview of steps to install Python 3.

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

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

Next Steps

To carry on with development environment setup, proceed to Step 2. Get ESP-IDF.
1.6 Step 2. Get ESP-IDF

To build applications for the ESP32, you need the software libraries provided by Espressif in ESP-IDF repository. To get ESP-IDF, navigate to your installation directory and clone the repository with `git clone`, following instructions below specific to your operating system.

1.6.1 Linux and macOS

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.

1.6.2 Windows

In addition to installing the tools, ESP-IDF Tools Installer for Windows introduced in Step 1 can also download a copy of ESP-IDF.

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

If you wish to download ESP-IDF without the help of ESP-IDF Tools Installer, refer to these instructions.

1.7 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.
Chapter 1. Get Started

1.7.1 Windows

*ESP-IDF Tools Installer* for Windows introduced in Step 1 installs all the required tools.

If you want to install the tools without the help of ESP-IDF Tools Installer, open the Command Prompt and follow these steps:

```
cd %userprofile%\esp\esp-idf
install.bat esp32
```

or with Windows PowerShell

```
cd ~/esp/esp-idf
./install.ps1 esp32
```

1.7.2 Linux and macOS

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

or with Fish shell

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

**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 or use ./install.sh all.
```

1.7.3 Alternative File Downloads

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

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

**Windows**

To prefer the Espressif download server when running the ESP-IDF Tools Installer, mark the *Use Espressif download mirror instead of GitHub* in the screen *Select Components* section *Optimization*.

**Linux and macOS**

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
```
1.7.4 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 and macOS, %USERPROFILE%\espressif on Windows. 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.

1.8 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.

1.8.1 Windows

ESP-IDF Tools Installer for Windows creates an “ESP-IDF Command Prompt” shortcut in the Start Menu. This shortcut opens the Command Prompt and sets up all the required environment variables. You can open this shortcut and proceed to the next step.

Alternatively, if you want to use ESP-IDF in an existing Command Prompt window, you can run:

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

or with Windows PowerShell

```
.$HOME/esp/esp-idf/export.ps1
```

1.8.2 Linux and macOS

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.
1.9  Step 5. Start a Project

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

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

1.9.1 Linux and macOS

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

1.9.2 Windows

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

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.

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

1.10  Step 6. Connect Your Device

Now connect your ESP32 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* for full details.

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

1.11  Step 7. Configure

Navigate to your hello_world directory from Step 5. Start a Project, set ESP32 chip as the target and run the project configuration utility menuconfig.

1.11.1 Linux and macOS

```bash
cd ~/esp/hello_world
idf.py set-target esp32
idf.py menuconfig
```
1.11.2 Windows

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

Setting the target with `idf.py set-target esp32` should be done once, after opening a new project. If the project contains some existing builds and configuration, they will be cleared and initialized. The target may be saved in 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:

![Fig. 57: Project configuration - Home window](image)

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

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

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

1.12 Step 8. 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.
Chapter 1. Get Started

$ 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 0x1000 build/bootloader/bootloader.bin 0x8000 build/partition_table/
--partition-table.bin
or run 'idf.py -p PORT flash'

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

1.13 Step 9. Flash onto the Device

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

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

Replace PORT with your ESP32 board’s serial port name from Step 6. Connect Your Device.

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.

1.13.1 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 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). The DTR and RTS control lines are in turn connected to GPIO0 and CHIP_PU (EN) pins of ESP32, thus changes in the voltage levels of DTR and RTS will boot ESP32 into Firmware Download mode. As an example, check the schematic for the ESP32 DevKitC development board.

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

- Your hardware does not have the DTR and RTS lines connected to GPIO0 and CHIP_PU
- The DTR and RTS lines are configured differently
- There are no such serial control lines at all
Depending on the kind of hardware you have, it may also be possible to manually put your ESP32 board into Firmware Download mode (reset).

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

### 1.13.2 Normal Operation

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

```plaintext
... esptool.py --chip esp32 -p /dev/ttyUSB0 -b 460800 --before=default_reset --
   --after=hard_reset write_flash --flash_mode dio --flash_freq 40m --flash_size 2MB--
   --0x8000 partition_table/partition-table.bin 0x1000 bootloader/bootloader.bin--
   --0x10000 hello_world.bin
esptool.py v3.0-dev
Serial port /dev/ttyUSB0
Connecting........
Chip is ESP32D0WDQ6 (revision 0)
Features: WiFi, BT, Dual Core, Coding Scheme None
Crystal is 40MHz
MAC: 24:0a:c4:05:b9:14
Uploading stub...
Running stub...
Stub running...
Changing baud rate to 460800
Changed.
Configuring flash size...
Compressed 3072 bytes to 103...
Writing at 0x00008000... (100 %)
Wrote 3072 bytes (103 compressed) at 0x00008000 in 0.0 seconds (effective 5962.8...
   --kbit/s)... 
Hash of data verified.
Compressed 26096 bytes to 15408...
Writing at 0x00001000... (100 %)
Wrote 26096 bytes (15408 compressed) at 0x00001000 in 0.4 seconds (effective 546.7...
   --kbit/s)... 
Hash of data verified.
Compressed 147104 bytes to 77364...
Writing at 0x00010000... (20 %)
Writing at 0x00014000... (40 %)
Writing at 0x00018000... (60 %)
Writing at 0x0001c000... (80 %)
Writing at 0x00020000... (100 %)
Wrote 147104 bytes (77364 compressed) at 0x00010000 in 1.9 seconds (effective 615.
   --5 kbit/s)... 
Hash of data verified.
Leaving...
Hard resetting via RTS pin...
Done
```

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

If you’d like to use the Eclipse or VS Code IDE instead of running `idf.py`, check out the [Eclipse guide](#) and the [VS Code guide](#).
Chapter 1. Get Started

1.14 Step 10. Monitor

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 /dev/ttyUSB0 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 /dev/ttyUSB0 115200 ---
--- Quit: Ctrl+] | Menu: Ctrl+T | Help: Ctrl+T followed by Ctrl+H ---
```

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

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

To exit IDF monitor use the shortcut Ctrl+] .

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

```
c600|Xn@y.!60(^Pw+)|60|Hn9a^-/90|0t566P8-6k60c6ea650jA
~zY66Y(10,160 c600)Xn@y.!Dr@zY(0 jpi9}@z5Ymp
```

If you have such a problem, do the following:

1. Exit the monitor.
2. Go back to `menuconfig`.
3. Go to Component config -> ESP32-specific -> Main XTAL frequency, then change `CONFIG_ESP32_XTAL_FREQ_SEL` to 26 MHz.
4. After that, build and flash the application again.

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

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

See also:

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

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

Now you are ready to try some other examples, or go straight to developing your own applications.
Chapter 1. Get Started

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

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

### 1.15 Updating ESP-IDF

You should update ESP-IDF from time to time, as newer versions fix bugs and provide new features. 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.*

### 1.16 Related Documents

#### 1.16.1 Establish Serial Connection with ESP32

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

**Connect ESP32 to PC**

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

Below is the list of USB to serial converter chips installed on most of the ESP32 boards produced by Espressif together with links to the drivers:

- CP210x: [CP210x USB to UART Bridge VCP Drivers](#)
- FTDI: [FTDI Virtual COM Port Drivers](#)

Please check the board user guide for specific USB to 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 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
Fig. 58: USB to UART bridge of ESP32-DevKitC in Windows Device Manager
Fig. 59: Two USB Serial Ports of ESP-WROVER-KIT in Windows Device Manager
Chapter 1. Get Started

Check port on Linux and macOS

To check the device name for the serial port of your ESP32 board (or external converter dongle), run this command two times, first with the board / dongle unplugged, then with plugged in. The port which appears the second time is the one you need:

**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 to the serial port over USB. On most Linux distributions, this is done by adding the user to `dialout` group with the following command:

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

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

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

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

Verify serial connection

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

**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. The log contents will depend on application loaded to ESP32, see Example Output.

**Note:** Close the serial terminal after verification that communication is working. If you keep the terminal session open, the serial port will be inaccessible for uploading firmware later.
Fig. 60: Setting Serial Communication in PuTTY on Windows
Fig. 61: Setting Serial Communication in PuTTY on Linux
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:

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

- You should see similar output:

  ```
  /dev/cu.Bluetooth-Incoming-Port /dev/cu.SLAB_USBtoUART  /dev/cu.SLAB_USBtoUART
  ```

- 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:

  ```bash
  screen /dev/cu.device_name 115200
  ```

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

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

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

### Example Output

An example log by ESP32 is shown below. Reset the board if you do not see anything.

```plaintext
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 firmware to ESP32.

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

If you got here from Step 6. Connect Your Device when installing s/w for ESP32 development, then you can continue with Step 7. Configure.

### 1.16.2 Build and Flash with Eclipse IDE

ESP-IDF V4.0 has a new CMake-based build system as the default build system.
Chapter 1. Get Started

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.

1.16.3 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.

1.16.4 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.

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

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

## IDF-specific features

**Automatic Address Decoding** Whenever 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:
Guru Meditation Error of type StoreProhibited occurred on core 0. Exception was unhandled.

Register dump:
PC : 0x400f360d PS : 0x00060330 A0 : 0x800dbf56 A1 : ...
A2 : 0x3fffb136c A3 : 0x00000005 A4 : 0x00000000 A5 : ...
A6 : 0x00000000 A7 : 0x00000080 A8 : 0x00000000 A9 : ...
A10 : 0x00000003 A11 : 0x00060f23 A12 : 0x00060f20 A13 : ...
A14 : 0x40000047 A15 : 0x0000000f SAR : 0x00000019 EXCCAUSE: ...
EXCVADDR: 0x00000000 LBEG : 0x4000c46c LEND : 0x4000c477 LCOUNT : ...

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

IDF Monitor adds more details to the dump:
Guru Meditation Error of type StoreProhibited occurred on core 0. Exception was unhandled.

Register dump:
PC : 0x400f360d PS : 0x00060330 A0 : 0x800dbf56 A1 : ...
A2 : 0x3fffb136c A3 : 0x00000005 A4 : 0x00000000 A5 : ...
A6 : 0x00000000 A7 : 0x00000080 A8 : 0x00000000 A9 : ...
A10 : 0x00000003 A11 : 0x00060f23 A12 : 0x00060f20 A13 : ...
A14 : 0x40000047 A15 : 0x0000000f SAR : 0x00000019 EXCCAUSE: ...
EXCVADDR: 0x00000000 LBEG : 0x4000c46c LEND : 0x4000c477 LCOUNT : ...

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

To decode each address, IDF Monitor runs the following command in the background:
```
xtensa-esp32-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:

```
xpenta-esp32-elf-gdb -ex "set serial baud BAUD" -ex "target remote PORT" -ex_
--interrupt build/PROJECT.elf :idf_target: 'Hello NAME chip'
```

Output Filtering  IDF monitor can be invoked as idf.py monitor --print-filter="xyz", where --print-filter is the parameter for output filtering. The default value is an empty string, which means that everything is printed.

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

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

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

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

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

Examples Of Filtering Rules:

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

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

```
load:0x40078000,len:13564
entry 0x40078d4c
E (31) esp_image: image at 0x30000 has invalid magic byte
W (31) esp_image: image at 0x30000 has invalid SPI mode 255
E (39) boot: Factory app partition is not bootable
I (568) cpu_start: 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.

1.16.5 Customized Setup of Toolchain

Instead of downloading binary toolchain from Espressif website (see Step 3. Set up the tools) you may build the toolchain yourself.

If you can’t think of a reason why you need to build it yourself, then probably it’s better to stick with the binary version. However, here are some of the reasons why you might want to compile it from source:

• if you want to customize toolchain build configuration
• if you want to use a different GCC version (such as 4.8.5)
• if you want to hack gcc or newlib or libstdc++
• if you are curious and/or have time to spare
• if you don’t trust binaries downloaded from the Internet

In any case, here are the instructions to compile the toolchain yourself.
Setup Windows Toolchain from Scratch

This is a step-by-step alternative to running the ESP-IDF Tools Installer for the CMake-based build system. Installing all of the tools by hand allows more control over the process, and also provides the information for advanced users to customize the install.

To quickly setup the toolchain and other tools in standard way, using the ESP-IDF Tools installer, proceed to section Standard Setup of Toolchain for Windows.

Get ESP-IDF

**Note:** Previous versions of ESP-IDF used the MSYS2 bash terminal command line. The current cmake-based build system can run in the regular Windows Command Prompt which is used here.

If you use PowerShell, please note that some command syntax will be different to what is shown below.

Open Command Prompt and run the following commands:

```
mkdir %userprofile%\esp
cd %userprofile%\esp
git clone --recursive https://github.com/espressif/esp-idf.git
```

ESP-IDF will be downloaded into %userprofile%\esp\esp-idf.

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

**Note:** This command will clone the master branch, which has the latest development (“bleeding edge”) version of ESP-IDF. It is fully functional and updated on weekly basis with the most recent features and bugfixes.

**Note:** GitHub’s “Download zip file” feature does not work with ESP-IDF, a git clone is required. As a fallback, Stable version can be installed without Git.

**Note:** Do not miss the --recursive option. If you have already cloned ESP-IDF without this option, run another command to get all the submodules:

```
cd esp-idf
git submodule update --init
```

Tools

**CMake**  Download the latest stable release of CMake for Windows and run the installer.

When the installer asks for Install Options, choose either “Add CMake to the system PATH for all users” or “Add CMake to the system PATH for the current user”.

**Ninja build**  

**Note:** Ninja currently only provides binaries for 64-bit Windows.

Download the Ninja latest stable Windows release from the (download page).

The Ninja for Windows download is a .zip file containing a single ninja.exe file which needs to be unzipped to a directory which is then added to your Path (or you can choose a directory which is already on your Path).
Chapter 1. Get Started

Python  Download the latest Python for Windows installer, and run it.

The “Customise” step of the Python installer gives a list of options. The last option is “Add python.exe to Path”. Change this option to select “Will be installed”.

Once Python is installed, open a Windows Command Prompt from the Start menu and run the following command:

```
pip install --user pyserial
```

Toolchain Setup  Download the precompiled Windows toolchain:


Unzip the file to C:\Program Files (or some other location). The zip file contains a single directory xtensa-esp32-elf.

Next, the bin subdirectory of this directory must be added to your Path. For example, the directory to add may be C:\Program Files\xtensa-esp32-elf\bin.

Adding Directory to Path  To add any new directory to your Windows Path environment variable:

Open the System control panel and navigate to the Environment Variables dialog. (On Windows 10, this is found under Advanced System Settings).

Double-click the Path variable (either User or System Path, depending if you want other users to have this directory on their path.) Go to the end of the value, and append ;<new value>.

Next Steps  To carry on with development environment setup, proceed to Step 3. Set up the tools.

Setup Linux Toolchain from Scratch

The following instructions are alternative to downloading binary toolchain from Espressif website. To quickly setup the binary toolchain, instead of compiling it yourself, backup and proceed to section Standard Setup of Toolchain for Linux.

Note: The reason you might need to build your own toolchain is to solve the Y2K38 problem (time_t expand to 64 bits instead of 32 bits).

Install Prerequisites  To compile with ESP-IDF you need to get the following packages:

- CentOS 7:

  ```
sudo yum -y update && sudo yum install git wget ncurses-devel flex bison gperf˓
  --python3 python3-pip cmake ninja-build ccache dfu-util libusbx
  
  CentOS 7 is still supported but CentOS version 8 is recommended for a better user experience.

- Ubuntu and Debian:

  ```
sudo apt-get install git wget libncurses-dev flex bison gperf python3 python3-˓
  --pip python3-setuptools python3-serial python3-cryptography python3-future˓
  --python3-pyparsing python3-pyelftools cmake ninja-build ccache libffi-dev˓
  --libssl-dev dfu-util libusb-1.0-0
  
- Arch:

  ```
sudo pacman -Sy --needed gcc git make ncurses flex bison gperf python-pyserial˓
  --python-cryptography python-future python-pyparsing python-pyelftools cmake˓
  --ninja ccache dfu-util libusb
  ```

Espressif Systems 121  Release v5.0-dev-1077-g397639d

Submit Document Feedback
Chapter 1. Get Started

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”.

Compile the Toolchain from Source

- Install dependencies:
  - CentOS 7:
    ```bash
    sudo yum install gawk gperf grep gettext ncurses-devel python3 python3-devel autowake bison flex texinfo help2man libtool make
    ```
  - Ubuntu pre-16.04:
    ```bash
    sudo apt-get install gawk gperf grep gettext libncurses-dev python python-dev, automake bison flex texinfo help2man libtool make
    ```
  - Ubuntu 16.04 or newer:
    ```bash
    sudo apt-get install gawk gperf grep gettext libncurses-dev python python-dev, automake bison flex texinfo help2man libtool libtool-bin make
    ```
  - Debian 9:
    ```bash
    sudo apt-get install gawk gperf grep gettext libncurses-dev python python-dev, automake bison flex texinfo help2man libtool libtool-bin make
    ```
  - Arch:
    ```bash
    sudo pacman -Sy --needed python-pip
    ```

Create the working directory and go into it:

```bash
mkdir -p ~/esp
cd ~/esp
```

Download crosstool-NG and build it:

```bash
git clone https://github.com/espressif/crosstool-NG.git
cd crosstool-NG
git checkout esp-2021r2
git submodule update --init
./bootstrap && ./configure --enable-local && make
```

Note: To create a toolchain with support for 64-bit time_t, you need to remove the `--enable-newlib-long-time_t` option from the crosstool-NG/samples/xtensa-esp32-elf/crosstool.config file in 33 and 43 lines.

Build the toolchain:

```bash
./ct-ng xtensa-esp32-elf
./ct-ng build
chmod -R u+w builds/xtensa-esp32-elf
```

Toolchain will be built in `~/esp/crosstool-NG/builds/xtensa-esp32-elf`.

Add Toolchain to PATH  The custom toolchain needs to be copied to a binary directory and added to the PATH. Choose a directory, for example `~/esp/xtensa-esp32-elf/`, and copy the build output to this directory.

To use it, you will need to update your PATH environment variable in `~/.profile` file. To make `xtensa-esp32-elf` available for all terminal sessions, add the following line to your `~/.profile` file:
export PATH="$HOME/esp/xtensa-esp32-elf/bin:$PATH"

**Note:** If you have /bin/bash set as login shell, and both .bash_profile and .profile exist, then update .bash_profile instead. In CentOS, alias should set in .bashrc.

Log off and log in back to make the .profile changes effective. Run the following command to verify if PATH is correctly set:

```
printenv PATH
```

You are looking for similar result containing toolchain’s path at the beginning of displayed string:

```
$ printenv PATH
/home/user-name/esp/xtensa-esp32-elf/bin:/home/user-name/bin:/home/user-name/.local/bin:/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin:/usr/games:/usr/local/games:/snap/bin
```

Instead of /home/user-name there should be a home path specific to your installation.

**Next Steps**  
To carry on with development environment setup, proceed to *Step 2. Get ESP-IDF*.

**Setup Toolchain for Mac OS from Scratch**

**Package Manager**  
To set up the toolchain from scratch, rather than downloading a pre-compiled toolchain, you will need to install either the MacPorts or Homebrew package manager.

MacPorts needs a full XCode installation, while Homebrew only needs XCode command line tools.

See *Customized Setup of Toolchain* section for some of the reasons why installing the toolchain from scratch may be necessary.

**Install Prerequisites**

- install pip:
  ```
sudo easy_install pip
  ```

- install pyserial:
  ```
  pip install --user pyserial
  ```

- 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
    ```

**Compile the Toolchain from Source**  
Install dependencies:

- with MacPorts:
  ```
sudo port install gsed gawk binutils gperf grep gettext wget libtool autoconf
      --automake make
  ```

- with Homebrew:
  ```
  ```
Chapter 1. Get Started

```bash
brew install gnu-sed gawk binutils gperftools gettext wget help2man libtool
      --autoconf automake
```

Create a case-sensitive filesystem image:

```bash
hdiutil create ~/esp/crosstool.dmg -volname "ctng" -size 10g -fs "Case-sensitive..<HFS+"
```

Mount it:

```bash
hdiutil mount ~/esp/crosstool.dmg
```

Create a symlink to your work directory:

```bash
mkdir -p ~/esp
ln -s /Volumes/ctng ~/esp/ctng-volume
```

Go into the newly created directory:

```bash
cd ~/esp/ctng-volume
```

Download crosstool-NG and build it:

```bash
git clone https://github.com/espressif/crosstool-NG.git
cd crosstool-NG
git checkout esp-2021r2
git submodule update --init
./bootstrap && ./configure --enable-local && make
```

Build the toolchain:

```bash
./ct-ng xtensa-esp32-elf
./ct-ng build
chmod -R u+w builds/xtensa-esp32-elf
```

Toolchain will be built in ~/esp/ctng-volume/crosstool-NG/builds/xtensa-esp32-elf. To use it, you need to add ~/esp/ctng-volume/crosstool-NG/builds/xtensa-esp32-elf/bin to PATH environment variable.

**Next Steps** To carry on with development environment setup, proceed to *Step 2. Get 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 Reset/ADV_PARAM/ADV_DATA/ADV_ENABLE HCI command for BLE advertising - bluetooth/hci/controller_vhci_ble_adv.

API Reference

Header File

- components/bt/include/esp32/include/esp_bt.h

Functions

`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)

`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

`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

```c
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

```c
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

```c
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.

```c
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

```c
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().

```c
esp_err_t esp_bt_controller_disable (void)
```

Disable BT controller.

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

```c
esp_err_t esp_bt_controller_get_status (void)
```

Get BT controller is initialised/de-initialised/enabled/disabled.

**Return** status value

```c
bool esp_vhci_host_check_send_available (void)
```

esp_vhci_host_check_send_available used for check actively if the host can send packet to controller or not.
Return  true for ready to send, false means cannot send packet

void esp_vhci_host_send_packet (uint8_t *data, uint16_t len)

esp_vhci_host_send_packet host send packet to controller

Should not call this function from within a critical section or when the scheduler is suspended.

Parameters
  • data: the packet point
  • len: the packet length

esp_err_t esp_vhci_host_register_callback (const esp_vhci_host_callback_t *callback)

esp_vhci_host_register_callback register the vhci reference callback struct defined by vhci_host_callback structure.

Return  ESP_OK - success, ESP_FAIL - failed

Parameters
  • callback: esp_vhci_host_callback type variable

esp_err_t esp_bt_controller_mem_release (esp_bt_mode_t mode)

esp_bt_controller_mem_release 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

esp_err_t esp_bt_mem_release (esp_bt_mode_t mode)

esp_bt_mem_release 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)
Chapter 2. API Reference

bool hli
Using high level interrupt or not

uint32_t magic
Magic number

struct esp_vhci_host_callback

\(\text{esp_vhci_host_callback}\) used for vhci call host function to notify what host need to do

Public Members

void (*\text{notify_host_send_available}) (void)
callback used to notify that the host can send packet to controller

int (*\text{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
\(\text{esp_vhci_host_callback}\) 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 \text{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
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/initialised/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_ADV : for advertising/scan response. ESP_BLE_PWR_TYPE_SCAN : for scan. ESP_BLE_PWR_TYPE_DEFAULT : if each connection’s TX power is not set, it will use this default value. if neither in scan mode nor in adv mode, it will use this default value. If none of power type is set, system will use ESP_PWR_LVL_P3 as default for ADV/SCAN/CONN0-9.
Values:

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
Overview

Application Example

API Reference

Header File

- components/bt/host/bluedroid/api/include/api/esp_btDefs.h

Structures

```c
struct esp_bt_uuid_t
UUID type.
```

Public Members

```c
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
```

Macros

```c
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, 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 (addr)

**Type Definitions**

\[
\text{typedef } \text{uint8_t esp_bt_octet16_t}[\text{ESP_BT_OCTET16_LEN}] \\
\text{typedef } \text{uint8_t esp_bt_octet8_t}[\text{ESP_BT_OCTET8_LEN}] \\
\text{typedef } \text{uint8_t esp_link_key}[\text{ESP_BT_OCTET16_LEN}] \\
\text{typedef } \text{uint8_t esp_bd_addr_t}[\text{ESP_BD_ADDR_LEN}] \\
   \text{Bluetooth device address.} \\
\text{typedef } \text{uint8_t esp_ble_key_mask_t}
\]

**Enumerations**

\[
\text{enum esp_bt_status_t} \\
   \text{Status Return Value.} \\
   \text{Values:} \\
   \text{ESP_BT_STATUS_SUCCESS} = 0 \\
   \text{ESP_BT_STATUS_FAIL} \\
   \text{ESP_BT_STATUS_NOT_READY} \\
   \text{ESP_BT_STATUS_NOMEM} \\
   \text{ESP_BT_STATUS_BUSY} \\
   \text{ESP_BT_STATUS_DONE} = 5 \\
   \text{ESP_BT_STATUS_UNSUPPORTED} \\
   \text{ESP_BT_STATUS_PARM_INVALID} \\
   \text{ESP_BT_STATUS_UNHANDLED} \\
   \text{ESP_BT_STATUS_AUTH_FAILURE} \\
   \text{ESP_BT_STATUS_RMT_DEV_DOWN} = 10
\]
Chapter 2. API Reference

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
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
Chapter 2. API Reference

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.

\[\text{esp_err_t esp_ble_gap_set_scan_params(esp_ble_scan_params_t *scan_params)}\]

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

\[\text{esp_err_t esp_ble_gap_start_scanning(uint32_t duration)}\]

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.

\[\text{esp_err_t esp_ble_gap_stop_scanning(void)}\]

This function call to stop the device scanning the peer device which advertising on the air.

Return

• ESP_OK : success
• other : failed

\[\text{esp_err_t esp_ble_gap_start_advertising(esp_ble_adv_params_t *adv_params)}\]

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.

\[\text{esp_err_t esp_ble_gap_stop_advertising(void)}\]

This function is called to stop advertising.

Return

• ESP_OK : success
• other : failed

\[\text{esp_err_t esp_ble_gap_update_conn_params(esp_ble_conn_update_params_t *params)}\]

Update connection parameters, can only be used when connection is up.

Return

• ESP_OK : success
• other : failed

Parameters

• [in] params: - connection update parameters

\[\text{esp_err_t esp_ble_gap_set_pkt_data_len(esp_bd_addr_t remote_device, uint16_t tx_data_length)}\]

This function is to set maximum LE data packet size.

Return

• ESP_OK : success
• other : failed

\[\text{esp_err_t esp_ble_gap_set_rand_addr(esp_bd_addr_t rand_addr)}\]

This function sets the static Random Address and Non-Resolvable Private Address for the application.
Chapter 2. API Reference

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] rand_addr: the random address which should be setting

*esp_err_t* esp_ble_gap_config_local_privacy (bool privacy_enable)

Enable/disable privacy on the local device.

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: whitelist address 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 whitelist size in the controller.*

Return

• ESP_OK : success
• other : failed

Parameters

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

- [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.

**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.

**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’.

To accept only secure connection mode, it is necessary do as following:
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

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

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

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.

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.

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
• [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.

**esp_err_t** esp_gap_ble_set_authorization**(esp_bd_addr_t bd_addr, bool authorize)**

This function is called to authorized 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, 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
**Chapter 2. API Reference**

- other : failed

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

```c
esp_err_t esp_ble_gap_config_ext_scan_rsp_data_raw(uint8_t instance, uint16_t length,
                                                  const uint8_t* scan_rsp_data)
```

This function is used to provide scan response data used in scanning response PDUs.

**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

```c
esp_err_t esp_ble_gap_ext_adv_start(uint8_t num_adv, const esp_ble_gap_ext_adv_t *ext_adv)
```

This function is used to request the Controller to enable one or more advertising sets using the advertising sets identified by the instance parameter.

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

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

```c
esp_err_t esp_ble_gap_ext_adv_stop(uint8_t num_adv, const uint8_t *ext_adv_inst)
```

This function is used to request the Controller to disable one or more advertising sets using the advertising sets identified by the instance parameter.

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

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

```c
esp_err_t esp_ble_gap_ext_adv_set_remove(uint8_t instance)
```

This function is used to remove an advertising set from the Controller.

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

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

```c
esp_err_t esp_ble_gap_ext_adv_set_clear(void)
```

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

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

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

```c
esp_err_t esp_ble_gap_periodic_adv_set_params(uint8_t instance, const esp_ble_gap_periodic_adv_params_t *params)
```

This function is used by the Host to set the parameters for periodic advertising.

**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**

```c
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**

```c
(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**

```c
(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**

```c
(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**

```c
(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**

```c
(void)
```

This function is used to disable scanning.

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

**esp_err_t esp_ble_gap_periodic_adv_create_sync**

```c
(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

**esp_err_t esp_ble_gap_periodic_adv_sync_cancel**

```c
(void)
```

This function is used to cancel the LE_Periodic_Advertising_Create_Sync command while it is pending.

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

\textit{esp_err_t esp_ble_gap_periodic_adv_sync_terminate} (uint16_t \textit{sync\_handle})

This function is used to stop reception of the periodic advertising identified by the Sync Handle parameter.

\textbf{Return} - ESP_OK : success
• other : failed

\textbf{Parameters}
• [in] \textit{sync\_handle} : : identify the periodic advertiser

\textit{esp_err_t esp_ble_gap_periodic_adv_add_dev_to_list} (esp_ble_addr_type_t \textit{addr\_type},
esp_bd_addr_t \textit{addr}, uint8_t \textit{sid})

This function is used to add a single device to the Periodic Advertiser list stored in the Controller.

\textbf{Return} - ESP_OK : success
• other : failed

\textbf{Parameters}
• [in] \textit{addr\_type} : : address type
• [in] \textit{addr} : : Device Address
• [in] \textit{sid} : : Advertising SID subfield in the ADI field used to identify the Periodic Advertising

\textit{esp_err_t esp_ble_gap_periodic_adv_remove_dev_from_list} (esp_ble_addr_type_t \textit{addr\_type},
esp_bd_addr_t \textit{addr}, uint8_t \textit{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.

\textbf{Return} - ESP_OK : success
• other : failed

\textbf{Parameters}
• [in] \textit{addr\_type} : : address type
• [in] \textit{addr} : : Device Address
• [in] \textit{sid} : : Advertising SID subfield in the ADI field used to identify the Periodic Advertising

\textit{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.

\textbf{Return} - ESP_OK : success
• other : failed

\textbf{Parameters}

\textit{esp_err_t esp_ble_gap_prefer_ext_connect_params_set} (esp_bd_addr_t \textit{addr},
esp_ble_gap_phy_mask_t \textit{phy\_mask},
const esp_ble_gap_conn_params_t *\textit{phy\_1m\_conn\_params},
const esp_ble_gap_conn_params_t *\textit{phy\_2m\_conn\_params},
const esp_ble_gap_conn_params_t *\textit{phy\_coded\_conn\_params})

This function is used to set aux connection parameters.

\textbf{Return} - ESP_OK : success
• other : failed

\textbf{Parameters}
• [in] \textit{addr} : : device address
• [in] \textit{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.
• [in] \textit{phy\_1m\_conn\_params} : : Scan connectable advertisements on the LE 1M PHY. Connection parameters for the LE 1M PHY are provided.
• [in] \textit{phy\_2m\_conn\_params} : : Connection parameters for the LE 2M PHY are provided.
• [in] \textit{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_SET COMPLETE_EVT

    struct esp_ble_gap_cb_param_t::ble_scan_rsp_data_cmpl_evt_param scan_rsp_data_cmpl
        Event parameter of ESP_GAP_BLE_SCAN_RSP_DATA_SET COMPLETE_EVT

    struct esp_ble_gap_cb_param_t::ble_scan_param_cmpl_evt_param scan_param_cmpl
        Event parameter of ESP_GAP_BLE_SCAN_PARAM_SET COMPLETE_EVT

    struct esp_ble_gap_cb_param_t::ble_scan_result_evt_param scan_rst
        Event parameter of ESP_GAP_BLE_SCAN_RESULT_EVT

    struct esp_ble_gap_cb_param_t::ble_adv_data_raw_cmpl evt_param adv_data_raw_cmpl
        Event parameter of ESP_GAP_BLE_ADV_DATA_RAW_SET COMPLETE_EVT

    struct esp_ble_gap_cb_param_t::ble_scan_rsp_data_raw_cmpl_evt_param scan_rsp_data_raw_cmpl
        Event parameter of ESP_GAP_BLE_SCAN_RSP_DATA_RAW_SET COMPLETE_EVT
struct esp_ble_gap_cb_param_t::ble_adv_start_cmpl_evt_param adv_start_cmpl

Event parameter of ESP_GAP_BLE_ADV_START_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_scan_start_cmpl_evt_param scan_start_cmpl

Event parameter of ESP_GAP_BLE_SCAN_START_COMPLETE_EVT

esp_ble_sec_t::ble_security

ble gap security union type

struct esp_ble_gap_cb_param_t::ble_scan_stop_cmpl_evt_param scan_stop_cmpl

Event parameter of ESP_GAP_BLE_SCAN_STOP_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_adv_stop_cmpl_evt_param adv_stop_cmpl

Event parameter of ESP_GAP_BLE_ADV_STOP_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_set_rand_cmpl_evt_param set_rand_addr_cmpl

Event parameter of ESP_GAP_BLE_SET_STATIC_RAND_ADDR_EVT

struct esp_ble_gap_cb_param_t::ble_update_conn_params_evt_param update_conn_params

Event parameter of ESP_GAP_BLE_UPDATE_CONN_PARAMS_EVT

struct esp_ble_gap_cb_param_t::ble_pkt_data_length_cmpl_evt_param pkt_data_length_cmpl

Event parameter of ESP_GAP_BLE_SET_PKT_LENGTH_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_local_privacy_cmpl_evt_param local_privacy_cmpl

Event parameter of ESP_GAP_BLE_SET_LOCAL_PRIVACY_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_remove_bond_dev_cmpl_evt_param remove_bond_dev_cmpl

Event parameter of ESP_GAP_BLE_REMOVE_BOND_DEV_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_clear_bond_dev_cmpl_evt_param clear_bond_dev_cmpl

Event parameter of ESP_GAP_BLE_CLEAR_BOND_DEV_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_get_bond_dev_cmpl_evt_param get_bond_dev_cmpl

Event parameter of ESP_GAP_BLE_GET_BOND_DEV_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_read_rssi_cmpl_evt_param read_rssi_cmpl

Event parameter of ESP_GAP_BLE_READ_RSSI_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_update_whitelist_cmpl_evt_param update_whitelist_cmpl

Event parameter of ESP_GAP_BLE_UPDATE_WHITELIST_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_update_duplicate_exceptional_list_cmpl_evt_param update_duplicate_exceptional_list_cmpl

Event parameter of ESP_GAP_BLE_UPDATE_DUPLICATE_EXCEPTIONAL_LIST_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_set_channels_evt_param ble_set_channels

Event parameter of ESP_GAP_BLE_SET_CHANNELS_EVT

struct esp_ble_gap_cb_param_t::ble_read_phy_cmpl_evt_param read_phy

Event parameter of ESP_GAP_BLE_READ_PHY_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_set_perf_def_phy_cmpl_evt_param set_perf_def_phy

Event parameter of ESP_GAP_BLE_SET_PREFERRED_DEFAULT_PHY_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_set_perf_phy_cmpl_evt_param set_perf_phy

Event parameter of ESP_GAP_BLE_SET_PREFERRED_PHY_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_set_rand_addr_cmpl_evt_param ext_adv_set_rand_addr

Event parameter of ESP_GAP_BLE_EXT_ADV_SET_RAND_ADDR_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_set_params_cmpl_evt_param ext_adv_set_params

Event parameter of ESP_GAP_BLE_EXT_ADV_SET_PARAMS_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_data_set_cmpl_evt_param ext_adv_data_set

Event parameter of ESP_GAP_BLE_EXT_ADV_DATA_SET_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_scan_rsp_set_cmpl_evt_param scan_rsp_set

Event parameter of ESP_GAP_BLE_EXT_SCAN_RSP_DATA_SET_COMPLETE_EVT
Chapter 2. API Reference

```c
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_periodic_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_periodic_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_periodic_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_periodic_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_periodic_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_periodic_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_adv_start_cmpl_param ext_scan_start
  Event parameter of ESP_GAP_BLE_EXT_ADV_START_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_stop_cmpl_param ext_scan_stop
  Event parameter of ESP_GAP_BLE_EXT_ADV_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_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_SEL_ALGORITHM_EVT.

Public Members

uint16_t conn_handle
connection handle

uint8_t channel_sel_alg
channel selection algorithm

struct ble_clear_bond_dev_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_CLEAR_BOND_DEV_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate the clear bond device operation success status

struct ble_ext_adv_data_set_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_ADV_DATA_SET_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate extend advertising data set status

struct ble_ext_adv_report_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_ADVREPORT_EVT.

Public Members

esp_gap_ble_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 scan response data set status

struct ble_ext_adv_set_clear_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_ADV_SET_CLEAR_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate advertising stop operation success status

struct ble_ext_adv_set_params_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_ADV_SET_PARAMS_COMPLETE_EVT.
Public Members

`esp_bt_status_t status`
Indicate extend advertising parameters set status

`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

`esp.bt_status_t status`
Indicate extend advertising random address set status

`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

`esp.bt_status_t status`
Indicate advertising stop operation success status

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

Public Members

`esp.bt_status_t status`
Indicate advertising start operation success status

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

Public Members

`esp.bt_status_t status`
Indicate advertising stop operation success status

`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

`esp.bt_status_t status`
Indicate extend connection parameters set status

`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

`esp_bt_status_t status`  
Indicate periodic advertising create sync status

`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

`esp_bt_status_t status`
Indicate periodic advertising device list remove status

struct `ble_period_adv_sync_cancel_cmpl_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_PERIODIC_ADV_SYNCCANCEL_COMPLETE_EVT.

Public Members

`esp_bt_status_t status`
Indicate periodic advertising sync cancle status

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

`esp_bt_status_t status`
Indicate periodic advertising sync terminate status

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

`esp_bt_status_t status`
Indicate periodic advertising data set status

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

Public Members

`esp_ble_gap_periodic_adv_report_t params`
periodic advertising report parameters

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

Public Members

`esp_bt_status_t status`
Indicate periodic advertisingparameters set status

struct `ble_periodic_adv_start_cmpl_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_PERIODIC_ADV_START_COMPLETE_EVT.

Public Members

`esp_bt_status_t status`
Indicate periodic advertising start status

struct `ble_periodic_adv_stop_cmpl_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_PERIODIC_ADV_STOP_COMPLETE_EVT.
Public Members

*esp_bt_status_t status*
Indicate periodic advertising stop status

`struct ble_periodic_adv_sync_estab_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_PERIODIC_ADV_SYNC_ESTAB_EVT.

Public Members

uint8_t status
periodic advertising sync status

uint16_t sync_handle
periodic advertising sync handle

uint8_t sid
periodic advertising sid

*esp_ble_addr_type_t adv_addr_type*
periodic advertising address type

*esp_bd_addr_t adv_addr*
periodic advertising address

*esp_ble_gap_phy_t adv_phy*
periodic advertising phy type

uint16_t period_adv_interval
periodic advertising interval

uint8_t adv_clk_accuracy
periodic advertising clock accuracy

`struct ble_periodic_adv_sync_lost_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_PERIODIC_ADV_SYNC_LOST_EVT.

Public Members

uint16_t sync_handle
sync handle

`struct ble_phy_update_cmpl_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_PHY_UPDATE_COMPLETE_EVT.

Public Members

*esp_bt_status_t status*
phy update status

*esp_bd_addr_t bda*
address

*esp_ble_gap_phy_t tx_phy*
tx phy type

*esp_ble_gap_phy_t rx_phy*
rx phy type

`struct ble_pkt_data_length_cmpl_evt_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_SET_PKT_LENGTH_COMPLETE_EVT.
Chapter 2. API Reference

Public Members

`esp_bt_status_t status`
Indicate the set pkt data length operation success status

`esp_ble_pkt_data_length_params_t params`
pkt data length value

```c
struct ble_read_phy_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_READ_PHY_COMPLETE_EVT.
```

Public Members

`esp_bt_status_t status`
read phy complete status

`esp_bd_addr_t bda`
read phy address

`esp_ble_gap_phy_t tx_phy`
tax 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

`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

`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

```c
struct ble_scan_param_cmpl_evt_param
#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
#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
#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.

Public Members

esp_bt_status_t status
Indicate perf default phy set status

struct ble_set_perf_phy_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_PREFERED_PHY_COMPLETE_EVT.
Public Members

\textit{esp\_bt\_status\_t status}
Indicate perf phy set status

\textbf{struct ble\_set\_rand\_cmpl\_evt\_param}

\textit{#include <esp\_gap\_ble\_api.h> ESP\_GAP\_BLE\_SET\_STATIC\_RAND\_ADDR\_EVT.}

Public Members

\textit{esp\_bt\_status\_t status}
Indicate set static rand address operation success status

\textbf{struct ble\_update\_conn\_params\_evt\_param}

\textit{#include <esp\_gap\_ble\_api.h> ESP\_GAP\_BLE\_UPDATE\_CONN\_PARAMS\_EVT.}

Public Members

\textit{esp\_bt\_status\_t status}
Indicate update connection parameters success status

\textit{esp\_bd\_addr\_t bda}
Bluetooth device address

uint16\_t \textbf{min\_int}
Min connection interval

uint16\_t \textbf{max\_int}
Max connection interval

uint16\_t \textbf{latency}
Slave latency for the connection in number of connection events. Range: 0x0000 to 0x01F3

uint16\_t \textbf{conn\_int}
Current connection interval

uint16\_t \textbf{timeout}
Supervision timeout for the LE Link. Range: 0x000A to 0x0C80. Mandatory Range: 0x000A to 0x0C80 Time = N * 10 msec

\textbf{struct ble\_update\_duplicate\_exceptional\_list\_cmpl\_evt\_param}

\textit{#include <esp\_gap\_ble\_api.h> ESP\_GAP\_BLE\_UPDATE\_DUPLICATE\_EXCEPTIONAL\_LIST\_COMPLETE\_EVT.}

Public Members

\textit{esp\_bt\_status\_t status}
Indicate update duplicatescan exceptional list operation success status

uint8\_t \textbf{subcode}
Define in esp\_bt\_duplicate\_exceptional\_subcode\_type\_t

uint16\_t \textbf{length}
The length of device\_info

\textit{esp\_duplicate\_info\_t device\_info}
device information, when subcode is ESP\_BLE\_DUPLICATE\_EXCEPTIONAL\_LIST\_CLEAN, the value is invalid

\textbf{struct ble\_update\_whitelist\_cmpl\_evt\_param}

\textit{#include <esp\_gap\_ble\_api.h> ESP\_GAP\_BLE\_UPDATE\_WHITELIST\_COMPLETE\_EVT.}
Public Members

*esp_bt_status_t* status
Indicate the add or remove whitelist operation success status

*esp_ble_wl_operation_t* wl_operation
The value is ESP_BLE_WHITELIST_ADD if add address to whitelist operation success,
ESP_BLE_WHITELIST_REMOVE if remove address from the whitelist operation success

Structures

struct esp_ble_adv_params_t
Advertising parameters.

Public Members

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

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

*esp_ble_adv_type_t* adv_type
Advertising type

*esp_ble_addr_type_t* own_addr_type
Owner bluetooth device address type

*esp_bd_addr_t* peer_addr
Peer device bluetooth device address

*esp_ble_addr_type_t* peer_addr_type
Peer device bluetooth device address type, only support public address type and random address type

*esp_ble_adv_channel_t* channel_map
Advertising channel map

*esp_ble_adv_filter_t* adv_filter_policy
Advertising filter policy

struct esp_ble_adv_data_t
Advertising data content, according to "Supplement to the Bluetooth Core Specification".

Public Members

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: \( \text{connIntervalMax} = \text{Conn Interval Max} \times 1.25 \) ms \( \text{Conn Interval Max} \) range: 0x0006 to 0x0C80 \( \text{Conn Interval Max} \) shall be equal to or greater than the \( \text{Conn Interval Min} \). 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

exp_ble_scan_duplicate_t scan_duplicate
The Scan_Duplicates parameter controls whether the Link Layer should filter out duplicate advertising reports (BLESCAN_DUPLICATE_ENABLE) to the Host, or if the Link Layer should generate advertising reports for each packet received

struct esp_gap_conn_params_t
connection parameters information
Public Members

uint16_t **interval**
connection interval

uint16_t **latency**
Slave latency for the connection in number of connection events. Range: 0x0000 to 0x01F3

uint16_t **timeout**
Supervision timeout for the LE Link. Range: 0x000A to 0x0C80. Mandatory Range: 0x000A to 0x0C80
Time = N * 10 msec Time Range: 100 msec to 32 seconds

```c
struct esp_ble_conn_update_params_t
Connection update parameters.
```

Public Members

```c
struct 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
Time = N * 10 msec Time Range: 100 msec to 32 seconds

```c
struct esp_ble_pkt_data_length_params_t
BLE pkt date length keys.
```

Public Members

uint16_t **rx_len**
pkt rx data length value

uint16_t **tx_len**
pkt tx data length value

```c
struct esp_ble_penc_keys_t
BLE encryption keys.
```

Public Members

```c
esp_bt_octet16_t ltk
The long term key
```

```c
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
Chapter 2. API Reference

```
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.

**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 which key is present

esp_ble_penc_keys_t *penc_key
    received peer encryption key

esp_ble_pcsrk_keys_t *pcsrk_key
    received peer device SRK

esp_ble_pid_keys_t *pid_key
    peer device ID key

struct esp_ble_bond_dev_t
    struct type of the bond device value

Public Members

esp_bd_addr_t *bd_addr
    peer address

esp_ble_bond_key_info_t *bond_key
    the bond key information

struct esp_ble_key_t
    union type of the security key value

Public Members

esp_bd_addr_t *bd_addr
    peer address

esp_ble_key_type_t *key_type
    key type of the security link

esp_ble_key_value_t *p_key_value
    the pointer to the key value
struct esp_ble_local_id_keys_t
structure type of the ble local id keys value

Public Members

esp_bt_octet16_t ir
the 16 bits of the ir value

esp_bt_octet16_t irk
the 16 bits of the ir key value

esp_bt_octet16_t dhk
the 16 bits of the dh key value

struct esp_ble_auth_cmpl_t
Structure associated with ESP_AUTH_CMPL_EVT.

Public Members

esp_bd_addr_t bd_addr
BD address peer device.

bool key_present
Valid link key value in key element

esp_link_key key
Link key associated with peer device.

uint8_t key_type
The type of Link Key

bool success
TRUE of authentication succeeded, FALSE if failed.

uint8_t fail_reason
The HCI reason/error code for when success=FALSE

esp_ble_addr_type_t addr_type
Peer device address type

esp_bt_dev_type_t dev_type
Device type

esp_ble_auth_req_t auth_mode
authentication mode

struct esp_ble_gap_ext_adv_params_t
ext adv parameters

Public Members

esp_ble_ext_adv_type_mask_t type
ext adv type

uint32_t interval_min
ext adv minimum interval

uint32_t interval_max
ext adv maximum interval

esp_ble_adv_channel_t channel_map
ext adv channel map
\texttt{esp\_ble\_addr\_type\_t} \texttt{own\_addr\_type}  
ext adv own addresss type

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

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

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

\texttt{int8\_t} \texttt{tx\_power}  
ext adv tx power

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

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

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

\texttt{uint8\_t} \texttt{sid}  
ext adv sid

\texttt{bool} \texttt{scan\_req\_notif}  
ext adv saen request event notify

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

**Public Members**

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

\texttt{uint16\_t} \texttt{scan\_interval}  
ext scan interval

\texttt{uint16\_t} \texttt{scan\_window}  
ext scan window

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

**Public Members**

\texttt{esp\_ble\_addr\_type\_t} \texttt{own\_addr\_type}  
ext scan own addresss type

\texttt{esp\_ble\_scan\_filter\_t} \texttt{filter\_policy}  
ext scan filter policy

\texttt{esp\_ble\_scan\_duplicate\_t} \texttt{scan\_duplicate}  
ext scan duplicate scan

\texttt{esp\_ble\_ext\_scan\_cfg\_mask\_t} \texttt{cfg\_mask}  
ext scan config mask

\texttt{esp\_ble\_ext\_scan\_cfg\_t} \texttt{uncoded\_cfg}  
ext scan uncoded config parameters

\texttt{esp\_ble\_ext\_scan\_cfg\_t} \texttt{coded\_cfg}  
ext scan coded config parameters
struct esp_ble_gap_conn_params_t
create extend connection parameters

Public Members

uint16_t scan_interval
init scan interval

uint16_t scan_window
init scan window

uint16_t interval_min
minimum interval

uint16_t interval_max
maximum interval

uint16_t latency
ext scan type

uint16_t supervision_timeout
connection supervision timeout

uint16_t min_ce_len
minimum ce length

uint16_t max_ce_len
maximum ce length

struct esp_ble_gap_ext_adv_t
extend adv enable parameters

Public Members

uint8_t instance
advertising handle

int duration
advertising duration

int max_events
maximum number of extended advertising events

struct esp_ble_gap_periodic_adv_params_t
periodic adv parameters

Public Members

uint16_t interval_min
periodic advertising minimum interval

uint16_t interval_max
periodic advertising maximum interval

uint8_t properties
periodic advertising properties

struct esp_ble_gap_periodic_adv_sync_params_t
periodic adv sync parameters
Public Members

`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

`struct esp_ble_gap_ext_adv_report_t`
extend adv report parameters

Public Members

`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

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 flag bit definition used for advertising data flag

ESP_BLE_ADV_FLAG_GEN_DISC

ESP_BLE_ADV_FLAG_BREDR_NOT_SPT

ESP_BLE_ADV_FLAG_DMT_CONTROLLER_SPT

ESP_BLE_ADV_FLAG_DMT_HOST_SPT

ESP_BLE_ADV_FLAG_NON_LIMIT_DISC

Submit Document Feedback
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
0101
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_GENERIC_SPORTS_WATCH
ESP_BLE_APPEARANCE_GENERIC_CLOCK
ESP_BLE_APPEARANCE_GENERIC_DISPLAY
ESP_BLE_APPEARANCE_GENERIC_REMOTE
ESP_BLE_APPEARANCE_GENERIC_EYEGGLASSES
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_OBSERVATION
ESP_BLE_APPEARANCE_PULSE_OBSERVATION.FINGERTIP
ESP_BLE_APPEARANCE_PULSE_OBSERVATION_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
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
Chapter 2. API Reference

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

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_gap_ble_cb_param_t *param)
  GAP callback function type.
Parameters

- **event**: Event type
- **param**: Point to callback parameter, currently is union type

Enumerations

define 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 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_PREFERRED_DEFAULT_PHY_COMPLETE_EVT
ESP_GAP_BLE_SET_PREFERRED_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_SYNC_CANCEL_COMPLETE_EVT
ESP_GAP_BLE_PERIODIC_ADV_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
### API Reference

- `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`

```c
enum esp_ble_adv_data_type
{
    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_AD_TYPE_SPAIR_C256 = 0x1D,
    ESP_BLE_AD_TYPE_SPAIR_R256 = 0x1E,
    ESP_BLE_AD_TYPE_32SOL_SRV_UUID = 0x1F,
    ESP_BLE_AD_TYPE_32SERVICE_DATA = 0x20,
    ESP_BLE_AD_TYPE_128SERVICE_DATA = 0x21,
    ESP_BLE_AD_TYPE_LE_SECURE_CONFIRM = 0x22,
}
```
ESP_BLE_AD_TYPE_LE_SECURE_RANDOM = 0x23
ESP_BLE_AD_TYPE_URI = 0x24
ESP_BLE_AD_TYPE_INDOOR_POSITION = 0x25
ESP_BLE_AD_TYPE_TRANS_DISC_DATA = 0x26
ESP_BLE_AD_TYPE_LE_SUPPORT_FEATURE = 0x27
ESP_BLE_AD_TYPE_CHAN_MAP_UPDATE = 0x28
ESP_BLE_AD_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
ESP_BLE_SEC_ENCRYPT_MITM

enum esp_ble_sm_param_t
Values:
ESP_BLE_SM_PASSKEY = 0
ESP_BLE_SM_AUTHEN_REQ_MODE
ESP_BLE_SM_IOCAP_MODE
Chapter 2. API Reference

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.
Values:

BLE_SCAN_TYPE_PASSIVE = 0x0
Passive scan

BLE_SCAN_TYPE_ACTIVE = 0x1
Active scan

enum esp_ble_scan_filter_t
Ble scan filter type.
Values:

BLE_SCAN_FILTER_ALLOW_ALL = 0x0
Accept all:
1. advertisement packets except directed advertising packets not addressed to this device (default).

BLE_SCAN_FILTER_ALLOW_ONLY_WLST = 0x1
Accept only:
1. advertisement packets from devices where the advertiser’s address is in the White list.
2. Directed advertising packets which are not addressed for this device shall be ignored.

BLE_SCAN_FILTER_ALLOW_UND_RPA_DIR = 0x2
Accept all:
1. undirected advertisement packets, and
2. directed advertising packets where the initiator address is a resolvable private address, and
3. directed advertising packets addressed to this device.

BLE_SCAN_FILTER_ALLOW_WLIST_RPA_DIR = 0x3
Accept all:
1. advertisement packets from devices where the advertiser’s address is in the White list, and
2. directed advertising packets where the initiator address is a resolvable private address, and
3. directed advertising packets addressed to this device.

enum esp_ble_scan_duplicate_t
Ble scan duplicate type.
Values:

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_BLE_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

GATTDefines

Overview Instructions

Application Example Instructions

API Reference

Header File

• components/bt/host/bluedroid/api/include/api/esp_gatt_defs.h

Unions

union esp_gatt_rsp_t
#include <esp_gatt_defs.h> GATT remote read request response type.
Public Members

`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_svc_id_t`
- Gatt service id, include id (uuid and instance id) and primary flag.

Public Members

`esp_gatt_id_t id`
- Gatt id, include uuid and instance

`bool is_primary`
- This service is primary or not

`struct esp_attr_desc_t`
- Attribute description (used to create database)

Public Members

`uint16_t uuid_length`
- UUID length

`uint8_t *uuid_p`
- UUID value

`uint16_t perm`
- Attribute permission

`uint16_t max_length`
- Maximum length of the element

`uint16_t length`
- Current length of the element

`uint8_t *value`
- Element value array

`struct esp_attr_control_t`
- attribute auto response flag
Public Members

```c
uint8_t auto_rsp
if auto_rsp 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.
```

```c
struct esp_gatts_attr_db_t
attribute type added to the gatt server database
```

Public Members

```c
esp_attr_control_t attr_control
The attribute control type
```

```c
esp_attr_desc_t att_desc
The attribute type
```

```c
struct esp_attr_value_t
set the attribute value type
```

Public Members

```c
uint16_t attr_max_len
attribute max value length
```

```c
uint16_t attr_len
attribute current value length
```

```c
uint8_t* attr_value
the pointer to attribute value
```

```c
struct esp_gatts_incl_svc_desc_t
Gatt include service entry element.
```

Public Members

```c
uint16_t start_hdl
Gatt start handle value of included service
```

```c
uint16_t end_hdl
Gatt end handle value of included service
```

```c
uint16_t uuid
Gatt attribute value UUID of included service
```

```c
struct esp_gatts_incl128_svc_desc_t
Gatt include 128 bit service entry element.
```

Public Members

```c
uint16_t start_hdl
Gatt start handle value of included 128 bit service
```

```c
uint16_t end_hdl
Gatt end handle value of included 128 bit service
```

```c
struct esp_gatt_value_t
Gatt attribute value.
```
Public Members

```c
uint8_t value[ESP_GATT_MAX_ATTR_LEN]
    Gatt attribute value
```

```c
uint16_t handle
    Gatt attribute handle
```

```c
uint16_t offset
    Gatt attribute value offset
```

```c
uint16_t len
    Gatt attribute value length
```

```c
uint8_t auth_req
    Gatt authentication request
```

```c
struct esp_gatt_attribute_value
    Connection parameters information.
```

```c
struct esp_gatt_conn_params_t
    Connection parameters information.
```

```c
uint16_t interval
    connection interval
```

```c
uint16_t latency
    Slave latency for the connection in number of connection events. Range: 0x0000 to 0x01F3
```

```c
uint16_t timeout
    Supervision timeout for the LE Link. Range: 0x000A to 0x0C80. Mandatory Range: 0x000A to 0x0C80
    Time = N * 10 msec Time Range: 100 msec to 32 seconds
```

```c
struct esp_gattc_multi_t
    read multiple attribute
```

```c
uint8_t num_attr
    The number of the attribute
```

```c
uint16_t handles[ESP_GATT_MAX_READ_MULTI_HANDLES]
    The handles list
```

```c
struct esp_gattc_db_elem_t
    data base attribute element
```

```c
esp_gatt_db_attr_type_t type
    The attribute type
```

```c
uint16_t attribute_handle
    The attribute handle, it’s valid for all of the type
```

```c
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
```

```c
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
```
Chapter 2. API Reference

- **esp_gatt_char_prop_t** properties
  The characteristic properties, its valid only when the type = ESP_GATT_DB_CHARACTERISTIC

- **esp_bt_uuid_t** uuid
  The attribute uuid, its valid for all of the type

```c
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

```c
uint16_t start_handle
The start handle of the service
```

```c
uint16_t end_handle
The end handle of the service
```

```c
esp_bt_uuid_t uuid
The uuid of the service
```

```c
struct esp_gattc_char_elem_t
characteristic element
```

**Public Members**

- `uint16_t char_handle`
  The characteristic handle

```c
esp_gatt_char_prop_t properties
The characteristic properties
```

```c
esp_bt_uuid_t uuid
The characteristic uuid
```

```c
struct esp_gattc_descr_elem_t
descriptor element
```

**Public Members**

- `uint16_t handle`
  The descriptor handle

```c
esp_bt_uuid_t uuid
The characteristic descriptor uuid
```

```c
struct esp_gattc_incl_svc_elem_t
include service element
```

**Public Members**

- `uint16_t handle`
  The include service current attribute handle

```c
uint16_t incl_srvc_s_handle
The start handle of the service which has been included
```

```c
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
ESP_GATT_UUID_LINK_LOSS_SVC
ESP_GATT_UUID_TX_POWER_SVC
ESP_GATT_UUID_CURRENT_TIME_SVC
ESP_GATT_UUID_REF_TIME_UPDATE_SVC
ESP_GATT_UUID_NEXT_DST_CHANGE_SVC
ESP_GATT_UUID_GLUCOSE_SVC
ESP_GATT_UUID_HEALTH_THERMOM_SVC
ESP_GATT_UUID_DEVICE_INFO_SVC
ESP_GATT_UUID_HEART_RATE_SVC
ESP_GATT_UUID_PHONE_ALERT_STATUS_SVC
ESP_GATT_UUID_BATTERY_SERVICE_SVC
ESP_GATT_UUID_BLOOD_PRESSURE_SVC
ESP_GATT_UUID_ALERT_NTF_SVC
ESP_GATT_UUID_HID_SVC
ESP_GATT_UUID_SCAN_PARAMETERS_SVC
ESP_GATT_UUID_RUNNING_SPEED_CADENCE_SVC
ESP_GATT_UUID_Automation_IO_SVC
ESP_GATT_UUID_CYCLING_SPEED_CADENCE_SVC
ESP_GATT_UUID_CYCLING_POWER_SVC
ESP_GATT_UUID_LOCATION_AND_NAVIGATION_SVC
ESP_GATT_UUID_ENVIRONMENTAL_SENSING_SVC
ESP_GATT_UUID_BODY_COMPOSITION
ESP_GATT_UUID_USER_DATA_SVC
ESP_GATT_UUID_WEIGHT_SCALE_SVC
ESP_GATT_UUID_BOND_MANAGEMENT_SVC
ESP_GATT_UUID_CONT_GLUCOSE_MONITOR_SVC
ESP_GATT_UUID_PRI_SERVICE
ESP_GATT_UUID_SEC_SERVICE
ESP_GATT_UUID_INCLUDE_SERVICE
ESP_GATT_UUID_CHAR_DECLARE
ESP_GATT_UUID_CHAR_EXT_PROP
ESP_GATT_UUID_CHAR_DESCRIPTION
ESP_GATT_UUID_CHAR_CLIENT_CONFIG
ESP_GATT_UUID_CHAR_SRVR_CONFIG
Chapter 2. API Reference

ESP_GATT_UUID_CHAR_PRESENT_FORMAT
ESP_GATT_UUID_CHAR_AGG_FORMAT
ESP_GATT_UUID_CHAR_VALID_RANGE
ESP_GATT_UUID_EXT_RPT_REF_DESCR
ESP_GATT_UUID_RPT_REF_DESCR
ESP_GATT_UUID_NUM_DIGITALS_DESCR
ESP_GATT_UUID_VALUE_TRIGGER_DESCR
ESP_GATT_UUID_ENV_SENSING_CONFIG_DESCR
ESP_GATT_UUID_ENV_SENSING_MEASUREMENT_DESCR
ESP_GATT_UUID_ENV_SENSING_TRIGGER_DESCR
ESP_GATT_UUID_TIME_TRIGGER_DESCR
ESP_GATT_UUID_GAP_DEVICE_NAME
ESP_GATT_UUID_GAP_ICON
ESP_GATT_UUID_GAP_PREF_CONN_PARAM
ESP_GATT_UUID_GAP CENTRAL_ADDR_RESOL
ESP_GATT_UUID_GATT_SRV_CHGD
ESP_GATT_UUID_ALERT_LEVEL
ESP_GATT_UUID_TX_POWER_LEVEL
ESP_GATT_UUID_CURRENT TIME
ESP_GATT_UUID_LOCAL_TIME_INFO
ESP_GATT_UUID_REF_TIME_INFO
ESP_GATT_UUID_NW_STATUS
ESP_GATT_UUID_NW_TRIGGER
ESP_GATT_UUID_ALERT_STATUS
ESP_GATT_UUID_RINGER_CP
ESP_GATT_UUID_RINGER_SETTING
ESP_GATT_UUID_GM_MEASUREMENT
ESP_GATT_UUID_GM_CONTEXT
ESP_GATT_UUID_GM_CONTROL_POINT
ESP_GATT_UUID_GM_FEATURE
ESP_GATT_UUID_SYSTEM_ID
ESP_GATT_UUID_MODEL_NUMBER_STR
ESP_GATT_UUID_SERIAL_NUMBER_STR
ESP_GATT_UUID_FW_VERSION_STR
ESP_GATT_UUID_HW_VERSION_STR
ESP_GATT_UUID_SW_VERSION_STR
ESP_GATT_UUID_MANU_NAME
ESP_GATT_UUID_IEEE_DATA
ESP_GATT_UUID_PNP_ID
ESP_GATT_UUID_HID_INFORMATION
ESP_GATT_UUID_HID_REPORT_MAP
ESP_GATT_UUID_HID_CONTROL_POINT
ESP_GATT_UUID_HID_REPORT
ESP_GATT_UUID_HID_PROTO_MODE
ESP_GATT_UUID_HID_BT_KB_INPUT
ESP_GATT_UUID_HID_BT_KB_OUTPUT
ESP_GATT_UUID_HID_BT_MOUSE_INPUT
ESP_GATT_HEART_RATE_MEAS
    Heart Rate Measurement.
ESP_GATT_BODY_SENSOR_LOCATION
    Body Sensor Location.
ESP_GATT_HEART_RATE_CNTL_POINT
    Heart Rate Control Point.
ESP_GATT_UUID_BATTERY_LEVEL
ESP_GATT_UUID_SC_CONTROL_POINT
ESP_GATT_UUID_SENSOR_LOCATION
ESP_GATT_UUID_RSC_MEASUREMENT
ESP_GATT_UUID_RSC_FEATURE
ESP_GATT_UUID_CSC_MEASUREMENT
ESP_GATT_UUID_CSC_FEATURE
ESP_GATT_UUID_SCAN_INT_WINDOW
ESP_GATT_UUID_SCAN_REFRESH
ESP_GATT_ILLEGAL_UUID
    GATT INVALID UUID.
ESP_GATT_ILLEGAL_HANDLE
    GATT INVALID HANDLE.
ESP_GATT_ATTR_HANDLE_MAX
    GATT attribute max handle.
ESP_GATT_MAX_READ_MULTI_HANDLES
ESP_GATT_PERM_READ
    Attribute permissions.
ESP_GATT_PERM_READ_ENCRYPTED
ESP_GATT_PERM_READ_ENC_MITM
ESP_GATT_PERM_WRITE
ESP_GATT_PERM_WRITE_ENCRYPTED
ESP_GATT_PERM_WRITE_ENC_MITM
ESP_GATT_PERM_WRITE_SIGNED
ESP_GATT_PERM_WRITE_SIGNED_MITM
ESP_GATT_PERM_READ_AUTHORIZATION
ESP_GATT_PERM_WRITE_AUTHORIZATION
Chapter 2. API Reference

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 gatec_if/gatts_if as this macro, means this event is not correspond to any app

Type Definitions
typedef uint16_t esp_gatt_perm_t
typedef uint8_t esp_gatt_char_prop_t
typedef uint8_t esp_gatt_if_t
    Gatt interface type, different application on GATT client use different gatt_if

Enumerations
enum esp_gatt_prep_write_type
    Attribute write data type from the client.
    Values:
    ESP_GATT_PREP_WRITE_CANCEL = 0x00
        Prepare write cancel
    ESP_GATT_PREP_WRITE_EXEC = 0x01
        Prepare write execute
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
    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
Chapter 2. API Reference

```c
#define ESP_GATT_NOT_LONG 0x0b
#define ESP_GATT_INSUF_KEY_SIZE 0x0c
#define ESP_GATT_INVALID_ATTR_LEN 0x0d
#define ESP_GATT_ERR_UNLIKELY 0x0e
#define ESP_GATT_INSUF_ENCRYPTION 0x0f
#define ESP_GATT_UNSUPPORT_GRP_TYPE 0x10
#define ESP_GATT_INSUF_RESOURCE 0x11
#define ESP_GATT_NO_RESOURCES 0x80
#define ESP_GATT_INTERNAL_ERROR 0x81
#define ESP_GATT_WRONG_STATE 0x82
#define ESP_GATT_DB_FULL 0x83
#define ESP_GATT_BUSY 0x84
#define ESP_GATT_ERROR 0x85
#define ESP_GATT_CMD_STARTED 0x86
#define ESP_GATT_ILLEGAL_PARAMETER 0x87
#define ESP_GATT_PENDING 0x88
#define ESP_GATT_AUTH_FAIL 0x89
#define ESP_GATT_MORE 0x8a
#define ESP_GATT_INVALID_CFG 0x8b
#define ESP_GATT_SERVICE_STARTED 0x8c
#define ESP_GATT_ENCRYPED_MITM 0x8d
#define ESP_GATT_ENCRYPED_NO_MITM 0x8e
#define ESP_GATT_NOT_ENCRYPTED 0x8f
#define ESP_GATT_CONGESTED 0x90
#define ESP_GATT_ALREADY_OPEN 0x91
#define ESP_GATT_CANCEL 0x92
#define ESP_GATT_STACK_RSP 0xe0
#define ESP_GATT_APP_RSP 0xe1
#define ESP_GATT_UNKNOWN_ERROR 0xef
#define ESP_GATT_CCC_CFG_ERR 0xfd
#define ESP_GATT_PRC_IN_PROGRESS 0xfe
#define ESP_GATT_OUT_OF_RANGE 0xff

typedef enum esp_gatt_conn_reason_t
{
    ESP_GATT_CONN_UNKNOWN = 0,
    ESP_GATT_CONN_L2C_FAILURE = 1
} GattConnectionReason;
```

---

**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
Gatt primary service attribute type in the cache

ESP_GATT_DB_SECONDARY_SERVICE
Gatt secondary service attribute type in the cache

ESP_GATT_DB_CHARACTERISTIC
Gatt characteristic attribute type in the cache

ESP_GATT_DB_DESCRIPTOR
Gatt characteristic descriptor attribute type in the cache
**ESP_GATT_DB_INCLUDED_SERVICE**

Gatter include service attribute type in the cache

**ESP_GATT_DB_ALL**

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

### GATT SERVER 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 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

```c
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

```c
esp_err_t esp_ble_gatts_app_register(uint16_t app_id)
```

This function is called to register application identifier.

**Return**

- ESP_OK : success
- other : failed

```c
esp_err_t esp_ble_gatts_app_unregister(esp_if_t gatts_if)
```

unregister with GATT Server.

**Return**

- ESP_OK : success
- other : failed

**Parameters**

- [in] gatts_if: GATT server access interface

```c
esp_err_t esp_ble_gatts_create_service(esp_if_t gatts_if, esp_gatt_srvc_id_t *service_id, uint16_t num_handle)
```

Create a service. When service creation is done, a callback event ESP_GATTS_CREATE_EVT is called to
report status and service ID to the profile. The service ID obtained in the callback function needs to be used when adding included service and characteristics/descriptors into the service.

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 srvc_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] srvc_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.
- [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_desc_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.
- [in] value: value to indicate.
- [in] need_confirm: Whether a confirmation is required. false sends a GATT notification, true sends a GATT indication.

**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
• [in] rsp: response data.

### 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

### 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

### 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

### 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(esp_gatt_if_t gatts_if, esp_bd_addr_t remote_bda)

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**

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

Public Members

struct esp_ble_gatts_cb_param_t:gatts_reg_evt_param reg
Gatt server callback param of ESP_GATTS_REG_EVT

struct esp_ble_gatts_cb_param_t:gatts_read_evt_param read
Gatt server callback param of ESP_GATTS_READ_EVT

struct esp_ble_gatts_cb_param_t:gatts_write_evt_param write
Gatt server callback param of ESP_GATTS_WRITE_EVT

struct esp_ble_gatts_cb_param_t:gatts_exec_write_evt_param exec_write
Gatt server callback param of ESP_GATTS_EXEC_WRITE_EVT

struct esp_ble_gatts_cb_param_t:gatts_mtu_evt_param mtu
Gatt server callback param of ESP_GATTS_MTU_EVT

struct esp_ble_gatts_cb_param_t:gatts_conf_evt_param conf
Gatt server callback param of ESP_GATTS_CONF_EVT (confirm)

struct esp_ble_gatts_cb_param_t:gatts_create_evt_param create
Gatt server callback param of ESP_GATTS_CREATE_EVT

struct esp_ble_gatts_cb_param_t:gatts_add_incl_srvc_evt_param add_incl_srvc
Gatt server callback param of ESP_GATTS_ADD_INCL_SRVC_EVT

struct esp_ble_gatts_cb_param_t:gatts_add_char_evt_param add_char
Gatt server callback param of ESP_GATTS_ADD_CHAR_EVT

struct esp_BLE_gatts_CB_param_t:gatts_add_chardescr_evt_param add_char_descr
Gatt server callback param of ESP_GATTS_ADD_CHAR_DESCR_EVT

struct esp_ble_gatts_cb_param_t:gatts_delete_evt_param del
Gatt server callback param of ESP_GATTS_DELETE_EVT

struct esp_ble_gatts_cb_param_t:gatts_start_evt_param start
Gatt server callback param of ESP_GATTS_START_EVT

struct esp_ble_gatts_cb_param_t:gatts_stop_evt_param stop
Gatt server callback param of ESP_GATTS_STOP_EVT

struct esp_ble_gatts_cb_param_t:gatts_connect_evt_param connect
Gatt server callback param of ESP_GATTS_CONNECT_EVT

struct esp_ble_gatts_cb_param_t:gatts_disconnect_evt_param disconnect
Gatt server callback param of ESP_GATTS_DISCONNECT_EVT

struct esp_ble_gatts_cb_param_t:gatts_open_evt_param open
Gatt server callback param of ESP_GATTS_OPEN_EVT

struct esp_ble_gatts_cb_param_t:gatts_cancel_open_evt_param cancel_open
Gatt server callback param of ESP_GATTS_CANCEL_OPEN_EVT

struct esp_ble_gatts_cb_param_t:gatts_close_evt_param close
Gatt server callback param of ESP_GATTS_CLOSE_EVT

struct esp_ble_gatts_cb_param_t:gatts_congest_evt_param congest
Gatt server callback param of ESP_GATTS_CONGEST_EVT

struct esp_ble_gatts_cb_param_t:gatts_rsp_evt_param rsp
Gatt server callback param of ESP_GATTS_RESPONSE_EVT

struct esp_ble_gatts_cb_param_t:gatts_add_attr_tab_evt_param add_attr_tab
Gatt server callback param of ESP_GATTS_CREAT_ATTR_TAB_EVT
struct esp_ble_gatts_cb_param_t::gatts_set_attr_val_evt_param
  set_attr_val
  Gatt server callback param of ESP_GATTS_SET_ATTR_VAL_EVT

struct esp_ble_gatts_cb_param_t::gatts_send_service_change_evt_param
  service_change
  Gatt server callback param of ESP_GATTS_SEND_SERVICE_CHANGE_EVT

struct gatts_add_attr_tab_evt_param
  #include <esp_gatts_api.h> ESP_GATTS_CREAT_ATTR_TAB_EVT.

Public Members

  esp_gatt_status_t status
  Operation status

  esp_bt_uuid_t svc_uuid
  Service uuid type

  uint8_t svc_inst_id
  Service id

  uint16_t num_handle
  The number of the attribute handle to be added to the gatts database

  uint16_t *handles
  The number to the handles

struct gatts_add_char_descr_evt_param
  #include <esp_gatts_api.h> ESP_GATTS_ADD_CHAR_DESCR_EVT.

Public Members

  esp_gatt_status_t status
  Operation status

  uint16_t attr_handle
  Descriptor attribute handle

  uint16_t service_handle
  Service attribute handle

  esp_bt_uuid_t descr_uuid
  Characteristic descriptor uuid

struct gatts_add_char_evt_param
  #include <esp_gatts_api.h> ESP_GATTS_ADD_CHAR_EVT.

Public Members

  esp_gatt_status_t status
  Operation status

  uint16_t attr_handle
  Characteristic attribute handle

  uint16_t service_handle
  Service attribute handle

  esp_bt_uuid_t char_uuid
  Characteristic uuid

struct gatts_add_incl_srvc_evt_param
  #include <esp_gatts_api.h> ESP_GATTS_ADD_INCL_SRVC_EVT.
Public Members

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

Public Members

```c
struct gatts_close_evt_param
#include <esp_gatts_api.h> ESP_GATTS_CLOSE_EVT.
```

Public Members

```c
struct gatts_conf_evt_param
#include <esp_gatts_api.h> ESP_GATTS_CONF_EVT.
```

Public Members

```c
struct gatts_congest_evt_param
#include <esp_gatts_api.h> ESP_GATTS_LISTEN_EVT.
ESP_GATTS_CONGEST_EVT
```

Public Members

```c
#include <esp_gatts_api.h> ESP_GATTS_LISTEN_EVT.
ESP_GATTS_CONGEST_EVT
```
bool congested
Congested or not

```c
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

```c
struct gatts_create_evt_param
#include <esp_gatts_api.h> ESP_GATTS_UNREG_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

```c
struct gatts_delete_evt_param
#include <esp_gatts_api.h> ESP_GATTS_DELETE_EVT.
```

**Public Members**

- `esp_gatt_status_t status`
  Operation status
- `uint16_t service_handle`
  Service attribute handle

```c
struct gatts_disconnect_evt_param
#include <esp_gatts_api.h> ESP_GATTS_DISCONNECT_EVT.
```

**Public Members**

- `uint16_t conn_id`
  Connection id
- `esp_bd_addr_t remote_bda`
  Remote bluetooth device address
- `esp_gatt_conn_reason_t reason`
  Indicate the reason of disconnection
struct gatts_exec_write_evt_param
#include <esp_gatts_api.h> ESP_GATTS_EXEC_WRITE_EVT.

Public Members

uint16_t conn_id
    Connection id

uint32_t trans_id
    Transfer id

esp_bd_addr_t bda
    The bluetooth device address which been written

uint8_t exec_write_flag
    Execute write flag

struct gatts_mtu_evt_param
#include <esp_gatts_api.h> ESP_GATTS_MTU_EVT.

Public Members

uint16_t conn_id
    Connection id

uint16_t mtu
    MTU size

struct gatts_open_evt_param
#include <esp_gatts_api.h> ESP_GATTS_OPEN_EVT.

Public Members

esp_gatt_status_t status
    Operation status

struct gatts_read_evt_param
#include <esp_gatts_api.h> ESP_GATTS_READ_EVT.

Public Members

uint16_t conn_id
    Connection id

uint32_t trans_id
    Transfer id

esp_bd_addr_t bda
    The bluetooth device address which been read

uint16_t handle
    The attribute handle

uint16_t offset
    Offset of the value, if the value is too long

bool is_long
    The value is too long or not

bool need_rsp
    The read operation need to do response
struct gatts_reg_evt_param
#include <esp_gatts_api.h> ESP_GATT_REG_EVT.

Public Members

esp_gatt_status_t status
Operation status

uint16_t app_id
Application id which input in register API

struct gatts_rsp_evt_param
#include <esp_gatts_api.h> ESP_GATT_RESPONSE_EVT.

Public Members

esp_gatt_status_t status
Operation status

uint16_t handle
Attribute handle which send response

struct gatts_send_service_change_evt_param
#include <esp_gatts_api.h> ESP_GATT_SEND_SERVICE_CHANGE_EVT.

Public Members

esp_gatt_status_t status
Operation status

struct gatts_set_attr_val_evt_param
#include <esp_gatts_api.h> ESP_GATT_SET_ATTR_VAL_EVT.

Public Members

uint16_t srvc_handle
The service handle

uint16_t attr_handle
The attribute handle

esp_gatt_status_t status
Operation status

struct gatts_start_evt_param
#include <esp_gatts_api.h> ESP_GATT_START_EVT.

Public Members

esp_gatt_status_t status
Operation status

uint16_t service_handle
Service attribute handle

struct gatts_stop_evt_param
#include <esp_gatts_api.h> ESP_GATT_STOP_EVT.
Public Members

\texttt{esp_gatt_status_t status}
Operation status

\texttt{uint16_t service_handle}
Service attribute handle

\begin{verbatim}
struct gatts_writeEvt_param
#include <esp_gatts_api.h> ESP_GATTS_WRITE_EVT.
\end{verbatim}

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

\texttt{uint8_t* value}
The write attribute value

Macros

\texttt{ESP_GATT_PREP_WRITE_CANCEL}
Prepare write flag to indicate cancel prepare write

\texttt{ESP_GATT_PREP_WRITE_EXEC}
Prepare write flag to indicate execute prepare write

Type Definitions

\texttt{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

- \texttt{event::} Event type
- \texttt{gatts_if::} GATT server access interface, normally different gatts_if correspond to different profile
- \texttt{param::} Point to callback parameter, currently is union type

Enumerations
enum 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

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
Chapter 2. API Reference

**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**

```c
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.

```c
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

```c
esp_err_t esp_ble_gattc_app_unregister(esp_gatt_if_t gattc_if)
```
This function is called to unregister 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_gatt_if_t gattc_if, esp_bd_addr_t remote_bda,
                             esp_ble_addr_type_t remote_addr_type, bool is_direct)
```

Open a direct connection or add a background auto connection.

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_gatt_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_gatt_if_t gattc_if, uint16_t conn_id)
```

Close the virtual connection to the GATT server. gattc may have multiple virtual GATT server connections when multiple app_id registered, this API only close one virtual GATT server connection. if there exist other virtual GATT server connections, it does not disconnect the physical connection. if you want to disconnect the physical connection directly, you can use esp_ble_gap_disconnect(esp_bd_addr_t remote_device).

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_gatt_if_t gattc_if, uint16_t conn_id)
```

Configure the MTU size in the GATT channel. This can be done only once per connection. Before using, use esp_ble_gatt_set_local_mtu() to configure the local MTU size.

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 report 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_gatt_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.
- [out] 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.

\[
\text{esp_gatt_status_t esp_ble_gattc_get_all_char(gattc_if, conn_id,svc_uuid,&result, &count,offset)}
\]

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
- [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.
- [in] offset: Offset of the characteristic position to get.

\[
\text{esp_gatt_status_t esp_ble_gattc_get_all_descr(gattc_if, conn_id,svc_uuid,&result, &count,offset)}
\]

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.

\[
\text{esp_gatt_status_t esp_ble_gattc_get_char_by_uuid(gattc_if, conn_id,svc_uuid,&result, &count)}
\]

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
Chapter 2. API Reference

- [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.
- [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
Chapter 2. API Reference

- 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.

```
esp_gatt_status_t esp_ble_gattc_get_attr_count(esp_gatt_if_t gattc_if, uint16_t conn_id, esp_gatt_db_attr_type_t type, uint16_t start_handle, uint16_t end_handle, uint16_t incl_uuid, 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] 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.

```
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_gatt_db_elem_t* db, uint16_t* count)
```

This function is called to get the GATT database. Note: It just get attribute data base from local cache, won’t get from remote devices.

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.

```
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.
Chapter 2. API Reference

- [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] read_multi: pointer to the read multiple parameter.
- [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 characteristic 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.
### esp_err_t esp_ble_gattc_write_char_descr

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`: descriptor 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.

### esp_err_t esp_ble_gattc_prepare_write

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.
- [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.

### esp_err_t esp_ble_gattc_prepare_write_char_descr

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.

### esp_err_t esp_ble_gattc_execute_write

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.
### Chapter 2. API Reference

- [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.

```c
esp_err_t esp_ble_gattc_cache_assoc(esp_gatt_if_t gattc_if, esp_bd_addr_t src_addr, esp_bd_addr_t assoc_addr, bool is_assoc)
```
Add or delete the associated address with the source address. Note: The role of this API is mainly when the client side has stored a server-side database, when it needs to connect another device, but the device’s attribute database is the same as the server database stored on the client-side, calling this API can use the database that the device has stored used as the peer server database to reduce the attribute database search and discovery process and speed up the connection time. The associated address mains that device want to used the database has stored in the local cache. The source address mains that device want to share the database to the associated address device.

**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.

```c
esp_err_t esp_ble_gattc_cache_get_addr_list(esp_gatt_if_t gattc_if)
```
Get the address list which has store the attribute table in the gattc cache. There will callback ESP_GATTC_GET_ADDR_LIST_EVT event when get address list complete.

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

• \[\text{in}\] gattc_if: Gatt client access interface.

\[
\text{esp_err_t esp_ble_gattc_cache_clean(esp_bd_addr_t remote_bda)}
\]
Clean the service cache of this device in the gattc stack.

Return

• ESP_OK: success
• other: failed

Parameters

• \[\text{in}\] remote_bda: remote device BD address.

Unions

\[
\text{union esp_ble_gattc_cb_param_t}
\]
#include <esp_gattc_api.h> Gatt client callback parameters union.

Public Members

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_reg_evt_param reg}
\]
Gatt client callback param of ESP_GATTC_REG_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_open_evt_param open}
\]
Gatt client callback param of ESP_GATTC_OPEN_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_close_evt_param close}
\]
Gatt client callback param of ESP_GATTC_CLOSE_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_cfg_mtu_evt_param cfg_mtu}
\]
Gatt client callback param of ESP_GATTC_CFG_MTU_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_search_cmpl_evt_param search_cmpl}
\]
Gatt client callback param of ESP_GATTC_SEARCH_CMPL_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_search_res_evt_param search_res}
\]
Gatt client callback param of ESP_GATTC_SEARCH_RES_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_read_char_evt_param read}
\]
Gatt client callback param of ESP_GATTC_READ_CHAR_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_write_evt_param write}
\]
Gatt client callback param of ESP_GATTC_WRITE_DESCR_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_exec_cmpl_evt_param exec_cmpl}
\]
Gatt client callback param of ESP_GATTC_EXEC_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_notify_evt_param notify}
\]
Gatt client callback param of ESP_GATTC_NOTIFY_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_srvc_chg_evt_param srvc_chg}
\]
Gatt client callback param of ESP_GATTC_SRVC_CHG_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_congest_evt_param congest}
\]
Gatt client callback param of ESP_GATTC_CONGEST_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_reg_for_notify_evt_param reg_for_notify}
\]
Gatt client callback param of ESP_GATTC_REG_FOR_NOTIFY_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_unreg_for_notify_evt_param unreg_for_notify}
\]
Gatt client callback param of ESP_GATTC_UNREG_FOR_NOTIFY_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_connect_evt_param connect}
\]
Gatt client callback param of ESP_GATTC_CONNECT_EVT

\[
\text{struct esp_ble_gattc_cb_param_t::gattc_disconnect_evt_param disconnect}
\]
Gatt client callback param of ESP_GATTC_DISCONNECT_EVT
struct esp_ble_gattc_cb_param_t::gattc_set_assoc_addr_cmp_evt_param set_assoc_cmp
  Gatt client callback param of ESP_GATTC_SET_ASSOC_EVT

struct esp_ble_gattc_cb_param_t::gattc_get_addr_list_evt_param get_addr_list
  Gatt client callback param of ESP_GATTC_GET_ADDR_LIST_EVT

struct esp_ble_gattc_cb_param_t::gattc_queue_full_evt_param queue_full
  Gatt client callback param of ESP_GATTC_QUEUE_FULL_EVT

struct esp_ble_gattc_cb_param_t::gattc_dis_srvc_cmpl_evt_param dis_srvc_cmpl
  Gatt client callback param of ESP_GATTC_DIS_SRVC_CMPL_EVT

struct gattc_cfg_mtu_evt_param
  #include <esp_gattc_api.h> ESP_GATTC_CFG_MTU_EVT.

Public Members

esp_gatt_status_t status
  Operation status

uint16_t conn_id
  Connection id

uint16_t mtu
  MTU size

struct gattc_close_evt_param
  #include <esp_gattc_api.h> ESP_GATTC_CLOSE_EVT.

Public Members

esp_gatt_status_t status
  Operation status

uint16_t conn_id
  Connection id

esp_bd_addr_t remote_bda
  Remote bluetooth device address

esp_gatt_conn_reason_t reason
  The reason of gatt connection close

struct gattc_congest_evt_param
  #include <esp_gattc_api.h> ESP_GATTC_CONGEST_EVT.

Public Members

uint16_t conn_id
  Connection id

bool congested
  Congested or not

struct gattc_connect_evt_param
  #include <esp_gattc_api.h> ESP_GATTC_CONNECT_EVT.
Public Members

uint16_t conn_id
  Connection id

uint8_t link_role
  Link role: master role = 0 ; slave role = 1

esp_bd_addr_t remote_bda
  Remote bluetooth device address

esp_gatt_conn_params_t conn_params
  current connection parameters

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

esp_gatt_conn_reason_t reason
  disconnection reason

uint16_t conn_id
  Connection id

esp_bd_addr_t remote_bda
  Remote bluetooth device address

struct gattc_exec_cmpl_evt_param
  #include <esp_gattc_api.h> ESP_GATTC_EXEC_EVT.

Public Members

esp_gatt_status_t status
  Operation status

uint16_t conn_id
  Connection id

struct gattc_get_addr_list_evt_param
  #include <esp_gattc_api.h> ESP_GATTC_GET_ADDR_LIST_EVT.

Public Members

esp_gatt_status_t status
  Operation status

uint8_t num_addr
  The number of address in the gattc cache address 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**

- `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**

- `esp_gatt_status_t status`  
  Operation status
- `uint16_t conn_id`  
  Connection id
- `esp_bd_addr_t remote_bda`  
  Remote bluetooth device address
- `uint16_t mtu`  
  MTU size

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

**Public Members**

- `esp_gatt_status_t status`  
  Operation status
- `uint16_t conn_id`  
  Connection id
- `bool is_full`  
  The gattc command queue is full or not

```c
struct gattc_read_char_evt_param
#include <esp_gattc_api.h> ESP_GATTC_READ_CHAR_EVT, ESP_GATTC_READ_DESCR_EVT.
```
Chapter 2. API Reference

Public Members

*esp_gatt_status_t* `status`
Operation status

`uint16_t conn_id`
Connection id

`uint16_t handle`
Characteristic handle

`uint8_t* value`
Characteristic value

`uint16_t value_len`
Characteristic value length

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

Public Members

*esp_gatt_status_t* `status`
Operation status

`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

*esp_gatt_status_t* `status`
Operation status

`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

*esp_gatt_status_t* `status`
Operation status

`uint16_t conn_id`
Connection id

*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_gatt_status_t status
Operation status
```

```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 conn_id
Connection id
```

```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.
```
**uint16_t offset**

The prepare write offset, this value is valid only when prepare write

**Type Definitions**

typedef void (*esp_gattc_cb_t)(esp_gattc_cb_event_t event, esp_gatt_if_t gattc_if, esp_ble_gattc_cb_param_t *param)

GATT Client callback function type.

**Parameters**

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

**Enumerations**

enum esp_gattc_cb_event_t

GATT Client callback function events.

**Values:**

ESP_GATTC_REG_EVT = 0

When GATT client is registered, the event comes

ESP_GATTC_UNREG_EVT = 1

When GATT client is unregistered, the event comes

ESP_GATTC_OPEN_EVT = 2

When GATT virtual connection is set up, the event comes

ESP_GATTC_READ_CHAR_EVT = 3

When GATT characteristic is read, the event comes

ESP_GATTC_WRITE_CHAR_EVT = 4

When GATT characteristic write operation completes, the event comes

ESP_GATTC_CLOSE_EVT = 5

When GATT virtual connection is closed, the event comes

ESP_GATTC_SEARCH_CMPL_EVT = 6

When GATT service discovery is completed, the event comes

ESP_GATTC_SEARCH_RES_EVT = 7

When GATT service discovery result is got, the event comes

ESP_GATTC_READ_DESCR_EVT = 8

When GATT characteristic descriptor read completes, the event comes

ESP_GATTC_WRITE_DESCR_EVT = 9

When GATT characteristic descriptor write completes, the event comes

ESP_GATTC_NOTIFY_EVT = 10

When GATT notification or indication arrives, the event comes

ESP_GATTC_PREP_WRITE_EVT = 11

When GATT prepare-write operation completes, the event comes

ESP_GATTC_EXEC_EVT = 12

When write execution completes, the event comes

ESP_GATTC_ACL_EVT = 13

When ACL connection is up, the event comes

ESP_GATTC_CANCEL_OPEN_EVT = 14

When GATT client ongoing connection is cancelled, the event comes
ESP_GATTC_SRVC_CHG_EVT = 15
When “service changed” occurs, the event comes

ESP_GATTC_ENC_CMPL_CB_EVT = 17
When encryption procedure completes, the event comes

ESP_GATTC_CFG_MTU_EVT = 18
When configuration of MTU completes, the event comes

ESP_GATTC_ADV_DATA_EVT = 19
When advertising of data, the event comes

ESP_GATTC_MULT_ADV_ENB_EVT = 20
When multi-advertising is enabled, the event comes

ESP_GATTC_MULT_ADV_UPD_EVT = 21
When multi-advertising parameters are updated, the event comes

ESP_GATTC_MULT_ADV_DATA_EVT = 22
When multi-advertising data arrives, the event comes

ESP_GATTC_MULT_ADV_DIS_EVT = 23
When multi-advertising is disabled, the event comes

ESP_GATTC_CONGEST_EVT = 24
When GATT connection congestion comes, the event comes

ESP_GATTC_BTH_SCAN_ENB_EVT = 25
When batch scan is enabled, the event comes

ESP_GATTC_BTH_SCAN_CFG_EVT = 26
When batch scan storage is configured, the event comes

ESP_GATTC_BTH_SCAN_RD_EVT = 27
When Batch scan read event is reported, the event comes

ESP_GATTC_BTH_SCAN_THR_EVT = 28
When Batch scan threshold is set, the event comes

ESP_GATTC_BTH_SCAN_PARAM_EVT = 29
When Batch scan parameters are set, the event comes

ESP_GATTC_BTH_SCAN_DIS_EVT = 30
When Batch scan is disabled, the event comes

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
Chapter 2. API Reference

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_SRVC_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

Functions

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

Return ESP_OK - success, other - failed

Parameters
• [in] callbacks: callback functions

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

Return ESP_OK - success, other - failed

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

Return ESP_OK - success, other - failed

esp_err_t esp_blufi_send_wifi_conn_report (wifi_mode_t opmode, esp_blufi_sta_conn_state_t sta_conn_state, uint8_t softap_conn_num, esp_blufi_extra_info_t *extra_info)
This function is called to send wifi connection report.

Return ESP_OK - success, other - failed

Parameters
• opmode: wifi opmode
• sta_conn_state: station is already in connection or not
Chapter 2. API Reference

- **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.

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

**Parameters**
- **apCount**: wifi list count
- **list**: wifi list

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

**Return**: Most 8bit significant is Great version, Least 8bit is Sub version

```c
esp_err_t esp_blufi_send_error_info (esp_blufi_error_state_t state)
```
This function is called to send blufi error information.

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

**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.

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

**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

```c
struct esp_blufi_cb_param_t::blufi_deinit_finish_evt_param deinit_finish
```
Blufi callback param of ESP_BLUFI_EVENT_DEINIT_FINISH

```c
struct esp_blufi_cb_param_t::blufi_set_wifi_mode_evt_param wifi_mode
```
Blufi callback param of ESP_BLUFI_EVENT_INIT_FINISH

```c
struct esp_blufi_cb_param_t::blufi_connect_evt_param connect
```
Blufi callback param of ESP_BLUFI_EVENT_CONNECT

```c
struct esp_blufi_cb_param_t::blufi_disconnect_evt_param disconnect
```
Blufi callback param of ESP_BLUFI_EVENT_DISCONNECT

```c
struct esp_blufi_cb_param_t::blufi_recv_sta_bssid_evt_param sta_bssid
```
Blufi callback param of ESP_BLUFI_EVENT_RECV_STA_BSSID

```c
struct esp_blufi_cb_param_t::blufi_recv_sta_ssid_evt_param sta_ssid
```
Blufi callback param of ESP_BLUFI_EVENT_RECV_STA_SSID

```c
struct esp_blufi_cb_param_t::blufi_recv_sta_passwd_evt_param sta_passwd
```
Blufi callback param of ESP_BLUFI_EVENT_RECV_STA_PASSWD

```c
struct esp_blufi_cb_param_t::blufi_recv_softap_ssid_evt_param softap_ssid
```
Blufi callback param of ESP_BLUFI_EVENT_RECV_SOFTAP_SSID
Chapter 2. API Reference

```c
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

esp_bd_addr_t remote_bda
    Blufi Remote bluetooth device address

uint8_t server_if
    server interface

uint16_t conn_id
    Connection id

struct blufi_deinit_finish_evt_param
    #include <esp_blufi_api.h> ESP_BLUFI_EVENT_DEINIT_FINISH.

Public Members

esp_blufi_deinit_state_t state
    De-initial status

struct blufi_disconnect_evt_param
    #include <esp_blufi_api.h> ESP_BLUFI_EVENT_DISCONNECT.
```
Public Members

`esp_bd_addr_t remote_bda`
Blufi Remote bluetooth device address

`struct blufi_get_error_evt_param`
`#include <esp_blufi_api.h>` ESP_BLUFI_EVENT_REPORT_ERROR.

Public Members

`esp_blufi_error_state_t state`
Blufi error state

`struct blufi_init_finish_evt_param`
`#include <esp_blufi_api.h>` ESP_BLUFI_EVENT_INIT_FINISH.

Public Members

`esp_blufi_init_state_t state`
Initial status

`struct blufi_recv_ca_evt_param`
`#include <esp_blufi_api.h>` ESP_BLUFI_EVENT_RECV_CA_CERT.

Public Members

uint8_t* cert
CA certificate point

int cert_len
CA certificate length

`struct blufi_recv_client_cert_evt_param`
`#include <esp_blufi_api.h>` ESP_BLUFI_EVENT_RECV_CLIENT_CERT

Public Members

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

```c
uint8_t *data
Custom data
```

```c
uint32_t data_len
Custom data Length
```

```c
struct blufi_recv_server_cert_evt_param
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_SERVER_CERT
```
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.
```

Public Members

```c
uint8_t *passwd
Password
```

```c
int passwd_len
Password Length
```

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

Public Members

```c
uint8_t *ssid
SSID
```

```c
int ssid_len
SSID length
```

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

Public Members

```c
uint8_t *name
Username point
```
struct blufi_set_wifi_mode_evt_param
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_SET_WIFI_MODE.

Public Members

wifi_mode_t op_mode
Wifi operation mode

Structures

struct esp_blufi_extra_info_t
BLUFI extra information structure.

Public Members

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
BLUFI callback functions type.

Public Members

esp_blufi_event_cb_t event_cb
BLUFI event callback

esp_blufi_negotiate_data_handler_t negotiate_data_handler
BLUFI negotiate data function for negotiate share key

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

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

esp_blufi_checksum_func_t checksum_func
BLUFI check sum function (FCS)

Macros

ESP_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_cb_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_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
Chapter 2. API Reference

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_REPORT_ERROR
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

enum esp_blufi_error_state_t
Values:
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 CLASSIC BT
CLASSIC BLUETOOTH GAP API

Overview Instructions

Application Example Instructions
API Reference

Header File

- components/bt/host/bluedroid/api/include/api/esp_gap_bt_api.h

Functions

```c
static uint32_t esp_bt_gap_get_cod_svc(uint32_t cod)
get major service field of COD

Return major service bits

Parameters
• [in] cod: Class of Device

static uint32_t esp_BT_gap_get_cod_major_dev(uint32_t cod)
get major device field of COD

Return major device bits

Parameters
• [in] cod: Class of Device

static uint32_t esp_BT_gap_get_cod_minor_dev(uint32_t cod)
get minor service field of COD

Return minor service bits

Parameters
• [in] cod: Class of Device

static uint32_t esp_BT_gap_get_cod_format_type(uint32_t cod)
get format type of COD

Return format type

Parameters
• [in] cod: Class of Device

static bool esp_BT_gap_is_valid_cod(uint32_t cod)
deck the integrity of COD

Return
• true if cod is valid
• false otherwise

Parameters
• [in] cod: Class of Device
```

```c
esp_err_t esp_BT_gap_register_callback(esp_BT_gap_cb_t callback)
register callback function. This function should be called after esp_bluedroid_enable() completes successfully

Return
• ESP_OK: Succeed
• ESP_FAIL: others

esp_err_t esp_BT_gap_set_scan_mode(esp_BT_connection_mode_t c_mode,
esp_BT_discovery_mode_t d_mode)
Set discoverability and connectability mode for legacy bluetooth. This function should be called after esp_bluedroid_enable() completes successfully.

Return
• ESP_OK: Succeed
• ESP_ERR_INVALID_ARG: if argument invalid
• ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

Parameters
• [in] c_mode:: one of the enums of esp_BT_connection_mode_t
• [in] d_mode:: one of the enums of esp_BT_discovery_mode_t
```
**esp_err_t** `esp_bt_gap_start_discovery**(esp_bt_inq_mode_t mode, uint8_t inq_len, uint8_t num_rsps)**

This function starts Inquiry and Name Discovery. This function should be called after `esp_bluedroid_enable()` completes successfully. When Inquiry is halted and cached results do not contain device name, then Name Discovery will connect to the peer target to get the device name. `esp_bt_gap_cb_t` will be called with `ESP_BT_GAP_DISC_STATE_CHANGED_EVT` when Inquiry is started or Name Discovery is completed. `esp_bt_gap_cb_t` will be called with `ESP_BT_GAP_DISC_RES_EVT` each time the two types of discovery results are got.

**Return**
- ESP_OK: Succeed
- ESP_ERR_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_ERR_INVALID_ARG: if invalid parameters are provided
- ESP_FAIL: others

**Parameters**
- [in] mode: - Inquiry mode
- [in] inq_len: - Inquiry duration in 1.28 sec units, ranging from 0x01 to 0x30. This parameter only specifies the total duration of the Inquiry process.
  - when this time expires, Inquiry will be halted.
- [in] num_rsps: - Number of responses that can be received before the Inquiry is halted, value 0 indicates an unlimited number of responses.

**esp_err_t** `esp_bt_gap_cancel_discovery**(void)**

Cancel Inquiry and Name Discovery. This function should be called after `esp_bluedroid_enable()` completes successfully. `esp_bt_gap_cb_t` will be called with `ESP_BT_GAP_DISC_STATE_CHANGED_EVT` if Inquiry or Name Discovery is cancelled by calling this function.

**Return**
- ESP_OK: Succeed
- ESP_ERR_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

**esp_err_t** `esp_bt_gap_get_remote_services**(esp_bd_addr_t remote_bda)**

Start SDP to get remote services. This function should be called after `esp_bluedroid_enable()` completes successfully. `esp_bt_gap_cb_t` will be called with `ESP_BT_GAP_RMT_SRVCS.EVT` after service discovery ends.

**Return**
- ESP_OK: Succeed
- ESP_ERR_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

**esp_err_t** `esp_bt_gap_get_remote_service_record**(esp_bd_addr_t remote_bda, esp_bt_uuid_t *uuid)**

Start SDP to look up the service matching uuid on the remote device. This function should be called after `esp_bluedroid_enable()` completes successfully.

`esp_bt_gap_cb_t` will be called with `ESP_BT_GAP_RMT_SRVC_REC.EVT` after service discovery ends.

**Return**
- ESP_OK: Succeed
- ESP_ERR_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

**uint8_t** `*esp_bt_gap_resolve_eir_data**(uint8_t *eir, esp_bt_type_t type, uint8_t *length)**

This function is called to get EIR data for a specific type.

**Return**
pointer of starting position of eir data excluding eir data type, NULL if not found

**Parameters**
- [in] eir: - pointer of raw eir data to be resolved
- [in] type: - specific EIR data type
- [out] length: - return the length of EIR data excluding fields of length and data type
esp_err_t esp_bt_gap_config_eir_data (esp_bt_eir_data_t *eir_data)

This function is called to config EIR data.

esp bt_gap cb t will be called with ESP_BT_GAP_CONFIG_EIR_DATA_EVT after config EIR ends.

Return
• ESP_OK : Succeed
• ESP_ERR_INVAL DS TATE: if bluetooth stack is not yet enabled
• ESP_ERR_INV ALD ARG: if param is invalid
• ESP_FAIL: others

Parameters
• [in] eir_data : pointer of EIR data content

esp_err_t esp bt_gap_set_co d (esp bt cod t cod, esp bt cod_mode t mode)

This function is called to set class of device. The structure esp bt_gap cb t will be called with ESP_BT_GAP_SET_COD_EVT after set COD ends. Some profile have special restrictions on class of device, changes may cause these profile do not work.

Return
• ESP_OK : Succeed
• ESP_ERR_INVAL DS TATE: if bluetooth stack is not yet enabled
• ESP_ERR_INV ALD ARG: if param is invalid
• ESP_FAIL: others

Parameters
• [in] cod: - class of device
• [in] mode: - setting mode

esp_err_t esp bt_gap_get_co d (esp bt cod t *cod)

This function is called to get class of device.

Return
• ESP_OK : Succeed
• ESP_FAIL: others

Parameters
• [out] cod: - class of device

esp_err_t esp bt_gap_read_rssi_delta (esp bd addr t remote_addr)

This function is called to read RSSI delta by address after connected. The RSSI value returned by ESP_BT_GAP_READ_RSSI_DELTA_EVT.

Return
• ESP_OK : Succeed
• ESP_FAIL: others

Parameters
• [in] remote_addr: - remote device address, corresponding to a certain connection handle

esp_err_t esp bt_gap_remove_bond_device (esp bd addr t bd_addr)

Removes a device from the security database list of peer device.

Return - ESP_OK : success
• ESP_FAIL : failed

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

int esp bt_gap_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 bt_gap_get_bond_device_list (int *dev_num, esp bd addr t *dev_list)

Get the device from the security database list of peer device. It will return the device bonded information immediately.
Chapter 2. API Reference

Return

- ESP_OK : Succeed
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

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_bd_addr_t type. Use for storing the bonded devices address. The dev_list should be allocated by who call this API.

`esp_err_t esp_bt_gap_set_pin(esp_bt_pin_type_t pin_type, uint8_t pin_code_len, esp_bt_pin_code_t pin_code)`

Set pin type and default pin code for legacy pairing.

Return - ESP_OK : success

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

Parameters

- [in] pin_type: Use variable or fixed pin. If pin_type is ESP_BT_PIN_TYPE_VARIABLE, pin_code and pin_code_len will be ignored, and ESP_BT_GAP_PIN_REQ_EVT will come when control requests for pin code. Else, will use fixed pin code and not callback to users.
- [in] pin_code_len: Length of pin_code
- [in] pin_code: Pin_code

`esp_err_t esp_bt_gap_pin_reply(esp_bd_addr_t bd_addr, bool accept, uint8_t pin_code_len, esp_bt_pin_code_t pin_code)`

Reply the pin code to the peer device for legacy pairing when ESP_BT_GAP_PIN_REQ_EVT is coming.

Return - ESP_OK : success

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

Parameters

- [in] bd_addr: BD address of the peer
- [in] accept: Pin_code reply successful or declined.
- [in] pin_code_len: Length of pin_code
- [in] pin_code: Pin_code

`esp_err_t esp_bt_gap_set_security_param(esp_bt_sp_param_t param_type, void *value, uint8_t len)`

Set a GAP security parameter value. Overrides the default value.

Return - ESP_OK : success

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

Parameters

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

`esp_err_t esp_bt_gap_ssp_passkey_reply(esp_bd_addr_t bd_addr, bool accept, uint32_t passkey)`

Reply the key value to the peer device in the legacy connection stage.

Return - ESP_OK : success

- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- 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.

`esp_err_t esp_bt_gap_ssp_confirm_reply(esp_bd_addr_t bd_addr, bool accept)`
Reply the confirm value to the peer device in the legacy connection stage.

**Return**
- ESP_OK: success
  - ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
  - 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_bt_gap_set_afh_channels(esp_bt_gap_afh_channels channels)
```
Set the AFH 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 78) contains the value for channel n:
  0 means channel n is bad. 1 means channel n is unknown. The most significant bit is reserved and shall be set to 0. At least 20 channels shall be marked as unknown.

```c
esp_err_t esp_bt_gap_read_remote_name(esp_bd_addr_t remote_bda)
```
Read the remote device name.

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

**Parameters**
- [in] remote_bda: The remote device’s address

```c
esp_err_t esp_bt_gap_set_qos(esp_bd_addr_t remote_bda, uint32_t t_poll)
```
Config Quality of service.

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

**Parameters**
- [in] remote_bda: The remote device’s address
- [in] t_poll: Poll interval, the maximum time between transmissions which from the master to a particular slave on the ACL logical transport. unit is 0.625 ms

**Unions**

```c
union esp_bt_gap_cb_param_t
```
GAP state callback parameters.

**Public Members**

```c
struct esp_bt_gap_cb_param_t::disc_res_param disc_res
```
discovery result parameter struct

```c
struct esp_bt_gap_cb_param_t::disc_state_changed_param disc_st_chg
```
discovery state changed parameter struct

```c
struct esp_bt_gap_cb_param_t::rmt_srvcs_param rmt_srvcs
```
services of remote device parameter struct

```c
struct esp_bt_gap_cb_param_t::rmt_srvc_rec_param rmt_srvc_rec
```
specific service record from remote device parameter struct

```c
struct esp_bt_gap_cb_param_t::read_rssi_delta_param read_rssi_delta
```
read rssi parameter struct

```c
struct esp_bt_gap_cb_param_t::config_eir_data_param config_eir_data
```
config EIR data
```c
struct esp_bt_gap_cb_param_t::auth_cmpl_param auth_cmpl
  authentication complete parameter struct

struct esp_bt_gap_cb_param_t::pin_req_param pin_req
  pin request parameter struct

struct esp_bt_gap_cb_param_t::cfm_req_param cfm_req
  confirm request parameter struct

struct esp_bt_gap_cb_param_t::key_notif_param key_notif
  passkey notif parameter struct

struct esp_bt_gap_cb_param_t::key_req_param key_req
  passkey request parameter struct

struct esp_bt_gap_cb_param_t::set_afh_channels_param set_afh_channels
  set AFH channel parameter struct

struct esp_bt_gap_cb_param_t::read_rmt_name_param read_rmt_name
  read Remote Name parameter struct

struct esp_bt_gap_cb_param_t::mode_chg_param mode_chg
  mode change event parameter struct

struct esp_bt_gap_cb_param_t::bt_remove_bond_dev_cmpl_evt_param remove_bond_dev_cmpl
  Event parameter of ESP_BT_GAP_REMOVE_BOND_DEV_COMPLETE_EVT

struct esp_bt_gap_cb_param_t::qos_cmpl_param qos_cmpl
  QoS complete parameter struct

struct auth_cmpl_param
  #include <esp_gap_bt_api.h> ESP_BT_GAP_AUTH_CMPL_EVT.

Public Members

  esp_bd_addr_t bda
    remote bluetooth device address

  esp_bt_status_t stat
    authentication complete status

  uint8_t device_name[ESP_BT_GAP_MAX_BDNAME_LEN + 1]
    device name

struct bt_remove_bond_dev_cmpl_evt_param
  #include <esp_gap_bt_api.h> ESP_BT_GAP_REMOVE_BOND_DEV_COMPLETE_EVT.

Public Members

  esp_bd_addr_t bda
    remote bluetooth device address

  esp_bt_status_t status
    Indicate the remove bond device operation success status

struct cfm_req_param
  #include <esp_gap_bt_api.h> ESP_BT_GAP_CFM_REQ_EVT.

Public Members

  esp_bd_addr_t bda
    remote bluetooth device address
```
uint32_t num_val
the numeric value for comparison.

**struct config_eir_data_param**
#include <esp_gap_bt_api.h> ESP_BT_GAP_CONFIG_EIR_DATA_EVT.

**Public Members**

*esp_bt_status_t stat*
config EIR status: ESP_BT_STATUS_SUCCESS: config success
ESP_BT_STATUS_EIR_TOO_LARGE: the EIR data is more than 240B. The EIR may not contain the whole data. others: failed

*uint8_t eir_type_num*
the number of EIR types in EIR type

*esp_bt_eir_type_t eir_type[ESP_BT_EIR_TYPE_MAX_NUM]*
EIR types in EIR type

**struct disc_res_param**
#include <esp_gap_bt_api.h> ESP_BT_GAP_DISC_RES_EVT.

**Public Members**

*esp_bd_addr_t bda*
remote bluetooth device address

*int num_prop*
number of properties got

*esp_bt_gap_dev_prop_t *prop*
properties discovered from the new device

**struct disc_state_changed_param**
#include <esp_gap_bt_api.h> ESP_BT_GAP_DISC_STATE_CHANGED_EVT.

**Public Members**

*esp_bt_gap_discovery_state_t state*
discovery state

**struct key_notif_param**
#include <esp_gap_bt_api.h> ESP_BT_GAP_KEY_NOTIF_EVT.

**Public Members**

*esp_bd_addr_t bda*
remote bluetooth device address

*uint32_t passkey*
the numeric value for passkey entry.

**struct key_req_param**
#include <esp_gap_bt_api.h> ESP_BT_GAP_KEY_REQ_EVT.
Public Members

```c
esp_bd_addr_t bda
remote bluetooth device address
```

```c
struct mode_chg_param
#include <esp_gap_bt_api.h> ESP_BT_GAP_MODE_CHG_EVT.
```

Public Members

```c
esp_bd_addr_t bda
remote bluetooth device address
```

```c
esp_bt_pm_mode_t mode
PM mode
```

```c
struct pin_req_param
#include <esp_gap_bt_api.h> ESP_BT_GAP_PIN_REQ_EVT.
```

Public Members

```c
esp_bd_addr_t bda
remote bluetooth device address
```

```c
bool min_16_digit
TRUE if the pin returned must be at least 16 digits
```

```c
struct qos_cmpl_param
#include <esp_gap_bt_api.h> ESP_BT_GAP_QOS_CMPL_EVT.
```

Public Members

```c
esp_bt_status_t stat
QoS status
```

```c
esp_bd_addr_t bda
remote bluetooth device address
```

```c
uint32_t t_poll
poll interval, the maximum time between transmissions which from the master to a particular slave on the ACL logical transport. unit is 0.625ms.
```

```c
struct read_rmt_name_param
#include <esp_gap_bt_api.h> ESP_BT_GAP_READ_REMOTE_NAME_EVT.
```

Public Members

```c
esp_bt_status_t stat
read Remote Name status
```

```c
uint8_t rmt_name[ESP_BT_GAP_MAX_BDNAME_LEN + 1]
Remote device name
```

```c
struct read_rssi_delta_param
#include <esp_gap_bt_api.h> ESP_BT_GAP_READ_RSSI_DELTA_EVT *.
```
Public Members

`esp_bd_addr_t bda`
remote bluetooth device address

`esp_bt_status_t stat`
read rssi status

`int8_t rssi_delta`
rsi delta value range -128 ~127. The value zero indicates that the RSSI is inside the Golden Receive Power Range, the Golden Receive Power Range is from ESP_BT_GAP_RSSI_LOW_THRLD to ESP_BT_GAP_RSSI_HIGH_THRLD

`struct rmt_srvc_rec_param`

```
#include <esp_gap_bt_api.h>
ESP_BT_GAP_RMT_SRVC_REC_EVT.
```

Public Members

`esp_bd_addr_t bda`
remote bluetooth device address

`esp_bt_status_t stat`
service search status

`struct rmt_srvcs_param`

```
#include <esp_gap_bt_api.h>
ESP_BT_GAP_RMT_SRVCS_EVT.
```

Public Members

`esp_bd_addr_t bda`
remote bluetooth device address

`esp_bt_status_t stat`
service search status

`int num_uuids`
number of UUID in uuid_list

`esp_bt_uuid_t *uuid_list`
list of service UUIDs of remote device

`struct set_afh_channels_param`

```
#include <esp_gap_bt_api.h>
ESP_BT_GAP_SET_AFH_CHANNELS_EVT.
```

Public Members

`esp_bt_status_t stat`
set AFH channel status

Structures

`struct esp_bt_cod_t`
Class of device.

Public Members

`uint32_t reserved_2 : 2`
undefined
uint32_t minor : 6
    minor class
uint32_t major : 5
    major class
uint32_t service : 11
    service class
uint32_t reserved_8 : 8
    undefined

**struct esp_bt_gap_dev_prop_t**
    Bluetooth Device Property Descriptor.

**Public Members**

* esp_bt_gap_dev_prop_type_t* type
    Device property type
int len
    Device property value length
void *val
    Device property value

**struct esp_bt_eir_data_t**
    EIR data content, according to “Supplement to the Bluetooth Core Specification”.

**Public Members**

bool fec_required
    FEC is required or not, true by default
bool include_txpower
    EIR data include TX power, false by default
bool include_uuid
    EIR data include UUID, false by default
uint8_t flag
    EIR flags, see ESP_BT_EIR_FLAG for details, EIR will not include flag if it is 0, 0 by default
uint16_t manufacturer_len
    Manufacturer data length, 0 by default
uint8_t *p_manufacturer_data
    Manufacturer data point
uint16_t url_len
    URL length, 0 by default
uint8_t *p_url
    URL point

**Macros**

ESP_BT_GAP_RSSI_HIGH_THRLD
    RSSI threshold.
    High RSSI threshold
ESP_BT_GAP_RSSI_LOW_THRLD
    Low RSSI threshold
ESP_BT_GAP_AFH_CHANNELS_LEN
    Espressif Systems 239
**ESP_BT_GAP_MAX_BDNAME_LEN**
Maximum bytes of Bluetooth device name.

**ESP_BT_GAP_EIR_DATA_LEN**
Maximum size of EIR Significant part.

**ESP_BT_EIR_TYPE_FLAGS**
Extended Inquiry Response data type.
Flag with information such as BR/EDR and LE support

**ESP_BT_EIR_TYPE_INCMPL_16BITS_UUID**
Incomplete list of 16-bit service UUIDs

**ESP_BT_EIR_TYPE_CMPL_16BITS_UUID**
Complete list of 16-bit service UUIDs

**ESP_BT_EIR_TYPE_INCMPL_32BITS_UUID**
Incomplete list of 32-bit service UUIDs

**ESP_BT_EIR_TYPE_CMPL_32BITS_UUID**
Complete list of 32-bit service UUIDs

**ESP_BT_EIR_TYPE_INCMPL_128BITS_UUID**
Incomplete list of 128-bit service UUIDs

**ESP_BT_EIR_TYPE_CMPL_128BITS_UUID**
Complete list of 128-bit service UUIDs

**ESP_BT_EIR_TYPE_SHORT_LOCAL_NAME**
Shortened Local Name

**ESP_BT_EIR_TYPE_CMPL_LOCAL_NAME**
Complete Local Name

**ESP_BT_EIR_TYPE_TX_POWER_LEVEL**
Tx power level, value is 1 octet ranging from -127 to 127, unit is dBm

**ESP_BT_EIR_TYPE_URL**
Uniform resource identifier

**ESP_BT_EIR_TYPE_MANU_SPECIFIC**
Manufacturer specific data

**ESP_BT_EIR_TYPE_MAX_NUM**
MAX number of EIR type

**ESP_BT_EIR_FLAG_LIMIT_DISC**

**ESP_BT_EIR_FLAG_GEN_DISC**

**ESP_BT_EIR_FLAG_BREDR_NOT_SPT**

**ESP_BT_EIR_FLAG_DMT_CONTROLLER_SPT**

**ESP_BT_EIR_FLAG_DMT_HOST_SPT**

**ESP_BT_EIR_MAX_LEN**

**ESP_BT_PIN_CODE_LEN**
Max pin code length

**ESP_BT_IO_CAP_OUT**

**ESP_BT_IO_CAP_IO**

**ESP_BT_IO_CAP_IN**

**ESP_BT_IO_CAP_NONE**

**ESP_BT_PM_MD_ACTIVE**
Active mode
**Chapter 2. API Reference**

**ESP_BT_PM_MD_HOLD**
- Hold mode

**ESP_BT_PM_MD_SNIFF**
- Sniff mode

**ESP_BT_PM_MD_PARK**
- Park state

**ESP_BT_COD_SRVC_BIT_MASK**
- Bits of major service class field.
- Major service bit mask

**ESP_BT_COD_SRVC_BIT_OFFSET**
- Major service bit offset

**ESP_BT_COD_MAJOR_DEV_BIT_MASK**
- Bits of major device class field.
- Major device bit mask

**ESP_BT_COD_MAJOR_DEV_BIT_OFFSET**
- Major device bit offset

**ESP_BT_COD_MINOR_DEV_BIT_MASK**
- Bits of minor device class field.
- Minor device bit mask

**ESP_BT_COD_MINOR_DEV_BIT_OFFSET**
- Minor device bit offset

**ESP_BT_COD_FORMAT_TYPE_BIT_MASK**
- Bits of format type.
- Format type bit mask

**ESP_BT_COD_FORMAT_TYPE_BIT_OFFSET**
- Format type bit offset

**ESP_BT_COD_FORMAT_TYPE_1**
- Class of device format type 1.

**ESP_BT_GAP_MIN_INQ_LEN**
- Minimum and Maximum inquiry length Minimum inquiry duration, unit is 1.28s

**ESP_BT_GAP_MAX_INQ_LEN**
- Maximum inquiry duration, unit is 1.28s

**Type Definitions**

```c
typedef uint8_t esp_bt_gap_afh_channels[ESP_BT_GAP_AFH_CHANNELS_LEN]
typedef uint8_t esp_bt_eir_type_t

typedef uint8_t esp_bt_pin_code_t[ESP_BT_PIN_CODE_LEN]
    Pin Code (upto 128 bits) MSB is 0

typedef uint8_t esp_bt_io_cap_t
    Combination of the IO Capability

typedef void(*esp_bt_gap_cb_t)(esp_bt_gap_cb_event_t event, esp_bt_gap_cb_param_t *param)
    bluetooth GAP callback function type
```

**Parameters**
- `event`: Event type
- `param`: Pointer to callback parameter
Enumerations

def enum esp_bt_cod_mode_t
    class of device settings
    
    Values:
    
    ESP_BT_SET_COD_MAJOR_MINOR = 0x01
    overwrite major, minor class
    
    ESP_BT_SET_COD_SERVICE_CLASS = 0x02
    set the bits in the input, the current bit will remain
    
    ESP_BT_CLR_COD_SERVICE_CLASS = 0x04
    clear the bits in the input, others will remain
    
    ESP_BT_SET_COD_ALL = 0x08
    overwrite major, minor, set the bits in service class
    
    ESP_BT_INIT_COD = 0x0a
    overwrite major, minor, and service class


def enum esp_bt_connection_mode_t
    Discoverability and Connectability mode.
    
    Values:
    
    ESP_BT_NON_CONNECTABLE
    Non-connectable
    
    ESP_BT_CONNECTABLE
    Connectable


def enum esp_bt_discovery_mode_t
    Values:
    
    ESP_BT_NON_DISCOVERABLE
    Non-discoverable
    
    ESP_BT_LIMITED_DISCOVERABLE
    Limited Discoverable
    
    ESP_BT_GENERAL_DISCOVERABLE
    General Discoverable


def enum esp_bt_gap_dev_prop_type_t
    Bluetooth Device Property type.
    
    Values:
    
    ESP_BT_GAP_DEV_PROP_BDNAME = 1
    Bluetooth device name, value type is int8_t []
    
    ESP_BT_GAP_DEV_PROP_COD
    Class of Device, value type is uint32_t
    
    ESP_BT_GAP_DEV_PROP_RSSI
    Received Signal strength Indication, value type is int8_t, ranging from -128 to 127
    
    ESP_BT_GAP_DEV_PROP_EIR
    Extended Inquiry Response, value type is uint8_t []


def enum esp_bt_cod_srvc_t
    Major service class field of Class of Device, multiple bits can be set.
    
    Values:
    
    ESP_BT_COD_SRVC_NONE = 0
    None indicates an invalid value
    
    ESP_BT_COD_SRVC_LMTD_DISCOVER = 0x01
    Limited Discoverable Mode
**ESP_BT_COD_SRVC_POSITIONING** = 0x8
Positioning (Location identification)

**ESP_BT_COD_SRVC_NETWORKING** = 0x10
Networking, e.g. LAN, Ad hoc

**ESP_BT_COD_SRVC_RENDERING** = 0x20
Rendering, e.g. Printing, Speakers

**ESP_BT_COD_SRVC_CAPTUREING** = 0x40
Capturing, e.g. Scanner, Microphone

**ESP_BT_COD_SRVC_OBJ_TRANSFER** = 0x80
Object Transfer, e.g. v-Inbox, v-Folder

**ESP_BT_COD_SRVC_AUDIO** = 0x100
Audio, e.g. Speaker, Microphone, Headset service

**ESP_BT_COD_SRVC_TELEPHONY** = 0x200
Telephony, e.g. Cordless telephony, Modem, Headset service

**ESP_BT_COD_SRVC_INFORMATION** = 0x400
Information, e.g., WEB-server, WAP-server

```
enum esp_bt_pin_type_t
Values:

ESP_BT_PIN_TYPE_VARIABLE = 0
Refer to BTM_PIN_TYPE_VARIABLE

ESP_BT_PIN_TYPE_FIXED = 1
Refer to BTM_PIN_TYPE_FIXED
```

```
enum esp_bt_sp_param_t
Values:

ESP_BT_SP_IOCAP_MODE = 0
Set IO mode
```

```
enum esp_bt_cod_major_dev_t
Major device class field of Class of Device.
Values:

ESP_BT_COD_MAJOR_DEV_MISC = 0
Miscellaneous

ESP_BT_COD_MAJOR_DEV_COMPUTER = 1
Computer

ESP_BT_COD_MAJOR_DEV_PHONE = 2
Phone(cellular, cordless, pay phone, modem

ESP_BT_COD_MAJOR_DEV_LAN_NAP = 3
LAN, Network Access Point

ESP_BT_COD_MAJOR_DEV_AV = 4
Audio/Video(headset, speaker, stereo, video display, VCR

ESP_BT_COD_MAJOR_DEV_PERIPHERAL = 5
Peripheral(mouse, joystick, keyboard)

ESP_BT_COD_MAJOR_DEV_IMAGING = 6
Imaging(printer, scanner, camera, display

ESP_BT_COD_MAJOR_DEV_WEARABLE = 7
Wearable

ESP_BT_COD_MAJOR_DEV_TOY = 8
Toy
```
ESP_BT_COD_MAJOR_DEV_HEALTH = 9
Health
ESP_BT_COD_MAJOR_DEV_UNCATEGORIZED = 31
Uncategorized: device not specified

enum esp_bt_gap_discovery_state_t
Bluetooth Device Discovery state
Values:
ESP_BT_GAP_DISCOVERY_STOPPED
Device discovery stopped
ESP_BT_GAP_DISCOVERY_STARTED
Device discovery started

enum esp_bt_gap_cb_event_t
BT GAP callback events.
Values:
ESP_BT_GAP_DISC_RES_EVT = 0
Device discovery result event
ESP_BT_GAP_DISC_STATE_CHANGED_EVT
Discovery state changed event
ESP_BT_GAP_RMT_SRVCS_EVT
Get remote services event
ESP_BT_GAP_RMT_SRVC_REC_EVT
Get remote service record event
ESP_BT_GAP_AUTH_CMPL_EVT
Authentication complete event
ESP_BT_GAP_PIN_REQ_EVT
Legacy Pairing Pin code request
ESP_BT_GAP_CFM_REQ_EVT
Security Simple Pairing User Confirmation request.
ESP_BT_GAP_KEY_NOTIF_EVT
Security Simple Pairing Passkey Notification
ESP_BT_GAP_KEY_REQ_EVT
Security Simple Pairing Passkey request
ESP_BT_GAP_READ_RSSI_DELTA_EVT
Read rssi event
ESP_BT_GAP_CONFIG_EIR_DATA_EVT
Config EIR data event
ESP_BT_GAP_SET_AFH_CHANNELS_EVT
Set AFH channels event
ESP_BT_GAP_READ_REMOTE_NAME_EVT
Read Remote Name event
ESP_BT_GAP_MODE_CHG_EVT
ESP_BT_GAP_REMOVE_BOND_DEV_COMPLETE_EVT
remove bond device complete event
ESP_BT_GAP_QOS_CMPL_EVT
QOS complete event
ESP_BT_GAP_EVT_MAX

enum esp_bt_inq_mode_t
Inquiry Mode

Values:

ESP_BT_INQ_MODE_GENERAL_INQUIRY
   General inquiry mode

ESP_BT_INQ_MODE_LIMITED_INQUIRY
   Limited inquiry mode

Bluetooth A2DP API

Overview

Instructions

Application Example

Check bluetooth/bluedroid/classic_bt folder in ESP-IDF examples, which contains the following application:

- This is a A2DP sink client demo. This demo can be discovered and connected by A2DP source device and receive the audio stream from remote device - bluetooth/bluedroid/classic_bt/a2dp_sink

API Reference

Header File

- components/bt/host/bluedroid/api/include/api/esp_a2dp_api.h

Functions

\texttt{esp_a2d_register_callback (esp_a2d_cb_t callback)}

Register application callback function to A2DP module. This function should be called only after esp_bluedroid_enable() completes successfully, used by both A2DP source and sink.

Return

- ESP_OK: success
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: if callback is a NULL function pointer

Parameters

- \texttt{[in] callback}: A2DP event callback function

\texttt{esp_a2d_sink_register_data_callback (esp_a2d_sink_data_cb_t callback)}

Register A2DP sink data output function; For now the output is PCM data stream decoded from SBC format. This function should be called only after esp_bluedroid_enable() completes successfully, used only by A2DP sink. The callback is invoked in the context of A2DP sink task whose stack size is configurable through menuconfig.

Return

- ESP_OK: success
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: if callback is a NULL function pointer

Parameters

- \texttt{[in] callback}: A2DP sink data callback function

\texttt{esp_a2d_sink_init (void)}

Initialize the bluetooth A2DP sink module. This function should be called after esp_bluedroid_enable() completes successfully, and ESP_A2D_PROF_STATE_EVT with ESP_A2D_INIT_SUCCESS will reported to the APP layer. Note: A2DP can work independently. If you want to use AVRC together, you should initiate AVRC first. This function should be called after esp_bluedroid_enable() completes successfully.

Return

- ESP_OK: if the initialization request is sent successfully
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

```
esp_err_t esp_a2d_sink_deinit (void)
```

De-initialize for A2DP sink module. This function should be called only after esp_bluedroid_enable() completes successfully, and ESP_A2D_PROF_STATE_EVT with ESP_A2D_DEINIT_SUCCESS will reported to APP layer.

**Return**

• ESP_OK: if the deinitialization request is sent successfully
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

```
esp_err_t esp_a2d_sink_connect (esp_bd_addr_t remote_bda)
```

Connect to remote bluetooth A2DP source device. This API must be called after esp_a2d_sink_init() and before esp_a2d_sink_deinit().

**Return**

• ESP_OK: connect request is sent to lower layer successfully
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

**Parameters**

• [in] remote_bda: remote bluetooth device address

```
esp_err_t esp_a2d_sink_disconnect (esp_bd_addr_t remote_bda)
```

Disconnect from the remote A2DP source device. This API must be called after esp_a2d_sink_init() and before esp_a2d_sink_deinit().

**Return**

• ESP_OK: disconnect request is sent to lower layer successfully
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

**Parameters**

• [in] remote_bda: remote bluetooth device address

```
esp_err_t esp_a2d_media_ctrl (esp_a2d_media_ctrl_t ctrl)
```

Media control commands. This API can be used for both A2DP sink and source and must be called after esp_a2d_sink_init() and before esp_a2d_sink_deinit().

**Return**

• ESP_OK: control command is sent to lower layer successfully
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

**Parameters**

• [in] ctrl: control commands for A2DP data channel

```
esp_err_t esp_a2d_source_init (void)
```

Initialize the bluetooth A2DP source module. A2DP can work independently. If you want to use AVRC together, you should initiate AVRC first. This function should be called after esp_bluedroid_enable() completes successfully, and ESP_A2D_PROF_STATE_EVT with ESP_A2D_INIT_SUCCESS will reported to the APP layer. Note: A2DP can work independently. If you want to use AVRC together, you should initiate AVRC first.

**Return**

• ESP_OK: if the initialization request is sent to lower layer successfully
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

```
esp_err_t esp_a2d_source_deinit (void)
```

De-initialize for A2DP source module. This function should be called only after esp_bluedroid_enable() completes successfully, and ESP_A2D_PROF_STATE_EVT with ESP_A2D_DEINIT_SUCCESS will reported to APP layer.

**Return**
Chapter 2. API Reference

- ESP_OK: success
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

`esp_err_t esp_a2d_source_register_data_callback (esp_a2d_source_data_cb_t callback)`
Register A2DP source data input function. For now, the input should be PCM data stream. This function should be called only after `esp_bluedroid_enable()` completes successfully. The callback is invoked in the context of A2DP source task whose stack size is configurable through menuconfig.

Return
- ESP_OK: success
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: if callback is a NULL function pointer

Parameters
- [in] callback: A2DP source data callback function

`esp_err_t esp_a2d_source_connect (esp_bd_addr_t remote_bda)`
Connect to remote A2DP sink device. This API must be called after `esp_a2d_source_init()` and before `esp_a2d_source_deinit()`.

Return
- ESP_OK: connect request is sent to lower layer successfully
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- [in] remote_bda: remote bluetooth device address

`esp_err_t esp_a2d_source_disconnect (esp_bd_addr_t remote_bda)`
Disconnect from the remote A2DP sink device. This API must be called after `esp_a2d_source_init()` and before `esp_a2d_source_deinit()`.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- [in] remote_bda: remote bluetooth device address

Unions

union esp_a2d_cb_param_t

A2DP state callback parameters.

Public Members

`struct esp_a2d_cb_param_t::a2d_conn_stat_param conn_stat`  
A2DP connection status

`struct esp_a2d_cb_param_t::a2d_audio_stat_param audio_stat`  
audio stream playing state

`struct esp_a2d_cb_param_t::a2d_audio_cfg_param audio_cfg`  
media codec configuration information

`struct esp_a2d_cb_param_t::media_ctrl_stat_param media_ctrl_stat`  
status in acknowledgement to media control commands

`struct esp_a2d_cb_param_t::a2d_prof_stat_param a2d_prof_stat`  
status to indicate a2d prof init or deinit

`struct a2d_audio_cfg_param`  
#include <esp_a2dp_api.h> ESP_A2D_AUDIO_CFG_EVT.
Public Members

`esp_bd_addr_t remote_bda`
remote bluetooth device address

`esp_a2d_mcc_t mcc`
A2DP media codec capability information

`struct a2d_audio_stat_param`
#include <esp_a2dp_api.h> ESP_A2D_AUDIO_STATE_EVT.

Public Members

`esp_a2d_audio_state_t state`
one of the values from esp_a2d_audio_state_t

`esp_bd_addr_t remote_bda`
remote bluetooth device address

`struct a2d_conn_stat_param`
#include <esp_a2dp_api.h> ESP_A2D_CONNECTION_STATE_EVT.

Public Members

`esp_a2d_connection_state_t state`
one of values from esp_a2d_connection_state_t

`esp_bd_addr_t remote_bda`
remote bluetooth device address

`esp_a2d_disc_rsn_t disc_rsn`
reason of disconnection for “DISCONNECTED”

`struct a2d_prof_stat_param`
#include <esp_a2dp_api.h> ESP_A2D_PROF_STATE_EVT.

Public Members

`esp_a2d_init_state_t init_state`
a2dp profile state param

`struct media_ctrl_stat_param`
#include <esp_a2dp_api.h> ESP_A2D_MEDIA_CTRL_ACK_EVT.

Public Members

`esp_a2d_media_ctrl_t cmd`
media control commands to acknowledge

`esp_a2d_media_ctrl_ack_t status`
acknowledgement to media control commands

Structures

`struct esp_a2d_mcc_t`
A2DP media codec capabilities union
Chapter 2. API Reference

Public Members

```c
enum esp_a2d_mct_t
    A2DP media codec type

typedef uint8_t esp_a2d_mct_t[ESP_A2D_CIE_LEN_SBC]
    SBC codec capabilities

typedef uint8_t esp_a2d_mct_t[ESP_A2D_CIE_LEN_M12]
    MPEG-1,2 audio codec capabilities

typedef uint8_t esp_a2d_mct_t[ESP_A2D_CIE_LEN_M24]
    MPEG-2,4 AAC audio codec capabilities

typedef uint8_t esp_a2d_mct_t[ESP_A2D_CIE_LEN_ATRAC]
    ATRAC family codec capabilities

union esp_a2d_mcc_t::[anonymous] cie
    A2DP codec information element
```

Macros

```c
#define ESP_A2D_MCT_SBC Media codec types supported by A2DP.
#define ESP_A2D_MCT_M12 MPEG-1,2 Audio
#define ESP_A2D_MCT_M24 MPEG-2,4 AAC
#define ESP_A2D_MCT_ATRAC ATRAC family
#define ESP_A2D_MCT_NON_A2DP
#define ESP_A2D_CIE_LEN_SBC
#define ESP_A2D_CIE_LEN_M12
#define ESP_A2D_CIE_LEN_M24
#define ESP_A2D_CIE_LEN_ATRAC
```

Type Definitions

```c
typedef uint8_t esp_a2d_mct_t
    A2DP profile callback function type.

typedef void (*esp_a2d_cb_t)(esp_a2d_cb_event_t event, esp_a2d_cb_param_t *param)
    A2DP profile callback function.

typedef void (*esp_a2d_sink_data_cb_t)(const uint8_t *buf, uint32_t len)
    A2DP sink data callback function.

typedef void (*esp_a2d_source_data_cb_t)(const uint8_t *buf, int32_t len)
    A2DP source data read callback function.
```

Parameters

- `event`: Event type
- `param`: Pointer to callback parameter
- `[in] buf`: Pointer to the data received from A2DP source device and is PCM format decoded from SBC decoder; buf references to a static memory block and can be overwritten by upcoming data
- `[in] len`: size(in bytes) in buf

Return

size of bytes read successfully, if the argument len is -1, this value is ignored.

Espressif Systems 249 Release v5.0-dev-1077-g397639d
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Parameters

- `{in} buf`: buffer to be filled with PCM data stream from higher layer
- `{in} len`: size (in bytes) of data block to be copied to `buf`. `-1` is an indication to user that data buffer shall be flushed

Enumerations

```
enum esp_a2d_connection_state_t
    Bluetooth A2DP connection states.
    Values:
    ESP_A2D_CONNECTION_STATE_DISCONNECTED = 0
        connection released
    ESP_A2D_CONNECTION_STATE_CONNECTING
        connecting remote device
    ESP_A2D_CONNECTION_STATE_CONNECTED
        connection established
    ESP_A2D_CONNECTION_STATE_DISCONNECTING
        disconnecting remote device

enum esp_a2d_disc_rsn_t
    Bluetooth A2DP disconnection reason.
    Values:
    ESP_A2D_DISC_RSN_NORMAL = 0
        Finished disconnection that is initiated by local or remote device
    ESP_A2D_DISC_RSN_ABNORMAL
        Abnormal disconnection caused by signal loss

enum esp_a2d_audio_state_t
    Bluetooth A2DP datapath states.
    Values:
    ESP_A2D_AUDIO_STATE_REMOTE_SUSPEND = 0
        audio stream datapath suspended by remote device
    ESP_A2D_AUDIO_STATE_STOPPED
        audio stream datapath stopped
    ESP_A2D_AUDIO_STATE_STARTED
        audio stream datapath started

enum esp_a2d_media_ctrl_ack_t
    A2DP media control command acknowledgement code.
    Values:
    ESP_A2D_MEDIA_CTRL_ACK_SUCCESS = 0
        media control command is acknowledged with success
    ESP_A2D_MEDIA_CTRL_ACK_FAILURE
        media control command is acknowledged with failure
    ESP_A2D_MEDIA_CTRL_ACK_BUSY
        media control command is rejected, as previous command is not yet acknowledged

enum esp_a2d_media_ctrl_t
    A2DP media control commands.
    Values:
    ESP_A2D_MEDIA_CTRL_NONE = 0
        Not for application use, use inside stack only.
```
ESP_A2D_MEDIA_CTRL_CHECK_SRC_RDY
check whether AVDTP is connected, only used in A2DP source

ESP_A2D_MEDIA_CTRL_START
command to set up media transmission channel

ESP_A2D_MEDIA_CTRL_STOP
command to stop media transmission

ESP_A2D_MEDIA_CTRL_SUSPEND
command to suspend media transmission

enum esp_a2d_init_state_t
Bluetooth A2DP Initiation states.

Values:

ESP_A2D_DEINIT_SUCCESS = 0
A2DP profile deinit successful event

ESP_A2D_INIT_SUCCESS
A2DP profile init successful event

enum esp_a2d_cb_event_t
A2DP callback events.

Values:

ESP_A2D_CONNECTION_STATE_EVT = 0
connection state changed event

ESP_A2D_AUDIO_STATE_EVT
audio stream transmission state changed event

ESP_A2D_AUDIO_CFG_EVT
audio codec is configured, only used for A2DP SINK

ESP_A2DMEDIA_CTRL_ACK_EVT
acknowledge event in response to media control commands

ESP_A2D_PROF_STATE_EVT
indicate a2dp init&deinit complete

BT AVRCP APIs

Overview       Bluetooth AVRCP reference APIs.
Instructions

Application Example       Instructions

API Reference

Header File

- components/bt/host/bluedroid/api/include/api/esp_avrc_api.h

Functions

esp_err_t esp_avrc_ct_register_callback(esp_avrc_ct_cb_t callback)
Register application callbacks to AVRCP module. This function should be called after esp_bluedroid_enable() completes successfully.

Return
Chapter 2. API Reference

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- [in] callback: AVRCP controller callback function

esp_err_t esp_avrc_ct_init (void)
Initialize the bluetooth AVRCP controller module. This function should be called after esp_bluedroid_enable() completes successfully. Note: AVRC cannot work independently, AVRC should be used along with A2DP and AVRC should be initialized before A2DP.

Return
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

esp_err_t esp_avrc_ct_deinit (void)
De-initialize AVRCP controller module. This function should be called after after esp_bluedroid_enable() completes successfully. Note: AVRC cannot work independently, AVRC should be used along with A2DP and AVRC should be deinitialized before A2DP.

Return
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

esp_err_t esp_avrc_ct_send_set_player_value_cmd (uint8_t tl, uint8_t attr_id, uint8_t value_id)
Send player application settings command to AVRCP target. This function should be called after ESP_AVRC_CT_CONNECTION_STATE_EVT is received and AVRCP connection is established.

Return
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- [in] tl: transaction label, 0 to 15, consecutive commands should use different values
- [in] attr_id: player application setting attribute IDs from one of esp_avrc_ps_attr_ids_t
- [in] value_id: attribute value defined for the specific player application setting attribute

esp_err_t esp_avrc_ct_send_get_rn_capabilities_cmd (uint8_t tl)
Send GetCapabilities PDU to AVRCP target to retrieve remote device’s supported notification event_ids. This function should be called after ESP_AVRC_CT_CONNECTION_STATE_EVT is received and AVRCP connection is established.

Return
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- [in] tl: transaction label, 0 to 15, consecutive commands should use different values

esp_err_t esp_avrc_ct_send_register_notification_cmd (uint8_t tl, uint8_t event_id, uint32_t event_parameter)
Send register notification command to AVRCP target. This function should be called after ESP_AVRC_CT_CONNECTION_STATE_EVT is received and AVRCP connection is established.

Return
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_ERR_NOT_SUPPORTED: if the event_id is not supported in current implementation
- ESP_FAIL: others

Parameters
- [in] tl: transaction label, 0 to 15, consecutive commands should use different values.
• [in] `event_id` : id of events, e.g. ESP_AVRC_RN_PLAY_STATUS_CHANGE, ESP_AVRC_RN_TRACK_CHANGE, etc.
• [in] `event_parameter` : playback interval for ESP_AVRC_RN_PLAY_POS_CHANGED; For other events, value of this parameter is ignored.

```
esp_err_t esp_avrc_ct_send_set_absolute_volume_cmd(uint8_t tl, uint8_t volume)
```

Send set absolute volume command to AVRCP target. This function should be called after ESP_AVRC_CT_CONNECTION_STATE_EVT is received and AVRCP connection is established.

Return

• ESP_OK: success
• ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_ERR_NOT_SUPPORTED: if the event_id is not supported in current implementation
• ESP_FAIL: others

Parameters

• [in] `tl`: transaction label, 0 to 15, consecutive commands should use different values
• [in] `volume`: volume, 0 to 0x7f, means 0% to 100%

```
esp_err_t esp_avrc_ct_send_metadata_cmd(uint8_t tl, uint8_t attr_mask)
```

Send metadata command to AVRCP target. This function should be called after ESP_AVRC_CT_CONNECTION_STATE_EVT is received and AVRCP connection is established.

Return

• ESP_OK: success
• ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

Parameters

• [in] `tl`: transaction label, 0 to 15, consecutive commands should use different values.
• [in] `attr_mask`: mask of attributes, e.g. ESP_AVRC_MD_ATTR_ID_TITLE | ESP_AVRC_MD_ATTR_ID_ARTIST.

```
esp_err_t esp_avrc_ct_send_passthrough_cmd(uint8_t tl, uint8_t key_code, uint8_t key_state)
```

Send passthrough command to AVRCP target. This function should be called after ESP_AVRC_CT_CONNECTION_STATE_EVT is received and AVRCP connection is established.

Return

• ESP_OK: success
• ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

Parameters

• [in] `tl`: transaction label, 0 to 15, consecutive commands should use different values.
• [in] `key_code`: passthrough command code, e.g. ESP_AVRC_PT_CMD_PLAY, ESP_AVRC_PT_CMD_STOP, etc.
• [in] `key_state`: passthrough command key state, ESP_AVRC_PT_CMD_STATE_PRESSED or ESP_AVRC_PT_CMD_STATE_RELEASED.

```
esp_err_t esp_avrc_tg_register_callback(esp_avrc_tg_cb_t callback)
```

Register application callbacks to AVRCP target module. This function should be called after esp_bluedroid_enable() completes successfully.

Return

• ESP_OK: success
• ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

Parameters

• [in] `callback`: AVRCP target callback function

```
esp_err_t esp_avrc_tg_init(void)
```

Initialize the bluetooth AVRCP target module. This function should be called after esp_bluedroid_enable() completes successfully. Note: AVRC cannot work independently, AVRC should be used along with A2DP and AVRC should be initialized before A2DP.
Return

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

`esp_err_t esp_avrc_tg_deinit(void)`

De-initialize AVRC target module. This function should be called after esp_bluedroid_enable() completes successfully. Note: AVRC cannot work independently, AVRC should be used along with A2DP and AVRC should be deinitialized before A2DP.

Return

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

`esp_err_t esp_avrc_tg_get_psth_cmd_filter(esp_avrc_psth_filter_t filter, esp_avrc_psth_bit_mask_t *cmd_set)`

Get the current filter of remote passthrough commands on AVRC target. Filter is given by filter type and bit mask for the passthrough commands. This function should be called after esp_avrc_tg_init(). For filter type ESP_AVRC_PSTH_FILTER_ALLOWED_CMD, the retrieved command set is constant and it covers all of the passthrough commands that can possibly be supported. For filter type ESP_AVRC_PSTH_FILTER_SUPPORT_COMMANDS, the retrieved command set covers the passthrough commands selected to be supported according to current configuration. The configuration can be changed using esp_avrc_tg_set_psth_cmd_filter().

Return

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if Bluetooth stack is not enabled or AVRC TG is not initialized
- ESP_ERR_INVALID_ARG: if filter type is invalid or cmd_set is NULL
- ESP_FAIL: otherwise

`esp_err_t esp_avrc_tg_set_psth_cmd_filter(esp_avrc_psth_filter_t filter, const esp_avrc_psth_bit_mask_t *cmd_set)`

Set the filter of remote passthrough commands on AVRC target. Filter is given by filter type and bit mask for the passthrough commands. This function should be called after esp_avrc_tg_init().

If filter type is ESP_AVRC_PSTH_FILTER_SUPPORT_CMD, the passthrough commands which are set “1” as given in cmd_set will generate ESP_AVRC_CT_PASSTHROUGH_RSP_EVT callback event and are auto-accepted in the protocol stack, other commands are replied with response type “NOT IMPLEMENTED” (8). The set of supported commands should be a subset of allowed command set. The allowed command set can be retrieved using esp_avrc_tg_get_psth_cmd_filter() with filter type “ESP_AVRC_PSTH_FILTER_ALLOWED_CMD”.

Filter type “ESP_AVRC_PSTH_FILTER_ALLOWED_CMD” does not apply to this function.

Return

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if Bluetooth stack is not enabled
- ESP_ERR_INVALID_ARG: if filter type is invalid or cmd_set is NULL
- ESP_ERR_NOT_SUPPORTED: if filter type is ESP_AVRC_PSTH_FILTER_ALLOWED_CMD, or cmd_set includes unallowed commands

`bool esp_avrc_psth_bit_mask_operation(esp_avrc_bit_mask_op_t op, esp_avrc_psth_bit_mask_t *psth, esp_avrc_pt_cmd_t cmd)`

Operate on the type esp_avrc_psth_bit_mask_t with regard to a specific PASSTHROUGH command.

Return

For operation ESP_AVRC_BIT_MASK_OP_SET or ESP_AVRC_BIT_MASK_OP_CLEAR, return true for a successful operation, otherwise return false. For operation ESP_AVRC_BIT_MASK_OP_TEST, return true if the corresponding bit is set, otherwise false.

Parameters

- [in] op: operation requested on the bit mask field
- [in] psth: pointer to passthrough command bit mask structure
- [in] cmd: passthrough command code
**esp_err_t esp_avrc_tg_get_rn_evt_cap**

Get the requested event notification capabilities on local AVRC target. The capability is returned in a bit mask representation in `evt_set`. This function should be called after `esp_avrc_tg_init()`.

For capability type `ESP_AVRC_RN_CAP_ALLOWED_EVT`, the retrieved event set is constant and it covers all of the notification events that can possibly be supported with current implementation.

For capability type `ESP_AVRC_RN_CAP_SUPPORTED_EVT`, the event set covers the notification events selected to be supported under current configuration. The configuration can be changed using `esp_avrc_tg_set_rn_evt_cap()`.

**Return**

- **ESP_OK**: success
- **ESP_ERR_INVALID_STATE**: if bluetooth stack is not enabled or AVRC TG is not initialized
- **ESP_ERR_INVALID_ARG**: if cap is invalid or `evt_set` is NULL
- **ESP_FAIL**: otherwise

**esp_err_t esp_avrc_tg_set_rn_evt_cap**

Set the event notification capabilities on local AVRCP target. The capability is given in a bit mask representation in `evt_set` and must be a subset of allowed event IDs with current implementation. This function should be called after `esp_avrc_tg_init()`.

**Return**

- **ESP_OK**: success
- **ESP_ERR_INVALID_STATE**: if bluetooth stack is not enabled
- **ESP_ERR_INVALID_ARG**: if `evt_set` is NULL

**bool esp_avrc_rn_evt_bit_mask_operation**

Operate on the type `esp_avrc_rn_evt_cap_mask_t` with regard to a specific event.

For operation `ESP_AVRC_BIT_MASK_OP_TEST`, return true if the corresponding bit is set, otherwise false.

**Return**

For operation `ESP_AVRC_BIT_MASK_OP_SET` or `ESP_AVRC_BIT_MASK_OP_CLEAR`, return true for a successful operation, otherwise return false.

**Parameters**

- `[in] op`: operation requested on the bit mask field
- `[in] events`: pointer to event notification capability bit mask structure
- `[in] event_id`: notification event code

**esp_err_t esp_avrc_tg_send_rn_rsp**

Send RegisterNotification Response to remote AVRCP controller. Local event notification capability can be set using `esp_avrc_tg_set_rn_evt_cap()`, in a bit mask representation in `evt_set`. This function should be called after `esp_avrc_tg_init()`.

**Return**

- **ESP_OK**: success
- **ESP_ERR_INVALID_STATE**: if bluetooth stack is not enabled or AVRC TG is not initialized
- **ESP_ERR_INVALID_ARG**: if `evt_set` is NULL

**Parameters**

- `[in] event_id`: notification event ID that remote AVRCP CT registers
- `[in] rsp`: notification response code
- `[in] param`: parameters included in the specific notification

**Unions**

**union esp_avrc_rn_param_t**

#include `<esp_avrc_api.h>` AVRCP notification parameters.
Public Members

uint8_t volume
response data for ESP_AVRC_RN_VOLUME_CHANGE, ranges 0..127

esp_avrc_playback_stat_t playback
response data for ESP_AVRC_RN_PLAY_STATUS_CHANGE

uint8_t elm_id[8]
response data for ESP_AVRC_RN_TRACK_CHANGE

uint32_t play_pos
response data for ESP_AVRC_RN_PLAY_POS_CHANGED, in millisecond

esp_avrc_batt_stat_t batt
response data for ESP_AVRC_RN_BATTERY_STATUS_CHANGE

union esp_avrc_ct_cb_param_t
#include <esp_avrc_api.h> AVRC controller callback parameters.

Public Members

struct esp_avrc_ct_cb_param_t::avrc_ct_conn_stat_param conn_stat
AVRC connection status

struct esp_avrc_ct_cb_param_t::avrc_ct_psth_rsp_param psth_rsp
passsthrough command response

struct esp_avrc_ct_cb_param_t::avrc_ct_meta_rsp_param meta_rsp
metadata attributes response

struct esp_avrc_ct_cb_param_t::avrc_ct_change_notify_param change_ntf
notifications

struct esp_avrc_ct_cb_param_t::avrc_ct_rmt_feats_param rmt_feats
AVRC features discovered from remote SDP server

struct esp_avrc_ct_cb_param_t::avrc_ct_get_rn_caps_rsp_param get_rn_caps_rsp
get supported event capabilities response from AVRCP target

struct esp_avrc_ct_cb_param_t::avrc_ct_set_volume_rsp_param set_volume_rsp
set absolute volume response event

struct avrc_ct_change_notify_param
#include <esp_avrc_api.h> ESP_AVRC_CT_CHANGE_NOTIFY_EVT.

Public Members

uint8_t event_id
id of AVRC event notification

esp_avrc_rn_param_t event_parameter
event notification parameter

struct avrc_ct_conn_stat_param
#include <esp_avrc_api.h> ESP_AVRC_CT_CONNECTION_STATE_EVT.

Public Members

bool connected
whether AVRC connection is set up
struct avrc_ct_get_rn_caps_rsp_param
#include <esp_avrc_api.h> ESP_AVRC_CT_GET_RN_CAPABILITIES_RSP_EVT.

Public Members

uint8_t cap_count
number of items provided in event or company_id according to cap_id used

esp_avrc_rn_evt_cap_mask_t evt_set
supported event_ids represented in bit-mask

struct avrc_ct_meta_rsp_param
#include <esp_avrc_api.h> ESP_AVRC_CT_METADATA_RSP_EVT.

Public Members

uint8_t attr_id
id of metadata attribute

uint8_t *attr_text
attribute itself

int attr_length
attribute character length

struct avrc_ct_psth_rsp_param
#include <esp_avrc_api.h> ESP_AVRC_CT_PASSTHROUGH_RSP_EVT.

Public Members

uint8_t ttl
transaction label, 0 to 15

uint8_t key_code
passthrough command code

uint8_t key_state
0 for PRESSED, 1 for RELEASED

struct avrc_ct_rmt_feats_param
#include <esp_avrc_api.h> ESP_AVRC_CT_REMOTE_FEATURES_EVT.

Public Members

uint32_t feat_mask
AVRC feature mask of remote device

uint16_t tg_feat_flag
feature flag of remote device as TG

esp_bd_addr_t remote_bda
remote bluetooth device address

struct avrc_ct_set_volume_rsp_param
#include <esp_avrc_api.h> ESP_AVRC_CT_SET_ABSOLUTE_VOLUME_RSP_EVT.

remote bluetooth device address
Public Members

```c
union esp_avrc_tg_cb_param_t
#include <esp_avrc_api.h> AVRC target callback parameters.
```

Public Members

```c
struct esp_avrc_tg_cb_param_t::avrc_tg_conn_stat_param conn_stat
AVRC connection status
```

```c
struct esp_avrc_tg_cb_param_t::avrc_tg_rmt_feats_param rmt_feats
AVRC features discovered through SDP
```

```c
struct esp_avrc_tg_cb_param_t::avrc_tg_psth_cmd_param psth_cmd
passthrough command
```

```c
struct esp_avrc_tg_cb_param_t::avrc_tg_set_abs_vol_param set_abs_vol
set absolute volume command targeted on audio sink
```

```c
struct esp_avrc_tg_cb_param_t::avrc_tg_reg_ntf_param reg_ntf
register notification
```

```c
struct esp_avrc_tg_cb_param_t::avrc_tg_set_app_value_param set_app_value
set player application value
```

```c
struct avrc_tg_conn_stat_param
#include <esp_avrc_api.h> ESP_AVRC_TG_CONNECTION_STATE_EVT.
```

Public Members

```c
bool connected
whether AVRC connection is set up
```

```c
esp_bd_addr_t remote_bda
remote bluetooth device address
```

```c
struct avrc_tg_psth_cmd_param
#include <esp_avrc_api.h> ESP_AVRC_TG_PASSTHROUGH_CMD_EVT.
```

Public Members

```c
uint8_t key_code
passthrough command code
```

```c
uint8_t key_state
0 for PRESSED, 1 for RELEASED
```

```c
struct avrc_tg_reg_ntf_param
#include <esp_avrc_api.h> ESP_AVRC_TG_REGISTER_NOTIFICATION_EVT.
```

Public Members

```c
uint8_t event_id
event id of AVRC RegisterNotification
```

```c
uint32_t event_parameter
event notification parameter
```
struct avrc_tg_rmt_feats_param
#include <esp_avrc_api.h> ESP_AVRC_TG_REMOTE_FEATURES_EVT.

Public Members

uint32_t feat_mask
  AVRC feature mask of remote device
uint16_t ct_feat_flag
  feature flag of remote device as CT

esp_bd_addr_t remote_bda
  remote bluetooth device address

struct avrc_tg_set_abs_vol_param
#include <esp_avrc_api.h> ESP_AVRC_TG_SET_ABSOLUTE_VOLUME_CMD_EVT.

Public Members

uint8_t volume
  volume ranges from 0 to 127

struct avrc_tg_set_app_value_param
#include <esp_avrc_api.h> ESP_AVRC_TG_SET_PLAYER_APP_VALUE_EVT.

Public Members

uint8_t num_val
  attribute num

esp_avrc_set_app_value_param_t *p_vals
  point to the id and value of player application attribute

Structures

struct esp_avrc_psth_bit_mask_t
  AVRC passthrough command bit mask.

Public Members

uint16_t bits[8]
  bit mask representation of PASSTHROUGH commands

struct esp_avrc_rn_evt_cap_mask_t
  AVRC target notification event capability bit mask.

Public Members

uint16_t bits
  bit mask representation of PASSTHROUGH commands

struct esp_avrc_set_app_value_param_t
  AVRCP set app value parameters.
Public Members

```c
uint8_t attr_id
player application attribute id

uint8_t attr_val
player application attribute value
```

Macros

```c
#define ESP_AVRC_TRANS_LABEL_MAX max transaction label
```

Type Definitions

```c
typedef void (*esp_avrc_ct_cb_t)(esp_avrc_ct_cb_event_t event, esp_avrc_ct_cb_param_t *param)
```
AVRCP controller callback function type.

**Parameters**

- `event`: Event type
- `param`: Pointer to callback parameter union

```c
typedef void (*esp_avrc_tg_cb_t)(esp_avrc_tg_cb_event_t event, esp_avrc_tg_cb_param_t *param)
```
AVRCP target callback function type.

**Parameters**

- `event`: Event type
- `param`: Pointer to callback parameter union

Enumerations

```c
eenum esp_avrc_features_t
AVRC feature bit mask.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_AVRC_FEAT_RCTG</td>
<td>0x0001</td>
</tr>
<tr>
<td>ESP_AVRC_FEAT_RCCT</td>
<td>0x0002</td>
</tr>
<tr>
<td>ESP_AVRC_FEAT_VENDOR</td>
<td>0x0008</td>
</tr>
<tr>
<td>ESP_AVRC_FEAT_BROWSE</td>
<td>0x0010</td>
</tr>
<tr>
<td>ESP_AVRC_FEAT_META_DATA</td>
<td>0x0040</td>
</tr>
<tr>
<td>ESP_AVRC_FEAT_ADV_CTRL</td>
<td>0x0200</td>
</tr>
</tbody>
</table>
```

**Values:**

- ESP_AVRC_FEAT_RCTG = 0x0001
  - remote control target
- ESP_AVRC_FEAT_RCCT = 0x0002
  - remote control controller
- ESP_AVRC_FEAT_VENDOR = 0x0008
  - remote control vendor dependent commands
- ESP_AVRC_FEAT_BROWSE = 0x0010
  - use browsing channel
- ESP_AVRC_FEAT_META_DATA = 0x0040
  - remote control metadata transfer command/response
- ESP_AVRC_FEAT_ADV_CTRL = 0x0200
  - remote control advanced control command/response

```c
eenum esp_avrc_feature_flag_t
AVRC supported features flag retrieved in SDP record.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_AVRC_FEAT_FLAG_CAT1</td>
<td>0x0001</td>
</tr>
<tr>
<td>ESP_AVRC_FEAT_FLAG_CAT2</td>
<td>0x0002</td>
</tr>
</tbody>
</table>
```

**Values:**

- ESP_AVRC_FEAT_FLAG_CAT1 = 0x0001
  - category 1
- ESP_AVRC_FEAT_FLAG_CAT2 = 0x0002
  - category 2
ESP_AVRC_FEAT_FLAG_CAT3 = 0x0004
    category 3
ESP_AVRC_FEAT_FLAG_CAT4 = 0x0008
    category 4
ESP_AVRC_FEAT_FLAG_BROWSING = 0x0040
    browsing
ESP_AVRC_FEAT_FLAG_COVER_ART_GET_IMAGE_PROP = 0x0080
    Cover Art GetImageProperties
ESP_AVRC_FEAT_FLAG_COVER_ART_GET_IMAGE = 0x0100
    Cover Art GetImage
ESP_AVRC_FEAT_FLAG_COVER_ART_GET_LINKED_THUMBNAIL = 0x0200
    Cover Art GetLinkedThumbnail

define enum esp_avrc_pt_cmd_t
    AVRC passthrough command code.
    Values:
ESP_AVRC_PT_CMD_SELECT = 0x00
    select
ESP_AVRC_PT_CMD_UP = 0x01
    up
ESP_AVRC_PT_CMD_DOWN = 0x02
    down
ESP_AVRC_PT_CMD_LEFT = 0x03
    left
ESP_AVRC_PT_CMD_RIGHT = 0x04
    right
ESP_AVRC_PT_CMD_RIGHT_UP = 0x05
    right-up
ESP_AVRC_PT_CMD_RIGHT_DOWN = 0x06
    right-down
ESP_AVRC_PT_CMD_LEFT_UP = 0x07
    left-up
ESP_AVRC_PT_CMD_LEFT_DOWN = 0x08
    left-down
ESP_AVRC_PT_CMD_ROOT_MENU = 0x09
    root menu
ESP_AVRC_PT_CMD_SETUP_MENU = 0x0A
    setup menu
ESP_AVRC_PT_CMD_CONT_MENU = 0x0B
    contents menu
ESP_AVRC_PT_CMD_FAV_MENU = 0x0C
    favorite menu
ESP_AVRC_PT_CMD_EXIT = 0x0D
    exit
ESP_AVRC_PT_CMD_0 = 0x20
    0
ESP_AVRC_PT_CMD_1 = 0x21
    1
Chapter 2. API Reference

ESP_AVRC_PT_CMD_2 = 0x22
2
ESP_AVRC_PT_CMD_3 = 0x23
3
ESP_AVRC_PT_CMD_4 = 0x24
4
ESP_AVRC_PT_CMD_5 = 0x25
5
ESP_AVRC_PT_CMD_6 = 0x26
6
ESP_AVRC_PT_CMD_7 = 0x27
7
ESP_AVRC_PT_CMD_8 = 0x28
8
ESP_AVRC_PT_CMD_9 = 0x29
9
ESP_AVRC_PT_CMD_DOT = 0x2A
dot
ESP_AVRC_PT_CMD_ENTER = 0x2B
enter
ESP_AVRC_PT_CMD_CLEAR = 0x2C
clear
ESP_AVRC_PT_CMD_CHAN_UP = 0x30
channel up
ESP_AVRC_PT_CMD_CHAN_DOWN = 0x31
channel down
ESP_AVRC_PT_CMD_PREV_CHAN = 0x32
previous channel
ESP_AVRC_PT_CMD_SOUND_SEL = 0x33
sound select
ESP_AVRC_PT_CMD_INPUT_SEL = 0x34
input select
ESP_AVRC_PT_CMD_DISP_INFO = 0x35
display information
ESP_AVRC_PT_CMD_HELP = 0x36
help
ESP_AVRC_PT_CMD_PAGE_UP = 0x37
page up
ESP_AVRC_PT_CMD_PAGE_DOWN = 0x38
page down
ESP_AVRC_PT_CMD_POWER = 0x40
power
ESP_AVRC_PT_CMD_VOL_UP = 0x41
volume up
ESP_AVRC_PT_CMD_VOL_DOWN = 0x42
volume down
ESP_AVRC_PT_CMD_MUTE = 0x43
mute

ESP_AVRC_PT_CMD_PLAY = 0x44
play

ESP_AVRC_PT_CMD_STOP = 0x45
stop

ESP_AVRC_PT_CMD_PAUSE = 0x46
pause

ESP_AVRC_PT_CMD_RECORD = 0x47
record

ESP_AVRC_PT_CMD_REWIND = 0x48
rewind

ESP_AVRC_PT_CMD_FAST_FORWARD = 0x49
fast forward

ESP_AVRC_PT_CMD_EJECT = 0x4A
eject

ESP_AVRC_PT_CMD_FORWARD = 0x4B
forward

ESP_AVRC_PT_CMD_BACKWARD = 0x4C
backward

ESP_AVRC_PT_CMD_ANGLE = 0x50
angle

ESP_AVRC_PT_CMD_SUBPICT = 0x51
subpicture

ESP_AVRC_PT_CMD_F1 = 0x71
F1

ESP_AVRC_PT_CMD_F2 = 0x72
F2

ESP_AVRC_PT_CMD_F3 = 0x73
F3

ESP_AVRC_PT_CMD_F4 = 0x74
F4

ESP_AVRC_PT_CMD_F5 = 0x75
F5

ESP_AVRC_PT_CMD_VENDOR = 0x7E
vendor unique

enum esp_avrc_psth_filter_t
AVRC passthrough command filter.

Values:

ESP_AVRC_PSTH_FILTER_ALLOWED_CMD = 0
all of the PASSTHROUGH commands that can possibly be used, immutable

ESP_AVRC_PSTH_FILTER_SUPPORTED_CMD = 1
PASSTHROUGH commands selectively supported according to the current configuration

ESP_AVRC_PSTH_FILTER_SUPPORT_MAX
**Chapter 2. API Reference**

```c
#define ESP_AVRC_BIT_MASK_OP_TEST 0
operation code to test a specific bit
#define ESP_AVRC_BIT_MASK_OP_SET 1
operation code to set a specific bit
#define ESP_AVRC_BIT_MASK_OP_CLEAR 2
operation code to clear a specific bit

enum esp_avrc_pt_cmd_state_t
AVRC passthrough command state.
Values:
#define ESP_AVRC_PT_CMD_STATE_PRESSED 0
key pressed
#define ESP_AVRC_PT_CMD_STATE_RELEASED 1
key released

enum esp_avrc_ct_cb_event_t
AVRC Controller callback events.
Values:
#define ESP_AVRC_CT_CONNECTION_STATE_EVT 0
connection state changed event
#define ESP_AVRC_CT_PASSTHROUGH_RSP_EVT 1
passthrough response event
#define ESP_AVRC_CT_METADATA_RSP_EVT 2
metadata response event
#define ESP_AVRC_CT_PLAY_STATUS_RSP_EVT 3
play status response event
#define ESP_AVRC_CT_CHANGE_NOTIFY_EVT 4
notification event
#define ESP_AVRC_CT_REMOTE_FEATURES_EVT 5
feature of remote device indication event
#define ESP_AVRC_CT_GET_RN_CAPABILITIES_RSP_EVT 6
supported notification events capability of peer device
#define ESP_AVRC_CT_SET_ABSOLUTE_VOLUME_RSP_EVT 7
set absolute volume response event

enum esp_avrc_tg_cb_event_t
AVRC Target callback events.
Values:
#define ESP_AVRC_TG_CONNECTION_STATE_EVT 0
connection state changed event
#define ESP_AVRC_TG_REMOTE_FEATURES_EVT 1
feature of remote device indication event
#define ESP_AVRC_TG_PASSTHROUGH_CMD_EVT 2
passthrough command event
#define ESP_AVRC_TG_SET_ABSOLUTE_VOLUME_CMD_EVT 3
set absolute volume command from remote device
#define ESP_AVRC_TG_REGISTER_NOTIFICATION_EVT 4
register notification event
```
ESP_AVRC_TG_SET_PLAYER_APP_VALUE_EVT = 5

set application attribute value, attribute refer to esp_avrc_ps_attr_ids_t

enum esp_avrc_md_attr_mask_t
AVRC metadata attribute mask.

Values:

ESP_AVRC_MD_ATTR_TITLE = 0x1
  title of the playing track

ESP_AVRC_MD_ATTR_ARTIST = 0x2
  track artist

ESP_AVRC_MD_ATTR_ALBUM = 0x4
  album name

ESP_AVRC_MD_ATTR_TRACK_NUM = 0x8
  track position on the album

ESP_AVRC_MD_ATTR_NUM_TRACKS = 0x10
  number of tracks on the album

ESP_AVRC_MD_ATTR_GENRE = 0x20
  track genre

ESP_AVRC_MD_ATTR_PLAYING_TIME = 0x40
  total album playing time in miliseconds

enum esp_avrc_rn_event_ids_t
AVRC event notification ids.

Values:

ESP_AVRC_RN_PLAY_STATUS_CHANGE = 0x01
  track status change, eg. from playing to paused

ESP_AVRC_RN_TRACK_CHANGE = 0x02
  new track is loaded

ESP_AVRC_RN_TRACK_REACHED_END = 0x03
  current track reached end

ESP_AVRC_RN_TRACK_REACHED_START = 0x04
  current track reached start position

ESP_AVRC_RN_PLAY_POS_CHANGED = 0x05
  track playing position changed

ESP_AVRC_RN_BATTERY_STATUS_CHANGE = 0x06
  battery status changed

ESP_AVRC_RN_SYSTEM_STATUS_CHANGE = 0x07
  system status changed

ESP_AVRC_RN_APP_SETTING_CHANGE = 0x08
  application settings changed

ESP_AVRC_RN_NOW_PLAYING_CHANGE = 0x09
  now playing content changed

ESP_AVRC_RN_AVAILABLE_PLAYERS_CHANGE = 0x0a
  available players changed

ESP_AVRC_RN_ADDRESSED_PLAYER_CHANGE = 0x0b
  the addressed player changed

ESP_AVRC_RN_UIDS_CHANGE = 0x0c
  UIDs changed
ESP_AVRC_RN_VOLUME_CHANGE = 0x0d
volume changed locally on TG

ESP_AVRC_RN_MAX_EVT

enum esp_avrc_rn_evt_cap_t
AVRC target notification event notification capability.

Values:

ESP_AVRC_RN_CAP_ALLOWED_EVT = 0
all of the notification events that can possibly be supported, immutable

ESP_AVRC_RN_CAP_SUPPORTED_EVT = 1
notification events selectively supported according to the current configuration

ESP_AVRC_RN_CAP_MAX

enum esp_avrc_rn_rsp_t
AVRC notification response type.

Values:

ESP_AVRC_RN_RSP_INTERIM = 13
initial response to RegisterNotification, should be sent T_mtp(1000ms) from receiving the command

ESP_AVRC_RN_RSP_CHANGED = 15
final response to RegisterNotification command

enum esp_avrc_ps_attr_ids_t
AVRC player setting ids.

Values:

ESP_AVRC_PS_EQUALIZER = 0x01
equalizer, on or off

ESP_AVRC_PS_REPEAT_MODE = 0x02
repeat mode

ESP_AVRC_PS_SHUFFLE_MODE = 0x03
shuffle mode

ESP_AVRC_PS_SCAN_MODE = 0x04
scan mode on or off

ESP_AVRC_PS_MAX_ATTR

enum esp_avrc_ps_eq_value_ids_t
AVRC equalizer modes.

Values:

ESP_AVRC_PS_EQUALIZER_OFF = 0x1
equalizer OFF

ESP_AVRC_PS_EQUALIZER_ON = 0x2
equalizer ON

enum esp_avrc_ps_rpt_value_ids_t
AVRC repeat modes.

Values:

ESP_AVRC_PS_REPEAT_OFF = 0x1
repeat mode off

ESP_AVRC_PS_REPEAT_SINGLE = 0x2
single track repeat
\texttt{ESP\_AVRC\_PS\_REPEAT\_GROUP} = 0x3
\texttt{group repeat}

\texttt{enum esp\_avrc\_ps\_shf\_value\_ids\_t}
\texttt{AVRC shuffle modes. Values:}
\texttt{ESP\_AVRC\_PS\_SHUFFLE\_OFF} = 0x1
\texttt{ESP\_AVRC\_PS\_SHUFFLE\_ALL} = 0x2
\texttt{ESP\_AVRC\_PS\_SHUFFLE\_GROUP} = 0x3

\texttt{enum esp\_avrc\_ps\_scn\_value\_ids\_t}
\texttt{AVRC scan modes. Values:}
\texttt{ESP\_AVRC\_PS\_SCAN\_OFF} = 0x1
\texttt{scan off}
\texttt{ESP\_AVRC\_PS\_SCAN\_ALL} = 0x2
\texttt{all tracks scan}
\texttt{ESP\_AVRC\_PS\_SCAN\_GROUP} = 0x3
\texttt{group scan}

\texttt{enum esp\_avrc\_rsp\_t}
\texttt{AVCTP response codes. Values:}
\texttt{ESP\_AVRC\_RSP\_NOT\_IMPL} = 8
\texttt{not implemented}
\texttt{ESP\_AVRC\_RSP\_ACCEPT} = 9
\texttt{accept}
\texttt{ESP\_AVRC\_RSP\_REJECT} = 10
\texttt{reject}
\texttt{ESP\_AVRC\_RSP\_IN\_TRANS} = 11
\texttt{in transition}
\texttt{ESP\_AVRC\_RSP\_IMPL\_STBL} = 12
\texttt{implemented/stable}
\texttt{ESP\_AVRC\_RSP\_CHANGED} = 13
\texttt{changed}
\texttt{ESP\_AVRC\_RSP\_INTERIM} = 15
\texttt{interim}

\texttt{enum esp\_avrc\_batt\_stat\_t}
\texttt{AVRCP battery status. Values:}
\texttt{ESP\_AVRC\_BATT\_NORMAL} = 0
\texttt{normal state}
\texttt{ESP\_AVRC\_BATT\_WARNING} = 1
\texttt{unable to operate soon}
\texttt{ESP\_AVRC\_BATT\_CRITICAL} = 2
\texttt{cannot operate any more}
\texttt{ESP\_AVRC\_BATT\_EXTERNAL} = 3
\texttt{plugged to external power supply}
ESP_AVRC_BATT_FULL_CHARGE = 4
when completely charged from external power supply

**enum esp_avrc_playback_stat_t**

AVRCP current status of playback.

*Values:*

ESP_AVRC_PLAYBACK_STOPPED = 0
stopped

ESP_AVRC_PLAYBACK_PLAYING = 1
playing

ESP_AVRC_PLAYBACK_PAUSED = 2
paused

ESP_AVRC_PLAYBACK_FWD_SEEK = 3
forward seek

ESP_AVRC_PLAYBACK_REV_SEEK = 4
reverse seek

ESP_AVRC_PLAYBACK_ERROR = 0xFF
error

### SPP API

**Overview**

**Instructions**

**Application Example**

Check bluetooth/bluedroid/classic_bt folder in ESP-IDF examples, which contains the following application:

- This is a SPP demo. This demo can discover the service, connect, send and receive SPP data bluetooth/bluedroid/classic_bt/bt_spp_acceptor, bluetooth/bluedroid/classic_bt/bt_spp_initiator

**API Reference**

**Header File**

- components/bt/host/bluedroid/api/include/api/esp_spp_api.h

**Functions**

`esp_err_t esp_spp_register_callback (esp_spp_cb_t callback)`

This function is called to init callbacks with SPP module.

*Return*

- ESP_OK: success
- other: failed

*Parameters*

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

`esp_err_t esp_spp_init (esp_spp_mode_t mode)`

This function is called to init SPP module. When the operation is completed, the callback function will be called with ESP_SPP_INIT_EVT. This function should be called after esp_bluedroid_enable() completes successfully.

*Return*

- ESP_OK: success
- other: failed

*Parameters*
Chapter 2. API Reference

- [in] mode: Choose the mode of SPP, ESP_SPP_MODE_CB or ESP_SPP_MODE_VFS.

```c
esp_err_t esp_spp_deinit (void)
```

This function is called to uninit SPP module. The operation will close all active SPP connection first, then the callback function will be called with ESP_SPP_CLOSE_EVT, and the number of ESP_SPP_CLOSE_EVT is equal to the number of connection. When the operation is completed, the callback function will be called with ESP_SPP_UNINIT_EVT. This function should be called after esp_spp_init() completes successfully.

Return

- ESP_OK: success
- other: failed

```c
esp_err_t esp_spp_start_discovery (esp_bd_addr_t bd_addr)
```

This function is called to performs service discovery for the services provided by the given peer device. When the operation is completed, the callback function will be called with ESP_SPP_DISCOVERY_COMP_EVT. This function must be called after esp_spp_init() successful and before esp_spp_deinit().

Return

- ESP_OK: success
- other: failed

Parameters

- [in] bd_addr: Remote device bluetooth device address.

```c
esp_err_t esp_spp_connect (esp_spp_sec_t sec_mask, esp_spp_role_t role, uint8_t remote_scn, esp_bd_addr_t peer_bd_addr)
```

This function makes an SPP connection to a remote BD Address. When the connection is initiated or failed to initiate, the callback is called with ESP_SPP_CL_INIT_EVT. When the connection is established or failed, the callback is called with ESP_SPP_OPEN_EVT. This function must be called after esp_spp_init() successful and before esp_spp_deinit().

Return

- ESP_OK: success
- other: failed

Parameters

- [in] role: Master or slave.
- [in] remote_scn: Remote device bluetooth device SCN.
- [in] peer_bd_addr: Remote device bluetooth device address.

```c
esp_err_t esp_spp_disconnect (uint32_t handle)
```

This function closes an SPP connection. When the operation is completed, the callback function will be called with ESP_SPP_CLOSE_EVT. This function must be called after esp_spp_init() successful and before esp_spp_deinit().

Return

- ESP_OK: success
- other: failed

Parameters

- [in] handle: The connection handle.

```c
esp_err_t esp_spp_start_srv (esp_spp_sec_t sec_mask, esp_spp_role_t role, uint8_t local_scn, const char *name)
```

This function create a SPP server and starts listening for an SPP connection request from a remote Bluetooth device. When the server is started successfully, the callback is called with ESP_SPP_SRV_START_EVT. When the connection is established, the callback is called with ESP_SPP_SRV_OPEN_EVT. This function must be called after esp_spp_init() successful and before esp_spp_deinit().

Return

- ESP_OK: success
- other: failed

Parameters
Chapter 2. API Reference

- **[in]** `sec_mask`: Security Setting Mask. Suggest to use `ESP_SPP_SEC_NONE`, `ESP_SPP_SEC_AUTHORIZE` or `ESP_SPP_SEC_AUTHENTICATE` only.
- **[in]** `role`: Master or slave.
- **[in]** `local_scn`: The specific channel you want to get. If channel is 0, means get any channel.
- **[in]** `name`: Server’s name.

```c
esp_err_t esp_spp_stop_srv (void)
```

This function stops all SPP servers. The operation will close all active SPP connection first, then the callback function will be called with ESP_SPP_CLOSE_EVT, and the number of ESP_SPP_CLOSE_EVT is equal to the number of connection. When the operation is completed, the callback is called with ESP_SPP_SRV_STOP_EVT. This function must be called after esp_spp_init() successful and before esp_spp_deinit().

Return
- ESP_OK: success
- other: failed

```c
esp_err_t esp_spp_stop_srv_scn (uint8_t scn)
```

This function stops a specific SPP server. The operation will close all active SPP connection first on the specific SPP server, then the callback function will be called with ESP_SPP_CLOSE_EVT, and the number of ESP_SPP_CLOSE_EVT is equal to the number of connection. When the operation is completed, the callback is called with ESP_SPP_SRV_STOP_EVT. This function must be called after esp_spp_init() successful and before esp_spp_deinit().

Return
- ESP_OK: success
- other: failed

Parameters
- **[in]** `scn`: Server channel number.

```c
esp_err_t esp_spp_write (uint32_t handle, int len, uint8_t *p_data)
```

This function is used to write data, only for ESP_SPP_MODE_CB. When this function need to be called repeatedly, it is strongly recommended to call this function again after the previous event ESP_SPP_WRITE_EVT is received and the parameter `cong` is equal to false. If the previous event ESP_SPP_WRITE_EVT with parameter `cong` is equal to true, the function can only be called again when the event ESP_SPP_CONG_EVT with parameter `cong` equal to false is received. This function must be called after an connection between initiator and acceptor has been established.

Return
- ESP_OK: success
- other: failed

Parameters
- **[in]** `handle`: The connection handle.
- **[in]** `len`: The length of the data written.
- **[in]** `p_data`: The data written.

```c
esp_err_t esp_spp_vfs_register (void)
```

This function is used to register VFS. For now, SPP only supports write, read and close.

Return
- ESP_OK: success
- other: failed

Unions

```c
union esp_spp_cb_param_t
#include <esp_spp_api.h> SPP callback parameters union.
```

Public Members

```c
struct esp_spp_cb_param_t::spp_init_evt_param init
SPP callback param of SPP_INIT_EVT
```
struct esp_spp_cb_param_t::spp_uninit_evt_param uninit
SPP callback param of SPP_UNINIT_EVT

struct esp_spp_cb_param_t::spp_discovery_comp_evt_param disc_comp
SPP callback param of SPP_DISCOVERY_COMP_EVT

struct esp_spp_cb_param_t::spp_open_evt_param open
SPP callback param of ESP_SPP_OPEN_EVT

struct esp_spp_cb_param_t::spp_srv_open_evt_param srv_open
SPP callback param of ESP_SPP_SRV_OPEN_EVT

struct esp_spp_cb_param_t::spp_close_evt_param close
SPP callback param of ESP_SPP_CLOSE_EVT

struct esp_spp_cb_param_t::spp_start_evt_param start
SPP callback param of ESP_SPP_START_EVT

struct esp_spp_cb_param_t::spp_srv_stop_evt_param srv_stop
SPP callback param of ESP_SPP_SRV_STOP_EVT

struct esp_spp_cb_param_t::spp_cl_init_evt_param cl_init
SPP callback param of ESP_SPP_CL_INIT_EVT

struct esp_spp_cb_param_t::spp_write_evt_param write
SPP callback param of ESP_SPP_WRITE_EVT

struct esp_spp_cb_param_t::spp_data_ind_evt_param data_ind
SPP callback param of ESP_SPP_DATA_IND_EVT

struct esp_spp_cb_param_t::spp_cong_evt_param cong
SPP callback param of ESP_SPP_CONG_EVT

struct spp_cl_init_evt_param
#include <esp_spp_api.h> ESP_SPP_CL_INIT_EVT.

Public Members

esp_spp_status_t status
status

uint32_t handle
The connection handle

uint8_t sec_id
security ID used by this server

bool use_co
TRUE to use co_rfc_data

struct spp_close_evt_param
#include <esp_spp_api.h> ESP_SPP_CLOSE_EVT.

Public Members

esp_spp_status_t status
status

uint32_t port_status
PORT status

uint32_t handle
The connection handle
bool async
   FALSE, if local initiates disconnect

struct spp_cong_evt_param
   #include <esp_spp_api.h> ESP_SPP_CONG_EVT.

Public Members

   esp_spp_status_t status
   uint32_t handle
      The connection handle
   bool cong
      TRUE, congested. FALSE, uncongested

struct spp_data_ind_evt_param
   #include <esp_spp_api.h> ESP_SPP_DATA_IND_EVT.

Public Members

   esp_spp_status_t status
   uint32_t handle
      The connection handle
   uint16_t len
      The length of data
   uint8_t* data
      The data received

struct spp_discovery_comp_evt_param
   #include <esp_spp_api.h> SPP_DISCOVERY_COMP_EVT.

Public Members

   esp_spp_status_t status
   uint8_t scn_num
      The num of scn_num
   uint8_t* scn[ESP_SPP_MAX_SCN]
      channel #
   const char* service_name[ESP_SPP_MAX_SCN]
      service_name

struct spp_init_evt_param
   #include <esp_spp_api.h> SPP_INIT_EVT.

Public Members

   esp_spp_status_t status

struct spp_open_evt_param
   #include <esp_spp_api.h> ESP_SPP_OPEN_EVT.
Public Members

```c
esp_spp_status_t status
uint32_t handle  // The connection handle
int fd          // The file descriptor only for ESP_SPP_MODE_VFS
esp_bd_addr_t rem_bda // The peer address
```

`struct spp_srv_open_evt_param`

```
#include <esp_spp_api.h>
```

ESP_SPP_SRV_OPEN_EVT.

Public Members

```c
esp_spp_status_t status
uint32_t handle  // The connection handle
uint32_t new_listen_handle  // The new listen handle
int fd          // The file descriptor only for ESP_SPP_MODE_VFS
esp_bd_addr_t rem_bda // The peer address
```

`struct spp_srv_stop_evt_param`

```
#include <esp_spp_api.h>
```

ESP_SPP_SRV_STOP_EVT.

Public Members

```c
esp_spp_status_t status
uint8_t scn  // Server channel number
```

`struct spp_start_evt_param`

```
#include <esp_spp_api.h>
```

ESP_SPP_START_EVT.

Public Members

```c
esp_spp_status_t status
uint32_t handle  // The connection handle
uint8_t sec_id // security ID used by this server
uint8_t scn  // Server channel number
```
bool use_co
    TRUE to use co_rfc_data

struct spp_uninit_evt_param
    #include <esp_spp_api.h> SPP_UNINIT_EVT.

Public Members

    esp_spp_status_t status

struct spp_write_evt_param
    #include <esp_spp_api.h> ESP_SPP_WRITE_EVT.

Public Members

    esp_spp_status_t status
    uint32_t handle
        The connection handle
    int len
        The length of the data written.
    bool cong
        congestion status

Macros

ESP_SPP_SEC_NONE
    No security. relate to BTA_SEC_NONE in bta/bta_api.h

ESP_SPP_SEC_AUTHORIZE
    Authorization required (only needed for out going connection ) relate to BTA_SEC_AUTHORIZE in bta/bta_api.h

ESP_SPP_SEC_AUTHENTICATE
    Authentication required. relate to BTA_SEC_AUTHENTICATE in bta/bta_api.h

ESP_SPP_SEC_ENCRYPT
    Encryption required. relate to BTA_SEC_ENCRYPT in bta/bta_api.h

ESP_SPP_SEC_MODE4_LEVEL4
    Mode 4 level 4 service, i.e. incoming/outgoing MITM and P-256 encryption relate to BTA_SEC_MODE4_LEVEL4 in bta/bta_api.h

ESP_SPP_SEC_MITM
    Man-In-The_Middle protection relate to BTA_SEC_MITM in bta/bta_api.h

ESP_SPP_SEC_IN_16_DIGITS
    Min 16 digit for pin code relate to BTA_SEC_IN_16_DIGITS in bta/bta_api.h

ESP_SPP_MAX_MTU
    SPP max MTU

ESP_SPP_MAX_SCN
    SPP max SCN
### Type Definitions

```c
typedef uint16_t esp_spp_sec_t
typedef void(esp_spp_cb_t)(esp_spp_cb_event_t event, esp_spp_cb_param_t *param)
```

SPP callback function type. When handle ESP_SPP_DATA_IND_EVT, it is strongly recommended to cache incoming data, and process them in other lower priority application task rather than in this callback directly.

**Parameters**
- `event`: Event type
- `param`: Point to callback parameter, currently is union type

### Enumerations

#### `enum esp_spp_status_t`

**Values:**
- `ESP_SPP_SUCCESS = 0`  
  Successful operation.
- `ESP_SPP_FAILURE`  
  Generic failure.
- `ESP_SPP_BUSY`  
  Temporarily can not handle this request.
- `ESP_SPP_NO_DATA`  
  No data
- `ESP_SPP_NO_RESOURCE`  
  No more resource
- `ESP_SPP_NEED_INIT`  
  SPP module shall init first
- `ESP_SPP_NEED_DEINIT`  
  SPP module shall deinit first
- `ESP_SPP_NO_CONNECTION`  
  Connection may have been closed
- `ESP_SPP_NO_SERVER`  
  No SPP server

#### `enum esp_spp_role_t`

**Values:**
- `ESP_SPP_ROLE_MASTER = 0`  
  Role: master
- `ESP_SPP_ROLE_SLAVE = 1`  
  Role: slave

#### `enum esp_spp_mode_t`

**Values:**
- `ESP_SPP_MODE_CB = 0`  
  When data is coming, a callback will come with data
- `ESP_SPP_MODE_VFS = 1`  
  Use VFS to write/read data

#### `enum esp_spp_cb_event_t`

SPP callback function events.

**Values:**
- `ESP_SPP_INIT_EVT = 0`  
  When SPP is inited, the event comes
ESP_SPP_UNINIT_EVT = 1
When SPP is uninited, the event comes

ESP_SPP_DISCOVERY_COMP_EVT = 8
When SDP discovery complete, the event comes

ESP_SPP_OPEN_EVT = 26
When SPP Client connection open, the event comes

ESP_SPP_CLOSE_EVT = 27
When SPP connection closed, the event comes

ESP_SPP_START_EVT = 28
When SPP server started, the event comes

ESP_SPP_CL_INIT_EVT = 29
When SPP client initiated a connection, the event comes

ESP_SPP_DATA_IND_EVT = 30
When SPP connection received data, the event comes, only for ESP_SPP_MODE_CB

ESP_SPP_CONG_EVT = 31
When SPP connection congestion status changed, the event comes, only for ESP_SPP_MODE_CB

ESP_SPP_WRITE_EVT = 33
When SPP write operation completes, the event comes, only for ESP_SPP_MODE_CB

ESP_SPP_SRV_OPEN_EVT = 34
When SPP Server connection open, the event comes

ESP_SPP_SRV_STOP_EVT = 35
When SPP server stopped, the event comes

HFP DEFINES

Overview Instructions

API Reference

Header File

- components/bt/host/bluedroid/api/include/api/esp_hf_defs.h

Macros

ESP_BT_HF_NUMBER_LEN
ESP_BT_HF_OPERATOR_NAME_LEN
BTC_HSAG_SERVICE_NAME
BTC_HFAG_SERVICE_NAME
BTC_HF_SERVICES
BTC_HF_SERVICE_NAMES
BTC_HF_SECURITY
BTC_HF_CALL_END_TIMEOUT
BTC_HF_INVALIDIDX
Type Definitions

typedef void (*esp_hf_connection_state_callback)(esp_hf_connection_state_t state, esp_bd_addr_t *bd_addr)

Callback for connection state change. state will have one of the values from BtHfConnectionState

typedef void (*esp_hf_audio_state_callback)(esp_hf_audio_state_t state, esp_bd_addr_t *bd_addr)

Callback for audio connection state change. state will have one of the values from BtHFAudioState

typedef void (*esp_hf_vr_cmd_callback)(esp_hf_vr_state_t state, esp_bd_addr_t *bd_addr)

Callback for VR connection state change. state will have one of the values from BtHfVRState

typedef void (*esp_hf_answer_call_cmd_callback)(esp_bd_addr_t *bd_addr)

Callback for answer incoming call (ATA)

typedef void (*esp_hf_hangup_call_cmd_callback)(esp_bd_addr_t *bd_addr)

Callback for disconnect call (AT+CHUP)

typedef void (*esp_hf_volume_cmd_callback)(esp_hf_volume_control_target_t type, int volume, esp_bd_addr_t *bd_addr)

Callback for disconnect call (AT+CHUP) type will denote Speaker/Mic gain (BtHfVolumeControl).

typedef void (*esp_hf_dial_call_cmd_callback)(char*number, esp_bd_addr_t *bd_addr)

Callback for dialing an outgoing call. If number is NULL, redial

typedef void (*esp_hf_dtmf_cmd_callback)(char tone, esp_bd_addr_t *bd_addr)

Callback for sending DTMF tones. tone contains the dtmf character to be sent

typedef void (*esp_hf_nrec_cmd_callback)(esp_hf_nrec_t nrec, esp_bd_addr_t *bd_addr)

Callback for enabling/disabling noise reduction/echo cancellation. value will be 1 to enable, 0 to disable

typedef void (*esp_hf_wbs_callback)(esp_hf_wbs_config_t wbs, esp_bd_addr_t *bd_addr)

Callback for AT+BSC and event from BAC WBS enable, WBS disable

typedef void (*esp_hf_chld_cmd_callback)(esp_hf_chld_type_t chld, esp_bd_addr_t *bd_addr)

Callback for call hold handling (AT+CHLD) value will contain the call hold command (0, 1, 2, 3)

typedef void (*esp_hf_cnum_cmd_callback)(esp_bd_addr_t *bd_addr)

Callback for CNUM (subscriber number)

typedef void (*esp_hf_cind_cmd_callback)(esp_bd_addr_t *bd_addr)

Callback for indicators (CIND)

typedef void (*esp_hf_cops_cmd_callback)(esp_bd_addr_t *bd_addr)

Callback for operator selection (COPS)

typedef void (*esp_hf_clcc_cmd_callback)(esp_bd_addr_t *bd_addr)

Callback for call list (AT+CLCC)

typedef void (*esp_hf_unknown_at_cmd_callback)(char *at_string, esp_bd_addr_t *bd_addr)

Callback for unknown AT command recd from AG at_string will contain the unparsed AT string

typedef void (*esp_hf_key_pressed_cmd_callback)(esp_bd_addr_t *bd_addr)

Callback for keypressed (HSP) event.

Enumerations

enum esp_hf_in_band_ring_state_t
    in-band ring tone state

Values:

    ESP_HF_IN_BAND_RINGTONE_NOT_PROVIDED = 0
    ESP_HF_IN_BAND_RINGTONE_PROVIDED
enum esp_hf_vr_state_t
voice recognition state

Values:

ESP_HF_VR_STATE_DISABLED = 0
voice recognition disabled

ESP_HF_VR_STATE_ENABLED
voice recognition enabled

enum esp_hf_volume_control_target_t
Bluetooth HFP audio volume control target.

Values:

ESP_HF_VOLUME_CONTROL_TARGET_SPK = 0
speaker

ESP_HF_VOLUME_CONTROL_TARGET_MIC
microphone

enum esp_hf_audio_state_t
Bluetooth HFP audio connection status.

Values:

ESP_HF_AUDIO_STATE_DISCONNECTED = 0
audio connection released

ESP_HF_AUDIO_STATE_CONNECTING
audio connection has been initiated

ESP_HF_AUDIO_STATE_CONNECTED
audio connection is established

ESP_HF_AUDIO_STATE_CONNECTED_MSBC
mSBC audio connection is established

enum esp_hf_volume_type_t

Values:

ESP_HF_VOLUME_TYPE_SPK = 0

ESP_HF_VOLUME_TYPE_MIC

enum esp_hf_network_state_t
+CIND network service availability status

Values:

ESP_HF_NETWORK_STATE_NOT_AVAILABLE = 0

ESP_HF_NETWORK_STATE_AVAILABLE

enum esp_hf_service_type_t
+CIEV Service type

Values:

ESP_HF_SERVICE_TYPE_HOME = 0

ESP_HF_SERVICE_TYPE_ROAMING

enum esp_hf_call_status_t
+CIND call status indicator values

Values:

ESP_HF_CALL_STATUS_NO_CALLS = 0
no call in progress
ESP_HF_CALL_STATUS_CALL_IN_PROGRESS = 1
call is present (active or held)

enum esp_hf_call_setup_status_t
+CIND call setup status indicator values
Values:

ESP_HF_CALL_SETUP_STATUS_IDLE = 0
no call setup in progress

ESP_HF_CALL_SETUP_STATUS_INCOMING = 1
incoming call setup in progress

ESP_HF_CALL_SETUP_STATUS_OUTGOING_DIALING = 2
outgoing call setup in dialing state

ESP_HF_CALL_SETUP_STATUS_OUTGOING_ALERTING = 3
outgoing call setup in alerting state

enum esp_hf_roaming_status_t
+CIND roaming status indicator values
Values:

ESP_HF_ROAMING_STATUS_INACTIVE = 0
roaming is not active

ESP_HF_ROAMING_STATUS_ACTIVE
a roaming is active

enum esp_hf_call_held_status_t
+CIND call held indicator values
Values:

ESP_HF_CALL_Held_STATUS_NONE = 0
no calls held

ESP_HF_CALL_Held_STATUS_HELD_AND_ACTIVE = 1
both active and held call

ESP_HF_CALL_Held_STATUS_HELD = 2
call on hold, no active call

enum esp_hf_current_call_status_t
+CLCC status of the call
Values:

ESP_HF_CURRENT_CALL_STATUS_ACTIVE = 0
active

ESP_HF_CURRENT_CALL_STATUS_HELD = 1
held

ESP_HF_CURRENT_CALL_STATUS_DIALING = 2
dialing (outgoing calls only)

ESP_HF_CURRENT_CALL_STATUS_ALERTING = 3
alerting (outgoing calls only)

ESP_HF_CURRENT_CALL_STATUS_INCOMING = 4
incoming (incoming calls only)

ESP_HF_CURRENT_CALL_STATUS_WAITING = 5
waiting (incoming calls only)

ESP_HF_CURRENT_CALL_STATUS_HELD_BY_RESP_HOLD = 6
call held by response and hold
enum esp_hf_current_call_direction_t
  +CLCC direction of the call
  Values:
  ESP_HF_CURRENT_CALL_DIRECTION_OUTGOING = 0
      outgoing
  ESP_HF_CURRENT_CALL_DIRECTION_INCOMING = 1
      incoming

enum esp_hf_current_call_mpty_type_t
  +CLCC multi-party call flag
  Values:
  ESP_HF_CURRENT_CALL_MPTY_TYPE_SINGLE = 0
      not a member of a multi-party call
  ESP_HF_CURRENT_CALL_MPTY_TYPE_MULTI = 1
      member of a multi-party call

enum esp_hf_current_call_mode_t
  +CLCC call mode
  Values:
  ESP_HF_CURRENT_CALL_MODE_VOICE = 0
  ESP_HF_CURRENT_CALL_MODE_DATA = 1
  ESP_HF_CURRENT_CALL_MODE_FAX = 2

enum esp_hf_call_addr_type_t
  +CLCC address type
  Values:
  ESP_HF_CALL_ADDR_TYPE_UNKNOWN = 0x81
      unknown address type
  ESP_HF_CALL_ADDR_TYPE_INTERNATIONAL = 0x91
      international address

enum esp_hf_subscriber_service_type_t
  +CNUM service type of the phone number
  Values:
  ESP_HF_SUBSCRIBER_SERVICE_TYPE_UNKNOWN = 0
      unknown
  ESP_HF_SUBSCRIBER_SERVICE_TYPE_VOICE
      voice service
  ESP_HF_SUBSCRIBER_SERVICE_TYPE_FAX
      fax service

enum esp_hf_btrh_status_t
  +BTRH response and hold result code
  Values:
  ESP_HF_BTRH_STATUS_HELD = 0
      incoming call is put on held in AG
  ESP_HF_BTRH_STATUS_ACCEPTED
      held incoming call is accepted in AG
  ESP_HF_BTRH_STATUS_REJECTED
      held incoming call is rejected in AG
enum esp_hf_btrh_cmd_t  
AT+BTRH response and hold action code.
Values:
ESP_HF_BTRH_CMD_HOLD = 0  
put the incoming call on hold
ESP_HF_BTRH_CMD_ACCEPT = 1  
accept a held incoming call
ESP_HF_BTRH_CMD_REJECT = 2  
reject a held incoming call

enum esp_hf_nrec_t  
Values:
ESP_HF_NREC_STOP = 0
ESP_HF_NREC_START

enum esp_hf_call_waiting_status_t  
+CCWA response status
Values:
ESP_HF_CALL_WAITING_INACTIVE
ESP_HF_CALL_WAITING_ACTIVE

enum esp_hf_wbs_config_t  
Values:
ESP_HF_WBS_NONE
ESP_HF_WBS_NO
ESP_HF_WBS_YES

enum esp_hf_connection_state_t  
Bluetooth HFP RFCOMM connection and service level connection status.
Values:
ESP_HF_CONNECTION_STATE_DISCONNECTED = 0  
RFCOMM data link channel released
ESP_HF_CONNECTION_STATE_CONNECTING  
connecting remote device on the RFCOMM data link
ESP_HF_CONNECTION_STATE_CONNECTED  
RFCOMM connection established
ESP_HF_CONNECTION_STATE_SLC_CONNECTED  
service level connection established
ESP_HF_CONNECTION_STATE_DISCONNECTING  
disconnecting with remote device on the RFCOMM data link

enum esp_hf_chld_type_t  
AT+CHLD command values.
Values:
ESP_HF_CHLD_TYPE_REL = 0  
<0>, Terminate all held or set UDUB (“busy”) to a waiting call
ESP_HF_CHLD_TYPE_REL_ACC  
<1>, Terminate all active calls and accepts a waiting/held call
ESP_HF_CHLD_TYPE_HOLD_ACC  
<2>, Hold all active calls and accepts a waiting/held call
ESP_HF_CHLD_TYPE_MERGE
<3>, Add all held calls to a conference

ESP_HF_CHLD_TYPE_MERGE_DETACH
<4>, connect the two calls and disconnects the subscriber from both calls

ESP_HF_CHLD_TYPE_REL_X
<1x>, releases specified calls only

ESP_HF_CHLD_TYPE_PRIV_X
<2x>, request private consultation mode with specified call

enum esp_hf_at_response_code_t
Values:
ESP_HF_AT_RESPONSE_CODE_OK = 0
acknowledges execution of a command line
ESP_HF_AT_RESPONSE_CODE_ERR
command not accepted
ESP_HF_AT_RESPONSE_CODE_NO_CARRIER
connection terminated
ESP_HF_AT_RESPONSE_CODE_BUSY
busy signal detected
ESP_HF_AT_RESPONSE_CODE_NO_ANSWER
connection completion timeout
ESP_HF_AT_RESPONSE_CODE_DELAYED
delayed
ESP_HF_AT_RESPONSE_CODE_BLACKLISTED
blacklisted
ESP_HF_AT_RESPONSE_CODE_CME
CME error

enum esp_hf_at_response_t
Values:
ESP_HF_AT_RESPONSE_ERROR = 0
ESP_HF_AT_RESPONSE_OK

enum esp_hf_cme_err_t
Extended Audio Gateway Error Result Code Response.
Values:
ESP_HF_CME_AG_FAILURE = 0
ag failure
ESP_HF_CME_NO_CONNECTION_TO_PHONE = 1
no connection to phone
ESP_HF_CME_OPERATION_NOT_ALLOWED = 3
operation not allowed
ESP_HF_CME_OPERATION_NOT_SUPPORTED = 4
operation not supported
ESP_HF_CME_PH_SIM_PIN_REQUIRED = 5
PH-SIM PIN Required
ESP_HF_CME_SIM_NOT_INSERTED = 10
SIM not inserted
ESP_HF_CME_SIM_PIN_REQUIRED = 11
SIM PIN required

ESP_HF_CME_SIM_PUK_REQUIRED = 12
SIM PUK required

ESP_HF_CME_SIM_FAILURE = 13
SIM failure

ESP_HF_CME_SIM_BUSY = 14
SIM busy

ESP_HF_CME_INCORRECT_PASSWORD = 16
incorrect password

ESP_HF_CME_SIM_PIN2_REQUIRED = 17
SIM PIN2 required

ESP_HF_CME_SIM_PUK2_REQUIRED = 18
SIM PUK2 required

ESP_HF_CME_MEMORY_FULL = 20
memory full

ESP_HF_CME_INVALID_INDEX = 21
invalid index

ESP_HF_CME_MEMORY_FAILURE = 23
memory failure

ESP_HF_CME_TEXT_STRING_TOO_LONG = 24
text string too long

ESP_HF_CME_INVALID_CHARACTERS_IN_TEXT_STRING = 25
invalid characters in text string

ESP_HF_CME_DIAL_STRING_TOO_LONG = 26
dial string too long

ESP_HF_CME_INVALID_CHARACTERS_IN_DIAL_STRING = 27
invalid characters in dial string

ESP_HF_CME_NO_NETWORK_SERVICE = 30
no network service

ESP_HF_CME_NETWORK_TIMEOUT = 31
network timeout

ESP_HF_CME_NETWORK_NOT_ALLOWED = 32
network not allowed emergency calls only

HFP CLIENT API

Overview

API Reference

Header File

components/bt/host/bluedroid/api/include/api/esp_hf_client_api.h
### Functions

#### `esp_err_t esp_hf_client_register_callback(esp_hf_client_cb_t callback)`

Register application callback function to HFP client module. This function should be called only after `esp_bluedroid_enable()` completes successfully.

**Return**

- ESP_OK: success
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: if callback is a NULL function pointer

**Parameters**

- `[in]` callback: HFP client event callback function

#### `esp_err_t esp_hf_client_init(void)`

Initialize the Bluetooth HFP client module. This function should be called after `esp_bluedroid_enable()` completes successfully.

**Return**

- ESP_OK: if the initialization request is sent successfully
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

#### `esp_err_t esp_hf_client_deinit(void)`

De-initialize for HFP client module. This function should be called only after `esp_bluedroid_enable()` completes successfully.

**Return**

- ESP_OK: success
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

#### `esp_err_t esp_hf_client_connect(esp_bd_addr_t remote_bda)`

Establish a Service Level Connection to remote Bluetooth HFP audio gateway (AG) device. This function must be called after `esp_hf_client_init()` and before `esp_hf_client_deinit()`.

**Return**

- ESP_OK: connect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

**Parameters**

- `[in]` remote_bda: remote Bluetooth device address

#### `esp_err_t esp_hf_client_disconnect(esp_bd_addr_t remote_bda)`

Disconnect from the remote HFP audio gateway. This function must be called after `esp_hf_client_init()` and before `esp_hf_client_deinit()`.

**Return**

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

**Parameters**

- `[in]` remote_bda: remote Bluetooth device address

#### `esp_err_t esp_hf_client_connect_audio(esp_bd_addr_t remote_bda)`

Create audio connection with remote HFP AG. As a precondition to use this API, Service Level Connection shall exist with AG.

**Return**

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

**Parameters**

- `[in]` remote_bda: remote Bluetooth device address

#### `esp_err_t esp_hf_client_disconnect_audio(esp_bd_addr_t remote_bda)`

Release the established audio connection with remote HFP AG. As a precondition to use this API, Service Level Connection shall exist with AG.

**Return**

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

**Parameters**

- `[in]` remote_bda: remote Bluetooth device address
Level Connection shall exist with AG.

Return

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters

- [in] remote_bda: remote bluetooth device address

```
esp_err_t esp_hf_client_start_voice_recognition (void)
```
Enable voice recognition in the AG. As a precondition to use this API, Service Level Connection shall exist with AG.

Return

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```
esp_err_t esp_hf_client_stop_voice_recognition (void)
```
Disable voice recognition in the AG. As a precondition to use this API, Service Level Connection shall exist with AG.

Return

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```
esp_err_t esp_hf_client_volume_update (esp_hf_volume_control_target_t type, int volume)
```
Volume synchronization with AG. As a precondition to use this API, Service Level Connection shall exist with AG.

Return

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters

- [in] type: volume control target, speaker or microphone
- [in] volume: gain of the speaker of microphone, ranges 0 to 15

```
esp_err_t esp_hf_client_dial (const char *number)
```
Place a call with a specified number. If number is NULL, last called number is called. As a precondition to use this API, Service Level Connection shall exist with AG.

Return

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters

- [in] number: number string of the call. If NULL, the last number is called (aka re-dial)

```
esp_err_t esp_hf_client_dial_memory (int location)
```
Place a call with number specified by location(speed dial). As a precondition to use this API, Service Level Connection shall exist with AG.

Return

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters

- [in] location: location of the number in the memory

```
esp_err_t esp_hf_client_send_chld_cmd (esp_hf_child_type_t child, int idx)
```
Send call hold and multiparty commands, or enhanced call control commands(Use AT+CHLD). As a precondition to use this API, Service Level Connection shall exist with AG.
Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- [in] chld: AT+CHLD call hold and multiparty handling AT command.
- [in] idx: used in Enhanced Call Control Mechanisms, used if chld is ESP_HF_CHLD_TYPE_REL_X or ESP_HF_CHLD_TYPE_PRIV_X

```c
esp_err_t esp_hf_client_send_btrh_cmd(esp_hf_btrh_cmd_t btrh)
```
Send response and hold action command(Send AT+BTRH command) As a precondition to use this API, Service Level Connection shall exist with AG.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- [in] btrh: response and hold action to send

```c
esp_err_t esp_hf_client_answer_call(void)
```
Answer an incoming call(send ATA command). As a precondition to use this API, Service Level Connection shall exist with AG.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_client_reject_call(void)
```
Reject an incoming call(send AT+CHUP command). As a precondition to use this API, Service Level Connection shall exist with AG.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_client_query_current_calls(void)
```
Query list of current calls in AG(send AT+CLCC command). As a precondition to use this API, Service Level Connection shall exist with AG.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_client_query_current_operator_name(void)
```
Query the name of currently selected network operator in AG(use AT+COPS commands). As a precondition to use this API, Service Level Connection shall exist with AG.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_client_retrieve_subscriber_info(void)
```
Get subscriber information number from AG(send AT+CNUM command) As a precondition to use this API, Service Level Connection shall exist with AG.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others
**esp_err_t esp_hf_client_send_dtmf (char code)**

Transmit DTMF codes during an ongoing call (use AT+VTS commands). As a precondition to use this API, Service Level Connection shall exist with AG.

**Return**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if蓝牙 stack is not yet enabled
- ESP_FAIL: others

**Parameters**
- [in] code: dtmf code, single ascii character in the set 0-9, #, *, A-D

**esp_err_t esp_hf_client_request_last_voice_tag_number (void)**

Request a phone number from AG corresponding to last voice tag recorded (send AT+BINP command). As a precondition to use this API, Service Level Connection shall exist with AG.

**Return**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

**esp_err_t esp_hf_client_send_nrec (void)**

Disable echo cancellation and noise reduction in the AG (use AT+NREC=0 command). As a precondition to use this API, Service Level Connection shall exist with AG.

**Return**
- ESP_OK: NREC=0 request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

**esp_err_t esp_hf_client_register_data_callback (esp_hf_client_incoming_data_cb_t recv, esp_hf_client_outgoing_data_cb_t send)**

Register HFP client data output function; the callback is only used in the case that Voice Over HCI is enabled.

**Return**
- ESP_OK: success
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: if callback is a NULL function pointer

**Parameters**
- [in] recv: HFP client incoming data callback function
- [in] send: HFP client outgoing data callback function

**void esp_hf_client_outgoing_data_ready (void)**

Trigger the lower-layer to fetch and send audio data. This function is only only used in the case that Voice Over HCI is enabled. After this function is called, lower layer will invoke esp_hf_client_outgoing_data_cb_t to fetch data.

As a precondition to use this API, Service Level Connection shall exist with AG.

**void esp_hf_client_pcm_resample_init (uint32_t src_sps, uint32_t bits, uint32_t channels)**

Initialize the down sampling converter. This is a utility function that can only be used in the case that Voice Over HCI is enabled.

**Parameters**
- [in] src_sps: original samples per second (source audio data, i.e. 48000, 32000, 16000, 44100, 22050, 11025)
- [in] bits: number of bits per pcm sample (16)
- [in] channels: number of channels (i.e. mono(1), stereo(2)…)

**void esp_hf_client_pcm_resample_deinit (void)**

Deinitialize the down sampling converter.

**int32_t esp_hf_client_pcm_resample (void *src, uint32_t in_bytes, void *dst)**

Down sampling utility to convert high sampling rate into 8K/16bits 1-channel mode PCM samples. This can only be used in the case that Voice Over HCI is enabled.
Return  number of samples converted

Parameters
- \([\text{in}]\) src: pointer to the buffer where the original sampling PCM are stored
- \([\text{in}]\) in_bytes: length of the input PCM sample buffer in byte
- \([\text{in}]\) dst: pointer to the buffer which is to be used to store the converted PCM samples

Unions

\[
\text{union esp HF client cb param t}
\]

#include <esp HF client api.h> HFP client callback parameters.

Public Members

\[
\text{struct esp HF client cb param t:HF client conn stat param conn stat}
\]
HF callback param of ESP_HF_CLIENT_CONNECTION_STATE_EVT

\[
\text{struct esp HF client cb param t:HF client audio stat param audio stat}
\]
HF callback param of ESP_HF_CLIENT_AUDIO_STATE_EVT

\[
\text{struct esp HF client cb param t:HF client bvra param bvra}
\]
HF callback param of ESP_HF_CLIENT_BVRA_EVT

\[
\text{struct esp HF client cb param t:HF client service availability param service availability}
\]
HF callback param of ESP_HF_CLIENT_CIND_SERVICE_AVAILABILITY_EVT

\[
\text{struct esp HF client cb param t:HF client network roaming param roaming}
\]
HF callback param of ESP_HF_CLIENT_CIND_ROAMING_STATUS_EVT

\[
\text{struct esp HF client cb param t:HF client signal strength ind param signal strength}
\]
HF callback param of ESP_HF_CLIENT_CIND_SIGNAL_STRENGTH_EVT

\[
\text{struct esp HF client cb param t:HF client battery level ind param battery level}
\]
HF callback param of ESP_HF_CLIENT_CIND_BATTERY_LEVEL_EVT

\[
\text{struct esp HF client cb param t:HF client current operator param cops}
\]
HF callback param of ESP_HF_CLIENT_COPS_CURRENT_OPERATOR_EVT

\[
\text{struct esp HF client cb param t:HF client call ind param call}
\]
HF callback param of ESP_HF_CLIENT_CIND_CALL_EVT

\[
\text{struct esp HF client cb param t:HF client call setup ind param call setup}
\]
HF callback param of ESP_HF_CLIENT_BVRA_EVT

\[
\text{struct esp HF client cb param t:HF client call held ind param call held}
\]
HF callback param of ESP_HF_CLIENT_CIND_CALL_HELD_EVT

\[
\text{struct esp HF client cb param t:HF client btrh param btrh}
\]
HF callback param of ESP_HF_CLIENT_BRTH_EVT

\[
\text{struct esp HF client cb param t:HF client clip param clip}
\]
HF callback param of ESP_HF_CLIENT_CLIP_EVT

\[
\text{struct esp HF client cb param t:HF client ccwa param ccwa}
\]
HF callback param of ESP_HF_CLIENT_BVRA_EVT

\[
\text{struct esp HF client cb param t:HF client clcc param clcc}
\]
HF callback param of ESP_HF_CLIENT_CLCC_EVT

\[
\text{struct esp HF client cb param t:HF client volume control param volume control}
\]
HF callback param of ESP_HF_CLIENT_VOLUME_CONTROL_EVT

\[
\text{struct esp HF client cb param t:HF client at response param at response}
\]
HF callback param of ESP_HF_CLIENT_AT_RESPONSE_EVT

\[
\text{struct esp HF client cb param t:HF client cnum param cnum}
\]
HF callback param of ESP_HF_CLIENT_CNUM_EVT


**struct esp_hf_client_cb_param_t::hf_client_bsirparam bsir**

HF callback param of ESP_HF_CLIENT_BSIR_EVT

**struct esp_hf_client_cb_param_t::hf_client_binp_param binp**

HF callback param of ESP_HF_CLIENT_BINP_EVT

**struct hf_client_at_response_param**

#include <esp_hf_client_api.h> ESP_HF_CLIENT_AT_RESPONSE_EVT.

**Public Members**

- `esp_hf_at_response_code_t code`
  AT response code
- `esp_hf_cme_err_t cme`
  Extended Audio Gateway Error Result Code

**struct hf_client_audio_stat_param**

#include <esp_hf_client_api.h> ESP_HF_CLIENT_AUDIO_STATE_EVT.

**Public Members**

- `esp_hf_client_audio_state_t state`
  audio connection state
- `esp_bd_addr_t remote_bda`
  remote bluetooth device address

**struct hf_client_battery_level_ind_param**

#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_BATTERY_LEVEL_EVT.

**Public Members**

- `int value`
  battery charge value, ranges from 0 to 5

**struct hf_client_binp_param**

#include <esp_hf_client_api.h> ESP_HF_CLIENT_BINP_EVT.

**Public Members**

- `const char * number`
  phone number corresponding to the last voice tag in the HF

**struct hf_client_bsirparam**

#include <esp_hf_client_api.h> ESP_HF_CLIENT_BSIR_EVT.

**Public Members**

- `esp_hf_client_in_band_ring_state_t state`
  setting state of in-band ring tone

**struct hf_client_btrh_param**

#include <esp_hf_client_api.h> ESP_HF_CLIENT_BTRH_EVT.

**Public Members**
Public Members

`esp_hf_btrh_status_t status`  
call hold and response status result code

`struct hf_client_bvra_param`  
#include <esp_hf_client_api.h> ESP_HF_CLIENT_BVRA_EVT.

Public Members

`esp_hf_vr_state_t value`  
voice recognition state

`struct hf_client_call_held_ind_param`  
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_CALL_HELD_EVT.

Public Members

`esp_hf_call_held_status_t status`  
bluetooth proprietary call hold status indicator

`struct hf_client_call_ind_param`  
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_CALL_EVT.

Public Members

`esp_hf_call_status_t status`  
call status indicator

`struct hf_client_call_setup_ind_param`  
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_CALL_SETUP_EVT.

Public Members

`esp_hf_call_setup_status_t status`  
call setup status indicator

`struct hf_client_ccwa_param`  
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CCWA_EVT.

Public Members

`const char *number`  
phone number string of waiting call

`struct hf_client_clcc_param`  
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CLCC_EVT.

Public Members

`int idx`  
numbering(starting with 1) of the call

`esp_hf_current_call_direction_t dir`  
direction of the call
`esp_hf_current_call_status_t status`
status of the call

`esp_hf_current_call_mpty_type_t mpty`
multi-party flag

`char *number`  
phone number (optional)

**struct hf_client_clip_param**
#include `<esp_hf_client_api.h>` ESP_HF_CLIENT_CLIP_EVT.

**Public Members**

```c
const char *number
```
phone number string of call

**struct hf_client_cnum_param**
#include `<esp_hf_client_api.h>` ESP_HF_CLIENT_CNUM_EVT.

**Public Members**

```c
const char *number
```
phone number string

`esp_hf_subscriber_service_type_t type`
service type that the phone number relates to

**struct hf_client_conn_stat_param**
#include `<esp_hf_client_api.h>` ESP_HF_CLIENT_CONNECTION_STATE_EVT.

**Public Members**

```c
esp_hf_client_connection_state_t state
```
HF connection state

```c
uint32_t peer_feat
```
AG supported features

```c
uint32_t chld_feat
```
AG supported features on call hold and multiparty services

`esp_bd_addr_t remote_bda`
remote bluetooth device address

**struct hf_client_current_operator_param**
#include `<esp_hf_client_api.h>` ESP_HF_CLIENT_COPS_CURRENT_OPERATOR_EVT.

**Public Members**

```c
const char *name
```
named of the network operator

**struct hf_client_network_roaming_param**
#include `<esp_hf_client_api.h>` ESP_HF_CLIENT_CIND_ROAMING_STATUS_EVT.
Public Members

`esp_hf_roaming_status_t status`
roaming status

`struct hf_client_service_availability_param`
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_SERVICE_AVAILABILITY_EVT.

Public Members

`esp_hf_network_state_t status`
service availability status

`struct hf_client_signal_strength_ind_param`
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_SIGNAL_STRENGTH_EVT.

Public Members

`int value`
signal strength value, ranges from 0 to 5

`struct hf_client_volume_control_param`
#include <esp_hf_client_api.h> ESP_HF_CLIENT_VOLUME_CONTROL_EVT.

Public Members

`esp_hf_volume_control_target_t type`
volume control target, speaker or microphone

`int volume`
gain, ranges from 0 to 15

Macros

ESP_BT_HF_CLIENT_NUMBER_LEN
ESP_BT_HF_CLIENT_OPERATOR_NAME_LEN
ESP_HF_CLIENT_PEER_FEAT_3WAY
ESP_HF_CLIENT_PEER_FEAT_ECNR
ESP_HF_CLIENT_PEER_FEAT_VREC
ESP_HF_CLIENT_PEER_FEAT_INBAND
ESP_HF_CLIENT_PEER_FEAT_VTAG
ESP_HF_CLIENT_PEER_FEAT_REJECT
ESP_HF_CLIENT_PEER_FEAT_ECS
ESP_HF_CLIENT_PEER_FEAT_ECC
ESP_HF_CLIENT_PEER_FEAT_EXTERR
ESP_HF_CLIENT_PEER_FEAT_CODEC
ESP_HF_CLIENT_CHLD_FEAT_REL
ESP_HF_CLIENT_CHLD_FEAT_REL_ACC
ESP_HF_CLIENT_CHLD_FEAT_REL_X
ESP_HF_CLIENT_CHLD_FEAT_HOLD_ACC
**Type Definitions**

```c
typedef void (*esp_hf_client_incoming_data_cb_t)(const uint8_t*buf, uint32_t len)
```

HFP client incoming data callback function, the callback is useful in case of Voice Over HCI.

**Parameters**

- `buf`: Pointer to incoming data (payload of HCI synchronous data packet), the buffer is allocated inside Bluetooth protocol stack and will be released after invoke of the callback is finished.
- `len`: Size (in bytes) in `buf`

```c
typedef uint32_t (*esp_hf_client_outgoing_data_cb_t)(uint8_t*buf, uint32_t len)
```

HFP client outgoing data callback function, the callback is useful in case of Voice Over HCI. Once audio connection is set up and the application layer has prepared data to send, the lower layer will call this function to read data and then send. This callback is supposed to be implemented as non-blocking, and if data is not enough, return value 0 is supposed.

**Return**

Length of data successfully read

**Parameters**

- `buf`: Pointer to incoming data (payload of HCI synchronous data packet), the buffer is allocated inside Bluetooth protocol stack and will be released after invoke of the callback is finished.
- `len`: Size (in bytes) in `buf`

```c
typedef void (*esp_hf_client_cb_t)(esp_hf_client_cb_event_t event, esp_hf_client_cb_param_t *param)
```

HFP client callback function type.

**Parameters**

- `event`: Event type
- `param`: Pointer to callback parameter

**Enumerations**

```c
class esp_hf_client_connection_state_t
```

Bluetooth HFP RFCOMM connection and service level connection status.

**Values**:

- `ESP_HF_CLIENT_CONNECTION_STATE_DISCONNECTED` = 0
  - RFCOMM data link channel released
- `ESP_HF_CLIENT_CONNECTION_STATE_CONNECTING`
  - Connecting remote device on the RFCOMM data link
- `ESP_HF_CLIENT_CONNECTION_STATE_CONNECTED`
  - RFCOMM connection established
- `ESP_HF_CLIENT_CONNECTION_STATE_SLC_CONNECTED`
  - Service level connection established
- `ESP_HF_CLIENT_CONNECTION_STATE_DISCONNECTING`
  - Disconnecting with remote device on the RFCOMM data link

```c
class esp_hf_client_audio_state_t
```

Bluetooth HFP audio connection status.

**Values**:

- `ESP_HF_CLIENT_AUDIO_STATE_DISCONNECTED` = 0
  - Audio connection released
- `ESP_HF_CLIENT_AUDIO_STATE_CONNECTING`
  - Audio connection has been initiated
Chapter 2. API Reference

```c
ESP_HF_CLIENT_AUDIO_STATE_CONNECTED
audio connection is established

ESP_HF_CLIENT_AUDIO_STATE_CONNECTED_MSBC
mSBC audio connection is established

enum esp_hf_client_in_band_ring_state_t
  in-band ring tone state

Values:

ESP_HF_CLIENT_IN_BAND_RINGTONE_NOT_PROVIDED = 0
ESP_HF_CLIENT_IN_BAND_RINGTONE_PROVIDED

enum esp_hf_client_cb_event_t
  HF CLIENT callback events.

Values:

ESP_HF_CLIENT_CONNECTION_STATE_EVT = 0
connection state change event

ESP_HF_CLIENT_AUDIO_STATE_EVT
audio connection state change event

ESP_HF_CLIENT_BVRA_EVT
voice recognition state change event

ESP_HF_CLIENT_CIND_CALL_EVT
call indication

ESP_HF_CLIENT_CIND_CALL_SETUP_EVT
call setup indication

ESP_HF_CLIENT_CIND_CALL_HELD_EVT
call held indication

ESP_HF_CLIENT_CIND_SERVICE_AVAILABILITY_EVT
network service availability indication

ESP_HF_CLIENT_CIND_SIGNAL_STRENGTH_EVT
signal strength indication

ESP_HF_CLIENT_CIND_ROAMING_STATUS_EVT
roaming status indication

ESP_HF_CLIENT_CIND_BATTERY_LEVEL_EVT
battery level indication

ESP_HF_CLIENT_COPS_CURRENT_OPERATOR_EVT
current operator information

ESP_HF_CLIENT_BTRH_EVT
call response and hold event

ESP_HF_CLIENT_CLIP_EVT
Calling Line Identification notification

ESP_HF_CLIENT_CCWA_EVT
call waiting notification

ESP_HF_CLIENT_CLCC_EVT
list of current calls notification

ESP_HF_CLIENT_VOLUME_CONTROL_EVT
audio volume control command from AG, provided by +VGM or +VGS message

ESP_HF_CLIENT_AT_RESPONSE_EVT
AT command response event
```
ESP_HF_CLIENT_CNUM_EVT
subscriber information response from AG

ESP_HF_CLIENT_BSIR_EVT
setting of in-band ring tone

ESP_HF_CLIENT_BINP_EVT
requested number of last voice tag from AG

ESP_HF_CLIENT_RING_IND_EVT
ring indication event

HFP AG API

API Reference

Header File
- components/bt/host/bluedroid/api/include/api/esp_hf_ag_api.h

Functions

\textbf{esp_err_t} \textbf{esp bt hf register callback (esp hf cb t callback)}
Register application callback function to HFP AG module. This function should be called only after esp_bluedroid_enable() completes successfully.

\textbf{Return}
- ESP_OK: success
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: if callback is a NULL function pointer

\textbf{Parameters}
- \([\text{in}]\) \text{callback}: HFP AG event callback function

\textbf{esp_err_t} \textbf{esp bt hf init (esp bd addr t remote addr)}
Initialize the bluetooth HF AG module. This function should be called after esp_bluedroid_enable() completes successfully.

\textbf{Return}
- ESP_OK: if the initialization request is sent successfully
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

\textbf{Parameters}
- \([\text{in}]\) \text{remote_addr}: remote bluetooth device address

\textbf{esp_err_t} \textbf{esp bt hf deinit (esp bd addr t remote addr)}
De-initialize for HF AG module. This function should be called only after esp_bluedroid_enable() completes successfully.

\textbf{Return}
- ESP_OK: success
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

\textbf{Parameters}
- \([\text{in}]\) \text{remote_addr}: remote bluetooth device address

\textbf{esp_err_t} \textbf{esp bt hf connect (esp bd addr t remote bda)}
To establish a Service Level Connection to remote bluetooth HFP client device. This function must be called after esp_bt_hf_init() and before esp_bt_hf_deinit().

\textbf{Return}
- ESP_OK: connect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others
Parameters
- \([\text{in}]\) remote_bda: remote bluetooth HFP client device address

`esp_err_t esp_bt_hf_disconnect(esp_bd_addr_t remote_bda)`
Disconnected from the remote HFP client. This function must be called after esp_bt_hf_init() and before esp_bt_hf_deinit().

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- \([\text{in}]\) remote_bda: remote bluetooth device address

`esp_err_t esp_bt_hf_connect_audio(esp_bd_addr_t remote_bda)`
Create audio connection with remote HFP client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- \([\text{in}]\) remote_bda: remote bluetooth device address

`esp_err_t esp_bt_hf_disconnect_audio(esp_bd_addr_t remote_bda)`
Release the established audio connection with remote HFP client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- \([\text{in}]\) remote_bda: remote bluetooth device address

`esp_err_t esp_bt_hf_vra(esp_bd_addr_t remote_bda, esp_hf_vr_state_t value)`
Response of Volume Recognition Command(AT+VRA) from HFP client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- \([\text{in}]\) remote_bda: the device address of voice recognition initiator
- \([\text{in}]\) value: 0 - voice recognition disabled, 1- voice recognition enabled

`esp_err_t esp_bt_hf_volume_control(esp_bd_addr_t remote_bda, esp_hf_volume_control_target_t type, int volume)`
Volume synchronization with HFP client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- \([\text{in}]\) remote_bda: remote bluetooth device address
- \([\text{in}]\) type: volume control target, speaker or microphone
- \([\text{in}]\) volume: gain of the speaker of microphone, ranges 0 to 15

`esp_err_t esp_hf_unat_response(esp_bd_addr_t remote_addr, char *unat)`
Handle Unknown AT command from HFP Client. As a precondition to use this API, Service Level Connection...
shall exist with HFP client.

Return

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters

- [in] remote_addr: remote bluetooth device address
- [in] unat: User AT command response to HF Client. It will response “ERROR” by default if unat is NULL.

\[ \text{esp_err_t esp_bt_hf_cmee_response(esp_bd_addr_t remote_bda, esp_hf_at_response_code_t response_code, esp_hf_cme_err_t error_code)} \]

Unsolicited send extend AT error code to HFP Client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Return

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters

- [in] remote_addr: remote bluetooth device address
- [in] response_code: AT command response code
- [in] error_code: CME error code

\[ \text{esp_err_t esp_bt_hf_indchange_notification(esp_bd_addr_t remote_addr, esp_hf_call_status_t call_state, esp_hf_call_setup_status_t call_setup_state, esp_hf_network_state_t ntk_state, int signal)} \]

Usolicited send device status notification to HFP Client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Return

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters

- [in] remote_addr: remote bluetooth device address
- [in] call_state: call state
- [in] call_setup_state: call setup state
- [in] ntk_state: network service state
- [in] signal: signal strength from 0 to 5

\[ \text{esp_err_t esp_bt_hf_cind_response(esp_bd_addr_t remote_addr, esp_hf_call_status_t call_state, esp_hf_call_setup_status_t call_setup_state, esp_hf_network_state_t ntk_state, int signal, esp_hf_roaming_status_t roam, int batt_lev, esp_hf_call_held_status_t call_held_status)} \]

Response to device individual indicators to HFP Client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Return

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters

- [in] remote_addr: remote bluetooth device address
- [in] call_state: call state
- [in] call_setup_state: call setup state
- [in] ntk_state: network service state
- [in] signal: signal strength from 0 to 5
- [in] roam: roam state
Chapter 2. API Reference

- [in] batt_lev: battery level from 0 to 5
- [in] call_held_status: call held status

```c
esp_err_t esp_bt_hf_cops_response(esp_bd_addr_t remote_addr, char *name)
```
Reponse for AT+COPS command from HF Client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- [in] remote_addr: remote bluetooth device address
- [in] name: current operator name

```c
esp_err_t esp_bt_hf_clcc_response(esp_bd_addr_t remote_addr, int index, esp_hf_current_call_direction_t dir, esp_hf_current_call_status_t current_call_state, esp_hf_current_call_mode_t mode, esp_hf_current_call_mpty_type_t mpty, char *number, esp_hf_call_addr_type_t type)
```
Response to AT+CLCC command from HFP Client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- [in] remote_addr: remote bluetooth device address
- [in] index: the index of current call
- [in] dir: call direction (incoming/outgoing)
- [in] current_call_state: current call state
- [in] mode: current call mode (voice/data/fax)
- [in] mpty: single or multi type
- [in] number: current call number
- [in] type: international type or unknow

```c
esp_err_t esp_bt_hf_cnum_response(esp_bd_addr_t remote_addr, char *number, esp_hf_subscriber_service_type_t type)
```
Response for AT+CNUM command from HF Client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- [in] remote_addr: remote bluetooth device address
- [in] number: registration number
- [in] type: service type (unknown/voice/fax)

```c
esp_err_t esp_bt_hf_bsir(esp_bd_addr_t remote_addr, esp_hf_in_band_ring_state_t state)
```
Inform HF Client that AG Provided in-band ring tone or not. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Return
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters
- [in] remote_addr: remote bluetooth device address
API Reference

- [in] state: in-band ring tone state

```c
esp_err_t esp_bt hf_answer_call (esp_bd_addr_t remote_addr, int num_active, int num_held,
    esp HF call status_t call_state, esp HF call setup status_t call_setup_state, char *number,
    esp HF call addr type_t call_addr_type)
```

Answer Incoming Call from AG. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Return**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

**Parameters**
- [in] remote_addr: remote Bluetooth device address
- [in] num_active: the number of active call
- [in] num_held: the number of held call
- [in] call_state: call state
- [in] call_setup_state: call setup state
- [in] number: number of the incoming call
- [in] call_addr_type: call address type

```c
esp_err_t esp bt hf reject call (esp bd addr_t remote_addr, int num active, int num held,
    esp HF call status_t call_state, esp HF call setup status_t call_setup_state, char *number,
    esp HF call addr type_t call_addr_type)
```

Reject Incoming Call from AG. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Return**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

**Parameters**
- [in] remote_addr: remote Bluetooth device address
- [in] num_active: the number of active call
- [in] num_held: the number of held call
- [in] call_state: call state
- [in] call_setup_state: call setup state
- [in] number: number of the incoming call
- [in] call_addr_type: call address type

```c
esp_err_t esp bt hf out call (esp bd addr_t remote_addr, int num active, int num held,
    esp HF call status_t call_state, esp HF call setup status_t call_setup_state, char *number,
    esp HF call addr type_t call_addr_type)
```

Initiate a call from AG. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Return**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

**Parameters**
- [in] remote_addr: remote Bluetooth device address
- [in] num_active: the number of active call
- [in] num_held: the number of held call
- [in] call_state: call state
- [in] call_setup_state: call setup state
- [in] number: number of the outgoing call
- [in] call_addr_type: call address type
esp_err_t esp_bt_hf_end_call(esp_bd_addr_t remote_addr, int num_active, int num_held, esp_hf_call_status_t call_state, esp_hf_call_setup_status_t call_setup_state, char *number, esp_hf_call_addr_type_t call_addr_type)

End an ongoing call. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Return
• ESP_OK: disconnect request is sent to lower layer
• ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
• ESP_FAIL: others

Parameters
• [in] remote_addr: remote Bluetooth device address
• [in] num_active: the number of active call
• [in] num_held: the number of held call
• [in] call_state: call state
• [in] call_setup_state: call setup state
• [in] number: number of the call
• [in] call_addr_type: call address type

esp_err_t esp_bt_hf_register_data_callback (esp_hf_incoming_data_cb_t recv, esp_hf_outgoing_data_cb_t send)

Register AG data output function. The callback is only used in the case that Voice Over HCI is enabled.

Return
• ESP_OK: success
• ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
• ESP_FAIL: if callback is a NULL function pointer

Parameters
• [in] recv: HFP client incoming data callback function
• [in] send: HFP client outgoing data callback function

void esp_hf_outgoing_data_ready (void)

Trigger the lower-layer to fetch and send audio data.

This function is only used in the case that Voice Over HCI is enabled. As a precondition to use this API, Service Level Connection shall exist with HFP client. After this function is called, lower layer will invoke esp_hf_client_outgoing_data_cb_t to fetch data

Unions
union esp_hf_cb_param_t

# include <esp_hf_ag_api.h> HFP AG callback parameters.

Public Members

struct esp_hf_cb_param_t::hf_conn_stat_param conn_stat
AG callback parameter of ESP_HF_CONNECTION_STATE_EVT

struct esp_hf_cb_param_t::hf_audio_stat_param audio_stat
AG callback parameter of ESP_HF_AUDIO_STATE_EVT

struct esp_hf_cb_param_t::hf_vra_rep_param vra_rep
AG callback parameter of ESP_HF_BVRA_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_volume_control_param volume_control
AG callback parameter of ESP_HF_VOLUME_CONTROL_EVT

struct esp_hf_cb_param_t::hf_unat_rep_param unat_rep
AG callback parameter of ESP_HF_UNAT_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_cind_param cind
AG callback parameter of ESP_HF_CIND_RESPONSE_EVT
struct esp_hf_cb_param_t::hf_out_call_param out_call
  AG callback param of ESP_HF_DIAL_EVT

struct esp_hf_cb_param_t::hf_vts_rep_param vts_rep
  AG callback param of ESP_HF_VTS_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_nrec_param nrec
  AG callback param of ESP_HF_NREC_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_wbs_rep_param wbs_rep
  AG callback param of ESP_HF_WBS_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_bcs_rep_param bcs_rep
  AG callback param of ESP_HF_BCS_RESPONSE_EVT

struct hf_audio_stat_param
  #include <esp_hf_ag_api.h> ESP_HF_AUDIO_STATE_EVT.

  Public Members

  esp_bd_addr_t remote_addr
    Remote bluetooth device address

  esp_hf_audio_state_t state
    Audio connection state

struct hf_bcs_rep_param
  #include <esp_hf_ag_api.h> ESP_HF_BCS_RESPONSE_EVT.

  Public Members

  esp_hf_wbs_config_t mode
    codec mode CVSD or mSBC

struct hf_cind_param
  #include <esp_hf_ag_api.h> ESP_HF_CIND_RESPONSE_EVT.

  Public Members

  esp_hf_call_status_t call_status
    call status indicator

  esp_hf_call_setup_status_t call_setup_status
    call setup status indicator

  esp_hf_network_state_t svc
    bluetooth proprietary call hold status indicator

  int signal_strength
    bluetooth proprietary call hold status indicator

  int battery_level
    battery charge value, ranges from 0 to 5

struct hf_conn_stat_param
  #include <esp_hf_ag_api.h> ESP_HS_CONNECTION_STATE_EVT.
Public Members

\textit{esp_bd_addr_t} \texttt{remote_bda}
Remote bluetooth device address

\textit{esp_HF_connection_state_t} \texttt{state}
Connection state

\texttt{uint32_t} \texttt{peer_feat}
HF supported features

\texttt{uint32_t} \texttt{chld_feat}
AG supported features on call hold and multiparty services

\texttt{struct hf_nrec_param}
\#include \texttt{<esp_hf_ag_api.h>} ESP_HF_NREC_RESPONSE_EVT.

Public Members

\textit{esp_hf_nrec_t} \texttt{state}
NREC enabled or disabled

\texttt{struct hf_out_call_param}
\#include \texttt{<esp_hf_ag_api.h>} ESP_HF_DIAL_EVT.

Public Members

\textit{esp_bd_addr_t} \texttt{remote_addr}
remote bluetooth device address

\texttt{char \*num_or_loc}
location in phone memory

\texttt{struct hf_unat_rep_param}
\#include \texttt{<esp_hf_ag_api.h>} ESP_HF_UNAT_RESPONSE_EVT.

Public Members

\texttt{char \*unat}
Unknown AT command string

\texttt{struct hf_volume_control_param}
\#include \texttt{<esp_hf_ag_api.h>} ESP_HF_VOLUME_CONTROL_EVT.

Public Members

\textit{esp_HF_volume_type_t} \texttt{type}
Volume control target, speaker or microphone

\texttt{int} \texttt{volume}
Gain, ranges from 0 to 15

\texttt{struct hf_vra_rep_param}
\#include \texttt{<esp_hf_ag_api.h>} ESP_HF_BVRA_RESPONSE_EVT.
Public Members

`esp_bd_addr_t remote_addr`
Remote bluetooth device address

`esp_hf_nr_state_t value`
Voice recognition state

`struct hf_vts_rep_param`
`#include <esp_hf_ag_api.h> ESP_HF_VTS_RESPOSNE_EVT.`

Public Members

`char *code`
MTF code from HF Client

`struct hf_wbs_rep_param`
`#include <esp_hf_ag_api.h> ESP_HF_WBS_RESPONSE_EVT.`

Public Members

`esp_hf_wbs_config_t codec`
codec mode CVSD or mSBC

Macros

`ESP_HF_PEER_FEAT_3WAY`
`ESP_HF_PEER_FEAT_ECNR`
`ESP_HF_PEER_FEAT_VREC`
`ESP_HF_PEER_FEAT_INBAND`
`ESP_HF_PEER_FEAT_VTAG`
`ESP_HF_PEER_FEAT_REJECT`
`ESP_HF_PEER_FEAT_ECS`
`ESP_HF_PEER_FEAT_ECC`
`ESP_HF_PEER_FEAT_EXERR`
`ESP_HF_PEER_FEAT_CODEC`
`ESP_HF_CHLD_FEAT_REL`
`ESP_HF_CHLD_FEAT_REL_ACC`
`ESP_HF_CHLD_FEAT_REL_X`
`ESP_HF_CHLD_FEAT_HOLD_ACC`
`ESP_HF_CHLD_FEAT_PRIV_X`
`ESP_HF_CHLD_FEAT_MERGE`
`ESP_HF_CHLD_FEAT_MERGE_DETACH`

Type Definitions

typedef void (*esp_hf_incoming_data_cb_t)(const uint8_t *buf, uint32_t len)
AG incoming data callback function, the callback is useful in case of Voice Over HCI.

Parameters
Chapter 2. API Reference

- **[in]** `buf`: pointer to incoming data (payload of HCI synchronous data packet), the buffer is allocated inside Bluetooth protocol stack and will be released after invoke of the callback is finished.

  ```c
  typedef uint32_t(*esp_hf_outgoing_data_cb_t)(uint8_t*buf, uint32_t len)
  ```

  AG outgoing data callback function, the callback is useful in case of Voice Over HCI. Once audio connection is set up and the application layer has prepared data to send, the lower layer will call this function to read data and then send. This callback is supposed to be implemented as non-blocking, and if data is not enough, return value 0 is supposed.

  **Return** length of data successfully read

  **Parameters**
  - **[in]** `buf`: pointer to incoming data (payload of HCI synchronous data packet), the buffer is allocated inside Bluetooth protocol stack and will be released after invoke of the callback is finished.
  - **[in]** `len`: size (in bytes) in `buf`

- **typedef** `void(*esp_hf_cb_t)(esp_hf_cb_event_t event, esp_hf_cb_param_t *param)`

  HF AG callback function type.

  **Parameters**
  - `event`: Event type
  - `param`: Pointer to callback parameter

**Enumerations**

```c
cenum esp_hf_cb_event_t
{
    ESP_HF_CONNECTION_STATE_EVT = 0,
    ESP_HF_AUDIO_STATE_EVT,
    ESP_HF_BVRA_RESPONSE_EVT,
    ESP_HF_VOLUME_CONTROL_EVT,
    ESP_HF_UNAT_RESPONSE_EVT,
    ESP_HF_IND_UPDATE_EVT,
    ESP_HF_CIND_RESPONSE_EVT,
    ESP_HF_COPS_RESPONSE_EVT,
    ESP_HF_CLCC_RESPONSE_EVT,
    ESP_HF_CNUM_RESPONSE_EVT,
    ESP_HF_VTS_RESPONSE_EVT,
    ESP_HF_NREC_RESPONSE_EVT,
    ESP_HF_ATA_RESPONSE_EVT
}
```
2.1.5 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.

![Fig. 1: ESP NimBLE Stack](image)

Threading Model

The NimBLE host can run inside the application thread or can have its own independent thread. This 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()`**

- **Description**: Initialize VHCI transport layer between NimBLE Host and ESP Bluetooth controller.
- **Returns**:
  - `ESP_OK` if the initialization is successful
  - Appropriate error code from `esp_err_t` in case of an error

**`esp_err_t esp_nimble_hci_and_controller_init()`**

- **Description**: Initialize ESP Bluetooth controller(link layer) and VHCI transport layer between NimBLE Host and ESP Bluetooth controller.
- **Returns**:
  - `ESP_OK` if the initialization is successful
  - Appropriate error code from `esp_err_t` in case of an error

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
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

`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

`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_-
    -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 de initialization is successful
  • Appropriate error codes from esp_err_t in case of an error

Macros

- BLE_HCI_UART_H4_NONE
- BLE_HCI_UART_H4_CMD
- BLE_HCI_UART_H4_ACL
- BLE_HCI_UART_H4_SCO
- BLE_HCI_UART_H4_EVT

2.1.6 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 un provisioned 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 un provisioned devices into ESP-BLE-MESH nodes and configure the nodes with various features.
Chapter 2. API Reference

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

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_prov_register_comp_param
provision_register_comp
Event parameter of ESP_BLE_MESH_PROV_REGISTER_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_set_unprov_dev_name_comp_param
node_set_unprov_dev_name_comp
Event parameter of ESP_BLE_MESH_NODE_SET_UNPROV_DEV_NAME_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_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
```

Submit Document Feedback
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_completeEvt_param node_prov_complete
    Event parameter of ESP_BLE_MESH_NODE_PROV_COMPLETE_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provision_reset_param node_prov_reset
    Event parameter of ESP_BLE_MESH_NODE_PROV_RESET_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_set_oob_pub_key_comp_param node_prov_set_oob_pub_key_comp
    Event parameter of ESP_BLE_MESH_NODE_PROV_SET_OOB_PUB_KEY_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_input_number_comp_param node_prov_input_num_comp
    Event parameter of ESP_BLE_MESH_NODE_PROV_INPUT_NUM_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_input_string_comp_param node_prov_input_str_comp
    Event parameter of ESP_BLE_MESH_NODE_PROV_INPUT_STR_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_identity_enable_comp_param node_proxy_identity_enable_comp
    Event parameter of ESP_BLE_MESH_NODE_PROXY_IDENTITY_ENABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_gatt_enable_comp_param node_proxy_gatt_enable_comp
    Event parameter of ESP_BLE_MESH_NODE_PROXY_GATT_ENABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_gatt_disable_comp_param node_proxy_gatt_disable_comp
    Event parameter of ESP_BLE_MESH_NODE_PROXY_GATT_DISABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_node_add_local_net_key_comp_param node_add_net_key_comp
    Event parameter of ESP_BLE_MESH_NODE_ADD_LOCAL_NET_KEY_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_node_add_local_app_key_comp_param node_add_app_key_comp
    Event parameter of ESP_BLE_MESH_NODE_ADD_LOCAL_APP_KEY_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_node_bind_local_mod_app_param node_bind_app_key_to_model
    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_evt_param provisioner_prov_read_oob_pub_key
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_READ_OOB_PUB_KEY_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_input_evt_param provisioner_prov_input
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_INPUT_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_output_evt_param provisioner_prov_output
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_OUTPUT_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_link_close_evt_param provisioner_prov_link_close
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_LINK_CLOSE_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_complete_param provisioner_prov_complete
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_COMPLETE_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_unprov_dev_comp_param provisioner_add_unprov_dev
    Event parameter of ESP_BLE_MESH_PROVISIONER_ADD_UNPROV_DEV_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_dev_with_addr_comp_param provisioner_prov_dev_with_addr
    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
 provisioning_delete_dev_comp
 Event parameter of ESP_BLE_MESH_PROVISIONER_DELETE_DEV_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_set_dev_uuid_match_comp_param
 provisioning_set_dev_uuid_match
 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
 provisioning_set_prov_data_info
 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
 provisioning_set_static_oob_val
 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
 provisioning_set_primary_elem_addr
 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
 provisioning_prov_read_oob_pub_key
 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
 provisioning_prov_input_num
 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
 provisioning_prov_input_str
 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
 provisioning_set_node_name
 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
 provisioning_add_app_key
 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
 provisioning_update_app_key
 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
 provisioning_bind_app_key_to_model
 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
 provisioning_add_net_key
 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
 provisioning_update_net_key
 Event parameter of ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_NET_KEY_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_store_node_comp_data_comp_param
 provisioning_store_node
 Event parameter of ESP_BLE_MESH_PROVISIONER_STORE_NODE_COMP_DATA_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_uuid_comp_param
 provisioning_delete_node
 Event parameter of ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_UUID_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_addr_comp_param
 provisioning_delete_node
 Event parameter of ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_ADDR_COMP_EVT

int err_code
 Indicate the result of enabling/disabling to receive heartbeat messages by the Provisioner
 Indicate the result of setting the heartbeat filter type by the Provisioner
 Indicate the result of setting the heartbeat filter address by the Provisioner
 Indicate the result of directly erasing settings by the Provisioner
 Indicate the result of opening settings with index by the Provisioner
 Indicate the result of opening settings with user id by the Provisioner
 Indicate the result of closing settings with index by the Provisioner
 Indicate the result of closing settings with user id by the Provisioner
 Indicate the result of deleting settings with index by the Provisioner
 Indicate the result of deleting settings with user id by the Provisioner
bool enable
   Indicate enabling or disabling receiving heartbeat messages

struct esp_ble_mesh_prov_cb_param_t::[anonymous] provisioner_enable_heartbeat_recv_comp
   ESP_BLE_MESH_PROVISIONER_ENABLE_HEARTBEAT_RECV_COMP_EVT.
   Event parameters of ESP_BLE_MESH_PROVISIONER_ENABLE_HEARTBEAT_RECV_COMP_EVT

uint8_t type
   Type of the filter used for receiving heartbeat messages

struct esp_ble_mesh_prov_cb_param_t::[anonymous] provisioner_set_heartbeat_filter_type_comp
   ESP_BLE_MESH_PROVISIONER_SET_HEARTBEAT_FILTER_TYPE_COMP_EVT.
   Event parameters of ESP_BLE_MESH_PROVISIONER_SET_HEARTBEAT_FILTER_TYPE_COMP_EVT

uint8_t op
   Operation (add, remove, clean)

uint16_t hb_src
   Heartbeat source address

uint16_t hb_dst
   Heartbeat destination address

struct esp_ble_mesh_prov_cb_param_t::[anonymous] provisioner_set_heartbeat_filter_info_comp
   ESP_BLE_MESH_PROVISIONER_SET_HEARTBEAT_FILTER_INFO_COMP_EVT.
   Event parameters of ESP_BLE_MESH_PROVISIONER_SET_HEARTBEAT_FILTER_INFO_COMP_EVT

uint8_t init_ttl
   Heartbeat InitTTL

uint8_t rx_ttl
   Heartbeat RxTTL

uint8_t hops
   Heartbeat hops (InitTTL - RxTTL + 1)

uint16_t feature
   Bit field of currently active features of the node

int8_t rssi
   RSSI of the heartbeat message

struct esp_ble_mesh_prov_cb_param_t::[anonymous] provisioner_recv_heartbeat
   ESP_BLE_MESH_PROVISIONER_RECV_HEARTBEAT_MESSAGE_EVT.
   Event parameters of ESP_BLE_MESH_PROVISIONER_RECV_HEARTBEAT_MESSAGE_EVT

struct esp_ble_mesh_prov_cb_param_t::[anonymous] provisioner_direct_erase_settings_comp
   ESP_BLE_MESH_PROVISIONER_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

char uid[ESP_BLE_MESH_SETTINGS_UID_SIZE + 1]
   Provisioner settings user id

struct esp_ble_mesh_prov_cb_param_t::[anonymous] provisioner_open_settings_with_uid_comp
   ESP_BLE_MESH_PROVISIONER_OPEN_SETTINGS_WITH_UID_COMP_EVT.
   Event parameters of ESP_BLE_MESH_PROVISIONER_OPEN_SETTINGS_WITH_UID_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::*[anonymous] provisioner_close_settings_with_index_comp
ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGS_WITH_INDEX_COMP_EVT.
Event parameter of ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGS_WITH_INDEX_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::*[anonymous] provisioner_close_settings_with_uid_comp
ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGS_WITH_UID_COMP_EVT.
Event parameters of ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGS_WITH_UID_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::*[anonymous] provisioner_delete_settings_with_index_comp
ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_INDEX_COMP_EVT.
Event parameter of ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_INDEX_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::*[anonymous] provisioner_delete_settings_with_uid_comp
ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_UID_COMP_EVT.
Event parameters of ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_UID_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_set_fast_prov_info_comp_param set_fast_prov_info_comp
Event parameter of ESP_BLE_MESH_SET_FAST_PROV_INFO_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_set_fast_prov_action_comp_param set_fast_prov_action_comp
Event parameter of ESP_BLE_MESH_SET_FAST_PROV_ACTION_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_heartbeat_msg_recv_param heartbeat_msg_recv
Event parameter of ESP_BLE_MESH_HEARTBEAT_MESSAGE_RECV_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_lpn_enable_comp_param lpn_enable_comp
Event parameter of ESP_BLE_MESH_LPN_ENABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_lpn_disable_comp_param lpn_disable_comp
Event parameter of ESP_BLE_MESH_LPN_DISABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_lpn_poll_param lpn_poll_comp
Event parameter of ESP_BLE_MESH_LPN_POLL_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_lpn_friendship_establish_param lpn_friendship_establish
Event parameter of ESP_BLE_MESH_LPN_FRIENDSHIP_ESTABLISH_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_lpn_friendship_terminate_param lpn_friendship_terminate
Event parameter of ESP_BLE_MESH_LPN_FRIENDSHIP_TERMINATE_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_friend_friendship_establish_param frnd_friendship_establish
Event parameter of ESP_BLE_MESH_FRIEND_FRIENDSHIP_ESTABLISH_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_friend_friendship_terminate_param frnd_friendship_terminate
Event parameter of ESP_BLE_MESH_FRIEND_FRIENDSHIP_TERMINATE_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_proxy_client_recv_adv_pkt_param proxy_client_recv_adv_pkt
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_RECV_ADV_PKT_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_proxy_client_connected_param proxy_client_connected
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_CONNECTED_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_proxy_client_disconnected_param proxy_client_disconnected
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_DISCONNECTED_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_proxy_client_recv_filter_status_param proxy_client_recv_filter_status
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_RECV_FILTER_STATUS_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_proxy_client_connect_comp_param proxy_client_connect_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_CONNECT_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_proxy_client_disconnect_comp_param proxy_client_disconnect_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_DISCONNECT_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::*ble_mesh_proxy_client_set_filter_type_comp_param proxy_client_set_filter_type
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_SET_FILTER_TYPE_COMP_EVT
**Chapter 2. API Reference**

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_add_filter_addr_comp_param proxy_client_add_filter_addr_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_ADD_FILTER_ADDR_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_remove_filter_addr_comp_param proxy_client_remove_filter_addr_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_REMOVE_FILTER_ADDR_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_model_sub_group_addr_comp_param model_sub_group_addr_comp
Event parameters of ESP_BLE_MESH_MODEL_SUBSCRIBE_GROUP_ADDR_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_model_unsub_group_addr_comp_param model_unsub_group_addr_comp
Event parameters of ESP_BLE_MESH_MODEL_UNSUBSCRIBE_GROUP_ADDR_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_deinit_mesh_comp_param deinit_mesh_comp
Event parameter of ESP_BLE_MESH_DEINIT_MESH_COMP_EVT
```

```c
struct ble_mesh_deinit_mesh_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_DEINIT_MESH_COMP_EVT.
```

**Public Members**

```c
int err_code
Indicate the result of BLE Mesh deinitialization
```

```c
struct ble_mesh_friend_friendship_establish_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_FRIEND_FRIENDSHIP_ESTABLISH_EVT.
```

**Public Members**

```c
uint16_t lpn_addr
Low Power Node unicast address
```

```c
struct ble_mesh_friend_friendship_terminate_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_FRIEND_FRIENDSHIP_TERMINATE_EVT.
```

**Public Types**

```c
enum [anonymous]
This enum value is the reason of friendship termination on the friend node side
```

**Values:**

```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
```

```c
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

esp_ble_mesh_prov_bearer_t bearer
Type of the bearer used when device link is closed

struct ble_mesh_link open EVT_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_LINK_OPEN_EVT.
Public Members

`esp_ble_mesh_prov_bearer_t bearer`
Type of the bearer used when device link is open

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

Public Members

int `err_code`
Indicate the result of disabling LPN functionality

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

Public Members

int `err_code`
Indicate the result of enabling LPN functionality

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

Public Members

uint16_t `friend_addr`
Friend Node unicast address

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

Public Members

uint16_t `friend_addr`
Friend Node unicast address

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

Public Members

int `err_code`
Indicate the result of sending Friend Poll

`struct ble_mesh_model_sub_group_addr_comp_param`
#include `<esp_ble_mesh_defs.h>` ESP_BLE_MESH_MODEL_SUBSCRIBE_GROUP_ADDR_COMP_EVT.

Public Members

int `err_code`
Indicate the result of local model subscribing group address

uint16_t `element_addr`
Element address
uint16_t company_id
  Company ID

uint16_t model_id
  Model ID

uint16_t group_addr
  Group Address

struct ble_mesh_model_unsub_group_addr_comp_param
  #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_MODEL_UNSUBSCRIBE_GROUP_ADDR_COMP_EVT.

Public Members

int err_code
  Indicate the result of local model unsubscribing group address

uint16_t element_addr
  Element address

uint16_t company_id
  Company ID

uint16_t model_id
  Model ID

uint16_t group_addr
  Group Address

struct ble_mesh_node_add_local_app_key_comp_param
  #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_ADD_LOCAL_APP_KEY_COMP_EVT.

Public Members

int err_code
  Indicate the result of adding local AppKey by the node

uint16_t net_idx
  NetKey Index

uint16_t app_idx
  AppKey Index

struct ble_mesh_node_add_local_net_key_comp_param
  #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_ADD_LOCAL_NET_KEY_COMP_EVT.

Public Members

int err_code
  Indicate the result of adding local NetKey by the node

uint16_t net_idx
  NetKey Index

struct ble_mesh_node_bind_local_mod_app_comp_param
  #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_BIND_APP_KEY_TO_MODEL_COMP_EVT.
Public Members

int **err_code**
Indicate the result of binding AppKey with model by the node

uint16_t **element_addr**
Element address

uint16_t **app_idx**
AppKey Index

uint16_t **company_id**
Company ID

uint16_t **model_id**
Model ID

**struct ble_mesh_output_num_evt_param**
```c
#include <esp_ble_mesh_defs.h>
ESP_BLE_MESH_NODE_PROV_OUTPUT_NUMBER_EVT.
```

Public Members

```c
esp_ble_mesh_output_action_t **action**
Action of Output OOB Authentication
```

```c
uint32_t **number**
Number of Output OOB Authentication
```

**struct ble_mesh_output_str_evt_param**
```c
#include <esp_ble_mesh_defs.h>
ESP_BLE_MESH_NODE_PROV_OUTPUT_STRING_EVT.
```

Public Members

```c
char **string**[8]
String of Output OOB Authentication
```

**struct ble_mesh_prov_disable_comp_param**
```c
#include <esp_ble_mesh_defs.h>
ESP_BLE_MESH_NODE_PROV_DISABLE_COMP_EVT.
```

Public Members

```c
int **err_code**
Indicate the result of disabling BLE Mesh device
```

**struct ble_mesh_prov_enable_comp_param**
```c
#include <esp_ble_mesh_defs.h>
ESP_BLE_MESH_NODE_PROV_ENABLE_COMP_EVT.
```

Public Members

```c
int **err_code**
Indicate the result of enabling BLE Mesh device
```

**struct ble_mesh_prov_register_comp_param**
```c
#include <esp_ble_mesh_defs.h>
ESP_BLE_MESH_PROV_REGISTER_COMP_EVT.
```
Chapter 2. API Reference

Public Members

```c
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
uint8_t net_key[16]
   NetKey
uint16_t addr
   Primary address
uint8_t flags
   Flags
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
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.
```
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.
```
Public Members

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

Public Members

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

int err_code
Indicate the result of enabling BLE Mesh Provisioner

struct ble_mesh_provisioner_prov_input_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_INPUT_EVT.

Public Members

esp_ble_mesh_oob_method_t method
Method of device Output OOB Authentication

esp_ble_mesh_output_action_t action
Action of device Output OOB Authentication

uint8_t size
Size of device Output OOB Authentication

uint8_t link_idx
Index of the provisioning link

struct ble_mesh_provisioner_prov_input_num_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_INPUT_NUMBER_COMP_EVT.

Public Members

int err_code
Indicate the result of inputting number by the Provisioner

struct ble_mesh_provisioner_prov_input_str_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_INPUT_STRING_COMP_EVT.

Public Members

int err_code
Indicate the result of inputting string by the Provisioner

struct ble_mesh_provisioner_prov_output_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_OUTPUT_EVT.

Public Members

esp_ble_mesh_oob_method_t method
Method of device Input OOB Authentication

esp_ble_mesh_input_action_t action
Action of device Input OOB Authentication

uint8_t size
Size of device Input OOB Authentication

uint8_t link_idx
Index of the provisioning link

char string[8]
String output by the Provisioner

uint32_t number
Number output by the Provisioner
union esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_output_evt_param::[anonymous] [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

struct ble_mesh_provisioner_set_primary_elem_addr_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_SET_PRIMARY_ELEM_ADDR_COMP_EVT.

Public Members

int err_code
Indicate the result of setting unicast address of primary element by the Provisioner

struct ble_mesh_provisioner_set_prov_data_info_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_SET_PROV_DATA_INFO_COMP_EVT.

Public Members

int err_code
Indicate the result of setting provisioning info by the Provisioner

struct ble_mesh_provisioner_set_static_oob_val_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_SET_STATIC_OOB_VALUE_COMP_EVT.

Public Members

int err_code
Indicate the result of setting static oob value by the Provisioner

struct ble_mesh_provisioner_store_node_comp_data_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_STORE_NODE_COMP_DATA_COMP_EVT.

Public Members

int err_code
Indicate the result of storing node composition data by the Provisioner

uint16_t addr
Node element address

struct ble_mesh_provisioner_update_local_app_key_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_APP_KEY_COMP_EVT.

Public Members

int err_code
Indicate the result of updating local AppKey by the Provisioner

uint16_t net_idx
NetKey Index

uint16_t app_idx
AppKey Index
struct ble_mesh_provisioner_update_local_net_key_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_NET_KEY_COMP_EVT.

Public Members

int err_code
Indicate the result of updating local NetKey by the Provisioner

uint16_t net_idx
NetKey Index

struct ble_mesh_proxy_client_add_filter_addr_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_CLIENT_ADD_FILTER_ADDR_COMP_EVT.

Public Members

int err_code
Indicate the result of Proxy Client add filter address

uint8_t conn_handle
Proxy connection handle

uint16_t net_idx
Corresponding NetKey Index

struct ble_mesh_proxy_client_connect_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_CLIENT_CONNECT_COMP_EVT.

Public Members

int err_code
Indicate the result of Proxy Client connect

esp_ble_mesh_bd_addr_t addr
Device address of the Proxy Server

esp_ble_mesh_addr_type_t addr_type
Device address type

uint16_t net_idx
Corresponding NetKey Index

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.
Chapter 2. API Reference

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

uint16_t **net_idx**
Corresponding NetKey Index

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
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
struct ble_mesh_set_fast_prov_action_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_SET_FAST_PROV_ACTION_COMP_EVT.

Public Members

uint8_t status_action
Indicate the result of setting action of fast provisioning

struct ble_mesh_set_fast_prov_info_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_SET_FAST_PROV_INFO_COMP_EVT.

Public Members

uint8_t status_unicast
Indicate the result of setting unicast address range of fast provisioning

uint8_t status_net_idx
Indicate the result of setting NetKey Index of fast provisioning

uint8_t status_match
Indicate the result of setting matching Device UUID of fast provisioning

struct ble_mesh_set_oob_pub_key_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_SET_OOB_PUB_KEY_COMP_EVT.

Public Members

int err_code
Indicate the result of setting OOB Public Key

struct ble_mesh_set_unprov_dev_name_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_SET_UNPROV_DEV_NAME_COMP_EVT.

Public Members

int err_code
Indicate the result of setting BLE Mesh device name

union esp_ble_mesh_server_state_value_t
#include <esp_ble_mesh_defs.h> Server model state value union.

Public Members

uint8_t onoff
The value of the Generic OnOff state

The value of the Light LC Light OnOff state

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

int16_t level
The value of the Generic Level state

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

uint8_t onpowerup
The value of the Generic OnPowerUp state
struct 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
```

```c
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
```

```c
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
```

```c
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
```

```c
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
```

```c
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
```

```c
esp_ble_mesh_model_t *model
    Pointer to the model which sends the previous message
```

```c
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
```

```c
esp_ble_mesh_model_t *model
    Pointer to the model which receives the message
```

```c
esp_ble_mesh_msg_ctx_t *ctx
    Pointer to the context of the message
```

```c
uint16_t length
    Length of the received message
```

```c
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.
```
Public Members

```c
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

```c
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

```c
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

```c
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
   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 FastPeriodDivider

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

const uint16_t model_id
16-bit model identifier

uint16_t company_id
16-bit company identifier

uint16_t model_id
16-bit model identifier

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

union esp_ble_mesh_model::[anonymous] [anonymous]
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
**esp_ble_mesh_prov_bearer_t**

Provisioning Bearer

**struct esp_ble_mesh_device_delete_t**

Information of the device which is going to be deleted.

**Public Members**

- **esp_ble_mesh_bd_addr_t** **addr**
  - Device address
- **esp_ble_mesh_addr_type_t** **addr_type**
  - Device address type
- **uint8_t** **uuid[16]**
  - Device UUID
- **uint8_t** **flag**
  - BIT0: device address; BIT1: device UUID

**struct esp_ble_mesh_prov_data_info_t**

Information of the provisioner which is going to be updated.

**Public Members**

- **uint16_t** **net_idx**
  - NetKey Index
- **uint8_t** **flags**
  - Flags
- **uint32_t** **iv_index**
  - IV Index
- **uint8_t** **flag**
  - BIT0: net_idx; BIT1: flags; BIT2: iv_index

**struct esp_ble_mesh_node_t**

Information of the provisioned node

**Public Members**

- **esp_ble_mesh_bd_addr_t** **addr**
  - Node device address
- **esp_ble_mesh_addr_type_t** **addr_type**
  - Node device address type
- **uint8_t** **dev_uuid[16]**
  - Device UUID
- **uint16_t** **oob_info**
  - Node OOB information
- **uint16_t** **unicast_addr**
  - Node unicast address
- **uint8_t** **element_num**
  - Node element number
- **uint16_t** **net_idx**
  - Node NetKey Index
uint8_t flags
   Node key refresh flag and iv update flag

uint32_t iv_index
   Node IV Index

uint8_t dev_key[16]
   Node device key

char name[ESP_BLE_MESH_NODE_NAME_MAX_LEN + 1]
   Node name

uint16_t comp_length
   Length of Composition Data

uint8_t* comp_data
   Value of Composition Data

struct esp_ble_mesh_fast_prov_info_t
   Context of fast provisioning which need to be set.

Public Members

uint16_t unicast_min
   Minimum unicast address used for fast provisioning

uint16_t unicast_max
   Maximum unicast address used for fast provisioning

uint16_t net_idx
   Netkey index used for fast provisioning

uint8_t flags
   Flags used for fast provisioning

uint32_t iv_index
   IV Index used for fast provisioning

uint8_t offset
   Offset of the UUID to be compared

uint8_t match_len
   Length of the UUID to be compared

uint8_t match_val[16]
   Value of UUID to be compared

struct esp_ble_mesh_heartbeat_filter_info_t
   Context of Provisioner heartbeat filter information to be set

Public Members

uint16_t hb_src
   Heartbeat source address (unicast address)

uint16_t hb_dst
   Heartbeat destination address (unicast address or group address)

struct esp_ble_mesh_client_op_pair_t
   BLE Mesh client models related definitions.
   Client model Get/Set message opcode and corresponding Status message opcode
Public Members

```c
uint32_t cli_op
```
The client message opcode

```c
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

```c
esp_ble_mesh_model_t *model
```
Pointer to the client model. Initialized by the stack.

```c
int op_pair_size
```
Size of the op_pair

```c
const esp_ble_mesh_client_op_pair_t *op_pair
```
Table containing get/set message opcode and corresponding status message opcode

```c
uint32_t publish_status
```
Callback used to handle the received unsolicited message. Initialized by the stack.

```c
void *internal_data
```
Pointer to the internal data of client model

```c
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

```c
esp_ble_mesh_opcode_t opcode
```
Message opcode

```c
esp_ble_mesh_model_t *model
```
Pointer to the client model structure

```c
esp_ble_mesh_msg_ctx_t ctx
```
The context used to send message

```c
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

```c
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.

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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

**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

**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 Set messages

```c
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_NET_PRIMARY**
  - Relay state value
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 delay).

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.
ESP_BLE_MESH_GET_TRANSMIT_INTERVAL (transmit)
Decode 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
ESP_BLE_MESH_ADDR_TYPE_PUBLIC
ESP_BLE_MESH_ADDR_TYPE_RANDOM
ESP_BLE_MESH_ADDR_TYPE_RPA_PUBLIC
ESP_BLE_MESH_ADDR_TYPE_RPA_RANDOM

ESP_BLE_MESH_MODEL_PUB_DEFINE (_name, _msg_len, _role)
Define a model publication context.

Parameters
- _name: Variable name given to the context.
- _msg_len: Length of the publication message.
- _role: Role of the device which contains the model.

ESP_BLE_MESH_MODEL_OP (_opcode, _min_len)
Define a model operation context.

Parameters
- _opcode: Message opcode.
- _min_len: Message minimum length.

ESP_BLE_MESH_MODEL_OP_END
Define the terminator for the model operation table. Each model operation struct array must use this terminator as the end tag of the operation unit.

ESP_BLE_MESH_MODEL_NONE
Helper to define an empty model array. This structure is associated with BLE_MESH_MODEL_NONE in mesh_access.h

ADD_DEV_RM_AFTER_PROV_FLAG
Device will be removed from queue after provisioned successfully

ADD_DEV_START_PROV_NOW_FLAG
Start provisioning device immediately

ADD_DEV_FLUSHABLE_DEV_FLAG
Device can be remove when queue is full and new device is going to added

DEL_DEV_ADDR_FLAG
DEL_DEV_UUID_FLAG
PROV_DATA_NET_IDX_FLAG
PROV_DATA_FLAGS_FLAG
PROV_DATA_IV_INDEX_FLAG
ESP_BLE_MESH_HEARTBEAT_FILTER_ACCEPTLIST
ESP_BLE_MESH_HEARTBEAT_FILTER_REJECTLIST
Provisioner heartbeat filter operation

ESP_BLE_MESH_HEARTBEAT_FILTER_ADD
ESP_BLE_MESH_HEARTBEAT_FILTER_REMOVE

ESP_BLE_MESH_MODEL_ID_CONFIG_SRV
BLE Mesh models related Model ID and Opcode definitions.

< Foundation Models

ESP_BLE_MESH_MODEL_ID_CONFIG_CLI
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_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_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
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_PUB_SET
Config Model Publication Set

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_ADD
Config Model Subscription Add

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_ADD
Config Model Subscription Virtual Address Add

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_DELETE
Config Model Subscription Delete

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_DELETE
Config Model Subscription Virtual Address Delete

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_OVERWRITE
Config Model Subscription Overwrite

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_OVERWRITE
Config Model Subscription Virtual Address Overwrite

ESP_BLE_MESH_MODEL_OP_NET_KEY_ADD
Config NetKey Add

ESP_BLE_MESH_MODEL_OP_APP_KEY_ADD
Config AppKey Add

ESP_BLE_MESH_MODEL_OP_MODEL_APP_BIND
Config Model App Bind

ESP_BLE_MESH_MODEL_OP_NODE_RESET
Config Node Reset

ESP_BLE_MESH_MODEL_OP_FRIEND_SET
Config Friend Set

ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_SET
Config Heartbeat Publication Set

ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_SET
Config Heartbeat Subscription Set

ESP_BLE_MESH_MODEL_OP_NET_KEY_UPDATE
Config NetKey Update

ESP_BLE_MESH_MODEL_OP_NET_KEY_DELETE
Config NetKey Delete
ESP_BLE_MESH_MODEL_OP_APP_KEY_UPDATE
  Config AppKey Update

ESP_BLE_MESH_MODEL_OP_APP_KEY_DELETE
  Config AppKey Delete

ESP_BLE_MESH_MODEL_OP_NODE_IDENTITY_SET
  Config Node Identity Set

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
**Chapter 2. API Reference**

- 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

**Health Fault Get**
- ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_GET

**Health Period Get**
- ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_GET

**Health Attention Get**
- ESP_BLE_MESH_MODEL_OP_ATTENTION_GET

**Health Fault Clear**
- ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR

**Health Fault Clear Unacknowledged**
- ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR_UNACK

**Health Fault Test**
- ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST

**Health Fault Test Unacknowledged**
- ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST_UNACK

**Health Period Set**
- ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET

**Health Period Set Unacknowledged**
- ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET_UNACK

**Health Attention Set**
- ESP_BLE_MESH_MODEL_OP_ATTENTION_SET

**Health Attention Set Unacknowledged**
- ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_UNACK

**Health Current Status**
- ESP_BLE_MESH_MODEL_OP_HEALTH_CURRENT_STATUS

**Health Fault Status**
- ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_STATUS

**Health Period Status**
- ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_STATUS

**Health Attention Status**
- ESP_BLE_MESH_MODEL_OP_ATTENTION_STATUS

**Health On/Off Get**
- 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_ADMIN_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_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_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET_UNACK

Light CTL Setup Message Opcode
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
  Light HSL Setup Message Opcode
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_SET_UNACK
  Light xyL Message Opcode
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_TARGET_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_TARGET_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_GET
  Light xyL Setup Message Opcode
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_SET_UNACK
Light Control Message Opcode
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_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_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_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_STATUS
ESP_BLE_MESH_MODEL_STATUS_SUCCESS
ESP_BLE_MESH_MODEL_STATUS_CANNOT_SET_RANGE_MIN
ESP_BLE_MESH_MODEL_STATUS_CANNOT_SET_RANGE_MAX
ESP_BLE_MESH_SERVER_RSP_BY_APP
Response need to be sent in the application
ESP_BLE_MESH_SERVER_AUTO_RSP
Response will be sent internally

Type Definitions
typedef uint8_t esp_ble_mesh_octet16_t[ESP_BLE_MESH_OCTET16_LEN]
  Define the BLE Mesh octet 8 bytes size
typedef uint8_t esp_ble_mesh_octet8_t[ESP_BLE_MESH_OCTET8_LEN]
  Invalid Company ID
typedef uint32_t esp_ble_mesh_cb_t
typedef uint8_t UINT8
typedef uint16_t UINT16
typedef uint32_t UINT32
typedef uint64_t UINT64
typedef UINT8 BT_OCTET32[BT_OCTET32_LEN]
typedef uint8_t BD_ADDR[BD_ADDR_LEN]
typedef uint8_t esp_ble_mesh_bd_addr_t[BD_ADDR_LEN]
typedef uint8_t esp_ble_mesh_addr_type_t
  BLE device address type.
typedef struct esp_ble_mesh_model esp_ble_mesh_model_t

typedef uint8_t esp_ble_mesh_dev_add_flag_t

typedef uint32_t esp_ble_mesh_opcode_config_client_get_t
esp_ble_mesh_opcode_config_client_get_t belongs to esp_ble_mesh_opcode_t, this typedef is only used to locate the opcodes used by esp_ble_mesh_config_client_get_state. The following opcodes will only be used in the esp_ble_mesh_config_client_get_state function.

typedef uint32_t esp_ble_mesh_opcode_config_client_set_t
esp_ble_mesh_opcode_config_client_set_t belongs to esp_ble_mesh_opcode_t, this typedef is only used to locate the opcodes used by esp_ble_mesh_config_client_set_state. The following opcodes will only be used in the esp_ble_mesh_config_client_set_state function.

typedef uint32_t esp_ble_mesh_opcode_config_status_t
esp_ble_mesh_opcode_config_status_t belongs to esp_ble_mesh_opcode_t, this typedef is only used to locate the opcodes used by the Config Model messages. The following opcodes are used by the BLE Mesh Config Server Model internally to respond to the Config Client Model’s request messages.

typedef uint8_t esp_ble_mesh_cfg_status_t
This typedef is only used to indicate the status code contained in some of the Configuration Server Model status 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
esp_ble_mesh_health_model_status_t belongs to esp_ble_mesh_opcode_t, this typedef is only used to locate the opcodes used by the Health Model messages. The following opcodes are used by the BLE Mesh Health Server Model internally to respond to the Health Client Model’s request messages.

typedef uint32_t esp_ble_mesh_generic_message_opcode_t
esp_ble_mesh_generic_message_opcode_t belongs to esp_ble_mesh_opcode_t, this typedef is only used to locate the opcodes used by functions esp_ble_mesh_generic_client_get_state & esp_ble_mesh_generic_client_set_state. Generic OnOff Message Opcode

typedef uint32_t esp_ble_mesh_sensor_message_opcode_t
esp_ble_mesh_sensor_message_opcode_t belongs to esp_ble_mesh_opcode_t, this typedef is only used to locate the opcodes used by functions esp_ble_mesh_sensor_client_get_state & esp_ble_mesh_sensor_client_set_state. Sensor Message Opcode

typedef uint32_t esp_ble_mesh_time_scene_message_opcode_t
esp_ble_mesh_time_scene_message_opcode_t belongs to esp_ble_mesh_opcode_t, this typedef is only used to locate the opcodes used by functions esp_ble_mesh_time_scene_client_get_state & esp_ble_mesh_time_scene_client_set_state. Time Message Opcode

typedef uint32_t esp_ble_mesh_light_message_opcode_t
esp_ble_mesh_light_message_opcode_t belongs to esp_ble_mesh_opcode_t, this typedef is only used to locate the opcodes used by functions esp_ble_mesh_light_client_get_state & esp_ble_mesh_light_client_set_state. Light Lightness Message Opcode

typedef uint32_t esp_ble_mesh_opcode_t
End of defines of esp_ble_mesh_opcode_t

typedef uint8_t esp_ble_mesh_model_status_t
This typedef is only used to indicate the status code contained in some of the server models (e.g. Generic Server Model) status message.
Enumerations

enum esp_ble_mesh_cb_type_t
Values:
- 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
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_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_PROVCOMPLETE_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
**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_CLOSE_SETTINGS_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
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

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
Chapter 2. API Reference

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


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**
- **[in]** model: Model instance pointer.

```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
dsp_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
dsp_ble_mesh_model_t *esp_ble_mesh_find_vendor_model (const esp_ble_mesh_elem_t *element, uint16_t company_id, uint16_t model_id)
```

Find the Vendor specific model with the given element, the company ID and the Vendor Model ID.

**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
dsp_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.
- **[in]** model_id: SIG model identifier.
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.

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]** company_id: A 16-bit company identifier.
- **[in]** model_id: A 16-bit model identifier.
- **[in]** group_addr: The group address to be subscribed.

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]** company_id: A 16-bit company identifier.
- **[in]** model_id: A 16-bit model identifier.
- **[in]** group_addr: The subscribed group address.

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.

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.

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.

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**

```c
esp_err_t esp_ble_mesh_lpn_enable(void)
```

Enable BLE Mesh device LPN functionality.

**Note** This API enables LPN functionality. Once called, the proper Friend Request will be sent.

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

```c
esp_err_t esp_ble_mesh_lpn_disable(bool force)
```

Disable BLE Mesh device LPN functionality.

**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.

```c
esp_err_t esp_ble_mesh_lpn_poll(void)
```

LPN tries to poll messages from the Friend Node.

**Note** The Friend Poll message is sent by a Low Power node to ask the Friend node to send a message that it has stored for the Low Power node. Users can call this API to send Friend Poll message manually. If this API is not invoked, the bottom layer of the Low Power node will send Friend Poll before the PollTimeout timer expires. If the corresponding Friend Update is received and MD is set to 0, which means there are no messages for the Low Power node, then the Low Power node will stop scanning.

**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**
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.

Add the message opcode to the beginning of the model message before sending or publishing the model message.

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

**Parameters**

- `[in] data`: Pointer to the message data.

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` variables within the `user_data` (defined using `esp_ble_mesh_client_t_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.

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**


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] 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 (exclude 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 (exclude 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.

```c
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.

```c
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’).

```c
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

```c
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

```c
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

```c
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’).

```c
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.

```c
const esp_ble_mesh_node_t** esp_ble_mesh_provisioner_get_node_table_entry(void)
```

This function is called by Provisioner to get the entry of the node table.

**Note**: After invoking the function to get the entry of nodes, users can use the “for” loop combined with the macro CONFIG_BLE_MESH_MAX_PROV_NODES to get each node’s information. Before trying to read the node’s information, users need to check if the node exists, i.e. if the `*(esp_ble_mesh_node_t**)node)` is NULL. For example:

```c
const esp_ble_mesh_node_t **entry = esp_ble_mesh_provisioner_get_node_table_entry(); for (int i = 0; i < Espressif Systems 367 Release v5.0-dev-1077-g397639d Submit Document Feedback`
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.

```c
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

```c
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

```c
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.

```c
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

```c
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.

```c
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
Chapter 2. API Reference

• [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.
• [in] net_idx: The network key index.

`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.
• [in] net_idx: The NetKey Index.

`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.
Chapter 2. API Reference

- 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 Ab) Start to provision and control nodes c) Close settings Ad) 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) Start to provision and control nodes c) Close settings A) 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.

 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.

 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.

 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.

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.

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.

 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)

: event, event code of user-defined model events; param, parameters of user-defined model events

ESP-BLE-MESH Node/Provisioner Provisioning
### Header File
- components/bt/esp_ble_mesh/api/core/include/esp_ble_mesh_provisioning_api.h

### Functions

**esp_err_t esp_ble_mesh_register_prov_callback(esp_ble_mesh_prov_cb_t callback)**

Register BLE Mesh provisioning callback.

**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**
- bearers: Bit-wise OR of provisioning bearers.

**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**
- bearers: Bit-wise OR of provisioning bearers.

**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.
Chapter 2. API Reference

```c
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

```c
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

```c
esp_err_t esp_ble_mesh_provisioner_input_string(const char *string, uint8_t link_idx)
```

Provide provisioning input OOB string.

This is intended to be called after the `esp_ble_mesh_prov_t prov_input_num` callback has been called with `ESP_BLE_MESH_ENTER_STRING` as the action.

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

**Parameters**
- `[in]` string: String input by Provisioner.
- `[in]` link_idx: The provisioning link index.

```c
esp_err_t esp_ble_mesh_provisioner_input_number(uint32_t number, uint8_t link_idx)
```

Provide provisioning input OOB number.

This is intended to be called after the `esp_ble_mesh_prov_t prov_input_num` callback has been called with `ESP_BLE_MESH_ENTER_NUMBER` as the action.

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

**Parameters**
- `[in]` number: Number input by Provisioner.
- `[in]` link_idx: The provisioning link index.

```c
esp_err_t esp_ble_mesh_provisioner_prov_enable(esp_ble_mesh_prov_bearer_t bearers)
```

Enable one or more provisioning bearers.

**Note** PB-ADV: Enable BLE scan. PB-GATT: Initialize corresponding BLE Mesh Proxy info.

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

**Parameters**

```c
esp_err_t esp_ble_mesh_provisioner_prov_disable(esp_ble_mesh_prov_bearer_t bearers)
```

Disable one or more provisioning bearers.

**Note** PB-ADV: Disable BLE scan. PB-GATT: Break any existing BLE Mesh Provisioning connections.

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

**Parameters**

```c
esp_err_t esp_ble_mesh_provisioner_add_unprov_dev(esp_ble_mesh_unprov_dev_add_t *add_dev, esp_ble_mesh_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.

1. If device UUID and/or device address as well as address type already exist in the device queue, but the bearer is different from the existing one, add operation will also be successful and it will update the provision bearer supported by the device.

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)

```c
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.

1. 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: 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

```
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.

```
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.

```
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.

```
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 prov_unicast_addr value in the struct esp_ble_mesh_prov_t will be ignored, and Provisioner will use this address as its own
primary element address. And if the unicast address going to assigned for the next unprovisioned de-
vice 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
typedef void (*esp_ble_mesh_prov_cb_t) (esp_ble_mesh_prov_cb_event_t event,
                                           esp_ble_mesh_prov_cb_param_t *param)
: event, event code of provisioning events; param, parameters of provisioning events

typedef void (*esp_ble_mesh_prov_adv_cb_t) (const esp_ble_mesh_bd_addr_t addr,
                                           const esp_ble_mesh_addr_type_t addr_type,
                                           const uint8_t adv_type,
                                           const uint8_t *dev_uuid, uint16_t oob_info,
                                           esp_ble_mesh_prov_bearer_t bearer)
Callback for Provisioner that received advertising packets from unprovisioned devices which are not in the
unprovisioned device queue.

Report on the unprovisioned device beacon and mesh provisioning service adv data to application.

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] 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
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.

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.

*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.

*esp_err_t* `esp_ble_mesh_proxy_client_connect (esp_ble_mesh_bd_addr_t addr, esp_ble_mesh_addr_type_t addr_type, uint16_t net_idx)`  
Proxy Client creates a connection with the Proxy Server.

**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 related with Network ID in the Mesh Proxy advertising packet.

*esp_err_t* `esp_ble_mesh_proxy_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.

*esp_err_t* `esp_ble_mesh_proxy_client_set_filter_type (uint8_t conn_handle, uint16_t net_idx, esp_ble_mesh_proxy_filter_type_t filter_type)`  
Proxy Client sets the filter type of the Proxy Server.

**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.

*esp_err_t* `esp_ble_mesh_proxy_client_add_filter_addr (uint8_t conn_handle, uint16_t net_idx, uint16_t *addr, uint16_t addr_num)`  
Proxy Client adds address to the Proxy Server filter list.

**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_err_t* `esp_ble_mesh_proxy_client_remove_filter_addr (uint8_t conn_handle, uint16_t net_idx, uint16_t *addr, uint16_t addr_num)`  
Proxy Client removes address from the Proxy Server filter list.

**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] 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_t 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_GET ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_GET
ESP_BLE_MESH_MODEL_OP_GATT_PROXY_GET ESP_BLE_MESH_MODEL_OP_RELAY_GET
ESP_BLE_MESH_MODEL_OP_MODEL_PUB_GET ESP_BLE_MESH_MODEL_OP_FRIEND_GET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_GET ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_GET
the get_state parameter in the esp_ble_mesh_config_client_get_state function should not be set to NULL.

Public Members

esp_ble_mesh_cfg_model_pub_get_t model_pub_get
For ESP_BLE_MESH_MODEL_OP_MODEL_PUB_GET.

esp_ble_mesh_cfg_composition_data_get_t comp_data_get
For ESP_BLE_MESH_MODEL_OP_COMPOSITION_DATA_GET.

esp_ble_mesh_cfg_sig_model_sub_get_t sig_model_sub_get
For ESP_BLE_MESH_MODEL_OP_SIG_MODEL_SUB_GET

esp_ble_mesh_cfg_vnd_model_sub_get_t vnd_model_sub_get
For ESP_BLE_MESH_MODEL_OP_VENDOR_MODEL_SUB_GET

esp_ble_mesh_cfg_app_key_get_t app_key_get
For ESP_BLE_MESH_MODEL_OP_APP_KEY_GET.

esp_ble_mesh_cfg_node_identity_get_t node_identity_get
For ESP_BLE_MESH_MODEL_OP_NODE_IDENTITY_GET.

esp_ble_mesh_cfg_sig_model_app_get_t sig_model_app_get
For ESP_BLE_MESH_MODEL_OP_SIG_MODEL_APP_GET

esp_ble_mesh_cfg_vnd_model_app_get_t vnd_model_app_get
For ESP_BLE_MESH_MODEL_OP_VENDOR_MODEL_APP_GET

esp_ble_mesh_cfg_kr_phase_get_t kr_phase_get
For ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_GET

esp_ble_mesh_cfg_lpn_polltimeout_get_t lpn_pollto_get
For ESP_BLE_MESH_MODEL_OP_LPN_POLLTIMEOUT_GET

union esp_ble_mesh_cfg_client_set_state_t

#include <esp_ble_mesh_config_model_api.h>
For ESP_BLE_MESH_MODEL_OP_BEACON_SET
ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_SET ESP_BLE_MESH_MODEL_OP_GATT_PROXY_SET
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_MODEL_SUB_DELETE ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR
ESP_BLE_MESH_MODEL_OP_MODEL_SUB_OVERWRITE
ESP_BLE_MESH_MODEL_OP_NET_KEY_ADD ESP_BLE_MESH_MODEL_OP_APP_KEY_ADD
ESP_BLE_MESH_MODEL_OP_APP_BIND ESP_BLE_MESH_MODEL_OP_NODE_RESET
ESP_BLE_MESH_MODEL_OP_FRIEND_SET ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_SET
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 default_ttl_set
For ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_SET

esp_ble_mesh_cfg_friend_set friend_set
For ESP_BLE_MESH_MODEL_OP_FRIEND_SET

esp_ble_mesh_cfg_gatt_proxy_set gatt_proxy_set
For ESP_BLE_MESH_MODEL_OP_GATT_PROXY_SET

esp_ble_mesh_cfg_relay_set relay_set
For ESP_BLE_MESH_MODEL_OP_RELAY_SET

esp_ble_mesh_cfg_net_key_add net_key_add
For ESP_BLE_MESH_MODEL_OP_NET_KEY_ADD

esp_ble_mesh_cfg_app_key_add app_key_add
For ESP_BLE_MESH_MODEL_OP_APP_KEY_ADD

esp_ble_mesh_cfg_model_app_bind model_app_bind
For ESP_BLE_MESH_MODEL_OP_MODEL_APP_BIND

esp_ble_mesh_cfg_model_pub_set model_pub_set
For ESP_BLE_MESH_MODEL_OP_MODEL_PUB_SET

esp_ble_mesh_cfg_model_sub_add model_sub_add
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_ADD

esp_ble_mesh_cfg_model_sub_delete model_sub_delete
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_DELETE

esp_ble_mesh_cfg_model_sub_overwrite model_sub_overwrite
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_OVERWRITE

esp_ble_mesh_cfg_model_sub_va_add model_sub_va_add
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_ADD

esp_ble_mesh_cfg_model_sub_va_delete model_sub_va_delete
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_DELETE

esp_ble_mesh_cfg_model_sub_va_overwrite model_sub_va_overwrite
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_OVERWRITE

esp_ble_mesh_cfg_heartbeat_pub_set heartbeat_pub_set
For ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_SET

esp_ble_mesh_cfg_heartbeat_sub_set heartbeat_sub_set
For ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_SET

esp_ble_mesh_cfg_model_pub_va_set model_pub_va_set
For ESP_BLE_MESH_MODEL_OP_MODEL_PUB_VIRTUAL_ADDR_SET

esp_ble_mesh_cfg_model_sub_delete_all model_sub_delete_all
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_DELETE_ALL

esp_ble_mesh_cfg_net_key_update net_key_update
For ESP_BLE_MESH_MODEL_OP_NET_KEY_UPDATE

esp_ble_mesh_cfg_net_key_delete net_key_delete
For ESP_BLE_MESH_MODEL_OP_NET_KEY_DELETE

esp_ble_mesh_cfg_app_key_update app_key_update
For ESP_BLE_MESH_MODEL_OP_APP_KEY_UPDATE

esp_ble_mesh_cfg_app_key_delete app_key_delete
For ESP_BLE_MESH_MODEL_OP_APP_KEY_DELETE

esp_ble_mesh_cfg_node_identity_set node_identity_set
For ESP_BLE_MESH_MODEL_OP_NODE_IDENTITY_SET
esp_ble_mesh_cfg_model_app_unbind_t \textbf{model_app_unbind} \\
For ESP_BLE_MESH_MODEL_OP_MODEL_APP_UNBIND

esp_ble_mesh_cfg_kr_phase_set_t \textbf{kr_phase_set} \\
For ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_SET

esp_ble_mesh_cfg_net_transmit_set_t \textbf{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.

\textbf{Public Members}

esp_ble_mesh_cfg_beacon_status_cb_t \textbf{beacon_status} \\
The beacon status value

esp_ble_mesh_cfg_comp_data_status_cb_t \textbf{comp_data_status} \\
The composition data status value

esp_ble_mesh_cfg_default_ttl_status_cb_t \textbf{default_ttl_status} \\
The default_ttl status value

esp_ble_mesh_cfg_gatt_proxy_status_cb_t \textbf{gatt_proxy_status} \\
The gatt_proxy status value

esp_ble_mesh_cfg_relay_status_cb_t \textbf{relay_status} \\
The relay status value

esp_ble_mesh_cfg_model_pub_status_cb_t \textbf{model_pub_status} \\
The model publication status value

esp_ble_mesh_cfg_model_sub_status_cb_t \textbf{model_sub_status} \\
The model subscription status value

esp_ble_mesh_cfg_net_key_status_cb_t \textbf{netkey_status} \\
The netkey status value

esp_ble_mesh_cfg_app_key_status_cb_t \textbf{appkey_status} \\
The appkey status value

esp_ble_mesh_cfg_mod_app_status_cb_t \textbf{model_app_status} \\
The model app status value

esp_ble_mesh_cfg_friend_status_cb_t \textbf{friend_status} \\
The friend status value

esp_ble_mesh_cfg_hb_pub_status_cb_t \textbf{heartbeat_pub_status} \\
The heartbeat publication status value

esp_ble_mesh_cfg_hb_sub_status_cb_t \textbf{heartbeat_sub_status} \\
The heartbeat subscription status value

esp_ble_mesh_cfg_net_transmit_status_cb_t \textbf{net_transmit_status} \\
The network transmit status value

esp_ble_mesh_cfg_model_sub_list_cb_t \textbf{model_sub_list} \\
The model subscription list value

esp_ble_mesh_cfg_net_key_list_cb_t \textbf{netkey_list} \\
The network key index list value

esp_ble_mesh_cfg_app_key_list_cb_t \textbf{appkey_list} \\
The application key index list value

esp_ble_mesh_cfg_node_id_status_cb_t \textbf{node_identity_status} \\
The node identity status value
Esp BLE mesh config model cb_t model_app_list
The model application key index list value

Esp BLE mesh config kr phase status cb_t kr_phase_status
The key refresh phase status value

Esp BLE mesh config lpn pollto status cb_t lpn_timeout_status
The low power node poll timeout status value

Union esp BLE mesh config server state change_t
#include <esp_ble_mesh_config_model_api.h> Configuration Server model state change value union.

Public Members

Esp BLE mesh state change cfg mod pub set t mod_pub_set
The recv_op in ctx can be used to decide which state is changed. Config Model Publication Set

Esp BLE mesh state change cfg 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 config server cb value_t
#include <esp_ble_mesh_config_model_api.h> Configuration Server model callback value union.

Public Members

Esp BLE mesh config server state change_t state_change
ESP_BLE_MESH_CFG_SERVER_STATE_CHANGE_EVT

Structures

Struct esp BLE mesh config 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

`struct esp_ble_mesh_cfg_srv::<anonymous>heartbeat_pub`
Heartbeat Publication

int64_t `expiry`
Timestamp when Heartbeat subscription period is expired

uint16_t `src`
Source address for Heartbeat messages

uint8_t `min_hops`
Minimum hops when receiving Heartbeat messages

uint8_t `max_hops`
Maximum hops when receiving Heartbeat messages

`esp_ble_mesh_cb_t heartbeat_recv_cb`
Optional heartbeat subscription tracking function

`struct esp_ble_mesh_cfg_srv::<anonymous>heartbeat_sub`
Heartbeat Subscription
**struct esp_ble_mesh_cfg_composition_data_get_t**
Parameters of Config Composition Data Get.

**Public Members**

`uint8_t page`
Page number of the Composition Data.

**struct esp_ble_mesh_cfg_model_pub_get_t**
Parameters of Config Model Publication Get.

**Public Members**

`uint16_t element_addr`
The element address

`uint16_t model_id`
The model id

`uint16_t company_id`
The company id, if not a vendor model, shall set to 0xFFFF

**struct esp_ble_mesh_cfg_sig_model_sub_get_t**
Parameters of Config SIG Model Subscription Get.

**Public Members**

`uint16_t element_addr`
The element address

`uint16_t model_id`
The model id

**struct esp_ble_mesh_cfg_vnd_model_sub_get_t**
Parameters of Config Vendor Model Subscription Get.

**Public Members**

`uint16_t element_addr`
The element address

`uint16_t model_id`
The model id

`uint16_t company_id`
The company id, if not a vendor model, shall set to 0xFFFF

**struct esp_ble_mesh_cfg_app_key_get_t**
Parameters of Config AppKey Get.

**Public Members**

`uint16_t net_idx`
The network key index

**struct esp_ble_mesh_cfg_node_identity_get_t**
Parameters of Config Node Identity Get.
Public Members

```c
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

```c
uint16_t element_addr
   The element address
```

```c
uint16_t model_id
   The model id
```

**struct esp_ble_mesh_cfg_vnd_model_app_get_t**
Parameters of Config Vendor Model App Get.

Public Members

```c
uint16_t element_addr
   The element address
```

```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_get_t**
Parameters of Config Key Refresh Phase Get.

Public Members

```c
uint16_t net_idx
   The network key index
```

**struct esp_ble_mesh_cfg_lpn_polltimeout_get_t**
Parameters of Config Low Power Node PollTimeout Get.

Public Members

```c
uint16_t lpn_addr
   The unicast address of the Low Power node
```

**struct esp_ble_mesh_cfg_beacon_set_t**
Parameters of Config Beacon Set.

Public Members

```c
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

```c
uint8_t ttl
The default TTL state value
```

```c
tstruct esp_ble_mesh_cfg_friend_set_t
Parameters of Config Friend Set.
```

Public Members

```c
uint8_t friend_state
The friend state value
```

```c
tstruct esp_ble_mesh_cfg_gatt_proxy_set_t
Parameters of Config GATT Proxy Set.
```

Public Members

```c
uint8_t gatt_proxy
The GATT Proxy state value
```

```c
tstruct esp_ble_mesh_cfg_relay_set_t
Parameters of Config Relay Set.
```

Public Members

```c
uint8_t relay
The relay value
```

```c
uint8_t relay_retransmit
The relay retransmit value
```

```c
tstruct esp_ble_mesh_cfg_net_key_add_t
Parameters of Config NetKey Add.
```

Public Members

```c
uint16_t net_idx
The network key index
```

```c
uint8_t net_key[16]
The network key value
```

```c
tstruct esp_ble_mesh_cfg_app_key_add_t
Parameters of Config AppKey Add.
```

Public Members

```c
uint16_t net_idx
The network key index
```

```c
uint16_t app_idx
The app key index
```

```c
uint8_t app_key[16]
The app key value
```

```c
tstruct 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

```c
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

```c
bool **cred_flag**
Value of the Friendship Credential Flag
```

```c
uint8_t **publish_ttl**
Default TTL value for the publishing messages
```

```c
uint8_t **publish_period**
Period for periodic status publishing
```

```c
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

```c
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

```c
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.

   Public Members

   uint16_t net_idx
      The network key index
    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

   uint16_t net_idx
      The network key index
    uint8_t identity
      New Node Identity state

struct esp_ble_mesh_cfg_model_app_unbind_t
   Parameters of Config Model App Unbind.
```
Public Members

```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
```

```c
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
```

```c
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
```

```c
struct esp_ble_mesh_cfg_heartbeat_pub_set_t
    Parameters of Config Model Heartbeat Publication Set.
```

Public Members

```c
uint16_t dst
    Destination address for Heartbeat messages
```

```c
uint8_t count
    Number of Heartbeat messages to be sent
```

```c
uint8_t period
    Period for sending Heartbeat messages
```

```c
uint8_t ttl
    TTL to be used when sending Heartbeat messages
```

```c
uint16_t feature
    Bit field indicating features that trigger Heartbeat messages when changed
```

```c
uint16_t net_idx
    NetKey Index
```

```c
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

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
Chapter 2. API Reference

uint8_t ttl
   TTL to be used when sending Heartbeat messages

uint16_t features
   Features that trigger Heartbeat messages when changed

uint16_t net_idx
   Index of the NetKey

struct esp_ble_mesh_cfg_hb_sub_status_cb_t
   Parameters of Config Heartbeat Subscription Status

Public Members

uint8_t status
   Status Code for the request message

uint16_t src
   Source address for Heartbeat messages

uint16_t dst
   Destination address for Heartbeat messages

uint8_t period
   Remaining Period for processing Heartbeat messages

uint8_t count
   Number of Heartbeat messages received

uint8_t min_hops
   Minimum hops when receiving Heartbeat messages

uint8_t max_hops
   Maximum hops when receiving Heartbeat messages

struct esp_ble_mesh_cfg_net_trans_status_cb_t
   Parameters of Config Network Transmit Status

Public Members

uint8_t net_trans_count
   Number of transmissions for each Network PDU originating from the node

uint8_t net_trans_step
   Maximum hops when receiving Heartbeat messages

struct esp_ble_mesh_cfg_model_sub_list_cb_t
   Parameters of Config SIG/Vendor Subscription List

Public Members

uint8_t status
   Status Code for the request message

uint16_t element_addr
   Address of the element

uint16_t company_id
   Company ID

uint16_t model_id
   Model ID
Chapter 2. API Reference

```
struct net_buf_simple *sub_addr
    A block of all addresses from the Subscription List

struct esp_ble_mesh_cfg_net_key_list_cb_t
    Parameter of Config NetKey List

Public Members

struct net_buf_simple *net_idx
    A list of NetKey Indexes known to the node

struct esp_ble_mesh_cfg_app_key_list_cb_t
    Parameters of Config AppKey List

Public Members

uint8_t status
    Status Code for the request message

uint16_t net_idx
    NetKey Index of the NetKey that the AppKeys are bound to

struct net_buf_simple *app_idx
    A list of AppKey indexes that are bound to the NetKey identified by NetKeyIndex

struct esp_ble_mesh_cfg_node_id_status_cb_t
    Parameters of Config Node Identity Status

Public Members

uint8_t status
    Status Code for the request message

uint16_t net_idx
    Index of the NetKey

uint8_t identity
    Node Identity state

struct esp_ble_mesh_cfg_model_app_list_cb_t
    Parameters of Config SIG/Vendor Model App List

Public Members

uint8_t status
    Status Code for the request message

uint16_t element_addr
    Address of the element

uint16_t company_id
    Company ID

uint16_t model_id
    Model ID

struct net_buf_simple *app_idx
    All AppKey indexes bound to the Model

struct esp_ble_mesh_cfg_kr_phase_status_cb_t
    Parameters of Config Key Refresh Phase Status
```
Public Members

uint8_t status
    Status Code for the request message

uint16_t net_idx
    Index of the NetKey

uint8_t phase
    Key Refresh Phase state

struct esp_ble_mesh_cfg_lpn_pollto_status_cb_t
    Parameters of Config Low Power Node PollTimeout Status

Public Members

uint16_t lpn_addr
    The unicast address of the Low Power node

int32_t poll_timeout
    The current value of the PollTimeout timer of the Low Power node

struct esp_ble_mesh_cfg_client_cb_param_t
    Configuration Client Model callback parameters

Public Members

int error_code
    Appropriate error code

esp_ble_mesh_client_common_param_t *params
    The client common parameters

esp_ble_mesh_cfg_client_common_cb_param_t status_cb
    The config status message callback values

struct esp_ble_mesh_state_change_cfg_mod_pub_set_t
    Configuration Server model related context.

Public Members

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

    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

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

   esp_ble_mesh_model_t *model
      Pointer to the server model structure
   esp_ble_mesh_msg_ctx_t *ctx
      Context of the received message
   esp_ble_mesh_cfg_server_cb_value_t value
      Value of the received configuration messages

Macros

ESP_BLE_MESH_MODEL_CFG_SRV(srv_data)
   Define a new Config Server Model.
   
   Note The Config Server Model can only be included by a Primary Element.
   
   Return New Config Server Model instance.
   
   Parameters
   
      • srv_data: Pointer to a unique Config Server Model user_data.

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)
```

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

```c
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

```c
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.

```c
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.

```c
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 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_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 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.

```c
esp_err_t esp_ble_mesh_health_server_fault_update(esp_ble_mesh_elem_t *element)
```

This function is called by the Health Server Model to update the context of its Health Current status.

Return ESP_OK on success or error code otherwise.

Parameters

• [in] element: The element to which the Health Server Model belongs.

Unions

```c
union esp_ble_mesh_health_client_get_state_t

#include <esp_ble_mesh_health_model_api.h> For ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_GET ESP_BLE_MESH_MODEL_OP_ATTENTION_GET ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_GET
```

the get_state parameter in the esp_ble_mesh_health_client_get_state function should not be set to NULL.

Public Members

```c
esp_ble_mesh_health_fault_get_t fault_get

For ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_GET.
```

```c
union esp_ble_mesh_health_client_set_state_t

```

the set_state parameter in the esp_ble_mesh_health_client_set_state function should not be set to NULL.

Public Members

```c
esp_ble_mesh_health_attention_set_t attention_set

For ESP_BLE_MESH_MODEL_OP_ATTENTION_SET or ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_UNACK.
```
Chapter 2. API Reference

**esp_ble_mesh_health_period_set_t**

The `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**

The `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**

The `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.

### Structures

**struct esp_ble_mesh_health_srv_cb_t**

ESP BLE Mesh Health Server callback.

### Public Members

**esp_ble_mesh_health_fault_update_comp_cb_t** `fault_update_comp`

Clear health registered faults. Initialized by the stack.

**esp_ble_mesh_health_fault_test_cb_t** `fault_test`

Run a specific health test. Initialized by the stack.
Chapter 2. API Reference

`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.

```c
struct esp_ble_mesh_health_test_t
ESP BLE Mesh Health Server test Context
```

**Public Members**

```c
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
```

```c
struct esp_ble_mesh_health_srv_t
ESP BLE Mesh Health Server Model Context
```

**Public Members**

```c
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**

```c
uint16_t company_id
Bluetooth assigned 16-bit Company ID

struct esp_ble_mesh_health_attention_set_t
Parameter of Health Attention Set
```
Public Members

uint8_t attention
Value of the Attention Timer state

struct esp_ble_mesh_health_period_set_t
Parameter of Health Period Set

Public Members

uint8_t fast_period_divisor
Divider for the Publish Period

struct esp_ble_mesh_health_fault_test_t
Parameter of Health Fault Test

Public Members

uint16_t company_id
Bluetooth assigned 16-bit Company ID
uint8_t test_id
ID of a specific test to be performed

struct esp_ble_mesh_health_fault_clear_t
Parameter of Health Fault Clear

Public Members

uint16_t company_id
Bluetooth assigned 16-bit Company ID

struct esp_ble_mesh_health_current_status_cb_t
Parameters of Health Current Status

Public Members

uint8_t test_id
ID of a most recently performed test
uint16_t company_id
Bluetooth assigned 16-bit Company ID

struct net_buf_simple *fault_array
FaultArray field contains a sequence of 1-octet fault values

struct esp_ble_mesh_health_fault_status_cb_t
Parameters of Health Fault Status

Public Members

uint8_t test_id
ID of a most recently performed test
uint16_t company_id
Bluetooth assigned 16-bit Company ID

struct net_buf_simple *fault_array
FaultArray field contains a sequence of 1-octet fault values
struct esp_ble_mesh_health_period_status_cb_t
Parameter of Health Period Status

Public Members

uint8_t fast_period_divisor
Divider for the Publish Period

struct esp_ble_mesh_health_attention_status_cb_t
Parameter of Health Attention Status

Public Members

uint8_t attention
Value of the Attention Timer state

struct esp_ble_mesh_health_client_cb_param_t
Health Client Model callback parameters

Public Members

int error_code
Appropriate error code

esp_ble_mesh_client_common_param_t *params
The client common parameters.

esp_ble_mesh_health_client_common_cb_param_t status_cb
The health message status callback values

struct esp_ble_mesh_health_fault_update_comp_cb_t
Parameter of publishing Health Current Status completion event

Public Members

int error_code
The result of publishing Health Current Status

esp_ble_mesh_elem_t *element
Pointer to the element which contains the Health Server Model

struct esp_ble_mesh_health_fault_clear_cb_t
Parameters of Health Fault Clear event

Public Members

esp_ble_mesh_model_t *model
Pointer to the Health Server Model

uint16_t company_id
Bluetooth assigned 16-bit Company ID

struct esp_ble_mesh_health_fault_test_cb_t
Parameters of Health Fault Test event
Public Members

```c
esp_ble_mesh_model_t *model
PointertotheHealthServerModel
```

```c
uint8_t test_id
IDofaspecifictesttobeperformed
```

```c
uint16_t company_id
Bluetoothassigned16-bitCompanyID
```

```c
struct esp_ble_mesh_health_attention_on_cb_t
ParameterofHealthAttentionOnevent
```

Public Members

```c
esp_ble_mesh_model_t *model
PointertotheHealthServerModel
```

```c
uint8_t time
Durationofattentiontimeron(inseconds)
```

```c
struct esp_ble_mesh_health_attention_off_cb_t
ParameterofHealthAttentionOffevent
```

Public Members

```c
esp_ble_mesh_model_t *model
PointertotheHealthServerModel
```

Macros

```c
ESP_BLE_MESH_MODEL_HEALTH_SRV (srv, pub)
DefineanewHealthServerModel.
```

**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`.

```c
ESP_BLE_MESH_MODEL_HEALTH_CLI (cli_data)
DefineanewHealthClientModel.
```

**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`.

```c
ESP_BLE_MESH_HEALTH_PUB_DEFINE (_name, _max, _role)
Ahelper todefeineahealthpublicationcontext
```

**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.

```c
ESP_BLE_MESH_HEALTH_STANDARD_TEST
SIGidentifierofHealthFaultTest. 0x01~0xFF:VendorSpecificTest.
```
ESP_BLE_MESH_NO_FAULT
  Fault values of Health Fault Test. 0x33 ~ 0x7F: Reserved for Future Use. 0x80 ~ 0xFF: Vendor Specific Warning/Error.

ESP_BLE_MESH_BATTERY_LOW_WARNING
ESP_BLE_MESH_BATTERY_LOW_ERROR
ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_LOW_WARNING
ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_LOW_ERROR
ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_HIGH_WARNING
ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_HIGH_ERROR
ESP_BLE_MESH_POWER_SUPPLY_INTERRUPTED_WARNING
ESP_BLE_MESH_POWER_SUPPLY_INTERRUPTED_ERROR
ESP_BLE_MESH_NO_LOAD_WARNING
ESP_BLE_MESH_NO_LOAD_ERROR
ESP_BLE_MESH_OVERLOAD_WARNING
ESP_BLE_MESH_OVERLOAD_ERROR
ESP_BLE_MESH_OVERHEAT_WARNING
ESP_BLE_MESH_OVERHEAT_ERROR
ESP_BLE_MESH_CONDITION_WARNING
ESP_BLE_MESH_CONDITION_ERROR
ESP_BLE_MESH_VIBRATION_WARNING
ESP_BLE_MESH_VIBRATION_ERROR
ESP_BLE_MESH_CONFIGURATION_WARNING
ESP_BLE_MESH_CONFIGURATION_ERROR
ESP_BLE_MESH_ELEMENT_NOT_CALIBRATED_WARNING
ESP_BLE_MESH_ELEMENT_NOT_CALIBRATED_ERROR
ESP_BLE_MESH_MEMORY_WARNING
ESP_BLE_MESH_MEMORY_ERROR
ESP_BLE_MESH_SELF_TEST_WARNING
ESP_BLE_MESH_SELF_TEST_ERROR
ESP_BLE_MESH_INPUT_TOO_LOW_WARNING
ESP_BLE_MESH_INPUT_TOO_LOW_ERROR
ESP_BLE_MESH_INPUT_TOO_HIGH_WARNING
ESP_BLE_MESH_INPUT_TOO_HIGH_ERROR
ESP_BLE_MESH_INPUT_NO_CHANGE_WARNING
ESP_BLE_MESH_INPUT_NO_CHANGE_ERROR
ESP_BLE_MESH_ACTUATOR_BLOCKED_WARNING
ESP_BLE_MESH_ACTUATOR_BLOCKED_ERROR
ESP_BLE_MESH_HOUSING_OPENED_WARNING
ESP_BLE_MESH_HOUSING_OPENED_ERROR
ESP_BLE_MESH_TAMPER_WARNING
**Chapter 2. API Reference**

### ESP_BLE_MESH_TAMPER_ERROR
### ESP_BLE_MESH_DEVICE_MOVED_WARNING
### ESP_BLE_MESH_DEVICE_MOVED_ERROR
### ESP_BLE_MESH_DEVICE_DROPPED_WARNING
### ESP_BLE_MESH_DEVICE_DROPPED_ERROR
### ESP_BLE_MESH_OVERFLOW_WARNING
### 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**
Chapter 2. API Reference

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

```c
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.

```c
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

`esp_ble_mesh_gen_user_property_get_t user_property_get`
For ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_GET

`esp_ble_mesh_gen_admin_property_get_t admin_property_get`
For ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_GET

`esp_ble_mesh_gen_manufacturer_property_get_t manufacturer_property_get`
For ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET

`esp_ble_mesh_gen_client_properties_get_t client_properties_get`
For ESP_BLE_MESH_MODEL_OP_GEN_CLIENT_PROPERTIES_GET

`union esp_ble_mesh_generic_client_set_state_t`

#include <esp_ble_mesh_generic_model_api.h> Generic Client Model set message union.

Public Members

`esp_ble_mesh_gen_onoff_set_t onoff_set`
For ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_SET & ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_SET_UNACK

`esp_ble_mesh_gen_level_set_t level_set`
For ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_SET & ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_SET_UNACK

`esp_ble_mesh_gen_delta_set_t delta_set`
For ESP_BLE_MESH_MODEL_OP_GEN_DELTA_SET & ESP_BLE_MESH_MODEL_OP_GEN_DELTA_SET_UNACK

`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

`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_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_t admin_property_set`
For ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_SET & ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_SET_UNACK
```c
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

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

```c
esp_ble_mesh_state_change_gen_onoff_set_t onoff_set
```

The `recv_op` in `ctx` can be used to decide which state is changed. Generic OnOff Set

```c
esp_ble_mesh_state_change_gen_level_set_t level_set
```

Generic Level Set

```c
esp_ble_mesh_state_change_gen_delta_set_t delta_set
```

Generic Delta Set

```c
esp_ble_mesh_state_change_gen_move_set_t move_set
```

Generic Move Set

```c
esp_ble_mesh_state_change_gen_def_trans_time_set_t def_trans_time_set
```

Generic Default Transition Time Set

```c
esp_ble_mesh_state_change_gen_onpowerup_set_t onpowerup_set
```

Generic OnPowerUp Set

```c
esp_ble_mesh_state_change_gen_power_level_set_t power_level_set
```

Generic Power Level Set

```c
esp_ble_mesh_state_change_gen_power_default_set_t power_default_set
```

Generic Power Default Set

```c
esp_ble_mesh_state_change_gen_power_range_set_t power_range_set
```

Generic Power Range Set

```c
esp_ble_mesh_state_change_gen_loc_global_set_t loc_global_set
```

Generic Location Global Set

```c
esp_ble_mesh_state_change_gen_loc_local_set_t loc_local_set
```

Generic Location Local Set

```c
esp_ble_mesh_state_change_gen_user_property_set_t user_property_set
```

Generic User Property Set

```c
esp_ble_mesh_state_change_gen_admin_property_set_t admin_property_set
```

Generic Admin Property Set

```c
esp_ble_mesh_state_change_gen_manu_property_set_t manu_property_set
```

Generic Manufacturer Property Set

```
union esp_ble_mesh_generic_server_recv_get_msg_t
#include <esp_ble_mesh_generic_model_api.h> Generic Server Model received get message union.
```

Public Members

```c
esp_ble_mesh_server_recv_gen_user_property_get_t user_property
```

Generic User Property Get

```c
esp_ble_mesh_server_recv_gen_admin_property_get_t admin_property
```

Generic Admin Property Get

```c
esp_ble_mesh_server_recv_gen_manufacturer_property_get_t manu_property
```

Generic Manufacturer Property Get

```c
esp_ble_mesh_server_recv_gen_client_properties_get_t client_properties
```

Generic Client Properties Get

```
union esp_ble_mesh_generic_server_recv_set_msg_t
#include <esp_ble_mesh_generic_model_api.h> Generic Server Model received set message union.
```
Chapter 2. API Reference

Public Members

```c
esp_ble_mesh_server_recv_gen_onoff_set_t onoff
Generic OnOff Set/Generic OnOff Set Unack

esp_ble_mesh_server_recv_gen_level_set_t level
Generic Level Set/Generic Level Set Unack

esp_ble_mesh_server_recv_gen_delta_set_t delta
Generic Delta Set/Generic Delta Set Unack

esp_ble_mesh_server_recv_gen_move_set_t move
Generic Move Set/Generic Move Set Unack

esp_ble_mesh_server_recv_gen_def_trans_time_set_t def_trans_time
Generic Default Transition Time Set/Generic Default Transition Time Set Unack

esp_ble_mesh_server_recv_gen_onpowerup_set_t onpowerup
Generic OnPowerUp Set/Generic OnPowerUp Set Unack

esp_ble_mesh_server_recv_gen_power_level_set_t power_level
Generic Power Level Set/Generic Power Level Set Unack

esp_ble_mesh_server_recv_gen_power_default_set_t power_default
Generic Power Default Set/Generic Power Default Set Unack

esp_ble_mesh_server_recv_gen_power_range_set_t power_range
Generic Power Range Set/Generic Power Range Set Unack

esp_ble_mesh_server_recv_gen_loc_global_set_t location_global
Generic Location Global Set/Generic Location Global Set Unack

esp_ble_mesh_server_recv_gen_loc_local_set_t location_local
Generic Location Local Set/Generic Location Local Set Unack

esp_ble_mesh_server_recv_gen_user_property_set_t user_property
Generic User Property Set/Generic User Property Set Unack

esp_ble_mesh_server_recv_gen_admin_property_set_t admin_property
Generic Admin Property Set/Generic Admin Property Set Unack

esp_ble_mesh_server_recv_gen_manufacturer_property_set_t manu_property
Generic Manufacturer Property Set/Generic Manufacturer Property Set Unack
```

```c
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
esp_ble_mesh_server_state_change_t state_change
ESP_BLE_MESH_GENERIC_SERVER_STATE_CHANGE_EVT

esp_ble_mesh_server_recv_get_msg_t get
ESP_BLE_MESH_GENERIC_SERVER_RECV_GET_MSG_EVT

esp_ble_mesh_server_recv_set_msg_t set
ESP_BLE_MESH_GENERIC_SERVER_RECV_SET_MSG_EVT
```

Structures

```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

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_gen_level_set_t
Parameters of Generic Level Set.

Public Members

bool op_en
Indicate if optional parameters are included

int16_t level
Target value of Generic Level state

uint8_t tid
Transaction ID

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)

struct esp_ble_mesh_gen_delta_set_t
Parameters of Generic Delta Set.

Public Members

bool op_en
Indicate if optional parameters are included

int32_t level
Delta change of Generic Level state

uint8_t tid
Transaction ID

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)

struct esp_ble_mesh_gen_move_set_t
Parameters of Generic Move Set.

Public Members

bool op_en
Indicate if optional parameters are included
**int16_t** `delta_level`
   Delta Level step to calculate Move speed for Generic Level state

**uint8_t** `tid`
   Transaction ID

**uint8_t** `trans_time`
   Time to complete state transition (optional)

**uint8_t** `delay`
   Indicate message execution delay (C.1)

**struct esp_ble_mesh_gen_def_trans_time_set_t**
   Parameter of Generic Default Transition Time Set.

**Public Members**

**uint8_t** `trans_time`
   The value of the Generic Default Transition Time state

**struct esp_ble_mesh_gen_onpowerup_set_t**
   Parameter of Generic OnPowerUp Set.

**Public Members**

**uint8_t** `onpowerup`
   The value of the Generic OnPowerUp state

**struct esp_ble_mesh_gen_power_level_set_t**
   Parameters of Generic Power Level Set.

**Public Members**

**bool** `op_en`
   Indicate if optional parameters are included

**uint16_t** `power`
   Target value of Generic Power Actual state

**uint8_t** `tid`
   Transaction ID

**uint8_t** `trans_time`
   Time to complete state transition (optional)

**uint8_t** `delay`
   Indicate message execution delay (C.1)

**struct esp_ble_mesh_gen_power_default_set_t**
   Parameter of Generic Power Default Set.

**Public Members**

**uint16_t** `power`
   The value of the Generic Power Default state

**struct esp_ble_mesh_gen_power_range_set_t**
   Parameters of Generic Power Range Set.
Public Members

```plaintext
ut16_t range_min
   Value of Range Min field of Generic Power Range state
```

```plaintext
ut16_t range_max
   Value of Range Max field of Generic Power Range state
```

```plaintext
struct esp_ble_mesh_gen_loc_global_set_t
   Parameters of Generic Location Global Set.
```

Public Members

```plaintext
int32_t global_latitude
   Global Coordinates (Latitude)
```

```plaintext
int32_t global_longitude
   Global Coordinates (Longitude)
```

```plaintext
int16_t global_altitude
   Global Altitude
```

```plaintext
struct esp_ble_mesh_gen_loc_local_set_t
   Parameters of Generic Location Local Set.
```

Public Members

```plaintext
int16_t local_north
   Local Coordinates (North)
```

```plaintext
int16_t local_east
   Local Coordinates (East)
```

```plaintext
int16_t local_altitude
   Local Altitude
```

```plaintext
uint8_t floor_number
   Floor Number
```

```plaintext
uint16_t uncertainty
   Uncertainty
```

```plaintext
struct esp_ble_mesh_gen_user_property_get_t
   Parameter of Generic User Property Get.
```

Public Members

```plaintext
uint16_t property_id
   Property ID identifying a Generic User Property
```

```plaintext
struct esp_ble_mesh_gen_user_property_set_t
   Parameters of Generic User Property Set.
```

Public Members

```plaintext
uint16_t property_id
   Property ID identifying a Generic User Property
```

```plaintext
struct net_buf_simple *property_value
   Raw value for the User Property
```
struct esp_ble_mesh_gen_admin_property_get_t
Parameter of Generic Admin Property Get.

Public Members

uint16_t property_id
Property ID identifying a Generic Admin Property

struct esp_ble_mesh_gen_admin_property_set_t
Parameters of Generic Admin Property Set.

Public Members

uint16_t property_id
Property ID identifying a Generic Admin Property

uint8_t user_access
Enumeration indicating user access

struct net_buf_simple *property_value
Raw value for the Admin Property

struct esp_ble_mesh_gen_manufacturer_property_get_t
Parameter of Generic Manufacturer Property Get.

Public Members

uint16_t property_id
Property ID identifying a Generic Manufacturer Property

struct esp_ble_mesh_gen_manufacturer_property_set_t
Parameters of Generic Manufacturer Property Set.

Public Members

uint16_t property_id
Property ID identifying a Generic Manufacturer Property

uint8_t user_access
Enumeration indicating user access

struct esp_ble_mesh_gen_client_properties_get_t
Parameter of Generic Client Properties Get.

Public Members

uint16_t property_id
A starting Client Property ID present within an element

struct esp_ble_mesh_gen_onoff_status_cb_t
Bluetooth Mesh Generic Client Model Get and Set callback parameters structure.
Parameters of Generic OnOff Status.
Public Members

bool op_en
   Indicate if optional parameters are included

uint8_t present_onoff
   Current value of Generic OnOff state

uint8_t target_onoff
   Target value of Generic OnOff state (optional)

uint8_t remain_time
   Time to complete state transition (C.1)

struct esp_ble_mesh_gen_level_status_cb_t
   Parameters of Generic Level Status.

Public Members

bool op_en
   Indicate if optional parameters are included

int16_t present_level
   Current value of Generic Level state

int16_t target_level
   Target value of the Generic Level state (optional)

uint8_t remain_time
   Time to complete state transition (C.1)

struct esp_ble_mesh_gen_def_trans_time_status_cb_t
   Parameter of Generic Default Transition Time Status.

Public Members

uint8_t trans_time
   The value of the Generic Default Transition Time state

struct esp_ble_mesh_gen_onpowerup_status_cb_t

Public Members

uint8_t onpowerup
   The value of the Generic OnPowerUp state

struct esp_ble_mesh_gen_power_level_status_cb_t
   Parameters of Generic Power Level Status.

Public Members

bool op_en
   Indicate if optional parameters are included

uint16_t present_power
   Current value of Generic Power Actual state

uint16_t target_power
   Target value of Generic Power Actual state (optional)
Chapter 2. API Reference

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
StatusCode for the request message
uint16_t range_min
Value of Range Min field of Generic Power Range state
uint16_t range_max
Value of Range Max field of Generic Power Range state

struct esp_ble_mesh_gen_battery_status_cb_t
Parameters of Generic Battery Status.

Public Members

uint32_t battery_level : 8
Value of Generic Battery Level state
uint32_t time_to_discharge : 24
Value of Generic Battery Time to Discharge state
uint32_t time_to_charge : 24
Value of Generic Battery Time to Charge state
uint32_t flags : 8
Value of Generic Battery Flags state

struct esp_ble_mesh_gen_loc_global_status_cb_t
Parameters of Generic Location Global Status.

Public Members

int32_t global_latitude
Global Coordinates (Latitude)
int32_t global_longitude
Global Coordinates (Longitude)
\[
\text{int16_t} \quad \text{global\_altitude}
\]
Global Altitude

\textbf{struct esp\_ble\_mesh\_gen\_loc\_local\_status\_cb\_t}
Parameters of Generic Location Local Status.

\textbf{Public Members}

\text{int16_t} \quad \text{local\_north}
Local Coordinates (North)

\text{int16_t} \quad \text{local\_east}
Local Coordinates (East)

\text{int16_t} \quad \text{local\_altitude}
Local Altitude

\text{uint8_t} \quad \text{floor\_number}
Floor Number

\text{uint16_t} \quad \text{uncertainty}
Uncertainty

\textbf{struct esp\_ble\_mesh\_gen\_user\_properties\_status\_cb\_t}
Parameter of Generic User Properties Status.

\textbf{Public Members}

\textbf{struct net\_buf\_simple *property\_ids}
Buffer contains a sequence of N User Property IDs

\textbf{struct esp\_ble\_mesh\_gen\_user\_property\_status\_cb\_t}
Parameters of Generic User Property Status.

\textbf{Public Members}

\text{bool} \quad \text{op\_en}
Indicate if optional parameters are included

\text{uint16_t} \quad \text{property\_id}
Property ID identifying a Generic User Property

\text{uint8_t} \quad \text{user\_access}
Enumeration indicating user access (optional)

\textbf{struct net\_buf\_simple *property\_value}
Raw value for the User Property (C.1)

\textbf{struct esp\_ble\_mesh\_gen\_admin\_properties\_status\_cb\_t}
Parameter of Generic Admin Properties Status.

\textbf{Public Members}

\textbf{struct net\_buf\_simple *property\_ids}
Buffer contains a sequence of N Admin Property IDs

\textbf{struct esp\_ble\_mesh\_gen\_admin\_property\_status\_cb\_t}
Parameters of Generic Admin Property Status.
Chapter 2. API Reference

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_adminufacturer_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_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 Client Property IDs

struct esp_ble_mesh_generic_client_properties_status_cb_t
Parameter of Generic Client Properties Status.

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

*model
Pointer to the Generic Level Server Model. Initialized internally.

rsp_ctrl
Response control of the server model received messages

state
Parameters of the Generic Level state

last
Parameters of the last received set message

transition
Parameters of state transition

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

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

*model
Pointer to the Generic Default Transition Time Server Model. Initialized internally.

rsp_ctrl
Response control of the server model received messages

state
Parameters of the Generic Default Transition Time state

struct esp_ble_mesh_gen_onpowerup_state_t
Parameter of Generic OnPowerUp state

Public Members

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

*model
Pointer to the Generic Power OnOff Server Model. Initialized internally.

rsp_ctrl
Response control of the server model received messages
Chapter 2. API Reference

`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

uint16_t `power_range_min`
The minimum value of the Generic Power Range state

uint16_t `power_range_max`
The maximum value of the Generic Power Range state

`struct esp_ble_mesh_gen_power_level_srv_t`
User data of Generic Power Level Server Model

**Public Members**

`esp_ble_mesh_model_t *model`
Pointer to the Generic Power Level Server Model. Initialized internally.

`esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl`
Response control of the server model received messages

`esp_ble_mesh_gen_power_level_state_t *state`
Parameters of the Generic Power Level state

`esp_ble_mesh_last_msg_info_t last`
Parameters of the last received set message

`esp_ble_mesh_state_transition_t *transition`
Parameters of state transition
Chapter 2. API Reference

```c
int32_t tt_delta_level
Delta change value of level state transition
```

```c
struct esp_ble_mesh_gen_power_level_setup_srv_t
User data of Generic Power Level Setup Server Model
```

**Public Members**

```c
esp_ble_mesh_model_t *model
Pointer to the Generic Power Level Setup Server Model. Initialized internally.
```

```c
esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages
```

```c
esp_ble_mesh_gen_power_level_state_t *state
Parameters of the Generic Power Level state
```

```c
struct esp_ble_mesh_gen_power_level_setup_srv_t
User data of Generic Power Level Setup Server Model
```

**Public Members**

```c
uint32_t battery_level : 8
The value of the Generic Battery Level state
```

```c
uint32_t time_to_discharge : 24
The value of the Generic Battery Time to Discharge state
```

```c
uint32_t time_to_charge : 24
The value of the Generic Battery Time to Charge state
```

```c
uint32_t battery_flags : 8
The value of the Generic Battery Flags state
```

```c
struct esp_ble_mesh_gen_battery_srv_t
User data of Generic Battery Server Model
```

**Public Members**

```c
esp_ble_mesh_model_t *model
Pointer to the Generic Battery Server Model. Initialized internally.
```

```c
esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages
```

```c
esp_ble_mesh_gen_battery_state_t *state
Parameters of the Generic Battery state
```

```c
struct esp_ble_mesh_gen_battery_srv_t
User data of Generic Battery Server Model
```

**Public Members**

```c
int32_t global_latitude
The value of the Global Latitude field
```

```c
int32_t global_longitude
The value of the Global Longitude field
```

```c
int16_t global_altitude
The value of the Global Altitude field
```

```c
struct esp_ble_mesh_gen_location_state_t
Parameters of Generic Location state
```

**Public Members**

```c
int32_t global_latitude
The value of the Global Latitude field
```

```c
int32_t global_longitude
The value of the Global Longitude field
```

```c
int16_t global_altitude
The value of the Global Altitude field
```
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.

   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_admin_prop_srv_t
User data of Generic Admin Property Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Generic Admin Property Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages

uint8_t property_count
Generic Admin Property count

esp_ble_mesh_generic_property_t *properties
Parameters of the Generic Admin Property state

struct esp_ble_mesh_gen_manu_prop_srv_t
User data of Generic Manufacturer Property Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Generic Manufacturer Property Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages

uint8_t property_count
Generic Manufacturer Property count

esp_ble_mesh_generic_property_t *properties
Parameters of the Generic Manufacturer Property state

struct esp_ble_mesh_gen_client_prop_srv_t
User data of Generic Client Property Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Generic Client Property Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages
Chapter 2. API Reference

uint8_t id_count
   Generic Client Property ID count

uint16_t *property_ids
   Parameters of the Generic Client Property state

struct esp_ble_mesh_state_change_gen_onoff_set_t
   Parameter of Generic OnOff Set state change event

Public Members

uint8_t onoff
   The value of Generic OnOff state

struct esp_ble_mesh_state_change_gen_level_set_t
   Parameter of Generic Level Set state change event

Public Members

int16_t level
   The value of Generic Level state

struct esp_ble_mesh_state_change_gen_delta_set_t
   Parameter of Generic Delta Set state change event

Public Members

int16_t level
   The value of Generic Level state

struct esp_ble_mesh_state_change_gen_move_set_t
   Parameter of Generic Move Set state change event

Public Members

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

```c
uint16_t id
    The property id of Generic User Property state

struct net_buf_simple *value
    The property value of Generic User Property state
```

```c
struct esp_ble_mesh_state_change_gen_admin_property_set_t
    Parameters of Generic Admin Property Set state change event
```

Public Members

```c
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
```

```c
struct esp_ble_mesh_state_change_gen_manu_property_set_t
    Parameters of Generic Manufacturer Property Set state change event
```

Public Members

```c
uint16_t id
    The property id of Generic Manufacturer Property state

uint8_t access
    The property value of Generic Manufacturer Property state
```

```c
struct esp_ble_mesh_server_recv_gen_user_property_get_t
    Context of the received Generic User Property Get message
```

Public Members

```c
uint16_t property_id
    Property ID identifying a Generic User Property
```

```c
struct esp_ble_mesh_server_recv_gen_admin_property_get_t
    Context of the received Generic Admin Property Get message
```

Public Members

```c
uint16_t property_id
    Property ID identifying a Generic Admin Property
```

```c
struct esp_ble_mesh_server_recv_gen_manufacturer_property_get_t
    Context of the received Generic Manufacturer Property message
```

Public Members

```c
uint16_t property_id
    Property ID identifying a Generic Manufacturer Property
```

```c
struct esp_ble_mesh_server_recv_gen_client_properties_get_t
    Context of the received Generic Client Properties Get message
```
Public Members

`uint16_t property_id`
A starting Client Property ID present within an element

`struct esp_ble_mesh_server_recv_gen_onoff_set_t`
Context of the received Generic OnOff Set message

Public Members

`bool op_en`
Indicate if optional parameters are included

`uint8_t onoff`
Target value of Generic OnOff state

`uint8_t tid`
Transaction ID

`uint8_t trans_time`
Time to complete state transition (optional)

`uint8_t delay`
Indicate message execution delay (C.1)

`struct esp_ble_mesh_server_recv_gen_level_set_t`
Context of the received Generic Level Set message

Public Members

`bool op_en`
Indicate if optional parameters are included

`int16_t level`
Target value of Generic Level state

`uint8_t tid`
Transaction ID

`uint8_t trans_time`
Time to complete state transition (optional)

`uint8_t delay`
Indicate message execution delay (C.1)

`struct esp_ble_mesh_server_recv_gen_delta_set_t`
Context of the received Generic Delta Set message

Public Members

`bool op_en`
Indicate if optional parameters are included

`int32_t delta_level`
Delta change of Generic Level state

`uint8_t tid`
Transaction ID

`uint8_t trans_time`
Time to complete state transition (optional)
**Chapter 2. API Reference**

```
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

int32_t global_latitude
Global Coordinates (Latitude)

int32_t global_longitude
Global Coordinates (Longitude)

int16_t global_altitude
Global Altitude

struct esp_ble_mesh_server_recv_gen_loc_local_set_t
Context of the received Generic Location Local Set message

Public Members

int16_t local_north
Local Coordinates (North)

int16_t local_east
Local Coordinates (East)

int16_t local_altitude
Local Altitude

uint8_t floor_number
Floor Number

uint16_t uncertainty
Uncertainty

struct esp_ble_mesh_server_recv_gen_user_property_set_t
Context of the received Generic User Property Set message

Public Members

uint16_t property_id
Property ID identifying a Generic User Property

struct net_buf_simple *property_value
Raw value for the User Property
Chapter 2. API Reference

```c
struct esp_ble_mesh_server_recv_gen_admin_property_set_t
  Context of the received Generic Admin Property Set message

Public Members

uint16_t property_id
  Property ID identifying a Generic Admin Property

uint8_t user_access
  Enumeration indicating user access

struct net_buf_simple *property_value
  Raw value for the Admin Property

struct esp_ble_mesh_server_recv_gen_manufacturer_property_set_t
  Context of the received Generic Manufacturer Property Set message

Public Members

uint16_t property_id
  Property ID identifying a Generic Manufacturer Property

uint8_t user_access
  Enumeration indicating user access

struct esp_ble_mesh_generic_server_cb_param_t
  Generic Server Model callback parameters

Public Members

esp_ble_mesh_model_t *model
  Pointer to Generic Server Models

esp_ble_mesh_msg_ctx_t ctx
  Context of the received messages

esp_ble_mesh_generic_server_cb_value_t value
  Value of the received Generic Messages

Macros

ESP_BLE_MESH_MODEL_GEN_ONOFF_CLI(cli_pub, cli_data)
  Define a new Generic OnOff Client Model.

  Note This API needs to be called for each element on which the application needs to have a Generic OnOff
  Client Model.

  Return New Generic OnOff 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_LEVEL_CLI(cli_pub, cli_data)
  Define a new Generic Level Client Model.

  Note This API needs to be called for each element on which the application needs to have a Generic Level
  Client Model.

  Return New Generic 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_DEF_TRANS_TIME_CLI** (cli_pub, cli_data)
Define a new Generic Default Transition Time Client Model.

**Note** This API needs to be called for each element on which the application needs to have a Generic Default Transition Time Client Model.

**Return** New Generic Default Transition Time 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_POWER_ONOFF_CLI** (cli_pub, cli_data)
Define a new Generic Power OnOff Client Model.

**Note** This API needs to be called for each element on which the application needs to have a Generic Power OnOff Client Model.

**Return** New Generic Power OnOff 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_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 Property 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.
Chapter 2. API Reference

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.
1. 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.
1. 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.
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_srv_t`.

`ESP_BLE_MESH_MODEL_GEN_POWER_ONOFF_SETUP_SRV` (srv_pub, srv_data)
Define a new Generic Power OnOff Setup Server Model.

1. This model shall support model subscription.


Parameters
• srv_pub: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
• srv_data: Pointer to the unique struct `esp_ble_mesh_gen_power_onoff_setup_srv_t`.

`ESP_BLE_MESH_MODEL_GEN_POWER_LEVEL_SRV` (srv_pub, srv_data)
Define a new Generic Power Level Server Model.

Note 1. The Generic Power Level Server model extends the Generic Power OnOff Server model and the Generic Level Server model. When this model is present on an Element, the corresponding Generic Power Level Setup Server model shall also be present.
1. 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`.

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Chapter 2. API Reference

ESP_BLE_MESH_MODEL_GEN_POWER_LEVEL_SETUP_SRV (srv_pub, srv_data)
Define a new Generic Power Level Setup Server Model.

1. 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.
1. This model shall support model publication and model subscription.
2. The model may be used to represent an element that is powered by a battery.

Return New Generic Battery 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_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.
1. This model shall support model publication and model subscription.
2. 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.
1. 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.
1. 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.
1. 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.
   1. 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 User Property Server Model.

**Note** 1. The Generic Client Property Server model is a root model.
   1. 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:
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.
Chapter 2. API Reference

```c
esp_err_t esp_ble_mesh_sensor_client_get_state(esp_ble_mesh_client_common_param_t *params,
                                           esp_ble_mesh_sensor_client_get_state_t *get_state)
```

Get the value of Sensor Server Model states using the Sensor Client Model get messages.

**Note** If you want to know the opcodes and corresponding meanings accepted by this API, please refer to esp_ble_mesh_sensor_message_opcode_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.

```c
esp_err_t esp_ble_mesh_sensor_client_set_state(esp_ble_mesh_client_common_param_t *params,
                                              esp_ble_mesh_sensor_client_set_state_t *set_state)
```

Set the value of Sensor Server Model states using the Sensor Client Model set messages.

**Note** If you want to know the opcodes and corresponding meanings accepted by this API, please refer to esp_ble_mesh_sensor_message_opcode_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.

```c
esp_err_t esp_ble_mesh_register_sensor_server_callback(esp_ble_mesh_sensor_server_cb_t callback)
```

Register BLE Mesh Sensor Server Model callback.

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

**Parameters**
- `[in] callback`: Pointer to the callback function.

Unions

```c
union esp_ble_mesh_sensor_client_get_state_t
#include <esp_ble_mesh_sensor_model_api.h> Sensor Client Model get message union.
```

**Public Members**

```c
esp_ble_mesh_sensor_descriptor_get_t descriptor_get
For ESP_BLE_MESH_MODEL_OP_SENSOR_DESCRIPTOR_GET
```

```c
esp_ble_mesh_sensor_cadence_get_t cadence_get
For ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_GET
```

```c
esp_ble_mesh_sensor_settings_get_t settings_get
For ESP_BLE_MESH_MODEL_OP_SENSOR_SETTINGS_GET
```

```c
esp_ble_mesh_sensor_setting_get_t setting_get
For ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_GET
```

```c
esp_ble_mesh_sensor_get_t sensor_get
For ESP_BLE_MESH_MODEL_OP_SENSOR_GET
```

```c
esp_ble_mesh_sensor_column_get_t column_get
For ESP_BLE_MESH_MODEL_OP_SENSOR_COLUMN_GET
```

```c
esp_ble_mesh_sensor_series_get_t series_get
For ESP_BLE_MESH_MODEL_OP_SENSOR_SERIES_GET
```

```c
union esp_ble_mesh_sensor_client_set_state_t
#include <esp_ble_mesh_sensor_model_api.h> Sensor Client Model set message union.
```
Chapter 2. API Reference

Public Members

```c
esp_ble_mesh_sensor_cadence_set_t cadence_set
```n For ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_SET &
ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_SET_UNACK

```c
esp_ble_mesh_sensor_setting_set_t setting_set
```n 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

```c
#include <esp_ble_mesh_sensor_model_api.h>
```n Sensor Client Model received message union.

Public Members

```c
esp_ble_mesh_sensor_descriptor_status_cb_t descriptor_status
```n For ESP_BLE_MESH_MODEL_OP_SENSOR_DESCRIPTOR_STATUS

```c
esp_ble_mesh_sensor_cadence_status_cb_t cadence_status
```n For ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_STATUS

```c
esp_ble_mesh_sensor_settings_status_cb_t settings_status
```n For ESP_BLE_MESH_MODEL_OP_SENSOR_SETTINGS_STATUS

```c
esp_ble_mesh_sensor_setting_status_cb_t setting_status
```n For ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_STATUS

```c
esp_ble_mesh_sensor_status_cb_t sensor_status
```n For ESP_BLE_MESH_MODEL_OP_SENSOR_STATUS

```c
esp_ble_mesh_sensor_column_status_cb_t column_status
```n For ESP_BLE_MESH_MODEL_OP_SENSOR_COLUMN_STATUS

```c
esp_ble_mesh_sensor_series_status_cb_t series_status
```n For ESP_BLE_MESH_MODEL_OP_SENSOR_SERIES_STATUS

union esp_ble_mesh_sensor_server_state_change_t

```c
#include <esp_ble_mesh_sensor_model_api.h>
```n Sensor Server Model state change value union.

Public Members

```c
esp_ble_mesh_state_change_sensor_cadence_set_t sensor_cadence_set
```n 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
```n Sensor Setting Set

union esp_ble_mesh_sensor_server_recv_get_msg_t

```c
#include <esp_ble_mesh_sensor_model_api.h>
```n Sensor Server Model received get message union.

Public Members

```c
esp_ble_mesh_server_recv_sensor_descriptor_get_t sensor_descriptor
```n Sensor Descriptor Get

```c
esp_ble_mesh_server_recv_sensor_cadence_get_t sensor_cadence
```n Sensor Cadence Get

```c
esp_ble_mesh_server_recv_sensor_settings_get_t sensor_settings
```n Sensor Settings Get

```c
esp_ble_mesh_server_recv_sensor_setting_get_t sensor_setting
```n Sensor Setting Get
**Chapter 2. API Reference**

```c
#include <esp_ble_mesh_sensor_model_api.h>
```

- **Esp_BLE_Mesh_Server_Recv_Sensor_Get_t**
  - `sensor_data` Get

- **Esp_BLE_Mesh_Server_Recv_Sensor_Column_Get_t**
  - `sensor_column` Column Get

- **Esp_BLE_Mesh_Server_Recv_Sensor_Series_Get_t**
  - `sensor_series` Series Get

**union Esp_BLE_Mesh_Server_Recv_Set_Msg_t**
- #include `<esp_ble_mesh_sensor_model_api.h>` Sensor Server Model received set message union.

**Public Members**

- **Esp_BLE_Mesh_Server_Recv_Sensor_Cadence_Set_t**
  - `sensor_cadence` Cadence Set

- **Esp_BLE_Mesh_Server_Recv_Sensor_Setting_Set_t**
  - `sensor_setting` Setting Set

**union Esp_BLE_Mesh_Server_Callback_Value_t**
- #include `<esp_ble_mesh_sensor_model_api.h>` Sensor Server Model callback value union.

**Public Members**

- **Esp_BLE_Mesh_Server_State_Change_t**
  - `state_change` ESP_BLE_MESH_SENSOR_SERVER_STATE_CHANGE_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

  ```c
  bool op_en
  
  Property ID 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**

  ```c
  uint16_t property_id
  Property ID of a sensor
  ```

  **struct Esp_BLE_Mesh_Sensor_Cadence_Set_t**
  - Parameters of Sensor Cadence Set

  ```c
  uint16_t property_id
  Property ID of a sensor
  ```
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
Chapter 2. API Reference

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

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

uint8_t sensor_setting_access
Read/Write access rights for the setting (optional)

struct net_buf_simple *sensor_setting_raw
Raw value for the setting

struct esp_ble_mesh_sensor_status_cb_t
Parameter of Sensor Status

Public Members

struct net_buf_simple *marshalled_sensor_data
Value of sensor data state (optional)

struct esp_ble_mesh_sensor_column_status_cb_t
Parameters of Sensor Column Status

Public Members

uint16_t property_id
Property identifying a sensor and the Y axis

struct net_buf_simple *sensor_column_value
Left values of sensor column status

struct esp_ble_mesh_sensor_series_status_cb_t
Parameters of Sensor Series Status

Public Members

uint16_t property_id
Property identifying a sensor and the Y axis

struct net_buf_simple *sensor_series_value
Left values of sensor series status

struct esp_ble_mesh_sensor_client_cb_param_t
Sensor Client Model callback parameters
Public Members

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.

esp_bleMeshClientCommonParam_t*params
The client common parameters.

esp_bleMeshSensorClientStatusCb_tstatus_cb
The sensor status message callback values

struct esp_bleMeshSensorDescriptor_t
Parameters of Sensor Descriptor state

Public Members

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_tsampling_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_bleMeshSensorSetting_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_bleMeshSensorCadence_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
**Public Members**

```c
struct net_buf_simple *trigger_delta_up
  The value of Status Trigger Delta Up field
```

```c
uint8_t min_interval
  The value of Status Min Interval field
```

```c
struct net_buf_simple *fast_cadence_low
  The value of Fast Cadence Low field
```

```c
struct net_buf_simple *fast_cadence_high
  The value of Fast Cadence High field
```

```c
struct esp_ble_mesh_sensor_data_t
Parameters of Sensor Data state
```

```c
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
```

```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
```

```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
```
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

```c
const uint8_t state_count
```
Sensor state count

```c
esp_ble_mesh_sensor_state_t *states
```
Parameters of the Sensor states

```c
struct esp_ble_mesh_sensor_setup_srv_t
```
User data of Sensor Setup Server Model

**Public Members**

```c
esp_ble_mesh_model_t *model
```
Pointer to the Sensor Setup Server Model. Initialized internally.

```c
esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
```
Response control of the server model received messages

```c
const uint8_t state_count
```
Sensor state count

```c
esp_ble_mesh_sensor_state_t *states
```
Parameters of the Sensor states

```c
struct esp_ble_mesh_state_change_sensor_cadence_set_t
```
Parameters of Sensor Cadence Set state change event

**Public Members**

```c
uint16_t property_id
```
The value of Sensor Property ID state

```c
uint8_t period_divisor : 7
```
The value of Fast Cadence Period Divisor state

```c
uint8_t trigger_type : 1
```
The value of Status Trigger Type state

```c
struct net_buf_simple *trigger_delta_down
```
The value of Status Trigger Delta Down state
struct net_buf_simple *trigger_delta_up
    The value of Status Trigger Delta Up state

uint8_t min_interval
    The value of Status Min Interval state

struct net_buf_simple *fast_cadence_low
    The value of Fast Cadence Low state

struct net_buf_simple *fast_cadence_high
    The value of Fast Cadence High state

struct esp_ble_mesh_state_change_sensor_setting_set_t
    Parameters of Sensor Setting Set state change event

Public Members

uint16_t property_id
    The value of Sensor Property ID state

uint16_t setting_property_id
    The value of Sensor Setting Property ID state

struct net_buf_simple *setting_value
    The value of Sensor Property Value state

struct esp_ble_mesh_server_recv_sensor_descriptor_get_t
    Context of the received Sensor Descriptor Get message

Public Members

bool op_en
    Indicate if optional parameters are included

uint16_t property_id
    Property ID of a sensor (optional)

struct esp_ble_mesh_server_recv_sensor_cadence_get_t
    Context of the received Sensor Cadence Get message

Public Members

uint16_t property_id
    Property ID of a sensor

struct esp_ble_mesh_server_recv_sensor_settings_get_t
    Context of the received Sensor Settings Get message

Public Members

uint16_t property_id
    Property ID of a sensor

struct esp_ble_mesh_server_recv_sensor_setting_get_t
    Context of the received Sensor Setting Get message
Chapter 2. API Reference

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_get_t
Context of the received Sensor 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 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
Chapter 2. API Reference

Public Members

`uint16_t property_id`
Property ID identifying a sensor

`uint16_t setting_property_id`
Setting ID identifying a setting within a sensor

`struct net_buf_simple *setting_raw`
Raw value for the setting

`struct esp_ble_mesh_sensor_server_cb_param_t`
Sensor Server Model callback parameters

Public Members

`esp_ble_mesh_model_t *model`
Pointer to Sensor Server Models

`esp_ble_mesh_msg_ctx_t ctx`
Context of the received messages

`esp_ble_mesh_sensor_server_cb_value_t value`
Value of the received Sensor Messages

Macros

`ESP_BLE_MESH_MODEL_SENSOR_CLI(cli_pub, cli_data)`
Define a new Sensor Client Model.

**Note** This API needs to be called for each element on which the application needs to have a Sensor Client Model.

**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)`
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

ESP_BLE_MESH_SENSOR_SETTING_ACCESS_READ_WRITE
   Sensor Setting Access - Read & Write

ESP_BLE_MESH_SENSOR_DIVISOR_TRIGGER_TYPE_LEN
   Length of Sensor Divisor Trigger Type

ESP_BLE_MESH_SENSOR_STATUS_MIN_INTERVAL_LEN
   Length of Sensor Status Min Interval

ESP_BLE_MESH_SENSOR_PERIOD_DIVISOR_MAX_VALUE
   Maximum value of Sensor Period Divisor

ESP_BLE_MESH_SENSOR_STATUS_MIN_INTERVAL_MAX
   Maximum value of Sensor Status Min Interval

ESP_BLE_MESH_SENSOR_STATUS_TRIGGER_TYPE_CHAR
   Sensor Status Trigger Type - Format Type of the characteristic that the Sensor Property ID state references

ESP_BLE_MESH_SENSOR_STATUS_TRIGGER_TYPE_UINT16
   Sensor Status Trigger Type - Format Type “uint16”

ESP_BLE_MESH_SENSOR_DATA_FORMAT_A
   Sensor Data Format A

ESP_BLE_MESH_SENSOR_DATA_FORMAT_B
   Sensor Data Format B

ESP_BLE_MESH_SENSOR_DATA_FORMAT_A_MPID_LEN
   MPID length of Sensor Data Format A

ESP_BLE_MESH_SENSOR_DATA_FORMAT_B_MPID_LEN
   MPID length of Sensor Data Format B

ESP_BLE_MESH_SENSOR_DATA_ZERO_LEN
   Zero length of Sensor Data.

   Note: The Length field is a 1-based uint7 value (valid range 0x0-0x7F, representing range of 1–127). The value 0x7F represents a length of zero.

ESP_BLE_MESH_GET_SENSOR_DATA_FORMAT(_data)
   Get format of the sensor data.
Chapter 2. API Reference

**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.

`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. Property values longer than 128 octets are not supported by the Sensor Status message.
5. 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**

```c
typedef void (*esp_ble_mesh_sensor_client_cb_t)(esp_ble_mesh_sensor_client_cb_event_t event, esp_ble_mesh_sensor_client_cb_param_t *param)
```

Bluetooth Mesh Sensor Client Model function.

Sensor Client Model callback function type

**Parameters**
Bluetooth Mesh Sensor Server Model function.

Sensor Server 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)

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.

`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.

`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

`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

- `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
```

```c
esp_ble_mesh_time_zone_set_t time_zone_set
For ESP_BLE_MESH_MODEL_OP_TIME_ZONE_SET
```

```c
esp_ble_mesh_tai_utc_delta_set_t tai_utc_delta_set
For ESP_BLE_MESH_MODEL_OP_TAI_UTC_DELTA_SET
```

```c
esp_ble_mesh_time_role_set_t time_role_set
For ESP_BLE_MESH_MODEL_OP_TIME_ROLE_SET
```

```c
esp_ble_mesh_scene_store_t scene_store
For ESP_BLE_MESH_MODEL_OP_SCENE_STORE & ESP_BLE_MESH_MODEL_OP_SCENE_STORE_UNACK
```

```c
esp_ble_mesh_scene_recall_t scene_recall
For ESP_BLE_MESH_MODEL_OP_SCENE_RECALL & ESP_BLE_MESH_MODEL_OP_SCENE_RECALL_UNACK
```

```c
esp_ble_mesh_scene_delete_t scene_delete
For ESP_BLE_MESH_MODEL_OP_SCENE_DELETE & ESP_BLE_MESH_MODEL_OP_SCENE_DELETE_UNACK
```

```c
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
```

```c
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

```c
esp_ble_mesh_time_status_cb_t time_status
For ESP_BLE_MESH_MODEL_OP_TIME_STATUS
```

```c
esp_ble_mesh_time_zone_status_cb_t time_zone_status
For ESP_BLE_MESH_MODEL_OP_TIME_ZONE_STATUS
```

```c
esp_ble_mesh_tai_utc_delta_status_cb_t tai_utc_delta_status
For ESP_BLE_MESH_MODEL_OP_TAI_UTC_DELTA_STATUS
```

```c
esp_ble_mesh_time_role_status_cb_t time_role_status
For ESP_BLE_MESH_MODEL_OP_TIME_ROLE_STATUS
```

```c
esp_ble_mesh_scene_status_cb_t scene_status
For ESP_BLE_MESH_MODEL_OP_SCENE_STATUS
```

```c
esp_ble_mesh_scene_register_status_cb_t scene_register_status
For ESP_BLE_MESH_MODEL_OP_SCENE_REGISTER_STATUS
```

```c
esp_ble_mesh_scheduler_status_cb_t scheduler_status
For ESP_BLE_MESH_MODEL_OP_SCHEDULER_STATUS
```

```c
esp_ble_mesh_scheduler_act_status_cb_t scheduler_act_status
For ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_STATUS
```

```c
union esp_ble_mesh_time_scene_server_state_change_t
#include <esp_ble_mesh_time_scene_model_api.h> Time Scene Server Model state change value union.
```

Public Members

```c
esp_ble_mesh_state_change_time_set_t time_set
The recv_op in ctx can be used to decide which state is changed.Time Set
```
Chapter 2. API Reference

```c
#include <esp_ble_mesh_time_scene_model_api.h>

Public Members

**esp_ble_mesh_server_recv_scheduler_act_get_t** scheduler_act
Scheduler Action Get

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.

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.
```

```c
#include <esp_ble_mesh_time_scene_model_api.h>

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_set
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

**esp_ble_mesh_server_recv_scene_recall_t** scene_recall
Scene Recall

**esp_ble_mesh_server_recv_scene_delete_t** scene_delete
Scene Delete

**esp_ble_mesh_server_recv_scheduler_act_set_t** scheduler_act_set
Scheduler Action Set
```

```c
#include <esp_ble_mesh_time_scene_model_api.h>

union **esp_ble_mesh_time_scene_server_recv_get_msg_t**
#include <esp_ble_mesh_time_scene_model_api.h> Time Scene Server Model received get message union.
```
Public Members

```c
esp_ble_mesh_server_recv_time_status_t time_status
Time Status
```

```c
union esp_ble_mesh_time_scene_server_cb_value_t
#include <esp_ble_mesh_time_scene_model_api.h> Time Scene Server Model callback value union.
```

Public Members

```c
esp_ble_mesh_time_scene_server_state_change_t state_change
ESP_BLE_MESH_TIME_SCENE_SERVER_STATE_CHANGE_EVT
```

```c
esp_ble_mesh_time_scene_server_recv_get_msg_t get
ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_GET_MSG_EVT
```

```c
esp_ble_mesh_time_scene_server_recv_set_msg_t set
ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_SET_MSG_EVT
```

```c
esp_ble_mesh_time_scene_server_recv_status_msg_t status
ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_STATUS_MSG_EVT
```

Structures

```c
struct esp_ble_mesh_time_set_t
Bluetooth Mesh Time Scene Client Model Get and Set parameters structure.
```

Public Members

```c
uint8_t tai_seconds[5]
The current TAI time in seconds
```

```c
uint8_t sub_second
The sub-second time in units of 1/256 second
```

```c
uint8_t uncertainty
The estimated uncertainty in 10-millisecond steps
```

```c
uint16_t time_authority : 1
0 = No Time Authority, 1 = Time Authority
```

```c
uint16_t tai_utc_delta : 15
Current difference between TAI and UTC in seconds
```

```c
uint8_t time_zone_offset
The local time zone offset in 15-minute increments
```

```c
struct esp_ble_mesh_time_zone_set_t
Parameters of Time Zone Set
```

Public Members

```c
uint8_t time_zone_offset_new
Upcoming local time zone offset
```

```c
uint8_t tai_zone_change[5]
TAI Seconds time of the upcoming Time Zone Offset change
```

```c
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

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
Chapter 2. API Reference

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

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_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


```c
uint8_t time_zone_offset
    The local time zone offset in 15-minute increments

struct esp_ble_mesh_time_zone_status_cb_t
    Parameters of Time Zone Status
```

**Public Members**

- `uint8_t time_zone_offset_curr`
  Current local time zone offset
- `uint8_t time_zone_offset_new`
  Upcoming local time zone offset
- `uint8_t tai_zone_change[5]`
  TAI Seconds time of the upcoming Time Zone Offset change

```c
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
- `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

```c
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

```c
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
Parameters 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
  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_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

    uint8_t uncertainty
        The value of the Uncertainty field

    uint8_t time_zone_offset_curr
        The value of the Time Zone Offset Current field

    uint8_t time_zone_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.
Chapter 2. API Reference

**esp_ble_mesh_server_rsp_ctrl_t**
- **rst_ctrl**
  - Response control of the server model received messages

**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**
- **rst_ctrl**
  - Response control of the server model received messages

**esp_ble_mesh_time_state_t**
- **state**
  - Parameters of the Time state

**struct esp_ble_mesh_time_setup_srv_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

`exp_ble_mesh_scene_register_t *scenes`
Parameters of the Scenes state

uint16_t `current_scene`
The Current Scene state is a 16-bit value that contains either the Scene Number of the currently active scene or a value of 0x0000 when no scene is active.

When a Scene Store operation or a Scene Recall operation completes with success, the Current Scene state value shall be to the Scene Number used during that operation.

When the Current Scene Number is deleted from a Scene Register state as a result of Scene Delete operation, the Current Scene state shall be set to 0x0000.

When any of the element’s state that is marked as “Stored with Scene” has changed not as a result of a Scene Recall operation, the value of the Current Scene state shall be set to 0x0000.

When a scene transition is in progress, the value of the Current Scene state shall be set to 0x0000. The value of the Current Scene state

uint16_t `target_scene`
The Target Scene state is a 16-bit value that contains the target Scene Number when a scene transition is in progress.

When the scene transition is in progress and the target Scene Number is deleted from a Scene Register state as a result of Scene Delete operation, the Target Scene state shall be set to 0x0000.

When the scene transition is in progress and a new Scene Number is stored in the Scene Register as a result of Scene Store operation, the Target Scene state shall be set to the new Scene Number.

When the scene transition is not in progress, the value of the Target Scene state shall be set to 0x0000. The value of the Target Scene state

uint8_t `status_code`
The status code of the last scene operation

bool `in_progress`
Indicate if the scene transition is in progress

`struct esp_ble_mesh_scene_srv_t`
User data of Scene Server Model

Public Members

`exp_ble_mesh_model_t *model`
Pointer to the Scene Server Model. Initialized internally.

`exp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl`
Response control of the server model received messages

`exp_ble_mesh_scenes_state_t *state`
Parameters of the Scenes state

`exp_ble_mesh_last_msg_info_t *last`
Parameters of the last received set message

`exp_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

uint64_t `second`: 6
   
   The value of Scheduled second for the action

uint64_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* 
Pointer to the Scheduler Server Model. Initialized internally.

*esp_ble_mesh_server_rsp_ctrl_t* 
Response control of the server model received messages

*esp_ble_mesh_scheduler_state_t* 
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* 
Pointer to the Scheduler Setup Server Model. Initialized internally.

*esp_ble_mesh_server_rsp_ctrl_t* 
Response control of the server model received messages

*esp_ble_mesh_scheduler_state_t* 
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 : 1**
0 = No Time Authority, 1 = Time Authority

**uint16_t tai_utc_delta_curr : 15**
Current difference between TAI and UTC in seconds

**uint8_t time_zone_offset_curr**
The local time zone offset in 15-minute increments

**struct esp_ble_mesh_state_change_time_status_t**
Parameters of Time Status state change event

Public Members

**uint8_t 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_curr**: 15
  Current difference between TAI and UTC in seconds

uint8_t **time_zone_offset_curr**
  The local time zone offset in 15-minute increments

**struct esp_ble_mesh_state_change_time_zone_set_t**
Parameters of Time Zone Set state change event

**Public Members**

uint8_t **time_zone_offset_new**
  Upcoming local time zone offset

uint8_t **tai_zone_change[5]**
  TAI Seconds time of the upcoming Time Zone Offset change

**struct esp_ble_mesh_state_change_tai_utc_delta_set_t**
Parameters of TAI UTC Delta Set state change event

**Public Members**

uint16_t **tai_utc_delta_new**: 15
  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

tuint64_t year : 7
Scheduled year for the action

tuint64_t month : 12
Scheduled month for the action

tuint64_t day : 5
Scheduled day of the month for the action

tuint64_t hour : 5
Scheduled hour for the action

tuint64_t minute : 6
Scheduled minute for the action

tuint64_t second : 6
Scheduled second for the action

tuint64_t day_of_week : 7
Schedule days of the week for the action

tuint64_t action : 4
Action to be performed at the scheduled time

tuint64_t trans_time : 8
Transition time for this action

tuint16_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 time zone offset in 15-minute increments

struct esp_ble_mesh_server_recv_time_zone_set_t
Context of the received Time Zone Set message

Public Members

uint8_t time_zone_offset_new
Upcoming local time zone offset

uint8_t tai_zone_change[5]
TAI 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
Chapter 2. API Reference

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 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
   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_time_status_t
   Context of the received Time Status message
Public Members

uint8_t tai_seconds[5]
    The current TAI time in seconds

uint8_t subsecond
    The sub-second time in units of 1/256 second

uint8_t uncertainty
    The estimated uncertainty in 10-millisecond steps

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_scene_server_cb_param_t
    Time Scene Server Model callback parameters

Public Members

esp_ble_mesh_model_t *model
    Pointer to Time and Scenes Server Models

esp_ble_mesh_msg_ctx_t ctx
    Context of the received messages

esp_ble_mesh_time_scene_server_cb_value_t value
    Value of the received Time and Scenes Messages

Macros

ESP_BLE_MESH_MODEL_TIME_CLI (cli_pub, cli_data)
    Define a new Time Client Model.
    Note This API needs to be called for each element on which the application needs to have a Time Client Model.
    Return New Time 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_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.
Chapter 2. API Reference

**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.

**Return** New 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_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.

**Return** New Time Setup Server Model instance.

**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.
   1. This model shall support model subscription.
   2. 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.
   1. This model shall support model publication and model subscription.
   2. The model may be present only on the Primary element of a node.
   3. 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`.
Chapter 2. API Reference

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_CLINET
Time Role - Mesh Time Client

ESP_BLE_MESH_SCENE_SUCCESS
Scene operation - Success

ESP_BLE_MESH_SCENE_REG_FULL
Scene operation - Scene Register Full

ESP_BLE_MESH_SCENE_NOT_FOUND
Scene operation - Scene Not Found

**Type Definitions**

```c
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

```c
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
**Enumerations**

```c
enum esp_ble_mesh_time_scene_client_cb_event_t
{
    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
};
```

This enum value is the event of Time Scene Client Model

**Values:**

1. `ESP_BLE_MESH_TIME_SCENE_CLIENT_GET_STATE_EVT`
2. `ESP_BLE_MESH_TIME_SCENE_CLIENT_SET_STATE_EVT`
3. `ESP_BLE_MESH_TIME_SCENE_CLIENT_PUBLISH_EVT`
4. `ESP_BLE_MESH_TIME_SCENE_CLIENT_TIMEOUT_EVT`
5. `ESP_BLE_MESH_TIME_SCENE_CLIENT_EVT_MAX`  

```c
enum esp_ble_mesh_time_scene_server_cb_event_t
{
    ESP_BLE_MESH_TIME_SCENE_SERVER_STATE_CHANGE_EVT,
    ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_GET_MSG_EVT,
    ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_SET_MSG_EVT,
    ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_STATUS_MSG_EVT,
    ESP_BLE_MESH_TIME_SCENE_SERVER_EVT_MAX
};
```

This enum value is the event of Time Scene Server Model

**Values:**

1. `ESP_BLE_MESH_TIME_SCENE_SERVER_STATE_CHANGE_EVT`
2. `ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_GET_MSG_EVT`
3. `ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_SET_MSG_EVT`
4. `ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_STATUS_MSG_EVT`

**Lighting Client/Server Models**

**Header File**

```c
#include <esp_ble_mesh_lighting_model_api.h>
```

**Functions**

```c
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.

```c
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

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

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

union esp_ble_mesh_light_client_set_state_t

#include <esp_ble_mesh_lighting_model_api.h> Lighting Client Model set message union.
Chapter 2. API Reference

```
# include <esp_ble_mesh_lighting_model_api.h> Lighting Client Model received message union.

union esp_ble_mesh_light_client_status_cb_t
Public Members

esp_ble_mesh_light_lightness_status_cb_t lightness_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_STATUS

esp_ble_mesh_light_lightness_linear_status_cb_t lightness_linear_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_STATUS

esp_ble_mesh_light_lightness_last_status_cb_t lightness_last_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LAST_STATUS
```
Chapter 2. API Reference

```c
esp_ble_mesh_light_lightness_default_status_cb_t lightness_default_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_STATUS

esp_ble_mesh_light_lightness_range_status_cb_t lightness_range_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_STATUS

esp_ble_mesh_light_ctl_status_cb_t ctl_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_STATUS

esp_ble_mesh_light_ctl_temperature_status_cb_t ctl_temperature_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_STATUS

esp_ble_mesh_light_ctl_temperature_range_status_cb_t ctl_temperature_range_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_STATUS

esp_ble_mesh_light_ctl_default_status_cb_t ctl_default_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_STATUS

esp_ble_mesh_light_hsl_status_cb_t hsl_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_STATUS

esp_ble_mesh_light_hsl_target_status_cb_t hsl_target_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_TARGET_STATUS

esp_ble_mesh_light_hsl_hue_status_cb_t hsl_hue_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_STATUS

esp_ble_mesh_light_hsl_saturation_status_cb_t hsl_saturation_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_STATUS

esp_ble_mesh_light_hsl_default_status_cb_t hsl_default_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_STATUS

esp_ble_mesh_light_hsl_range_status_cb_t hsl_range_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_STATUS

esp_ble_mesh_light_xyl_status_cb_t xyl_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_STATUS

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_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
**Chapter 2. API Reference**

```c
#include <esp_ble_mesh_lighting_model_api.h>

public:
    union esp_ble_mesh_lighting_server_recv_get_msg_t
    {
        esp_ble_mesh_state_change_light_lightness_linear_set_t lightness_linear_set
            Light Lightness Linear Set
        esp_ble_mesh_state_change_light_lightness_default_set_t lightness_default_set
            Light Lightness Default Set
        esp_ble_mesh_state_change_light_lightness_range_set_t lightness_range_set
            Light Lightness Range Set
        esp_ble_mesh_state_change_light_ctl_set_t ctl_set
            Light CTL Set
        esp_ble_mesh_state_change_light_ctl_temperature_set_t ctl_temp_set
            Light CTL Temperature Set
        esp_ble_mesh_state_change_light_ctl_temperature_range_set_t ctl_temp_range_set
            Light CTL Temperature Range Set
        esp_ble_mesh_state_change_light_ctl_default_set_t ctl_default_set
            Light CTL Default Set
        esp_ble_mesh_state_change_light_hsl_set_t hsl_set
            Light HSL Set
        esp_ble_mesh_state_change_light_hsl_hue_set_t hsl_hue_set
            Light HSL Hue Set
        esp_ble_mesh_state_change_light_hsl_saturation_set_t hsl_saturation_set
            Light HSL Saturation Set
        esp_ble_mesh_state_change_light_hsl_default_set_t hsl_default_set
            Light HSL Default Set
        esp_ble_mesh_state_change_light_hsl_range_set_t hsl_range_set
            Light HSL Range Set
        esp_ble_mesh_state_change_light_xyl_set_t xyl_set
            Light xyl Set
        esp_ble_mesh_state_change_light_xyl_default_set_t xyl_default_set
            Light xyl Default Set
        esp_ble_mesh_state_change_light_xyl_range_set_t xyl_range_set
            Light xyl Range Set
        esp_ble_mesh_state_change_light_lc_mode_set_t lc_mode_set
            Light LC Mode Set
        esp_ble_mesh_state_change_light_lc_om_set_t lc_om_set
            Light LC Occupancy Mode Set
        esp_ble_mesh_state_change_light_lc_light_onoff_set_t lc_light_onoff_set
            Light LC Light OnOff Set
        esp_ble_mesh_state_change_light_lc_property_set_t lc_property_set
            Light LC Property Set
        esp_ble_mesh_state_change_sensor_status_t sensor_status
            Sensor Status
    }

union esp_ble_mesh_lighting_server_recv_get_msg_t
    #include <esp_ble_mesh_lighting_model_api.h> Lighting Server Model received get message union.

**Public Members**

esp_ble_mesh_server_recv_light_lc_property_get_t lc_property
    Light LC Property Get
union esp_ble_mesh_lighting_server_recv_set_msg_t
#include <esp_ble_mesh_lighting_model_api.h> Lighting Server Model received set message union.

Public Members

esp_ble_mesh_server_recv_light_lightness_set_t lightness
Light Lightness Set/Light Lightness Set Unack

esp_ble_mesh_server_recv_light_lightness_linear_set_t lightness_linear
Light Lightness Linear Set/Light Lightness Linear Set Unack

esp_ble_mesh_server_recv_light_lightness_default_set_t lightness_default
Light Lightness Default Set/Light Lightness Default Set Unack

esp_ble_mesh_server_recv_light_lightness_range_set_t lightness_range
Light Lightness Range Set/Light Lightness Range Set Unack

esp_ble_mesh_server_recv_light_ctl_set_t ctl
Light CTL Set/Light CTL Set Unack

esp_ble_mesh_server_recv_light_ctl_temperature_set_t ctl_temp
Light CTL Temperature Set/Light CTL Temperature Set Unack

esp_ble_mesh_server_recv_light_ctl_temperature_range_set_t ctl_temp_range
Light CTL Temperature Range Set/Light CTL Temperature Range Set Unack

esp_ble_mesh_server_recv_light_ctl_default_set_t ctl_default
Light CTL Default Set/Light CTL Default Set Unack

esp_ble_mesh_server_recv_light_hsl_set_t hsl
Light HSL Set/Light HSL Set Unack

esp_ble_mesh_server_recv_light_hsl_hue_set_t hsl_hue
Light HSL Hue Set/Light HSL Hue Set Unack

esp_ble_mesh_server_recv_light_hsl_saturation_set_t hsl_saturation
Light HSL Saturation Set/Light HSL Saturation Set Unack

esp_ble_mesh_server_recv_light_hsl_default_set_t hsl_default
Light HSL Default Set/Light HSL Default Set Unack

esp_ble_mesh_server_recv_light_hsl_range_set_t hsl_range
Light HSL Range Set/Light HSL Range Set Unack

esp_ble_mesh_server_recv_light_xyl_set_t xyl
Light xyL Set/Light xyL Set Unack

esp_ble_mesh_server_recv_light_xyl_default_set_t xyl_default
Light xyL Default Set/Light xyL Default Set Unack

esp_ble_mesh_server_recv_light_xyl_range_set_t xyl_range
Light xyL Range Set/Light xyL Range Set Unack

esp_ble_mesh_server_recv_light_lc_mode_set_t lc_mode
Light LC Mode Set/Light LC Mode Set Unack

esp_ble_mesh_server_recv_light_lc_om_set_t lc_om
Light LC OM Set/Light LC OM Set Unack

esp_ble_mesh_server_recv_light_lc_light_onoff_set_t lc_light_onoff
Light LC Light OnOff Set/Light LC Light OnOff Set Unack

esp_ble_mesh_server_recv_light_lc_property_set_t lc_property
Light LC Property Set/Light LC Property Set Unack

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.
Chapter 2. API Reference

Public Members

```c
esp_ble_mesh_server_recv_sensor_status_t sensor_status
```
Sensor Status

```c
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

```c
esp_ble_mesh_lighting_server_state_change_t state_change
```
ESP_BLE_MESH_LIGHTING_SERVER_STATE_CHANGE_EVT

```c
esp_ble_mesh_lighting_server_recv_get_msg_t get
```
ESP_BLE_MESH_LIGHTING_SERVER_RECV_GET_MSG_EVT

```c
esp_ble_mesh_lighting_server_recv_set_msg_t set
```
ESP_BLE_MESH_LIGHTING_SERVER_RECV_SET_MSG_EVT

```c
esp_ble_mesh_lighting_server_recv_status_msg_t status
```
ESP_BLE_MESH_LIGHTING_SERVER_RECV_STATUS_MSG_EVT

Structures

```c
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

```c
bool op_en
```
Indicate if optional parameters are included

```c
uint16_t lightness
```
Target value of light lightness actual state

```c
uint8_t tid
```
Transaction ID

```c
uint8_t trans_time
```
Time to complete state transition (optional)

```c
uint8_t delay
```
Indicate message execution delay (C.1)

```c
struct esp_ble_mesh_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)
**Chapter 2. API Reference**

```cpp
uint8_t delay
    Indicate message execution delay (C.1)

struct esp_ble_mesh_light_lightness_default_set_t
    Parameter of Light Lightness Default Set

Public Members

uint16_t lightness
    The value of the Light Lightness Default state

struct esp_ble_mesh_light_lightness_range_set_t
    Parameters of Light Lightness Range Set

Public Members

uint16_t range_min
    Value of range min field of light lightness range state
uint16_t range_max
    Value of range max field of light lightness range state

struct esp_ble_mesh_light_ctl_set_t
    Parameters of Light CTL Set

Public Members

bool op_en
    Indicate if optional parameters are included
uint16_t ctl_lightness
    Target value of light ctl lightness state
uint16_t ctl_temperatrue
    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_temperatrue
    Target value of light ctl temperature state
int16_t ctl_delta_uv
    Target value of light ctl delta UV state
```

Espressif Systems 484 Release v5.0-dev-1077-g397639d
Chapter 2. API Reference

```c
uint8_t tid
Transaction ID

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)
```

```c
struct esp_ble_mesh_light_ctl_temperature_range_set_t
Parameters of Light CTL Temperature Range Set

Public Members

uint16_t range_min
Value of temperature range min field of light ctl temperature range state

uint16_t range_max
Value of temperature range max field of light ctl temperature range state
```

```c
struct esp_ble_mesh_light_ctl_default_set_t
Parameters of Light CTL Default Set

Public Members

uint16_t lightness
Value of light lightness default state

uint16_t temperature
Value of light temperature default state

int16_t delta_uv
Value of light delta UV default state
```

```c
struct esp_ble_mesh_light_hsl_set_t
Parameters of Light HSL Set

Public Members

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
```

```c
struct esp_ble_mesh_light_hsl_hue_set_t
Parameters of Light HSL Hue Set

Public Members

uint8_t tid
Transaction ID

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)
Public Members

bool op_en
  Indicate if optional parameters are included

uint16_t hue
  Target value of light hsl hue state

uint8_t tid
  Transaction ID

uint8_t trans_time
  Time to complete state transition (optional)

uint8_t delay
  Indicate message execution delay (C.1)

struct esp_ble_mesh_light_hsl_saturation_set_t
Parameters of Light HSL Saturation Set

Public Members

bool op_en
  Indicate if optional parameters are included

uint16_t saturation
  Target value of light hsl hue state

uint8_t tid
  Transaction ID

uint8_t trans_time
  Time to complete state transition (optional)

uint8_t delay
  Indicate message execution delay (C.1)

struct esp_ble_mesh_light_hsl_default_set_t
Parameters of Light HSL Default Set

Public Members

uint16_t lightness
  Value of light lightness default state

uint16_t hue
  Value of light hue default state

uint16_t saturation
  Value of light saturation default state

struct esp_ble_mesh_light_hsl_range_set_t
Parameters of Light HSL Range Set

Public Members

uint16_t hue_range_min
  Value of hue range min field of light hsl hue range state

uint16_t hue_range_max
  Value of hue range max field of light hsl hue range state
uint16_t saturation_range_min
Value of saturation range min field of light hsl saturation range state

uint16_t saturation_range_max
Value of saturation range max field of light hsl saturation range state

struct esp_ble_mesh_light_xyl_set_t
Parameters of Light xyl Set

Public Members

bool op_en
  Indicate whether optional parameters included

uint16_t xyl_lightness
The target value of the Light xyl Lightness state

uint16_t xyl_x
The target value of the Light xyl x state

uint16_t xyl_y
The target value of the Light xyl y state

uint8_t tid
Transaction Identifier

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)

struct esp_ble_mesh_light_xyl_default_set_t
Parameters of Light xyl Default Set

Public Members

uint16_t lightness
The value of the Light Lightness Default state

uint16_t xyl_x
The value of the Light xyl x Default state

uint16_t xyl_y
The value of the Light xyl y Default state

struct esp_ble_mesh_light_xyl_range_set_t
Parameters of Light xyl Range Set

Public Members

uint16_t xyl_x_range_min
The value of the xyl x Range Min field of the Light xyl x Range state

uint16_t xyl_x_range_max
The value of the xyl x Range Max field of the Light xyl x Range state

uint16_t xyl_y_range_min
The value of the xyl y Range Min field of the Light xyl y Range state

uint16_t xyl_y_range_max
The value of the xyl y Range Max field of the Light xyl y Range state
struct esp_ble_mesh_light_lc_mode_set_t
Parameter of Light LC Mode Set

Public Members

uint8_t mode
The target value of the Light LC Mode state

struct esp_ble_mesh_light_lc_om_set_t
Parameter of Light LC OM Set

Public Members

uint8_t mode
The target value of the Light LC Occupancy Mode state

struct esp_ble_mesh_light_lc_light_onoff_set_t
Parameters of Light LC Light OnOff Set

Public Members

bool op_en
Indicate whether optional parameters included

uint8_t light_onoff
The target value of the Light LC Light OnOff state

uint8_t tid
Transaction Identifier

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)

struct esp_ble_mesh_light_lc_property_get_t
Parameter of Light LC Property Get

Public Members

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
Chapter 2. API Reference

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

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

```c
uint16_t lightness
    Value of light lightness default state
```

```c
uint16_t temperature
    Value of light temperature default state
```

```c
int16_t delta_uv
    Value of light delta UV default state
```

```c
struct esp_ble_mesh_light_hsl_status_cb_t
    Parameters of Light HSL Status
```

Public Members

```c
bool op_en
    Indicate if optional parameters are included
```

```c
uint16_t hsl_lightness
    Current value of light hsl lightness state
```

```c
uint16_t hsl_hue
    Current value of light hsl hue state
```

```c
uint16_t hsl_saturation
    Current value of light hsl saturation state
```

```c
uint8_t remain_time
    Time to complete state transition (optional)
```

```c
struct esp_ble_mesh_light_hsl_target_status_cb_t
    Parameters of Light HSL Target Status
```

Public Members

```c
bool op_en
    Indicate if optional parameters are included
```

```c
uint16_t hsl_lightness_target
    Target value of light hsl lightness state
```

```c
uint16_t hsl_hue_target
    Target value of light hsl hue state
```

```c
uint16_t hsl_saturation_target
    Target value of light hsl saturation state
```

```c
uint8_t remain_time
    Time to complete state transition (optional)
```

```c
struct esp_ble_mesh_light_hsl_hue_status_cb_t
    Parameters of Light HSL Hue Status
```

Public Members

```c
bool op_en
    Indicate if optional parameters are included
```

```c
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

uint8_t target_light_onoff
    The target value of the Light LC Light OnOff state (Optional)

uint8_t remain_time
    Time to complete state transition (C.1)

struct esp_ble_mesh_light_lc_property_status_cb_t
    Parameters of Light LC Property Status

Public Members

uint16_t property_id
    Property ID identifying a Light LC Property

struct net_buf_simple *property_value
    Raw value for the Light LC Property

struct esp_ble_mesh_light_client_cb_param_t
    Lighting Client Model callback parameters
Public Members

int **error_code**
Appropriate error code

*esp_ble_mesh_client_common_param_t* **params**
The client common parameters.

*esp_ble_mesh_light_client_status_cb_t* **status_cb**
The light status message callback values

*struct esp_ble_mesh_light_lightness_state_t*
Parameters of Light Lightness state

Public Members

uint16_t **lightness_linear**
The present value of Light Lightness Linear state

uint16_t **target_lightness_linear**
The target value of Light Lightness Linear state

uint16_t **lightness_actual**
The present value of Light Lightness Actual state

uint16_t **target_lightness_actual**
The target value of Light Lightness Actual state

uint16_t **lightness_last**
The value of Light Lightness Last state

uint16_t **lightness_default**
The value of Light Lightness Default state

uint8_t **status_code**
The status code of setting Light Lightness Range state

uint16_t **lightness_range_min**
The minimum value of Light Lightness Range state

uint16_t **lightness_range_max**
The maximum value of Light Lightness Range state

*struct esp_ble_mesh_light_lightness_srv_t*
User data of Light Lightness Server Model

Public Members

*esp_ble_mesh_model_t* **model**
Pointer to the Lighting Lightness Server Model. Initialized internally.

*esp_ble_mesh_server_rsp_ctrl_t* **rsp_ctrl**
Response control of the server model received messages

*esp_ble_mesh_light_lightness_state_t* **state**
Parameters of the Light Lightness state

*esp_ble_mesh_last_msg_info_t* **last**
Parameters of the last received set message

*esp_ble_mesh_state_transition_t* **actual_transition**
Parameters of state transition

*esp_ble_mesh_state_transition_t* **linear_transition**
Parameters of state transition
int32_t *tt_delta_lightness_actual
    Delta change value of lightness actual state transition

int32_t *tt_delta_lightness_linear
    Delta change value of lightness linear state transition

struct esp_ble_mesh_light_lightness_setup_srv_t
User data of Light Lightness Setup Server Model

Public Members

esp_ble_mesh_model_t *model
    Pointer to the Lighting Lightness Setup Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
    Response control of the server model received messages

esp_ble_mesh_light_lightness_state_t *state
    Parameters of the Light Lightness state

struct esp_ble_mesh_light_ctl_state_t
Parameters of Light CTL state

Public Members

uint16_t lightness
    The present value of Light CTL Lightness state

uint16_t target_lightness
    The target value of Light CTL Lightness state

uint16_t temperature
    The present value of Light CTL Temperature state

uint16_t target_temperature
    The target value of Light CTL Temperature state

int16_t delta_uv
    The present value of Light CTL Delta UV state

int16_t target_delta_uv
    The target value of Light CTL Delta UV state

uint8_t status_code
    The 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

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 xyL 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 x_range_max
The maximum value of Light xyL x Range state

uint16_t y_range_min
The minimum value of Light xyL y Range state

uint16_t y_range_max
The maximum value of Light xyL y Range state

struct esp_ble_mesh_light_xyl_srv_t
User data of Light xyL Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Lighting xyL Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages

esp_ble_mesh_light_xyl_state_t *state
Parameters of the Light xyL state
```
### esp_ble_mesh_last_msg_info_t
Parameters of the last received set message

### esp_ble_mesh_state_transition_t
Parameters of state transition

- int32_t tt_delta_lightness
  Delta change value of lightness state transition

- int32_t tt_delta_x
  Delta change value of x state transition

- int32_t tt_delta_y
  Delta change value of y state transition

### struct esp_ble_mesh_light_xyl_setup_srv_t
User data of Light xyl Setup Server Model

#### Public Members

- esp_ble_mesh_model_t *model
  Pointer to the Lighting xyl Setup Server Model. Initialized internally.

- esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
  Response control of the server model received messages

- esp_ble_mesh_light_xyl_state_t *state
  Parameters of the Light xyl state

### struct esp_ble_mesh_light_lc_state_t
Parameters of Light LC states

#### Public Members

- uint32_t mode
  The controller is turned off.
  - 0b0 The binding with the Light Lightness state is disabled.
  - 0b1 The controller is turned on.

- uint32_t occupancy_mode
  The value of Light LC Occupancy Mode state

- uint32_t light_onoff
  The present value of Light LC Light OnOff state

- uint32_t target_light_onoff
  The target value of Light LC Light OnOff state

- uint32_t occupancy
  The value of Light LC Occupancy state

- uint32_t ambient_luxlevel
  The value of Light LC Ambient LuxLevel state

- uint16_t linear_output
  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
Chapter 2. API Reference

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 the value of the Light LC Occupancy Delay state and the received Time Since Motion value

struct esp_ble_mesh_light_lc_state_machine_t
Parameters of Light LC state machine

Public Members

uint8_t fade_on
The value of transition time of Light LC Time Fade On

uint8_t fade
The value of transition time of Light LC Time Fade

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

```c
uint16_t lightness
The value of Light Lightness Linear state
```

```c
struct esp_ble_mesh_state_change_light_lightness_default_set_t
Parameter of Light Lightness Default state change event
```

Public Members

```c
uint16_t lightness
The value of Light Lightness Default state
```

```c
struct esp_ble_mesh_state_change_light_lightness_range_set_t
Parameters of Light Lightness Range state change event
```

Public Members

```c
uint16_t range_min
The minimum value of Light Lightness Range state
```

```c
uint16_t range_max
The maximum value of Light Lightness Range state
```

```c
struct esp_ble_mesh_state_change_light_ctl_set_t
Parameters of Light CTL state change event
```

Public Members

```c
uint16_t lightness
The value of Light CTL Lightness state
```

```c
uint16_t temperature
The value of Light CTL Temperature state
```

```c
int16_t delta_uv
The value of Light CTL Delta UV state
```

```c
struct esp_ble_mesh_state_change_light_ctl_temperature_set_t
Parameters of Light CTL Temperature state change event
```

Public Members

```c
uint16_t temperature
The value of Light CTL Temperature state
```

```c
int16_t delta_uv
The value of Light CTL Delta UV state
```

```c
struct esp_ble_mesh_state_change_light_ctl_temperature_range_set_t
Parameters of Light CTL Temperature Range state change event
```

Public Members

```c
uint16_t range_min
The minimum value of Light CTL Temperature Range state
```

```c
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_onoff_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

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)

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 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)
Public Members

bool op_en
Indicate if optional parameters are included

uint16_t saturation
Target value of light hsl hue state

uint8_t tid
Transaction ID

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)

struct esp_ble_mesh_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

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
Chapter 2. API Reference

\texttt{uint16_t \ y}

The target value of the Light xyL y state

\texttt{uint8_t \ tid}

Transaction Identifier

\texttt{uint8_t \ trans_time}

Time to complete state transition (optional)

\texttt{uint8_t \ delay}

Indicate message execution delay (C.1)

\textbf{struct esp_ble_mesh_server_recv_light_xyl_default_set_t}

Context of the received Light xyL Default Set message

\textbf{Public Members}

\texttt{uint16_t \ lightness}

The value of the Light Lightness Default state

\texttt{uint16_t \ x}

The value of the Light xyL x Default state

\texttt{uint16_t \ y}

The value of the Light xyL y Default state

\textbf{struct esp_ble_mesh_server_recv_light_xyl_range_set_t}

Context of the received Light xyL Range Set message

\textbf{Public Members}

\texttt{uint16_t \ x_range_min}

The value of the xyL x Range Min field of the Light xyL x Range state

\texttt{uint16_t \ x_range_max}

The value of the xyL x Range Max field of the Light xyL x Range state

\texttt{uint16_t \ y_range_min}

The value of the xyL y Range Min field of the Light xyL y Range state

\texttt{uint16_t \ y_range_max}

The value of the xyL y Range Max field of the Light xyL y Range state

\textbf{struct esp_ble_mesh_server_recv_light_lc_mode_set_t}

Context of the received Light LC Mode Set message

\textbf{Public Members}

\texttt{uint8_t \ mode}

The target value of the Light LC Mode state

\textbf{struct esp_ble_mesh_server_recv_light_lc_om_set_t}

Context of the received Light OM Set message

\textbf{Public Members}

\texttt{uint8_t \ mode}

The target value of the Light LC Occupancy Mode state

\textbf{struct esp_ble_mesh_server_recv_light_lc_light_onoff_set_t}

Context of the received Light LC Light OnOff Set message

\textbf{Public Members}

\texttt{uint8_t \ mode}

The target value of the Light LC Light OnOff Set state
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

esp_ble_mesh_model_t *model
  Pointer to Lighting Server Models

esp_ble_mesh_msg_ctx_t ctx
  Context of the received messages

esp_ble_mesh_lighting_server_cb_value_t value
  Value of the received Lighting Messages

Macros

ESP_BLE_MESH_MODEL_LIGHT_LIGHTNESS_CLI (cli_pub, cli_data)
  Define a new Light Lightness Client Model.

Note  This API needs to be called for each element on which the application needs to have a Light Lightness Client Model.

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.
Chapter 2. API Reference

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.

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.

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.

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.

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.

1. This model shall support model subscription.
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.
1. This model shall support model publication and model subscription.

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.
1. This model shall support model publication and model subscription.

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.
Chapter 2. API Reference

1. The Light LC (Lightness Control) Setup model extends the Light LC Server model.
2. This model shall support model publication and model subscription.
3. 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

```c
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

```c
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

```c
enum 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
Chapter 2. API Reference

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 usescases involving classic Bluetooth as well as BLE, Bluedroid should be used.
- For BLE-only usecases, using NimBLE is recommended. It is less demanding in terms of code footprint and runtime memory, making it suitable for such scenarios.

For the overview of the ESP32 Bluetooth stack architecture, follow the links below:

- ESP32 Bluetooth Architecture (PDF) [English]
- ESP32 Bluetooth Architecture (PDF) [中文]

Code examples for this API section are provided in the bluetooth/bluedroid directory of ESP-IDF examples.

The following examples contain detailed walkthroughs:

- GATT Client Example Walkthrough
- GATT Server Service Table Example Walkthrough
- GATT Server Example Walkthrough
- GATT Security Client Example Walkthrough
- GATT Security Server Example Walkthrough
- GATT Client Multi-connection Example Walkthrough

2.2 Networking APIs

2.2.1 Wi-Fi

Wi-Fi

Introduction The Wi-Fi libraries provide support for configuring and monitoring the ESP32 Wi-Fi networking functionality. This includes configuration for:

- Station mode (aka STA mode or Wi-Fi client mode). ESP32 connects to an access point.
- AP mode (aka Soft-AP mode or Access Point mode). Stations connect to the ESP32.
- Station/AP-coexistence mode (ESP32 is concurrently an access point and a station connected to another access point).
- Various security modes for the above (WPA, WPA2, 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

Functions

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
• others: refer to error code in esp_err.h

Parameters
• [out] mode: WiFi operating mode

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
**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 create 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

**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

**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

**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
2. If the ESP32 is connected to an AP, call esp_wifi_disconnect to disconnect.
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 re-connection 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

Parameters
- [out] number: store number of APIs 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 don’t 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_1r 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) mode.

**Attention**
Currently we only support 802.11b or 802.11bg or 802.11bgn mode

**Return**

- 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

**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
### Chapter 2. API Reference

- ifx: interface
- [out] protocol_bitmap: store current WiFi protocol bitmap of interface ifx

**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

**esp_err_t esp_wifi_get_bandwidth** *(wifi_interface_t ifx, wifi_bandwidth_t *bw)*

Get the bandwidth of ESP32 specified interface.

**Attention**
1. API return false if try to get a interface that is not enabled

**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

**Parameters**
- ifx: interface to be configured
- *bw: store bandwidth of interface ifx

**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
- 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

**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
- *second: store current second channel
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="USA", .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

Esp_err_t esp_wifi_get_country (wifi_country_t *country)

ger 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

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

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
• ESP_ERR_WIFI_IF: invalid interface

**Parameters**
- `ifx`: interface
- `[out] mac`: store mac of the interface ifx

```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
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

**Parameters**
- `cb`: callback

```c
esp_err_t esp_wifi_set_promiscuous (bool en)
```

Enable the promiscuous mode.

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

**Parameters**
- `en`: false - disable, true - enable

```c
esp_err_t esp_wifi_get_promiscuous (bool *en)
```

Get the promiscuous mode.

**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] 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
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

**Parameters**
- `filter`: the packet type filtered in promiscuous mode.

```c
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

```c
esp_err_t esp_wifi_set_promiscuous_ctrl_filter (const wifi_promiscuous_ctrl_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
- ESP_ERR_WIFI_ARG: invalid argument

**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
2. For station configuration, bssid_set needs to be 0; and it needs to be 1 only when users need to check the MAC address of the AP.
3. 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 error 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_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_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_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, const 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, 19], 8}, {[20, 27], 20}, {[28, 33], 28}, {[34, 43], 34}, {[44, 51], 44}, {[52, 55], 52}, {[56, 59], 56}, {[60, 65], 60}, {[66, 71], 66}, {[72, 79], 72}, {[80, 84], 80}}.
Chapter 2. API Reference

- 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.

```c
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.

```c
esp_err_t esp_wifi_set_event_mask (uint32_t mask)
```
Set mask to enable or disable some WiFi events.

Attention 1. Mask can be created by logical OR of various WiFi_EVENT_MASK_constants. Events which have corresponding bit set in the mask will not be delivered to the system event handler.

Attention 2. Default WiFi event mask is WIFI_EVENT_MASK_AP_PROBEREQRECVED.

Attention 3. There may be lots of stations sending probe request data around. Don’t unmask this event unless you need to receive probe request data.

Return
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

Parameters
- mask: WiFi event mask.

```c
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.

```c
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_ARG: invalid argument

- 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_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_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_ARG: invalid argument, e.g. parameter is NULL, invalid GPIO number etc

- Parameters
  - `config`: Antenna GPIO configuration.

```c
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_ARG: invalid argument, e.g. parameter is NULL

- Parameters
  - `config`: Antenna GPIO configuration.

```c
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.

`esp_err_t esp_wifi_get_ant(wifi_ant_config_t *config)`
Get current 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

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().
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.

**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.
**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.
2. This configuration only work for station mode and disconnected status.
3. This configuration would influence nothing until some module configure wake_window.
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.

**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.
2. When ieee80211d_enabled is disabled, then the configured country info is used always.
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.
4. The country configuration is stored into flash.
5. Supported country codes are “01” (world safe mode), “AT”,” AU”,” BE”,” BG”,” BR”,” CA”,” CH”,” CN”,” CY”,” CZ”,” DE”,” DK”,” EE”,” ES”,” FI”,” FR”,” GB”,” GR”,” HK”,” HR”,” HU”,” IE”,” IN”,” IS”,” IT”,” JP”,” KR”,” LI”,” LT”,” LU”,” LV”,” MT”,” MX”,” NL”,” NO”,” NZ”,” PL”,” PT”,” RO”,” SE”,” SI”,” SK”,” TW”,” US”.
6. When country code “01” (world safe mode) is set, SoftAP mode won’t contain country IE.
7. 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

**esp_err_t esp_wifi_get_country_code** (char *country)

generate the current country code

**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)

Configure 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.
struct wifi_init_config_t
WiFi stack configuration parameters passed to esp_wifi_init call.

Public Members

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_NV
    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_NV_S_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.

- `wifi_country_policy_t policy`
  - country policy

struct wifi_active_scan_time_t

Range of active scan times per channel.

Public Members

- `uint32_t min`
  - minimum active scan time per channel, units: millisecond
- `uint32_t max`
  - maximum active scan time per channel, units: millisecond, values above 1500ms may cause station to disconnect from AP and are not recommended.

struct wifi_scan_time_t

Aggregate of active & passive scan time per channel.

Public Members

- `wifi_active_scan_time_t active`
  - active scan time per channel, units: millisecond.
- `uint32_t passive`
  - passive scan time per channel, units: millisecond, values above 1500ms may cause station to disconnect from AP and are not recommended.
struct wifi_scan_config_t
Parameters for an SSID scan.

Public Members

uint8_t * ssid
SSID of AP

uint8_t * bssid
MAC address of AP

uint8_t channel
channel, scan the specific channel

bool show_hidden
enable to scan AP whose SSID is hidden

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

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

struct 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
    Advertizes support for Protected Management Frame. Device will prefer to 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
**Chapter 2. API Reference**

**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

**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 rss 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 advertized 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]
    mac 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

signed noise_floor : 8
  noise floor of Radio Frequency Module(RF). unit: 0.25dBm

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 __pad4__ : 8
  reserved
Chapter 2. API Reference

unsigned \texttt{timestamp} : 32
\hspace*{1em} timestamp: The local time when this packet is received. It is precise only if modem sleep or light sleep is not enabled. unit: microsecond

unsigned \_\_\_pad5\_\_ : 32
\hspace*{1em} reserved

unsigned \_\_\_pad6\_\_ : 31
\hspace*{1em} reserved

unsigned \texttt{ant} : 1
\hspace*{1em} antenna number from which this packet is received. 0: WiFi antenna 0; 1: WiFi antenna 1

unsigned \texttt{sig\_len} : 12
\hspace*{1em} length of packet including Frame Check Sequence(FCS)

unsigned \_\_\_pad7\_\_ : 12
\hspace*{1em} reserved

unsigned \texttt{rx\_state} : 8
\hspace*{1em} state of the packet. 0: no error; others: error numbers which are not public

\textbf{struct wifi\_promiscuous\_pkt\_t}
\hspace*{1em} Payload passed to ‘\texttt{buf}’ parameter of promiscuous mode RX callback.

\textbf{Public Members}

\texttt{wifi\_pkt\_rx\_ctrl\_t} \texttt{rx\_ctrl}
\hspace*{1em} metadata header

\texttt{uint8\_t} \texttt{payload}[0]
\hspace*{1em} Data or management payload. Length of payload is described by \texttt{rx\_ctrl\_sig\_len}. Type of content determined by packet type argument of callback.

\textbf{struct wifi\_promiscuous\_filter\_t}
\hspace*{1em} Mask for filtering different packet types in promiscuous mode.

\textbf{Public Members}

\texttt{uint32\_t} \texttt{filter\_mask}
\hspace*{1em} OR of one or more filter values WIFI\_PROMIS\_FILTER\_ *

\textbf{struct wifi\_csi\_config\_t}
\hspace*{1em} Channel state information(CSI) configuration type.

\textbf{Public Members}

\texttt{bool} \texttt{lltf\_en}
\hspace*{1em} enable to receive legacy long training field(lltf) data. Default enabled

\texttt{bool} \texttt{htlltf\_en}
\hspace*{1em} enable to receive HT long training field(htlltf) data. Default enabled

\texttt{bool} \texttt{stbc\_htlltf2\_en}
\hspace*{1em} enable to receive space time block code HT long training field(stbc-htlltf2) data. Default enabled

\texttt{bool} \texttt{ltf\_merge\_en}
\hspace*{1em} enable to generate htlf data by averaging lltf and ht_ltf data when receiving HT packet. Otherwise, use hltf data directly. Default enabled

\texttt{bool} \texttt{channel\_filter\_en}
\hspace*{1em} enable to turn on channel filter to smooth adjacent sub-carrier. Disable it to keep independence of adjacent sub-carrier. Default enabled
bool manu_scale
manually scale the CSI data by left shifting or automatically scale the CSI data. If set true, please set the
shift bits. false: automatically. true: manually. Default false

uint8_t shift
manually left shift bits of the scale of the CSI data. The range of the left shift bits is 0~15

struct wifi_csi_info_t
CSI data type.

Public Members

wifi_pkt_rx_ctrl_t rx_ctrl
received packet radio metadata header of the CSI data

uint8_t [mac[6]
source MAC address of the CSI data

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
Chapter 2. API Reference

```c
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**

```c
wifi_interface_t ifx
    WiFi interface to send request to

uint8_t dest_mac[6]
    Destination MAC address

bool no_ack
    Indicates no ack required

wifi_action_rx_cb_t rx_cb
    Rx Callback to receive any response

uint32_t data_len
    Length of the appended Data

uint8_t data[0]
    Appended Data payload
```

```c
struct wifi_ftm_initiator_cfg_t
    FTM Initiator configuration.
```

**Public Members**

```c
uint8_t resp_mac[6]
    MAC address of the FTM Responder

uint8_t channel
    Primary channel of the FTM Responder

uint8_t frm_count
    No. of FTM frames requested in terms of 4 or 8 bursts (allowed values - 0(No pref), 16, 24, 32, 64)

uint16_t burst_period
    Requested time period between consecutive FTM bursts in 100’s of milliseconds (0 - No pref)
```

```c
struct wifi_event_sta_scan_done_t
    Argument structure for WIFI_EVENT_SCAN_DONE event
```

**Public Members**

```c
uint32_t status
    status of scanning APs: 0 — success, 1 - failure

uint8_t number
    number of scan results

uint8_t scan_id
    scan sequence number, used for block scan
```

```c
struct wifi_event_sta_connected_t
    Argument structure for WIFI_EVENT_STA_CONNECTED event
```
Public Members

uint8_t ssid[32]
SSID of connected AP

uint8_t ssid_len
SSID length of connected AP

uint8_t bssid[6]
BSSID of connected AP

uint8_t channel
channel of connected AP

wifi_auth_mode_t authmode
authentication mode used by AP

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
**Chapter 2. API Reference**

```c
uint8_t ssid[MAX_SSID_LEN]
SSID of AP

uint8_t passphrase[MAX_PASSPHRASE_LEN]
Passphrase for the AP

struct wifi_event_sta_wps_er_success_t::[anonymous] ap_cred[MAX_WPS_AP_CRED]
All AP credentials received from WPS handshake

struct wifi_event_ap_staconnected_t
Argument structure for WIFI_EVENT_AP_STACONNECTED event

**Public Members**

uint8_t 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
Chapter 2. API Reference

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

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_tlen, uint8_tchannel)
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_AUTH_LEAVE = 3
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

enum wifi_phy_rate_t
   WiFi PHY rate encodings.
   Values:
   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

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

enum wifi_event_t
Wi-Fi event declarations

Values:

WIFI_EVENT_WIFI_READY = 0
ESP32 Wi-Fi 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

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
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

    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 devices, check Provisioning API.

Application Example  Connect ESP32 to target AP using SmartConfig: wifi/smart_config.

API Reference

Header File

* components/esp_wifi/include/esp_smartconfig.h

Functions

*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 sniffer special packets from the air that containing SSID and password of target AP.

Attention  1. This API can be called in station or softAP-station mode.
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 smart-config_start.

**Return**  
- ESP_OK: succeed  
- others: fail

```c
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.

**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.  
2. Fast mode have corresponding APP(phone).  
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.
uint8_t bssid[6]
   MAC address of target AP.

smartconfig_type_t type
   Type of smartconfig (ESPTouch or AirKiss).

uint8_t token
   Token from cellphone which is used to send ACK to cellphone.

uint8_t cellphone_ip[4]
   IP address of cellphone.

struct smartconfig_start_config_t
   Configure structure for esp_smartconfig_start

Public Members

bool enable_log
   Enable smartconfig logs.

bool esp_touch_v2_enable_crypt
   Enable ESPTouch v2 crypt.

char *esp_touch_v2_key
   ESPTouch v2 crypt key, len should be 16.

Macros

SMARTCONFIG_START_CONFIG_DEFAULT ()

Enumerations

define smartconfig_type_t
   Values:

   SC_TYPE_ESPTOUCH = 0
      protocol: ESPTouch

   SC_TYPE_AIRKISS
      protocol: AirKiss

   SC_TYPE_ESPTOUCH_AIRKISS
      protocol: ESPTouch and AirKiss

   SC_TYPE_ESPTOUCH_V2
      protocol: ESPTouch v2

enum smartconfig_event_t
   Smartconfig event declarations

   Values:

   SC_EVENT_SCAN_DONE
      ESP32 station smartconfig has finished to scan for APs

   SC_EVENT_FOUND_CHANNEL
      ESP32 station smartconfig has found the channel of the target AP

   SC_EVENT_GOT_SSID_PSWD
      ESP32 station smartconfig got the SSID and password

   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~</td>
<td></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 filed is used to prevents relay attacks.
- Vendor Specific Content: The Vendor Specific Content contains vendor-specific fields as follows:

```
<table>
<thead>
<tr>
<th>Element ID</th>
<th>Length</th>
<th>Organization Identifier</th>
<th>Type</th>
<th>Version</th>
<th>Body</th>
</tr>
</thead>
<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.

- 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
• 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

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
Attention 2. If peer_addr is NULL, send data to all of the peers that are added to the peer list
Attention 3. The maximum length of data must be less than ESP_NOW_MAX_DATA_LEN
Attention 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
Chapter 2. API Reference

- ESP_ERR_ESPNOW_ARG: invalid argument
- ESP_ERR_ESPNOW_FULL: peer list is full
- ESP_ERR_ESPNOW_NO_MEM: out of memory
- ESP_ERR_ESPNOW_EXIST: peer has existed

### 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
Chapter 2. API Reference

```c
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
```

```c
esp_err_t esp_now_set_pmk(const uint8_t *pmk)
Set the primary master key.

Attention 1. primary master key is used to encrypt local master key

Return
• ESP_OK : succeed
• ESP_ERR_ESPNOW_NOT_INIT : ESPNOW is not initialized
• ESP_ERR_ESPNOW_ARG : invalid argument

Parameters
• pmk: primary master key
```

```c
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**

```c
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

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
• status: status of sending ESPNOW data (succeed or fail)

Enumerations
define esp_now_send_status_t
Status of sending ESPNOW data.

Values:
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.

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, users should not call Wi-Fi APIs after `esp_mesh_start()` is called, and before `esp_mesh_stop()` is called.

**LwIP & ESP-WIFI-MESH** The application can access the ESP-WIFI-MESH stack directly without having to go through the LwIP stack. The LwIP stack is only required by the root node to transmit/receive data to/from an external IP network. However, since every node can potentially become the root node (due to automatic root node selection), each node must still initialize the LwIP stack. Each node 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();
```
Chapter 2. API Reference

(continued from previous page)

```c
/*
 * 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
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));

/* event initialization */
ESP_ERROR_CHECK(esp_event_loop_create_default());

/* Wi-Fi initialization */
wifi_init_config_t config = WIFI_INIT_CONFIG_DEFAULT();
ESP_ERROR_CHECK(esp_wifi_init(&config));
/* register IP events handler */
ESP_ERROR_CHECK(esp_event_handler_register(IP_EVENT,
ESP_EVENT_ANY_ID,
&ip_,
event_handler,
NULL));
ESP_ERROR_CHECK(esp_wifi_set_storage(WIFI_STORAGE_FLASH));
ESP_ERROR_CHECK(esp_wifi_start());
```

After initializing LwIP and Wi-Fi, the process of getting an ESP-WIFI-MESH network up and running can be summarized into the following three steps:

1. **Initialize Mesh**
2. **Configuring an ESP-WIFI-MESH Network**
3. **Start Mesh**

**Initialize Mesh** The following code snippet demonstrates how to initialize ESP-WIFI-MESH

```c
/* mesh initialization */
ESP_ERROR_CHECK(esp_mesh_init());
/* register mesh events handler */
ESP_ERROR_CHECK(esp_event_handler_register(MESH_EVENT,
ESP_EVENT_ANY_ID,
&mesh_,
&event_handler,
NULL));
```

**Configuring an ESP-WIFI-MESH Network** ESP-WIFI-MESH is configured via `esp_mesh_set_config()` which receives its arguments using the `mesh_cfg_t` structure. The structure contains the following parameters used to configure ESP-WIFI-MESH:
### Parameter Description

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel</td>
<td>Range from 1 to 14</td>
</tr>
<tr>
<td>Mesh ID</td>
<td>ID of ESP-WIFI-MESH Network, see <code>mesh_addr_t</code></td>
</tr>
<tr>
<td>Router</td>
<td>Router Configuration, see <code>mesh_router_t</code></td>
</tr>
<tr>
<td>Mesh AP</td>
<td>Mesh AP Configuration, see <code>mesh_ap_cfg_t</code></td>
</tr>
<tr>
<td>Crypto Functions</td>
<td>Crypto Functions for Mesh IE, see <code>mesh_crypto_funcs_t</code></td>
</tr>
</tbody>
</table>

The following code snippet demonstrates how to configure ESP-WIFI-MESH.

```c
/* Enable the Mesh IE encryption by default */
mesh_cfg_t cfg = MESH_INIT_CONFIG_DEFAULT();
/* mesh ID */
memcpy((uint8_t *) &cfg.mesh_id, MESH_ID, 6);
/* channel (must match the router’s channel) */
cfg.channel = CONFIG_MESH_CHANNEL;
/* router */
cfg.router.ssid_len = strlen(CONFIG_MESH_ROUTER_SSID);
memcpy((uint8_t *) &cfg.router.ssid, CONFIG_MESH_ROUTER_SSID, cfg.router.ssid_len);
memcpy((uint8_t *) &cfg.router.password, CONFIG_MESH_ROUTER_PASSWD, strlen(CONFIG_MESH_ROUTER_PASSWD));
/* mesh softAP */
cfg.mesh_ap.max_connection = CONFIG_MESH_AP_CONNECTIONS;
memcpy((uint8_t *) &cfg.mesh_ap.password, CONFIG_MESH_AP_PASSWD, strlen(CONFIG_MESH_AP_PASSWD));
ESP_ERROR_CHECK(esp_mesh_set_config(&cfg));
```

### Start Mesh

The following code snippet demonstrates how to start ESP-WIFI-MESH.

```c
/* mesh start */
ESP_ERROR_CHECK(esp_mesh_start());
```

After starting ESP-WIFI-MESH, the application should check for ESP-WIFI-MESH events to determine when it has connected to the network. After connecting, the application can start transmitting and receiving packets over the ESP-WIFI-MESH network using `esp_mesh_send()` and `esp_mesh_recv()`.

### Self Organized Networking

Self organized networking is a feature of ESP-WIFI-MESH where nodes can autonomously scan/select/connect/reconnect to other nodes and routers. This feature allows an ESP-WIFI-MESH network to operate with high degree of autonomy by making the network robust to dynamic network topologies and conditions. With self organized networking enabled, nodes in an ESP-WIFI-MESH network are able to carry out the following actions without autonomously:

- Selection or election of the root node (see Automatic Root Node Selection in Building a Network)
- Selection of a preferred parent node (see Parent Node Selection in Building a Network)
- Automatic reconnection upon detecting a disconnection (see Intermediate Parent Node Failure in Managing a Network)

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 on the node type and the node’s current state. This parameter is unused when disabling self organized networking.
Disabling Self Organized Networking  The following code snippet demonstrates how to disable self organized networking.

```c
//Disable self organized networking
esp_mesh_set_self_organized(false, false);
```

ESP-WIFI-MESH will attempt to maintain the node’s current Wi-Fi state when disabling self organized networking.

- If the node was previously connected to other nodes, it will remain connected.
- If the node was previously disconnected and was scanning for a parent node or router, it will stop scanning.
- If the node was previously attempting to reconnect to a parent node or router, it will stop reconnecting.

Enabling Self Organized Networking  ESP-WIFI-MESH will attempt to maintain the node’s current Wi-Fi state when enabling self organized networking. However, depending on the node type and whether a new parent is selected, the Wi-Fi state of the node can change. The following table shows effects of enabling self organized networking.

<table>
<thead>
<tr>
<th>Select Parent</th>
<th>Is Root Node</th>
<th>Effects</th>
</tr>
</thead>
</table>
| N             | N            | • Nodes already connected to a parent node will remain connected.  
|               |              | • Nodes previously scanning for a parent node will stop scanning. Call `esp_mesh_connect()` to restart. |
| Y             |              | • A root node already connected to router will stay connected.  
|               |              | • A root node disconnected from router will need to call `esp_mesh_connect()` to reconnect. |
| Y             | N            | • Nodes without a parent node will automatically select a preferred parent and connect.  
|               |              | • Nodes already connected to a parent node will disconnect, reselect a preferred parent node, and connect. |
| Y             |              | • For a root node to connect to a parent node, it must give up its role as root. Therefore, a root node will disconnect from the router and all child nodes, select a preferred parent node, and connect. |

The following code snippet demonstrates how to enable self organized networking.

```c
//Enable self organized networking and select a new parent
esp_mesh_set_self_organized(true, true);
```

(continues on next page)
//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.

//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
Chapter 2. API Reference

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.

**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
Chapter 2. API Reference

- ESP_ERR_MESH_NOT_START
- ESP_ERR_MESH_DISCONNECTED
- ESP_ERR_MESH_OPT_UNKNOWN
- ESP_ERR_MESH_EXCEED_MTU
- ESP_ERR_MESH_NO_MEMORY
- ESP_ERR_MESH_TIMEOUT
- ESP_ERR_MESH_QUEUE_FULL
- ESP_ERR_MESH_NO_ROUTE_FOUND
- ESP_ERR_MESH_DISCARD

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.

```
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

```
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

```c
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

```c
esp_err_t esp_mesh_set_config(const mesh_cfg_t *config)
```

Set mesh stack configuration.

- Use MESH_INIT_CONFIG_DEFAULT() to initialize the default values, mesh IE is encrypted by default.
- Mesh network is established on a fixed channel (1-14).
- Mesh event callback is mandatory.
- Mesh ID is an identifier of an MBSS. Nodes with the same mesh ID can communicate with each other.
- Regarding to the router configuration, if the router is hidden, BSSID field is mandatory.

If BSSID field isn’t set and there exists more than one router with same SSID, there is a risk that more roots than one connected with different BSSID will appear. It means more than one mesh network is established with the same mesh ID.

Root conflict function could eliminate redundant roots connected with the same BSSID, but couldn’t handle roots connected with different BSSID. Because users might have such requirements of setting up routers with same SSID for the future replacement. But in that case, if the above situations happen, please make sure applications implement forward functions on the root to guarantee devices in different mesh networks can communicate with each other. max_connection of mesh softAP is limited by the max number of Wi-Fi softAP supported (max:10).

**Attention** This API shall be called before mesh is started after mesh is initialized.

**Return**

- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

```c
esp_err_t esp_mesh_get_config(mesh_cfg_t *config)
```

Get mesh stack configuration.

**Parameters**

- [in] `config`: pointer to mesh stack configuration

**Return**

- ESP_OK
- ESP_ERR_MESH_ARGUMENT

```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
**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

**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
Chapter 2. API Reference

- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

Parameters
- [in] pwd: pointer to the password
- [in] len: password length

\texttt{esp_err_t esp_mesh_set_ap_authmode(wifi_auth_mode_t authmode)}
Set mesh softAP authentication mode.

\textbf{Attention} This API shall be called before mesh is started.

\textbf{Return}
- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

Parameters
- [in] authmode: authentication mode

\textbf{wifi_auth_mode_t esp_mesh_get_ap_authmode(void)}
Get mesh softAP authentication mode.

\textbf{Return} authentication mode

\textbf{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

\textbf{Attention} This API shall be called before mesh is started.

\textbf{Return}
- ESP_OK
- ESP_ERR_MESH_ARGUMENT

Parameters
- [in] connections: the number of max connections

\textbf{int esp_mesh_get_ap_connections(void)}
Get mesh max connection configuration.

\textbf{Return} the number of mesh max connections

\textbf{int esp_mesh_get_non_mesh_connections(void)}
Get non-mesh max connection configuration.

\textbf{Return} the number of non-mesh max connections

\textbf{int esp_mesh_get_layer(void)}
Get current layer value over the mesh network.

\textbf{Attention} This API shall be called after having received the event MESH_EVENT_PARENT_CONNECTED.

\textbf{Return} layer value

\textbf{esp_err_t esp_mesh_get_parent_bssid(mesh_addr_t *bssid)}
Get the parent BSSID.

\textbf{Attention} This API shall be called after having received the event MESH_EVENT_PARENT_CONNECTED.

\textbf{Return}
- ESP_OK
- ESP_FAIL

Parameters
- [out] bssid: pointer to parent BSSID

\textbf{bool esp_mesh_is_root(void)}
Return whether the device is the root node of the network.

\textbf{Return} true/false
**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
- ESP_ERR_MESH_QUEUE_FULL
- ESP_ERR_MESH_DISCARD

**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.
Chapter 2. API Reference

Return
• ESP_OK
• ESP_FAIL

Parameters
• [out] pending: pointer to the RX pending

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

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)

int esp_mesh_get_xon_qsize(void)
Get queue size.

esp_err_t esp_mesh_allow_root_conflicts(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

bool esp_mesh_is_root_conflicts_allowed(void)
Check whether allow more than one root to exist in one network.
Return true/false

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

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

int esp_mesh_get_group_num(void)
Get the number of group ID addresses.
**Return** the number of group ID addresses

*esp_err_t* **esp_mesh_get_group_list** (*mesh_addr_t** *addr*, **int** *num*)

Get group ID addresses.

**Return**
- ESP_OK
- ESP_MESH_ERR_ARGUMENT

**Parameters**
- **[out]** addr: pointer to group ID addresses
- **[in]** num: the number of group ID addresses

*bool* **esp_mesh_is_my_group** (*const* *mesh_addr_t* *addr*)

Check whether the specified group address is my group.

**Return** true/false

*esp_err_t* **esp_mesh_set_capacity_num** (**int** *num*)

Set mesh network capacity (max:1000, default:300)

**Attention** This API shall be called before mesh is started.

**Return**
- ESP_OK
- ESP_ERR_MESH_NOT_ALLOWED
- ESP_MESH_ERR_ARGUMENT

**Parameters**
- **[in]** num: mesh network capacity

*int* **esp_mesh_get_capacity_num** (**void**)?

Get mesh network capacity.

**Return** mesh network capacity

*esp_err_t* **esp_mesh_set_ie_crypto_funcs** (*const* *mesh_crypto_funcs_t** *crypto_funcs*)

Set mesh IE crypto functions.

**Attention** This API can be called at any time after mesh is initialized.

**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_err_t* **esp_mesh_set_ie_crypto_key** (*const* *char** *key*, **int** *len*)

Set mesh IE crypto key.

**Attention** This API can be called at any time after mesh is initialized.

**Return**
- ESP_OK
- ESP_MESH_ERR_ARGUMENT

**Parameters**
- **[in]** key: ASCII crypto key
- **[in]** len: length in bytes, range:8~64

*esp_err_t* **esp_mesh_get_ie_crypto_key** (**char** *key*, **int** *len*)

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_err_t* **esp_mesh_set_root_healing_delay** (**int** *delay_ms*)

Set delay time before starting root healing.
Chapter 2. API Reference

Return

• ESP_OK

Parameters

• [in] delay_ms: delay time in milliseconds

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
Chapter 2. API Reference

• [out] len: mesh networking IE length

```c
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

```c
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

```c
esp_err_t esp_mesh_get_subnet_nodes_num (const mesh_addr_t *child_mac, int *nodes_num)
```
Get the number of nodes in the subnet of a specific child.

**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

```c
esp_err_t esp_mesh_get_subnet_nodes_list (const mesh_addr_t *child_mac, mesh_addr_t *nodes, int nodes_num)
```
Get nodes in the subnet of a specific child.

**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

```c
esp_err_t esp_mesh_disconnect (void)
```
Disconnect from current parent.

**Return**
- ESP_OK

```c
esp_err_t esp_mesh_connect (void)
```
Connect to current parent.

**Return**
- ESP_OK

```c
esp_err_t esp_mesh_flush_scan_result (void)
```
Flush scan result.

**Return**
- ESP_OK

```c
esp_err_t esp_mesh_switch_channel (const uint8_t *new_bssid, int csa_newchan, int csa_count)
```
Cause the root device to add Channel Switch Announcement Element (CSA IE) to beacon.
Chapter 2. API Reference

- Set the new channel
- Set how many beacons with CSA IE will be sent before changing a new channel
- Enable the channel switch function

**Attention** This API is only called by the root.

**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.

```c
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

```c
int64_t esp_mesh_get_tsf_time (void)
```
Get the TSF time.

**Return** the TSF time

```c
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

```c
esp_mesh_topology_t esp_mesh_get_topology (void)
```
Get mesh topology.

**Return** MESH_TOPO_TREE or MESH_TOPO_CHAIN

```c
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

```c
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

```c
bool esp_mesh_is_ps_enabled (void)
```
Check whether the mesh Power Save function is enabled.
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_PSDEVICE_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

desk_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

desk_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

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.
Public Members

**uint16_t new_layer**
new layer

**struct mesh_event_vote_started_t**
vote started information

**Public Members**

**int reason**
vote reason, vote could be initiated by children or by the root itself

**int attempts**
max vote attempts before stopped

**mesh_addr_t rc_addr**
root address specified by users via API esp_mesh_waive_root()

**struct mesh_event_find_network_t**
find a mesh network that this device can join

Public Members

**uint8_t channel**
channel number of the new found network

**uint8_t router_bssid[6]**
router BSSID

**struct mesh_event_root_switch_req_t**
Root switch request information.

**Public Members**

**int reason**
root switch reason, generally root switch is initialized by users via API esp_mesh_waive_root()

**mesh_addr_t rc_addr**
the address of root switch requester

**struct mesh_event_root_conflict_t**
Other powerful root address.

**Public Members**

**int8_t rssi**
rssi with router

**uint16_t capacity**
the number of devices in current network

**uint8_t addr[6]**
other powerful root address

**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()
```
**Public Members**

```c
uint8_t* data
```

data

```c
uint16_t size
```

data size

```c
mesh_proto_t proto
```

data protocol

```c
mesh_tos_t tos
```

data type of service

**struct mesh_router_t**

Router configuration.

**Public Members**

```c
uint8_t ssid[32]
```

SSID

```c
uint8_t ssid_len
```

length of SSID

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

BSSID, if this value is specified, users should also specify “allow_router_switch”.

```c
uint8_t password[64]
```

cpassword

```c
bool allow_router_switch
```

if the BSSID is specified and this value is also set, when the router of this specified BSSID fails to be found after “fail” (mesh_attempts_t) times, the whole network is allowed to switch to another router with the same SSID. The new router might also be on a different channel. The default value is false. There is a risk that if the password is different between the new switched router and the previous one, the mesh network could be established but the root will never connect to the new switched router.

**struct mesh_ap_cfg_t**

Mesh softAP configuration.

**Public Members**

```c
uint8_t password[64]
```

mesh softAP password

```c
uint8_t max_connection
```

max number of stations allowed to connect in, default 6, max 10 = max_connection + non-mesh_max_connection max mesh connections

```c
uint8_t nonmesh_max_connection
```

max non-mesh connections

**struct mesh_cfg_t**

Mesh initialization configuration.

**Public Members**

```c
uint8_t channel
```

channel, the mesh network on
bool allow_channel_switch
    if this value is set, when “fail” (mesh_attempts_t) times is reached, device will change to a full channel
    scan for a network that could join. The default value is false.

mesh_addr_t mesh_id
    mesh network identification

mesh_router_t router
    router configuration

mesh_ap_cfg_t mesh_ap
    mesh softAP configuration

const mesh_crypto_funcs_t *crypto_funcs
    crypto functions

struct mesh_vote_t
    Vote.

Public Members

float percentage
    vote percentage threshold for approval of being a root

bool is_rc_specified
    if true, rc_addr shall be specified (Unimplemented). if false, attempts value shall be specified to make
    network start root election.

mesh_rc_config_t config
    vote address configuration

struct mesh_tx_pending_t
    The number of packets pending in the queue waiting to be sent by the mesh stack.

Public Members

int to_parent
    to parent queue

int to_parent_p2p
    to parent (P2P) queue

int to_child
    to child queue

int to_child_p2p
    to child (P2P) queue

int mgmt
    management queue

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

```c
typedef mesh_addr_t mesh_event_root_address_t
  Root address.

typedef wifi_event_sta_disconnected_t mesh_event_disconnected_t
  Parent disconnected information.

typedef wifi_event_ap_staconnected_t mesh_event_child_connected_t
  Child connected information.

typedef wifi_event_ap_stadisconnected_t mesh_event_child_disconnected_t
  Child disconnected information.

typedef wifi_event_sta_connected_t mesh_event_router_switch_t
  New router information.
```

Enumerations

```c
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

```c
enum mesh_proto_t
{
    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
}
```

**MESH_TOS**

For reliable transmission, mesh stack provides three type of services.

```c
enum mesh_tos_t
{
    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
}
```

**MESH_VOTE_REASON**

Vote reason.

```c
enum mesh_vote_reason_t
{
    MESH_VOTE_REASON_ROOT_INITIATED = 1  // vote is initiated by the root
    MESH_VOTE_REASON_CHILD_INITIATED   // vote is initiated by children
}
```

**MESH_DISCONNECT_REASON**

Mesh disconnect reason code.

```c
enum mesh_disconnect_reason_t
{
    MESH_REASON_CYCLIC = 100  // cyclic is detected
}
```
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

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
• Works with electronic or printed QR codes, or human-readable strings
• Supports both WPA2 and WPA3 networks

Please refer to Wi-Fi Alliance’s official page on Easy Connect for more information.

ESP32 supports Enrollee mode of Easy Connect with QR Code as the provisioning method. A display is required to display this QR Code. Users can scan this QR Code using their capable device and provision the ESP32 to their Wi-Fi network. The provisioning device needs to be connected to the AP which need not support Wi-Fi Easy Connect™. Easy Connect is still an evolving protocol. Of known platforms that support the QR Code method are some Android smartphones with Android 10 or higher. To use Easy Connect no additional App needs to be installed on the supported smartphone.

**Application Example** Example on how to provision ESP32 using a supported smartphone: wifi/wifi_easy_connect/dpp-enrollee.

**API Reference**

**Header File**

• components/wpa_supplicant/esp_supplicant/include/esp_dpp.h

**Functions**

```c
esp_err_t esp_supp_dpp_init (esp_supp_dpp_event_cb_t evt_cb)
Initialize DPP Supplicant.
Starts DPP Supplicant and initializes related Data Structures.
return
• ESP_OK: Success
• ESP_FAIL: Failure
```

**Parameters**

• evt_cb: Callback function to receive DPP related events

```c
void esp_supp_dpp_deinit (void)
De-initialize DPP Supplicant.
Frees memory from DPP Supplicant Data Structures.
```

```c
esp_err_t esp_supp_dpp_bootstrap_gen (const char *chan_list, esp_supp_dpp_bootstrap_t type,
const char *key, const char *info)
Generates Bootstrap Information as an Enrollee.
Generates Out Of Band Bootstrap information as an Enrollee which can be used by a DPP Configurator to provision the Enrollee.
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

```c
esp_err_t esp_supp_dpp_start_listen (void)
Start listening on Channels provided during esp_supp_dpp_bootstrap_gen.
Listens on every Channel from Channel List for a pre-defined wait time.
Return
• ESP_OK: Success
```
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 Aced
ESP_ERR_DPP_INVALID_ATTR
Encountered invalid DPP Attribute

Type Definitions
typedef enum dpp_bootstrap_type esp_supp_dpp_bootstrap_t
Types of Bootstrap Methods for DPP.
typedef void (*esp_supp_dpp_event_cb_t)(esp_supp_dpp_event_t evt, void *data)
Callback function for receiving DPP Events from Supplicant.
Callback function will be called with DPP related information.
Parameters
• evt: DPP event ID
• data: Event data payload

Enumerations
enum 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
enum 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_RECVED
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

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 rage 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 blow:

![Fig. 4: Ethernet Data Frame Format](image)

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](#).

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.
Chapter 2. API Reference

**Note:** Besides the basic data frame described above, there’re two other common frame types in 10/100 Mbps Ethernet: control frames and VLAN tagged frames. They’re not supported in ESP-IDF.

**Configure MAC and PHY**  Ethernet driver is composed of two parts: MAC and PHY.

The communication between MAC and PHY can have diverse choices: MII (Media Independent Interface), RMII (Reduced Media Independent Interface) and etc.

One of the obvious difference between MII and RMII is the signal consumption. For MII, it usually costs up to 18 signals. Instead, RMII interface can reduce the consumption to 9.

In RMII mode, both the receiver and transmitter signals are referenced to the REF_CLK. **REF_CLK must be stable during any access to PHY and MAC.** Generally there’re three ways to generate the REF_CLK depending on the PHY device in your design:

- Some PHY chip can derive the REF_CLK from its external connected 25MHz crystal oscillator (as seen the option a in the picture). In this case, you should select `CONFIG_ETH_RMII_CLK_INPUT` in `CONFIG_ETH_RMII_CLK_MODE`.
- Some PHY chip uses an external connected 50MHz crystal oscillator or other clock source, which can also be used as the REF_CLK for MAC side (as seen the option b in the picture). In this case, you still need to select `CONFIG_ETH_RMII_CLK_INPUT` in `CONFIG_ETH_RMII_CLK_MODE`.
- Some EMAC controller can generate the REF_CLK using its internal high precision PLL (as seen the option c in the picture). In this case, you should select `CONFIG_ETH_RMII_CLK_OUTPUT` in `CONFIG_ETH_RMII_CLK_MODE`.

**Note:** REF_CLK is configured via Project Configuration as described above by default. However, it can be overwritten from user application code by appropriately setting interface and clock_config members of `eth_mac_config_t` structure. See `emac_rmii_clock_mode_t` and `emac_rmii_clock_gpio_t` for more details.

**Warning:** If the RMII clock mode is selected to `CONFIG_ETH_RMII_CLK_OUTPUT`, then GPIO0 can be used to output the REF_CLK signal. See `CONFIG_ETH_RMII_CLK_OUTPUT_GPIO` for more information. What’s more, if you’re not using PSRAM in your design, GPIO16 and GPIO17 are also available to output the reference clock. See `CONFIG_ETH_RMII_CLK_OUT_GPIO` for more information.

If the RMII clock mode is selected to `CONFIG_ETH_RMII_CLK_INPUT`, then GPIO0 is the only choice to input the REF_CLK signal. Please note that, GPIO0 is also an important strapping GPIO on ESP32. If GPIO0 samples a low level during power up, ESP32 will go into download mode. The system will get halted until a manually reset. The workaround of this issue is disabling the REF_CLK in hardware by default, so that the strapping pin won’t be interfered by other signals in boot stage. Then re-enable the REF_CLK in Ethernet driver installation stage. The ways to disable the REF_CLK signal can be:

- Disable or power down the crystal oscillator (as the case b in the picture).
- Force the PHY device in reset status (as the case a in the picture). **This could fail for some PHY device** (i.e. it still outputs signal to GPIO0 even in reset state).

No matter which RMII clock mode you select, you really need to take care of the signal integrity of REF_CLK in your hardware design! Keep the trace as short as possible. Keep it away from RF devices. Keep it away from inductor elements.

**Note:** ESP-IDF only supports the RMII interface (i.e. always select `CONFIG_ETH_PHY_INTERFACE_RMII` in Kconfig option `CONFIG_ETH_PHY_INTERFACE`). Signals used in data plane are fixed to specific GPIOs via MUX, they can’t be modified to other GPIOs. Signals used in control plane can be routed to any free GPIOs via Matrix. Please refer to `ESP32-Ethernet-Kit` for hardware
Fig. 5: Ethernet RMII Interface
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`.
- `smi_mdc_gpio_num` and `smi_mdio_gpio_num`: the GPIO number used to connect the SMI signals.
- `interface`: configuration of MAC Data interface to PHY (MII/RMII).
- `clock_config`: configuration of EMAC Interface clock (REF_CLK mode and GPIO number in case of RMII).

Configuration for PHY is described in `eth_phy_config_t`, including:

- `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.

Internal EMAC + External PHY

```c
eth_mac_config_t mac_config = ETH_MAC_DEFAULT_CONFIG(); // apply default MAC
      ~configuration
mac_config.smi_mdc_gpio_num = CONFIG_EXAMPLE_ETH_MDC_GPIO; // alter the GPIO
      ~used for MDC signal
mac_config.smi_mdio_gpio_num = CONFIG_EXAMPLE_ETH_MDIO_GPIO; // alter the GPIO
      ~used for MDIO signal
esp_eth_mac_t *mac = esp_eth_mac_new_esp32(&mac_config); // create MAC instance

eth_phy_config_t phy_config = ETH_PHY_DEFAULT_CONFIG(); // apply default PHY
      ~configuration
phy_config.phy_addr = CONFIG_EXAMPLE_ETH_PHY_ADDR; // alter the PHY
      ~address according to your board design
phy_config.reset_gpio_num = CONFIG_EXAMPLE_ETH_PHY_RST_GPIO; // alter the GPIO
      ~used for PHY reset
esp_eth_phy_t *phy = esp_eth_phy_new_ip101(&phy_config); // create PHY instance
      // ESP-IDF officially supports several different Ethernet PHY chip driver
      // esp_eth_phy_t *phy = esp_eth_phy_new_rt18201(&phy_config);
      // esp_eth_phy_t *phy = esp_eth_phy_new_lan8720(&phy_config);
      // esp_eth_phy_t *phy = esp_eth_phy_new_dp83848(&phy_config);
```
Optional Runtime MAC Clock Configuration

EMAC REF_CLK can be optionally configured from user application code.

```c
eth_mac_config_t mac_config = ETH_MAC_DEFAULT_CONFIG(); // apply default MAC configuration

// ...

mac_config.interface = EMAC_DATA_INTERFACE_RMII; // alter EMAC Data Interface
mac_config.clock_config.rmii.clock_mode = EMAC_CLK_OUT; // select EMAC REF_CLK mode
mac_config.clock_config.rmii.clock_gpio = EMAC_CLK_OUT_GPIO; // select GPIO number used to input/output EMAC REF_CLK

esp_eth_mac_t *mac = esp_eth_mac_new_esp32(mac_config); // create MAC instance
```

SPI-Ethernet Module

```c
eth_mac_config_t mac_config = ETH_MAC_DEFAULT_CONFIG(); // apply default MAC configuration
eth_phy_config_t phy_config = ETH_PHY_DEFAULT_CONFIG(); // apply default PHY configuration

phy_config.phy_addr = CONFIG_EXAMPLE_ETH_PHY_ADDR; // alter the PHY address according to your board design
phy_config.reset_gpio_num = CONFIG_EXAMPLE_ETH_PHY_RST_GPIO; // alter the GPIO used for PHY reset

// Install GPIO interrupt service (as the SPI-Ethernet module is interrupt driven)
gpio_install_isr_service(0);

spi_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
};

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(&phy_config);
```

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.
Chapter 2. API Reference

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 responsible to deal with the incoming frames. You can even update this field at runtime via function `esp_eth_update_input_path()` after driver installation.
- **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`.

```c
esp_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.

```c
/** Event handler for Ethernet events */
static void eth_event_handler(void *arg, esp_event_base_t event_base, int32_t event_id, void *event_data)
{
    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

(continues on next page)
### Chapter 2. API Reference

(continued from previous page)

```c
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.

```c
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*.

```c
/** Event handler for IP_EVENT_ETH_GOT_IP */
static void got_ip_event_handler(void *arg, esp_event_base_t event_base, int32_t event_id, void *event_data)
{
    ip_event_got_ip_t *event = (ip_event_got_ip_t *) event_data;
    const esp_netif_ip_info_t *ip_info = &event->ip_info;

    ESP_LOGI(TAG, "Ethernet Got IP Address");
    ESP_LOGI(TAG, "~~~~~~~~~~~");
    ESP_LOGI(TAG, "ETHIP:" IPSTR, IP2STR(&ip_info->ip));
    ESP_LOGI(TAG, "ETHMASK:" IPSTR, IP2STR(&ip_info->netmask));
    ESP_LOGI(TAG, "ETHGW:" IPSTR, IP2STR(&ip_info->gw));
    ESP_LOGI(TAG, "~~~~~~~~~~~");
}
```

esp_netif_init();  // Initialize TCP/IP network interface (should be called only once in application)

esp_netif_config_t cfg = ESP_NETIF_DEFAULT_ETH();  // apply default network interface configuration for Ethernet

esp_netif_t *eth_netif = esp_netif_new(&cfg);  // create network interface for Ethernet driver

esp_netif_attach(eth_netif, esp_eth_new_netif_glue(eth_handle));  // attach Ethernet driver to TCP/IP stack

esp_event_handler_register(IP_EVENT, IP_EVENT_ETH_GOT_IP, &got_ip_event_handler, NULL);  // register user defined IP event handlers

esp_eth_start(eth_handle);  // start Ethernet driver state machine

---

**Warning:** It is recommended to fully initialize the Ethernet driver and network interface 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.
Chapter 2. API Reference

- 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**

```c
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_INVAL_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

```c
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

```c
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

```c
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_err_t (*stack_input) esp_eth_handle_t hdl, uint8_t *buffer, uint32_t length, 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

```
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

```
esp_err_t esp_eth_ioctl(esp_eth_handle_t hdl, esp_eth_io_cmd_t cmd, void* data)
```

Misc IO function of Etherent driver.

The following 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
• [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

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
• [in] hdl: handle of Ethernet driver

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
struct esp_eth_config_t
Configuration of Ethernet driver.

Public Members

esp_eth_mac_t *mac
Ethernet MAC object.

esp_eth_phy_t *phy
Ethernet PHY object.

uint32_t check_link_period_ms
Period time of checking Ethernet link status.

esp_err_t (*stack_input)(esp_eth_handle_t eth_handle, uint8_t *buffer, uint32_t length, void *priv)
Input frame buffer to user’s stack.

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

`esp_err_t (*on_lowlevel_init_done)(esp_eth_handle_t eth_handle)`

Callback function invoked when low level 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

`esp_err_t (*on_lowlevel_deinit_done)(esp_eth_handle_t eth_handle)`

Callback function invoked when low level 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

`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

`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: write PHY register failed because of invalid argument
- ESP_ERR_TIMEOUT: write PHY register failed because of timeout
- ESP_FAIL: write PHY register failed because some other error occurred

**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
enum 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

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_PHYLOOPBACK
    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
  • [in] phy_addr: PHY Chip address (0–31)
  • [in] phy_reg: PHY register index code
  • [in] reg_value: PHY register value

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

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

typedef struct esp_eth_mediator_s esp_eth_mediator_t
  Ethernet mediator.

Enumerations
enum esp_eth_state_t
    Ethernet driver state.

    Values:
    ETH_STATE_LLINIT
        Low level 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

enum eth_event_t
    Ethernet event declarations.

    Values:
    ETHERNET_EVENT_START
        Ethernet driver start
    ETHERNET_EVENT_STOP
        Ethernet driver stop
    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

Functions

esp_eth_mac_t *esp_eth_mac_new_esp32 (const eth_mac_config_t *config)
    Create ESP32 Ethernet MAC instance.

    Return
    - instance: create MAC instance successfully
    - NULL: create MAC instance failed because some error occurred

    Parameters
    - config: Ethernet MAC configuration

Unions

union eth_mac_clock_config_t
    #include <esp_eth_mac.h> Ethernet MAC Clock Configuration.

Public Members

struct eth_mac_clock_config_t::[anonymous] mii
    EMAC MII Clock Configuration
**emac_rmii_clock_mode_t**
RMII Clock Mode Configuration

**emac_rmii_clock_gpio_t**
RMII Clock GPIO Configuration

**struct eth_mac_clock_conf_t**: [anonymous] rmii
EMAC RMII Clock Configuration

### Structures
**struct esp_eth_mac_s**
Ethernet MAC.

### Public Members

**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

**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

**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 other error occurred

- **Parameters**
  - [in] mac: Ethernet MAC instance

**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

**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
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

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.
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.

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

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
- [in] duplex: MAC duplex

`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

`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 other error occurred

Parameters

- [in] mac: Ethernet MAC instance
- [in] enable: set true to enable promiscuous mode; set false to disable promiscuous mode
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

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

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

int smi_mdc_gpio_num
SMI MDC GPIO number, set to -1 could bypass the SMI GPIO configuration

int smi_mdio_gpio_num
SMI MDIO GPIO number, set to -1 could bypass the SMI GPIO configuration

uint32_t flags
Flags that specify extra capability for mac driver

eth_data_interface_t *interface
EMAC Data interface to PHY (MII/RMII)

eth_mac_clock_config_t *clock_config
EMAC Interface clock configuration

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**

```c
typedef struct esp_eth_mac_s esp_eth_mac_t

Ethernet MAC.
```

**Enumerations**

```c
defined 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.

```

```c
defined 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_APPL_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 a direct 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**

```c
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
```
Chapter 2. API Reference

- NULL: create PHY instance failed because some error occurred

Parameters
  - [in] config: configuration of PHY

```
esp_eth_phy_t *esp_eth_phy_new_rt8201(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
```
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
```
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

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

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

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

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
```
Chapter 2. API Reference

- 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

```c
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

```c
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

```c
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

```c
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

```c
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
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**

```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
```

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
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
Chapter 2. API Reference

Functions

```c
esp_eth_netif_glue_handle_t esp_eth_new_netif_glue(esp_eth_handle_t eth_hdl)
```
Create a netif glue for Ethernet driver.

**Note** netif glue is used to attach io driver to TCP/IP netif

**Parameters**

- `eth_hdl`: Ethernet driver handle

```c
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

```c
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 an IP-based mesh networking protocol. It’s based on the 802.15.4 physical and MAC layer.

**Application Examples** The openthread directory of ESP-IDF examples contains the following applications:

- The OpenThread interactive shell `openthread/ot_cli`.
- The Thread border router `openthread/ot_br`.
- The Thread radio co-processor `openthread/ot_rcp`.

**API Reference** For manipulating the Thread network, the OpenThread api shall be used. The OpenThread api docs can be found at the OpenThread official website.

ESP-IDF provides extra apis for launching and managing the OpenThread stack, binding to network interfaces and border routing features.

**Header File**

- `components/openthread/include/esp_openthread.h`

**Functions**

```c
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.

```c
esp_err_t esp_openthread_launch_mainloop(void)
```
Launches the OpenThread main loop.
Chapter 2. API Reference

Note This 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

```c
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

```c
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

```c
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

```c
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

```c
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_host_connection_config_t*
The OpenThread port specific configuration.

Public Members

*const char* storage_partition_name
The partition for storing OpenThread dataset

*uint8_t* netif_queue_size
The packet queue size for the network interface

*uint8_t* task_queue_size
The task queue size

*struct esp_openthread_platform_config_t*
The OpenThread platform configuration.

Public Members

*esp_openthread_radio_config_t* radio_config
The radio configuration

*esp_openthread_host_connection_config_t* host_config
The host connection configuration

*esp_openthread_port_config_t* port_config
The port configuration

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
Chapter 2. API Reference

**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

**OPENTHREAD_EVENT_TREL_MULTICAST_GROUP_JOIN**
OpenThread stack joined TREL IPv6 multicast group

**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

**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 initialzied.

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_FIAL 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>
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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 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.
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 \texttt{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, \texttt{write()} returns the number of bytes written. Zero is returned when size of the input buffer is 0. On error, -1 is returned, and \texttt{errno} is set to indicate the error.

\textbf{EBADF} - not a valid file descriptor.

\textbf{EBADMSG} - Ethernet type of the frame is different then file descriptor configured filter.

\textbf{EIO} - Network interface not available or busy.

\textbf{close()} \quad \text{Opened ESP-NETIF L2 TAP file descriptor can be closed by the \texttt{close()} to free its allocated resources. The ESP-NETIF L2 TAP implementation of \texttt{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 task read operation then ends with error.}

On success, \texttt{close()} returns zero. On error, -1 is returned, and \texttt{errno} is set to indicate the error.

\textbf{EBADF} - not a valid file descriptor.

\textbf{select()} \quad \text{Select is used in a standard way, just \textit{CONFIG\_VFS\_SUPPORT\_SELECT} needs to be enabled to be the \texttt{select()} function available.}

\textbf{ESP-NETIF programmer’s manual} \quad \text{Please refer to the example section for basic initialization of default interfaces:}

\begin{itemize}
  \item WiFi Station: \texttt{wifi/getting_started/station/main/station_example_main.c}
  \item WiFi Access Point: \texttt{wifi/getting_started/softAP/main/softap_example_main.c}
  \item Ethernet: \texttt{ethernet/basic/main/ethernet_example_main.c}
\end{itemize}

For more specific cases please consult this guide: \textit{ESP-NETIF Custom I/O Driver}.

\textbf{WiFi default initialization} \quad \text{The initialization code as well as registering event handlers for default interfaces, such as softAP and station, are provided in two separate APIs to facilitate simple startup code for most applications:}

\begin{itemize}
  \item \texttt{esp\_netif\_create\_default\_wifi\_ap()}
  \item \texttt{esp\_netif\_create\_default\_wifi\_sta()}
\end{itemize}

Please note that these functions return the \texttt{esp\_netif} handle, i.e. a pointer to a network interface object allocated and configured with default settings, which as a consequence, means that:

\begin{itemize}
  \item The created object has to be destroyed if a network de-initialization is provided by an application using \texttt{esp\_netif\_destroy\_default\_wifi()}.\n  \item These \texttt{default} interfaces must not be created multiple times, unless the created handle is deleted using \texttt{esp\_netif\_destroy()}.\n  \item When using Wifi in \texttt{AP+STA} mode, both these interfaces has to be created.
\end{itemize}
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)

**Note:** Deinitialization is not supported yet

**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**
- [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_hookAttach(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

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 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 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 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 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 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. May be 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

**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_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

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

**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_DHCP_CLIENT_FAILED

**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

esp_err_t esp_netif_get_dns_info(esp_netif_t *esp_netif, esp_netif_dns_type_t type, esp_netif_dns_info_t *dns)
Get DNS Server information.
Return the currently configured DNS Server address for the specified interface and Server type.
This may be result of a previous call to `esp_netif_set_dns_info()`. If the interface’s DHCP client is enabled, the Main or Backup DNS Server may be set by the current DHCP lease.

**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

`esp_err_t esp_netif_create_ip6_linklocal (esp_netif_t *esp_netif)`
Create interface link-local IPv6 address.
Cause the TCP/IP stack to create a link-local IPv6 address for the specified interface.
This function also registers a callback for the specified interface, so that if the link-local address becomes verified as the preferred address then a SYSTEM_EVENT_GOT_IP6 event will be sent.

**Return**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS

**Parameters**
- [in] esp_netif: Handle to esp-netif instance

`esp_err_t esp_netif_get_ip6_linklocal (esp_netif_t *esp_netif, esp_ip6_addr_t *if_ip6)`
Get interface link-local IPv6 address.
If the specified interface is up and a preferred link-local IPv6 address has been created for the interface, return a copy of it.

**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.

`esp_err_t esp_netif_get_ip6_global (esp_netif_t *esp_netif, esp_ip6_addr_t *if_ip6)`
Get interface global IPv6 address.
If the specified interface is up and a preferred global IPv6 address has been created for the interface, return a copy of it.

**Return**
- ESP_OK
- ESP_FAIL If interface is down, does not have a global IPv6 address, or the global IPv6 address is not a preferred address.

**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`: 

`char *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_ip4_addr_t. Zeros in the IP address can be stripped or completely omitted: “2001:db8:85a3:0:0:0:2:1” or “2001:db8::2:1”

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:db8:85a3:0000:0000:0000:0002:0001”)
• `[out] dst`: Address of the target esp_ip6_addr_t structure to receive converted address

`esp_netif_iiodriver_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
Chapter 2. API Reference

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)`
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.

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

`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
Chapter 2. API Reference

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

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(); 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:\n", IP2STR(esp_netif_event->ip_info.ip));
```

Instead of

```c
ESP_LOGI(TAG, "got ip:%s\n", ip4addr_ntoa(esp_netif_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:

```c
esp_netif_attach(esp_netif_t *esp_netif, esp_netif_iodriver_handle driver_handle);
```

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:
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

```c
esp_netif_t *esp_netif_get_handle_from_netif_impl (void *dev)
  Returns esp_netif handle.
  Parameters
  • [in] dev: opaque ptr to network interface of specific TCP/IP stack
```  

```c
void *esp_netif_get_netif_impl (esp_netif_t *esp_netif)
  Returns network stack specific implementation handle (if supported)
  Note that it is not supported to acquire PPP netif impl pointer and this function will return NULL for esp_netif instances configured to PPP mode
  Parameters
  • [in] esp_netif: Handle to esp-netif instance
```  

```c
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.
  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
```  

```c
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.
  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
```  

```c
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 integrates 2 SAR (Successive Approximation Register) ADCs, supporting a total of 18 measurement channels (analog enabled pins).

These channels are supported:

**ADC1:**
- 8 channels: GPIO32 - GPIO39

**ADC2:**
- 10 channels: GPIO0, GPIO2, GPIO4, GPIO12 - GPIO15, GPIO25 - GPIO27

ADC Attenuation

Vref is the reference voltage used internally by ESP32 ADCs for measuring the input voltage. The ESP32 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>100 mV - 950 mV</td>
</tr>
<tr>
<td>ADC_ATTEN_DB_2_5</td>
<td>100 mV - 1250 mV</td>
</tr>
<tr>
<td>ADC_ATTEN_DB_6</td>
<td>150 mV - 1750 mV</td>
</tr>
<tr>
<td>ADC_ATTEN_DB_11</td>
<td>150 mV - 2450 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 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:

\[
V_{out} = D_{out} \times \frac{V_{max}}{D_{max}} \tag{1}
\]

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 <em>ADC Attenuation</em>.</td>
</tr>
<tr>
<td>Dmax</td>
<td>Maximum of the output ADC raw digital reading result, which is 4095 under Single Read mode, 4095 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*.

ADC Limitations

Note:
Some of the ADC2 pins are used as strapping pins (GPIO 0, 2, 15) thus cannot be used freely. Such is the case in the following official Development Kits:

- ESP32 DevKitC: GPIO 0 cannot be used due to external auto program circuits.
- ESP-WROVER-KIT: GPIO 0, 2, 4 and 15 cannot be used due to external connections for different purposes.

Since the ADC2 module is also used by the Wi-Fi, only one of them could get the preemption when using together, which means the \texttt{adc2\_get\_raw()} may get blocked until Wi-Fi stops, and vice versa.

**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 \texttt{adc1\_config\_width()} and \texttt{adc1\_config\_channel\_atten()}.
- For ADC2, configure the attenuation by \texttt{adc2\_config\_channel\_atten()}. The reading width of ADC2 is configured every time you take the reading.

Attenuation configuration is done per channel, see \texttt{adc1\_channel\_t} and \texttt{adc2\_channel\_t}, set as a parameter of above functions.

Then it is possible to read ADC conversion result with \texttt{adc1\_get\_raw()} and \texttt{adc2\_get\_raw()}. Reading width of ADC2 should be set as a parameter of \texttt{adc2\_get\_raw()} instead of in the configuration functions.

Single Read mode ADC example can be found in \texttt{peripherals/adc\_single\_read} directory of ESP-IDF examples.

It is also possible to read the internal hall effect sensor via ADC1 by calling dedicated function \texttt{hall\_sensor\_read()}. Note that even the hall sensor is internal to ESP32, reading from it uses channels 0 and 3 of ADC1 (GPIO 36 and 39). Do not connect anything else to these pins and do not change their configuration. Otherwise it may affect the measurement of low value signal from the sensor.

This API provides convenient way to configure ADC1 for reading from ULP. To do so, call function \texttt{adc1\_ulp\_enable()} and then set precision and attenuation as discussed above.

There is another specific function \texttt{adc\_vref\_to\_gpio()} used to route internal reference voltage to a GPIO pin. It comes handy to calibrate ADC reading and this is discussed in section **ADC Calibration**.

**Note:** See **ADC Limitations** for the limitation of using ADC single read mode.

**Minimizing Noise**

The ESP32 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**

The \texttt{esp\_adc\_cal/include/esp\_adc\_cal.h} API provides functions to correct for differences in measured voltages caused by variation of ADC reference voltages (Vref) between chips. Per design the ADC reference voltage is 1100 mV, however the true reference voltage can range from 1000 mV to 1200 mV amongst different ESP32s.

Correcting ADC readings using this API involves characterizing one of the ADCs at a given attenuation to obtain a characteristics curve (ADC-Voltage curve) that takes into account the difference in ADC reference voltage. The
Fig. 6: Graph illustrating noise mitigation using capacitor and multisampling of 64 samples.

Fig. 7: Graph illustrating effect of differing reference voltages on the ADC voltage curve.
characteristics curve is in the form of \( y = \text{coeff}_a \times x + \text{coeff}_b \) and is used to convert ADC readings to voltages in mV. Calculation of the characteristics curve is based on calibration values which can be stored in eFuse or provided by the user.

**Calibration Values** Calibration values are used to generate characteristic curves that account for the variation of ADC reference voltage of a particular ESP32 chip. There are currently 3 source(s) of calibration values on ESP32. The availability of these calibration values will depend on the type and production date of the ESP32 chip/module.

- **Two Point** values represent each of the ADCs’ readings at 150 mV and 850 mV. To obtain more accurate calibration results these values should be measured by user and burned into eFuse BLOCK3.
- **eFuse Vref** represents the true ADC reference voltage. This value is measured and burned into eFuse BLOCK0 during factory calibration.
- **Default Vref** is an estimate of the ADC reference voltage provided by the user as a parameter during characterization. If Two Point or eFuse Vref values are unavailable, Default Vref will be used.

Individual measurement and burning of the eFuse Vref has been applied to ESP32-D0WD and ESP32-D0WDQ6 chips produced on/after the 1st week of 2018. Such chips may be recognized by date codes on/later than 012018 (see Line 4 on figure below).

![ESP32 Chip Surface Marking](image)

If you would like to purchase chips or modules with calibration, double check with distributor or Espressif (sales@espressif.com) directly.

If you are unable to check the date code (i.e. the chip may be enclosed inside a canned module, etc.), you can still verify if eFuse Vref is present by running the espefuse.py tool with adc_info parameter

```bash
$IDF_PATH/components/esptool_py/esptool/espefuse.py --port /dev/ttyUSB0 adc_info
```

Replace /dev/ttyUSB0 with ESP32 board’s port name.

A chip that has specific eFuse Vref value programmed (in this case 1093 mV) will be reported as follows:

**ADC VRef calibration: 1093 mV**

In another example below the eFuse Vref is not programmed:

**ADC VRef calibration: None (1100 mV nominal)**

For a chip with two point calibration the message will look similar to:
ADC VRef calibration: 1149 mV
ADC readings stored in efuse BLK3:
  ADC1 Low reading (150 mV): 306
  ADC1 High reading (850 mV): 3153
  ADC2 Low reading (150 mV): 389
  ADC2 High reading (850 mV): 3206

Application Extensions

For a full example see esp-idf: peripherals/adc/single_read

Characterizing an ADC at a particular attenuation:

```c
#include "driver/adc.h"
#include "esp_adc_cal.h"
...

  esp_adc_cal_characteristics_t *adc_chars = calloc(1, sizeof(esp_adc_cal_characteristics_t));
  esp_adc_cal_value_t val_type = esp_adc_cal_characterize(unit, atten, ADC_WIDTH_BIT_12, DEFAULT_VREF, adc_chars);
  //Check type of calibration value used to characterize ADC
  if (val_type == ESP_ADC_CAL_VAL_EFUSE_VREF) {
    printf("eFuse Vref\n");
  } else if (val_type == ESP_ADC_CAL_VAL_EFUSE_TP) {
    printf("Two Point\n");
  } else {
    printf("Default\n");
  }
```

Reading an ADC then converting the reading to a voltage:

```c
#include "driver/adc.h"
#include "esp_adc_cal.h"
...

  uint32_t reading = adc1_get_raw(ADC1_CHANNEL_5);
  uint32_t voltage = esp_adc_cal_raw_to_voltage(reading, adc_chars);
```

Routing ADC reference voltage to GPIO, so it can be manually measured (for Default Vref):

```c
#include "driver/adc.h"
...

  esp_err_t status = adc_vref_to_gpio(ADC_UNIT_1, GPIO_NUM_25);
  if (status == ESP_OK) {
    printf("v_ref routed to GPIO\n");
  } else {
    printf("failed to route v_ref\n");
  }
```

GPIO Lookup Macros

There are macros available to specify the GPIO number of a ADC channel, or vice versa. e.g.

1. ADC1_CHANNEL_0_GPIO_NUM is the GPIO number of ADC1 channel 0.
2. ADC1_GPIO0 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</th>
<th>suggested range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(dB)</td>
<td>(mV)</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td>-----------------</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>100 ~ 950</td>
</tr>
<tr>
<td>2.5</td>
<td>100 ~ 1250</td>
<td></td>
</tr>
<tr>
<td>ESP32</td>
<td>6</td>
<td>150 ~ 1750</td>
</tr>
<tr>
<td>11</td>
<td>150 ~ 2450</td>
<td></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)
```
Set ADC source clock.

Return
- ESP_OK success

Parameters
- clk_div: ADC clock divider, ADC clock is divided from APB clock

```c
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.

```c
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.

```c
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

```c
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.

```
+----------+-------------+-----------------+
| SoC      | attenuation | suggested range |
|----------|-------------+-----------------|
|         | (dB)        | (mV)            |
|----------+-------------+-----------------|
|         | 0           | 100 ~ 950       |
|         | 2.5         | 100 ~ 1250      |
| ESP32   | 6           | 150 ~ 1750      |
|         | 11          | 150 ~ 2450      |
|         | 0           | 0 ~ 750         |
|         | 2.5         | 0 ~ 1050        |
| ESP32-S2| 6           | 0 ~ 1300        |
|         | 11          | 0 ~ 2500        |
+----------+-------------+-----------------+
```
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 use 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_channe_t`’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_channe_t`’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)
Chapter 2. API Reference

```
\texttt{esp_err_t \textbf{adc_digi_initialize}(const \texttt{adc_digi_init_config_t \*init_config})}

Initialize the Digital ADC.

\textbf{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

\textbf{Parameters}
- \texttt{init_config}: Pointer to Digital ADC initialization config. Refer to \texttt{adc_digi_init_config_t}.

\texttt{esp_err_t \textbf{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.

\textbf{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

\textbf{Parameters}
- \texttt{[out] buf}: Buffer to read from ADC.
- \texttt{[in] length_max}: Expected length of data read from the ADC.
- \texttt{[out] out_length}: Real length of data read from the ADC via this API.
- \texttt{[in] timeout_ms}: Time to wait for data via this API, in millisecond.

\texttt{esp_err_t \textbf{adc_digi_start}()}

Start the Digital ADC and DMA peripherals. After this, the hardware starts working.

\textbf{Return}
- ESP_ERR_INVALID_STATE Driver state is invalid.
- ESP_OK On success

\texttt{esp_err_t \textbf{adc_digi_stop}()}

Stop the Digital ADC and DMA peripherals. After this, the hardware stops working.

\textbf{Return}
- ESP_ERR_INVALID_STATE Driver state is invalid.
- ESP_OK On success

\texttt{esp_err_t \textbf{adc_digi_deinitialize}()}

Deinitialize the Digital ADC.

\textbf{Return}
- ESP_ERR_INVALID_STATE Driver state is invalid.
- ESP_OK On success

\texttt{esp_err_t \textbf{adc_digi_controller_configure}(const \texttt{adc_digi_configuration_t \*config})}

Setting the digital controller.

\textbf{Return}
- ESP_ERR_INVALID_STATE Driver state is invalid.
- ESP_ERR_INVALID_ARG If the combination of arguments is invalid.
- ESP_OK On success

\textbf{Parameters}
- \texttt{config}: Pointer to digital controller parameter. Refer to \texttt{adc_digi_config_t}.

\texttt{int \textbf{hall_sensor_read}()}

Read Hall Sensor.

\textbf{Note} 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.

Espressif Systems 662 Release v5.0-dev-1077-g397639d

Submit Document Feedback
Note: The Hall Sensor uses channels 0 and 3 of ADC1. Do not configure these channels for use as ADC channels.

Note: The ADC1 module must be enabled by calling adc1_config_width() before calling hall_sensor_read(). ADC1 should be configured for 12 bit readings, as the hall sensor readings are low values and do not cover the full range of the ADC.

Return: The hall sensor reading.

`esp_err_t adc_set_i2s_data_source(adc_i2s_source_t src)`
Set I2S data source.

- **Return**: ESP_OK success
- **Parameters**:
  - `src`: I2S DMA data source, I2S DMA can get data from digital signals or from ADC.

`esp_err_t adc_i2s_mode_init(adc_unit_t adc_unit, adc_channel_t channel)`
Initialize I2S ADC mode.

- **Return**:
  - ESP_OK success
  - ESP_ERR_INVALID_ARG Parameter error

- **Parameters**:
  - `adc_unit`: ADC unit index
  - `channel`: ADC channel index

**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 GPIO36

`ADC1_CHANNEL_1`
ADC1 channel 1 is GPIO37

`ADC1_CHANNEL_2`
ADC1 channel 2 is GPIO38

`ADC1_CHANNEL_3`
ADC1 channel 3 is GPIO39

`ADC1_CHANNEL_4`
ADC1 channel 4 is GPIO32

`ADC1_CHANNEL_5`
ADC1 channel 5 is GPIO33

`ADC1_CHANNEL_6`
ADC1 channel 6 is GPIO34
ADC1_CHANNEL_7
ADC1 channel 7 is GPIO35

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.


```c
uint8_t channel
ADC channel.

uint8_t unit
ADC unit.

uint8_t bit_width
ADC output bit width.
```

```c
struct adc_digi_output_data_t
ADC digital controller (DMA mode) output data format. Used to analyze the acquired ADC (DMA) data.
```

**Note** ESP32: Only type1 is valid. ADC2 does not support DMA mode.

**Note** ESP32-S2: Member channel can be used to judge the validity of the ADC data, because the role of the arbiter may get invalid ADC data.

### Public Members

```c
uint16_t data: 12
ADC real output data info. Resolution: 12 bit.

uint16_t channel: 4
ADC channel index info.
```

ADC channel index info. For ESP32-S2: If (channel < ADC_CHANNEL_MAX), The data is valid. If (channel > ADC_CHANNEL_MAX), The data is invalid.

```c
uint16_t unit: 1
ADC unit index info. 0: ADC1; 1: ADC2.
```

```c
struct adc_digi_output_data_t::<anonymous>::<anonymous> type2
When the configured output format is 11bit. ADC_DIGI_FORMAT_11BIT
```

```c
uint16_t val
Raw data value
```

### Enumerations

```c
defined 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.

```c
defined 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

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_9 = 0
                ADC capture width is 9Bit.
            ADC_WIDTH_BIT_10 = 1
                ADC capture width is 10Bit.
            ADC_WIDTH_BIT_11 = 2
                ADC capture width is 11Bit.
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 adc_digi_output_data_t.type2

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 \[ y = \text{coeff}_a \times x + \text{coeff}_b \]. 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 bit_width
ADC bit width

uint32_t coeff_a
Gradient of ADC-Voltage curve

uint32_t coeff_b
Offset of ADC-Voltage curve

uint32_t vref
Vref used by lookup table

const uint32_t* low_curve
Pointer to low Vref curve of lookup table (NULL if unused)

const uint32_t* high_curve
Pointer to high Vref curve of lookup table (NULL if unused)

uint8_t version
ADC Calibration

Enumerations

enum 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/esp32/include/soc/adc_channel.h

Macros

ADC1_GPIO36_CHANNEL
ADC1_CHANNEL_0_GPIO_NUM
ADC1_GPIO37_CHANNEL
ADC1_CHANNEL_1_GPIO_NUM
ADC1_GPIO38_CHANNEL
ADC1_CHANNEL_2_GPIO_NUM
ADC1_GPIO39_CHANNEL
ADC1_CHANNEL_3_GPIO_NUM
ADC1_GPIO32_CHANNEL
ADC1_CHANNEL_4_GPIO_NUM
ADC1_GPIO33_CHANNEL
ADC1_CHANNEL_5_GPIO_NUM
ADC1_GPIO34_CHANNEL
ADC1_CHANNEL_6_GPIO_NUM
ADC1_GPIO35_CHANNEL
ADC1_CHANNEL_7_GPIO_NUM
ADC2_GPIO4_CHANNEL
ADC2_CHANNEL_0_GPIO_NUM
ADC2_GPIO0_CHANNEL
ADC2_CHANNEL_1_GPIO_NUM
ADC2_GPIO2_CHANNEL
ADC2_CHANNEL_2_GPIO_NUM
ADC2_GPIO15_CHANNEL
ADC2_CHANNEL_3_GPIO_NUM
ADC2_GPIO13_CHANNEL
ADC2_CHANNEL_4_GPIO_NUM
ADC2_GPIO12_CHANNEL
ADC2_CHANNEL_5_GPIO_NUM
ADC2_GPIO14_CHANNEL
ADC2_GPIO27_CHANNEL
ADC2_CHANNEL_7_GPIO_NUM
2.3.2 Digital To Analog Converter (DAC)

Overview

ESP32 has two 8-bit DAC (digital to analog converter) channels, connected to GPIO25 (Channel 1) and GPIO26 (Channel 2).

The DAC driver allows these channels to be set to arbitrary voltages.

The DAC channels can also be driven with DMA-style written sample data by the digital controller, via the \textit{I2S driver} when using the “built-in DAC mode”.

For other analog output options, see the \textit{Sigma-delta Modulation module} and the \textit{LED Control module}. Both these modules produce high frequency PWM output, which can be hardware low-pass filtered in order to generate a lower frequency analog output.

Application Example

Setting DAC channel 1 (GPIO25) voltage to approx 0.78 of VDD_A voltage (VDD * 200 / 255). For VDD_A 3.3V, this is 2.59V:

```c
#include <driver/dac.h>

... 

dac_output_enable(DAC_CHANNEL_1);

dac_output_voltage(DAC_CHANNEL_1, 200);
```

API Reference

Header File

- components/driver/esp32/include/driver/dac.h

Functions

\textit{esp_err_t dac_i2s_enable} (void)

Enable DAC output data from I2S.

\textbf{Return}

- ESP_OK success

\textit{esp_err_t dac_i2s_disable} (void)

Disable DAC output data from I2S.

\textbf{Return}

- ESP_OK success

Header File

- components/driver/include/driver/dac_common.h
## Functions

**esp_err_t dac_pad_get_io_num**(dac_channel_t channel, gpio_num_t *gpio_num)
Get the GPIO number of a specific DAC channel.

- **Return**
  - ESP_OK if success
- **Parameters**
  - channel: Channel to get the gpio number
  - gpio_num: output buffer to hold the gpio number

**esp_err_t dac_output_voltage**(dac_channel_t channel, uint8_t dac_value)
Set DAC output voltage. DAC output is 8-bit. Maximum (255) corresponds to VDD3P3_RTC.

- **Note** Need to configure DAC pad before calling this function. DAC channel 1 is attached to GPIO25, DAC channel 2 is attached to GPIO26
- **Return**
  - ESP_OK success
- **Parameters**
  - channel: DAC channel
  - dac_value: DAC output value

**esp_err_t dac_output_enable**(dac_channel_t channel)
DAC pad output enable.

- **Note** DAC channel 1 is attached to GPIO25, DAC channel 2 is attached to GPIO26 I2S left channel will be mapped to DAC channel 2 I2S right channel will be mapped to DAC channel 1
- **Parameters**
  - channel: DAC channel

**esp_err_t dac_output_disable**(dac_channel_t channel)
DAC pad output disable.

- **Note** DAC channel 1 is attached to GPIO25, DAC channel 2 is attached to GPIO26
- **Return**
  - ESP_OK success
- **Parameters**
  - channel: DAC channel

**esp_err_t dac_cw_generator_enable**(void)
Enable cosine wave generator output.

- **Return**
  - ESP_OK success

**esp_err_t dac_cw_generator_disable**(void)
Disable cosine wave generator output.

- **Return**
  - ESP_OK success

**esp_err_t dac_cw_generator_config**(dac cw config_t *cw)
Config the cosine wave generator function in DAC module.

- **Return**
  - ESP_OK success
  - ESP_ERR_INVALID_ARG The parameter is NULL.
- **Parameters**
  - cw: Configuration.

### GPIO Lookup Macros

Some useful macros can be used to specified the GPIO number of a DAC channel, or vice versa. e.g.

1. `DAC_CHANNEL_1_GPIO_NUM` is the GPIO number of channel 1 (GPIO25);
2. `DAC_GPIO26_CHANNEL` is the channel number of GPIO 26 (channel 2).
Chapter 2. API Reference

Header File

- components/soc/esp32/include/soc/dac_channel.h

Macros

DAC_GPIO25_CHANNEL
DAC_CHANNEL_1_GPIO_NUM
DAC_GPIO26_CHANNEL
DAC_CHANNEL_2_GPIO_NUM

Header File

- components/hal/include/hal/dac_types.h

Structures

struct dac_cw_config_t
Config the cosine wave generator function in DAC module.

Public Members

dac_channel_t en_ch
Enable the cosine wave generator of DAC channel.

dac_cw_scale_t scale
Set the amplitude of the cosine wave generator output.

dac_cw_phase_t phase
Set the phase of the cosine wave generator output.

uint32_t freq
Set frequency of cosine wave generator output. Range: 130(130Hz) ~ 55000(100KHz).

int8_t offset
Set the voltage value of the DC component of the cosine wave generator output. Note: Unreasonable settings can cause waveform to be oversaturated. Range: -128 ~ 127.

Enumerations

enum dac_channel_t
Values:

DAC_CHANNEL_1 = 0
DAC channel 1 is GPIO25(ESP32) / GPIO17(ESP32S2)

DAC_CHANNEL_2 = 1
DAC channel 2 is GPIO26(ESP32) / GPIO18(ESP32S2)

DAC_CHANNEL_MAX

enum dac_cw_scale_t
The multiple of the amplitude of the cosine wave generator. The max amplitude is VDD3P3_RTC.

Values:

DAC_CW_SCALE_1 = 0x0
1/1. Default.

DAC_CW_SCALE_2 = 0x1
1/2.

DAC_CW_SCALE_4 = 0x2
1/4.
**Chapter 2. API Reference**

\[
\text{DAC_CW_SCALE_8} = 0x3
\]

1/8.

**enum dac_cw_phase_t**

Set the phase of the cosine wave generator output.

*Values:*

\[
\text{DAC_CW_PHASE_0} = 0x2
\]

Phase shift +0°

\[
\text{DAC_CW_PHASE_180} = 0x3
\]

Phase shift +180°

### 2.3.3 GPIO & RTC GPIO

**Overview**

The ESP32 chip features 34 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 Technical Reference Manual > IO MUX and GPIO Matrix (GPIO, IO_MUX)* [PDF].

Each pin 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.

<table>
<thead>
<tr>
<th>GPIO</th>
<th>Analog Function</th>
<th>RTC_GPIO</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO0</td>
<td>ADC2_CH1</td>
<td>RTC_GPIO11</td>
<td>Strapping pin</td>
</tr>
<tr>
<td>GPIO1</td>
<td>TXD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO2</td>
<td>ADC2_CH2</td>
<td>RTC_GPIO12</td>
<td>Strapping pin</td>
</tr>
<tr>
<td>GPIO3</td>
<td>RXD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO4</td>
<td>ADC2_CH0</td>
<td>RTC_GPIO10</td>
<td></td>
</tr>
<tr>
<td>GPIO5</td>
<td>Strapping pin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO6</td>
<td>TXD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO7</td>
<td>SPI0/1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO8</td>
<td>SPI0/1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO9</td>
<td>SPI0/1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO10</td>
<td>SPI0/1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO11</td>
<td>SPI0/1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO12</td>
<td>ADC2_CH5</td>
<td>RTC_GPIO15</td>
<td>Strapping pin; JTAG</td>
</tr>
<tr>
<td>GPIO13</td>
<td>ADC2_CH4</td>
<td>RTC_GPIO14</td>
<td>JTAG</td>
</tr>
<tr>
<td>GPIO14</td>
<td>ADC2_CH6</td>
<td>RTC_GPIO16</td>
<td>JTAG</td>
</tr>
<tr>
<td>GPIO15</td>
<td>ADC2_CH3</td>
<td>RTC_GPIO13</td>
<td>Strapping pin; JTAG</td>
</tr>
<tr>
<td>GPIO16</td>
<td>SPI0/1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO17</td>
<td>SPI0/1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO18</td>
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<td></td>
<td></td>
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<tr>
<td>GPIO19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO20</td>
<td></td>
<td></td>
<td>This pin is only available on ESP32-PICO-V3 chip package</td>
</tr>
<tr>
<td>GPIO21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPIO22</td>
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<tr>
<td>GPIO23</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>GPIO25</td>
<td>ADC2_CH8</td>
<td>RTC_GPIO6</td>
<td></td>
</tr>
<tr>
<td>GPIO26</td>
<td>ADC2_CH9</td>
<td>RTC_GPIO7</td>
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</tr>
<tr>
<td>GPIO27</td>
<td>ADC2_CH7</td>
<td>RTC_GPIO17</td>
<td></td>
</tr>
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<td>GPIO32</td>
<td>ADC1_CH4</td>
<td>RTC_GPIO9</td>
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<td>ADC1_CH5</td>
<td>RTC_GPIO8</td>
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</tr>
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<td>GPIO34</td>
<td>ADC1_CH6</td>
<td>RTC_GPIO4</td>
<td>GPI</td>
</tr>
</tbody>
</table>

*Continued on next page*
### Table 1 – continued from previous page

<table>
<thead>
<tr>
<th>GPIO</th>
<th>Analog Function</th>
<th>RTC_GPIO</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO35</td>
<td>ADC1_CH7</td>
<td>RTC_GPIO5</td>
<td>GPI</td>
</tr>
<tr>
<td>GPIO36</td>
<td>ADC1_CH0</td>
<td>RTC_GPIO0</td>
<td>GPI</td>
</tr>
<tr>
<td>GPIO37</td>
<td>ADC1_CH1</td>
<td>RTC_GPIO1</td>
<td>GPI</td>
</tr>
<tr>
<td>GPIO38</td>
<td>ADC1_CH2</td>
<td>RTC_GPIO2</td>
<td>GPI</td>
</tr>
<tr>
<td>GPIO39</td>
<td>ADC1_CH3</td>
<td>RTC_GPIO3</td>
<td>GPI</td>
</tr>
</tbody>
</table>

**Note:**

- Strapping pin: GPIO0, GPIO2, GPIO5, GPIO12 (MTDI), and GPIO15 (MTDO) are strapping pins. For more information, please refer to ESP32 datasheet.
- SPI0/1: GPIO6-11 and GPIO16-17 are usually connected to the SPI flash and PSRAM integrated on the module and therefore should not be used for other purposes.
- JTAG: GPIO12-15 are usually used for inline debug.
- GPI: GPIO34-39 can only be set as input mode and do not have software-enabled pullup or pulldown functions.
- TXD & RXD are usually used for flashing and debugging.
- ADC2: ADC2 pins cannot be used when Wi-Fi is used. So, if you’re using Wi-Fi and you’re having trouble getting the value from an ADC2 GPIO, you may consider using an ADC1 GPIO instead, that should solve your problem. For more details, please refer to ADC limitations.

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)
```

GPIO common configuration.

**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. 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.
```

**Return** Configure GPIO direction, such as output_only,input_only,output_and_input

```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);
Chapter 2. API Reference

- 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_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 *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.
## Chapter 2. API Reference

**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

### `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.

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

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

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

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

gpio_hold_dis (gpio_num_t gpio_num)
Disable gpio pad hold function.

When the chip is woken up from Deep-sleep, the gpio will be set to the default mode, so, the gpio will output the default level if this function is called. If you don’t want the level changes, the gpio should be configured to a known state before this function is called. e.g. If you hold gpio18 high during Deep-sleep, after the chip is woken up and gpio_hold_dis is called, gpio18 will output low level(because gpio18 is input mode by
default). If you don’t want this behavior, you should configure gpio18 as output mode and set it to high level before calling `gpio_hold_dis`.

Return
- ESP_OK Success
- ESP_ERR_NOT_SUPPORTED Not support pad hold function

Parameters
- `gpio_num`: GPIO number, only support output-capable GPIOs

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.

void `gpio_deep_sleep_hold_dis` (void)

Disable all digital gpio pad hold function during Deep-sleep.

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_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**
`typedef intr_handle_t gpio_isr_handle_t`**

**Header File**
• components/hal/include/hal/gpio_types.h

**Structures**
`struct gpio_config_t`
Configuration parameters of GPIO pad for gpio_config function.

**Public Members**
`uint64_t pin_bit_mask`
GPIO pin: set with bit mask, each bit maps to a GPIO

`gpio_mode_t mode`
GPIO mode: set input/output mode

`gpio_pullup_t pull_up_en`
GPIO pull-up

`gpio_pulldown_t pull_down_en`
GPIO pull-down

`gpio_int_type_t intr_type`
GPIO interrupt type

**Macros**
`GPIO_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_22
Pin 22 selected

GPIO_SEL_23
Pin 23 selected
GPIO_SEL_25
Pin 25 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_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

typedef void (*gpio_isr_t)(void *)
Enumerations

```c
enum gpio_port_t
{
    GPIO_PORT_0 = 0,
    GPIO_PORT_MAX
};
```

```c
enum gpio_num_t
{
    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 */
};
```
Chapter 2. API Reference

```c
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_22 = 22
GPIO22, input and output

GPIO_NUM_23 = 23
GPIO23, input and output

GPIO_NUM_25 = 25
GPIO25, 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 mode only

GPIO_NUM_35 = 35
GPIO35, input mode only

GPIO_NUM_36 = 36
GPIO36, input mode only

GPIO_NUM_37 = 37
GPIO37, input mode only

GPIO_NUM_38 = 38
GPIO38, input mode only

GPIO_NUM_39 = 39
GPIO39, input mode only

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
```

Espressif Systems 687 Release v5.0-dev-1077-g397639d
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Chapter 2. API Reference

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

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)

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)

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
- \texttt{gpio\_num}: GPIO number (e.g. \texttt{GPIO\_NUM\_12})

\texttt{esp\_err\_t rtc\_gpio\_set\_level (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
- \texttt{gpio\_num}: GPIO number (e.g. \texttt{GPIO\_NUM\_12})
- \texttt{level}: output level

\texttt{esp\_err\_t rtc\_gpio\_set\_direction (gpio\_num, rtc\_gpio\_mode\_t mode)}

RTC GPIO 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
- \texttt{gpio\_num}: GPIO number (e.g. \texttt{GPIO\_NUM\_12})
- \texttt{mode}: GPIO direction

\texttt{esp\_err\_t rtc\_gpio\_set\_direction\_in\_sleep (gpio\_num, rtc\_gpio\_mode\_t mode)}

RTC GPIO set direction in deep sleep mode or disable sleep status (default). In some application scenarios, IO needs to have another states during deep sleep.

NOTE: ESP32 support INPUT\_ONLY mode. ESP32S2 support INPUT\_ONLY, OUTPUT\_ONLY, INPUT\_OUTPUT mode.

Return
- ESP\_OK Success
- ESP\_ERR\_INVALID\_ARG GPIO is not an RTC IO

Parameters
- \texttt{gpio\_num}: GPIO number (e.g. \texttt{GPIO\_NUM\_12})
- \texttt{mode}: GPIO direction

\texttt{esp\_err\_t rtc\_gpio\_pullup\_en (gpio\_num)}

RTC GPIO pullup enable.

This function only works for RTC IOs. In general, call \texttt{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
- \texttt{gpio\_num}: GPIO number (e.g. \texttt{GPIO\_NUM\_12})

\texttt{esp\_err\_t rtc\_gpio\_pulldown\_en (gpio\_num)}

RTC GPIO pulldown enable.

This function only works for RTC IOs. In general, call \texttt{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
- \texttt{gpio\_num}: GPIO number (e.g. \texttt{GPIO\_NUM\_12})

\texttt{esp\_err\_t rtc\_gpio\_pullup\_dis (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
- 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 EXT1 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.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if gpio_num is not an RTC IO

**Parameters**
- gpio_num: GPIO number

**Macros**

RTC_GPIO_IS_VALID_GPIO(gpio_num)

**Header File**
- components/hal/include/hal/rtc_io_types.h

**Enumerations**

enum rtc_gpio_mode_t

RTCIO output/input mode type.

**Values:**

- RTC_GPIO_MODE_INPUT_ONLY
  - Pad input
- RTC_GPIO_MODE_OUTPUT_ONLY
  - Pad output
2.3.4 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.
- **Start and Stop timer** - covers which parameters should be set up to start the timer with specific alarm event 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.

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 \(\frac{1}{\text{resolution}_hz}\) seconds.

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.
• 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
gptimer_handle_t gptimer = NULL;
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.

### 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;
    // 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.

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;
}
gptimer_alarm_config_t alarm_config = {
    .alarm_count = 1000000, // initial 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, &alarm_config));

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)

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()

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

On_alarm callback and the functions invoked by itself should also be placed in IRAM, users need to take care of them by themselves.
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_INVALID_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

```c
esp_err_t gptimer_set_alarm_action (gptimer_handle_t timer, const gptimer_alarm_config_t *config)
```

Set alarm event actions for GPTimer.

**Note** This function is allowed to run within ISR context

**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

```c
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()`

```c
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**

```c
struct gptimer_alarm_event_data_t
```

GPTimer event data.
Chapter 2. API Reference

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 / resolution_hz) seconds

uint32_t intr_shared: 1
Set true, the timer interrupt number can be shared with other peripherals

struct gptimer_alarm_config_t
General Purpose Timer alarm configuration.

Public Members

uint64_t alarm_count
Alarm target count value

uint64_t reload_count
Alarm reload count value, effect only when auto_reload_on_alarm is set to true

uint32_t auto_reload_on_alarm: 1
Reload the count value by hardware, immediately at the alarm event

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.

Return Whether a high priority task has been waken up by this function

Parameters

• [in] timer: Timer handle created by gptimer_new_timer()
• [in] edata: Alarm event data, fed by driver
• [in] user_ctx: User data, passed from gptimer_config_t

Header File

• components/hal/include/hal/timer_types.h

Enumerations

enum gptimer_clock_source_t
GPTimer clock source.

Note: The clock source listed here is not supported on all targets
Note: Users 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>

Values:

GPTIMER_CLK_SRC_APB
Select APB as the source clock

enum gptimer_count_direction_t
GPTimer count direction.

Values:

GPTIMER_COUNT_DOWN
Decrease count value

GPTIMER_COUNT_UP
Increase count value

2.3.5 Inter-Integrated Circuit (I2C)

Overview

I2C is a serial, synchronous, half-duplex communication protocol that allows co-existence of multiple masters and slaves on the same bus. The I2C bus consists of two lines: serial data line (SDA) and serial clock (SCL). Both lines require pull-up resistors.

With such advantages as simplicity and low manufacturing cost, I2C is mostly used for communication of low-speed peripheral devices over short distances (within one foot).

ESP32 has two I2C controllers (also referred to as ports) which are responsible for handling communications on the I2C bus. Each I2C controller can operate as master or slave. As an example, one controller can act as a master and the other as a slave at the same time.

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’s internal pull-ups
- (Master only) Set I2C **clock speed**
- (Slave only) Configure the following
  - Whether to enable **10 bit address mode**
  - Define **slave address**

After that, initialize the configuration for a given I2C port. For this, call the function `i2c_param_config()` and pass to it the port number and the structure `i2c_config_t`.

Configuration example (master):

```c
int i2c_master_port = 0;
i2c_config_t conf = {
    .mode = I2C_MODE_MASTER,
    .sda_io_num = I2C_MASTER_SDA_IO, // select GPIO specific to your project
    .sda_pullup_en = GPIO_PULLUP_ENABLE,
    .scl_io_num = I2C_MASTER_SCL_IO, // select GPIO specific to your project
    .scl_pullup_en = GPIO_PULLUP_ENABLE,
    .master.clk_speed = I2C_MASTER_FREQ_HZ, // select frequency specific to your project
    // .clk_flags = 0, /*!< Optional, you can use I2C_SCLK_SRC_FLAG_* flags to choose i2c source clock here. */
};
```

Configuration example (slave):

```c
int i2c_slave_port = I2C_SLAVE_NUM;
i2c_config_t conf_slave = {
    .sda_io_num = I2C_SLAVE_SDA_IO, // select GPIO specific to your project
    .sda_pullup_en = GPIO_PULLUP_ENABLE,
    .scl_io_num = I2C_SLAVE_SCL_IO, // select GPIO specific to your project
    .scl_pullup_en = GPIO_PULLUP_ENABLE,
    .mode = I2C_MODE_SLAVE,
    .slave.addr_10bit_en = 0,
    .slave.addr_10bit_en = 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 2: Characteristics of ESP32 clock sources

<table>
<thead>
<tr>
<th>Clock name</th>
<th>Clock frequency</th>
<th>MAX freq for SCL</th>
<th>Clock capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>APB clock</td>
<td>80 MHz</td>
<td>4 MHz</td>
<td>/</td>
</tr>
</tbody>
</table>

Explanations for `i2c_config_t::clk_flags` are as follows:

1. **I2C_SCLK_SRC_FLAG_AWARE_DFS**: Clock’s baud rate will not change while APB clock is changing.
2. **I2C_SCLK_SRC_FLAG_LIGHT_SLEEP**: It supports Light-sleep mode, which APB clock cannot do.
3. Some flags may not be supported on ESP32, reading technical reference manual before using it.

**Note:** The clock frequency of SCL in master mode should not be larger than max frequency for SCL mentioned in the table above.

### Install Driver

After the I2C driver is configured, install it by calling the function `i2c_driver_install()` with the following parameters:

- Port number, one of the two port numbers from `i2c_port_t`
- Master or slave, selected from `i2c_mode_t`
- (Slave only) Size of buffers to allocate for sending and receiving data. As I2C is a master-centric bus, data can only go from the slave to the master at the master’s request. Therefore, the slave will usually have a send buffer where the slave application writes data. The data remains in the send buffer to be read by the master at the master’s own discretion.
- Flags for allocating the interrupt (see ESP_INTR_FLAG_* values in `esp_hw_support/include/esp_intr_alloc.h`)

**Communication as Master**  
After installing the I2C driver, ESP32 is ready to communicate with other I2C devices. ESP32’s I2C controller operating as master is responsible for establishing communication with I2C slave devices and sending commands to trigger a slave to action, for example, to take a measurement and send the readings back to the master.

For better process organization, the driver provides a container, called a “command link”, that should be populated with a sequence of commands and then passed to the I2C controller for execution.
**Master Write**  The example below shows how to build a command link for an I2C master to send \( n \) bytes to a slave.

The following describes how a command link for a “master write” is set up and what comes inside:

1. Create a command link with `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:

```c
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:
Fig. 10: I2C command link - master read example

```c
i2c_master_write_byte(cmd, (ESP_SLAVE_ADDR << 1) | I2C_MASTER_READ, ACK_EN);
```

**Communication as Slave** After installing the I2C driver, ESP32 is ready to communicate with other I2C devices.

The API provides the following functions for slaves

- **i2c_slave_read_buffer()**
  Whenever the master writes data to the slave, the slave will automatically store it in the receive buffer. This allows the slave application to call the function `i2c_slave_read_buffer()` at its own discretion. This function also has a parameter to specify block time if no data is in the receive buffer. This will allow the slave application to wait with a specified timeout for data to arrive to the buffer.

- **i2c_slave_write_buffer()**
  The send buffer is used to store all the data that the slave wants to send to the master in FIFO order. The data stays there until the master requests for it. The function `i2c_slave_write_buffer()` has a parameter to specify block time if the send buffer is full. This will allow the slave application to wait with a specified timeout for the adequate amount of space to become available in the send buffer.

A code example showing how to use these functions can be found in `peripherals/i2c`.

**Interrupt Handling** During driver installation, an interrupt handler is installed by default. However, you can register your own interrupt handler instead of the default one by calling the function `i2c_isr_register()`. When implementing your own interrupt handler, refer to *ESP32 Technical Reference Manual > I2C Controller (I2C) > Interrupts [PDF]* for the description of interrupts triggered by the I2C controller.

To delete an interrupt handler, call `i2c_isr_free()`.

**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`. 

---

**Communication as Slave**

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  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.

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To delete an interrupt handler, call `i2c_isr_free()`.

**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`. 

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To delete an interrupt handler, call `i2c_isr_free()`.

**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 3: Other Configurable I2C Communication Parameters

<table>
<thead>
<tr>
<th>Parameters to Change</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>High time and low time for SCL pulses</td>
<td><code>i2c_set_period()</code></td>
</tr>
<tr>
<td>SCL and SDA signal timing used during generation of <strong>start</strong> signals</td>
<td><code>i2c_set_start_timing()</code></td>
</tr>
<tr>
<td>SCL and SDA signal timing used during generation of <strong>stop</strong> signals</td>
<td><code>i2c_set_stop_timing()</code></td>
</tr>
<tr>
<td>Timing relationship between SCL and SDA signals when slave samples, as well as when master toggles</td>
<td><code>i2c_set_data_timing()</code></td>
</tr>
<tr>
<td>I2C timeout</td>
<td><code>i2c_set_timeout()</code></td>
</tr>
<tr>
<td>Choice between transmitting / receiving the LSB or MSB first, choose one of the modes defined in <code>i2c_trans_mode_t</code></td>
<td><code>i2c_set_data_mode()</code></td>
</tr>
</tbody>
</table>

Each of the above functions has a _get_ counterpart to check the currently set value. For example, to check the I2C timeout value, call `i2c_get_timeout()`.

To check the default parameter values which are set during the driver configuration process, please refer to the file `driver/i2c.c` and look for defines with the suffix _DEFAULT_.

You can also select different pins for SDA and SCL signals and alter the configuration of pull-ups with the function `i2c_set_pin()`. If you want to modify already entered values, use the function `i2c_param_config()`.

**Note:** ESP32’s internal pull-ups are in the range of tens of kOhm, which is, in most cases, insufficient for use as I2C pull-ups. Users are advised to use external pull-ups with values described in the I2C specification.

**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
Chapter 2. API Reference

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 psram (if psram 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

**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

**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

**esp_err_t i2c_isr_register**(i2c_port_t i2c_num, void (*fn)(), void *arg, int intr_alloc_flags, intr_handle_t *handle)

Register an I2C ISR handler.
Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- i2c_num: I2C port number to attach handler to
- fn: ISR handler function
- arg: Parameter for the ISR handler
- 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: Handle return from esp_intr_alloc.

```c
esp_err_t i2c_isr_free (intr_handle_t handle)
```

Delete and free I2C ISR handle.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- handle: Handle of isr to delete.

```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

Espressif Systems
• 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.

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.

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

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
Chapter 2. API Reference

- **cmd_handle**: I2C commands list allocated statically. This handle should be created thanks to `i2c_cmd_link_create_static()` function

```c
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

```c
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

```c
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

```c
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

```c
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

```c
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

```c
esp_err_t i2c_master_stop(i2c_cmd_handle_t cmd_handle)
```

Queue a “STOP signal” to the given commands list. This function shall only be called in I2C master mode. Call `i2c_master_cmd_begin()` to send all the queued commands.

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

```c
esp_err_t i2c_master_cmd_begin(i2c_port_t i2c_num, i2c_cmd_handle_t cmd_handle, TickType_t ticks_to_wait)
```

Send all the queued commands on the I2C bus, in master mode. The task will be blocked until all the commands have been sent out. The I2C 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.

```c
int i2c_slave_write_buffer(i2c_port_t i2c_num, const uint8_t *data, int size, TickType_t ticks_to_wait)
```

Write bytes to internal ringbuffer of the I2C slave data. When the TX fifo empty, the ISR will fill the hardware FIFO with the internal ringbuffer’s data.

Note: This function shall only be called in I2C slave mode.

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
Chapter 2. API Reference

Parameters
- `i2c_num`: I2C port number

```c
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.

```c
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

```c
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 num 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.

```c
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.

```c
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
**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

**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)

**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

**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

**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**

**struct i2c_config_t**

I2C initialization parameters.
Public Members

\texttt{i2c_mode_t \_mode}
\begin{itemize}
\item I2C mode
\end{itemize}

\texttt{int \_sda\_io\_num}
\begin{itemize}
\item GPIO number for I2C sda signal
\end{itemize}

\texttt{int \_scl\_io\_num}
\begin{itemize}
\item GPIO number for I2C scl signal
\end{itemize}

\texttt{bool \_sda\_pullup\_en}
\begin{itemize}
\item Internal GPIO pull mode for I2C sda signal
\end{itemize}

\texttt{bool \_scl\_pullup\_en}
\begin{itemize}
\item Internal GPIO pull mode for I2C scl signal
\end{itemize}

\texttt{uint32\_t \_clk\_speed}
\begin{itemize}
\item I2C clock frequency for master mode, (no higher than 1MHz for now)
\end{itemize}

\texttt{struct \_i2c\_config\_t:\{anonymous\}:\{anonymous\} master}
\begin{itemize}
\item I2C master config
\end{itemize}

\texttt{uint8\_t \_addr\_10bit\_en}
\begin{itemize}
\item I2C 10bit address mode enable for slave mode
\end{itemize}

\texttt{uint16\_t \_slave\_addr}
\begin{itemize}
\item I2C address for slave mode
\end{itemize}

\texttt{uint32\_t \_maximum\_speed}
\begin{itemize}
\item I2C expected clock speed from SCL.
\end{itemize}

\texttt{struct \_i2c\_config\_t:\{anonymous\}:\{anonymous\} slave}
\begin{itemize}
\item I2C slave config
\end{itemize}

\texttt{uint32\_t \_clk\_flags}
\begin{itemize}
\item Bitwise of I2C\_SCLK\_SRC\_FLAG\_**FOR\_DFS** for clk source choice
\end{itemize}

Macros

\texttt{I2C\_APB\_CLK\_FREQ}
\begin{itemize}
\item I2C source clock is APB clock, 80MHz
\end{itemize}

\texttt{I2C\_NUM\_MAX}
\begin{itemize}
\item I2C port max
\end{itemize}

\texttt{I2C\_NUM\_0}
\begin{itemize}
\item I2C port 0
\end{itemize}

\texttt{I2C\_NUM\_1}
\begin{itemize}
\item I2C port 1
\end{itemize}

\texttt{I2C\_SCLK\_SRC\_FLAG\_FOR\_NOMAL}
\begin{itemize}
\item Any one clock source that is available for the specified frequency may be choosen
\end{itemize}

\texttt{I2C\_SCLK\_SRC\_FLAG\_AWARE\_DFS}
\begin{itemize}
\item For REF tick clock, it won’t change with APB.
\end{itemize}

\texttt{I2C\_SCLK\_SRC\_FLAG\_LIGHT\_SLEEP}
\begin{itemize}
\item For light sleep mode.
\end{itemize}

\texttt{I2C\_INTERNAL\_STRUCT\_SIZE}
\begin{itemize}
\item Minimum size, in bytes, of the internal private structure used to describe I2C commands link.
\end{itemize}

\texttt{I2C\_LINK\_RECOMMENDED\_SIZE(TRANSACTIONS)}
\begin{itemize}
\item The following macro is used to determine the recommended size of the buffer to pass to \texttt{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**

```c
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
enum i2c_mode_t
Values:

I2C_MODE_SLAVE = 0
I2C slave mode

I2C_MODE_MASTER
I2C master mode

I2C_MODE_MAX

enum i2c_rw_t
Values:

I2C_MASTER_WRITE = 0
I2C write data

I2C_MASTER_READ
I2C read data

enum 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

enum i2c_addr_mode_t
Values:

I2C_ADDR_BIT_7 = 0
I2C 7bit address for slave mode
```
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_APB
I2C source clock from APB, 80M
I2C_SCLK_MAX

enum i2c_opmode_t
Values:
I2C_CMD_RESTART = 0
I2C restart command
I2C_CMD_WRITE
I2C write command
I2C_CMD_READ
I2C read command
I2C_CMD_STOP
I2C stop command
I2C_CMD_END
I2C end command

2.3.6 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 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.

I2S0 output can be routed directly to the digital-to-analog converter’s (DAC) output channels (GPIO 25 & GPIO 26) to produce direct analog output without involving any external I2S codecs. I2S0 can also be used for transmitting PDM (Pulse-density modulation) signals.

The I2S peripherals also support LCD mode for communicating data over a parallel bus, as used by some LCD displays and camera modules. LCD mode has the following operational modes:

• LCD master transmitting mode
• Camera slave receiving mode
• ADC/DAC mode

For more information, see ESP32 Technical Reference Manual > I2S Controller (I2S) > LCD Mode [PDF].

Note: For high accuracy clock applications, use the APLL_CLK clock source, which has the frequency range of 16 ~ 128 MHz. You can enable the APLL_CLK clock source by setting `i2s_config_t::use_apll` to TRUE. If `i2s_config_t::use_apll = TRUE` and `i2s_config_t::fixed_mclk > 0`, then the master clock output frequency for I2S will be equal to the value of `i2s_config_t::fixed_mclk`, which means that the mclk frequency is provided by the user, instead of being calculated by the driver.

The clock rate of the word select line, which is called audio left-right clock rate (LRCK) here, is always the divisor of the master clock output frequency and for which the following is always true: 0 < MCLK/LRCK/channels/bits_per_sample < 64.

Functional Overview

Installing the Driver

Install the I2S driver by calling the function `i2s_driver_install` and passing the following arguments:

• Port number
• The structure `i2s_config_t` with defined communication parameters
• Event queue size and handle

Once `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_frame_num = 64,
  .use_apll = false,
  .intr_alloc_flags = ESP_INTR_FLAG_LEVEL1 // Interrupt level 1, default 0
};

i2s_driver_install(I2S_NUM, &i2s_config, 0, NULL);
```
Chapter 2. API Reference

Setting Communication Pins  Once the driver is installed, configure physical GPIO pins to which signals will be routed. For this, call the function `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.

```
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.

```
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.

```
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 `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 are two short configuration examples for the I2S driver.

I2S configuration  Example for general usage.

```
#include "driver/i2s.h"

static const int i2s_num = 0; // I2S port number
```

(continues on next page)
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,
    .use_apll = false,
    .intr_alloc_flags = ESP_INTR_FLAG_LEVEL1 // Interrupt level 1, default 0
};

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_num, 22050, bits_cfg, I2S_CHANNEL_STEREO);
...

i2s_driver_uninstall(i2s_num); //stop & destroy i2s driver

Configuring I2S to use internal DAC for analog output

#include "driver/i2s.h"
#include "freertos/queue.h"

static const int i2s_num = 0; // i2s port number

static const i2s_config_t i2s_config = {
    .mode = I2S_MODE_MASTER | I2S_MODE_TX | I2S_MODE_DAC_BUILT_IN,
    .sample_rate = 44100,
    .bits_per_sample = 16, /* the DAC module will only take the 8bits from MSB */
    .channel_format = I2S_CHANNEL_FMT_RIGHT_LEFT,
    .intr_alloc_flags = ESP_INTR_FLAG_LEVEL1 // default interrupt priority
    .dma_desc_num = 8,
    .dma_frame_num = 64,
    .use_apll = false
};
...

i2s_driver_install(i2s_num, &i2s_config, 0, NULL); //install and start i2s...

...
i2s_set_pin(i2s_num, NULL); // for internal DAC, this will enable both of the internal channels

// You can call i2s_set_dac_mode to set built-in DAC output mode.
// i2s_set_dac_mode(I2S_DAC_CHANNEL_BOTH_EN);

i2s_set_sample_rates(i2s_num, 22050); // set sample rates

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 = \(2 \times 32 / 8 = 8\) 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 loop 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 consequently 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();

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 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**

```c
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)
Chapter 2. API Reference

**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

```c
esp_err_t i2s_set_pdm_rx_down_sample(i2s_port_t i2s_num, i2s_pdm_dsr_t downsamp);
```

Set PDM mode down-sample rate. In PDM RX mode, there would be 2 rounds of downsample process in hardware. In the first downsample process, the sampling number can be 16 or 8. In the second downsample 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
- downsamp: i2s RX down sample rate for PDM mode.

```c
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**
- 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 up-sample 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

```c
esp_err_t i2s_write_expand(i2s_port_t i2s_num, const void *src, size_t size, 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
- `[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_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.

```
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…)

```
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

```
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

```
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

```
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)

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

esp_err_t i2s_set_adc_mode (adc_unit_t adc_unit, adc1_channel_t adc_channel)
Set built-in ADC mode for I2S DMA, this function will initialize ADC pad, and set ADC parameters.

Note In this mode, the ADC maximum sampling rate is 150KHz. Set the sampling rate through i2s_config_t.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• adc_unit: SAR ADC unit index
• adc_channel: ADC channel index

esp_err_t i2s_adc_enable (i2s_port_t i2s_num)
Start to use I2S built-in ADC mode.

Note This function would acquire the lock of ADC to prevent the data getting corrupted during the I2S peripheral is being used to do fully continuous ADC sampling.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error
• ESP_ERR_INVALID_STATE Driver state error

Parameters
• i2s_num: i2s port index

esp_err_t i2s_adc_disable (i2s_port_t i2s_num)
Stop to use I2S built-in ADC mode.

Note This function would release the lock of ADC so that other tasks can use ADC.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error
• ESP_ERR_INVALID_STATE Driver state error

Parameters
• i2s_num: i2s port index

esp_err_t i2s_set_dac_mode (i2s_dac_mode_t dac_mode)
Set I2S dac mode, I2S built-in DAC is disabled by default.

Note Built-in DAC functions are only supported on I2S0 for current ESP32 chip. If either of the built-in DAC channel are enabled, the other one cannot be used as RTC DAC function at the same time.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
Chapter 2. API Reference

- `dac_mode`: DAC mode configurations - see `i2s_dac_mode_t`

**Structures**

`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**

```c
int sample_rate
I2S PDM sample rate

int fp
I2S PDM TX upsampling parameter. Normally it should be set to 960

int fs
I2S PDM TX upsampling parameter. 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**

```c
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**

```c
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 channel_format
I2S channel format.

i2s_comm_format_t communication_format
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’

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:
Chapter 2. API Reference

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_DMA finish sent 1 buffer

I2S_EVENT_TX_DONE
I2S DMA finish received 1 buffer

I2S_EVENT_RX_DONE
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.

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_PCM_SHORT = 0x04
PCM Short standard, also known as DSP mode. The period of synchronization signal (WS) is 1 bck cycle.

I2S_COMM_FORMAT_PCM_LONG = 0x0C
PCM Long standard. The period of synchronization signal (WS) is channel_bit*bck cycles.

I2S_COMM_FORMAT_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
Chapter 2. API Reference

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)

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_DAC_BUILT_IN = (0x1 << 4)
Output I2S data to built-in DAC, no matter the data format is 16bit or 32 bit, the DAC module will only take the 8bits from MSB

I2S_MODE_ADC_BUILT_IN = (0x1 << 5)
Input I2S data from built-in ADC, each data can be 12-bit width at most

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)

I2S_CLK_APLL
Clock from APLL

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_MCLK_MULTIPLE_384 = 384
mclk = sample_rate * 384

enum i2s_dac_mode_t
I2S DAC mode for i2s_set_dac_mode.

Note: Built-in DAC functions are only supported on I2S0 for current ESP32 chip.

Values:
I2S_DAC_CHANNEL_DISABLE = 0
Disable I2S built-in DAC signals

I2S_DAC_CHANNEL_RIGHT_EN = 1
Enable I2S built-in DAC right channel, maps to DAC channel 1 on GPIO25

I2S_DAC_CHANNEL_LEFT_EN = 2
Enable I2S built-in DAC left channel, maps to DAC channel 2 on GPIO26

I2S_DAC_CHANNEL_BOTH_EN = 0x3
Enable both of the I2S built-in DAC channels.

I2S_DAC_CHANNEL_MAX = 0x4
I2S built-in DAC mode max index

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 = 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

2.3.7 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:

- 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
- LVGL porting and animation UI - peripherals/lcd/lvgl
- GC9A01 user customized driver and dash board UI - peripherals/lcd/ge9a01

API Reference

Header File

- components/hal/include/hal/lcd_types.h

Enumerations

enum lcd_clock_source_t

LCD clock source.

Note User should select the clock source based on the real requirement:

<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_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_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

typedef struct esp_lcd_panel_io_t *esp_lcd_panel_io_handle_t
Type of LCD panel IO handle

typedef struct esp_lcd_panel_t *esp_lcd_panel_handle_t
Type of LCD panel handle

Enumerations

enum esp_lcd_color_space_t

LCD color space type definition.

Values:

- **ESP_LCD_COLOR_SPACE_RGB**
  Color space: RGB

- **ESP_LCD_COLOR_SPACE_BGR**
  Color space: BGR

- **ESP_LCD_COLOR_SPACE_MONOCHROME**
  Color space: monochrome
Chapter 2. API Reference

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)
```

Destory 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()`.

```c
esp_err_t esp_lcd_new_panel_io_spi(esp_lcd_spi_bus_handle_t bus, const esp_lcd_panel_io_spi_config_t *io_config, esp_lcd_panel_io_handle_t *ret_io)
```

Create LCD panel IO handle, for SPI interface.

**Return**

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_ERR_NO_MEM if out of memory
- ESP_OK on success
Chapter 2. API Reference

Parameters

- **[in]** bus: SPI bus handle
- **[in]** io_config: IO configuration, for SPI interface
- **[out]** ret_io: Returned IO handle

```c
esp_err_t esp_lcd_new_panel_io_i2c(esp_lcd_i2c_bus_handle_t bus, const esp_lcd_panel_io_i2c_config_t *io_config, esp_lcd_panel_io_handle_t *ret_io)
```

Create LCD panel IO handle, for I2C interface.

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

```c
esp_err_t esp_lcd_new_i80_bus(const esp_lcd_i80_bus_config_t *bus_config, esp_lcd_i80_bus_handle_t *ret_bus)
```

Create Intel 8080 bus handle.

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

```c
esp_err_t esp_lcd_del_i80_bus(esp_lcd_i80_bus_handle_t bus)
```

Destroy 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()

```c
esp_err_t esp_lcd_new_panel_io_i80(esp_lcd_i80_bus_handle_t bus, const esp_lcd_panel_io_i80_config_t *io_config, esp_lcd_panel_io_handle_t *ret_io)
```

Create LCD panel IO, for Intel 8080 interface.

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

```c
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

struct esp_lcd_panel_io_i2c_config_t

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_i80_bus_config_t**

LCD Intel 8080 bus configuration structure.

**Public Members**

- **int dc_gpio_num**
  - GPIO used for D/C line
- **int wr_gpio_num**
  - GPIO used for WR line
- **lcd_clock_source_t clk_src**
  - Clock source for the I80 LCD peripheral
- **int data_gpio_nums[(24)]**
  - GPIOs used for data lines
- **size_t bus_width**
  - Number of data lines, 8 or 16
- **size_t max_transfer_bytes**
  - Maximum transfer size, this determines the length of internal DMA link

**struct esp_lcd_panel_io_i80_config_t**

Panel IO configuration structure, for intel 8080 interface.

**Public Members**

- **int cs_gpio_num**
  - GPIO used for CS line, set to -1 will declaim exclusively use of I80 bus
- **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 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

**Header File**
- components/esp_lcd/include/esp_lcd_panel_vendor.h

**Functions**

**esp_err_t esp_lcd_new_panel_st7789** *(const esp_lcd_panel_io_handle_t io, const esp_lcd_panel_dev_config_t *panel_dev_config, esp_lcd_panel_handle_t *ret_panel)*

Create LCD panel for model ST7789.

**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

**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

**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

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

.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
    Setting this if the panel reset is high level active

2.3.8 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 16 channels which can generate independent waveforms that can be used, for example, to drive RGB LED devices.

LEDC channels are divided into two groups of 8 channels each. One group of LEDC channels operates in high speed mode. This mode is implemented in hardware and offers automatic and glitch-free changing of the PWM duty cycle. The other group of channels operate in low speed mode, the PWM duty cycle must be changed by the driver in software. Each group of channels is also able to use different clock sources.

The PWM controller can automatically increase or decrease the duty cycle gradually, allowing for fades without any processor interference.

Functionality Overview

Setting up a channel of the LEDC in either high or low speed mode is done in three steps:

1. Timer Configuration by specifying the PWM signal’s frequency and duty cycle resolution.
2. Channel Configuration by associating it with the timer and GPIO to output the PWM signal.
3. Change PWM Signal that drives the output in order to change LED’s intensity. This can be done under the full control of software or with hardware fading functions.

As an optional step, it is also possible to set up an interrupt on fade end.
Chapter 2. API Reference

Fig. 11: Key Settings of LED PWM Controller’s API

**Timer Configuration** Setting the timer is done by calling the function `ledc_timer_config()` and passing the data structure `ledc_timer_config_t` that contains the following configuration settings:

- Speed mode `ledc_mode_t`
- Timer number `ledc_timer_t`
- PWM signal frequency
- Resolution of PWM duty

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.

**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.

**Change PWM Duty Cycle Using Software** To set the duty cycle, use the dedicated function `ledc_set_duty()`. After that, call `ledc_update_duty()` to activate the changes. To check the currently set value, use the corresponding get function `ledc_get_duty()`.

Another way to set the duty cycle, as well as some other channel parameters, is by calling `ledc_channel_config()` covered in Section Channel Configuration.
The range of the duty cycle values passed to functions depends on selected `duty_resolution` and should be from 0 to \((2^{\text{duty_resolution}}) - 1\). For example, if the selected duty resolution is 10, then the duty cycle values can range from 0 to 1023. This provides the resolution of ~0.1%.

### Change PWM Duty Cycle using Hardware
The LEDC hardware provides the means to gradually transition from one duty cycle value to another. To use this functionality, enable fading with `ledc_fade_func_install()` and then configure it by calling one of the available fading functions:

- `ledc_set_fade_with_time()`
- `ledc_set_fade_with_step()`
- `ledc_set_fade()`

Finally start fading with `ledc_fade_start()`.

If not required anymore, fading and an associated interrupt can be disabled with `ledc_fade_func_uninstall()`.

### Change PWM Frequency
The LEDC API provides several ways to change the PWM frequency “on the fly”:

- Set the frequency by calling `ledc_set_freq()`. There is a corresponding function `ledc_get_freq()` to check the current frequency.
- Change the frequency and the duty resolution by calling `ledc_bind_channel_timer()` to bind some other timer to the channel.
- Change the channel’s timer by calling `ledc_channel_config()`.

### More Control Over PWM
There are several lower level timer-specific functions that can be used to change PWM settings:

- `ledc_timer_set()`
- `ledc_timer_rst()`
- `ledc_timer_pause()`
- `ledc_timer_resume()`

The first two functions are called “behind the scenes” by `ledc_channel_config()` to provide a startup of a timer after it is configured.

### Use Interrupts
When configuring an LEDC channel, one of the parameters selected within `ledc_channel_config_t` is `ledc_intr_type_t` which triggers an interrupt on fade completion.

For registration of a handler to address this interrupt, call `ledc_isr_register()`.

### LEDC High and Low Speed Mode
High speed mode enables a glitch-free changeover of timer settings. This means that if the timer settings are modified, the changes will be applied automatically on the next overflow interrupt of the timer. In contrast, when updating the low-speed timer, the change of settings should be explicitly triggered by software. The LEDC driver handles it in the background, e.g., when `ledc_timer_config()` or `ledc_timer_set()` is called.


### 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% (\(2^{13} \approx 8192\) discrete levels of the LED intensity). Note, however, that these parameters depend on the clock signal clocking the LED PWM Controller.
Chapter 2. API Reference

timer which in turn clocks the channel (see timer configuration and the ESP32 Technical Reference Manual > LED PWM Controller (LEDC) [PDF]).

The LEDC can be used for generating signals at much higher frequencies that are sufficient enough to clock other devices, e.g., a digital camera module. In this case, the maximum available frequency is 40 MHz with duty resolution of 1 bit. This means that the duty cycle is fixed at 50% and cannot be adjusted.

The LEDC API is designed to report an error when trying to set a frequency and a duty resolution that exceed the range of LEDC’s hardware. For example, an attempt to set the frequency to 20 MHz and the duty resolution to 3 bits will result in the following error reported on a serial monitor:

```
E (196) ledc: requested frequency and duty resolution cannot be achieved, try 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.

**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.

**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.
Chapter 2. API Reference

- timer_num: LEDC timer index (0-3), select from ledc_timer_t

```c
esp_err_t ledc_set_duty_with_hpoint (ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t duty, uint32_t hpoint)
```

LEDC set duty and hpoint value. Only after calling ledc_update_duty will the duty update.

**Note** ledc_set_duty, ledc_set_duty_with_hpoint and ledc_update_duty are not thread-safe, do not call these functions to control one LEDC channel in different tasks at the same time. A thread-safe version of API is ledc_set_duty_and_update.

**Note** If a fade operation is running in progress on that channel, the driver would not allow it to be stopped. 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)

```c
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.

**Note** If a fade operation is running in progress on that channel, the driver would not allow it to be stopped. 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]

```c
uint32_t ledc_get_duty (ledc_mode_t speed_mode, ledc_channel_t channel)
```

LEDC get duty.

**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
**Chapter 2. API Reference**

```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** If a fade operation is running in progress on that channel, the driver would not allow it to be stopped.
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 (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.

```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
**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

**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

**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**
- 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

**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** If a fade operation is running in progress on that channel, the driver would not allow it to be stopped. 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

**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.
Chapter 2. API Reference

**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** If a fade operation is running in progress on that channel, the driver would not allow it to be stopped. 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.

**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** If a fade operation is running in progress on that channel, the driver would not allow it to be stopped. 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.

```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** If a fade operation is running in progress on that channel, the driver would not allow it to be stopped. Other duty operations will have to wait until the fade operation has finished.

**Parameters**
- `speed_mode`: Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- `channel`: LEDC channel (0 - LEDC_CHANNEL_MAX-1), select from `ledc_channel_t`
- `duty`: Set the LEDC duty, the range of duty setting is [0, (2**(duty_resolution) - 1]`)
- `hpoint`: Set the LEDC hpoint value(max: 0xfffff)
esp_err_t ledc_set_fade_time_and_start (ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t target_duty, uint32_t max_fade_time_ms, ledc_fade_mode_t fade_mode)

A thread-safe API to set and start LEDC fade function, with a limited time.

Note Call ledc_fade_func_install() once, before calling this function.
Note If a fade operation is running in progress on that channel, the driver would not allow it to be stopped. 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).
- fade_mode: choose blocking or non-blocking mode

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 If a fade operation is running in progress on that channel, the driver would not allow it to be stopped. 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

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

- `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

```c
struct ledc_channel_config_t::[anonymous] flags
```
LEDC flags

```c
struct ledc_timer_config_t
```
Configuration parameters of LEDC Timer timer for `ledc_timer_config` function.

### Public Members

- `ledc_mode_t speed_mode`
  - LEDC speed speed_mode, high-speed mode or low-speed mode
- `ledc_timer_bit_t duty_resolution`
  - LEDC channel duty resolution
- `ledc_timer_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)

```c
struct ledc_clk_cfg_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`

```c
struct ledc_cb_param_t
```
LEDC callback parameter.
Public Members

```c
ledc_cb_event_t event
    Event name
```

```c
uint32_t speed_mode
    Speed mode of the LEDC channel group
```

```c
uint32_t channel
    LEDC channel (0 - LEDC_CHANNEL_MAX-1)
```

```c
uint32_t duty
    LEDC current duty of the channel, the range of duty is [0, (2**duty_resolution) - 1]
```

```c
struct ledc_cbs_t
    Group of supported LEDC callbacks.
```

**Note** The callbacks are all running under ISR environment

Public Members

```c
ledc_cb_t fade_cb
    LEDC fade_end callback function
```

Macros

```c
LEDC_APB_CLK_HZ
LEDC_REF_CLK_HZ
LEDC_ERR_DUTY
LEDC_ERR_VAL
```

Type Definitions

```c
typedef intr_handle_t ledc_isr_handle_t
```

```c
typedef bool (*ledc_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

```c
enum ledc_cb_event_t
    LEDC callback event type.
```

**Values**:

```c
LEDC_FADE_END_EVT
    LEDC fade end event
```

Header File

- components/hal/include/hal/ledc_types.h

Enumerations

```c
enum ledc_mode_t
    Values:
```

```c
LEDC_HIGH_SPEED_MODE = 0
    LEDC high speed speed_mode
```
LEDC_LOW_SPEED_MODE
   LEDC low speed speed_mode

LEDC_SPEED_MODE_MAX
   LEDC speed limit

enum ledc_intr_type_t
   Values:
   LEDC_INTR_DISABLE = 0
      Disable LEDC interrupt
   LEDC_INTR_FADE_END
      Enable LEDC interrupt
   LEDC_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

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_REF_TICK
      LEDC timer select REF_TICK clock as source clock

enum ledc_clk_src_t
   Values:
   LEDC_REF_TICK = LEDC_USE_REF_TICK
      LEDC timer clock divided from reference tick (1Mhz)
   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

LEDC_TIMER_1
  LEDC timer 1

LEDC_TIMER_2
  LEDC timer 2

LEDC_TIMER_3
  LEDC timer 3

LEDC_TIMER_MAX

enum ledc_channel_t
Values:

LEDC_CHANNEL_0 = 0
  LEDC channel 0

LEDC_CHANNEL_1
  LEDC channel 1

LEDC_CHANNEL_2
  LEDC channel 2

LEDC_CHANNEL_3
  LEDC channel 3

LEDC_CHANNEL_4
  LEDC channel 4

LEDC_CHANNEL_5
  LEDC channel 5

LEDC_CHANNEL_6
  LEDC channel 6

LEDC_CHANNEL_7
  LEDC channel 7

LEDC_CHANNEL_MAX

enum ledc_timer_bit_t
Values:

LEDC_TIMER_1_BIT = 1
  LEDC PWM duty resolution of 1 bits

LEDC_TIMER_2_BIT
  LEDC PWM duty resolution of 2 bits

LEDC_TIMER_3_BIT
  LEDC PWM duty resolution of 3 bits

LEDC_TIMER_4_BIT
  LEDC PWM duty resolution of 4 bits

LEDC_TIMER_5_BIT
  LEDC PWM duty resolution of 5 bits

LEDC_TIMER_6_BIT
  LEDC PWM duty resolution of 6 bits

LEDC_TIMER_7_BIT
  LEDC PWM duty resolution of 7 bits
### LEDC_TIMER_8_BIT
- LEDC PWM duty resolution of 8 bits

### LEDC_TIMER_9_BIT
- LEDC PWM duty resolution of 9 bits

### 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_15_BIT
- LEDC PWM duty resolution of 15 bits

### LEDC_TIMER_16_BIT
- LEDC PWM duty resolution of 16 bits

### LEDC_TIMER_17_BIT
- LEDC PWM duty resolution of 17 bits

### LEDC_TIMER_18_BIT
- LEDC PWM duty resolution of 18 bits

### LEDC_TIMER_19_BIT
- LEDC PWM duty resolution of 19 bits

### LEDC_TIMER_20_BIT
- LEDC PWM duty resolution of 20 bits

### LEDC_TIMER_BIT_MAX

```c
enum ledc_fade_mode_t
{
    LEDC_FADE_NO_WAIT = 0,
    LEDC_FADE_WAIT_DONE,
    LEDC_FADE_MAX
};
```

#### 2.3.9 Motor Control Pulse Width Modulator (MCPWM)

ESP32 has two MCPWM units which can be used to control different types of motors. Each unit has three pairs of PWM outputs.

Further in documentation the outputs of a single unit are labeled `PWMxA / PWMxB`.

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`. 
Fig. 12: MCPWM Overview

Fig. 13: MCPWM Block Diagram
Chapter 2. API Reference

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.

![Fig. 14: Example of Brushed DC Motor Control with MCPWM](image)

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 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 Generator, 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. 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 Technical Reference Manual > Motor Control PWM (MCPWM) [PDF].
Chapter 2. API Reference

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.

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.

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 \texttt{mcpwm_fault_signal_t} and specific action on outputs A and B defined in \texttt{mcpwm_action_on_pwmxa_t} and \texttt{mcpwm_action_on_pwmxb_t}. Particular fault signal may be disabled at the runtime by calling \texttt{mcpwm_fault_deinit()}. 

\textbf{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 \texttt{mcpwm_carrier_init()}. The carrier parameters are defined in \texttt{mcpwm_carrier_config_t} structure invoked within the function call. Then the carrier functionality may be enabled by calling \texttt{mcpwm_carrier_enable()}. 

The carrier parameters may be then altered at a runtime by calling dedicated functions to change individual fields of the \texttt{mcpwm_carrier_config_t} structure, like \texttt{mcpwm_carrier_set_period()}, \texttt{mcpwm_carrier_set_duty_cycle()}, \texttt{mcpwm_carrier_output_invert()}, etc. 

This includes enabling and setting duration of the first pulse of the carrier with \texttt{mcpwm_carrier_oneshot_mode_enable()}. For more details, see \textit{ESP32 Technical Reference Manual > Motor Control PWM (MCPWM) > PWM Carrier Submodule [PDF]}. 

To disable carrier functionality call \texttt{mcpwm_carrier_disable()}. 

\textbf{Interrupts} 

Registering of the MCPWM interrupt handler is possible by calling \texttt{mcpwm_isr_register()}. Note if \texttt{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. 

\textbf{Resolution} 

The default resolution for MCPWM group and MCPWM timer are configured to \textbf{10MHz} and \textbf{1MHz} in \texttt{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: \texttt{mcpwm_group_set_resolution()} and \texttt{mcpwm_timer_set_resolution()}. 

Note that, these two APIs won’t update the frequency and duty automatically, to achieve that, one has to call \texttt{mcpwm_set_frequency()} and \texttt{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. 

\textbf{Application Example} 

MCPWM example are located under: \texttt{peripherals/mcpwm}: 

- Control of BLDC (brushless DC) motor with hall sensor feedback - \texttt{peripherals/mcpwm/mcpwm_bldc_hall_control} 
- Brushed DC motor control - \texttt{peripherals/mcpwm/mcpwm_bdc_speed_control} 
- Servo motor control - \texttt{peripherals/mcpwm/mcpwm_servo_control} 
- HC-SR04 sensor with capture - \texttt{peripherals/mcpwm/mcpwm_capture_hr04}
API Reference

Header File

- components/hal/include/hal/mcpwm_types.h

Enumerations

enum mcpwm_timer_direction_t

* 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

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

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

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

```c
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

**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.
```
Chapter 2. API Reference

**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.

**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.

**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

```c
float mcpwm_get_duty(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

```c
uint32_t mcpwm_get_duty_in_us(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

```c
esp_err_t mcpwm_set_signal_high(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 operator(MCPWMXA/MCPWMXB), ‘x’ is timer number selected

```c
esp_err_t mcpwm_set_signal_low(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 operator(MCPWMX/YPWMX), ‘x’ is timer number selected

```c
esp_err_t mcpwm_start(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_stop(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
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
- **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)

```c
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)

```c
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

```c
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

```c
esp_err_t mcpwm_deadtime_enable(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_deadtime_type_t dt_mode, uint32_t t_red, uint32_t 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
Chapter 2. API Reference

- `dt_mode`: set deadtime mode
- `red`: set rising edge delay = red*100ns
- `fed`: set rising edge delay = fed*100ns

```c
esp_err_t mcpwm_deadtime_disable(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num)
```

Enable 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

```c
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)
- `input_level`: set fault signal level, which will cause fault to occur
- `fault_sig`: set the fault pin, which needs to be enabled

```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
Chapter 2. API Reference

- 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
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

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)

Initialize 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.

```c
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_SOURCE_SYNCIN` 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 cannot be propagated to others.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Function pointer 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_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 *arg), intr_alloc_flags 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
  - MCPWM0B out pin
- int mcpwm1a_out_num
  - MCPWM0A out pin
struct cap_event_data_t
  event data that will be passed into ISR callback

Public Members

  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)

struct mcpwm_config_t
  MCPWM config structure.

Public Members

  uint32_t frequency
  Set frequency of MCPWM in Hz

  float cmpx_a
  Set % duty cycle for operator a(MCPWMXA), i.e for 62.3% duty cycle, duty_a = 62.3

  float cmpx_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
struct mcpwm_carrier_config_t
   MCPWM carrier configuration structure.

Public Members

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 than 16

mcpwm_carrier_os_t carrier_os_mode
   Enable or disable carrier one shot mode

mcpwm_carrier_out_ivt_t carrier_ivt_mode
   Invert output of carrier

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

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

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
Chapter 2. API Reference

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

enum 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

enum 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

enum 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
Chapter 2. API Reference

MCPWM_GEN_MAX
Num of generators to each operator of MCPWM

enum 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

enum 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

enum 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

enum mcpwm_timer_sync_trigger_t
MCPWM timer sync event trigger.

Values:
Chapter 2. API Reference

MCPWM_SWSYNC_SOURCE_SYNCIN
the input sync signal will be routed to its sync output path

MCPWM_SWSYNC_SOURCE_TEZ
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_HAL_GENERATOR_MODE_FORCE_LOW
MCPWM_HAL_GENERATOR_MODE_FORCE_HIGH
MCPWM_DUTY_MODE_MAX
Num of duty cycle modes

enum 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 complement 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

enum 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

enum mcpwm_capture_signal_t
MCPWM select capture signal input.
Values:
MCPWM_SELECT_CAP0
Select CAP0 as input
MCPWM_SELECT_CAP1
Select CAP1 as input
MCPWM_SELECT_CAP2
Select CAP2 as input

2.3.10 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 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

**esp_err_t pcnt_unit_config(const pcnt_config_t *pcnt_config)**

Configure Pulse Counter unit.

**Note** 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 pcnt driver already initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- pcnt_config: Pointer of Pulse Counter unit configure parameter

**esp_err_t pcnt_get_counter_value (pcnt_unit_t pcnt_unit, int16_t *count)**

Get pulse counter value.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- pcnt_unit: Pulse Counter unit number
- count: Pointer to accept counter value

**esp_err_t pcnt_counter_pause (pcnt_unit_t pcnt_unit)**

Pause PCNT counter of 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_counter_resume (pcnt_unit_t pcnt_unit)**

Resume counting for PCNT counter.

**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, select from pcnt_unit_t

**esp_err_t pcnt_counter_clear (pcnt_unit_t pcnt_unit)**

Clear and reset PCNT counter value to zero.

**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, select from pcnt_unit_t

**esp_err_t pcnt_intr_enable (pcnt_unit_t 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 `pcnt_event_enable()` and `pcnt_event_disable()`

**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

```c
esp_err_t pcnt_intr_disable (pcnt_unit_t 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

```c
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).

```c
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).

```c
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

```c
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
Chapter 2. API Reference

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

```c
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
- **ESP_ERR_INVALID_ARG** Parameter error

Parameters
- **unit**: PCNT unit number
- **status**: Pointer to accept event status word

```c
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** Cannot find the interrupt that matches the flags.
- **ESP_ERR_INVALID_ARG** Function pointer error.

Parameters
- **handle**: handle to unregister the ISR service.

```c
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** Cannot 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.

```c
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

```c
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

```c
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 *args)) void *
```

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: Interrupt handler function.
- args: Parameter for handler function

```c
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 (ORred) ESP_INTR_FLAG_* values. See esp_intr_alloc.h for more info.

```c
void pcnt_isr_service_uninstall (void)
```
Uninstall PCNT ISR service, freeing related resources.

```c
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**

```c
struct pcnt_config_t
```
Pulse Counter configuration for a single channel.

**Public Members**

```c
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

```c
int ctrl_gpio_num
```
Control signal input GPIO number, a negative value will be ignored

```c
pcnt_ctrl_mode_t lctrl_mode
```
PCNT low control mode

```c
pcnt_ctrl_mode_t hctrl_mode
```
PCNT high control mode
Chapter 2. API Reference

```c
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

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**

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

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**

enum pcnt_port_t
   PCNT port number, the max port number is (PCNT_PORT_MAX - 1).

   **Values:**

   PCNT_PORT_0
      PCNT port 0
Chapter 2. API Reference

```
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
    PCNT_UNIT_2
        PCNT unit 2
    PCNT_UNIT_3
        PCNT unit 3
    PCNT_UNIT_4
        PCNT unit 4
    PCNT_UNIT_5
        PCNT unit 5
    PCNT_UNIT_6
        PCNT unit 6
    PCNT_UNIT_7
        PCNT unit 7
    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 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

PCNT_CHANNEL_EDGE_ACTION_INCREASE
Increase count value

PCNT_CHANNEL_EDGE_ACTION_DECREASE
Decrease count value

enum pcnt_unit_count_sign_t
PCNT unit counter value’s sign.

Values:

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

2.3.11 Remote Control (RMT)

The RMT (Remote Control) module driver can be used to send and receive infrared remote control signals. Due to flexibility of 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 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
Chapter 2. API Reference

Fig. 16: RMT Transmitter Overview

Fig. 17: RMT Receiver Overview
4. **Use Interrupts**

The RMT has eight channels numbered from zero to seven. Each channel is able to independently transmit or receive data. They are referred to using indexes defined in structure `rmt_channel_t`.

**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` members 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 signal 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`

**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.
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.

```
Fig. 18: Structure of RMT items (L - signal level)
```

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

**Warning:** RMT RX channel can’t receive packet whose items are larger than its memory block size. If you set the memory block number to 1, then this RX channel can’t receive packet with more than 64 items. This is a hardware limitation.
Before starting the receiver we need some storage for incoming items. The RMT controller has 512 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`

**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 be 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 describes 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 \texttt{rmt\_set\_tx\_thr\_intr\_en()}
• Ownership to the RMT memory block has been violated - \texttt{rmt\_set\_err\_intr\_en()}

Setting or clearing an interrupt enable mask for specific channels and events may be also done by calling \texttt{rmt\_set\_intr\_enable\_mask()} or \texttt{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 \texttt{RMT.int.clr.val.chN\_event\_name} and defined as a volatile struct in \texttt{soc/esp32/include/soc/rmt\_struct.h}, where \(N\) is the RMT channel number \([0, n]\) and the \texttt{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 \texttt{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 \texttt{rmt\_driver\_isr\_default}. Instead, if what you want is to get a notification when transaction is done, go ahead with \texttt{rmt\_register\_tx\_end\_callback()}.  

**Uninstall Driver**

If the RMT driver has been installed with \texttt{rmt\_driver\_install()} for some specific period of time and then not required, the driver may be removed to free allocated resources by calling \texttt{rmt\_driver\_uninstall()}.  

**Application Examples**

• Using RMT to send morse code: \texttt{peripherals/rmt/morse\_code}.
• Using RMT to drive RGB LED strip: \texttt{peripherals/rmt/led\_strip}.
• NEC remote control TX and RX example: \texttt{peripherals/rmt/ir\_protocols}.
• Musical buzzer example: \texttt{peripherals/rmt/musical\_buzzer}.

**API Reference**

**Header File**

• components/driver/include/driver/rmt.h

**Functions**

\texttt{esp\_err\_t \texttt{rmt\_set\_clk\_div}(rmt\_channel\_t channel, uint8\_t div\_cnt)}

Set RMT clock divider, channel clock is divided from source clock.

\texttt{Return}

• ESP\_ERR\_INVALID\_ARG Parameter error
• ESP\_OK Success

\texttt{Parameters}

• channel: RMT channel
• div\_cnt: RMT counter clock divider

\texttt{esp\_err\_t \texttt{rmt\_get\_clk\_div}(rmt\_channel\_t channel, uint8\_t \*div\_cnt)}

Get RMT clock divider, channel clock is divided from source clock.

\texttt{Return}

• ESP\_ERR\_INVALID\_ARG Parameter error
• ESP\_OK Success

\texttt{Parameters}

• channel: RMT channel
• div\_cnt: pointer to accept RMT counter divider
**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

**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

**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

**Note** 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.

**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

**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

\texttt{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. 1: 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.

\texttt{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
- tx_idx_rst: Set true to reset memory index for TX. Otherwise, transmitter will continue sending from the last index in memory.

\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
- rx_idx_rst: Set true to reset memory index for receiver. Otherwise, receiver will continue receiving data to the last index in memory.
```c
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

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

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.

```c
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.

```c
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.

```c
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.

```c
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.

```c
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
**Chapter 2. API Reference**

- **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.

```c
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.

```c
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.

```c
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.

```c
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.

```c
esp_err_t rmt_set_tx_thr_intr_en (rmt_channel_t channel, bool en, uint16_tevt_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

```c
esp_err_t rmt_set_gpio (rmt_channel_t channel, rmt_mode_t mod, gpio_num_t gpio_num, bool in-
vert_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

```c
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

```c
esp_err_t rmt_isr_register(void (*fn) void *) void *, 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, cannot 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.

```c
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

```c
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.

```c
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
Chapter 2. API Reference

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.

```c
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

```c
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**

- ESP_ERR_INVALID_ARG Parameter is NULL
- ESP_OK Success

**Parameters**

- **[out] 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
- **[out] 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.

This API allows user to send waveform with any length.

**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**
Chapter 2. API Reference

- 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).

`esp_err_t rmt_get_ringbuf_handle(rmt_channel_t channel, RingbufHandle_t *buf_handle)`

Get ringbuffer from RMT.

Users can get the RMT RX ringbuffer handle, and process the RX data.

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.

`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
Chapter 2. API Reference

- 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_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 rmt_set_intr_enable_mask (uint32_t mask)`

Set mask value to RMT interrupt enable register.

**Parameters**
- mask: Bit mask to set to the register

`void rmt_clr_intr_enable_mask (uint32_t mask)`

Clear mask value to RMT interrupt enable register.

**Parameters**
- mask: Bit mask to clear the register

`esp_err_t rmt_set_pin (rmt_channel_t channel, rmt_mode_t mode, gpio_num_t gpio_num)`

Set RMT pin.

**Return**
- ESP.ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- mode: TX or RX mode for RMT
- gpio_num: GPIO number to transmit or receive the signal.

**Structures**

`struct rmt_item32_t`

Definition of RMT item.

**Public Members**

`uint32_t duration0 : 15`

Duration of level0

`uint32_t level0 : 1`

Level of the first part

`uint32_t duration1 : 15`

Duration of level1
uint32_t level1
    Level of the second part

uint32_t val
    Equivalent unsigned value for the RMT item

struct rmt_tx_config_t
    Data struct of RMT TX configure parameters.

Public Members

uint32_t carrier_freq_hz
    RMT carrier frequency

rmt_carrier_level_t carrier_level
    Level of the RMT output, when the carrier is applied

rmt_idle_level_t idle_level
    RMT idle level

uint8_t carrier_duty_percent
    RMT carrier duty (%)

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

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
```c
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

rmt_tx_end_fn_t function
    Function which is called on RMT TX end

void *arg
    Optional argument passed to function

Macros

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

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).

This function may be called from an ISR, so, the code should be short and efficient.

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.
```
Chapter 2. API Reference

- [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

struct rmt_channel_status_result_t
Data struct of RMT channel status.

Public Members

\[ \text{rmt\_channel\_status\_t \ status[RMT\_CHANNEL\_MAX]} \]
Store the current status of each channel

Enumerations

enum rmt_channel_t
RMT channel ID.

Values:

\[ \text{RMT\_CHANNEL\_0} \]
RMT channel number 0
\[ \text{RMT\_CHANNEL\_1} \]
RMT channel number 1
\[ \text{RMT\_CHANNEL\_2} \]
RMT channel number 2
\[ \text{RMT\_CHANNEL\_3} \]
RMT channel number 3
\[ \text{RMT\_CHANNEL\_4} \]
RMT channel number 4
\[ \text{RMT\_CHANNEL\_5} \]
RMT channel number 5
\[ \text{RMT\_CHANNEL\_6} \]
RMT channel number 6
\[ \text{RMT\_CHANNEL\_7} \]
RMT channel number 7
\[ \text{RMT\_CHANNEL\_MAX} \]
Number of RMT channels

enum rmt_mem_owner_t
RMT Internal Memory Owner.

Values:

\[ \text{RMT\_MEM\_OWNER\_TX} \]
RMT RX mode, RMT transmitter owns the memory block
\[ \text{RMT\_MEM\_OWNER\_RX} \]
RMT RX mode, RMT receiver owns the memory block
\[ \text{RMT\_MEM\_OWNER\_MAX} \]
enum rmt_source_clk_t
Clock Source of RMT Channel.

Values:

-RMT_BASECLK_REF = 0
   RMT source clock is REF_TICK, 1MHz by default

-RMT_BASECLK_APB = 1
   RMT source clock is APB CLK, 80Mhz by default

-RMT_BASECLK_MAX

enum 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.

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:
2.3.12 SD Pull-up Requirements

Espressif hardware products are designed for multiple use cases which may require different pull states on pins. For this reason, the pull state of particular pins on certain products will need to be adjusted to provide the pull-ups required in the SD bus.

SD pull-up requirements apply to cases where ESP32 uses the SPI 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. Slaves should also have pull-ups on all above-mentioned lines (regardless of whether these lines are connected to the host) in order to prevent SD cards from entering a wrong state.

By default, the MTDI bootstrapping pin is incompatible with the DAT2 line pull-up if the flash voltage is 3.3 V. For more information, see *MTDI Strapping Pin* below.

This document has the following structure:

- **Overview of compatibility** between the default pull states on pins of Espressif’s products and the states required by the SD bus
- **Solutions** - ideas on how to resolve compatibility issues
- **Related information** - other relevant information

### Overview of Compatibility

This section provides an overview of compatibility issues that might occur when using SDIO (secure digital input output). Since the SD bus needs to be connected to pull-ups, these issues should be resolved regardless of whether they are related to master (host) or slave (device). Each issue has links to its respective solution. A solution for a host and device may differ.

#### Systems on a Chip (SoCs)

- **ESP32 (except for D2WD versions, see ESP32 datasheet):**
  - **No Pull-ups**
  - **Conflicts Between Bootstrap and SDIO on DAT2** for models with 3.3 V flash chip
- **ESP32-D2WD:**
  - **No Pull-ups**
  - **No Pull-up on GPIO12**

#### Systems in Packages (SIP)

- **ESP32-PICO-D4:**
  - **No Pull-ups**
  - **Conflicts Between Bootstrap and SDIO on DAT2**

#### Modules

  - **No Pull-ups**
  - **Conflicts Between Bootstrap and SDIO on DAT2**
- **ESP32-WROVER Series, including ESP32-WROVER and ESP32-WROVER-I**
– **No Pull-ups**
  - ESP32-WROVER-B Series, including ESP32-WROVER-B and ESP32-WROVER-IB
    – **No Pull-ups**
    – **Conflicts Between Bootstrap and SDIO on DAT2**

**Development Boards**

- ESP32-PICO-KIT, including PICO-KIT v4.1, v4.0, and v3
  – **No Pull-ups**
  – **Conflicts Between Bootstrap and SDIO on DAT2**
  – **Download Mode Not Working (minor issue)**
- ESP32-DevKitC, including ESP32-DevKitC v4 and v2
  – **No Pull-ups**
  – **Conflicts Between Bootstrap and SDIO on DAT2**
  – **Download Mode Not Working (minor issue)**
- ESP-WROVER-KIT
  – Required pull-ups are provided
  – **Pull-up Conflicts on GPIO13** (v4.1, v3, v2, and v1)
  – **Conflicts Between Bootstrap and SDIO on DAT2** (v4.1, v2, and v1)
  – **Download Mode Not Working (minor issue)** (v2, v1)
  You can determine the version of your ESP32-WROVER-KIT by checking which module is mounted on it:
    – ESP32-WROVER-B on v4.1
    – ESP32-WROVER on v3
    – ESP32-WROOM-32 on v1 and v2
- ESP32-LyraTD-MSC
  – Required pull-ups are provided
  – **Conflicts Between Bootstrap and SDIO on DAT2**
- ESP32-LyraT
  – Required pull-ups are provided
  – **Pull-up Conflicts on GPIO13**

**Non-Espressif Hosts** Please make sure that your SDIO host provides necessary pull-ups for all SD bus signals.

**Solutions**

**No Pull-ups** If you use a development board without pull-ups, you can do the following:

- If your host and slave device are on separate boards, replace one of them with a board that has pull-ups. For the list of Espressif’s development boards with pull-ups, go to *Development Boards*.
- Attach external pull-ups by connecting each pin which requires a pull-up to VDD via a 10 kOhm resistor.

**Pull-up Conflicts on GPIO13** If DAT3 of your device is not properly pulled up, you have the following options:

- Use 1-bit SD mode and tie the device’s DAT3 to VDD
- Use SPI mode
- **Perform one of the following actions on the GPIO13 pin:**
  - Remove the pull-down resistors
  - Attach a pull-up resistor of less than 5 kOhm (2 kOhm suggested)
  - Pull it up or drive it high either by using the host or with 3.3 V on VDD in 1-bit SD mode

**Conflicts Between Bootstrap and SDIO on DAT2** There is a conflict between the boot strapping requirements of the ESP32 and the SDIO protocol. For details, see *MTDI Strapping Pin*.

To resolve the conflict, you have the following options:
1. (Recommended) Burn the flash voltage selection eFuses. This will permanently configure the internal regulator’s output voltage to 3.3 V, and GPIO12 will not be used as a bootstrapping pin. After that, connect a pull-up resistor to GPIO12.

**Warning:** Burning eFuses is irreversible! The issue list above might be out of date, so please make sure that the module you are burning has a 3.3 V flash chip by checking the information on [http://www.espressif.com/](http://www.espressif.com/). If you burn the 3.3 V eFuses on a module with a 1.8 V flash chip, the module will stop functioning.

If you are sure that you need to irreversibly burn eFuses, go to your ESP-IDF directory and run the following command:

```
components/esptool_py/esptool/espefuse.py set_flash_voltage 3.3V
```

This command will burn the XPD_SDIO_TIEH, XPD_SDIO_FORCE, and XPD_SDIO_REG eFuses. After all the three eFuses are burned to value 1, the internal VDD_SDIO flash voltage regulator will be permanently set to 3.3 V. You will see the following log if the burning succeeds:

```
espefuse.py v2.6
Connecting....
Enable internal flash voltage regulator (VDD_SDIO) to 3.3 V.  
The following eFuses are burned: XPD_SDIO_FORCE, XPD_SDIO_REG, XPD_SDIO_TIEH.  
This is an irreversible operation. 
Type 'BURN' (all capitals) to continue. 
BURN 
VDD_SDIO setting complete. 
```

To check the status of the eFuses, run:

```
"components/esptool_py/esptool/espefuse.py summary"
```

If running from an automated flashing script, espefuse.py has an option --do-not-confirm.

For more details, see ESP32 Technical Reference Manual [PDF].

2. **If using 1-bit SD mode or SPI mode**, disconnect the DAT2 pin and make sure it is pulled high. For this, do one of the following:

   - Leave the host’s DAT2 floating and directly connect the slave’s DAT2 to VDD.
   - For a slave device, build a firmware with the option SDIO_SLAVE_FLAG_DAT2_DISABLED and re-flash your device. This option will help avoid slave detecting on the DAT2 line. Note that 4-bit SD mode will no longer be supported by the standard Card Common Control Register (CCCR); however, the host will not be aware of that. The use of 4-bit SD mode will have to be disabled on the host’s side.

**No Pull-up on GPIO12** Your module is compatible with the SDIO protocol. Just connect GPIO12 to VDD via a 10 kOhm resistor.

**Download Mode Not Working (minor issue)** When the GPIO2 pin is pulled high in accordance with the SD pull-up requirements, you cannot enter Download mode because GPIO2 is a bootstrapping pin which in this case must be pulled low.

There are the following solutions:

   - For boards that require shorting the GPIO0 and GPIO2 pins with a jumper, put the jumper in place, and the auto-reset circuit will pull GPIO2 low along with GPIO0 before entering Download mode.
   - For boards with components attached to their GPIO2 pin (such as pull-down resistors and/or LEDs), check the schematic of your development board for anything connected to GPIO2.
     - **LEDs** would not affect operation in most cases.
     - **Pull-down resistors** can interfere with DAT0 signals and must be removed.

If the above solutions do not work for you, please determine if it is the host or slave device that has pull-ups affecting their GPIO2, then locate these pull-ups and remove them.
Related Information

MTDI Strapping Pin  MTDI (GPIO12) is used as a bootstrapping pin to select the output voltage of an internal regulator (VDD_SDIO) which powers the flash chip. This pin has an internal pull-down, so, if left unconnected, it will read low at startup, which will lead to selecting the default 3.3 V operation.

All ESP32-WROVER modules, excluding ESP32-WROVER-B, use 1.8 V flash and have internal pull-ups on GPIO12. Other modules that use 3.3 V flash have no pull-ups on the GPIO12 pin, and this pin is slightly pulled down internally.

When adding a pull-up to this pin for SD card operation, consider the following:

- For boards that do not use the internal regulator (VDD_SDIO) to power flash, GPIO12 can be pulled high.
- For boards using 1.8 V flash chips, GPIO12 needs to be pulled high at reset. This is fully compatible with the SD card operation.
- On boards using the internal regulator and a 3.3 V flash chip, GPIO12 must be pulled low at reset. This is incompatible with the SD card operation. For reference information on compatibility of Espressif’s boards with the SD card operation, see Overview of Compatibility.

Internal Pull-ups and Strapping Requirements  Using external resistors is always preferable. However, Espressif’s products have internal weak pull-up and pull-down resistors which can be enabled and used instead of external ones. Please keep in mind that this solution cannot guarantee reliable SDIO communication.

With that said, the information about these internal pull-ups and strapping requirements can still be useful. Espressif hardware products have different weak internal pull-ups / pull-downs connected to CMD and DATA pins. The table below shows the default pull-up and pull-down states of the CMD and DATA pins.

The following abbreviations are used in the table:

- **WPU**: Weak pull-up inside the SoC
- **WPD**: Weak pull-down inside the SoC
- **PU**: Pull-up inside Espressif modules but outside the SoC

<table>
<thead>
<tr>
<th>GPIO number</th>
<th>Pin Name</th>
<th>Startup State</th>
<th>Strapping Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>CMD</td>
<td>WPU</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>DAT0</td>
<td>WPD</td>
<td>Low for Download mode</td>
</tr>
<tr>
<td>4</td>
<td>DAT1</td>
<td>WPD</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>DAT2</td>
<td>PU for 1.8 V flash; WPD for 3.3 V flash</td>
<td>High for 1.8 V flash; Low for 3.3 V flash</td>
</tr>
<tr>
<td>13</td>
<td>DAT3</td>
<td>WPU</td>
<td></td>
</tr>
</tbody>
</table>

2.3.13 SDMMC Host Driver

Overview

ESP32’s SDMMC host peripheral has two slots:

- Slot 0 ([SDMMC_HOST_SLOT_0](#)) is an 8-bit slot. It uses HS1_* signals in the PIN MUX.
- Slot 1 ([SDMMC_HOST_SLOT_1](#)) is a 4-bit slot. It uses HS2_* signals in the PIN MUX.

Pin mappings of these slots are given in the table below.
The Card Detect and Write Protect signals can be routed to arbitrary pins using the GPIO matrix. To reserve the pins, set the gpio_cd and gpio_wp members of the `sdmmc_slot_config_t` structure before calling `sdmmc_host_init_slot()`. Please note that it is not advised to specify a Card Detect pin when working with SDIO cards, because the card detect signal in ESP32 can also trigger SDIO slave interrupt.

<table>
<thead>
<tr>
<th>Signal</th>
<th>Slot 0</th>
<th>Slot 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMD</td>
<td>GPIO11</td>
<td>GPIO15</td>
</tr>
<tr>
<td>CLK</td>
<td>GPIO06</td>
<td>GPIO14</td>
</tr>
<tr>
<td>D0</td>
<td>GPIO07</td>
<td>GPIO02</td>
</tr>
<tr>
<td>D1</td>
<td>GPIO08</td>
<td>GPIO04</td>
</tr>
<tr>
<td>D2</td>
<td>GPIO09</td>
<td>GPIO12</td>
</tr>
<tr>
<td>D3</td>
<td>GPIO10</td>
<td>GPIO13</td>
</tr>
<tr>
<td>D4</td>
<td>GPIO16</td>
<td></td>
</tr>
<tr>
<td>D5</td>
<td>GPIO17</td>
<td></td>
</tr>
<tr>
<td>D6</td>
<td>GPIO05</td>
<td></td>
</tr>
<tr>
<td>D7</td>
<td>GPIO08</td>
<td></td>
</tr>
<tr>
<td>CD</td>
<td>any input via GPIO matrix</td>
<td>any input via GPIO matrix</td>
</tr>
<tr>
<td>WP</td>
<td>any input via GPIO matrix</td>
<td>any input via GPIO matrix</td>
</tr>
</tbody>
</table>

**Warning:** Pins used by Slot 0 (HS1_*) are also used to connect the SPI flash chip in ESP32-WROOM and ESP32-WROVER modules. These pins cannot be shared between an SD card and SPI flash. If you need to use Slot 0, connect SPI flash to different pins and set eFuses accordingly.

**Supported Speed Modes**

SDMMC Host driver supports the following speed modes:

- Default Speed (20 MHz), 1/4-line (with SD cards), and 1/4/8-line (with 3.3 V eMMC)
- High Speed (40 MHz), 1/4-line (with SD cards), and 1/4/8-line (with 3.3 V eMMC)
- High Speed DDR (40 MHz), 4-line (with 3.3 V eMMC)

Speed modes not supported at present:

- High Speed DDR mode, 8-line eMMC
- UHS-I 1.8 V modes, 4-line SD cards

**Using the SDMMC Host Driver**

Of all the functions listed below, only the following ones will be used directly by most applications:

- `sdmmc_host_init()`
- `sdmmc_host_init_slot()`
- `sdmmc_host_deinit()`

Other functions, such as the ones given below, will be called by the SD/MMC protocol layer via function pointers in the `sdmmc_host_t` structure:

- `sdmmc_host_set_bus_width()`
- `sdmmc_host_set_card_clk()`
- `sdmmc_host_do_transaction()`

**Configuring Bus Width and Frequency**

With the default initializers for `sdmmc_host_t` and `sdmmc_slot_config_t` (`SDMMC_HOST_DEFAULT` and `SDMMC_SLOT_CONFIG_DEFAULT`), SDMMC Host driver will attempt to use the widest bus supported by the card (4 lines for SD, 8 lines for eMMC) and the frequency of 20 MHz.
In the designs where communication at 40 MHz frequency can be achieved, it is possible to increase the bus frequency by changing the `max_freq_khz` field of `sdmmc_host_t`:

```c
sdmmc_host_t host = SDMMC_HOST_DEFAULT();
host.max_freq_khz = SDMMC_FREQ_HIGHSPEED;
```

To configure the bus width, set the `width` field of `sdmmc_slot_config_t`. For example, to set 1-line mode:

```c
sdmmc_slot_config_t slot = SDMMC_SLOT_CONFIG_DEFAULT();
slot.width = 1;
```

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
  - ESP_ERR_INVALID_STATE if `sdmmc_host_init` was already called
  - ESP_ERR_NO_MEM if memory cannot be allocated

- `esp_err_t sdmmc_host_init_slot(int slot, const sdmmc_slot_config_t *slot_config)`

  Initialize given slot of SDMMC peripheral.

  On the ESP32, SDMMC peripheral has two slots:
  - Slot 0: 8-bit wide, maps to HS1_* signals in PIN MUX
  - Slot 1: 4-bit wide, maps to HS2_* signals in PIN MUX

  Card detect and write protect signals can be routed to arbitrary GPIOs using GPIO matrix.

  **Note** This function is not thread safe

  **Return**
  - ESP_OK on success
  - ESP_ERR_INVALID_STATE if host has not been initialized using `sdmmc_host_init`

- `esp_err_t sdmmc_host_set_bus_width(int slot, size_t width)`

  Select bus width to be used for data transfer.

  SD/MMC card must be initialized prior to this command, and a command to set bus width has to be sent to the card (e.g. `SD_APP_SET_BUS_WIDTH`)

  **Note** This function is not thread safe

  **Return**
  - ESP_OK on success
  - ESP_ERR_INVALID_ARG if slot number or width is not valid
Chapter 2. API Reference

Parameters
- **slot**: slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- **width**: bus width (1, 4, or 8 for slot 0; 1 or 4 for slot 1)

`size_t sdmmc_host_get_slot_width (int slot)`
Get bus width configured in sdmmc_host_init_slot to be used for data transfer.

Return configured bus width of the specified slot.

Parameters
- **slot**: slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)

`esp_err_t sdmmc_host_set_card_clk (int slot, uint32_t freq_khz)`
Set card clock frequency.

Currently only integer fractions of 40MHz clock can be used. For High Speed cards, 40MHz can be used. For Default Speed cards, 20MHz can be used.

Note This function is not thread safe

Return
- ESP_OK on success
- other error codes may be returned in the future

Parameters
- **slot**: slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- **freq_khz**: card clock frequency, in kHz

`esp_err_t sdmmc_host_set_bus_ddr_mode (int slot, bool ddr_enabled)`
Enable or disable DDR mode of SD interface.

Return
- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if DDR mode is not supported on this slot

Parameters
- **slot**: slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- **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**

**struct sdmmc_slot_config_t**

Extra configuration for SDMMC peripheral slot

**Public Members**

- `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**

- `SDMMC_HOST_SLOT_0`
  
  SDMMC slot 0.
**SDMMC_HOST_SLOT_1**
SDMMC slot 1.

**SDMMC_HOST_DEFAULT()**
Default `sdmmc_host_t` structure initializer for SDMMC peripheral.

Uses SDMMC peripheral, with 4-bit mode enabled, and max frequency set to 20MHz

**SDMMC_SLOT_FLAG_INTERNAL_PULLUP**
Enable internal 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

### 2.3.14 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_handle` returned when attaching the device to an SPI bus by calling `sdspi_host_init_device`. The bus should be already initialized before (`spi_bus_initialize`).

This driver’s naming pattern was adopted from the SDMMC Host driver due to their similarity. Likewise, the APIs of both drivers are also very similar.

SD SPI driver (access the SD card in SPI mode) offers lower throughput but makes pin selection more flexible. With the help of the GPIO matrix, an SPI peripheral’s signals can be routed to any ESP32 pin. Otherwise, if SDMMC host driver is used (See SDMMC Host) to access the card in SD 1-bit/4-bit mode, higher throughput can be reached but it requires routing the signals through their dedicated IO_MUX pins only.

With the help of 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_handle` just returned from `sdspi_host_init_device`. Call `sdmmc_card_init` with the `sdmmc_host_t` to probe and initialize the SD card.

Now you can use SD/SDIO/MMC driver functions to access your card!
Chapter 2. API Reference

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 cad, it’s the rising edge.)

1. Use an oscilloscope to see the clock and compare the data line to the clock. - If you see the clock is not fast enough (for example, the rising/falling edge is longer than 1/4 of the clock cycle), it means the clock is skewed too much. - If you see the data line unstable before the latch edge of the clock, it means the load of the data line is too large.
   You may also observed the corresponding phenomenon (data delayed largely from launching edge of clock) with logic analyzers. But it’s not as obvious as with an oscilloscope.
2. Try to use slower clock frequency. If the lower frequency can work while the higher frequency can’t, it’s an indication of the AC loading on the pins is too large.

If the AC loading of the pins is too large, you can either use other faster devices (with lower pin load) or slow down the clock speed.
**DC loading** The pull-ups required by SD cards are usually around 10 kOhm to 50 kOhm, which may be too strong for some other SPI devices.

Check the specification of your device about its DC output current, it should be larger than 700uA, otherwise the device output may not be read correctly.

**Initialization sequence**

**Note:** If you see any problem in the following steps, please make sure the timing is correct first. You can try to slow down the clock speed (SDMMC_FREQ_PROBING = 400 KHz for SD card) to avoid the influence of pin AC loading (see above section).

When using an 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**

```c
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

```c
esp_err_t sdspi_host_init_device(const sdspi_device_config_t *dev_config, sdspi_dev_handle_t *out_handle)
```

Attach and initialize an SD SPI device on the specific SPI bus.

**Note** This function is not thread safe

**Note** Initialize the SPI bus by `spi_bus_initialize()` before calling this function.

**Note** The SDIO 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 cannot 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.

```c
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

```c
esp_err_t sdspi_host_do_transaction (sdspi_dev_handle_t handle, sdmmc_command_t *cmdinfo)
```
Send command to the card and get response.

This function returns when command is sent and response is received, or data is transferred, or timeout occurs.

**Note**
This function is not thread safe w.r.t. init/deinit functions, and bus width/clock speed configuration functions. Multiple tasks can call `sdspi_host_do_transaction` as long as other `sdspi_host_*` functions are not called.

**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**
Chapter 2. API Reference

```
• handle: Handle of the sdspi device
• timeout_ticks: Ticks to wait before timeout.

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 dspi 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
• ESP_ERR_NO_MEM if memory cannot be allocated
• other errors from the underlying spi_master and gpio drivers

Structures

struct sdspi_device_config_t
Extra configuration for SD SPI device.

Public Members

spi_host_device_t host_id
SPI host to use, SPIx_HOST (see spi_types.h).

gpio_num_t gpio_cs
GPIO number of CS signal.

gpio_num_t gpio_cd
GPIO number of card detect signal.

gpio_num_t gpio_wp
GPIO number of write protect signal.

gpio_num_t gpio_int
GPIO number of interrupt line (input) for SDIO card.

struct sdspi_slot_config_t
Extra configuration for SPI host.

Public Members

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.
```
### gpi_num_t gpio_sck
GPIO number of SCK signal.

### int dma_channel
DMA channel to be used by SPI driver (1 or 2).

### Macros

**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

typedef int sdspi_dev_handle_t
Handle representing an SD SPI device.

### 2.3.15 SDIO Card Slave Driver

### Overview

The ESP32 SDIO Card peripherals (Host, Slave) shares two sets of pins as below table. The first set is usually occupied by SPI0 bus which is responsible for the SPI flash holding the code to run. This means SDIO slave driver can only runs on the second set of pins while SDIO host is not using it.

The SDIO slave can run under 3 modes: SPI, 1-bit SD and 4-bit SD modes, which is detected automatically by the hardware. According to the SDIO specification, CMD and DAT0-3 lines should be pulled up no matter in 1-bit, 4-bit or SPI mode.

#### Connections

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Corresponding pins in SPI mode</th>
<th>Slot1</th>
<th>Slot2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLK</td>
<td>SCLK</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>CMD</td>
<td>MOSI</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>DAT0</td>
<td>MISO</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>DAT1</td>
<td>Interrupt</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>DAT2</td>
<td>N.C. (pullup)</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>DAT3</td>
<td>#CS</td>
<td>10</td>
<td>13</td>
</tr>
</tbody>
</table>

- 1-bit SD mode: Connect CLK, CMD, DAT0, DAT1 pins and the ground.
- 4-bit SD mode: Connect all pins and the ground.
- SPI mode: Connect SCLK, MOSI, MISO, Interrupt, #CS pins and the ground.
**Note:** Please check if CMD and DATA lines D0-D3 of the card are properly pulled up by 10 kOhm resistors. This should be ensured even in 1-bit mode or SPI mode. Most official modules don’t offer these pullups internally. If you are using official development boards, check *Overview of Compatibility* to see whether your development boards have such pullups.

**Note:** Most official modules have conflicts on strapping pins with the SDIO slave function. If you are using a ESP32 module with 3.3 V flash inside, you have to burn the EFUSE when you are developing on the module for the first time. See *Overview of Compatibility* to see how to make your modules compatible with the SDIO.

Here is a list for modules/kits with 3.3 V flash:

- **Modules:** ESP32-PICO-D4, ESP32-WROOM-32 series (including ESP32-SOLO-1), ESP32-WROVER-B and ESP32-WROVER-IB
- **Kits:** ESP32-PICO-KIT, ESP32-DevKitC (till v4), ESP32-WROVER-KIT (v4.1 (also known as ESP32-WROVER-KIT-VB), v2, v1 (also known as DevKitJ v1))

You can tell the version of your ESP32-WROVER-KIT version from the module on it: v4.1 are with ESP32-WROVER-B modules, v3 are with ESP32-WROVER modules, while v2 and v1 are with ESP32-WROOM-32 modules.

Refer to *SD Pull-up Requirements* for more technical details of the pullups.

The host initialize the slave into SD mode by first sending CMD0 with DAT3 pin high, or in SPI mode by sending CMD0 with CS pin (the same pin as DAT3) low.

After the initialization, the host can enable the 4-bit SD mode by writing CCCR register 0x07 by CMD52. All the bus detection process are handled by the slave peripheral.

The host has to communicate with the slave by an ESP-slave-specific protocol. The slave driver offers 3 services over Function 1 access by CMD52 and CMD53: (1) a sending FIFO and a receiving FIFO, (2) 52 8-bit R/W registers shared by host and slave, (3) 16 interrupt sources (8 from host to slave, and 8 from slave to host).

**Terminology** The SDIO slave driver uses the following terms:

- **Transfer:** a transfer is always started by a command token from the host, and may contain a reply and several data blocks. ESP32 slave software is based on transfers.
- **Sending:** slave to host transfers.
- **Receiving:** host to slave transfers.

**Note:** Register names in *ESP32 Technical Reference Manual > SDIO Slave Controller [PDF]* are oriented from the point of view of the host, i.e. ‘rx’ registers refer to sending, while ‘tx’ registers refer to receiving. We’re not using `tx` or `rx` in the driver to avoid ambiguities.

- **FIFO:** specific address in Function 1 that can be access by CMD53 to read/write large amount of data. The address is related to the length requested to read from/write to the slave in a single transfer: \( \text{requested length} = 0x1F800\text{-address} \).
- **Ownership:** When the driver takes ownership of a buffer, it means the driver can randomly read/write the buffer (usually via DMA). The application should not read/write the buffer until the ownership is returned to the application. If the application reads from a buffer owned by a receiving driver, the data read can be random; if the application writes to a buffer owned by a sending driver, the data sent may be corrupted.
- **Requested length:** The length requested in one transfer determined by the FIFO address.
- **Transfer length:** The length requested in one transfer determined by the CMD53 byte/block count field.

**Note:** Requested length is different from the transfer length. ESP32 slave DMA base on the *requested length* rather than the *transfer length*. The *transfer length* should be no shorter than the *requested length*, and the rest part will be...
Chapter 2. API Reference

Communication with ESP SDIO Slave

The host should initialize the ESP32 SDIO slave according to the standard SDIO initialization process (Sector 3.1.2 of SDIO Simplified Specification), which is described briefly in ESP SDIO Slave Initialization.

Furthermore, there’s an ESP32-specific upper-level communication protocol upon the CMD52/CMD53 to Func 1. Please refer to ESP SDIO Slave Protocol. There is also a component ESP Serial Slave Link for ESP32 master to communicate with ESP32 SDIO slave, see example peripherals/sdio when programming your host.

Interrupts

There are interrupts from host to slave, and from slave to host to help communicating conveniently.

Slave Interrupts

The host can interrupt the slave by writing any one bit in the register 0x08D. Once any bit of the register is set, an interrupt is raised and the SDIO slave driver calls the callback function defined in the slave_intr_cb member in the sdio_slave_config_t structure.

Note: The callback function is called in the ISR, do not use any delay, loop or spinlock in the callback.

Host Interrupts

The slave can interrupt the host by an interrupt line (at certain time) which is level sensitive. When the host see the interrupt line pulled down, it may read the slave interrupt status register, to see the interrupt source. Host can clear interrupt bits, or choose to disable a interrupt source. The interrupt line will hold active until all the sources are cleared or disabled.

There are several dedicated interrupt sources as well as general purpose sources. see sdio_slave_hostint_t for more information.

Shared Registers

There are 52 8-bit R/W shared registers to share information between host and slave. The slave can write or read the registers at any time by sdio_slave_read_reg and sdio_slave_write_reg. The host can access (R/W) the register by CMD52 or CMD53.

Receiving FIFO

When the host is going to send the slave some packets, it has to check whether the slave is ready to receive by reading the buffer number of slave.

To allow the host sending data to the slave, the application has to load buffers to the slave driver by the following steps:

1. Register the buffer by calling sdio_slave_recv_register_buf, and get the handle of the registered buffer. The driver will allocate memory for the linked-list descriptor needed to link the buffer onto the hardware. The size of these buffers should equal to the Receiving buffer size.
2. Load buffers onto the driver by passing the buffer handle to sdio_slave_recv_load_buf.
3. Get the received data by calling sdio_slave_recv or sdio_slave_recv_packet. If non-blocking call is needed, set wait=0.
Chapter 2. API Reference

The difference between two APIs is that, `sdio_slave_recv_packet` gives more information about packet, which can consist of several buffers. When `ESP_ERR_NOT_FINISHED` is returned by this API, you should call this API iteratively until the return value is `ESP_OK`. All the continuous buffers returned with `ESP_ERR_NOT_FINISHED`, together with the last buffer returned with `ESP_OK`, belong to one packet from the host. Call `sdio_slave_recv_get_buf` to get the address of the received data, and the actual length received in each buffer. The packet length is the sum of received length of all the buffers in the packet.

If the host never send data longer than the Receiving buffer size, or you don’t care about the packet boundary (e.g. the data is only a byte stream), you can call the simpler version `sdio_slave_recv` instead.

4. Pass the handle of processed buffer back to the driver by `sdio_recv_load_buf` again.

**Note:** To avoid overhead from copying data, the driver itself doesn’t have any buffer inside, the application is responsible to offer new buffers in time. The DMA will automatically store received data to the buffer.

---

**Sending FIFO** Each time the slave has data to send, it raises an interrupt and the host will request for the packet length. There are two sending modes:

- **Stream Mode:** when a buffer is loaded to the driver, the buffer length will be counted into the packet length requested by host in the incoming communications. Regardless previous packets are sent or not. This means the host can get data of several buffers in one transfer.
- **Packet Mode:** the packet length is updated packet by packet, and only when previous packet is sent. This means that the host can only get data of one buffer in one transfer.

**Note:** To avoid overhead from copying data, the driver itself doesn’t have any buffer inside. Namely, the DMA takes data directly from the buffer provided by the application. The application should not touch the buffer until the sending is finished.

The sending mode can be set in the `sending_mode` member of `sdio_slave_config_t`, and the buffer numbers can be set in the `send_queue_size`. All the buffers are restricted to be no larger than 4092 bytes. Though in the stream mode several buffers can be sent in one transfer, each buffer is still counted as one in the queue.

The application can call `sdio_slave_transmit` to send packets. In this case the function returns when the transfer is successfully done, so the queue is not fully used. When higher efficiency is required, the application can use the following functions instead:

1. Pass buffer information (address, length, as well as an `arg` indicating the buffer) to `sdio_slave_send_queue`. If non-blocking call is needed, set `wait=0`. If the wait is not `portMAX_DELAY` (wait until success), application has to check the result to know whether the data is put in to the queue or discard.

2. Call `sdio_slave_send_get_finished` to get and deal with a finished transfer. A buffer should be keep unmodified until returned from `sdio_slave_send_get_finished`. This means the buffer is actually sent to the host, rather than just staying in the queue.

There are several ways to use the `arg` in the queue parameter:

1. Directly point `arg` to a dynamic-allocated buffer, and use the `arg` to free it when transfer finished.
2. Wrap transfer informations in a transfer structure, and point `arg` to the structure. You can use the structure to do more things like:

```c
typedef struct {
    uint8_t* buffer;
    size_t size;
    int id;
} sdio_transfer_t;

// and send as:
sdio_transfer_t trans = {
    .buffer = ADDRESS_TO_SEND,
    .size = 8,

    // (continues on next page)
```
### Chapter 2. API Reference (continued from previous page)

```c
.id = 3, // the 3rd transfer so far
};
sdio_slave_send_queue(trans.buffer, trans.size, &trans, portMAX_DELAY);

// ... maybe more transfers are sent here

// and deal with finished transfer as:
sdio_transfer_t* arg = NULL;
sdio_slave_send_get_finished((void**)arg, portMAX_DELAY);
ESP_LOGI("tag", "(\%d) successfully send \%d bytes of \%p", arg->id, arg->size, ...
-arg->buffer);
some_post_callback(arg); // do more things
```

3. Working with the receiving part of this driver, point `arg` to the receive buffer handle of this buffer. So that we can directly use the buffer to receive data when it’s sent:

```c
uint8_t buffer[256] = {1, 2, 3, 4, 5, 6, 7, 8};
sdio_slave_buf_handle_t handle = sdio_slave_recv_register_buf(buffer);
sdio_slave_send_queue(buffer, 8, handle, portMAX_DELAY);

// ... maybe more transfers are sent here

// and load finished buffer to receive as
sdio_slave_buf_handle_t handle = NULL;
sdio_slave_send_get_finished((void**)handle, portMAX_DELAY);
sdio_slave_recv_load_buf(handle);
```

More about this, see `peripherals/sdio`.

### Application Example

Slave/master communication: `peripherals/sdio`.

### API Reference

#### Header File

- components/hal/include/hal/sdio_slave_types.h

#### Enumerations

`enum sdio_slave_hostint_t`

Mask of interrupts sending to the host.

**Values:**

- `SDIO_SLAVE_HOSTINT_BIT0` = BIT(0)
  - General purpose interrupt bit 0.
- `SDIO_SLAVE_HOSTINT_BIT1` = BIT(1)
- `SDIO_SLAVE_HOSTINT_BIT2` = BIT(2)
- `SDIO_SLAVE_HOSTINT_BIT3` = BIT(3)
- `SDIO_SLAVE_HOSTINT_BIT4` = BIT(4)
- `SDIO_SLAVE_HOSTINT_BIT5` = BIT(5)
- `SDIO_SLAVE_HOSTINT_BIT6` = BIT(6)
- `SDIO_SLAVE_HOSTINT_BIT7` = BIT(7)
**SDIO_SLAVE_HOSTINT_SEND_NEW_PACKET** = BIT(23)

New packet available.

**enum sdio_slave_timing_t**

Timing of SDIO slave.

Values:

**SDIO_SLAVE_TIMING_PSEND_PSAMPLE** = 0

Send at posedge, and sample at posedge. Default value for HS mode. Normally there’s no problem using this to work in DS mode.

**SDIO_SLAVE_TIMING_NSEND_PSAMPLE**

Send at negedge, and sample at posedge. Default value for DS mode and below.

**SDIO_SLAVE_TIMING_PSEND_NSAMPLE**

Send at posedge, and sample at negedge.

**SDIO_SLAVE_TIMING_NSEND_NSAMPLE**

Send at negedge, and sample at negedge.

**enum sdio_slave_sending_mode_t**

Configuration of SDIO slave mode.

Values:

**SDIO_SLAVE_SEND_STREAM** = 0

Stream mode, all packets to send will be combined as one if possible.

**SDIO_SLAVE_SEND_PACKET** = 1

Packet mode, one packets will be sent one after another (only increase packet_len if last packet sent).

**Header File**

- components/driver/include/driver/sdio_slave.h

**Functions**

```c
esp_err_t sdio_slave_initialize(sdio_slave_config_t *config)

Initialize the sdio slave driver
```

Return

- ESP_ERR_NOT_FOUND if no free interrupt found.
- ESP_ERR_INVALID_STATE if already initialized.
- ESP_ERR_NO_MEM if fail due to memory allocation failed.
- ESP_OK if success

Parameters

- **config**: Configuration of the sdio slave driver.

```c
void sdio_slave_deinit (void)

De-initialize the sdio slave driver to release the resources.
```

```c
esp_err_t sdio_slave_start (void)

Start hardware for sending and receiving, as well as set the IOREADY1 to 1.
```

Note

The driver will continue sending from previous data and PKT_LEN counting, keep data received as well as start receiving from current TOKEN1 counting. See sdio_slave_reset.

Return

- ESP_ERR_INVALID_STATE if already started.
- ESP_OK otherwise.

```c
void sdio_slave_stop (void)

Stop hardware from sending and receiving, also set IOREADY1 to 0.
```

Note

This will not clear the data already in the driver, and also not reset the PKT_LEN and TOKEN1 counting. Call sdio_slave_reset to do that.
**esp_err_t** `sdio_slave_reset` *(void)*

Clear the data still in the driver, as well as reset the PKT_LEN and TOKEN1 counting.

**Return**

always return **ESP_OK**.

**sdio_slave_buf_handle_t** `sdio_slave_recv_register_buf` *(uint8_t *start)*

Register buffer used for receiving. All buffers should be registered before used, and then can be used (again) in the driver by the handle returned.

**Note**

The driver will use and only use the amount of space specified in the **recv_buffer_size** member set in the **sdio_slave_config_t**. All buffers should be larger than that. The buffer is used by the DMA, so it should be DMA capable and 32-bit aligned.

**Return**

The buffer handle if success, otherwise **NULL**.

**Parameters**

- **start**: The start address of the buffer.

**esp_err_t** `sdio_slave_recv_unregister_buf` *(sdio_slave_buf_handle_t handle)*

Unregister buffer from driver, and free the space used by the descriptor pointing to the buffer.

**Return**

**ESP_OK** if success, **ESP_ERR_INVALID_ARG** if the handle is **NULL** or the buffer is being used.

**Parameters**

- **handle**: Handle to the buffer to release.

**esp_err_t** `sdio_slave_recv_load_buf` *(sdio_slave_buf_handle_t handle)*

Load buffer to the queue waiting to receive data. The driver takes ownership of the buffer until the buffer is returned by **sdio_slave_send_get_finished** after the transaction is finished.

**Return**

- **ESP_ERR_INVALID_ARG** if invalid handle or the buffer is already in the queue. Only after the buffer is returned by **sdio_slave_recv** can you load it again.
- **ESP_OK** if success

**Parameters**

- **handle**: Handle to the buffer ready to receive data.

**esp_err_t** `sdio_slave_recv_packet` *(sdio_slave_buf_handle_t *handle_ret, TickType_t wait)*

Get buffer of received data if exist with packet information. The driver returns the ownership of the buffer to the app.

When you see return value is **ESP_ERR_NOT_FINISHED**, you should call this API iteratively until the return value is **ESP_OK**. All the continuous buffers returned with **ESP_ERR_NOT_FINISHED**, together with the last buffer returned with **ESP_OK**, belong to one packet from the host.

You can call simpler **sdio_slave_recv** instead, if the host never send data longer than the Receiving buffers size, or you don’t care about the packet boundary (e.g. the data is only a byte stream).

**Note**

Call **sdio_slave_load_buf** with the handle to re-load the buffer onto the link list, and receive with the same buffer again. The address and length of the buffer got here is the same as got from **sdio_slave_get_buffer**.

**Return**

- **ESP_ERR_INVALID_ARG** if **handle_ret** is **NULL**
- **ESP_ERR_TIMEOUT** if timeout before receiving new data
- **ESP_ERR_NOT_FINISHED** if returned buffer is not the end of a packet from the host, should call this API again until the end of a packet
- **ESP_OK** if success

**Parameters**

- **handle_ret**: Handle of the buffer holding received data. Use this handle in **sdio_slave_recv_load_buf**() to receive in the same buffer again.
- **wait**: Time to wait before data received.

**esp_err_t** `sdio_slave_recv` *(sdio_slave_buf_handle_t *handle_ret, uint8_t **out_addr, size_t *out_len, TickType_t wait)*

Get received data if exist. The driver returns the ownership of the buffer to the app.

**Note**

Call **sdio_slave_load_buf** with the handle to re-load the buffer onto the link list, and receive with the same buffer again. The address and length of the buffer got here is the same as got from **sdio_slave_get_buffer**.
sdio_slave_get_buffer.

Return
- ESP_ERR_INVALID_ARG if handle_ret is NULL
- ESP_ERR_TIMEOUT if timeout before receiving new data
- ESP_OK if success

Parameters
- handle_ret: Handle to the buffer holding received data. Use this handle in sdio_slave_recv_load_buf to receive in the same buffer again.
- [out] out_addr: Output of the start address, set to NULL if not needed.
- [out] out_len: Actual length of the data in the buffer, set to NULL if not needed.
- wait: Time to wait before data received.

uint8_t *sdio_slave_recv_get_buf(sdio_slave_buf_handle_t handle, size_t *len_o)

Retrieve the buffer corresponding to a handle.

Return buffer address if success, otherwise NULL.

Parameters
- handle: Handle to get the buffer.
- len_o: Output of buffer length

esp_err_t sdio_slave_send_queue(uint8_t *addr, size_t len, void *arg, TickType_t wait)

Put a new sending transfer into the send queue. The driver takes ownership of the buffer until the buffer is returned by sdio_slave_send_get_finished after the transaction is finished.

Return
- ESP_ERR_INVALID_ARG if the length is not greater than 0.
- ESP_ERR_TIMEOUT if the queue is still full until timeout.
- ESP_OK if success.

Parameters
- addr: Address for data to be sent. The buffer should be DMA capable and 32-bit aligned.
- len: Length of the data, should not be longer than 4092 bytes (may support longer in the future).
- arg: Argument to returned in sdio_slave_send_get_finished. The argument can be used to indicate which transaction is done, or as a parameter for a callback. Set to NULL if not needed.
- wait: Time to wait if the buffer is full.

esp_err_t sdio_slave_send_get_finished(void **out_arg, TickType_t wait)

Return the ownership of a finished transaction.

Return ESP_ERR_TIMEOUT if no transaction finished, or ESP_OK if succeed.

Parameters
- out_arg: Argument of the finished transaction. Set to NULL if unused.
- wait: Time to wait if there’s no finished sending transaction.

esp_err_t sdio_slave_transmit(uint8_t *addr, size_t len)

Start a new sending transfer, and wait for it (blocked) to be finished.

Return
- ESP_ERR_INVALID_ARG if the length of descriptor is not greater than 0.
- ESP_ERR_TIMEOUT if the queue is full or host do not start a transfer before timeout.
- ESP_OK if success.

Parameters
- addr: Start address of the buffer to send
- len: Length of buffer to send.

uint8_t sdio_slave_read_reg(int pos)

Read the spi slave register shared with host.

Note register 28 to 31 are reserved for interrupt vector.

Return value of the register.

Parameters
- pos: register address, 0-27 or 32-63.
esp_err_t sdio_slave_write_reg (int pos, uint8_t reg)
  Write the spi slave register shared with host.

  Note  register 29 and 31 are used for interrupt vector.
  Return  ESP_ERR_INVALID_ARG if address wrong, otherwise ESP_OK.
  Parameters
  • pos: register address, 0-11, 14-15, 18-19, 24-27 and 32-63, other address are reserved.
  • reg: the value to write.

sdio_slave_hostint_t sdio_slave_get_host_intena (void)
  Get the interrupt enable for host.
  Return  the interrupt mask.

void sdio_slave_set_host_intena (sdio_slave_hostint_t mask)
  Set the interrupt enable for host.
  Parameters
  • mask: Enable mask for host interrupt.

esp_err_t sdio_slave_send_host_int (uint8_t pos)
  Interrupt the host by general purpose interrupt.
  Return
  • ESP_ERR_INVALID_ARG if interrupt num error
  • ESP_OK otherwise
  Parameters
  • pos: Interrupt num, 0-7.

void sdio_slave_clear_host_int (sdio_slave_hostint_t mask)
  Clear general purpose interrupt to host.
  Parameters
  • mask: Interrupt bits to clear, by bit mask.

esp_err_t sdio_slave_wait_int (int pos, TickType_t wait)
  Wait for general purpose interrupt from host.
  Note  this clears the interrupt at the same time.
  Return  ESP_OK if success, ESP_ERR_TIMEOUT if timeout.
  Parameters
  • pos: Interrupt source number to wait for. is set.
  • wait: Time to wait before interrupt triggered.

Structures

struct sdio_slave_config_t
  Configuration of SDIO slave.

Public Members

sdio_slave_timing_t timing
  timing of sdio_slave. see sdio_slave_timing_t.

sdio_slave_sending_mode_t sending_mode
  mode of sdio_slave. SDIO_SLAVE_MODE_STREAM if the data needs to be sent as much as possible;
  SDIO_SLAVE_MODE_PACKET if the data should be sent in packets.

int send_queue_size
  max buffers that can be queued before sending.

size_t recv_buffer_size
  If buffer_size is too small, it costs more CPU time to handle larger number of buffers. If buffer_size is
  too large, the space larger than the transaction length is left blank but still counts a buffer, and the buffers
  are easily run out. Should be set according to length of data really transferred. All data that do not fully
fill a buffer is still counted as one buffer. E.g. 10 bytes data costs 2 buffers if the size is 8 bytes per buffer. Buffer size of the slave pre-defined between host and slave before communication. All receive buffer given to the driver should be larger than this.

```c
sdio_event_cb_t event_cb
```
when the host interrupts slave, this callback will be called with interrupt number (0-7).

```c
uint32_t flags
```
Features to be enabled for the slave, combinations of `SDIO_SLAVE_FLAG_*`.

### Macros

- **SDIO_SLAVE_RECV_MAX_BUFFER**
- **SDIO_SLAVE_FLAG_DAT2_DISABLED**

It is required by the SD specification that all 4 data lines should be used and pulled up even in 1-bit mode or SPI mode. However, as a feature, the user can specify this flag to make use of DAT2 pin in 1-bit mode. Note that the host cannot read CCCR registers to know we don’t support 4-bit mode anymore, please do this at your own risk.

- **SDIO_SLAVE_FLAG_HOST_INTR_DISABLED**

The DAT1 line is used as the interrupt line in SDIO protocol. However, as a feature, the user can specify this flag to make use of DAT1 pin of the slave in 1-bit mode. Note that the host has to do polling to the interrupt registers to know whether there are interrupts from the slave. And it cannot read CCCR registers to know we don’t support 4-bit mode anymore, please do this at your own risk.

- **SDIO_SLAVE_FLAG_INTERNAL_PULLUP**

Enable internal pullups for enabled pins. It is required by the SD specification that all the 4 data lines should be pulled up even in 1-bit mode or SPI mode. Note that the internal pull-ups are not sufficient for stable communication, please do connect external pull-ups on the bus. This is only for example and debug use.

### Type Definitions

```c
typedef void (*sdio_event_cb_t)(uint8_t event)
typedef void* sdio_slave_buf_handle_t
```
Handle of a receive buffer, register a handle by calling `sdio_slave_recv_register_buf`. Use the handle to load the buffer to the driver, or call `sdio_slave_recv_unregister_buf` if it is no longer used.

### 2.3.16 Sigma-delta Modulation

#### Introduction

ESP32 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.

![Fig. 19: Sallen-Key Low Pass Filter](image)

**Application Example**

Sigma-delta Modulation example: `peripherals/sigmadelta`.

**API Reference**

**Header File**

- `components/driver/include/driver/sigmadelta.h`

**Functions**

```c
esp_err_t sigmadelta_config(const sigmadelta_config_t *config)
```

Configure Sigma-delta channel.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_STATE sigmadelta driver already initialized
- ESP_ERR_INVALID_ARG Parameter error
Chapter 2. API Reference

Parameters

- **config**: Pointer of Sigma-delta channel configuration struct

```c
esp_err_t sigmadelta_set_duty(sigmadelta_channel_t channel, int8_t duty)
```

Set Sigma-delta channel duty.

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 \( V_{dc} = \frac{VDDIO}{256} \times duty + \frac{VDDIO}{2} \), where \( VDDIO \) is the power supply voltage.

Return

- ESP_OK Success
- ESP_ERR_INVALID_STATE sigmadelta driver 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.

```c
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 sigmadelta driver 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

```c
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 sigmadelta driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- **channel**: Sigma-delta channel number
- **gpio_num**: GPIO number of output pin.

Structures

```c
struct sigmadelta_config_t
```

Sigma-delta configure struct.

Public Members

```c
sigmadelta_channel_t channel
```

Sigma-delta channel number

```c
int8_t sigmadelta_duty
```

Sigma-delta duty, duty ranges from -128 to 127.

```c
uint8_t sigmadelta_prescale
```

Sigma-delta prescale, prescale ranges from 0 to 255.

```c
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:
    SIGMADELTA_CHANNEL_0
        Sigma-delta channel 0
    SIGMADELTA_CHANNEL_1
        Sigma-delta channel 1
    SIGMADELTA_CHANNEL_2
        Sigma-delta channel 2
    SIGMADELTA_CHANNEL_3
        Sigma-delta channel 3
    SIGMADELTA_CHANNEL_4
        Sigma-delta channel 4
    SIGMADELTA_CHANNEL_5
        Sigma-delta channel 5
    SIGMADELTA_CHANNEL_6
        Sigma-delta channel 6
    SIGMADELTA_CHANNEL_7
        Sigma-delta channel 7
    SIGMADELTA_CHANNEL_MAX
        Sigma-delta channel max
```

2.3.17 SPI Master Driver

SPI Master driver is a program that controls ESP32’s SPI peripherals while they function as masters.

Overview of ESP32’s SPI peripherals

ESP32 integrates 4 SPI peripherals.

- SPI0 and SPI1 are used internally to access the ESP32’s attached flash memory. Both controllers share the same SPI bus signals, and there is an arbiter to determine which can access the bus.

  There are quite a few limitations when using SPI Master driver on the SPI1 bus, see Notes on Using the SPI Master driver on SPI1 Bus.

- SPI2 and SPI3 are general purpose SPI controllers, sometimes referred to as HSPI and VSPI, respectively. They are open to users. SPI2 and SPI3 have independent bus signals with the same respective names. Each bus has three CS lines to drive up to same number of SPI slaves.
Terminology

The terms used in relation to the SPI master driver are given in the table below.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host</td>
<td>The SPI controller peripheral inside ESP32 that initiates SPI transmissions over the bus, and acts as an SPI Master.</td>
</tr>
<tr>
<td>Device</td>
<td>SPI slave device. An SPI bus may be connected to one or more Devices. Each Device shares the MOSI, MISO and SCLK signals but is only active on the bus when the host asserts the Device’s individual CS line.</td>
</tr>
<tr>
<td>Bus</td>
<td>A signal bus, common to all Devices connected to one Host. In general, a bus includes the following lines: 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>MOSI</td>
<td>Master Out, Slave In, a.k.a. D. Data transmission from a Host to Device. Also data0 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>MISO</td>
<td>Master In, Slave Out, a.k.a. Q. Data transmission from a Device to Host. Also data1 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>SCLK</td>
<td>Serial Clock. Oscillating signal generated by a Host that keeps the transmission of data bits in sync.</td>
</tr>
<tr>
<td>CS</td>
<td>Chip Select. Allows a Host to select individual Device(s) connected to the bus in order to send or receive data.</td>
</tr>
<tr>
<td>QUADWP</td>
<td>Write Protect signal. Used for 4-bit (qio/qout) transactions. Also for data2 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>QUADHD</td>
<td>Hold signal. Used for 4-bit (qio/qout) transactions. Also for data3 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>DATA4</td>
<td>Data4 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>DATA5</td>
<td>Data5 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>DATA6</td>
<td>Data6 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>DATA7</td>
<td>Data7 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>Assert</td>
<td>The action of activating a line.</td>
</tr>
<tr>
<td>Deassert</td>
<td>The action of returning the line back to inactive (back to idle) status.</td>
</tr>
<tr>
<td>Transact</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>Launedge</td>
<td>Edge of the clock at which the source register launches the signal onto the line.</td>
</tr>
<tr>
<td>Latchedge</td>
<td>Edge of the clock at which the destination register latches in the signal.</td>
</tr>
</tbody>
</table>

Driver Features

The SPI master driver governs communications of Hosts with Devices. The driver supports the following features:

- Multi-threaded environments
- Transparent handling of DMA transfers while reading and writing data
- Automatic time-division multiplexing of data coming from different Devices on the same signal bus, see SPI Bus Lock.

Warning: The SPI master driver has the concept of multiple Devices connected to a single bus (sharing a single ESP32 SPI peripheral). As long as each Device is accessed by only one task, the driver is thread safe. However, if multiple tasks try to access the same SPI Device, the driver is not thread-safe. In this case, it is recommended to either:

- Refactor your application so that each SPI peripheral is only accessed by a single task at a time.
- Add a mutex lock around the shared Device using xSemaphoreCreateMutex.
Chapter 2. API Reference

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).
- There are quite a few limitations when using SPI Master driver on the SPI1 bus, see Notes on Using the SPI Master driver on SPI1 Bus.

- 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 (0-64 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 are listed as follows, to make use of these modes, set the member `flags` in the struct `spi_transaction_t` as shown in the Transaction Flag column. If you want to check if corresponding IO pins are set or not, set the member `flags` in the `spi_bus_config_t` as shown in the Bus IO setting Flag column.

<table>
<thead>
<tr>
<th>Mode name</th>
<th>Command Line Width</th>
<th>Address Line Width</th>
<th>Data Line Width</th>
<th>Transaction Flag</th>
<th>Bus IO setting Flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal SPI</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dual Output</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td><code>SPI_TRANS_MODE_DIO</code></td>
<td><code>SPICOMMON_BUSFLAG_DUAL</code></td>
</tr>
<tr>
<td>Dual I/O</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td><code>SPI_TRANS_MODE_DIO</code></td>
<td><code>SPI_TRANS_MULTILINE_ADDR</code></td>
</tr>
<tr>
<td>Quad Output</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td><code>SPI_TRANS_MODE_QIO</code></td>
<td><code>SPICOMMON_BUSFLAG_QUAD</code></td>
</tr>
<tr>
<td>Quad I/O</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td><code>SPI_TRANS_MODE_QIO</code></td>
<td><code>SPI_TRANS_MULTILINE_ADDR</code></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 `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 `SPIDEVICE_HALFDUPLEX` flag for the member `flags` in the struct `spi_device_interface_config_t`. And the member `flags` in the struct `spi_transaction_t` should be set as described in `Transaction Line Mode`.

**Note:** Half-duplex transactions with both read and write phases are not supported when using DMA. For details and workarounds, see `Known Issues`.

### Bus Acquiring

Sometimes you might want to send SPI transactions exclusively and continuously so that it takes as little time as possible. For this, you can use bus acquiring, which helps to suspend transactions (both polling or interrupt) to other devices until the bus is released. To acquire and release a bus, use the functions `spi_device_acquire_bus()` and `spi_device_release_bus()`.

### Driver Usage

- Initialize an SPI bus by calling the function `spi_bus.initialize()`. Make sure to set the correct I/O pins in the struct `spi_bus_config_t`. Set the signals that are not needed to -1.
- Register a Device connected to the bus with the driver by calling the function `spi_bus_add_device()`. Make sure to configure any timing requirements the device might need with the parameter `dev_config`.
- 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 is a little-endian chip, which means that the least significant byte of `uint16_t` and `uint32_t` variables is stored at the smallest address. Hence, if `uint16_t` is stored in memory, bits [7:0] are sent first, followed by bits [15:8].

For cases when the data to be transmitted has the size differing from `uint8_t` arrays, the following macros can be used to transform data to the format that can be sent by the SPI driver directly:

- `SPI_SWAP_DATA_TX` for data to be transmitted
- `SPI_SWAP_DATA_RX` for data received

Notes on Sending Mixed Transactions to the Same Device To reduce coding complexity, send only one type of transactions (interrupt or polling) to one Device. However, you still can send both interrupt and polling transactions alternately. The notes below explain how to do this.

The polling transactions should be initiated only after all the polling and interrupt transactions are finished.

Since an unfinished polling transaction blocks other transactions, please do not forget to call the function `spi_device_polling_end()` after `spi_device_polling_start()` to allow other transactions or to allow other Devices to use the bus. Remember that if there is no need to switch to other tasks during your polling transaction, you can initiate a transaction with `spi_device_polling_transmit()` so that it will be ended automatically.

In-flight polling transactions are disturbed by the ISR operation to accommodate interrupt transactions. Always make sure that all the interrupt transactions sent to the ISR are finished before you call `spi_device_polling_start()`. To do that, you can keep calling `spi_device_get_trans_result()` until all the transactions are returned.

To have better control of the calling sequence of functions, send mixed transactions to the same Device only within a single task.

Notes on Using the SPI Master driver on SPI1 Bus

Note: Though the SPI Bus Lock feature makes it possible to use SPI Master driver on the SPI1 bus, it’s still tricky and needs a lot of special treatment. It’s a feature for advanced developers.

To use SPI Master driver on SPI1 bus, you have to take care of two problems:

1. The code and data, required at the meanwhile the driver is operating SPI1 bus, should be in the internal memory. SPI1 bus is shared among devices and the cache for data (code) in the Flash as well as the PSRAM. The cache should be disabled during the other devices are operating the SPI1 bus. Hence the data (code) in the flash as well as the PSRAM cannot be fetched at the meanwhile the driver acquires the SPI1 bus by:
   - Explicit bus acquiring between `spi_device_acquire_bus()` and `spi_device_release_bus()`.
   - Implicit bus acquiring between `spi_device_polling_start()` and `spi_device_polling_end()` (or inside `spi_device_polling_transmit()`).
During the time above, all other tasks and most ISRs will be disabled (see *IRAM-Safe Interrupt Handlers*). Application code and data used by current task should be placed in internal memory (DRAM or IRAM), or already in the ROM. Access to external memory (flash code, const data in the flash, and static/heap data in the PSRAM) will cause a *Cache disabled but cached memory region accessed* exception. For differences between IRAM, DRAM, and flash cache, please refer to the *application memory layout* documentation.

To place functions into the IRAM, you can either:

1. Add `IRAM_ATTR` (include “esp_attr.h”) to the function like:
   ```c
   IRAM_ATTR void foo(void)
   ```
   Please note that when a function is inlined, it will follow its caller’s segment, and the attribute will not take effect. You may need to use `NOLINE_ATTR` to avoid this.

2. Use the `noflash` placement in the `linker.elf`. See more in *Linker Script Generation*. Please note that, some code may be transformed into lookup table in the const data by the compiler, so `noflash_text` is not safe. Please do take care that the optimization level may affect the compiler behavior of inline, or transforming some code into lookup table in the const data, etc.

To place data into the DRAM, you can either:

1. Add `DRAM_ATTR` (include “esp_attr.h”) to the data definition like:
   ```c
   DRAM_ATTR int g_foo = 3;
   ```

2. Use the `noflash` placement in the `linker.elf`. See more in *Linker Script Generation*.

Please also see the example `peripherals/spi_master/hd_eeprom`.

**GPIO Matrix and IO_MUX**  Most of ESP32’s peripheral signals have direct connection to their dedicated IO_MUX pins. However, the signals can also be routed to any other available pins using the less direct GPIO matrix. If at least one signal is routed through the GPIO matrix, then all signals will be routed through it.

The GPIO matrix introduces flexibility of routing but also brings the following disadvantages:

- Increases the input delay of the MISO signal, which makes MISO setup time violations more likely. If SPI needs to operate at high speeds, use dedicated IO_MUX pins.
- Allows signals with clock frequencies only up to 40 MHz, as opposed to 80 MHz if IO_MUX pins are used.

**Note:** For more details about the influence of the MISO input delay on the maximum clock frequency, see *Timing Considerations*.

The IO_MUX pins for SPI buses are given below.

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>SPI2</th>
<th>SPI3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS0*</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>SCLK</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>MISO</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>MOSI</td>
<td>13</td>
<td>23</td>
</tr>
<tr>
<td>QUADWP</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>QUADHD</td>
<td>4</td>
<td>21</td>
</tr>
</tbody>
</table>

- Only the first Device attached to the bus can use the CS0 pin.

**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 us per transaction. When a master is transferring data, it automatically reads the data from the linked list. If DMA is not enabled, the CPU has to write and read each byte from the FIFO by itself. Usually, this is faster than 2 us, but the transaction length is limited to 64 bytes for both write and read.

Typical transaction duration for one byte of data are given below.
- Interrupt Transaction via DMA: 28 µs.
- Interrupt Transaction via CPU: 25 µs.
- Polling Transaction via DMA: 10 µs.
- Polling Transaction via CPU: 8 µs.

**SPI Clock Frequency**  
Transferring each byte takes eight times the clock period $8/f_{spi}$.

If the clock frequency is too high, the use of some functions might be limited. See **Timing Considerations**.

**Cache Miss**  
The default config puts only the ISR into the IRAM. Other SPI related functions, including the driver itself and the callback, might suffer from cache misses and will need to wait until the code is read from flash. Select `CONFIG_SPI_MASTER_IN_IRAM` to put the whole SPI driver into IRAM and put the entire callback(s) and its callee functions into IRAM to prevent cache misses.

For an interrupt transaction, the overall cost is $20+8n/f_{spi}[MHz][us]$ for n bytes transferred in one transaction. Hence, the transferring speed is: $n/(20+8n/f_{spi})$. An example of transferring speed at 8 MHz clock speed is given in the following table.

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Transaction Interval (us)</th>
<th>Transaction Length (bytes)</th>
<th>Total Time (us)</th>
<th>Total Speed (KBps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>25</td>
<td>1</td>
<td>26</td>
<td>38.5</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>8</td>
<td>33</td>
<td>242.4</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>16</td>
<td>41</td>
<td>490.2</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>64</td>
<td>89</td>
<td>719.1</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>128</td>
<td>153</td>
<td>836.6</td>
</tr>
</tbody>
</table>

When a transaction length is short, the cost of transaction interval is high. If possible, try to squash several short transactions into one transaction to achieve a higher transfer speed.

Please note that the ISR is disabled during flash operation by default. To keep sending transactions during flash operations, enable `CONFIG_SPI_MASTER_ISR_IN_IRAM` and set `ESP_INTR_FLAG_IRAM` in the member `spi_bus_config_t::intr_flags`. In this case, all the transactions queued before starting flash operations will be handled by the ISR in parallel. Also note that the callback of each Device and their callee functions should be in IRAM, or your callback will crash due to cache miss. For more details, see **IRAM-Safe Interrupt Handlers**.

**Timing Considerations**

As shown in the figure below, there is a delay on the MISO line after the SCLK launch edge and before the signal is latched by the internal register. As a result, the MISO pin setup time is the limiting factor for the SPI clock speed. When the delay is too long, the setup slack is < 0, which means the setup timing requirement is violated and the reading might be incorrect.
The maximum allowed frequency is dependent on:

- `input_delay_ns` - maximum data valid time on the MISO bus after a clock cycle on SCLK starts
- If the IO_MUX pin or the GPIO Matrix is used

When the GPIO matrix is used, the maximum allowed frequency is reduced to about 33-77% in comparison to the existing `input delay`. To retain a higher frequency, you have to use the IO_MUX pins or the dummy bit workaround. You can obtain the maximum reading frequency of the master by using the function `spi_get_freq_limit()`.

**Dummy bit workaround**: Dummy clocks, during which the Host does not read data, can be inserted before the read phase begins. The Device still sees the dummy clocks and sends out data, but the Host does not read until the read phase comes. This compensates for the lack of the MISO setup time required by the Host and allows the Host to do reading at a higher frequency.

In the ideal case, if the Device is so fast that the input delay is shorter than an APB clock cycle - 12.5 ns - the maximum frequency at which the Host can read (or read and write) in different conditions is as follows:

<table>
<thead>
<tr>
<th>Frequency Limit (MHz)</th>
<th>Dummy Bits Used By Driver</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO matrix</td>
<td>IO_MUX pins</td>
<td></td>
</tr>
<tr>
<td>26.6</td>
<td>80</td>
<td>No</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>Yes</td>
</tr>
</tbody>
</table>

If the Host only writes data, the dummy bit workaround and the frequency check can be disabled by setting the bit `SPI_DEVICE_NO_DUMMY` in the member `spi_device_interface_config_t::flags`. When disabled, the output frequency can be 80MHz, even if the GPIO matrix is used.

**spi_device_interface_config_t::flags**

The SPI master driver still works even if the `input_delay_ns` in the structure `spi_device_interface_config_t` is set to 0. However, setting an accurate value helps to:

- Calculate the frequency limit for full-duplex transactions
- Compensate the timing correctly with dummy bits for half-duplex transactions

You can approximate the maximum data valid time after the launch edge of SPI clocks by checking the statistics in the AC characteristics chapter of your Device’s specification or measure the time using an oscilloscope or logic analyzer.

Please note that the actual PCB layout design and excessive loads may increase the input delay. It means that non-optimal wiring and/or a load capacitor on the bus will most likely lead to input delay values exceeding the values given in the Device specification or measured while the bus is floating.
Some typical delay values are shown in the following table. (These data are retrieved when the slave device is on a different physical chip)

<table>
<thead>
<tr>
<th>Device</th>
<th>Input delay (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideal Device</td>
<td>0</td>
</tr>
<tr>
<td>ESP32 slave using IO_MUX*</td>
<td>50</td>
</tr>
<tr>
<td>ESP32 slave using GPIO_MUX*</td>
<td>75</td>
</tr>
</tbody>
</table>

The MISO path delay (valid time) consists of a slave’s input delay plus master’s GPIO matrix delay. This delay determines the frequency limit above which full-duplex transfers will not work as well as the dummy bits used in the half-duplex transactions. The frequency limit is:

\[
\text{Freq limit [MHz]} = \frac{80}{\left(\text{floor}(\text{MISO delay[ns]}/12.5) + 1\right)}
\]

The figure below shows the relationship between frequency limit and input delay. Two extra APB clock cycle periods should be added to the MISO delay if the master uses the GPIO matrix.

Corresponding frequency limits for different Devices with different input delay times are shown in the table below.

<table>
<thead>
<tr>
<th>Master</th>
<th>Input delay (ns)</th>
<th>MISO path delay (ns)</th>
<th>Freq. limit (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IO_MUX (0ns)</td>
<td>0</td>
<td>0</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>50</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>75</td>
<td>11.43</td>
</tr>
<tr>
<td>GPIO (25ns)</td>
<td>0</td>
<td>25</td>
<td>26.67</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>75</td>
<td>11.43</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>100</td>
<td>8.89</td>
</tr>
</tbody>
</table>

**Known Issues**

1. Half-duplex transactions are not compatible with DMA when both writing and reading phases are used.
If such transactions are required, you have to use one of the alternative solutions:
1. Use full-duplex transactions instead.
2. Disable DMA by setting the bus initialization function’s last parameter to 0 as follows:
   ```c
   ret=spi_bus_initialize(VSPI_HOST, &buscfg, 0);
   ```
   This can prohibit you from transmitting and receiving data longer than 64 bytes. 3. Try using the command and address fields to replace the write phase.
2. Full-duplex transactions are not compatible with the dummy bit workaround, hence the frequency is limited. See dummy bit speed-up workaround.
3. dummy_bits in `spi_device_interface_config_t` and `spi_transaction_ext_t` are not available when SPI read and write phases are both enabled (regardless of full duplex or half duplex mode).
4. `cs_ena_pretrans` is not compatible with the command and address phases of full-duplex transactions.

Application Example

The code example for using the SPI master half duplex mode to read/write a AT93C46D EEPROM (8-bit mode) can be found in the `peripherals/spi_master/hd_eeprom` directory of ESP-IDF examples.

API Reference - SPI Common

Header File

- components/hal/include/hal/spi_types.h

Structures

```c
struct spi_line_mode_t
```
Line mode of SPI transaction phases: CMD, ADDR, DOUT/DIN.

Public Members

- `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

```c
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

```c
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.

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

```c
esp_err_t spi_bus_initialize(spi_host_device_t host_id, const spi_bus_config_t *bus_config, spi_dma_chan_t dma_chan)
```

Initialize a SPI bus.

**Warning** SPI0/1 is not supported
**Warning** If a DMA channel is selected, any transmit and receive buffer used should be allocated in DMA-capable memory.
**Warning** The ISR of SPI is always executed on the core which calls this function. Never starve the ISR on this core or the SPI transactions will not be handled.

**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_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_DISABED 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.

```c
esp_err_t spi_bus_free(spi_host_device_t host_id)
```

Free a SPI bus.

**Warning** In order for this to succeed, all devices have to be removed first.

**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 sphi0 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 sphi1 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 sphi2 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 sphi3 signal in quad/octal mode, or -1 if not used.

int data4_io_num
    GPIO pin for sphi4 signal in octal mode, or -1 if not used.

int data5_io_num
    GPIO pin for sphi5 signal in octal mode, or -1 if not used.

int data6_io_num
    GPIO pin for sphi6 signal in octal mode, or -1 if not used.

int data7_io_num
    GPIO pin for sphi7 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:

   ```c
   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_SCLK
   Check existing of SCLK pin. Or indicates CLK line initialized.

SPICOMMON_BUSFLAG_MISO
   Check existing of MISO pin. Or indicates MISO line initialized.

SPICOMMON_BUSFLAG_MOSI
   Check existing of MOSI pin. Or indicates MOSI line initialized.

SPICOMMON_BUSFLAG_DUAL
   Check MOSI and MISO pins can output. Or indicates bus able to work under DIO mode.

SPICOMMON_BUSFLAG_WPHD
   Check existing of WP and HD pins. Or indicates WP & HD pins initialized.

SPICOMMON_BUSFLAG_QUAD
   Check existing of MOSI/MISO/ WP/HD pins as output. Or indicates bus able to work under QIO mode.

SPICOMMON_BUSFLAG_IO4_IO7
   Check existing of IO4-IO7 pins. Or indicates IO4-IO7 pins initialized.
**Chapter 2. API Reference**

**SPICOMMON_BUSFLAG_OCTAL**
Check existing of MOSI/MISO/WD/HD/SPIO4/SPIO5/SPIO6/SPIO7 pins as output. Or indicates bus able to work under octal mode.

**SPICOMMON_BUSFLAG_NATIVE_PINS**

**Type Definitions**
typedef spi_common_dma_t spi_dma_chan_t

**Enumerations**
enum spi_common_dma_t
SPI DMA channels.

*Values:*
- SPI_DMA_DISABLED = 0
  Do not enable DMA for SPI.
- SPI_DMA_CH1 = 1
  Enable DMA, select DMA Channel 1.
- SPI_DMA_CH2 = 2
  Enable DMA, select DMA Channel 2.
- 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

**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**: Tick 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**: Tick to wait until there’s a returned item; use portMAX_DELAY to never time out.

**esp_err_t spi_device_transmit** (**spi_device_handle_t** handle, **spi_transaction_t** *trans_desc)

Send a SPI transaction, wait for it to complete, and return the result.

This function is the equivalent of calling **spi_device_queue_trans()** followed by **spi_device_get_trans_result()**. Do not use this when there is still a transaction separately queued (started) from **spi_device_queue_trans()** or polling_start/transmit that hasn’t been finalized.

**Note** This function is not thread safe when multiple tasks access the same SPI device. Normally a device cannot start (queue) polling and interrupt transactions simultaneously.

**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.
Chapter 2. API Reference

**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 port-MAX_DELAY is supported.

```c
esp_err_t spi_device_polling_end(spi_device_handle_t handle, TickType_t ticks_to_wait)
```

Poll until the polling transaction ends.

This routine will not return until the transaction to the given device has successfully completed. The task is not blocked, but actively busy-spins for the transaction to be completed.

**Return**
- 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 port-MAX_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.
Chapter 2. API Reference

Parameters
• dev: The device to release the bus.

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.

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 setting 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 launched geto 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
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

uint8_t command_bits
Default amount of bits in command phase (0-16), used when SPI_TRANS_VARIABLE_CMD is not
used, otherwise ignored.

uint8_t address_bits
Default amount of bits in address phase (0-64), used when SPI_TRANS_VARIABLE_ADDR is not
used, otherwise ignored.
Chapter 2. API Reference

uint8_t dummy_bits
Amount of dummy bits to insert between address and data phase.

uint8_t mode
SPI mode, representing a pair of (CPOL, CPHA) configuration:

- 0: (0, 0)
- 1: (0, 1)
- 2: (1, 0)
- 3: (1, 1)

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.

uint16_t cs_ena_pretrans
Amount of SPI bit-cycles the cs should be activated before the transmission (0-16). This only works on half-duplex transactions.

uint8_t cs_ena_posttrans
Amount of SPI bit-cycles the cs should stay active after the transmission (0-16)

int clock_speed_hz
Clock speed, divisors of 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
- 8.89MHz
- 10MHz
Chapter 2. API Reference

**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.

**SPIDEVICE_CLK_AS_CS**
Output clock on CS line if CS is active.

**SPI_DEVICE_HALFDUPLEX**
If 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.

2.3.18 SPI Slave Driver

SPI Slave driver is a program that controls ESP32’s SPI peripherals while they function as slaves.

Overview of ESP32’s SPI peripherals

ESP32 integrates two general purpose SPI controllers which can be used as slave nodes driven by an off-chip SPI master

• SPI2, sometimes referred to as HSPI
• SPI3, sometimes referred to as VSPI

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>Host</td>
<td>The SPI controller peripheral external to ESP32 that initiates SPI transmissions over the bus, and acts as an SPI Master.</td>
</tr>
<tr>
<td>Device</td>
<td>SPI slave device (general purpose SPI controller). Each Device shares the MOSI, MISO and SCLK signals but is only active on the bus when the Host asserts the Device’s individual CS line.</td>
</tr>
<tr>
<td>Bus</td>
<td>A signal bus, common to all Devices connected to one Host. In general, a bus includes the following lines: MISO, MOSI, SCLK, one or more CS lines, and, optionally, QUADWP and QUADHD. So Devices are connected to the same lines, with the exception that each Device has its own CS line. Several Devices can also share one CS line if connected in the daisy-chain manner.</td>
</tr>
</tbody>
</table>

- **MISO**  
  Master In, Slave Out, a.k.a. Q. Data transmission from a Device to Host.

- **MOSI**  
  Master Out, Slave in, a.k.a. D. Data transmission from a Host to Device.

- **SCLK**  
  Serial Clock. Oscillating signal generated by a Host that keeps the transmission of data bits in sync.

- **CS**  
  Chip Select. Allows a Host to select individual Device(s) connected to the bus in order to send or receive data.

- **QUADWP**  
  Write Protect signal. Only used for 4-bit (qio/qout) transactions.

- **QUADHD**  
  Hold signal. Only used for 4-bit (qio/qout) transactions.

- **Assertion**  
  The action of activating a line. The opposite action of returning the line back to inactive (back to idle) is called de-assertion.

**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.
Chapter 2. API Reference

The attributes of a transaction are determined by the configuration structure for an SPI host acting as a slave device \texttt{spi_slave_interface_config_t}, and transaction configuration structure \texttt{spi_slave_transaction_t}.

As not every transaction requires both writing and reading data, you have a choice to configure the \texttt{spi_transaction_t} structure for TX only, RX only, or TX and RX transactions. If \texttt{spi_slave_transaction_t::rx_buffer} is set to NULL, the read phase will be skipped. If \texttt{spi_slave_transaction_t::tx_buffer} is set to NULL, the write phase will be skipped.

\textbf{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 \textit{Transaction Interval}.

\subsection*{Driver Usage}

- Initialize an SPI peripheral as a Device by calling the function \texttt{spi_slave_initialize}. Make sure to set the correct I/O pins in the structure \texttt{bus_config}. Set the unused signals to -1.

  If transactions will be longer than 32 bytes, allow a DMA channel 1 or 2 by setting the parameter \texttt{dma_chan} to 1 or 2 respectively. Otherwise, set \texttt{dma_chan} to 0.

- Before initiating transactions, fill one or more \texttt{spi_slave_transaction_t} structs with the transaction parameters required. Either queue all transactions by calling the function \texttt{spi_slave_queue_trans()} and, at a later time, query the result by using the function \texttt{spi_slave_get_trans_result()}, or handle all requests individually by feeding them into \texttt{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 \texttt{spi_slave_free()}. 

\subsection*{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 \texttt{rx_buffer} and \texttt{tx_buffer} members of the \texttt{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 \texttt{pvPortMallocCaps(size, MALLOC_CAP_DMA)}.

The amount of data that the driver can read or write to the buffers is limited by the member \texttt{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 \texttt{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 \texttt{length} member will be sent and received. In this case, \texttt{trans_len} is set to \texttt{length} instead of the actual transaction length. To meet the actual transaction length requirements, set \texttt{length} to a value greater than the maximum \texttt{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.

\subsection*{GPIO Matrix and IO_MUX}

Most of ESP32’s peripheral signals have direct connection to their dedicated IO_MUX pins. However, the signals can also be routed to any other available pins using the less direct GPIO matrix.

If at least one signal is routed through the GPIO matrix, then all signals will be routed through it. The GPIO matrix samples all signals at 80 MHz and transmits them between the GPIO and the peripheral.

If the driver is configured so that all SPI signals are either routed to their dedicated IO_MUX pins or are not connected at all, the GPIO matrix will be bypassed.
The GPIO matrix introduces flexibility of routing but also increases the input delay of the MISO signal, which makes MISO setup time violations more likely. If SPI needs to operate at high speeds, use dedicated IO_MUX pins.

**Note:** For more details about the influence of the MISO input delay on the maximum clock frequency, see *Timing Considerations*.

The IO_MUX pins for SPI buses are given below.

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>SPI2 GPIO Number</th>
<th>SPI3 GPIO Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS0*</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>SCLK</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>MISO</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>MOSI</td>
<td>13</td>
<td>23</td>
</tr>
<tr>
<td>QUADWP</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>QUADHD</td>
<td>4</td>
<td>21</td>
</tr>
</tbody>
</table>

- Only the first Device attached to the bus can use the CS0 pin.

### Speed and Timing Considerations

**Transaction Interval**   The ESP32 SPI slave peripherals are designed as general purpose Devices controlled by a CPU. As opposed to dedicated slaves, CPU-based SPI Devices have a limited number of pre-defined registers. All transactions must be handled by the CPU, which means that the transfers and responses are not real-time, and there might be noticeable latency.

As a solution, a Device’s response rate can be doubled by using the functions `spi_slave_queue_trans()` and then `spi_slave_get_trans_result()` instead of using `spi_slave_transmit()`.

You can also configure a GPIO pin through which the Device will signal to the Host when it is ready for a new transaction. A code example of this can be found in `peripherals/spi_slave`.

**SCLK Frequency Requirements**   The SPI slaves are designed to operate at up to 10 MHz. The data cannot be recognized or received correctly if the clock is too fast or does not have a 50% duty cycle.

On top of that, there are additional requirements for the data to meet the timing constraints:

- **Read (MOSI):** The Device can read data correctly only if the data is already set at the launch edge. Although it is usually the case for most masters.
- **Write (MISO):** The output delay of the MISO signal needs to be shorter than half of a clock cycle period so that the MISO line is stable before the next latch edge. Given that the clock is balanced, the output delay and frequency limitations in different cases are given below.

<table>
<thead>
<tr>
<th>IO_MUX</th>
<th>Output delay of MISO (ns)</th>
<th>Freq. limit (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>43.75</td>
<td>&lt;11.4</td>
<td></td>
</tr>
<tr>
<td>GPIO matrix</td>
<td>68.75</td>
<td>&lt;7.2</td>
</tr>
</tbody>
</table>

Note: 1. If the frequency is equal to the limitation, it can lead to random errors. 2. The clock uncertainty between Host and Device (12.5ns) is included. 3. The output delay is measured under ideal circumstances (no load). If the MISO pin is heavily loaded, the output delay will be longer, and the maximum allowed frequency will be lower.

Exception: The frequency is allowed to be higher if the master has more tolerance for the MISO setup time, e.g., latch data at the next edge, or configurable latching time.
Restrictions and Known Issues

1. If DMA is enabled, the rx buffer should be word-aligned (starting from a 32-bit boundary and having a length of multiples of 4 bytes). Otherwise, DMA may write incorrectly or not in a boundary aligned manner. The driver reports an error if this condition is not satisfied. Also, a Host should write lengths that are multiples of 4 bytes. The data with inappropriate lengths will be discarded.

2. Furthermore, DMA requires SPI modes 1 and 3. For SPI modes 0 and 2, the MISO signal has to be launched half a clock cycle earlier to meet the timing. The new timing is as follows:

![Timing Diagram]

If DMA is enabled, a Device’s launch edge is half of an SPI clock cycle ahead of the normal time, shifting to the Master’s actual latch edge. In this case, if the GPIO matrix is bypassed, the hold time for data sampling is 68.75 ns and no longer a half of an SPI clock cycle. If the GPIO matrix is used, the hold time will increase to 93.75 ns. The Host should sample the data immediately at the latch edge or communicate in SPI modes 1 or 3. If your Host cannot meet these timing requirements, initialize your Device without DMA.

Application Example

The code example for Device/Host communication can be found in the `peripherals/spi_slave` directory of ESP-IDF examples.

API Reference

Header File

- components/driver/include/driver/spi_slave.h

Functions

```c
esp_err_t spi_slave_initialize (spi_host_device_t host, const spi_bus_config_t *bus_config, 
const spi_slave_interface_config_t *slave_config, 
spi_dma_chan_t dma_chan)
```

Initialize a SPI bus as a slave interface.

**Warning** SPI0/1 is not supported

**Warning** If a DMA channel is selected, any transmit and receive buffer used should be allocated in DMA-capable memory.

**Warning** The ISR of SPI is always executed on the core which calls this function. Never starve the ISR on this core or the SPI transactions will not be handled.

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: SPI peripheral to use as a 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
Chapter 2. API Reference

- **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_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

**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_init.) 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.

**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.

**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

int spics_io_num
CS GPIO pin for this device.

uint32_t flags
Bitwise OR of SPI_SLAVE_* flags.

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.

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

size_t length
Total data length, in bits.

size_t trans_len
Transaction data length, in bits.

const void *tx_buffer
Pointer to transmit buffer, or NULL for no MOSI phase.
void *rx_buffer
    Pointer to receive buffer, or NULL for no MISO phase. When the DMA is enabled, must start at WORD boundary ($rx\_buffer\%4==0$), and has length of a multiple of 4 bytes.

void *user
    User-defined variable. Can be used to store eg transaction ID.

**Macros**

- **SPI_SLAVE_TXBIT_LSBFIRST**
  Transmit command/address/data LSB first instead of the default MSB first.

- **SPI_SLAVE_RXBIT_LSBFIRST**
  Receive data LSB first instead of the default MSB first.

- **SPI_SLAVE_BIT_LSBFIRST**
  Transmit and receive LSB first.

**Type Definitions**

typedef struct spi_slave_transaction_t spi_slave_transaction_t
typedef void (*slave_transaction_cb_t)(spi_slave_transaction_t *trans)

### 2.3.19 ESP32-WROOM-32SE (Secure Element)

**Overview**

The ESP32-WROOM-32SE has integrated Microchip's ATECC608A cryptoauth chip in the module. ATECC608A is secure element which would generate and store ECC private key in the hardware. The ECC private key can be used to enhance security to connect to IoT cloud services with use of X.509 based mutual authentication. The application example demonstrates ECDSA sign and verify functions using ECC private key stored in ATECC608A

**Application Example**

Secure Element ECDSA Sign/Verify example: peripherals/secure_element/atecc608_ecdsa.

**How to configure and provision ESP32-WROOM-32SE for TLS**

To configure and provision ATECC608A chip on ESP32-WROOM-32SE please visit esp_cryptoauth_utility

**How to use ATECC608A of ESP32-WROOM-32SE for TLS**

ATECC608A can be used for TLS connections using ESP-TLS. To configure ESP-TLS for using secure element please refer ATECC608A with ESP-TLS in ESP-TLS documentation.

### 2.3.20 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 can support up to 10 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 Technical Reference Manual > On-Chip Sensors and Analog Signal Processing [PDF].

In-depth design details of touch sensors and firmware development guidelines for ESP32 are available in Touch Sensor Application Note.

For more information about testing touch sensors in various configurations, please check the Guide for ESP32-Sense-Kit.

Functionality Overview

Description of API is broken down into groups of functions to provide a quick overview of the following features:

- Initialization of touch pad driver
- Configuration of touch pad GPIO pins
- Taking measurements
- Adjusting parameters of measurements
- Filtering measurements
- Touch detection methods
- Setting up interrupts to report touch detection
- Waking up from Sleep mode on interrupt

For detailed description of a particular function, please go to Section API Reference. Practical implementation of this API is covered in Section Application Examples.

Initialization

Before using a touch pad, you need to initialize the touch pad driver by calling the function `touch_pad_init()`. This function sets several "_DEFAULT" driver parameters listed in API Reference under Macros. It also removes the information about which pads have been touched before, if any, and disables interrupts.

If the driver is not required anymore, deinitialize it by calling `touch_pad_deinit()`.

Configuration

Enabling the touch sensor functionality for a particular GPIO is done with `touch_pad_config()`.

Use the function `touch_pad_set_fsm_mode()` to select if touch pad measurement (operated by FSM) should be started automatically by a hardware timer, or by software. If software mode is selected, use `touch_pad_sw_start()` to start the FSM.

Touch State Measurements

The following two functions come in handy to read raw or filtered measurements from the sensor:

- `touch_pad_read_raw_data()`  
- `touch_pad_read_filtered()`

They can also be used, for example, to evaluate a particular touch pad design by checking the range of sensor readings when a pad is touched or released. This information can be then used to establish a touch threshold.

Note: Before using `touch_pad_read_filtered()`, you need to initialize and configure the filter by calling specific filter functions described in Section Filtering of Measurements.

For the demonstration of how to read the touch pad data, check the application example peripherals/touch_sensor/touch_sensor_v1/touch_pad_read.

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.

![Diagram showing the relationship between measurement parameters](image)

**Fig. 20:** Touch pad - relationship between measurement parameters

The last chart `Output` represents the touch sensor reading, i.e., the count of pulses collected within the measurement time.

All functions are provided in pairs to set a specific parameter and to get the current parameter’s value, e.g., `touch_pad_set_voltage()` and `touch_pad_get_voltage()`.

**Filtering of Measurements** If measurements are noisy, you can filter them with provided API functions. Before using the filter, please start it by calling `touch_pad_filter_start()`.

The filter type is IIR (infinite impulse response), and it has a configurable period that can be set with the function `touch_pad_set_filter_period()`.

You can stop the filter with `touch_pad_filter_stop()`. If not required anymore, the filter can be deleted by invoking `touch_pad_filter_delete()`.

**Touch Detection** Touch detection is implemented in ESP32’s hardware based on the user-configured threshold and raw measurements executed by FSM. Use the functions `touch_pad_get_status()` to check which pads have been touched and `touch_pad_clear_status()` to clear the touch status information.

Hardware touch detection can also be wired to interrupts. This is described in the next section.

If measurements are noisy and capacity changes are small, hardware touch detection might be unreliable. To resolve this issue, instead of using hardware detection / provided interrupts, implement measurement filtering and perform
touch detection in your own application. For sample implementation of both methods of touch detection, see peripherals/touch_sensor/touch_sensor_v1/touch_pad_interrupt.

**Touch Triggered Interrupts** Before enabling an interrupt on a touch detection, you should establish a touch detection threshold. Use the functions described in Touch State Measurements to read and display sensor measurements when a pad is touched and released. Apply a filter if measurements are noisy and relative capacity changes are small. 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_thres()`. 

In the next step, configure how interrupts are triggered. They can be triggered below or above the threshold, which is set with the function `touch_pad_set_trigger_mode()`. 

Finally, configure and manage interrupt calls using the following functions:

- `touch_pad_isr_register()` / `touch_pad_isr_deregister()` 
- `touch_pad_intr_enable()` / `touch_pad_intr_disable()` 

When interrupts are operational, you can obtain the information from which particular pad an interrupt came by invoking `touch_pad_get_status()` and clear the pad status with `touch_pad_clear_status()`.

**Note:** Interrupts on touch detection operate on raw / unfiltered measurements checked against user established threshold and are implemented in hardware. Enabling the software filtering API (see Filtering of Measurements) does not affect this process.

**Wakeup from Sleep Mode** If touch pad interrupts are used to wake up the chip from a sleep mode, you can select a certain configuration of pads (SET1 or both SET1 and SET2) that should be touched to trigger the interrupt and cause the subsequent wakeup. To do so, use the function `touch_pad_set_trigger_source()`.

Configuration of required bit patterns of pads may be managed for each ‘SET’ with:

- `touch_pad_set_group_mask()` / `touch_pad_get_group_mask()` 
- `touch_pad_clear_group_mask()`

**Application Examples**

- Touch sensor read example: peripherals/touch_sensor/touch_sensor_v1/touch_pad_read. 
- Touch sensor interrupt example: peripherals/touch_sensor/touch_sensor_v1/touch_pad_interrupt.

**API Reference**

**Header File**

```
• components/driver/esp32/include/driver/touch_sensor.h
```

**Functions**

`esp_err_t touch_pad_config (touch_pad_t touch_num, uint16_t threshold)` 

Configure touch pad interrupt threshold.

**Note** If FSM mode is set to TOUCH_FSM_MODE_TIMER, this function will be blocked for one measurement cycle and wait for data to be valid.

**Return**

- ESP_OK Success 
- ESP_ERR_INVALID_ARG if argument wrong 
- ESP_FAIL if touch pad not initialized
Parameters

- `touch_num`: touch pad index
- `threshold`: interrupt threshold,

```c
esp_err_t touch_pad_read(touch_pad_t touch_num, uint16_t* touch_value)
```

get touch sensor counter value. Each touch sensor has a counter to count the number of charge/discharge cycles. When the pad is not ‘touched’, we can get a number of the counter. When the pad is ‘touched’, the value in counter will get smaller because of the larger equivalent capacitance.

**Note** This API requests hardware measurement once. If IIR filter mode is enabled, please use ‘touch_pad_read_raw_data’ interface instead.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Touch pad parameter error
- ESP_ERR_INVALID_STATE This touch pad hardware connection is error, the value of “touch_value” is 0.
- ESP_FAIL Touch pad not initialized

```c
esp_err_t touch_pad_read_filtered(touch_pad_t touch_num, uint16_t* touch_value)
```

get filtered touch sensor counter value by IIR filter.

**Note** touch_pad_filter_start has to be called before calling touch_pad_read_filtered. This function can be called from ISR

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Touch pad parameter error
- ESP_ERR_INVALID_STATE This touch pad hardware connection is error, the value of “touch_value” is 0.
- ESP_FAIL Touch pad not initialized

```c
esp_err_t touch_pad_read_raw_data(touch_pad_t touch_num, uint16_t* touch_value)
```

get raw data (touch sensor counter value) from IIR filter process. Need not request hardware measurements.

**Note** touch_pad_filter_start has to be called before calling touch_pad_read_raw_data. This function can be called from ISR

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Touch pad parameter error
- ESP_ERR_INVALID_STATE This touch pad hardware connection is error, the value of “touch_value” is 0.
- ESP_FAIL Touch pad not initialized

```c
esp_err_t touch_pad_set_filter_read_cb(filter_cb_t read_cb)
```

Register the callback function that is called after each IIR filter calculation.

**Note** The ‘read_cb’ callback is called in timer task in each filtering cycle.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG set error

```c
esp_err_t touch_pad_isr_register(intr_handler_t fn, void* arg)
```

Register the touch pad interrupt handler.

**Note** If the `fn` is NULL, the handler will be disabled.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Touch pad parameter error
- ESP_ERR_INVALID_STATE This touch pad hardware connection is error, the value of “touch_value” is 0.
- ESP_FAIL Touch pad not initialized
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 GPIO error
- ESP_ERR_NO_MEM No memory

Parameters
- fn: Pointer to ISR handler
- arg: Parameter for ISR

```c
esp_err_t touch_pad_set_meas_time(uint16_t sleep_cycle, uint16_t meas_cycle)
```
Set touch sensor measurement and sleep time. Excessive total time will slow down the touch response. Too small measurement time will not be sampled enough, resulting in inaccurate measurements.

Note The 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. \( t_{sleep} = \frac{sleep\_cycle}{RTC\_SLOW\_CLK\ \text{frequency}} \). The approximate frequency value of RTC\_SLOW\_CLK can be obtained using \( \text{rtc\_clk\_slow\_freq\_get\_hz} \) function.
- meas_cycle: The duration of the touch sensor measurement. \( t_{meas} = \frac{meas\_cycle}{8M} \), the maximum measure time will be \( 0xffff/8M = 8.19 \text{ ms} \)

```c
esp_err_t touch_pad_get_meas_time(uint16_t *sleep_cycle, uint16_t *meas_cycle)
```
Get touch sensor measurement and sleep time.

Return
- ESP_OK on success

Parameters
- sleep_cycle: Pointer to accept sleep cycle number
- meas_cycle: Pointer to accept measurement cycle count.

```c
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

```c
esp_err_t touch_pad_set_thresh(touch_pad_t touch_num, uint16_t threshold)
```
Set touch sensor interrupt threshold.

Return
- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong

Parameters
- touch_num: touch pad index
- threshold: threshold of touchpad count, refer to touch_pad_set_trigger_mode to see how to set trigger mode.

```c
esp_err_t touch_pad_get_thresh(touch_pad_t touch_num, uint16_t *threshold)
```
Get touch sensor interrupt 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_trigger_mode(touch_trigger_mode_t mode)
```
Set touch sensor interrupt trigger mode. Interrupt can be triggered either when counter result is less than threshold or when counter result is more than threshold.
Return
• ESP_OK on success
• ESP_ERR_INVALID_ARG if argument is wrong

Parameters
• mode: touch sensor interrupt trigger mode

\texttt{esp_err_t touch_pad_get_trigger_mode (touch_trigger_mode_t* mode)}

Get touch sensor interrupt trigger mode.

Return
• ESP_OK on success

Parameters
• mode: pointer to accept touch sensor interrupt trigger mode

\texttt{esp_err_t touch_pad_set_trigger_source (touch_trigger_src_t src)}

Set touch sensor interrupt trigger source. There are two sets of touch signals. Set1 and set2 can be mapped to several touch signals. Either set will be triggered if at least one of its touch signal is ‘touched’. The interrupt can be configured to be generated if set1 is triggered, or only if both sets are triggered.

Return
• ESP_OK on success
• ESP_ERR_INVALID_ARG if argument is wrong

Parameters
• src: touch sensor interrupt trigger source

\texttt{esp_err_t touch_pad_get_trigger_source (touch_trigger_src_t* src)}

Get touch sensor interrupt trigger source.

Return
• ESP_OK on success

Parameters
• src: pointer to accept touch sensor interrupt trigger source

\texttt{esp_err_t touch_pad_set_group_mask (uint16_t set1_mask, uint16_t set2_mask, uint16_t en_mask)}

Set touch sensor group mask. Touch pad module has two sets of signals, ‘Touched’ signal is triggered only if at least one of touch pad in this group is ‘touched’. This function will set the register bits according to the given bitmask.

Return
• ESP_OK on success
• ESP_ERR_INVALID_ARG if argument is wrong

Parameters
• set1_mask: bitmask of touch sensor signal group1, it’s a 10-bit value
• set2_mask: bitmask of touch sensor signal group2, it’s a 10-bit value
• en_mask: bitmask of touch sensor work enable, it’s a 10-bit value

\texttt{esp_err_t touch_pad_get_group_mask (uint16_t *set1_mask, uint16_t *set2_mask, uint16_t *en_mask)}

Get touch sensor group mask.

Return
• ESP_OK on success

Parameters
• set1_mask: pointer to accept bitmask of touch sensor signal group1, it’s a 10-bit value
• set2_mask: pointer to accept bitmask of touch sensor signal group2, it’s a 10-bit value
• en_mask: pointer to accept bitmask of touch sensor work enable, it’s a 10-bit value

\texttt{esp_err_t touch_pad_clear_group_mask (uint16_t set1_mask, uint16_t set2_mask, uint16_t en_mask)}

Clear touch sensor group mask. Touch pad module has two sets of signals, Interrupt is triggered only if at least one of touch pad in this group is “touched”. This function will clear the register bits according to the given bitmask.

Return
• ESP_OK on success
Chapter 2. API Reference

- ESP_ERR_INVALID_ARG if argument is wrong

**Parameters**
- **set1_mask**: bitmask touch sensor signal group1, it’s a 10-bit value
- **set2_mask**: bitmask touch sensor signal group2, it’s a 10-bit value
- **en_mask**: bitmask of touch sensor work enable, it’s a 10-bit value

```c
esp_err_t touch_pad_intr_enable (void)
To enable touch pad interrupt.
```
Return
- ESP_OK on success

```c
esp_err_t touch_pad_intr_disable (void)
To disable touch pad interrupt.
```
Return
- ESP_OK on success

```c
esp_err_t touch_pad_intr_clear (void)
To clear touch pad interrupt.
```
Return
- ESP_OK on success

```c
esp_err_t touch_pad_set_filter_period (uint32_t new_period_ms)
set touch pad filter calibration period, in ms. Need to call touch_pad_filter_start before all touch filter APIs
```
Return
- ESP_OK Success
- ESP_ERR_INVALID_STATE driver state error
- ESP_ERR_INVALID_ARG parameter error

**Parameters**
- **new_period_ms**: filter period, in ms

```c
esp_err_t touch_pad_get_filter_period (uint32_t *p_period_ms)
get touch pad filter calibration period, in ms Need to call touch_pad_filter_start before all touch filter APIs
```
Return
- ESP_OK Success
- ESP_ERR_INVALID_STATE driver state error
- ESP_ERR_INVALID_ARG parameter error

**Parameters**
- **p_period_ms**: pointer to accept period

```c
esp_err_t touch_pad_filter_start (uint32_t filter_period_ms)
start touch pad filter function This API will start a filter to process the noise in order to prevent false triggering when detecting slight change of capacitance. Need to call touch_pad_filter_start before all touch filter APIs
```
Note
This filter uses FreeRTOS timer, which is dispatched from a task with priority 1 by default on CPU 0. So if some application task with higher priority takes a lot of CPU0 time, then the quality of data obtained from this filter will be affected. You can adjust FreeRTOS timer task priority in menuconfig.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG parameter error
- ESP_ERR_NO_MEM No memory for driver
- ESP_ERR_INVALID_STATE driver state error

**Parameters**
- **filter_period_ms**: filter calibration period, in ms

```c
esp_err_t touch_pad_filter_stop (void)
stop touch pad filter function Need to call touch_pad_filter_start before all touch filter APIs
```
Return
- ESP_OK Success
- ESP_ERR_INVALID_STATE driver state error
```c
esp_err_t touch_pad_filter_delete(void)
delete touch pad filter driver and release the memory Need to call touch_pad_filter_start before all touch filter APIs

Return
  • ESP_OK Success
  • ESP_ERR_INVALID_STATE driver state error
```

**Type Definitions**

```c
typedef void(*filter_cb_t)(uint16_t*raw_value, uint16_t*filtered_value)
```

Callback function that is called after each IIR filter calculation.

**Note** This callback is called in timer task in each filtering cycle.

**Note** This callback should not be blocked.

**Parameters**

- `raw_value`: The latest raw data (touch sensor counter value) that points to all channels (`raw_value[0..TOUCH_PAD_MAX-1]`).
- `filtered_value`: The latest IIR filtered data (calculated from raw data) that points to all channels (`filtered_value[0..TOUCH_PAD_MAX-1]`).

**Header File**

- `components/driver/include/driver/touch_sensor_common.h`

**Functions**

```c
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
```

```c
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
```

```c
esp_err_t touch_pad_io_init(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
```

```c
esp_err_t touch_pad_set_voltage(touch_high_volt_t refh, touch_low_volt_t refl, touch_volt_atten_t atten)
Set touch sensor high voltage threshold of chanrge. The touch sensor measures the channel capacitance value by charging and discharging the channel. So the high threshold should be less than the supply voltage.

Return
  • ESP_OK on success
  • ESP_ERR_INVALID_ARG if argument is wrong

Parameters
  • `refh`: the value of DREFH
  • `refl`: the value of DREFL
```
Chapter 2. API Reference

- **atten**: the attenuation on DREFH

```c
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

```c
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

```c
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

```c
esp_err_t touch_pad_isr_deregister(void (*fn) 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`)

```c
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

```c
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

```c
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

```c
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

```c
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).

```c
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/esp32/include/soc/touch_sensor_channel.h

**Macros**

TOUCH_PAD_GPIO4_CHANNEL
TOUCH_PAD_NUM0_GPIO_NUM
TOUCH_PAD_GPIO0_CHANNEL
TOUCH_PAD_NUM1_GPIO_NUM
TOUCH_PAD_GPIO2_CHANNEL
TOUCH_PAD_NUM2_GPIO_NUM
TOUCH_PAD_GPIO15_CHANNEL
TOUCH_PAD_NUM3_GPIO_NUM
TOUCH_PAD_GPIO13_CHANNEL
TOUCH_PAD_NUM4_GPIO_NUM
TOUCH_PAD_GPIO12_CHANNEL
Chapter 2. API Reference

** TOUCH_PAD_NUM5_GPIO_NUM  
** TOUCH_PAD_GPIO14_CHANNEL  
** TOUCH_PAD_NUM6_GPIO_NUM  
** TOUCH_PAD_GPIO27_CHANNEL  
** TOUCH_PAD_NUM7_GPIO_NUM  
** TOUCH_PAD_GPIO33_CHANNEL  
** TOUCH_PAD_NUM8_GPIO_NUM  
** TOUCH_PAD_GPIO32_CHANNEL  
** TOUCH_PAD_NUM9_GPIO_NUM  

** Header File  
- components/hal/include/hal/touch_sensor_types.h  

** Macros  
- TOUCH_PAD_BIT_MASK_ALL  
- TOUCH_PAD_SLOPE_DEFAULT  
- TOUCH_PAD_TIE_OPT_DEFAULT  
- TOUCH_PAD_BIT_MASK_MAX  
- TOUCH_PAD_HIGH_VOLTAGE_THRESHOLD  
- TOUCH_PAD_LOW_VOLTAGE_THRESHOLD  
- TOUCH_PAD_ATTEN_VOLTAGE_THRESHOLD  
- TOUCH_PAD_IDLE_CH_CONNECT_DEFAULT  
- TOUCH_PAD_THRESHOLD_MAX  
  If set touch threshold max value, The touch sensor can’t be in touched status  
- TOUCH_PAD_SLEEP_CYCLE_DEFAULT  
  The timer frequency is RTC_SLOW_CLK (can be 150k or 32k depending on the options), max value is 0xffff  
- TOUCH_PAD_MEASURE_CYCLE_DEFAULT  
  The timer frequency is 8Mhz, the max value is 0x7fff  
- TOUCH_FSM_MODE_DEFAULT  
  The touch FSM my bestarted by the software or timer  
- TOUCH_TRIGGER_MODE_DEFAULT  
  Interrupts can be triggered if sensor value gets below or above threshold  
- TOUCH_TRIGGER_SOURCE_DEFAULT  
  The wakeup trigger source can be SET1 or both SET1 and SET2  

** Enumerations  
- enum touch_pad_t  
  Touch pad channel  
  Values:  
  - TOUCH_PAD_NUM0 = 0  
    Touch pad channel 0 is GPIO4(ESP32)  
  - TOUCH_PAD_NUM1  
    Touch pad channel 1 is GPIO0(ESP32) / GPIO1(ESP32-S2)
Chapter 2. API Reference

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_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 = 0
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 = 1
Touch sensor high reference voltage attenuation, 1.0V attenuation

TOUCH_HVOLT_ATTEN_0V5 = 2
Touch sensor high reference voltage attenuation, 0.5V attenuation

TOUCH_HVOLT_ATTEN_0V = 3
Touch sensor high reference voltage attenuation, 0V attenuation

TOUCH_HVOLT_ATTEN_MAX = 4

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 = 8

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 = 2

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.

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

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’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 a integrated transceiver. Therefore, to connect the TWAI controller to a TWAI bus, an external transceiver is required. The type of external transceiver used should depend on the application’s physical layer specification (e.g. using SN65HVD23x transceivers for ISO 11898-2 compatibility).

The TWAI controller’s interface consists of 4 signal lines known as **TX, RX, BUS-OFF, and CLKOUT**. These four signal lines can be routed through the GPIO Matrix to the ESP32’s GPIO pads.

**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 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 5: TWAI Driver 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 правитель ACTIVE</td>
<td>TWAI controller has become error active</td>
</tr>
<tr>
<td>TWAI_ALERT_RECOVERY_IN_PROGRESS</td>
<td>TWAI controller is undergoing bus recovery</td>
</tr>
<tr>
<td>TWAI_ALERT_BUS_RECOVERED</td>
<td>TWAI controller has successfully completed bus recovery</td>
</tr>
<tr>
<td>TWAI_ALERT_ARB_LOST</td>
<td>The previous transmission lost arbitration</td>
</tr>
<tr>
<td>TWAI_ALERT_above_ERR_WARN</td>
<td>One of the error counters have exceeded the error warning limit</td>
</tr>
<tr>
<td>TWAI_ALERT_BUS_ERROR</td>
<td>A (Bit, Stuff, CRC, Form, ACK) error has occurred on the bus</td>
</tr>
<tr>
<td>TWAI_ALERT_TX_FAILED</td>
<td>The previous transmission has failed</td>
</tr>
<tr>
<td>TWAI_ALERT_RX_QUEUE_FULL</td>
<td>The RX queue is full causing a received frame to be lost</td>
</tr>
<tr>
<td>TWAI_ALERT_ERR_PASS</td>
<td>TWAI controller has become error passive</td>
</tr>
<tr>
<td>TWAI_ALERT_BUS_OFF</td>
<td>Bus-off condition occurred. TWAI controller can no longer influence bus</td>
</tr>
</tbody>
</table>

**Note:** The TWAI controller’s error warning limit is used to preemptively warn the application of bus errors before the error passive state is reached. By default, the TWAI driver sets the error warning limit to 96. The TWAI_ALERT_above_ERR_WARN is raised when the TEC or REC becomes larger then or equal to the error warning limit. The TWAI_ALERT_below_ERR_WARN is raised when both TEC and REC return back to values below 96.

**Note:** When enabling alerts, the TWAI_ALERT_AND_LOG flag can be used to cause the TWAI driver to log any raised alerts to UART. However, alert logging is disabled and TWAI_ALERT_AND_LOG if the CONFIG_TWAI_ISR_IN_IRAM option is enabled (see Placing ISR into IRAM).

**Note:** The TWAI_ALERT_ALL and TWAI_ALERT_NONE macros can also be used to enable/disable all alerts during configuration/reconfiguration.

### Bit Timing

The operating bit rate of the TWAI driver is configured using the `twai_timing_config_t` structure. The period of each bit is made up of multiple time quanta, and the period of a time quantum is determined by a prescaled version of the TWAI controller’s source clock. A single bit contains the following segments in the following order:

1. The Synchronization Segment consists of a single time quantum
2. Timing Segment 1 consists of 1 to 16 time quanta before sample point
3. Timing Segment 2 consists of 1 to 8 time quanta after sample point

The Baudrate Prescaler is used to determine the period of each time quantum by dividing the TWAI controller’s source clock (80 MHz APB clock). On the ESP32, the `brp` can be any even number from 2 to 128.

If the ESP32 is a revision 2 or later chip, the `brp` will also support any multiple of 4 from 132 to 256, and can be enabled by setting the `CONFIG_ESP32_REV_MIN` to revision 2 or higher.

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.
Chapter 2. API Reference

**Fig. 22:** Bittiming configuration for 500kbit/s given BRP = 8

**Note:** Multiple combinations of \( \text{brp}, \text{tseg}_1, \text{tseg}_2, \) and \( \text{sjw} \) 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:

- `TWAI_TIMING_CONFIG_1MBITS()`
- `TWAI_TIMING_CONFIG_800KBITS()`
- `TWAI_TIMING_CONFIG_500KBITS()`
- `TWAI_TIMING_CONFIG_250KBITS()`
- `TWAI_TIMING_CONFIG_125KBITS()`
- `TWAI_TIMING_CONFIG_100KBITS()`
- `TWAI_TIMING_CONFIG_50KBITS()`
- `TWAI_TIMING_CONFIG_25KBITS()`

Revision 2 or later of the ESP32 also supports the following bit rates:

- `TWAI_TIMING_CONFIG_20KBITS()`
- `TWAI_TIMING_CONFIG_16KBITS()`
- `TWAI_TIMING_CONFIG_12_5KBITS()`

**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 `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 a 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. 23:** Bit layout of single filter mode (Right side MSBit)
**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).

![Bit layout of dual filter mode](image)

**Disabling TX Queue** The TX queue can be disabled during configuration by setting the `tx_queue_len` member of `twai_general_config_t` to 0. This will allow applications that do not require message transmission to save a small amount of memory when using the TWAI driver.

**Placing ISR into IRAM** The TWAI driver’s ISR (Interrupt Service Routine) can be placed into IRAM so that the ISR can still run whilst the cache is disabled. Placing the ISR into IRAM may be necessary to maintain the TWAI driver’s functionality during lengthy cache disabling operations (such as SPI Flash writes, OTA updates etc). Whilst the cache is disabled, the ISR will continue to:

- Read received messages from the RX buffer and place them into the driver’s RX queue.
- Load messages pending transmission from the driver’s TX queue and write them into the TX buffer.

To place the TWAI driver’s ISR, users must do the following:

- Enable the `CONFIG_TWAI_ISR_IN_IRAM` option using `idf.py menuconfig`.
- When calling `twai_driver_install()`, the `intr_flags` member of `twai_general_config_t` should set the `ESP_INTR_FLAG_IRAM` set.

**Note:** When the `CONFIG_TWAI_ISR_IN_IRAM` option is enabled, the TWAI driver will no longer log any alerts (i.e., the `TWAI_ALERT_AND_LOG` flag will not have any effect).

**Driver Operation**

The TWAI driver is designed with distinct states and strict rules regarding the functions or conditions that trigger a state transition. The following diagram illustrates the various states and their transitions.

![State transition diagram of the TWAI driver](image)
### 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.
```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.
#include "driver/twai.h"

//Wait for message to be received
twai_message_t message;
if (twai_receive(&message, pdMS_TO_TICKS(10000)) == ESP_OK) {
    printf("Message received\n");
} else {
    printf("Failed to receive message\n");
    return;
}

//Process received message
if (message.extd) {
    printf("Message is in Extended Format\n");
} else {
    printf("Message is in Standard Format\n");
}
printf("ID is %d\n", message.identifier);
if (!message.rtr) {
    for (int i = 0; i < message.data_length_code; i++) {
        printf("Data byte %d = %d\n", i, message.data[i]);
    }
}

Reconfiguring and Reading Alerts  The following code snippet demonstrates how to reconfigure and read TWAI driver alerts via the use of the twai_reconfigure_alerts() and twai_read_alerts() functions.

#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;
}
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:

```
ID1 = 11'b101 1010 0000
ID2 = 11'b101 1010 0001
ID3 = 11'b101 1010 0100
ID4 = 11'b101 1010 1000

//Acceptance Mask
MASK = 11'b000 0000 1101
```

**Application Examples**  

**Network Example:** The TWAI Network example demonstrates communication between two ESP32s using the TWAI driver API. One TWAI node acts as a network master that initiates and ceases the transfer of 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
```
Chapter 2. API Reference

uint32_t ss: 1
Transmit as a Single Shot Transmission. Unused for received.

uint32_t self: 1
Transmit as a Self Reception Request. Unused for received.

uint32_t dlc_non_comp: 1
Message’s Data length code is larger than 8. This will break compliance with ISO 11898-1

uint32_t reserved: 27
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

```c
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**(const **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

`twai_state_t state`
Current state of TWAI controller (Stopped/Running/Bus-Off/Recovery)

`uint32_t msgs_to_tx`
Number of messages queued for transmission or awaiting transmission completion

`uint32_t msgs_to_rx`
Number of messages in RX queue waiting to be read

`uint32_t tx_error_counter`
Current value of Transmit Error Counter

`uint32_t rx_error_counter`
Current value of Receive Error Counter

`uint32_t tx_failed_count`
Number of messages that failed transmissions

`uint32_t rx_missed_count`
Number of messages that were lost due to a full RX queue (or errata workaround if enabled)

`uint32_t rx_overrun_count`
Number of messages that were lost due to a RX FIFO overrun

`uint32_t arb_lost_count`
Number of instances arbitration was lost

`uint32_t bus_error_count`
Number of instances a bus error has occurred

Macros

`TWAI_IO_UNUSED`
Marks GPIO as unused in TWAI configuration

Enumerations

`enum twai_state_t`
TWAI driver states.

Values:

`TWAI_STATE_STOPPED`
Stopped state. The TWAI controller will not participate in any TWAI bus activities

`TWAI_STATE_RUNNING`
Running state. The TWAI controller can transmit and receive messages

`TWAI_STATE_BUS_OFF`
Bus-off state. The TWAI controller cannot participate in bus activities until it has recovered

`TWAI_STATE_RECOVERING`
Recovering state. The TWAI controller is undergoing bus recovery

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 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 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’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>
<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 `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 `uart_set_pin()` and specify the GPIO pin numbers to which the driver should route the Tx, Rx, RTS, and CTS signals. If you want to keep a currently allocated pin number for a specific signal, pass the macro `UART_PIN_NO_CHANGE`.

The same macro 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 `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 `uart_write_bytes()` and `uart_read_bytes()` respectively, and the FSM will do the rest.

**Transmitting**  After preparing the data for transmission, call the function `uart_write_bytes()` and pass the data buffer’s address and data length to it. The function will copy the data to the Tx ring buffer (either immediately or after enough space is available), and then exit. When there is free space in the Tx FIFO buffer, an interrupt service routine (ISR) moves the data from the Tx ring buffer to the Tx FIFO buffer in the background. The code below demonstrates the use of this function.

```c
// Write data to UART.
char* test_str = "This is a test string.\n";
uart_write_bytes(uart_num, (const char*)test_str, strlen(test_str));
```
Chapter 2. API Reference

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.

```
// 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.

```
// 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.

```
// Read data from UART.
const uart_port_t uart_num = UART_NUM_2;
uint8_t data[128];
int length = 0;
ESP_ERROR_CHECK(uart_get_buffered_data_len(uart_num, (size_t *)&length));
length = uart_read_bytes(uart_num, data, length, 100);
```

If the data in the Rx FIFO buffer is no longer needed, you can clear the buffer by calling `uart_flush()`.

**Software Flow Control** If the hardware flow control is disabled, you can manually set the RTS and DTR signal levels by using the functions `uart_set_rts()` and `uart_set_dtr()` respectively.

**Communication Mode Selection** The UART controller supports a number of communication modes. A mode can be selected using the function `uart_set_mode()`. Once a specific mode is selected, the UART driver will handle the behavior of a connected UART device accordingly. As an example, it can control the RS485 driver chip using the RTS line to allow half-duplex RS485 communication.

```
// Setup UART in rs485 half duplex mode
ESP_ERROR_CHECK(uart_set_mode(uart_num, UART_MODE_RS485_HALF_DUPLEX));
```

**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 Technical Reference Manual > UART Controller (UART) > UART Interrupts and UHCI Interrupts [PDF]. You can enable or disable specific interrupts by calling `uart_enable_intr_mask()` or `uart_disable_intr_mask()` respectively. The mask of all interrupts is available as UART_INTR_MASK.

By default, 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). It is also possible to register a lower level interrupt handler instead using `uart_isr_register()`, and to free it again using `uart_isr_free()`. Some UART driver functions which use the Tx and Rx ring buffers, events, etc. will not automatically work in this case - it is necessary to handle the interrupts directly in the ISR. Inside the custom handler implementation, clear the interrupt status bits using `uart_clear_intr_status()`.
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 Technical Reference Manual > UART Controller (UART) > Register Summary [PDF]. Use the register name to navigate to the register description and then find the field/bit.

- `UART_RS485_CONF_REG.UART_RS485_EN`: setting this bit enables RS485 communication mode support.
- `UART_RS485_CONF_REG.UART_RS485TX_RX_EN`: if this bit is set, the transmitter’s output signal loops back to the receiver’s input signal.
- `UART_RS485_CONF_REG.UART_RS485RXBY_TX_EN`: if this bit is set, the transmitter will still be sending data if the receiver is busy (remove collisions automatically by hardware).

The ESP32’s RS485 UART hardware can detect signal collisions during transmission of a datagram and generate the interrupt `UART_RS485_CLASH_INT` if this interrupt is enabled. The term collision means that a transmitted datagram is not equal to the one received on the other end. Data collisions are usually associated with the presence of other active devices on the bus or might occur due to bus errors.

The collision detection feature allows handling collisions when their interrupts are activated and triggered. The interrupts `UART_RS485_FRM_ERR_INT` and `UART_RS485_PARITY_ERR_INT` can be used with the collision detection feature to control frame errors and parity bit errors accordingly in RS485 mode. This functionality is supported in the UART driver and can be used by selecting the `UART_MODE_RS485_APP_CTRL` mode (see the function `uart_set_mode()`).

The collision detection feature can work with circuit A and circuit C (see Section Interface Connection Options). In the case of using circuit A or B, the RTS pin connected to the DE pin of the bus driver should be controlled by the...
user application. Use the function `uart_get_collision_flag()` to check if the collision detection flag has been raised.

The ESP32 UART controllers themselves do not support half-duplex communication as they cannot provide automatic control of the RTS pin connected to the -RE/DE input of RS485 bus driver. However, half-duplex communication can be achieved via software control of the RTS pin by the UART driver. This can be enabled by selecting the `UART_MODE_RS485_HALF_DUPLEX` mode when calling `uart_set_mode()`.

Once the host starts writing data to the Tx FIFO buffer, the UART driver automatically asserts the RTS pin (logic 1); once the last bit of the data has been transmitted, the driver de-asserts the RTS pin (logic 0). To use this mode, the software would have to disable the hardware flow control function. This mode works with all the used circuits shown below.

**Interface Connection Options**  This section provides example schematics to demonstrate the basic aspects of ESP32’s RS485 interface connection.

**Note:**

- The schematics below do not necessarily contain all required elements.
- The analog devices ADM483 & ADM2483 are examples of common RS485 transceivers and can be replaced with other similar transceivers.

---

**Circuit A: Collision Detection Circuit**

```
VCC ------------------
          |               |
RXD   <----| R       x------B        |
        |         |               |
      TXD ----->| D ADM483 |
        |         |       RS485 bus side |
        |         |               |
      RTS ----->| DE       | A|<--|--| A
        |         |               |
      +----| /RE   |
       |       |
      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 ------------------
          |               |
RXD   <----| R       x------B        |
        |         |               |
      TXD ----->| D ADM483 |
        |         |       RS485 bus side |
        |         |               |
      RTS ----->| DE       | A|<--|--| A
        |         |               |
      +----| /RE   |
       |       |
      GND     GND
```

---

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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

<table>
<thead>
<tr>
<th>Code Example</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>peripherals/uart/uart_echo</td>
<td>Configuring UART settings, installing the UART driver, and reading/writing over the UART1 interface.</td>
</tr>
<tr>
<td>peripherals/uart/uart_events</td>
<td>Reporting various communication events, using pattern detection interrupts.</td>
</tr>
<tr>
<td>peripherals/uart/uart_async_rxtxtasks</td>
<td>Transmitting and receiving data in two separate FreeRTOS tasks over the same UART.</td>
</tr>
<tr>
<td>peripherals/uart/uart_select</td>
<td>Using synchronous I/O multiplexing for UART file descriptors.</td>
</tr>
<tr>
<td>peripherals/uart/uart_echo_rs485</td>
<td>Setting up UART driver to communicate over RS485 interface in half-duplex mode. This example is similar to peripherals/uart/uart_echo but allows communication through an RS485 interface chip connected to ESP32 pins.</td>
</tr>
<tr>
<td>peripherals/uart/nmea0183_parser</td>
<td>Obtaining GPS information by parsing NMEA0183 statements received from GPS via the UART peripheral.</td>
</tr>
</tbody>
</table>

API Reference

Header File

- components/driver/include/driver/uart.h
Functions

`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_bit)

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, uint32_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

```c
esp_err_t uart_set_hw_flow_ctrl(uart_port_t uart_num, uart_hw_flowcontrol_t flow_ctrl, uint8_t rx_thresh)
```

Set hardware flow control.

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.

```c
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

```c
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.

```c
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.

```c
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.

```c
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).

`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).

`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

`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

`esp_err_t uart_isr_register(uart_port_t uart_num, void (*fn)(void,* arg), int intr_alloc_flags, uart_isr_handle_t* handle)`
Register UART interrupt handler (ISR).

Note
UART ISR handler will be attached to the same CPU core that this function is running on.

Return
• ESP_OK Success
• ESP_FAIL Parameter error

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX - 1).
• 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.

`esp_err_t uart_isr_free(uart_port_t uart_num)`
Free UART interrupt handler registered by uart_isr_register. Must be called on the same core as uart_isr_register was called.

Return
### Chapter 2. API Reference

#### ESP_OK Success
- Success

#### ESP_FAIL Parameter error
- Parameter error

### Parameters
- **uart_num**: UART port number, the max port number is (UART_NUM_MAX - 1).

#### 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.

#### 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 (active); 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).
• intr_conf: UART interrupt 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
• (-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

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

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 \texttt{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**

\begin{itemize}
  \item (-1) Parameter error
  \item OTHERS (>=0) The number of bytes pushed to the TX FIFO
\end{itemize}

**Parameters**

\begin{itemize}
  \item \texttt{uart_num}: UART port number, the max port number is (UART_NUM_MAX - 1).
  \item \texttt{src}: data buffer address
  \item \texttt{size}: data length to send
  \item \texttt{brk_len}: break signal duration (unit: the time it takes to send one bit at current baudrate)
\end{itemize}

\begin{verbatim}
int uart_read_bytes (uart_port_t uart_num, void *buf, uint32_t length, TickType_t ticks_to_wait)
\end{verbatim}

UART read bytes from UART buffer.

**Return**

\begin{itemize}
  \item (-1) Error
  \item OTHERS (>=0) The number of bytes read from UART FIFO
\end{itemize}

**Parameters**

\begin{itemize}
  \item \texttt{uart_num}: UART port number, the max port number is (UART_NUM_MAX - 1).
  \item \texttt{buf}: pointer to the buffer.
  \item \texttt{length}: data length
  \item \texttt{ticks_to_wait}: sTimeout, count in RTOS ticks
\end{itemize}

\begin{verbatim}
esp_err_t uart_flush (uart_port_t uart_num)
\end{verbatim}

Alias of \texttt{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 \texttt{uart_wait_tx_done} function.

**Return**

\begin{itemize}
  \item ESP_OK Success
  \item ESP_FAIL Parameter error
\end{itemize}

**Parameters**

\begin{itemize}
  \item \texttt{uart_num}: UART port number, the max port number is (UART_NUM_MAX - 1).
\end{itemize}

\begin{verbatim}
esp_err_t uart_flush_input (uart_port_t uart_num)
\end{verbatim}

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 \texttt{uart_wait_tx_done} function.

**Return**

\begin{itemize}
  \item ESP_OK Success
  \item ESP_FAIL Parameter error
\end{itemize}

**Parameters**

\begin{itemize}
  \item \texttt{uart_num}: UART port number, the max port number is (UART_NUM_MAX - 1).
\end{itemize}

\begin{verbatim}
esp_err_t uart_get_buffered_data_len (uart_port_t uart_num, size_t *size)
\end{verbatim}

UART get RX ring buffer cached data length.

**Return**

\begin{itemize}
  \item ESP_OK Success
  \item ESP_FAIL Parameter error
\end{itemize}

**Parameters**

\begin{itemize}
  \item \texttt{uart_num}: UART port number, the max port number is (UART_NUM_MAX - 1).
  \item \texttt{size}: Pointer of size_t to accept cached data length
\end{itemize}

\begin{verbatim}
esp_err_t uart_disable_pattern_det_intr (uart_port_t uart_num)
\end{verbatim}

UART disable pattern detect function. Designed for applications like \texttt{AT commands}. When the hardware detects a series of one same character, the interrupt will be triggered.

**Return**

\begin{itemize}
  \item ESP_OK Success
  \item ESP_FAIL Parameter error
\end{itemize}

**Parameters**

\begin{itemize}
  \item \texttt{uart_num}: UART port number, the max port number is (UART_NUM_MAX - 1).
\end{itemize}
uart_num: UART port number, the max port number is (UART_NUM_MAX - 1).

```c
esp_err_t uart_enable_pattern_det_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.

**Note** This function only works for esp32. And this function is deprecated, please use `uart_enable_pattern_det_baud_intr` instead.

**Return**
- ESP_OK Success
- ESP_FAIL Parameter error

**Parameters**
- `uart_num`: UART port number.
- `pattern_chr`: character of the pattern.
- `chr_num`: number of the character, 8bit value.
- `chr_tout`: timeout of the interval between each pattern characters, 24bit value, unit is APB (80Mhz) clock cycle. When the duration is less than this value, it will not take this data as at_cmd char.
- `post_idle`: idle time after the last pattern character, 24bit value, unit is APB (80Mhz) clock cycle. When the duration is less than this value, it will not take the previous data as the last at_cmd char.
- `pre_idle`: idle time before the first pattern character, 24bit value, unit is APB (80Mhz) clock cycle. When the duration is less than this value, it will not take this data as the first at_cmd char.

```c
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

**Parameters**
- `uart_num`: UART port number.
- `pattern_chr`: character of the pattern.
- `chr_num`: number of the character, 8bit value.
- `chr_tout`: timeout of the interval between each pattern characters, 16bit value, unit is the baud-rate cycle you configured. When the duration is more than this value, it will not take this data as at_cmd char.
- `post_idle`: idle time after the last pattern character, 16bit value, unit is the baud-rate cycle you configured. When the duration is less than this value, it will not take the previous data as the last at_cmd char.
- `pre_idle`: idle time before the first pattern character, 16bit value, unit is the baud-rate cycle you configured. When the duration is less than this value, it will not take this data as the first at_cmd char.

```c
int uart_pattern_pop_pos(uart_port_t uart_num)
```

Return the nearest detected pattern position in buffer. The positions of the detected pattern are saved in a queue, this function will dequeue the first pattern position and move the pointer to next pattern position.

The following APIs will modify the pattern position info: `uart_flush_input`, `uart_read_bytes`, `uart_driver_delete`, `uart_pop_pattern_pos` It is the application’s responsibility to ensure atomic access to the pattern queue and the rx data buffer when using pattern detect feature.

**Note** If the RX buffer is full and flow control is not enabled, the detected pattern may not be found in the rx buffer due to overflow.

**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

\[ \text{esp_err_t uart_set_rx_timeout(uart_port_t uart_num, const uint8_t tout_thresh)} \]
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.

\[ \text{esp_err_t uart_get_collision_flag(uart_port_t uart_num, bool *collision_flag)} \]
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.

\[ \text{esp_err_t uart_set_wakeup_threshold(uart_port_t uart_num, int wakeup_threshold)} \]
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 cannot 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).
• wakeup_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
- uart_num: UART number, the max port number is (UART_NUM_MAX -1).
- [out] out_wakeup_threshold: output, set to the current value of wakeup threshold for the given UART.

\texttt{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
- uart_num: UART number

\texttt{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
- uart_num: UART number
- loop_back_en: Set true to enable the loop back function, else set it false.

\texttt{void uart_set_always_rx_timeout(uart_port_t uart_num, bool always_rx_timeout_en)}
Configure behavior of UART RX timeout interrupt.

When always_rx_timeout is true, timeout interrupt is triggered even if FIFO is full. This function can cause extra timeout interrupts triggered only to send the timeout event. Call this function only if you want to ensure timeout interrupt will always happen after a byte stream.

Parameters
- uart_num: UART number
- always_rx_timeout_en: Set to false enable the default behavior of timeout interrupt, set it to true to always trigger timeout interrupt.

Structures
\
struct uart_intr_config_t

UART interrupt configuration parameters for uart_intr_config function.

Public Members

\texttt{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

\texttt{uint8_t rx_timeout_thresh}
UART timeout interrupt threshold (unit: time of sending one byte)

\texttt{uint8_t txfifo_empty_intr_thresh}
UART TX empty interrupt threshold.

\texttt{uint8_t txfifo_full_thresh}
UART RX full interrupt threshold.

\texttt{struct uart_event_t}
Event structure used in UART event queue.
Chapter 2. API Reference

Public Members

```c
uart_event_type_t type
UART event type
```

```c
size_t size
UART data size for UART_DATA event
```

```c
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

<table>
<thead>
<tr>
<th>Macro</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>UART_NUM_0</td>
<td>UART port 0</td>
</tr>
<tr>
<td>UART_NUM_1</td>
<td>UART port 1</td>
</tr>
<tr>
<td>UART_NUM_2</td>
<td>UART port 2</td>
</tr>
<tr>
<td>UART_NUM_MAX</td>
<td>UART port max</td>
</tr>
<tr>
<td>UART_PIN_NO_CHANGE</td>
<td></td>
</tr>
<tr>
<td>UART_FIFO_LEN</td>
<td>Length of the UART HW FIFO.</td>
</tr>
<tr>
<td>UART_BITRATE_MAX</td>
<td>Maximum configurable bitrate.</td>
</tr>
</tbody>
</table>

Type Definitions

```c
typedef intr_handle_t uart_isr_handle_t
```

Enumerations

```c
enum uart_event_type_t
UART event types used in the ring buffer.
```

Values:

```c
UART_DATA
UART data event
```

```c
UART_BREAK
UART break event
```

```c
UART_BUFFER_FULL
UART RX buffer full event
```

```c
UART_FIFO_OVF
UART FIFO overflow event
```

```c
UART_FRAME_ERR
UART RX frame error event
```

```c
UART_PARITY_ERR
UART RX parity event
```

```c
UART_DATA_BREAK
UART TX data and break event
```
UART_PATTERN_DET
UART pattern detected

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 differ 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
**Chapter 2. API Reference**

```c
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_ctrl_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**

```c
typedef int uart_port_t
    UART port number, can be UART_NUM_0 ~ UART_NUM_MAX.
```

**Enumerations**

```c
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 rxd signal

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)
inversethe UART rts signal

UART_SIGNAL_DTR_INV = (0x1 << 7)
inversethe UART dtr signal

enum uart_sclk_t
UART source clock.

Values:

UART_SCLK_APB = 0x0
UART source clock from APB

UART_SCLK_REF_TICK = 0x3
UART source clock from REF_TICK

**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/esp32/include/soc/uart_channel.h

**Macros**

- UART_GPIO1_DIRECT_CHANNEL
- UART_NUM_0_TXD_DIRECT_GPIO_NUM
- UART_GPIO3_DIRECT_CHANNEL
- UART_NUM_0_RXD_DIRECT_GPIO_NUM
- UART_GPIO19_DIRECT_CHANNEL
- UART_NUM_0_CTS_DIRECT_GPIO_NUM
- UART_GPIO22_DIRECT_CHANNEL
- UART_NUM_0_RTS_DIRECT_GPIO_NUM
- UART_TXD_GPIO1_DIRECT_CHANNEL
- UART_RXD_GPIO3_DIRECT_CHANNEL
- UART_CTS_GPIO19_DIRECT_CHANNEL
- UART_RTS_GPIO22_DIRECT_CHANNEL
Chapter 2. API Reference

UART_GPIO10_DIRECT_CHANNEL
UART_NUM_1_TXD_DIRECT_GPIO_NUM
UART_GPIO9_DIRECT_CHANNEL
UART_NUM_1_RXD_DIRECT_GPIO_NUM
UART_GPIO6_DIRECT_CHANNEL
UART_NUM_1_CTS_DIRECT_GPIO_NUM
UART_GPIO11_DIRECT_CHANNEL
UART_NUM_1_RTS_DIRECT_GPIO_NUM
UART_TXD_GPIO10_DIRECT_CHANNEL
UART_RXD_GPIO9_DIRECT_CHANNEL
UART_CTS_GPIO6_DIRECT_CHANNEL
UART_RTS_GPIO11_DIRECT_CHANNEL
UART_gpio17_DIRECT_CHANNEL
UART_NUM_2_TXD_DIRECT_GPIO_NUM
UART_GPIO16_DIRECT_CHANNEL
UART_NUM_2_RXD_DIRECT_GPIO_NUM
UART_GPIO8_DIRECT_CHANNEL
UART_NUM_2_CTS_DIRECT_GPIO_NUM
UART_GPIO7_DIRECT_CHANNEL
UART_NUM_2_RTS_DIRECT_GPIO_NUM
UART_TXD_GPIO17_DIRECT_CHANNEL
UART_RXD_GPIO16_DIRECT_CHANNEL
UART_CTS_GPIO8_DIRECT_CHANNEL
UART_RTS_GPIO8_DIRECT_CHANNEL

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 find 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:
Chapter 2. API Reference

- `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:8883`
  - `mqtts://mqtt.eclipseprojects.io:8884`: MQTT over SSL, port 8884

- **MQTT over Websocket samples:**
  - `ws://mqtt.eclipseprojects.io:80/mqtt`
  - `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, ...
  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 openssl 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
Chapter 2. API Reference

- 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
- 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.
Chapter 2. API Reference

- **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**

- **esp_mqtt_client_init**

  \[
  \text{esp_mqtt_client_init(esp_mqtt_client_config_t *config)}
  \]

  Creates mqtt client handle based on the configuration.

  \[
  \text{ Returns: mqtt_client_handle if successfully created, NULL on error}
  \]

  \[
  \text{ Parameters: config: mqtt configuration structure}
  \]

- **esp_mqtt_client_set_uri**

  \[
  \text{esp_mqtt_client_set_uri(esp_mqtt_client_t client, const char *uri)}
  \]

  Sets mqtt connection URI. This API is usually used to overrides the URI configured in esp_mqtt_client_init.

  \[
  \text{ Returns: ESP_FAIL if URI parse error, ESP_OK on success}
  \]

  \[
  \text{ Parameters: client: mqtt client handle}
  \]

- **esp_mqtt_client_start**

  \[
  \text{esp_mqtt_client_start(esp_mqtt_client_t client)}
  \]

  Starts mqtt client with already created client handle.

  \[
  \text{ Returns: ESP_OK on success ESP_ERR_INVALID_ARG on wrong initialization ESP_FAIL on other error}
  \]

  \[
  \text{ Parameters: client: mqtt client handle}
  \]

- **esp_mqtt_client_reconnect**

  \[
  \text{esp_mqtt_client_reconnect(esp_mqtt_client_t client)}
  \]

  This api is typically used to force reconnection upon a specific event.

  \[
  \text{ Returns: ESP_OK on success ESP_ERR_INVALID_ARG on wrong initialization ESP_FAIL if client is in invalid state}
  \]

  \[
  \text{ Parameters: client: mqtt client handle}
  \]

- **esp_mqtt_client_disconnect**

  \[
  \text{esp_mqtt_client_disconnect(esp_mqtt_client_t client)}
  \]

  This api is typically used to force disconnection from the broker.

  \[
  \text{ Returns: ESP_OK on success ESP_ERR_INVALID_ARG on wrong initialization}
  \]

  \[
  \text{ Parameters: client: mqtt client handle}
  \]

- **esp_mqtt_client_stop**

  \[
  \text{esp_mqtt_client_stop(esp_mqtt_client_t client)}
  \]

  Stops mqtt client tasks.

  \[
  \text{ Notes: Cannot be called from the mqtt event handler}
  \]

  \[
  \text{ Returns: ESP_OK on success ESP_ERR_INVALID_ARG on wrong initialization ESP_FAIL if client is in invalid state}
  \]

  \[
  \text{ Parameters: client: mqtt client handle}
  \]
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:

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:

int esp_mqtt_client_publish(esp_mqtt_client_handle_t client, const char *topic, const char *data, int len, int qos, int retain)

Client to send a publish message to the broker.

Notes:

- This API might block for several seconds, either due to network timeout (10s) or if publishing payloads longer than internal buffer (due to message fragmentation)
- Client doesn’ t have to be connected for this API to work, enqueueing the messages with qos>1 (returning -1 for all the qos=0 messages if disconnected). If MQTT_SKIP_PUBLISH_IF_DISCONNECTED is enabled, this API will not attempt to publish when the client is not connected and will always return -1.
- It is thread safe, please refer to esp_mqtt_client_subscribe for details

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 qos 1 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.

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:

| error_type | related member variables | note | | MQTT_ERROR_TYPE_TCP_TRANSPORT | esp_tls_last_espr, esp_tls_stack_err, esp_tls_cert_verify_flags, sock_errno | Error reported from tcp_transport/esp-tls | MQTT_ERROR_TYPE_CONNECTION_REFUSED | connect_return_code | Internal error reported from MQTT broker on connection |
Public Members

`esp_err_t esp_tls_last_esp_err`
- last `esp_err` code reported from esp-tls component

`int esp_tls_stack_err`
- tls specific error code reported from underlying tls stack

`int esp_tls_cert_verify_flags`
- tls flags reported from underlying tls stack during certificate verification

`esp_mqtt_error_type_t error_type`
- error type referring to the source of the error

`esp_mqtt_connect_return_code_t connect_return_code`
- connection refused error code reported from MQTT broker on connection

`int esp_transport_sock_errno`
- errno from the underlying socket

`struct esp_mqtt_event_t`  
- MQTT event configuration structure

Public Members

`esp_mqtt_event_id_t event_id`
- MQTT event type

`esp_mqtt_client_handle_t client`
- MQTT client handle for this event

`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

esp_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
mqtt clean session, default clean_session is true

int keepalive
mqtt 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 *client_password
Client key decryption password string

int client_password_len
String length of the password pointed to by client_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 failed packet

Macros

MQTT_ERROR_TYPE_ESP_TLS
MQTT_ERROR_TYPE_TCP_TRANSPORT error type hold all sorts of transport layer errors, including ESP-TLS error, but in the past only the errors from MQTT_ERROR_TYPE_ESP_TLS layer were reported, so the ESP-TLS error type is re-defined here for backward compatibility

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:

| error_type | related member variables | note | | MQTT_ERROR_TYPE_TCP_TRANSPORT | esp_tls_last_err, esp_tls_stack_err, esp_tls_cert_verify_flags, sock_errno | Error reported from tcp_transport/esp-tls | | MQTT_ERROR_TYPE_CONNECTION_REFUSED | connect_return_code | Internal error reported from MQTT broker on connection |

typedef esp_mqtt_event_t *esp_mqtt_event_handle_t
typedef esp_err_t (*mqtt_event_callback_t)(esp_mqtt_event_handle_t event)

Enumerations

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:
```c
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
```
Chapter 2. API Reference

**MQTT_CONNECTION_REFUSE_BAD_USERNAME**
MQTT connection refused reason: Wrong user

**MQTT_CONNECTION_REFUSE_NOT_AUTHORIZED**
MQTT connection refused reason: Wrong username or password

```c
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**

```c
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`
- **MQTT_TRANSPORT_OVER_WS**
  MQTT over Websocket, using scheme: `ws`
- **MQTT_TRANSPORT_OVER_WSS**
  MQTT over Websocket Secure, using scheme: `wss`

```c
enum esp_mqtt_protocol_ver_t
MQTT protocol version used for connection
```
Values:

- **MQTT_PROTOCOL_UNDEFINED** = 0
- **MQTT_PROTOCOL_V_3_1**
- **MQTT_PROTOCOL_V_3_1_1**

### 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](#).
Chapter 2. API Reference

Tree structure for ESP-TLS component

```
├── esp_tls.c
├── esp_tls.h
├── esp_tls_mbedtls.c
├── esp_tls_wolfssl.c
└── private_include
    ├── esp_tls_mbedtls.h
    └── esp_tls_wolfssl.h
```

The ESP-TLS component has a file esp-tls/esp_tls.h which contain the public API headers for the component. Internally ESP-TLS component uses one of the two SSL/TLS Libraries between mbedtls and wolfssl for its operation. API specific to mbedtls are present in esp-tls/private_include/esp_tls_mbedtls.h and API specific to wolfssl are present in esp-tls/private_include/esp_tls_wolfssl.h.

TLS Server verification

The ESP-TLS provides multiple options for TLS server verification on the client side. The ESP-TLS client can verify the server by validating the peer's server certificate or with the help of pre-shared keys. The user should select only one of the following options in the esp_tls_cfg_t structure for TLS server verification. If no option is selected then client will return a fatal error by default at the time of the TLS connection setup.

- **cacert_buf** and **cacert_bytes**: The CA certificate can be provided in a buffer to the esp_tls_cfg_t structure. The ESP-TLS will use the CA certificate present in the buffer to verify the server. The following variables in esp_tls_cfg_t structure must be set.
  - cacert_buf: pointer to the buffer which contains the CA cert.
  - cacert_bytes: size of the CA certificate in bytes.
- **use_global_ca_store**: The global_ca_store can be initialized and set at once. Then it can be used to verify the server for all the ESP-TLS connections which have set use_global_ca_store = true in their respective esp_tls_cfg_t structure. See API Reference section below on information regarding different API used for initializing and setting up the global_ca_store.
- **crt_bundle_attach**: The ESP x509 Certificate Bundle API provides an easy way to include a bundle of custom x509 root certificates for TLS server verification. More details can be found at ESP x509 Certificate Bundle
- **psk_hint_key**: To use pre-shared keys for server verification, CONFIG_ESP_TLS_PSK_VERIFICATION should be enabled in the ESP-TLS menuconfig. Then the pointer to PSK hint and key should be provided to the esp_tls_cfg_t structure. The ESP-TLS will use the PSK for server verification only when no other option regarding the server verification is selected.
- **skip server verification**: This is an insecure option provided in the ESP-TLS for testing purpose. The option can be set by enabling CONFIG_ESP_TLS_INSECURE and CONFIG_ESP_TLS_SKIP_SERVER_CERT_VERIFY in the ESP-TLS menuconfig. When this option is enabled the ESP-TLS will skip server verification by default when no other options for server verification are selected in the esp_tls_cfg_t structure. WARNING: Enabling this option comes with a potential risk of establishing a TLS connection with a server which has a fake identity, provided that the server certificate is not provided either through API or other mechanism like ca_store etc.

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:

```
(First change directory (cd) to your project directory)
mkdir components
cd components
git clone https://github.com/espressif/esp-wolfssl.git
```

2) Add wolfssl as an extra component in your project.
   • Download wolfssl with:

```
git clone https://github.com/espressif/esp-wolfssl.git
```

   • Include esp-wolfssl in ESP-IDF with setting EXTRA_COMPONENT_DIRS in CMakeLists.txt of your project as done in wolfssl/examples. For reference see Optional Project variables in build-system.

After above steps, you will have option to choose wolfssl as underlying SSL/TLS library in configuration menu of your project as follows:

```
idf.py menuconfig -> ESP-TLS -> choose SSL/TLS Library -> mbedtls/wolfssl
```

Comparison between mbedtls and wolfssl

The following table shows a typical comparison between wolfssl and mbedtls when protocols/https_request example (which has server authentication) was run with both SSL/TLS libraries and with all respective configurations set to default. (mbedtls IN_CONTENT length and OUT_CONTENT length were set to 16384 bytes and 4096 bytes respectively)

<table>
<thead>
<tr>
<th>Property</th>
<th>Wolfssl</th>
<th>Mbedtls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Heap Consumed</td>
<td>~19 Kb</td>
<td>~37 Kb</td>
</tr>
<tr>
<td>Task Stack Used</td>
<td>~2.2 Kb</td>
<td>~3.6 Kb</td>
</tr>
<tr>
<td>Bin size</td>
<td>~858 Kb</td>
<td>~736 Kb</td>
</tr>
</tbody>
</table>

Note: These values are subject to change with change in configuration options and version of respective libraries.

ATECC608A (Secure Element) with ESP-TLS

ESP-TLS provides support for using ATECC608A cryptoauth chip with ESP32-WROOM-32SE. Use of ATECC608A is supported only when ESP-TLS is used with mbedTLS as its underlying SSL/TLS stack. ESP-TLS uses mbedts as its underlying TLS/SSL stack by default unless changed manually.

Note: ATECC608A chip on ESP32-WROOM-32SE must be already configured and provisioned, for details refer esp_cryptoauth_utility

To enable the secure element support, and use it in you project for TLS connection, you will have to follow below steps

1) Add esp-cryptoauthlib in your project, for details please refer esp-cryptoauthlib with ESP_IDF
2) Enable following menuconfig option:

```
menuconfig->Component config->ESP-TLS->Use Secure Element (ATECC608A) with ESP-TLS
```
3) Select type of ATECC608A chip with following option:

```
menuconfig->Component config->esp-cryptoauthlib->Choose Type of ATECC608A chip
```

To know more about different types of ATECC608A chips and how to obtain type of ATECC608A connected to your ESP module please visit ATECC608A chip type

4) Enable use of ATECC608A in ESP-TLS by providing following config option in `esp_tls_cfg_t`

```
esp_tls_cfg_t cfg = {
    /* other configurations options */
    .use_secure_element = true,
};
```

### API Reference

**Header File**

- `components/esp-tls/esp_tls.h`

**Functions**

```c
esp_tls_t *esp_tls_init (void)
```

Create TLS connection.

**Return**

- Pointer to esp-tls as esp-tls handle if successfully initialized, NULL if allocation error

```c
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.

**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.

```c
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.

**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.
- 1 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, const 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 occurred or an action must be taken by the calling process.
- ESP_TLS_ERR_SSL_WANT_READ/ ESP_TLS_ERR_SSL_WANT_WRITE. if the handshake is incomplete and waiting for data to be available for reading. In this case this functions needs to be called again when the underlying transport is ready for operation.

**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 occurred 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.

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_pembuf: 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
• 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

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

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.

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] hostlen: Length of hostname.
• [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
const uint8_t *key
key in PSK authentication mode in binary format

const size_t key_size
length of the Key

const char *hint
hint in PSK authentication mode in string format
```

```c
struct tls_keep_alive_cfg
esp-tls client session ticket ctx
Keep alive parameters structure
```

**Public Members**

```c
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
```

```c
struct esp_tls_cfg
ESP-TLS configuration parameters.
```

**Note**

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**

```c
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 clientcert_bytes
Size of client certificate pointed to by clientcert_pem_buf (including NULL-terminator in case of PEM format)

unsigned int clientcert_pem_bytes
Size of client certificate legacy name

const unsigned char *clientkey_buf
Client key in a buffer Format may be PEM or DER, depending on mbedtls-support This buffer should be NULL terminated in case of PEM

const unsigned char *clientkey_pem_buf
Client key legacy name

unsigned int clientkey_bytes
Size of client key pointed to by clientkey_pem_buf (including NULL-terminator in case of PEM format)

unsigned int clientkey_pem_bytes
Size of client key legacy name

const unsigned char *clientkey_password
Client key decryption password string

unsigned int clientkey_password_len
String length of the password pointed to by clientkey_password

bool non_block
Configure non-blocking mode. If set to true the underneath socket will be configured in non blocking mode after tls session is established

bool use_secure_element
Enable this option to use secure element or atecc608a chip (Integrated with ESP32-WROOM-32SE)

int timeout_ms
Network timeout in milliseconds

bool use_global_ca_store
Use a global ca_store for all the connections in which this bool is set.

const char *common_name
If non-NULL, server certificate CN must match this name. If NULL, server certificate CN must match hostname.
bool skip_common_name
Skip any validation of server certificate CN field

tls_keep_alive_cfg_t *keep_alive_cfg
Enable TCP keep-alive timeout for SSL connection

const psk_hint_key_t *psk_hint_key
Pointer to PSK hint and key. If not NULL (and certificates are NULL) then PSK authentication is enabled
with configured setup. Important note: the pointer must be valid for connection

esp_err_t (*crt_bundle_attach)(void *conf)
Function pointer to esp_crt_bundle_attach. Enables the use of certification bundle for server verification,
must be enabled in menuconfig

void *ds_data
Pointer for digital signature peripheral context

bool is_plain_tcp
Use non-TLS connection: When set to true, the esp-tls uses plain TCP transport rather than
TLS/SSL connection. Note, that it is possible to connect using a plain tcp transport directly with
esp_tls_plain_tcp_connect() API

struct ifreq *if_name
The name of interface for data to go through. Use the default interface without setting

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.
**Chapter 2. API Reference**

**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**
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 preshared 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:
Chapter 2. API Reference

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:
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:
none

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)
Chapter 2. API Reference

Arguments:

none

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();
    ...
}
```

### Chapter 2. SSL Context Function

#### 2.1 `SSL_CTX* SSL_CTX_new(const SSL_METHOD * method)`

**Arguments:**

- `method` - the SSL context method pointer

**Return:**

- SSL context pointer

**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 pointer

**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:

tctx - SSL context point
meth - SSL method point

Return:

1 : OK
0 : failed

Description:

set the SSL context version

Example:

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:

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 * ss)

Arguments:

ssl - SSL point

Return:

none

Description:

free SSL

Example:

```c
void example(void)
{
    SSL *ssl;
    ...
    SSL_free(ssl);
}
```

3.3 int SSL_do_handshake (SSL * ss)

Arguments:

ssl - SSL point

Return:

1 : OK
0 : failed, connect is close by remote
-1 : a error catch

Description:

perform the SSL handshake

Example:
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);
}
```
Chapter 2. API Reference

(continued from previous page)

```c
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)
{
    SSL *ssl;
    int ret;
    
    ret = SSL_shutdown(ssl);
}
```

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:
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:
Chapter 2. API Reference

3.10

ssl - SSL point

Return:

SSL context

Description:

get SSL context of the SSL

Example:

```c
void example(void)
{
    SSL *ssl;
    SSL_CTX *ctx;
    ...
    ctx = SSL_get_SSL_CTX(ssl);
}
```

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:
### 3.13 `const SSL_METHOD* SSL_get_ssl_method (SSL * ssl)`

**Arguments:**

- `ssl` - SSL point

**Return:**

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:**

- `ssl` - SSL point
- `meth` - SSL method point

**Return:**

- `1` : OK
- `0` : failed

**Description:**

Set the SSL method

**Example:**

```c
void example(void)
{
    int ret;
    SSL *ssl;
    const SSL_METHOD *method;
    ... ...
}
```

(continues on next page)
3.15 int SSL_pending (const SSL * ssl)

Arguments:

ssl - SSL point

Return:

data bytes

Description:

get received data bytes

Example:

```c
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:

```c
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:
Chapter 2. API Reference

3.18 int SSL_get_rfd (const SSL * ssl)

Arguments:

ssl - SSL point

Return:

>= 0 : socket id
< 0 : a error catch

Description:

get the read only socket of the SSL

Example:

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 : a error catch

Description:

get the write only socket of the SSL

Example:
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:

1 : OK
0 : failed

Description:

set socket to SSL

Example:

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:

ssl - SSL point
fd - socket id

Return:

1 : OK
0 : failed

Description:

set read only socket to SSL

Example:

void example(void)
{
    int ret;
    SSL *ssl;
    int socket;
    ...
}  

(continues on next page)
... ...
ret = SSL_set_rfd(ssl, socket);
}

### 3.22 int SSL_set_wfd (SSL * ssl, int fd)

**Arguments:**

- ssl - SSL point
- fd - socket id

**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);
}
```

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:

```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)

Arguments:

ssl - SSL point

Return:

state string

Description:
get the state string

Example:

```c
void example(void)
{
    SSL *ssl;
    const char *str;
    ...
    str = SSL_state_string(ssl);
}
```

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:
Chapter 2. API Reference

```c
void example(void)
{
    SSL *ssl;
    char *str;
    ...
    str = SSL_state_string(ssl);
}
```

3.34 int SSL_get_error (const SSL * ssl, int ret_code)

Arguments:

<table>
<thead>
<tr>
<th>ssl</th>
<th>- SSL point</th>
</tr>
</thead>
<tbody>
<tr>
<td>ret_code</td>
<td>- SSL return code</td>
</tr>
</tbody>
</table>

Return:

SSL error number

Description:

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:

specifical statement

Description:

get the SSL specifical 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:

0 : false
1 : true

Description:

check if SSL want nothing

Example:

```c
void example(void)
{
    SSL *ssl;
    int ret;
    ...
    ret = SSL_want_nothing(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:

```c
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
Chapter 2. API Reference

Description:

check if SSL want to write

Example:

```c
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_CTX_add_client_CA(ctx, new);
}
```

4.4 X509* SSL_get_certificate (const SSL *ssl)

Arguments:

- ssl - SSL point

Return:

SSL certification point

Description:
get the SSL certification point

Example:
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:

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:
ctx - 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:

void example(void)
{
    int ret;
    SSL_CTX *ctx
    X509 *new;
    ...
}
4.7 int SSL_CTX_use_certificate_ASN1 (SSL_CTX * ctx, int len, const unsigned char * d)

Arguments:

ctx - SSL context point
len - certification length
d - data point

Return:

1 : OK
0 : failed

Description:

load the ASN1 certification into SSL context

Example:

```c
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:

cxt - SSL context point
pkey - private key object point

Return:

1 : OK
0 : failed

Description:

load the private key into the context object

Example:

```c
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:

```c
void example(void)
{
    int ret;
    int pk;
    SSL_CTX * ctx;
    const unsigned char * buf;
    long len;

    ...

    ret = SSL_CTX_use_PrivateKey_ASN1(pk, ctx, buf, len);
}
```

4.10 int SSL_CTX_use_RSAPrivateKey_ASN1 (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 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(ctx, buf, len);
}
```

4.11 int SSL_use_certificate_ASN1 (SSL * ssl, int len, const unsigned char * d)
Chapter 2. API Reference

Arguments:

- ssl - SSL point
- len - data bytes
- d - data point

Return:

- 1 : OK
- 0 : failed

Description:

Load certification into the SSL

Example:

```c
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:

```c
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](https://example.com/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_ENABLE_HTTPS` (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)
**API Reference**

- `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

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 invokes 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

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

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

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


**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

**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

**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

**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

**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

**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.
Chapter 2. API Reference

Return
• ESP_OK
• ESP_ERR_INVALID_ARG

Parameters
• [in] client: The esp_http_client handle
• [in] password: The password value

```
esp_err_t esp_http_client_set_auth_type(esp_http_client_handle_t client, esp_http_client_auth_type_t auth_type)
esp_http_client_set_auth_type
```
Set http request auth_type.

Return
• ESP_OK
• ESP_ERR_INVALID_ARG

Parameters
• [in] client: The esp_http_client handle
• [in] auth_type: The esp_http_client auth type

```
int esp_http_client_get_errno(esp_http_client_handle_t client)
get http client session errno.
```

Return
• (-1) if invalid argument
• errno

Parameters
• [in] client: The esp_http_client handle

```
esp_err_t esp_http_client_set_method(esp_http_client_handle_t client, esp_http_client_method_t method)
esp_http_client_set_method
```
Set http request method.

Return
• ESP_OK
• ESP_ERR_INVALID_ARG

Parameters
• [in] client: The esp_http_client handle
• [in] method: The method

```
esp_err_t esp_http_client_set_timeout_ms(esp_http_client_handle_t client, int timeout_ms)
esp_http_client_set_timeout_ms
```
Set http request timeout.

Return
• ESP_OK
• ESP_ERR_INVALID_ARG

Parameters
• [in] client: The esp_http_client handle
• [in] timeout_ms: The timeout value

```
esp_err_t esp_http_client_delete_header(esp_http_client_handle_t client, const char *key)
delete http request header.
```

Return
• ESP_OK
• ESP_FAIL

Parameters
• [in] client: The esp_http_client handle
• [in] key: The key

```
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.

Return
• ESP_OK
• ESP_FAIL
Parameters
• \texttt{[in]} \texttt{client}: The \texttt{esp\_http\_client} handle
• \texttt{[in]} \texttt{write\_len}: HTTP Content length need to write to the server

\texttt{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 \texttt{esp\_http\_client\_open()}

Return
• (-1) if any errors
• Length of data written

Parameters
• \texttt{[in]} \texttt{client}: The \texttt{esp\_http\_client} handle
• \texttt{buffer}: The buffer
• \texttt{[in]} \texttt{len}: This value must not be larger than the \texttt{write\_len} parameter provided to \texttt{esp\_http\_client\_open()}

\texttt{int64\_t esp\_http\_client\_fetch\_headers (esp\_http\_client\_handle\_t client)}

This function need to call after \texttt{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 \texttt{esp\_http\_client\_is\_chunked\_response})
• (-1: ESP\_FAIL) if any errors
• Download data length defined by content-length header

Parameters
• \texttt{[in]} \texttt{client}: The \texttt{esp\_http\_client} handle

\texttt{bool esp\_http\_client\_is\_chunked\_response (esp\_http\_client\_handle\_t client)}

Check response data is chunked.

Return true or false

Parameters
• \texttt{[in]} \texttt{client}: The \texttt{esp\_http\_client} handle

\texttt{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
• \texttt{[in]} \texttt{client}: The \texttt{esp\_http\_client} handle
• \texttt{buffer}: The buffer
• \texttt{[in]} \texttt{len}: The length

\texttt{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 \texttt{esp\_http\_client\_perform}

Return Status code

Parameters
• \texttt{[in]} \texttt{client}: The \texttt{esp\_http\_client} handle

\texttt{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 \texttt{esp\_http\_client\_perform}

Return
• (-1) Chunked transfer
• Content-Length value as bytes

Parameters
• \texttt{[in]} \texttt{client}: The \texttt{esp\_http\_client} handle

\texttt{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
• ESP_OK
• ESP_FAIL

Parameters
• [in] client: The esp_http_client handle

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 preferable 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**

```c
struct esp_http_client_event

HTTP Client events data.
```

**Public Members**

```c
esp_http_client_event_id_t event_id

event_id, to know the cause of the event
```

```c
esp_http_client_handle_t client

esp_http_client_handle_t context
```

```c
void *data

data of the event
```

```c
int data_len

data length of data
```

```c
void *user_data

user_data context, from esp_http_client_config_t user_data
```
Chapter 2. API Reference

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

Submit Document Feedback
Chapter 2. API Reference

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

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

denum 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. 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

/* 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;
}

(continues on next page)
/* Our URI handler function to be called during POST /uri request */
esp_err_t post_handler(httpd_req_t *req)
{
    /* Destination buffer for content of HTTP POST request. 
    * httpd_req_recv() accepts char* only, but content could 
    * as well be any binary data (needs type casting). 
    * In case of string data, null termination will be absent, and 
    * content length would give length of string */
    char content[100];

    /* Truncate if content length larger than the buffer */
    size_t recv_size = MIN(req->content_len, sizeof(content));

    int ret = httpd_req_recv(req, content, recv_size);
    if (ret <= 0) {/* 0 return value indicates connection closed */
        /* Check if timeout occurred */
        if (ret == HTTPD_SOCK_ERR_TIMEOUT) {
            /* In case of timeout one can choose to retry calling 
            * httpd_req_recv(), but to keep it simple, here we 
            * respond with an HTTP 408 (Request Timeout) error */
            httpd_resp_send_408(req);
        }
        /* In case of error, returning ESP_FAIL will 
        * ensure that the underlying socket is closed */
        return ESP_FAIL;
    }

    /* Send a simple response */
    const char resp[] = "URI POST Response";
    httpd_resp_send(req, resp, HTTPD_RESP_USE_STRLEN);
    return ESP_OK;
}

/* URI handler structure for GET /uri */
httpd_uri_t uri_get = {
    .uri = "/uri",
    .method = HTTP_GET,
    .handler = get_handler,
    .user_ctx = NULL
};

/* URI handler structure for POST /uri */
httpd_uri_t uri_post = {
    .uri = "/uri",
    .method = HTTP_POST,
    .handler = post_handler,
    .user_ctx = NULL
};

/* Function for starting the webserver */
httpd_handle_t start_webserver(void)
{
    /* Generate default configuration */
    httpd_config_t config = HTTPD_DEFAULT_CONFIG();

    /* Empty handle to esp_http_server */
    httpd_handle_t server = NULL;

    /* Start the httpd server */
    if (httpd_start(&server, &config) == ESP_OK) {
        /* Register URI handlers */

    (continues on next page)
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

/* 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

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;
}

// URI handler structure
httpd_uri_t my_uri {
    .uri = "/my_uri/path/xyz",
    .method = HTTPD_GET,
    .handler = my_uri_handler,
    .user_ctx = NULL
};

// Register handler
if (httpd_register_uri_handler(server_handle, &my_uri) != ESP_OK) {
    // 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
**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

**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

**esp_err_t** `httpd_sess_set_recv_override` (**httpd_handle_t** `hd`, **int** `sockfd`, **httpd_recv_func_t** `recv_func`)

Override web server’s receive function (by session FD)

This function overrides the web server’s receive function. This same function is used to read HTTP request packets.

**Note** This API is supposed to be called either from the context of
- an http session APIs where sockfd is a valid parameter
- a URI handler where sockfd is obtained using httpd_req_to_sockfd()

**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

**esp_err_t** `httpd_sess_set_send_override` (**httpd_handle_t** `hd`, **int** `sockfd`, **httpd_send_func_t** `send_func`)

Override web server’s send function (by session FD)

This function overrides the web server’s send function. This same function is used to send out any response to any HTTP request.

**Note** This API is supposed to be called either from the context of
- an http session APIs where sockfd is a valid parameter
- a URI handler where sockfd is obtained using httpd_req_to_sockfd()

**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

**esp_err_t** `httpd_sess_set_pending_override` (**httpd_handle_t** `hd`, **int** `sockfd`, **httpd_pending_func_t** `pending_func`)

Override web server’s pending function (by session FD)
This function overrides the web server’s pending function. This function is used to test for pending bytes in a socket.

**Note** This API is supposed to be called either from the context of
- an http session APIs where sockfd is a valid parameter
- a URI handler where sockfd is obtained using httpd_req_to_sockfd()

**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

```c
int httpd_req_to_sockfd (httpd_req_t *r)
```

Get the Socket Descriptor from the HTTP request.

This API will return the socket descriptor of the session for which URI handler was executed on reception of HTTP request. This is useful when user wants to call functions that require session socket fd, from within a URI handler, ie. : 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 it’s value.

**Note**
- This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
- Once httpd_resp_send() API is called all request headers are purged, so request headers need be copied into separate buffers if they are required later.

**Return**
Chapter 2. API Reference

- 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.
- 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 “val”

```c
size_t httpd_req_get_url_query_len(httpd_req_t *r)
```

Get Querystring 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’ (e.g. 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

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 (URL encoded 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.

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 “val”

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 “val”. This variable will contain cookie length if ESP_OK is returned and required buffer length incase ESP_ERR_HTTPD_RESULT_TRUNC is returned.

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
Chapter 2. API Reference

- [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: `httpdRespSetStatus()` - for setting the HTTP status string, `httpdRespSetType()` - for setting the Content Type, `httpdRespSetHdr()` - 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()

```c
esp_err_t httpd_resp_send_chunk(httpd_req_t *r, const char *buf, ssize_t buf_len)
```

API to send one HTTP chunk.

This API will send the data as an HTTP response to the request. This API will use chunked-encoding and send the response in the form of chunks. If you have the entire response contained in a single buffer, please use `httpdRespSend()` 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: `httpdRespSetStatus()` - for setting the HTTP status string, `httpdRespSetType()` - for setting the Content Type, `httpdRespSetHdr()` - for appending any additional field value entries in the response header.

**Note**
- This API is supposed to be called only from the context of a URI handler where `httpd_req_t*` request pointer is valid.
- When you are finished sending all your chunks, you must call this function with buf_len as 0.
- Once this API is called, all request headers are purged, so request headers need be copied into separate buffers if they are required later.

**Return**
- ESP_OK: On successfully sending the response packet chunk
- ESP_ERR_INVALID_ARG: Null request pointer
- ESP_ERR_HTTPD_RESP_HDR: Essential headers are too large for internal buffer
- ESP_ERR_HTTPD_RESP_SEND: Error in raw send
- ESP_ERR_HTTPD_INVALID_REQ: Invalid request pointer

**Parameters**
- [in] r: The request being responded to
- [in] buf: Pointer to a buffer that stores the data
• [in] buf_len: Length of the buffer, HTTPD_RESP_USE_STRLEN to use strlen()

```c
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 `http_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

```c
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)

```c
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

```c
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.
Chapter 2. API Reference

• 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.
• 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()
Chapter 2. API Reference

- 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

*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

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

*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

**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
    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

```c
esp_err_t httpd_stop(httpd_handle_t handle)
```

 Stops the web server.

Deallocates memory/resources used by an HTTP server instance and deletes it. Once deleted the handle can no longer be used for accessing the instance.

Example usage:

```c
// Function for stopping the webserver
void stop_webserver(httpd_handle_t server)
{
    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.

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 HTTDP 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 HTTDP 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.

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
  • [in] handle: Handle to server returned by httpd_start
  • [in] sockfd: The socket descriptor of the session to be closed

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 sock-
ets/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
  • [in] handle: Handle to server returned by httpd_start
  • [in] sockfd: The socket descriptor of the session for which LRU counter is to be updated

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
  • [in] handle: Handle to server returned by httpd_start
  • [inout] fds: In: Size of provided client_fds array Out: Number of valid client fds returned in
    client_fds,
  • [out] client_fds: 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**

- **unsigned** `task_priority`  
  Priority of FreeRTOS task which runs the server

- **size_t** `stack_size`  
  The maximum stack size allowed for the server task

- **BaseType_t** `core_id`  
  The core the HTTP server task will run on

- **uint16_t** `server_port`  
  TCP Port number for receiving and transmitting HTTP traffic

- **uint16_t** `ctrl_port`  
  UDP Port number for asynchronously exchanging control signals between various components of the server

- **uint16_t** `max_open_sockets`  
  Max number of sockets/clients connected at any time

- **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.

  ```c
  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.

  ```c
  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
Chapter 2. API Reference

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()
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()
Chapter 2. API Reference

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 HTTPD's 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
- 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 HTTPD's 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
Chapter 2. API Reference

- [in] error: Error type

```c
typedef void *httpd_handle_t
```

HTTP Server Instance Handle.
Every instance of the server will have a unique handle.

```c
typedef enum http_method httpd_method_t
```

HTTP Method Type wrapper over “enum http_method” available in “http_parser” library.

```c
typedef void(*httpd_free_ctx_fn_t)(void *ctx)
```

Prototype for freeing context data (if any)

**Parameters**
- [in] ctx: object to free

```c
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
enum 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`. 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**

```c
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

```c
void httpd_ssl_stop(httpd_handle_t handle)
```

Stop the server. Blocks until the server is shut down.

**Parameters**

- [in] handle:

**Structures**

```c
struct esp_https_server_user_cb_arg
```

Callback data struct, contains the ESP-TLS connection handle.

```c
struct httpd_ssl_config
```

HTTPS server config struct

Please use `HTTPD_SSL_CONFIG_DEFAULT()` to initialize it.

**Public Members**

```c
httpd_config_t httpd
```

Underlying HTTPD server config

Parameters like task stack size and priority can be adjusted here.

```c
const uint8_t *cacert_pem
```

CA certificate (here it is treated as server cert) Todo: Fix this change in release/v5.0 as it would be a breaking change i.e. Rename the nomenclature of variables holding different certs in `https_server` component as well as example 1)The cacert variable should hold the CA which is used to authenticate clients (should inherit current role of `client_verify_cert_pem` var) 2)There should be another variable `servercert` which should hold servers own certificate (should inherit current role of cacert var)

```c
size_t cacert_len
```

CA certificate byte length

```c
const uint8_t *client_verify_cert_pem
```

Client verify authority certificate (CA used to sign clients, or client cert itself
size_t client_verify_cert_len
   Client verify authority cert len

const uint8_t *prvkey_pem
   Private key

size_t prvkey_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 tlts session tickets

esp_https_server_user_cb *user_cb
   User callback for esp_https_server

Macros
HTTPD_SSL_CONFIG_DEFAULT()
   Default config struct init

   (http_server default config had to be copied for customization)

   Notes:

   • port is set when starting the server, according to ‘transport_mode’
   • one socket uses ~ 40kB RAM with SSL, we reduce the default socket count to 4
   • SSL sockets are usually long-lived, closing LRU prevents pool exhaustion DOS
   • Stack size may need adjustments depending on the user application

Type Definitions
typedef struct esp_https_server_user_cb_arg esp_https_server_user_cb_arg_t
   Callback data struct, contains the ESP-TLS connection handle.

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

typedef struct httpd_ssl_config httpd_ssl_config_t

Enumerations
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 utility ping is implemented based on the ICMP packets with the type field value of 0, also called Echo Reply.

During a ping session, the source host firstly sends out an ICMP echo request packet and wait for an ICMP echo reply with specific times. In this way, it also measures the round-trip time for the messages. After receiving a valid ICMP echo reply, the source host will generate statistics about the IP link layer (e.g. packet loss, elapsed time, etc).

It is common that IoT device needs to check whether a remote server is alive or not. The device should show the warnings to users when it got offline. It can be achieved by creating a ping session and sending/parsing ICMP echo packets periodically.

To make this internal procedure much easier for users, ESP-IDF provides some out-of-box APIs.

Create a new ping session  To create a ping session, you need to fill in the esp_ping_config_t configuration structure firstly, specifying target IP address, interval times, and etc. Optionally, you can also register some callback functions with the esp_ping_callbacks_t structure.

Example method to create a new ping session and register callbacks:

```c
static void test_on_ping_success(esp_ping_handle_t hdl, void *args)
{
    // optionally, get callback arguments
    // const char* str = (const char*) args;
    // printf("%s\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));

    printf("%d packets transmitted, %d received, %d lost, round-trip = %d ms\n",
            transmitted, received, (transmitted-received), total_time_ms);
}
```

(continues on next page)
void initialize_ping()
{
    /* convert URL to IP address */
    ip_addr_t target_addr;
    struct addrinfo hint;
    struct addrinfo *res = NULL;
    memset(&hint, 0, sizeof(hint));
    memset(&target_addr, 0, sizeof(target_addr));
    getaddrinfo("www.espressif.com", NULL, &hint, &res);
    struct in_addr addr4 = ((struct sockaddr_in *) res->ai_addr)->sin_addr;
    inet_addr_to_ip4addr(ip_2_ip4(&target_addr), &addr4);
    freeaddrinfo(res);

    esp_ping_config_t ping_config = ESP_PING_DEFAULT_CONFIG();
    ping_config.target_addr = target_addr; // target IP address
    ping_config.count = ESP_PING_COUNT_INFINITE; // ping in infinite mode, esp_
    ping_stop can stop it

    /* set callback functions */
    esp_ping_callbacks_t cbs;
    cbs.on_ping_success = test_on_ping_success;
    cbs.on_ping_timeout = test_on_ping_timeout;
    cbs.on_ping_end = test_on_ping_end;
    cbs.cb_args = "foo"; // arguments that will feed to all callback functions, _
    can be NULL
    cbs.cb_args = eth_event_group;

    esp_ping_handle_t ping;
    esp_ping_new_session(&ping_config, &cbs, &ping);
}

Start and Stop ping session You can start and stop ping session with the handle returned by
esp_ping_new_session. Note that, the ping session won’t start automatically after creation. If the ping
session is stopped, and restart again, the sequence number in ICMP packets will recount from zero again.

Delete a ping session If a ping session won’t be used any more, you can delete it with
esp_ping_delete_session. Please make sure the ping session is in stop state (i.e. you have called
esp_ping_stop before or the ping session has finished all the procedures) when you call this function.

Get runtime statistics As the example code above, you can call esp_ping_get_profile to get different
runtime statistics of ping session in the callback function.

Application Example

ICMP echo example: protocols/icmp_echo

API Reference

Header File
Chapter 2. API Reference

- 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

**Parameters**

- `hdl`: handle of ping session

```c
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

```c
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

```c
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**

```c
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

`uint32_t interval_ms`
Milliseconds between each ping procedure

`uint32_t timeout_ms`
Timeout value (in milliseconds) of each ping procedure

`uint32_t data_size`
Size of the data next to ICMP packet header

`uint8_t tos`
Type of Service, a field specified in the IP header

`ip_addr_t target_addr`
Target IP address, either IPv4 or IPv6

`uint32_t task_stack_size`
Stack size of internal ping task

`uint32_t task_prio`
Priority of internal ping task

`uint32_t interface`
Netif index, interface=0 means NETIF_NO_INDEX

Macros

`ESP_PING_DEFAULT_CONFIG()`
Default ping configuration.

`ESP_PING_COUNT_INFINITE`
Set ping count to zero will ping target indefinitely

Type Definitions

`typedef void *esp_ping_handle_t`
Type of “ping” session handle.

Enumerations

`enum esp_ping_profile_t`
Profile of ping session.

`Values:`
Chapter 2. API Reference

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 = & (protocomm_ble_config_t) {
            .device_name = SERVICE_NAME,
            .service_uuid = {
                /* LSB <---------------------------------------
                   * ---------------------------------------> MSB */
                0x21,
                0xd5,
                0x3b,
                0x8d,
                0xbd,
                0x75,
                0x68,
                0x8a,
                0xb4,
                0x42,
                0xeb,
                0x31,
                0x4a,
                0x1e,
                0x98,
                0x3d
            }
        },
        .proto_sec = {
            .version = 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
    },
};
```

(continues on next page)
/* Start esp_local_ctrl service */
ESP_ERROR_CHECK(esp_local_ctrl_start(&config));

Similarly for HTTPS transport:

```
/* 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;

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) {
            /* Obtain the timer function from ctx */
            int32_t (*func_get_time)(void) = props[i].ctx;

            /* Use static variable for saving the value. */
            /* This is essential because the value has to be valid even after this function returns. */
            /* Alternative is to use dynamic allocation and set the free_fn field */
            static int32_t ts = func_get_time();
            prop_values[i].data = &ts;
        }
    }
    return ESP_OK;
}
```

Here is an example of set_prop_values() handler. Notice how we restrict from writing to read-only properties.

```c
static esp_err_t set_property_values(size_t props_count, const esp_local_ctrl_prop_t *props,
                                     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);
        }
    }
}
```

(continues on next page)
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
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 can be added is limited by configuration option max_properties

Return
• ESP_OK : Success
• ESP_FAIL : Failure

Parameters
• [in] prop: Property description structure

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

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

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
Chapter 2. API Reference

- [in] ep_name: Name of the endpoint
- [in] handler: Endpoint handler function
- [in] user_ctx: User data

Unions

union esp_local_ctrl_transport_config_t
#include <esp_local_ctrl.h>  Transport mode (BLE / HTTPD) configuration.

Public Members

esp_local_ctrl_transport_config_ble_t *ble
This is same as protocomm_ble_config_t. See protocomm_ble.h for available configuration parameters.

esp_local_ctrl_transport_config_httpd_t *httpd
This is same as httpd_ssl_config_t. See esp_https_server.h for available configuration parameters.

Structures

struct esp_local_ctrl_prop
Property description data structure, which is to be populated and passed to the esp_local_ctrl_add_property() function.

Once a property is added, its structure is available for read-only access inside get_prop_values() and set_prop_values() handlers.

Public Members

char *name
Unique name of property

uint32_t type
Type of property. This may be set to application defined enums

size_t size
Size of the property value, which:
- if zero, the property can have values of variable size
- if non-zero, the property can have values of fixed size only, therefore, checks are performed internally by esp_local_ctrl when setting the value of such a property

uint32_t flags
Flags set for this property. This could be a bit field. A flag may indicate property behavior, e.g. read-only / constant

void *ctx
Pointer to some context data relevant for this property. This will be available for use inside the get_prop_values and set_prop_values handlers as a part of this property structure. When set, this is valid throughout the lifetime of a property, till either the property is removed or the esp_local_ctrl service is stopped.

void (*ctx_free_fn)(void *ctx)
Function used by esp_local_ctrl to internally free the property context when esp_local_ctrl_remove_property() or esp_local_ctrl_stop() is called.

struct esp_local_ctrl_prop_val
Property value data structure. This gets passed to the get_prop_values() and set_prop_values() handlers for the purpose of retrieving or setting the present value of a property.
Public Members

```c
void *data
```
Pointer to memory holding property value

```c
size_t size
```
Size of property value

```c
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

```c
esp_err_t (*get_prop_values)(size_t props_count, const esp_local_ctrl_prop_t props[], esp_local_ctrl_prop_val_t prop_values[], void *usr_ctx)
```
Handler function to be implemented for retrieving current values of properties.

**Note** If any of the properties have fixed sizes, the size field of corresponding element in `prop_values` need to be set.

**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

```c
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

```c
void *usr_ctx
```
Context pointer to be passed to above handler functions upon invocation. This is different from the
property level context, as this is valid throughout the lifetime of the \texttt{esp\_local\_ctrl} service, and freed only when the service is stopped.

```c
void (*\texttt{usr\_ctx\_free\_fn})(\texttt{void *}usr\_ctx)
```

Pointer to function which will be internally invoked on \texttt{usr\_ctx} for freeing the context resources when \texttt{esp\_local\_ctrl\_stop()} is called.

```c
struct esp\_local\_ctrl\_proto\_sec\_cfg
```

Protocom security configs

**Public Members**

```c
\texttt{esp\_local\_ctrl\_proto\_sec\_cfg}\_t version
```

This sets protocom security version, sec0/sec1 or custom If custom, user must provide handle via \texttt{proto\_sec\_custom\_handle} below

```c
void *\texttt{custom\_handle}
```

Custom security handle if security is set custom via \texttt{proto\_sec} above This handle must follow proto comm\_security\_t signature

```c
void *\texttt{pop}
```

Proof of possession to be used for local control. Could be NULL.

```c
struct esp\_local\_ctrl\_config
```

Configuration structure to pass to \texttt{esp\_local\_ctrl\_start()}

**Public Members**

```c
const \texttt{esp\_local\_ctrl\_transport\_t} *\texttt{transport}
```

Transport layer over which service will be provided

```c
\texttt{esp\_local\_ctrl\_transport\_config\_t} transport\_config
```

Transport layer over which service will be provided

```c
\texttt{esp\_local\_ctrl\_proto\_sec\_cfg\_t} proto\_sec
```

Security version and POP

```c
\texttt{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
\texttt{ESP\_LOCAL\_CTRL\_TRANSPORT\_BLE}
\texttt{ESP\_LOCAL\_CTRL\_TRANSPORT\_HTTPD}
```

**Type Definitions**

```c
typedef struct \texttt{esp\_local\_ctrl\_prop} \texttt{esp\_local\_ctrl\_prop\_t}
```

Property description data structure, which is to be populated and passed to the \texttt{esp\_local\_ctrl\_add\_property()} function.

Once a property is added, its structure is available for read-only access inside \texttt{get\_prop\_values()} and \texttt{set\_prop\_values()} handlers.

```c
typedef struct \texttt{esp\_local\_ctrl\_prop\_val} \texttt{esp\_local\_ctrl\_prop\_val\_t}
```

Property value data structure. This gets passed to the \texttt{get\_prop\_values()} and \texttt{set\_prop\_values()} handlers for the purpose of retrieving or setting the present value of a property.

```c
typedef struct \texttt{esp\_local\_ctrl\_handlers} \texttt{esp\_local\_ctrl\_handlers\_t}
```

Handlers for receiving and responding to local control commands for getting and setting properties.
typedef struct esp_local_ctrl_transport **esp_local_ctrl_transport_t
Transport mode (BLE / HTTPD) over which the service will be provided.

This is forward declaration of a private structure, implemented internally by esp_local_ctrl.

typedef struct protocomm_ble_config **esp_local_ctrl_transport_config_ble_t
Configuration for transport mode BLE.

This is a forward declaration for protocomm_ble_config_t. To use this, application must set CONFIG_BT_BLUEDROID_ENABLED and include protocomm_ble.h.

typedef struct httpd_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 CONFIG_ESP_HTTPS_SERVER_ENABLE and include esp_https_server.h.

typedef enum esp_local_ctrl_proto_sec **esp_local_ctrl_proto_sec_t
Security types for esp_local_control.

typedef struct esp_local_ctrl_proto_sec_cfg **esp_local_ctrl_proto_sec_cfg_t
Protocom security configs

typedef struct esp_local_ctrl_config **esp_local_ctrl_config_t
Configuration structure to pass to esp_local_ctrl_start()

Enumerations
enum esp_local_ctrl_proto_sec
Security types for esp_local_control.
Values:
    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-esp32 will resolve to my-esp32.local
- default_instance: friendly name for your device, like Jhon’s ESP32 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);
    }
}
```
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 EESP32 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:

```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 Web Server");

    mdns_txt_item_t serviceTxtData[3] = {
        {"board","{esp32}"},
        {"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", 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!");
        return;
    }
    printf("Query Failed");
    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]);
        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 ]", 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;
    }
}
```

```c
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;
    }
} (continues on next page)
```
```c
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 esp32-mdns.local
    resolve_mdns_host("esp32-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

`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
Chapter 2. API Reference

```c
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

```c
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**
- `hostname`: Hostname to remove

```c
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

```c
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

```c
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_MULTIPLE_INSTANCE 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
```c
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_MULTIPLE_INSTANCE 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, local hostname 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

```c
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.

```c
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.

```c
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)

```c
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

`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

`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

`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
Chapter 2. API Reference

• 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

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)
• txt: array of TXT data (eg. {[ “var” ,” val” },{ “other” ,” 2” }])
• num_items: number of items in TXT data

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 (eg. {[ “var” ,” val” },{ “other” ,” 2” }])
• num_items: number of items in TXT data

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
Set/Add 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 add/update
- value: the new value of the key
- value_len: the length of the value

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
- value_len: the length of the value

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, local hostname 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.
Chapter 2. API Reference

- 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)

```c
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

```c
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. 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_*)
- timeout: time in milliseconds to wait for answers.
- max_results: maximum results to be collected
Chapter 2. API Reference

- 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

**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
Chapter 2. API Reference

- 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_ip4_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**

- `const char *key`
  item key name

- `const char *value`
  item value string

```c
struct mdns_ip_addr_s
```

mDNS query linked list IP item

**Public Members**

- `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
mdns_if_t tcpip_if
text 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

cchar *proto
service protocol

cchar *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
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)
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

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.

**Note:** It is assumed that the number of slaves and their register maps are known by the Modbus master before the start of stack.
Fig. 26: Modbus segment diagram

UID-1 (UNIT ID = slave address)  N - number of slaves in the network segment usually <= 32

Modbus Slave 1

Modbus Master

Modbus master device initiates transactions to read/write slave registers

Modbus Slave 2

UID-2

Network (RS485 for Modbus RTU and ASCII, Ethernet or WiFi connection for Modbus TCP)

UID-N

Modbus Slave N

Slave devices listen for communication from the master and simply respond as instructed
Chapter 2. API Reference

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.

![Modbus data model](image)

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):

```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:

![Device Application memory](image)
```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 8: Table 1 Modbus master Data Dictionary description

<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_name</td>
<td>Character Name</td>
<td>String description of the characteristic.</td>
</tr>
<tr>
<td>param_units</td>
<td>Character Units</td>
<td>Physical Units of the characteristic.</td>
</tr>
<tr>
<td>mb_slave_address</td>
<td>Modbus Slave Address</td>
<td>The short address of the device with correspond parameter UID.</td>
</tr>
<tr>
<td>mb_reg_type</td>
<td>Modbus 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>Modbus Register Start</td>
<td>Relative register address of the characteristic in the register area.</td>
</tr>
<tr>
<td>mb_size</td>
<td>Modbus Register Size</td>
<td>Length of characteristic in registers.</td>
</tr>
<tr>
<td>param_offset</td>
<td>Instance 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>paramopts</td>
<td>Parameter Options</td>
<td>Limits, options of characteristic used during processing of alarm in user application (optional)</td>
</tr>
<tr>
<td>access</td>
<td>Parameter 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>
</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.

Table 9: Table 2 Example Register mapping table of Modbus slave

<table>
<thead>
<tr>
<th>CID</th>
<th>RegUL</th>
<th>Type</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>30000</td>
<td>MAX_UINT</td>
<td>32</td>
<td>Serial number of device (4 bytes) read-only</td>
</tr>
<tr>
<td>1</td>
<td>30002</td>
<td>MAX_UINT</td>
<td>16</td>
<td>Software version (4 bytes) read-only</td>
</tr>
<tr>
<td>2</td>
<td>40000</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>

```c
// Enumeration of modbus slave addresses accessed by master device
enum {
    MB_DEVICE_ADDR1 = 1,
    MB_DEVICE_ADDR2,
    MB_SLAVE_COUNT
};
```

(continues on next page)
// 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
    // 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_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_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("--"), MB_DEVICE_ADDR2, MB_PARAM_INPUT, 0, 2,
        0, PARAM_TYPE_U32, 4, OPTS( 0, 0, 0 ), PAR_PERMS_READ_WRITE_TRIGGER },
    { CID_SW_VER2, STR("Software_version_2"), STR("--"), MB_DEVICE_ADDR2, MB_PARAM_INPUT, 2, 1,
        0, PARAM_TYPE_U16, 2, OPTS( 0, 0, 0 ), PAR_PERMS_READ_WRITE_TRIGGER },
    { CID_TEMP_DATA_2, STR("Temperature_2"), STR("C"), MB_DEVICE_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
uint16_t num_device_parameters = (sizeof(device_parameters) / sizeof(device_parameters[0]));

During initialization of the Modbus stack, a pointer to the Data Dictionary (called descriptor) must be provided as the parameter of the function below.

mbc_master_set_descriptor(): Initialization of master descriptor.

ESP_ERROR_CHECK(mbc_master_set_descriptor(&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.
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));
```

**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) {
    // Error handling...
}
```
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 {
    ESP_LOGE(TAG, "Could not get information for characteristic %d.", cid);
}
```

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
uint8_t 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).", (uint32_t*)temp_data, &type);
    ESP_LOGE(TAG, "Set parameter data successfully.");
    (char*)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();
ESP_ERROR_CHECK(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>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>start</td>
<td>Zero based register relative offset for defined register area. Example: register address = 40002 ( 4x</td>
</tr>
<tr>
<td></td>
<td>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
```

(continues on next page)
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).

```c
mbc_slave_setup()
```

The function is used to setup communication parameters of the Modbus stack.

Example initialization of Modbus TCP communication:

```c
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
    .address_to_bind, NULL = bind to any client
    .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:

```c
#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: Table 4 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 time stamp 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_RATE_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,
            ESP_ERROR_CHECK(mbc_slave_setup((void*)comm_info));
```

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(continued from previous page)

```c
(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.

```c
mbc_slave_destroy()
```c
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:

```c
E (1692332) MB_CONTROLLER_MASTER: mbc_master_get_parameter(111): SERIAL master get_--parameter failure error=(0x107) (ESP_ERR_TIMEOUT).
```
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>0x10</td>
<td>ESP_ERR_NOT_SUPPORTED - Invalid register request - slave returned an exception because the requested register is not supported.</td>
<td>Refer to slave register map. Check the master data dictionary for correctness.</td>
</tr>
<tr>
<td>0x10</td>
<td>ESP_ERR_TIMEOUT - Slave response timeout - Modbus slave did not send response during configured slave response timeout.</td>
<td>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>0x10</td>
<td>ESP_ERR_INVALID_RESPONSE - 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.</td>
<td>Check the physical connection then refer to register map of your slave to configure the master data dictionary properly.</td>
</tr>
<tr>
<td>0x10</td>
<td>ESP_ERR_INVALID_STATE - Critical failure or FSM sequence failure or master FSM is busy processing previous request.</td>
<td>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_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

**MB_PARAM_HOLDING** = 0x00
Modbus Holding register.

**MB_PARAM_INPUT**
Modbus Input register.

**MB_PARAM_COIL**
Modbus Coils.

**MB_PARAM_DISCRETE**
Modbus Discrete bits.

**MB_PARAM_COUNT**

**MB_PARAM_UNKNOWN** = 0xFF

```c
enum mb_mode_type_t
Modbus serial transmission modes (RTU/ASCII).
```

**Values:**

- **MB_MODE_RTU**
  RTU transmission mode.

- **MB_MODE_ASCII**
  ASCII transmission mode.

- **MB_MODE_TCP**
  TCP communication mode.

- **MB_MODE_UDP**
  UDP communication mode.

```c
enum mb_tcp_addr_type_t
Modbus TCP type of address.
```

**Values:**

- **MB_IPV4** = 0
  TCP IPV4 addressing

- **MB_IPV6** = 1
  TCP IPV6 addressing

**Header File**

- components/freemodbus/common/include/esp_modbus_master.h

**Functions**

```c
esp_err_t mbc_master_init_tcp(void **handler)
```
Initialize Modbus 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

```c
esp_err_t mbc_master_init(mb_port_type_t port_type, void **handler)
```
Initialize Modbus Master controller and stack for Serial port.

**Return**

- ESP_OK Success
- ESP_ERR_NO_MEM Parameter error
- ESP_ERR_NOT_SUPPORTED Port type not supported

Submit Document Feedback
• 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

desc p i 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)

desc p i 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
- [in] param_info: pointer to pointer of characteristic data.

```c
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.

```c
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
```

Modbus parameter options for description table.

---

*Espressif Systems*
Chapter 2. API Reference

Public Members

```c
int opt1
    Parameter option 1
int opt2
    Parameter option 2
int opt3
    Parameter option 3
```

### Structures

```c
tstruct mb_parameter_opt_t::[anonymous] [anonymous]
```

```c
int min
    Parameter minimum value
int max
    Parameter maximum value
int step
    Step of parameter change tracking
```

```c
tstruct mb_parameter_opt_t::[anonymous] [anonymous]
```

### Structures

```c
tstruct 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
```

```c
const char *param_key
    The key (name) of the parameter
```

```c
const char *param_units
    The physical units of the parameter
```

```c
uint8_t mb_slave_addr
    Slave address of device in the Modbus segment
```

```c
mb_param_type_t mb_param_type
    Type of modbus parameter
```

```c
uint16_t mb_reg_start
    This is the Modbus register address. This is the 0 based value.
```

```c
uint16_t mb_size
    Size of mb parameter in registers
```

```c
uint16_t param_offset
    Parameter name (OFFSET in the parameter structure)
```

```c
mb_descr_type_t param_type
    Float, U8, U16, U32, ASCII, etc.
```

```c
mb_descr_size_t param_size
    Number of bytes in the parameter.
```

```c
mb_parameter_opt_t param_opts
    Parameter options used to check limits and etc.
```

```c
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

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
    PARAM_MAX_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.
\textbf{Return}

- ESP\_OK: Success
- ESP\_ERR\_INVALID\_ARG: Modbus stack start error

\texttt{esp\_err\_t mbc\_slave\_setup (void *\textit{comm\_info})}
Set Modbus communication parameters for the controller.

\textbf{Return}

- ESP\_OK: Success
- ESP\_ERR\_INVALID\_ARG: Incorrect parameter data

\textbf{Parameters}

- \textit{comm\_info}: Communication parameters structure.

\texttt{mb\_event\_group\_t mbc\_slave\_check\_event (mb\_event\_group\_t \textit{group})}
Wait for specific event on parameter change.

\textbf{Return}

- mb\_event\_group\_t: Event bits triggered

\textbf{Parameters}

- \textit{group}: Group event bit mask to wait for change

\texttt{esp\_err\_t mbc\_slave\_get\_param\_info (mb\_param\_info\_t *\textit{reg\_info}, uint32\_t \textit{timeout})}
Get parameter information.

\textbf{Return}

- ESP\_OK: Success
- ESP\_ERR\_TIMEOUT: Cannot get data from parameter queue or queue overflow

\textbf{Parameters}

- [\textit{out}] \textit{reg\_info}: Parameter info structure
- \textit{timeout}: Timeout in milliseconds to read information from parameter queue

\texttt{esp\_err\_t mbc\_slave\_set\_descriptor (mb\_register\_area\_descriptor\_t \textit{descr\_data})}
Set Modbus area descriptor.

\textbf{Return}

- ESP\_OK: The appropriate descriptor is set
- ESP\_ERR\_INVALID\_ARG: The argument is incorrect

\textbf{Parameters}

- \textit{descr\_data}: Modbus registers area descriptor structure

\textbf{Structures}

\texttt{struct mb\_param\_info\_t}
Parameter access event information type.

\textbf{Public Members}

\texttt{uint32\_t time\_stamp}
Timestamp of Modbus Event (uS)

\texttt{uint16\_t mb\_offset}
Modbus register offset

\texttt{mb\_event\_group\_t type}
Modbus event type

\texttt{uint8\_t *address}
Modbus data storage address

\texttt{size\_t size}
Modbus event register size (number of registers)

\texttt{struct mb\_register\_area\_descriptor\_t}
Parameter storage area descriptor.
Public Members

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)

2.4.12 ESP WebSocket Client

Overview

The ESP WebSocket client is an implementation of WebSocket protocol client for ESP32

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:

```c
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:

```c
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

```c
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:

```
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:

```
esp_websocket_client_send_text(client, data, len, portMAX_DELAY);
```

API Reference

Header File

- components/esp_websocket_client/include/esp_websocket_client.h

Functions

```
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

```
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

```
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

```
esp_err_t esp_websocket_client_stop(esp_websocket_client_handle_t client)
```

 Stops 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
Chapter 2. API Reference

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 echos 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 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

```c
bool esp_websocket_client_is_connected(esp_websocket_client_handle_t client)
```

Check the WebSocket client connection state.

**Parameters**

- [in] client: The client handle

```c
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**

- [in] client: The client handle
  - event: The event id
  - event_handler: The callback function
  - event_handler_arg: User context

**Structures**

```c
struct esp_websocket_event_data_t
```

Websocket event data.

**Public Members**

```c
const char *data_ptr
```

Data pointer

```c
int data_len
```

Data length

```c
uint8_t op_code
```

Received opcode

```c
esp_websocket_client_handle_t client
```

esp_websocket_client_handle_t context

```c
void *user_context
```

user_data context, from `esp_websocket_client_config_t` user_data

```c
int payload_len
```

Total payload length, payloads exceeding buffer will be posted through multiple events

```c
int payload_offset
```

Actual offset for the data associated with this event

```c
struct esp_websocket_client_config_t
```

Websocket client setup configuration.

**Public Members**

```c
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

espwebsocket_transport_t transport
    Websocket transport type, see 'espwebsocket_transport_t

const char *subprotocol
    Websocket subprotocol

const char *user_agent
    Websocket user-agent

const char *headers
    Websocket additional headers
int **pingpong_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 **pingpong_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

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**

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:

- **WEBSOCKET_TRANSPORT_UNKNOWN** = 0x0
  
  Transport unknown

- **WEBSOCKET_TRANSPORT_OVER_TCP**  
  Transport over tcp
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.

Communication with ESP SDIO Slave

This document describes the process of initialization of an ESP SDIO Slave device and then provides details on the ESP SDIO Slave protocol - a non-standard protocol that allows an SDIO Host to communicate with an ESP SDIO slave.

The ESP SDIO Slave protocol was created to implement the communication between SDIO host and slave, because the SDIO specification only shows how to access the custom region of a card (by sending CMD52 and CMD53 to Functions 1-7) without any details regarding the underlying hardware implementation.

SDIO Slave Capabilities of Espressif chips

The services provided by the SDIO Slave peripheral of the ESP32 chip are listed in the table below:

<table>
<thead>
<tr>
<th>Services</th>
<th>ESP32</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDIO slave</td>
<td>Y</td>
</tr>
<tr>
<td>Tohost intr</td>
<td>8</td>
</tr>
<tr>
<td>Frhost intr</td>
<td>8</td>
</tr>
<tr>
<td>TX DMA</td>
<td>Y</td>
</tr>
<tr>
<td>RX DMA</td>
<td>Y</td>
</tr>
<tr>
<td>Shared registers</td>
<td>56*</td>
</tr>
</tbody>
</table>

* Not including the interrupt registers

ESP SDIO Slave Initialization

The host should initialize the ESP32 SDIO slave according to the standard SDIO initialization process (Section 3.1.2 of SDIO Simplified Specification). In this specification as well as below, the SDIO slave is called an (SD)IO card. Here is a brief example of an ESP SDIO Slave initialization process:

1. SDIO reset CMD52 (Write 0x6=0x8)
2. SD reset CMD0
3. Check whether IO card (optional) CMD8
4. Send SDIO op cond and wait for card ready CMD5 arg = 0x00000000
   CMD5 arg = 0x00ff8000 (according to the response above, poll until ready)
   Example: Arg of R4 after first CMD5 (arg=0x00000000) is 0XFFFF00.
   Keep sending CMD5 with arg=0x00FFFF00 until the R4 shows card ready (arg bit 31=1).
5. Set address CMD3
6. Select card CMD7 (arg address according to CMD3 response)
   Example: Arg of R6 after CMD3 is 0x0001xxxx.
   Arg of CMD7 should be 0x00010000.
7. Select 4-bit mode (optional) CMD52 (Write 0x07=0x02)
8. Enable func1 CMD52 (Write 0x02=0x02)
9. Enable SDIO interrupt (required if interrupt line (DAT1) is used) CMD52 (Write 0x04=0x03)
10. Set Func0 blocksize (optional, default value is 512 (0x200)) CMD52/53 (Read 0x10~0x11)
    CMD52/53 (Write 0x10=0x00)
    CMD52/53 (Write 0x11=0x02)
    CMD52/53 (Read 0x10~0x11, read to check the final value)
11. Set Func1 blocksize (optional, default value is 512 (0x200)) CMD52/53 (Read 0x110~0x111)
    CMD52/53 (Write 0x110=0x00)
    CMD52/53 (Write 0x111=0x02)
    CMD52/53 (Read 0x110~0x111, read to check the final value)

ESP SDIO Slave Protocol  The ESP SDIO Slave protocol is based on the SDIO Specification’s I/O Read/Write commands, i.e., CMD52 and CMD53. The protocol offers the following services:

- Sending FIFO and receiving FIFO
- 52 8-bit R/W registers shared by host and slave (For details, see ESP32 Technical Reference Manual > SDIO Slave Controller > Register Summary > SDIO SLC Host registers [PDF])
- 16 general purpose interrupt sources, 8 from host to slave and 8 from slave to host

To begin communication, the host needs to enable the I/O Function 1 in the slave and access its registers as described below.

Check the code example peripherals/sdio.

The ESP Serial Slave Link component implements the logic of this protocol for ESP32 SDIO Host when communicating with an ESP32 SDIO slave.

Slave register table

32-bit

- 0x044 (TOKEN_RDATA): in which bit 27-16 holds the number of the receiving buffer.
- 0x058 (INT_ST): holds the interrupt source bits from slave to host.
- 0x060 (PKT_LEN): holds the accumulated data length (in bytes) already read by host plus the data copied to the buffer but yet to be read.
- 0x0D4 (INT_CLR): write 1 to clear interrupt bits corresponding to INT_ST.
- 0x0DC (INT_ENA): mask bits for interrupts from slave to host.

8-bit  Shared general purpose registers:

- 0x06C-0x077: R/W registers 0-11 shared by slave and host.
- 0x07A-0x07B: R/W registers 14-15 shared by slave and host.
- 0x07E-0x07F: R/W registers 18-19 shared by slave and host.
- 0x088-0x08B: R/W registers 24-27 shared by slave and host.
- 0x09C-0x0BB: R/W registers 32-63 shared by slave and host.

Interrupt Registers: - 0x08D (SLAVE_INT): bits for host to interrupt slave. auto clear.

FIFO (sending and receiving)  0x090 - 0x1F7FF are reserved for FIFOs.

The address of CMD53 is related to the length requested to read from or write to the slave in a single transfer, as demonstrated by the equation below:

\[
\text{requested length} = 0x1F800-\text{address}
\]

The slave will respond with data that has a length equal to the length field of CMD53. In cases where the data is longer than the requested length, the data will be zero filled (when sending) or discarded (when receiving). This includes both the block and the byte mode of CMD53.
Chapter 2. API Reference

**Note:** The function number should be set to 1, OP Code should be set to 1 (for CMD53).

In order to achieve higher efficiency when accessing the FIFO by an arbitrary length, the block and byte modes of CMD53 can be used in combination. For example, given that the block size is set to 512 by default, you can write/get 1031 bytes of data from the FIFO by doing the following:

1. Send CMD53 in block mode, block count=2 (1024 bytes) to address 0x1F3F9=0x1F800-1031.
2. Then send CMD53 in byte mode, byte count=8 (or 7 if your controller supports that) to address 0x1F7F9=0x1F800-7.

**Interrupts**  SDIO interrupts are “level sensitive”. For host interrupts, the slave sends an interrupt by pulling the DAT1 line down at a proper time. The host detects when the interrupt line is pulled down and reads the INT_ST register to determine the source of the interrupt. After that, the host can clear the interrupt bits by writing the INT_CLR register and process the interrupt. The host can also mask unneeded sources by clearing the bits in the INT_ENA register corresponding to the sources. If all the sources are cleared (or masked), the DAT1 line goes inactive.

On ESP32, the corresponding host_int bits are: bit 0 to bit 7.

For slave interrupts, the host sends a transfer to write the SLAVE_INT register. Once a bit is set to 1, the slave hardware and the driver will detect it and inform the application.

**Receiving FIFO**  To write to the slave’s receiving FIFO, the host should complete the following steps:

1. Read the TOKEN1 field (bits 27-16) of the register TOKEN_RDATA (0x044). The buffer number remaining is TOKEN1 minus the number of buffers used by host.
2. Make sure the buffer number is sufficient (buffer_size × buffer_num is greater than the data to write, buffer_size is pre-defined between the host and the slave before the communication starts). Otherwise, keep returning to Step 1 until the buffer size is sufficient.
3. Write to the FIFO address with CMD53. Note that the requested length should not exceed the length calculated at Step 2, and the FIFO address is related to requested length.
4. Calculate used buffers. Note that a partially used buffer at the tail is counted as used.

**Sending FIFO**  To read the slave’s sending FIFO, the host should complete the following steps:

1. Wait for the interrupt line to become active (optional, low by default).
2. Read (poll) the interrupt bits in the INT_ST register to monitor if new packets exist.
3. If new packets are ready, read the PKT_LEN register. Before reading the packets, determine the length of data to be read. As the host keeps the length of data already read from the slave, subtract this value from PKT_LEN, the result will be the maximum length of data available for reading. If no data has been added to the sending FIFO yet, wait and poll until the slave is ready and update PKT_LEN.
4. Read from the FIFO using CMD53. Note that the requested length should not be greater than calculated at Step 3, and the FIFO address is related to requested length.
5. Update the read length.

**Warning:** The driver for ESP32 hasn’t been developed yet.

ESP SPI Slave HD (Half Duplex) Mode Protocol


**SPI Slave Capabilities of Espressif chips**

<table>
<thead>
<tr>
<th></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>Frhost 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 I/O 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.
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Command</th>
<th>Address</th>
<th>Data Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRBUF</td>
<td>Write buffer</td>
<td>0x01</td>
<td>Buf addr</td>
<td>master to slave, no longer than buffer size</td>
</tr>
<tr>
<td>RDBUF</td>
<td>Read buffer</td>
<td>0x02</td>
<td>Buf addr</td>
<td>slave to master, no longer than buffer size</td>
</tr>
<tr>
<td>WRDMA</td>
<td>Write DMA</td>
<td>0x03</td>
<td>8 bits</td>
<td>master to slave, no longer than length provided by slave</td>
</tr>
<tr>
<td>RDDMA</td>
<td>Read DMA</td>
<td>0x04</td>
<td>8 bits</td>
<td>slave to master, no longer than length provided by slave</td>
</tr>
<tr>
<td>SEG_DONE</td>
<td>Segments done</td>
<td>0x05</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>ENQPI</td>
<td>Enter QPI mode</td>
<td>0x06</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>WR_DONE</td>
<td>Write segments done</td>
<td>0x07</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>CMD8</td>
<td>Interrupt</td>
<td>0x08</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>CMD9</td>
<td>Interrupt</td>
<td>0x09</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>CMDA</td>
<td>Interrupt</td>
<td>0x0A</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>EXQPI</td>
<td>Exit QPI mode</td>
<td>0xDD</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Moreover, WRBUF, RDBUF, WRDMA, RDDMA commands have their 2-bit and 4-bit version. To do transactions in 2-bit or 4-bit mode, send the original command ORed by the corresponding command mask below. For example, command 0xA1 means WRBUF in QIO mode.

<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. Fhost 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 [SDIO Slave Capabilities of Espressif chips](#) and [SPI Slave Capabilities of Espressif chips](#) for more details.

Initialization of ESP Serial Slave Link

**ESP SDIO Slave** The ESP SDIO slave link (ESSL SDIO) devices relies on the sdmmc component. It includes the usage of communicating with ESP SDIO Slave device via SDSPI feature. The ESSL device should be initialized as below:

1. Initialize a sdmmc card (see `doc:` Document of SDMMC driver `<api-reference/storage/sdmmc>` ) structure.
2. Call `sdmmc_card_init()` to initialize the card.
3. Initialize the ESSL device with `essl_sdio_config_t`. The `card` member should be the `sdmmc_card_t` got in step 2, and the `recv_buffer_size` member should be filled correctly according to pre-negotiated value.
4. Call `essl_init()` to do initialization of the SDIO part.
5. Call `essl_wait_for_ready()` to wait for the slave to be ready.

ESP SPI Slave

**Note:** If you are communicating with the ESP SDIO Slave device through SPI interface, you should use the **SDIO interface** instead.

Hasn’t been supported yet.

**APIs**

After the initialization process above is performed, you can call the APIs below to make use of the services provided by the slave:

**To host Interrupts (optional)**

1. Call `essl_get_intr_ena()` to know which events will trigger the interrupts to the master.
2. Call `essl_set_intr_ena()` to set the events that will trigger interrupts to the master.
3. Call `essl_wait_int()` to wait until interrupt from the slave, or timeout.
4. When interrupt is triggered, call `essl_get_intr()` to know which events are active, and call `essl_clear_intr()` to clear them.

**Fr host Interrupts**

1. Call `essl_send_slave_intr()` to trigger general purpose interrupt of the slave.

**TX FIFO**

1. Call `essl_get_tx_buffer_num()` to know how many buffers the slave has prepared to receive data from the master. This is optional. The master will poll `tx_buffer_num` when it try to send packets to the slave, until the slave has enough buffer or timeout.
2. Call `essl_send_paket()` 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_size` keeps 0, until timeout.
2. Call `essl_get_packet()` to receive data from the slave.

**Reset counters (Optional)**

Call `essl_reset_cnt()` to reset the internal counter if you find the slave has reset its counter.

**Application Example**

The example below shows how ESP32 SDIO host and slave communicate with each other. The host use the ESSL SDIO.

Please refer to the specific example README.md for details.
API Reference

Header File

- components/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**

- 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.
**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.

**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 addr, 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.
Chapter 2. API Reference

- **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.

```c
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.

```c
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.

```c
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
- 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, 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.

```c
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**

```c
struct essl_sdio_config_t
```

Configuration for the ESSL SDIO device.

**Public Members**

```c
sdmmc_card_t *card
```

The initialized sdmmc card pointer of the slave.

```c
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 rxync_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.
Chapter 2. API Reference

**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_ADDR: 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 note 1)
- `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_ADDR: 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`)

**`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.

**`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] 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_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:`spi_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
esp_err_t essl_spi_rddma (spi_device_handle_t spi, uint8_t *out_data, int len, int seg_len, uint32_t flags)
```
Receive long buffer in segments from the slave through its DMA.

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:`spi_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.

```
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:spi_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.

```
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: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.

```
esp_err_t essl_spi_wrdma(spi_device_handle_t spi, const uint8_t *data, int len, int seg_len, uint32_t flags)
```

Send long buffer in segments to the slave through its DMA.

**Note** This function combines several :cpp:func: essl_spi_wrdma_seg and one :cpp:func: essl_spi_wrdma_done at the end. Used when the slave is working in segment mode.

**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.

```
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**

- `spi_device_handle_t *spi`
  Pointer to SPI device handle.

- `uint32_t tx_buf_size`
  The pre-negotiated Master TX buffer size used by both the host and the slave.

- `uint8_t tx_sync_reg`
  The pre-negotiated register ID for Master-TX-SLAVE-RX synchronization. 1 word (4 Bytes) will be reserved for the synchronization.

- `uint8_t rx_sync_reg`
  The pre-negotiated register ID for Master-RX-Slave-TX synchronization. 1 word (4 Bytes) will be reserved for the synchronization.

### 2.4.14 ESP x509 Certificate Bundle

**Overview**

The ESP x509 Certificate Bundle API provides an easy way to include a bundle of custom x.509 root certificates for TLS server verification.

**Note:** The bundle is currently not available when using WolfSSL.

The bundle comes with the complete list of root certificates from Mozilla’s NSS root certificate store. Using the `gen_crt_bundle.py` python utility the certificates’ subject name and public key are stored in a file and embedded in the ESP32 binary.

When generating the bundle you may choose between:

- The full root certificate bundle from Mozilla, containing more than 130 certificates. The current bundle was updated Tue 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 cacert_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_crt_authorities.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.

**void esp_crt_bundle_detach**(mbedtls_ssl_config *conf)

Disable and dealloc the certification bundle.

Removes the certificate verification callback and deallocates used resources.

**Parameters**

- [in] conf: The config struct for the SSL connection.

**void 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)
Chapter 2. API Reference

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 complete example see provisioning/legacy/softap_prov

```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 */
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 removal */
    const static protocomm_security_pop_t pop_obj = {
        .data = (const uint8_t *) strdup(pop_string),
        .len = strlen(pop_string)
    }
```

(continues on next page)
/* 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 */
    protocomm_unset_security(pc, "security_endpoint");

    /* Stop HTTP server */
    protocomm_httpd_stop(pc);

    /* Delete (deallocate) the protocomm instance */
    protocomm_delete(pc);
}

Transport Example (BLE) with Security 0

For complete example see provisioning/legacy/ble_prov

    /* 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}
        };
    }

(continues on next page)
/* Config for protocomm_ble_start() */
protocomm_ble_config_t config = {
    .service_uuid = {
        /* LSB <---------------------------------------
        * ---------------------------------------> MSB */
        0xfb, 0x34, 0x9b, 0x5f, 0x80, 0x00, 0x00, 0x00,
        0x00, 0x10, 0x00, 0x00, 0xFF, 0xFF, 0x00, 0x00,
    },
    .nu_lookup_count = sizeof(nu_lookup_table) / sizeof(nu_lookup_table[0]),
    .nu_lookup = nu_lookup_table
};

/* Start protocomm layer on top of 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", &protocomm_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);
}

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
Chapter 2. API Reference

- [in] pc: Pointer to the protocomm instance to be deleted

```c
esp_err_t protocomm_add_endpoint (protocomm_t *pc, const char *ep_name, proto-
    comm_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.

```c
esp_err_t protocomm_remove_endpoint (protocomm_t *pc, const char *ep_name)
```

Remove endpoint request handler for a protocomm instance.

This API will remove a registered endpoint handler identified by an endpoint name.

**Note**
- This function internally calls the registered remove_endpoint() function which is a member
  of the protocomm_t instance structure.

**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

```c
esp_err_t protocomm_open_session (protocomm_t *pc, uint32_t session_id)
```

Allocates internal resources for new transport session.

**Note**
- An endpoint must be bound to a valid protocomm instance, created using protocomm_new().

**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

```c
esp_err_t protocomm_close_session (protocomm_t *pc, uint32_t session_id)
```

Frees internal resources used by a transport session.

**Note**
- An endpoint must be bound to a valid protocomm instance, created using protocomm_new().

**Return**
- ESP_OK : Request handled successfully
- ESP_ERR_INVALID_ARG : Null instance/name arguments

**Parameters**
Chapter 2. API Reference

- [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_ERR_INVALID_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**
Chapter 2. API Reference

- `[in] pc: Pointer to the protocomm instance`
- `[in] ep_name: Endpoint identifier(name) string`

```c
esp_err_t protocomm_set_version(protocomm_t *pc, const char *ep_name, const char *version)
```

Set endpoint for version verification.

This API can be used for setting an application specific protocol version which can be verified by clients through the endpoint.

**Note**
- An endpoint must be bound to a valid protocomm instance, created using `protocomm_new()`.

**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`

```c
esp_err_t protocomm_unset_version(protocomm_t *pc, const char *ep_name)
```

Remove version verification endpoint from a protocomm instance.

This API will remove a registered version endpoint identified by an endpoint name.

**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**

```c
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.

```c
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**

```c
struct protocomm_security_pop
```

Proof Of Possession for authenticating a secure session.

**Public Members**

```c
const uint8_t *data
```

Pointer to buffer containing the proof of possession data


### Chapter 2. API Reference

**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

**Typedef Definitions**

**typedef struct protocomm_security_pop protocomm_security_pop_t**
Proof Of Possession 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()
unsigned task_priority
    Priority of server task

struct protocomm_httpd_config_t
    Config parameters for protocomm HTTP server.

Public Members

bool ext_handle_provided
    Flag to indicate of an external HTTP Server Handle has been provided. In such as case, protocomm will
    use the same HTTP Server and not start a new one internally.

protocomm_httpd_config_data_t data
    Protocomm HTTPD Configuration Data

Macros

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 characteris-
    tics/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

esp_err_t protocomm_ble_stop (protocomm_t *pc)
    Stop Bluetooth Low Energy based transport layer for provisioning.
    Stops service/task responsible for BLE based interactions for provisioning.
    Note You might want to optionally reclaim memory from Bluetooth. Refer to the documentation of
    esp_bt_mem_release in that case.
    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.
Chapter 2. API Reference

Public Members

**const char *name**
Name of the handler, which is passed to protocomm layer

**uint16_t uuid**
UUID to be assigned to the BLE characteristic which is mapped to the handler

**struct protocomm_ble_config**
Config parameters for protocomm BLE service.

Public Members

char *device_name[MAX_BLE_DEVNAME_LEN]
BLE device name being broadcast at the time of provisioning

uint8_t *service_uuid[BLE_UUID128_VAL_LENGTH]
128 bit UUID of the provisioning service

uint8_t *manufacturer_data
BLE device manufacturer data pointer in advertisement

ssize_t manufacturer_data_len
BLE device manufacturer data length in advertisement

ssize_t nu_lookup_count
Number of entries in the Name-UUID lookup table

protocomm_ble_name_uuid_t *nu_lookup
Pointer to the Name-UUID lookup table

Macros

**MAX_BLE_DEVNAME_LEN**
BLE device name cannot be larger than this value 31 bytes (max scan response size) - 1 byte (length) - 1 byte (type) = 29 bytes

**BLE_UUID128_VAL_LENGTH**

**MAX_BLE_MANUFACTURER_DATA_LEN**
Theoretically, the limit for max manufacturer length remains same as BLE device name i.e. 31 bytes (max scan response size) - 1 byte (length) - 1 byte (type) = 29 bytes However, manufacturer data goes along with BLE device name in scan response. So, it is important to understand the actual length should be smaller than (29 - (BLE device name length) - 2).

Type Definitions

**typedef struct name_uuid protocomm_ble_name_uuid_t**
This structure maps handler required by protocomm layer to UUIDs which are used to uniquely identify BLE characteristics from a smartphone or a similar client device.

**typedef struct protocomm_ble_config protocomm_ble_config_t**
Config parameters for protocomm BLE service.

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.

**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.
Fig. 28: Typical Provisioning Process

1. Transport specific discovery and connection
   - Some form of beaconing
   - 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, Pessphrase...)
   - 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
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.

![Unified Provisioning Architecture](image)

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 Protocomm to provide simple call-backs 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 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:
Fig. 30: Security 1

Generate Key Pair

\{cli\_privkey, cli\_pubkey\} = curve25519\_keygen()

SessionCmd0(cli\_pubkey)

\{dev\_privkey, dev\_pubkey\} = curve25519\_keygen()

dev\_rand = gen\_16\_byte\_random()

shared\_key(No PoP) = curve25519(dev\_privkey, cli\_pubkey)
shared\_key(with PoP) = curve25519(dev\_privkey, cli\_pubkey) ^ SHA256(pop)

SessionResp0(dev\_pubkey, dev\_rand)

Shared Key

shared\_key(No PoP) = curve25519(cli\_privkey, dev\_pubkey)
shared\_key(with PoP) = curve25519(cli\_privkey, dev\_pubkey) ^ SHA256(pop)

Verification Token

cli\_verify = aes\_ctr\_enc(key=shared\_key, data=dev\_pubkey, nonce=dev\_rand)

SessionCmd1(cli\_verify)

Verify Client

check (dev\_pubkey == aes\_ctr\_dec(cli\_verify...))

dev\_verify = aes\_ctr\_enc(key=shared\_key, data=cli\_pubkey, nonce=(prev-context))

SessionResp1(dev\_verify)

Verify Device

check (cli\_pubkey == aes\_ctr\_dec(dev\_verify...))
• 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");
                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
                "
                "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!
                "
                "Reason : %s"
                "Please reset to factory and retry
                "
                "Wi-Fi station authentication failed : "
                "Wi-Fi access-point not found";
```
(continues on next page)
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(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 13: Endpoints provided by Provisioning Service

<table>
<thead>
<tr>
<th>Endpoint Name (BLE + GATT Server)</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:

```json
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** (output) - 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
wifi_prov_mgr_init(config);
wifi_prov_mgr_endpoint_create("custom-endpoint");
wifi_prov_mgr_start_provisioning(security, pop, service_name, service_--key);
wifi_prov_mgr_endpoint_register("custom-endpoint", custom_ep_handler,--custom_ep_data);
```

When the provisioning service stops, the endpoint is unregistered automatically.

One can also choose to call `wifi_prov_mgr_endpoint_unregister()` to manually deactivate an endpoint at runtime. This can also be used to deactivate the internal endpoints used by the provisioning service.

**When / How To Stop 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 device 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 delay ensures that the transport resources are freed only after the response from the protocomm handler reaches the client side application.

**Application Examples**

For complete example implementation see `provisioning/wifi_prov_mgr`
Provisioning Tools

Provisioning applications are available for various platforms, along with source code:

- **Android:**
  - 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

`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

```
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

```
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.

```
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.

\[\text{esp_err_t wifi_prov_mgr_disable_auto_stop(\text{uint32_t cleanup_delay})}\]

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 \text{wifi_prov_mgr_stop_provisioning()} later when the device is fully configured and the provisioning service is no longer required.

\textbf{Note} This must be called before executing \text{wifi_prov_mgr_start_provisioning()}

\textbf{Return}
- ESP_OK : Success
- ESP_ERR_INVALID_STATE : Manager not initialized or provisioning service already started

\textbf{Parameters}
- \textsf{[in]} cleanup_delay: Sets the delay after which the actual cleanup of transport related resources is done after a call to \text{wifi_prov_mgr_stop_provisioning()} returns. Minimum allowed value is 100ms. If not specified, this will default to 1000ms.

\[\text{esp_err_t wifi_prov_mgr_set_app_info(const char *label, const char *version, const char **capabilities, size_t total_capabilities)}\]

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. Applications services should use a label other than “prov” so as not to overwrite this.

\textbf{Note} This must be called before executing \text{wifi_prov_mgr_start_provisioning()}

\textbf{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

\textbf{Parameters}
- \textsf{[in]} label: String indicating the application name.
- \textsf{[in]} version: String indicating the application version. There is no constraint on format.
- \textsf{[in]} capabilities: Array of strings with capabilities. These could be used by the client side app to know the application registered endpoint capabilities
- \textsf{[in]} total_capabilities: Size of capabilities array

\[\text{esp_err_t wifi_prov_mgr_endpoint_create(const char *ep_name)}\]

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.

protocomm handler for the created endpoint is to be registered later using \text{wifi_prov_mgr_endpoint_register()} after provisioning has started.

\textbf{Note} This API can only be called BEFORE provisioning is started

\textbf{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

\textbf{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

\textbf{Return}
Chapter 2. API Reference

- ESP_OK : Success
- ESP_FAIL : Failure

**Parameters**

- **[in]** ep_name: unique name of the endpoint

`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

`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

`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

**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

`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

`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**
Chapter 2. API Reference

- 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

`esp_err_t wifi_prov_mgr_configure_sta(wifi_config_t *wifi_cfg)`
Runs Wi-Fi as Station with the supplied configuration.

Configures the Wi-Fi station mode to connect to the AP with SSID and password specified in config structure and sets Wi-Fi to run as station.

This is automatically called by provisioning service upon receiving new credentials.

If credentials are to be supplied to the manager via a different mode other than through protocomm, then this API needs to be called.

Event WIFI_PROV_CRED_RECV is emitted after credentials have been applied and Wi-Fi station started

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

`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

`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

```c
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.

```c
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.

```c
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()`.

```c
void (*delete_config) (void *config)
```

Function which is to be called by the manager to delete a configuration generated using `new_config()`.

```c
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.

```c
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.

```c
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

```c
struct wifi_prov_mgr_config_t
```

Structure for specifying the manager configuration.

Public Members

```c
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)

```c
wifi_prov_event_handler_t scheme_event_handler
```

Event handler required by the scheme for incorporating scheme specific behavior while provisioning manager is running. Various options may be provided by the scheme for setting this field. Use WIFI_PROV_EVENT_HANDLER_NONE when not used. When using scheme `wifi_prov_scheme_ble`, the following options are available:

- WIFI_PROV.Scheme_BLE_EVENT_HANDLER_FREE_BTDM
- WIFI_PROV.Scheme_BLE_EVENT_HANDLER_FREE_BLE
- WIFI_PROV.Scheme_BLE_EVENT_HANDLER_FREE_BT

```c
wifi_prov_event_handler_t app_event_handler
```

Event handler that can be set for the purpose of incorporating application specific behavior. Use WIFI_PROV_EVENT_HANDLER_NONE when not used.

Macros

```c
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

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
Chapter 2. API Reference

**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);
```

```c
esp_err_t wifi_prov_scheme_ble_set_service_uuid (uint8_t *uuid128);
```

Set the 128 bit GATT service UUID used for provisioning.

This API is used to override the default 128 bit provisioning service UUID, which is 0000fff-0000-1000-8000-00805f9b34fb.

This must be called before starting provisioning, i.e. before making a call to wifi_prov_mgr_start_provisioning(), otherwise the default UUID will be used.

**Note** The data being pointed to by the argument must be valid at least till provisioning is started. Upon start, the manager will store an internal copy of this UUID, and this data can be freed or invalidated afterwards.

**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 length exceeds this limit, the length will be truncated.

**Return**

- ESP_OK : Success
- ESP_ERR_INVALID_ARG : Null argument

**Parameters**

- [in] mfg_data: Custom manufacturer data
- [in] 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**
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**
    
    • [in] 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**

*esp_err_t* wifi_prov_config_data_handler
    
    Handler for receiving and responding to requests from master.

    This is to be registered as the *wifi_config* endpoint handler (*protocomm proto-
    comm_req_handler_t*) using *protocomm_add_endpoint()*

**Structures**

struct wifi_prov_sta_conn_info_t
    
    WiFi STA connected status information.

**Public Members**

char *ip_addr*[IP4ADDR_STRLEN_MAX]
    
    IP Address received by station

char *bssid*[6]
    
    BSSID of the AP to which connection was established

char *ssid*[33]
    
    SSID of the to which connection was established

uint8_t *channel
    
    Channel of the AP

uint8_t *auth_mode
    
    Authorization mode of the AP

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)
Chapter 2. API Reference

`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 (e.g. AP SSID, password, etc.) of the slave (in WiFi station mode) is to be set to user provided values
- `esp_err_t (*apply_config_handler)(wifi_prov_ctx_t **ctx)`  
  Handler function for applying the configuration that was set in `set_config_handler`. After applying the station may get connected to the AP or may fail to connect. The slave must be ready to convey the updated connection status information when `get_status_handler` is invoked again by the master.

`wifi_prov_ctx_t *ctx`
Context pointer to be passed to above handler functions upon invocation

**Type Definitions**

typedef struct wifi_prov_ctxt wifi_prov_ctxt_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.

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**

enum wifi_prov_sta_state_t
WiFi STA status for conveying back to the provisioning master.

Values:
Chapter 2. API Reference

WIFI_PROV_STA_CONNECTING
WIFI_PROV_STA_CONNECTED
WIFI_PROV_STA_DISCONNECTED
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.

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_register() (for example, "/sdcard/hello.txt"). The filesystem uses 8.3 filenames format (SNF) 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 \texttt{f\_mount} for the same drive number, with NULL \texttt{FATFS*} argument, to unmount the filesystem.

9. Call the FatFs function \texttt{ff\_diskio\_register()} with NULL \texttt{ff\_diskio\_impl\_t*} argument and the same drive number to unregister the disk I/O driver.

10. Call \texttt{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 \texttt{esp\_vfs\_fat\_sdmmc\_mount}, \texttt{esp\_vfs\_fat\_sdspi\_mount} and \texttt{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.

\texttt{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, \texttt{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 \texttt{f\_mount} call.

\textbf{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.

\textbf{Return}

- ESP\_OK on success
- ESP\_ERR\_INVALID\_STATE if \texttt{esp\_vfs\_fat\_register} was already called
- ESP\_ERR\_NO\_MEM if not enough memory or too many VFSes already registered

\textbf{Parameters}

- \texttt{base\_path}: path prefix where FATFs should be registered
- \texttt{fat\_drive}: FATFs drive specification; if only one drive is used, can be an empty string
- \texttt{max\_files}: maximum number of files which can be open at the same time
- \texttt{[out]} \texttt{out\_fs}: pointer to FATFs structure which can be used for FATFs \texttt{f\_mount} call is returned via this argument.

\texttt{esp\_err\_t esp\_vfs\_fat\_unregister\_path(const char *base\_path)}

Un-register FATFs from VFS.

\textbf{Note} FATFs structure returned by \texttt{esp\_vfs\_fat\_register} is destroyed after this call. Make sure to call \texttt{f\_mount} function to unmount it before calling \texttt{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

\textbf{Return}

- ESP\_OK on success
- ESP\_ERR\_INVALID\_STATE if FATFs is not registered in VFS

\textbf{Parameters}

- \texttt{base\_path}: path prefix where FATFs is registered. This is the same used when \texttt{esp\_vfs\_fat\_register} was called

**Using FatFs with VFS and SD cards**

The header file \texttt{fatfs/vfs/esp\_vfs\_fat.h} defines convenience functions \texttt{esp\_vfs\_fat\_sdmmc\_mount()}, \texttt{esp\_vfs\_fat\_sdspi\_mount()} and \texttt{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 \texttt{esp\_vfs\_fat\_sdmmc\_unmount()} unmounds the filesystem and releases the resources acquired by \texttt{esp\_vfs\_fat\_sdmmc\_mount()}. 

\texttt{esp\_err\_t esp\_vfs\_fat\_sdmmc\_mount(const char *base\_path, const sdmmc\_host\_t *host\_config,}
\texttt{ const void *slot\_config, const esp\_vfs\_fat\_mount\_config\_t}
\texttt{*mount\_config, sdmmc\_card\_t **out\_card)}

Convenience function to get FAT filesystem on SD card registered in VFS.

This is an all-in-one function which does the following:
initializes SDMMC driver or SPI driver with configuration in host_config
initializes SD card with configuration in slot_config
mounts FAT partition on SD card using FATFS library, with configuration in mount_config
registers FATFS library with VFS, with prefix given by base_prefix variable

This function is intended to make example code more compact. For real world applications, developers should implement the logic of probing SD card, locating and mounting partition, and registering FATFS in VFS, with proper error checking and handling of exceptional conditions.

Note Use this API to mount a card through SDSPI is deprecated. Please call esp_vfs_fat_sdspi_mount() instead for that case.

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: 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 registered in VFS.

This is an all-in-one function which does the following:
• initializes an SPI Master device based on the SPI Master driver with configuration in slot_config, and attach it to an initialized SPI bus.
• initializes SD card with configuration in host_config_input
• mounts FAT partition on SD card using FATFS library, with configuration in mount_config
• registers FATFS library with VFS, with prefix given by base_prefix variable

This function is intended to make example code more compact. For real world applications, developers should implement the logic of probing SD card, locating and mounting partition, and registering FATFS in VFS, with proper error checking and handling of exceptional conditions.

Note This function try to attach the new SD SPI device to the bus specified in host_config. Make sure the SPI bus specified in host_config->slot have been initialized by spi_bus_initialize() before.

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**: 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. 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

- **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.

```c
esp_err_t esp_vfs_fat_sdcard_unmount (const char* base_path, sdmmc_card_t* card)
```

Unmount an SD card from the FAT filesystem and release resources acquired using esp_vfs_fat_sdmmc_mount() or esp_vfs_fat_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_rawflashUnmount()`. 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 VFS 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
Chapter 2. API Reference

- 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

```
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()`.

```
void ff_diskio_register(BYTE pdrv, const ff_diskio_impl_t *discio_impl)
```

Register or unregister diskio driver for given drive number.

When FATFS library calls one of disk_xxx functions for driver number pdrv, corresponding function in discio_impl for given pdrv will be called.

Parameters
- pdrv: drive number
- discio_impl: pointer to ff_diskio_impl_t structure with diskio functions or NULL to unregister and free previously registered drive

```
struct ff_diskio_impl_t
```

Structure of pointers to disk I/O driver functions.

See FatFs documentation for details about these functions

Public Members

- DSTATUS (*init)(unsigned char pdrv) disk initialization function
- DSTATUS (*status)(unsigned char pdrv) disk status check function
- DRESULT (*read)(unsigned char pdrv, unsigned char *buff, uint32_t sector, unsigned count) sector read function
- DRESULT (*write)(unsigned char pdrv, const unsigned char *buff, uint32_t sector, unsigned count) sector write function
- DRESULT (*ioctl)(unsigned char pdrv, unsigned char cmd, void *buff) function to get info about disk and do some misc operations
void ff_diskio_register_sdmmc(unsigned char pdrv, sdmmc_card_t *card)
    Register SD/MMC diskio driver

    Parameters
    • pdrv: drive number
    • card: pointer to sdmmc_card_t structure describing a card; card should be initialized before calling f_mount.

esp_err_t ff_diskio_register_wl_partition(unsigned char pdrv, wl_handle_t flash_handle)
    Register spi flash partition

    Parameters
    • pdrv: drive number
    • flash_handle: handle of the wear levelling partition.

esp_err_t ff_diskio_register_raw_partition(unsigned char pdrv, const esp_partition_t *part_handle)
    Register spi flash partition

    Parameters
    • pdrv: drive number
    • part_handle: pointer to raw flash partition.

FATFS partition generator

We provide a partition generator for FATFS (wl_fatfsgen.py) which is integrated into the build system and could be easily used in the user project.

The tool is used to create filesystem images on a host and populate it with content of the specified host folder.

The script is based on the partition generator (fatfsgen.py) and except for generating partition also initializes wear levelling.

Current implementation supports short file names and FAT12. Long file names, and FAT16 are subjects 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:

```c
fatfs_create_rawflash_image(<partition> <base_dir> [FLASH_IN_PROJECT])
```

fatfs_create_spiflash_image respectively fatfs_create_rawflash_image must be called from project’s CMakeLists.txt.

If you 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:
Chapter 2. API Reference

```c
fatfs_create_spiflash_image(my_fatfs_partition my_folder FLASH_IN_PROJECT)
```

If FLASH_IN_PROJECT is not specified, the image will still be generated, but you will have to flash it manually using `esptool.py` or a custom build system target.

For an example, see `storage/fatfsgen`.

### 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.

**Workflow**

![Workflow diagram](image)

**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):
Chapter 2. API Reference

name1,namespace,  \(\text{<-- First entry should be of type "namespace" }\)
key1,type1,encoding1
derkey2,type2,encoding2,REPEAT
name2,namespace,
key3,type3,encoding3
dkey4,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.

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:

<table>
<thead>
<tr>
<th>id</th>
<th>firmware_key</th>
<th>serial_no</th>
<th>device_no</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1a2b3c4d5e6faabb</td>
<td>A1,101</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1a2b3c4d5e6fccccd</td>
<td>,,102</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>1a2b3c4d5e6ffeed</td>
<td>,,103</td>
<td>3</td>
</tr>
</tbody>
</table>
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:

```
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:**

```
python mfg_gen.py [-h] {generate,generate-key} ...
```

**Optional Arguments:**

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-h, --help</td>
<td>show this help message and exit</td>
</tr>
</tbody>
</table>

**Commands:**

Run `mfg_gen.py {command} -h` for additional help

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>generate</td>
<td>Generate NVS partition</td>
</tr>
<tr>
<td>2</td>
<td>generate-key</td>
<td>Generate keys for encryption</td>
</tr>
</tbody>
</table>

**To generate factory images for each device (Default):**

**Usage:**

```
python mfg_gen.py generate [-h] [--fileid FILEID] [--version {1,2}] [--keygen]
                            [--keyfile KEYFILE] [--inputkey INPUTKEY]
                            [--outdir OUTDIR]
                            conf values prefix size
```

**Positional Arguments:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>conf</td>
<td>Path to configuration csv file to parse</td>
</tr>
<tr>
<td>values</td>
<td>Path to values csv file to parse</td>
</tr>
<tr>
<td>prefix</td>
<td>Unique name for each output filename prefix</td>
</tr>
<tr>
<td>size</td>
<td>Size of NVS partition in bytes</td>
</tr>
<tr>
<td></td>
<td>(must be multiple of 4096)</td>
</tr>
</tbody>
</table>

**Optional Arguments:**
### Parameter Description

<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:

```bash
python mfg_gen.py generate samples/sample_config.csv samples/sample_values_~singlepage_blob.csv Sample 0x3000
```

The master value CSV file should have the path in the file type relative to the directory from which you are running the utility.

**To generate encrypted factory images for each device:**

You can run the utility to encrypt factory images for each device using the command below. A sample CSV file is provided with the utility:

- Encrypt by allowing the utility to generate encryption keys:
  ```bash
  python mfg_gen.py generate samples/sample_config.csv samples/sample_values_~singlepage_blob.csv Sample 0x3000 --keygen
  ```

**Note:** Encryption key of the following format `<outdir>/keys/keys-<prefix>-<fileid>.bin` is created. This newly created file having encryption keys in `keys/` directory is compatible with NVS key-partition structure. Refer to `NVS key partition` for more details.

- Encrypt by providing the encryption keys as input binary file:
  ```bash
  python mfg_gen.py generate samples/sample_config.csv samples/sample_values_~singlepage_blob.csv Sample 0x3000 --inputkey keys/sample_keys.bin
  ```

**To generate only encryption keys:**

**Usage:** python mfg_gen.py generate-key [-h] [-keyfile KEYFILE] [-outdir OUTDIR]

**Optional Arguments:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-h, --help</td>
<td>show this help message and exit</td>
</tr>
<tr>
<td>--keyfile KEYFILE</td>
<td>Path to output encryption keys file</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 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 `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.
Chapter 2. API Reference

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 flash encryption system. However, data can still be stored in encrypted form if NVS encryption is used together with ESP32 flash encryption. Please refer to `NVS Encryption` for more details.

If NVS encryption is not used, it is possible for anyone with physical access to the flash chip to alter, erase, or add key-value pairs. With NVS encryption enabled, it is not possible to alter or add a key-value pair and get recognized as a valid pair without knowing corresponding NVS encryption keys. However, there is no tamper-resistance against the erase operation.

The library does try to recover from conditions when flash memory is in an inconsistent state. In particular, one should be able to power off the device at any point and time and then power it back on. This should not result in loss of data, except for the new key-value pair if it was being written at the moment of powering off. The library should also be able to initialize properly with any random data present in flash memory.

NVS Encryption

Data stored in NVS partitions can be encrypted using AES-XTS in the manner similar to the one mentioned in disk encryption standard IEEE P1619. For the purpose of encryption, each entry is treated as one `sector` and relative address of the entry (w.r.t. partition-start) is fed to the encryption algorithm as `sector-number`. The NVS Encryption can be enabled by enabling `CONFIG_NVS_ENCRYPTION`. The keys required for NVS encryption are stored in yet another partition, which is protected using Flash Encryption. Therefore, enabling Flash Encryption is a prerequisite for NVS encryption.

The NVS Encryption is enabled by default when Flash Encryption is enabled. This is done because Wi-Fi driver stores credentials (like SSID and passphrase) in the default NVS partition. It is important to encrypt them as default choice if platform level encryption is already enabled.

For using NVS encryption, the partition table must contain the NVS key partition. Two partition tables containing the NVS key partition are provided for NVS encryption under the partition table option (menuconfig->Partition Table). They can be selected with the project configuration menu (`idf.py menuconfig`). Please refer to the example security/flash_encryption for how to configure and use NVS encryption feature.

NVS key partition

An application requiring NVS encryption support needs to be compiled with a key-partition of the type `data` and subtype `key`. This partition should be marked as `encrypted` and its size should be the minimum partition size (4KB). Refer to Partition Tables for more details. Two additional partition tables which
Chapter 2. API Reference

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 these 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 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 module restarts.
    - value - tracks the number of the ESP32 module soft and hard restarts.
    - blob - contains a table with module run times. The table is read from NVS to dynamically allocated RAM. A new run time is added to the table on each manually triggered soft restart, and then the added run time is written to NVS. Triggering is done by pulling down GPIO0.
  - The example also shows how to implement the diagnostic procedure to check if the read / write operation was successful.

- `storage/nvs_rw_value_cxx`
  - This example does exactly the same as `storage/nvs_rw_value`, except that it uses the C++ NVS handle class.

Internals

**Log of key-value pairs**

NVS stores key-value pairs sequentially, with new key-value pairs being added at the end. When a value of any given key has to be updated, a new key-value pair is added at the end of the log and the old key-value pair is marked as erased.
Pages and entries  NVS library uses two main entities in its operation: pages and entries. Page is a logical structure which stores a portion of the overall log. Logical page corresponds to one physical sector of flash memory. Pages which are in use have a sequence number associated with them. Sequence numbers impose an ordering on pages. Higher sequence numbers correspond to pages which were created later. Each page can be in one of the following states:

Empty/ uninitialized  Flash storage for the page is empty (all bytes are 0xff). Page is not used to store any data at this point and does not have a sequence number.

Active  Flash storage is initialized, page header has been written to flash, page has a valid sequence number. Page has some empty entries and data can be written there. No more than one page can be in this state at any given moment.

Full  Flash storage is in a consistent state and is filled with key-value pairs. Writing new key-value pairs into this page is not possible. It is still possible to mark some key-value pairs as erased.

Erasing  Non-erased key-value pairs are being moved into another page so that the current page can be erased. This is a transient state, i.e., page should never stay in this state at the time when any API call returns. In case of a sudden power off, the move-and-erase process will be completed upon the next power-on.

Corrupted  Page header contains invalid data, and further parsing of page data was canceled. Any items previously written into this page will not be accessible. The corresponding flash sector will not be erased immediately and will be kept along with sectors in uninitialized state for later use. This may be useful for debugging.

Mapping from flash sectors to logical pages does not have any particular order. The library will inspect sequence numbers of pages found in each flash sector and organize pages in a list based on these numbers.

<table>
<thead>
<tr>
<th>State (4)</th>
<th>Seq. no. (4)</th>
<th>version (1)</th>
<th>Unused (19)</th>
<th>CRC32 (4)</th>
<th>Header (32)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry state bitmap (32)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entry 0 (32)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entry 1 (32)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entry 125 (32)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Structure of a page  For now, we assume that flash sector size is 4096 bytes and that ESP32 flash encryption hardware operates on 32-byte blocks. It is possible to introduce some settings configurable at compile-time (e.g., via menuconfig) to accommodate flash chips with different sector sizes (although it is not clear if other components in the system, e.g., SPI flash driver and SPI flash cache can support these other sizes).

Page consists of three parts: header, entry state bitmap, and entries themselves. To be compatible with ESP32 flash encryption, the entry size is 32 bytes. For integer types, an entry holds one key-value pair. For strings and blobs, an entry holds part of key-value pair (more on that in the entry structure description).

The following diagram illustrates the page structure. Numbers in parentheses indicate the size of each part in bytes.
Chapter 2. API Reference

Page header and entry state bitmap are always written to flash unencrypted. Entries are encrypted if flash encryption feature of ESP32 is used.

Page state values are defined in such a way that changing state is possible by writing 0 into some of the bits. Therefore it is not necessary to erase the page to change its state unless that is a change to the erased state.

The version field in the header reflects the NVS format version used. For backward compatibility reasons, it is decremented for every version upgrade starting at 0xff (i.e., 0xff for version-1, 0xfe for version-2 and so on).

CRC32 value in the header is calculated over the part which does not include a state value (bytes 4 to 28). The unused part is currently filled with 0xff bytes.

The following sections describe the structure of entry state bitmap and entry itself.

**Entry and entry state bitmap** Each entry can be in one of the following three states represented with two bits in the entry state bitmap. The final four bits in the bitmap (256 - 2 * 126) are not used.

**Empty (2’ b11)** Nothing is written into the specific entry yet. It is in an uninitialized state (all bytes are 0xff).

**Written (2’ b10)** A key-value pair (or part of key-value pair which spans multiple entries) has been written into the entry.

**Erased (2’ b00)** A key-value pair in this entry has been discarded. Contents of this entry will not be parsed anymore.

**Structure of entry** For values of primitive types (currently integers from 1 to 8 bytes long), entry holds one key-value pair. For string and blob types, entry holds part of the whole key-value pair. For strings, in case when a key-value pair spans multiple entries, all entries are stored in the same page. Blobs are allowed to span over multiple pages by dividing them into smaller chunks. For tracking these chunks, an additional fixed length metadata entry is stored called “blob index”. Earlier formats of blobs are still supported (can be read and modified). However, once the blobs are modified, they are stored using the new format.

Individual fields in entry structure have the following meanings:

**NS** Namespace index for this entry. For more information on this value, see the section on namespaces implementation.

**Type** One byte indicating the value data type. See the `ItemType` enumeration in `nvs_flash/include/nvs_handle.hpp` for possible values.
Span  Number of entries used by this key-value pair. For integer types, this is equal to 1. For strings and blobs, this depends on value length.

ChunkIndex  Used to store the index of a blob-data chunk for blob types. For other types, this should be 0xff.

CRC32  Checksum calculated over all the bytes in this entry, except for the CRC32 field itself.

Key  Zero-terminated ASCII string containing a key name. Maximum string length is 15 bytes, excluding a zero terminator.

Data  For integer types, this field contains the value itself. If the value itself is shorter than 8 bytes, it is padded to the right, with unused bytes filled with 0xff.

For “blob index” entry, these 8 bytes hold the following information about data-chunks:

- Size  (Only for blob index.) Size, in bytes, of complete blob data.
- ChunkCount  (Only for blob index.) Total number of blob-data chunks into which the blob was divided during storage.
- ChunkStart  (Only for blob index.) ChunkIndex of the first blob-data chunk of this blob. Subsequent chunks have chunkIndex incrementally allocated (step of 1).

For string and blob data chunks, these 8 bytes hold additional data about the value, which are described below:

- Size  (Only for strings and blobs.) Size, in bytes, of actual data. For strings, this includes zero terminators.
- CRC32  (Only for strings and blobs.) Checksum calculated over all bytes of data.

Variable length values (strings and blobs) are written into subsequent entries, 32 bytes per entry. The Span field of the first entry indicates how many entries are used.

Namespaces  As mentioned above, each key-value pair belongs to one of the namespaces. Namespace identifiers (strings) are stored as keys of key-value pairs in namespace with index 0. Values corresponding to these keys are indexes of these namespaces.

```
+-------------------------------------------+ Entry describing namespace "wifi"
| NS=0 Type=uint8_t Key="wifi" Value=1 |
+-------------------------------------------+ Key "channel" in namespace "wifi"
| NS=1 Type=uint32_t Key="channel" Value=6 |
+-------------------------------------------+ Entry describing namespace "pwm"
| NS=0 Type=uint8_t Key="pwm" Value=2 |
+-------------------------------------------+ Key "channel" in namespace "pwm"
| NS=2 Type=uint16_t Key="channel" Value=20 |
+-------------------------------------------+
```

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).

```c
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.

```c
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.

```c
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

```c
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

`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 initialized 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)

`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 initialized 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

`esp_err_t nvs_flash_erase_partition_ptr (const esp_partition_t *partition)`
Erase custom partition.

Erase all content of specified custom partition.

**Note** If the partition is initialized, this function first de-initializes it. Afterwards, the partition has to be initialized again to be used.

**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.

`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.
Chapter 2. API Reference

`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.

`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 nvs security configuration structure. Pointer must be non-NULL. Generated keys will be populated in this structure.

`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 nvs security configuration structure. Pointer must be non-NULL.

Structures

`struct nvs_sec_cfg_t`

Key for encryption and decryption.

Public Members

- `uint8_t eky[NVS_KEY_SIZE]` XTS encryption and decryption key
- `uint8_t tky[NVS_KEY_SIZE]` XTS tweak key

Macros

- `NVS_KEY_SIZE`

Header File

- components/nvs_flash/include/nvs.h
Functions

`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)`

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)`

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)`

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)`

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)`

This function is the same as `nvs_set_i8` except for the data type.

`esp_err_t nvs_set_i64 (nvs_handle_t handle, const char* key, int64_t value)`

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)`

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.

```c
esp_err_t nvs_get_i8 (nvs_handle_t handle, const char *key, int8_t *out_value)
```

get int8_t value for given key

These functions retrieve value for the key, given its name. If key does not exist, or the requested variable type doesn’t match the type which was used when setting a value, an error is returned.

In case of any error, out_value is not modified.

```c
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_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_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 if 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 if 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.

```c
esp_err_t nvs_set_blob(nvs_handle_t handle, const char *key, const void *value, size_t length)
```

set variable length binary value for given key

This family of functions set value for the key, given its name. Note that actual storage will not be updated until nvs_commit function is called.

**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.

```c
esp_err_t nvs_erase_key(nvs_handle_t handle, const char *key)
```

Erase key-value pair with given key name.

Note that actual storage may not be updated until nvs_commit function is called.

**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.

```c
esp_err_t nvs_erase_all(nvs_handle_t handle)
```

Erase all key-value pairs in a namespace.

Note that actual storage may not be updated until nvs_commit function is called.

**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.

```c
esp_err_t nvs_commit(nvs_handle_t handle)
```

Write any pending changes to non-volatile storage.

After setting any values, nvs_commit() must be called to ensure changes are written to non-volatile storage. Individual implementations may write to storage at other times, but this is not guaranteed.

**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**
Chapter 2.  API Reference

- [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.

```
// Example of nvs_get_stats() to get the number of used entries and free_entries:
void nvs_stats_t nvs_stats;
const char *partition_name = NULL;
if (nvs_get_stats(partition_name, &nvs_stats) == ESP_OK){
    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_NVS_INVALID_HANDLE if handle has been closed or is NULL. Return param `nvs_stats` will be filled 0.
- ESP_ERR_INVALID_ARG if `nvs_stats` equal to NULL.
- Other error codes from the underlying storage driver. Return param `nvs_stats` will be filled 0.

Parameters

- [in] part_name: Partition name NVS in the partition table. If pass a NULL than will use NVS_DEFAULT_PART_NAME ("nvs").
- [out] nvs_stats: Returns filled structure `nvs_states_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.

```
// Example of nvs_get_used_entry_count() to get amount of all key-value pairs in one namespace:
const char *partition_name = NULL;
void nvs_stats_t nvs_stats;
if (nvs_get_used_entry_count(handle, &nvs_stats) == ESP_OK){
    size_t used_entries;
    size_t 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.

```c
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.

```c
// 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);
};
```

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.

```c
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.

```c
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

• [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

```c
char namespace_name[16]
```

Namespace to which key-value belong
Chapter 2. API Reference

char key[16]
    Key of stored key-value pair

nvs_type_t type
    Type of stored key-value pair

struct nvs_stats_t
    Note Info about storage space NVS.

Public Members

size_t used_entries
    Amount of used entries.

size_t free_entries
    Amount of free entries.

size_t total_entries
    Amount all available entries.

size_t namespace_count
    Amount name space.

Macros

ESP_ERR_NVS_BASE
    Starting number of error codes

ESP_ERR_NVS_NOT_INITIALIZED
    The storage driver is not initialized

ESP_ERR_NVS_NOT_FOUND
    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

ESP_ERR_NVSINVALID_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_NVSKEY_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)

NVS_KEY_NAME_MAX_SIZE
Maximum length of NVS key name (including null terminator)

**Type Definitions**

typedef uint32_t nvs_handle_t
Opaque pointer type representing non-volatile storage 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**

typedef uint32_t nvs_open_mode_t
Mode of opening the non-volatile storage.

*Values:*
Chapter 2. API Reference

**NVS_READONLY**
Read only

**NVS_READWRITE**
Read and write

```c
enum nvs_type_t
```
Types of variables.

**Values:**

```c
NVS_TYPE_U8 = 0x01
  Type uint8_t
NVS_TYPE_I8 = 0x11
  Type int8_t
NVS_TYPE_U16 = 0x02
  Type uint16_t
NVS_TYPE_I16 = 0x12
  Type int16_t
NVS_TYPE_U32 = 0x04
  Type uint32_t
NVS_TYPE_I32 = 0x14
  Type int32_t
NVS_TYPE_U64 = 0x08
  Type uint64_t
NVS_TYPE_I64 = 0x18
  Type int64_t
NVS_TYPE_STR = 0x21
  Type string
NVS_TYPE_BLOB = 0x42
  Type blob
NVS_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.</td>
<td>As of now, for the file type, only hex2bin, base64, string, and binary encoding is supported.</td>
</tr>
<tr>
<td>4</td>
<td>Value</td>
<td>Data value.</td>
<td>Encoding and Value cells for the namespace field type should be empty. Encoding and Value of namespace is fixed and is not configurable. Any values in these cells are ignored.</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:**

```
python nvs_partition_gen.py [-h] {generate,generate-key,encrypt,decrypt} ...
```

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-h, --help</td>
<td>show this help message and exit</td>
</tr>
</tbody>
</table>

Commands:

Run nvs_partition_gen.py {command} -h for additional help

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>generate</td>
<td>Generate NVS partition</td>
</tr>
<tr>
<td>2</td>
<td>generate-key</td>
<td>Generate keys for encryption</td>
</tr>
<tr>
<td>3</td>
<td>encrypt</td>
<td>Generate NVS encrypted partition</td>
</tr>
<tr>
<td>4</td>
<td>decrypt</td>
<td>Decrypt NVS encrypted partition</td>
</tr>
</tbody>
</table>

To generate NVS partition (Default):
You can run the utility to generate NVS partition using the command below: A sample CSV file is provided with the utility:

```python
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>
<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>-outdir OUTDIR</td>
<td>Output directory to store files created</td>
</tr>
<tr>
<td></td>
<td>(Default: current directory)</td>
</tr>
</tbody>
</table>
```

To generate only encryption keys:
Usage:

```
python nvs_partition_gen.py generate-key [-h] [--keyfile KEYFILE] [--outdir OUTDIR]
```

Optional Arguments:

```
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-h, --help</td>
<td>show this help message and exit</td>
</tr>
<tr>
<td>--keyfile</td>
<td>Path to output encryption keys file</td>
</tr>
<tr>
<td></td>
<td>(Default: current directory)</td>
</tr>
</tbody>
</table>
```

You can run the utility to generate only encryption keys using the command below:

```
python nvs_partition_gen.py generate-key
```

To generate encrypted NVS partition:

Usage:

```
python nvs_partition_gen.py encrypt [-h] [--version {1,2}] [--keygen] [--keyfile KEYFILE] [--inputkey] [--outdir OUTDIR]
```

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:

(continues on next page)
You can run the utility to encrypt NVS partition using the command below: A sample CSV file is provided with the utility:

- Encrypt by allowing the utility to generate encryption keys:

```
python nvs_partition_gen.py encrypt sample_singlepage_blob.csv sample_encr.bin --0x3000 --keygen
```

**Note:** Encryption key of the following format `<outdir>/keys/keys-<timestamp>.bin` is created.

- Encrypt by allowing the utility to generate encryption keys and store it in provided custom filename:

```
python nvs_partition_gen.py encrypt sample_singlepage_blob.csv sample_encr.bin --0x3000 --keygen --keyfile sample_keys.bin
```

**Note:** Encryption key of the following format `<outdir>/keys/sample_keys.bin` is created.

**Note:** This newly created file having encryption keys in keys/ directory is compatible with NVS key-partition
structure. Refer to *NVS key partition* for more details.

- Encrypt by providing the encryption keys as input binary file:

  ```
  python nvs_partition_gen.py encrypt sample_singlepage_blob.csv sample_encr.bin --0x3000 --inputkey sample_keys.bin
  ```

**To decrypt encrypted NVS partition:**

**Usage:**

```python
python nvs_partition_gen.py decrypt [-h] [--outdir OUTDIR] input key_
    -output

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>

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>
```

You can run the utility to decrypt encrypted NVS partition using the command below:

```python
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:
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 multiline strings with `file` type and singleline strings with `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/sdspi_host.h`) provide API functions for:

- Sending commands to slave devices
- Sending and receiving data
- Handling error conditions within the bus

For functions used to initialize and configure:

- SDMMC host, see [SDMMC Host API](#)
- SD SPI host, see [SD SPI Host API](#)

The SDMMC protocol layer described in this document handles the specifics of the SD protocol, such as the card initialization and data transfer commands.

The protocol layer works with the host via the `sdmmc_host_t` structure. This structure contains pointers to various functions of the host.

**Application Example**

An example which combines the SDMMC driver with the FATFS library is provided in the `storage/sd_card` directory of ESP-IDF examples. This example initializes the card, then writes and reads data from it using POSIX and C library APIs. See README.md file in the example directory for more information.
**Combo (memory + IO) cards**  The driver does not support SD combo cards. Combo cards are treated as IO cards.

**Thread safety**  Most applications need to use the protocol layer only in one task. For this reason, the protocol layer does not implement any kind of locking on the `sdmmc_card_t` structure, or when accessing SDMMC or SD SPI host drivers. Such locking is usually implemented on a higher layer, e.g., in the filesystem driver.

**Protocol layer API**

The protocol layer is given the `sdmmc_host_t` structure. This structure describes the SD/MMC host driver, lists its capabilities, and provides pointers to functions of the driver. The protocol layer stores card-specific information in the `sdmmc_card_t` structure. When sending commands to the SD/MMC host driver, the protocol layer uses the `sdmmc_command_t` structure to describe the command, arguments, expected return values, and data to transfer if there is any.

**Using API with SD memory cards**

1. To initialize the host, call the host driver functions, e.g., `sdmmc_host_init()`, `sdmmc_host_init_slot()`.
2. To initialize the card, call `sdmmc_card_init()` and pass to it the parameters `host` - the host driver information, and `card` - a pointer to the structure `sdmmc_card_t` which will be filled with information about the card when the function completes.
3. To read and write sectors of the card, use `sdmmc_read_sectors()` and `sdmmc_write_sectors()` respectively and pass to it the parameter `card` - a pointer to the card information structure.
4. If the card is not used anymore, call the host driver function - e.g., `sdmmc_host_deinit()` - to disable the host peripheral and free the resources allocated by the driver.

**Using API with eMMC chips**  From the protocol layer’s perspective, eMMC memory chips behave exactly like SD memory cards. Even though eMMCs are chips and do not have a card form factor, the terminology for SD cards can still be applied to eMMC due to the similarity of the protocol (`sdmmc_card_t`, `sdmmc_card_init`). Note that eMMC chips cannot be used over SPI, which makes them incompatible with the SD SPI host driver.

To initialize eMMC memory and perform read/write operations, follow the steps listed for SD cards in the previous section.

**Using API with SDIO cards**  Initialization and the probing process are the same as with SD memory cards. The only difference is in data transfer commands in SDIO mode.

During the card initialization and probing, performed with `sdmmc_card_init()`, the driver only configures the following registers of the IO card:

1. The IO portion of the card is reset by setting RES bit in the I/O Abort (0x06) register.
2. If 4-line mode is enabled in host and slot configuration, the driver attempts to set the Bus width field in the Bus Interface Control (0x07) register. If setting the filed is successful, which means that the slave supports 4-line mode, the host is also switched to 4-line mode.
3. If high-speed mode is enabled in the host configuration, the SHS bit is set in the High Speed (0x13) register.

In particular, the driver does not set any bits in (1) I/O Enable and Int Enable registers, (2) I/O block sizes, etc. Applications can set them by calling `sdmmc_io_write_byte()`.

For card configuration and data transfer, choose the pair of functions relevant to your case from the table below.

<table>
<thead>
<tr>
<th>Action</th>
<th>Read Function</th>
<th>Write Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read and write a single byte using IO_RW_DIRECT (CMD52)</td>
<td><code>sdmmc_io_read_byte()</code></td>
<td><code>sdmmc_io_write_byte()</code></td>
</tr>
<tr>
<td>Read and write multiple bytes using IO_RW_EXTENDED (CMD53) in byte mode</td>
<td><code>sdmmc_io_read_bytes()</code></td>
<td><code>sdmmc_io_write_bytes()</code></td>
</tr>
<tr>
<td>Read and write blocks of data using IO_RW_EXTENDED (CMD53) in block mode</td>
<td><code>sdmmc_io_read_blocks()</code></td>
<td><code>sdmmc_io_write_blocks()</code></td>
</tr>
</tbody>
</table>
SDIO interrupts can be enabled by the application using the function `sdmmc_io_enable_int()`. When using SDIO in 1-line mode, the D1 line also needs to be connected to use SDIO interrupts.

If you want the application to wait until the SDIO interrupt occurs, use `sdmmc_io_wait_int()`.

There is a component ESSL (ESP Serial Slave Link) to use if you are communicating with an ESP32 SDIO slave. See [ESP Serial Slave Link](#) and example `peripherals/sdio/host`.

### 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
  - One of the error codes from SDMMC host controller

  **Parameters**
  
  - `card`: pointer to card information structure previously initialized using `sdmmc_card_init`

- **`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->sectorsize`
  - `start_sector`: sector where to start writing
  - `sector_count`: number of sectors to write

- **`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
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`
- `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_write_bytes(sdmmc_card_t *card, uint32_t function, uint32_t addr, const void *src, size_t size)
```

Write multiple bytes to an SDIO card using IO_RW_EXTENDED (CMD53)

This function performs write operation using CMD53 in byte mode. For block mode, see `sdmmc_io_write_blocks`.

**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

```
esp_err_t sdmmc_io_read_blocks (sdmmc_card_t *card, uint32_t function, uint32_t addr, void *dst, size_t size)
```

Read blocks of data from an SDIO card using IO_RW_EXTENDED (CMD53)

This function performs read operation using CMD53 in block mode. For byte mode, see sdmmc_io_read_bytes.

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**: buffer which receives the data read from card
- **size**: number of bytes to read, must be divisible by the card block size.

```
esp_err_t sdmmc_io_write_blocks (sdmmc_card_t *card, uint32_t function, uint32_t addr, const void *src, size_t size)
```

Write blocks of data to an SDIO card using IO_RW_EXTENDED (CMD53)

This function performs write operation using CMD53 in block mode. For byte mode, see sdmmc_io_write_bytes.

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.

```
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

```
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
** 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.

** 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

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.

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

```c
int command_timeout_ms
```
timeout, in milliseconds, of a single command. Set to 0 to use the default value.

```c
struct sdmmc_card_t
```
SD/MMC card information structure

**Public Members**

`sdmmc_host_t host`
Host with which the card is associated

`uint32_t ocr`
OCR (Operation Conditions Register) value

`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

`sdmmc_scr_t scr`
decoded SCR (SD card Configuration Register) value

`sdmmc_ext_csd_t ext_csd`
decoded EXT_CSD (Extended Card Specific Data) register value

`uint16_t rca`
RCA (Relative Card Address)

`uint16_t max_freq_khz`
Maximum frequency, in kHz, supported by the card

`uint32_t is_mem : 1`
Bit indicates if the card is a memory card

`uint32_t is_sdio : 1`
Bit indicates if the card is an IO card

`uint32_t is_mmc : 1`
Bit indicates if the card is MMC

`uint32_t num_io_functions : 3`
If is_sdio is 1, contains the number of IO functions on the card

`uint32_t log_bus_width : 2`
log2(bus width supported by card)

`uint32_t is_ddr : 1`
Card supports DDR mode
Chapter 2. API Reference

```c
uint32_t reserved : 23
    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

### Type Definitions

```c
typedef uint32_t sdmmc_response_t[4]
    SD/MMC command response buffer
```

#### 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

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
  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

**Concurrency Constraints for flash on SPI1** The SPI0/1 bus is shared between the instruction & data cache (for firmware execution) and the SPI1 peripheral (controlled by the drivers including this SPI Flash driver). Hence, operations to SPI1 will cause significant influence to the whole system. This kind of operations include calling SPI Flash API or other drivers on SPI1 bus, any operations like read/write/erase or other user defined SPI operations, regardless to the main flash or other SPI slave devices.

On ESP32, these caches must be disabled while reading/writing/erasing.

**When the caches are disabled** This means that all CPUs must be running code from IRAM and must only be reading data from DRAM while flash write operations occur. If you use the API functions documented here, then the caches will be disabled automatically and transparently. However, note that it will have some performance impact on other tasks in the system.

There are no such constraints and impacts for flash chips on other SPI buses than SPI0/1.

For differences between IRAM, DRAM, and flash cache, please refer to the application memory layout documentation.

To avoid reading flash cache accidentally, when one CPU initiates a flash write or erase operation, the other CPU is put into a blocked state, and all non-IRAM-safe interrupts are disabled on all CPUs until the flash operation completes.

See also OS Functions, SPI Bus Lock.
IRAM-Safe Interrupt Handlers  If you have an interrupt handler that you want to execute while a flash operation is in progress (for example, 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.

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 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 memory-spi functionalities. However due to the speed limitations of ESP32, the HAL layer can’t provide high-speed implementations to some reading commands (So we didn’t do it at 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 require 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.

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.

API Reference - SPI Flash

Header File

- components/spi_flash/include/esp_flash_spi_init.h

Functions

```c
esp_err_t spi_bus_add_flash_device(esp_flash_t **out_chip, const esp_flash_spi_device_config_t *config)
```

Add a SPI Flash device onto the SPI bus.

The bus should be already initialized by spi_bus_initialization.
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.

`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

`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

`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.

```c
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.
```

```c
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.
```

```c
esp_err_t esp_flash_read_unique_chip_id(esp_flash_t *chip, uint64_t *out_id)
    Read flash unique ID via the common “RDUID” SPI flash command.
    
    ID is a 64-bit value.
    
    **Parameters**
    - chip: Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init()
    - [out] 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.
```

```c
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()
```

```c
esp_err_t esp_flash_erase_region(esp_flash_t *chip, uint32_t start, uint32_t len)
    Erase a region of the flash chip.
    
    **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.

```c
esp_err_t esp_flash_get_chip_write_protect (esp_flash_t *chip, bool *write_protected)
```

Read if the entire chip is write protected.

**Note** A correct result for this flag depends on the SPI flash chip model and chip_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()
- [out] write_protected: Pointer to boolean, set to the value of the write protect flag.

```c
esp_err_t esp_flash_set_chip_write_protect (esp_flash_t *chip, bool write_protect)
```

Set write protection for the SPI flash chip.

Some SPI flash chips may require a power cycle before write protect status can be cleared. Otherwise, write protection can be removed via a follow-up call to this function.

**Note** Correct behaviour of this function depends on the SPI flash chip model and chip_drv in use (via the ‘chip->drv’ field).

**Parameters**
- chip: Pointer to identify flash chip. 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.

```c
esp_err_t esp_flash_get_protectable_regions (const esp_flash_t *chip, const esp_flash_region_t **out_regions, uint32_t *out_num_regions)
```

Read the list of individually protectable regions of this SPI flash chip.

**Note** Correct behaviour of this function depends on the SPI flash chip model and chip_drv in use (via the ‘chip->drv’ field).

**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’.

```c
esp_err_t esp_flash_get_protected_region (esp_flash_t *chip, const esp_flash_region_t *region, bool *out_protected)
```

Detect if a region of the SPI flash chip is protected.

**Note** It is possible for this result to be false and write operations to still fail, if protection is enabled for the entire chip.

**Note** Correct behaviour of this function depends on the SPI flash chip model and chip_drv in use (via the ‘chip->drv’ field).

**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

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_read_encrypted(esp_flash_t *chip, uint32_t address, void *out_buffer, uint32_t length)
```

Read and decrypt data from the SPI flash chip using on-chip hardware flash encryption.

**Return**
- ESP_OK: on success
- ESP_ERR_NOT_SUPPORTED: encrypted read not supported for this chip.
- or other flash error code from spi_flash_read_encrypted().

**Parameters**
- *chip*: Pointer to identify flash chip. Must be NULL (the main flash chip). For other chips, encrypted read is not supported.
- *address*: Address on flash to read from.
- *out_buffer*: Pointer to a buffer for the data to read to.
- *length*: Length (in bytes) of data to read.

```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

**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.

**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 is called at most once for each call to ‘end’).

```c
esp_err_t (*end)(void *arg)
```

Called after completing any flash operation.

```c
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

```c
esp_err_t (*delay_us)(void *arg, uint32_t us)
```

Delay for at least ‘us’ microseconds. Called in between ‘start’ and ‘end’.
Chapter 2. API Reference

- `void *(*get_temp_buffer)(void *arg, size_t request_size, size_t*out_size)`
  Called for get temp buffer when buffer from application cannot be directly read into/write from.

- `void *(*release_temp_buffer)(void *arg, void *temp_buf)`
  Called for release temp buffer.

- `esp_err_t (*check_yield)(void *arg, uint32_t chip_status, uint32_t*out_request)`
  Yield to other tasks. Called during erase operations.
  Return: ESP_OK means need 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.

**Public Members**

- `spi_flash_host_inst_t *host`
  Pointer to hardware-specific “host_driver” structure. Must be initialized before used.

- `const spi_flash_chip_t *chip_drv`
  Pointer to chip-model-specific “adapter” structure. If NULL, will be detected during initialisation.

- `const esp_flash_os_functions_t *os_func`
  Pointer to os-specific hook structure. Call esp_flash_init_os_functions() to setup this field, after the host is properly initialized.

- `void *os_func_data`
  Pointer to argument for os-specific hooks. Left NULL and will be initialized with os_func.

- `esp_flash_io_mode_t read_mode`
  Configured SPI flash read mode. Set before esp_flash_init is called.

- `uint32_t size`
  Size of SPI flash in bytes. If 0, size will be detected during initialisation.

- `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_cmd_conf
Configuration structure for the flash chip suspend feature.

Public Members

uint32_t sus_mask
SUS/SUS1/SUS2 bit in flash register.

uint32_t cmd_rdsr : 8
Read flash status register(2) command.

uint32_t sus_cmd : 8
Flash suspend command.

uint32_t res_cmd : 8
Flash resume command.
Chapter 2. API Reference

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 reconfigure those registers when we send continuously

esp_err_t (*common_command) (spi_flash_host_inst_t *host, spi_flash_trans_t *t)
  Send an user-defined spi transaction to the device.

esp_err_t (*read_id) (spi_flash_host_inst_t *host, uint32_t *id)
  Read flash ID.

void (*erase_chip) (spi_flash_host_inst_t *host)
  Erase whole flash chip.
Chapter 2. API Reference

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.

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

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.

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.

```
esp_err_t esp_partition_write(const esp_partition_t *partition, size_t dst_offset, const void *src, 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.

```
esp_err_t esp_partition_read_raw(const esp_partition_t *partition, size_t src_offset, void *dst, size_t size)
```

Read data from the partition without any transformation/decryption.

**Note** This function is essentially the same as `esp_partition_read()` above. It just never decrypts data but returns it as is.

**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.

```
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 handle 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:
• `[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.

```c
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
Chapter 2. API Reference

- 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).

```c
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

```c
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**

```c
struct esp_partition_t
```

partition information structure

This is not the format in flash, that format is `esp_partition_info_t`.

However, this is the format used by this API.

**Public Members**

```c
esp_flash_t *flash_chip
```

SPI flash chip on which the partition resides
**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**: 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.

```c
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.
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.

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**

define **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:

```
python spiffsgen.py <image_size> <base_dir> <output_file>
```

The required arguments are as follows:
- **image_size**: size of the partition onto which the created SPIFFS image will be flashed.
- **base_dir**: directory for which the SPIFFS image needs to be created.
- **output_file**: SPIFFS image output file.
There are also other arguments that control image generation. Documentation on these arguments can be found in the tool’s help:

```
python spiffsgen.py --help
```

These optional arguments correspond to a possible SPIFFS build configuration. To generate the right image, please make sure that you use the same arguments/configuration as were used to build SPIFFS. As a guide, the help output indicates the SPIFFS build configuration to which the argument corresponds. In cases when these arguments are not specified, the default values shown in the help output will be used.

When the image is created, it can be flashed using `esptool.py` or `parttool.py`.

Aside from invoking the `spiffsgen.py` standalone by manually running it from the command line or a script, it is also possible to invoke `spiffsgen.py` directly from the build system by calling `spiffs_create_partition_image`:

```
spiffs_create_partition_image(<partition> <base_dir> [FLASH_IN_PROJECT] [DEPENDS... --dep dep dep...])
```

This is more convenient as the build configuration is automatically passed to the tool, ensuring that the generated image is valid for that build. An example of this is while the `image_size` is required for the standalone invocation, only the `partition` name is required when using `spiffs_create_partition_image`; the image size is automatically obtained from the project’s partition table.

`spiffs_create_partition_image` must be called from one of the component CMakeLists.txt files.

Optionally, users can opt to have the image automatically flashed together with the app binaries, partition tables, etc. on `idf.py flash` by specifying `FLASH_IN_PROJECT`. For example:

```
spiffs_create_partition_image(my_spiffs_partition my_folder FLASH_IN_PROJECT)
```

If `FLASH_IN_PROJECT/SPIFFS_IMAGE_FLASH_IN_PROJECT` is not specified, the image will still be generated, but you will have to flash it manually using `esptool.py`. `parttool.py`, or a custom build system target.

There are cases where the contents of the base directory itself is generated at build time. Users can use `DEPENDS/SPIFFS_IMAGE_DEPENDS` to specify targets that should be executed before generating the image:

```
add_custom_target(dep COMMAND ...)
spiffs_create_partition_image(my_spiffs_partition my_folder DEPENDS dep)
```

For an example, see `storage/spiffsgen.mkspiffs`.

`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:

```
mkspiffs -c [src_folder] -b 4096 -p 256 -s 0x100000 spiffs.bin
```

To flash the image onto ESP32 at offset 0x110000, run:

```
python esptool.py --chip esp32 --port [port] --baud [baud] write_flash -z 0x110000... --spiffs.bin
```
Notes on which SPIFFS tool to use  The two tools presented above offer very similar functionality. However, there are reasons to prefer one over the other, depending on the use case.

Use `spiffsgen.py` in the following cases:

1. If you want to simply generate a SPIFFS image during the build. `spiffsgen.py` makes it very convenient by providing functions/commands from the build system itself.
2. If the host has no C/C++ compiler available, because `spiffsgen.py` does not require compilation.

Use `mkspiffs` in the following cases:

1. If you need to unpack SPIFFS images in addition to image generation. For now, it is not possible with `spiffsgen.py`.
2. If you have an environment where a Python interpreter is not available, but a host compiler is available. Otherwise, a pre-compiled `mkspiffs` binary can do the job. However, there is no build system integration for `mkspiffs` and the user has to do the corresponding work: compiling `mkspiffs` during build (if a pre-compiled binary is not used), creating build rules/targets for the output files, passing proper parameters to the tool, etc.

See also

- `Partition Table documentation`

Application Example

An example of using SPIFFS is provided in the `storage/spiffs` directory. This example Initializes and mounts a SPIFFS partition, then writes and reads data from it using POSIX and C library APIs. See the README.md file in the example directory for more information.

High-level API Reference

Header File

- `components/spiffs/include/esp_spiffs.h`

Functions

```c
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

```c
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`.

```c
bool esp_spiffs_mounted(const char *partition_label)
```
Check if SPIFFS is mounted

Return
Chapter 2. API Reference

- 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.

```c
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.

```c
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**

```c
struct esp_vfs_spiffs_conf_t
```

Configuration structure for esp_vfs_spiffs_register.

**Public Members**

```c
const char *base_path
```

File path prefix associated with the filesystem.

```c
const char *partition_label
```

Optional, label of SPIFFS partition to use. If set to NULL, first partition with subtype=spiffs will be used.

```c
size_t max_files
```

Maximum files that could be open at the same time.

```c
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 how the FS driver declares its API functions, either `read`, `write`, etc., or `read_p`, `write_p`, etc., should be used.

Case 1: API functions are declared without an extra context pointer (the FS driver is a singleton):

```c
ssize_t myfs_write(int fd, const void * data, size_t size);

// 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:
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.
**Chapter 2. API Reference**

**Note:** If `select()` is only used on socket file descriptors, you can enable the `CONFIG_LWIP_USE_ONLY_LWIP_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 *, int fd, void *dst, size_t size)

int esp_vfs_open(struct _reent *, const char *path, int flags, int mode)

int esp_vfs_close(struct _reent *, int fd)

int esp_vfs_fstat(struct _reent *, int fd, struct stat *st)

int esp_vfs_stat(struct _reent *, const char *path, struct stat *st)

int esp_vfs_link(struct _reent *, const char *r, const char *n2)

int esp_vfs_unlink(struct _reent *, const char *path)

int esp_vfs_rename(struct _reent *, const char *src, const char *dst)

int esp_vfs_utime(const char *, const struct utimbuf *times)

esp_err_t esp_vfs_register(const char *base_path, const esp_vfs_t *vfs, void *ctx)

Register a virtual filesystem for given path prefix.

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 must not end with `/`. For example, `~/data` or `~/dev/spi` are valid. These VFSes would then be called to handle file paths such as `~/data/myfile.txt` or `~/dev/spi/0`. In the special case of an empty base_path, a “fallback” VFS is registered. Such VFS will handle paths which are not matched by any other registered VFS.

• vfs: Pointer to esp_vfs_t, a structure which maps syscalls to the filesystem driver functions. VFS component doesn’t assume ownership of this pointer.

• ctx: If vfs->flags has ESP_VFS_FLAG_CONTEXT_PTR set, a pointer which should be passed to VFS functions. Otherwise, NULL.

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.

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
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

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 identifier returned by esp_vfs_register_with_id.
• fd: The registered file descriptor will be written to this address.

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 identifier returned by esp_vfs_register_with_id.
• fd: File descriptor which should be unregistered.

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.
• 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.

void esp_vfs_select_triggered (esp_vfs_select_sem_t sem)

Notification from a VFS driver about a read/write/error condition.
This function is called when the VFS driver detects a read/write/error condition as it was requested by the previous call to start_select.

Parameters

• `sem`: semaphore structure which was passed to the driver by the start_select call

```c
void esp_vfs_select_triggered_isr(esp_vfs_select_sem_t sem, BaseType_t *woken)
```

Notification from a VFS driver about a read/write/error condition (ISR version)

This function is called when the VFS driver detects a read/write/error condition as it was requested by the previous call to start_select.

Parameters

• `sem`: semaphore structure which was passed to the driver by the start_select call
• `woken`: is set to pdTRUE if the function wakes up a task with higher priority

```c
ssize_t esp_vfs_pread(int fd, void *dst, size_t size, off_t offset)
```

Implements the VFS layer of POSIX pread()

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`

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-file-system-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_FLAGCONTEXT_PTR and provide the context pointer to esp_vfs_register function. If the implementation doesn’t use this extra argument, populate the members without _p suffix and set flags member to ESP_VFS_FLAG_DEFAULT.
If the FS driver doesn’t provide some of the functions, set corresponding members to NULL.

**Public Members**

- `int flags`  
  ESP_VFS_FLAG_CONTEXT_PTR or ESP_VFS_FLAG_DEFAULT

- `ssize_t (*write_p)(void *p, int fd, const void *data, size_t size)`  
  Write with context pointer

- `ssize_t (*write)(int fd, const void *data, size_t size)`  
  Write without context pointer

- `off_t (*lseek_p)(void *p, int fd, off_t size, int mode)`  
  Seek with context pointer

- `off_t (*lseek)(int fd, off_t size, int mode)`  
  Seek without context pointer

- `ssize_t (*read_p)(void *ctx, int fd, void *dst, size_t size)`  
  Read with context pointer

- `ssize_t (*read)(int fd, void *dst, size_t size)`  
  Read without context pointer

- `ssize_t (*pread_p)(void *ctx, int fd, void *dst, size_t size, off_t offset)`  
  Pread with context pointer

- `ssize_t (*pread)(int fd, void *dst, size_t size, off_t offset)`  
  Pread without context pointer

- `ssize_t (*pwrite_p)(void *ctx, int fd, const void *src, size_t size, off_t offset)`  
  Pwrite with context pointer

- `ssize_t (*pwrite)(int fd, const void *src, size_t size, off_t offset)`  
  Pwrite without context pointer

- `int (*open_p)(void *ctx, const char *path, int flags, int mode)`  
  Open with context pointer

- `int (*open)(const char *path, int flags, int mode)`  
  Open without context pointer

- `int (*close_p)(void *ctx, int fd)`  
  Close with context pointer

- `int (*close)(int fd)`  
  Close without context pointer

- `int (*fstat_p)(void *ctx, int fd, struct stat *st)`  
  Fstat with context pointer

- `int (*fstat)(int fd, struct stat *st)`  
  Fstat without context pointer

- `int (*stat_p)(void *ctx, const char *path, struct stat *st)`  
  Stat with context pointer

- `int (*stat)(const char *path, struct stat *st)`  
  Stat without context pointer

- `int (*link_p)(void *ctx, const char *n1, const char *n2)`  
  Link with context pointer

- `int (*link)(const char *n1, const char *n2)`  
  Link without context pointer
Chapter 2. API Reference

int (*unlink_p)(void *ctx, const char *path)
  unlink with context pointer

int (*unlink)(const char *path)
  unlink without context pointer

int (*rename_p)(void *ctx, const char *src, const char *dst)
  rename with context pointer

int (*rename)(const char *src, const char *dst)
  rename without context pointer

DIR *(*opendir_p)(void *ctx, const char *name)
  opendir with context pointer

DIR *(*opendir)(const char *name)
  opendir without context pointer

struct dirent *(*readdir_p)(void *ctx, DIR *pdir)
  readdir with context pointer

struct dirent *(*readdir)(DIR *pdir)
  readdir without context pointer

int (*readdir_r_p)(void *ctx, DIR *pdir, struct dirent *entry, struct dirent **out_dirent)
  readdir_r with context pointer

int (*readdir_r)(DIR *pdir, struct dirent *entry, struct dirent **out_dirent)
  readdir_r without context pointer

long (*telldir_p)(void *ctx, DIR *pdir)
  telldir with context pointer

long (*telldir)(DIR *pdir)
  telldir without context pointer

void (*seekdir_p)(void *ctx, DIR *pdir, long offset)
  seekdir with context pointer

void (*seekdir)(DIR *pdir, long offset)
  seekdir without context pointer

int (*closedir_p)(void *ctx, DIR *pdir)
  closedir with context pointer

int (*closedir)(DIR *pdir)
  closedir without context pointer

int (*mkdir_p)(void *ctx, const char *name, mode_t mode)
  mkdir with context pointer

int (*mkdir)(const char *name, mode_t mode)
  mkdir without context pointer

int (*rmdir_p)(void *ctx, const char *name)
  rmdir with context pointer

int (*rmdir)(const char *name)
  rmdir without context pointer

int (*fcntl_p)(void *ctx, int fd, int cmd, int arg)
  fcntl with context pointer

int (*fcntl)(int fd, int cmd, int arg)
  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
Chapter 2. API Reference

- `ioctl`: int(* ioctl)(intfd, intcmd, va_listargs)
- `ioctl without context pointer`: int(* ioctl)(intfd, intcmd, va_listargs)
- `fsync`: int(* fsync)(void* ctx, intfd)
- `fsync with context pointer`: int(* fsync)(void* ctx, intfd)
- `access`: int(* access)(const char* path, intamode)
- `access without context pointer`: int(* access)(const char* path, intamode)
- `truncate`: int(* truncate)(const char* path, off_tlength)
- `truncate without context pointer`: int(* truncate)(const char* path, off_tlength)
- `utime`: int(* utime)(const char* path, const struct utimbuf*times)
- `utime without context pointer`: int(* utime)(const char* path, const struct utimbuf*times)
- `tcsetattr`: int(* tcsetattr)(intfd, intoptional_actions, const struct termios*p)
- `tcsetattr without context pointer`: int(* tcsetattr)(intfd, intoptional_actions, const struct termios*p)
- `tcgetattr`: int(* tcgetattr)(intfd, struct termios*p)
- `tcgetattr without context pointer`: int(* tcgetattr)(intfd, struct termios*p)
- `tcdrain`: int(* tcdrain)(intfd)
- `tcdrain without context pointer`: int(* tcdrain)(intfd)
- `tcflush`: int(* tcflush)(intfd, intselect)
- `tcflush without context pointer`: int(* tcflush)(intfd, intselect)
- `tcflow`: int(* tcflow)(intfd, intaction)
- `tcflow without context pointer`: int(* tcflow)(intfd, intaction)
- `tcgetsid`: pid_t(* tcgetsid)(intfd)
- `tcgetsid without context pointer`: pid_t(* tcgetsid)(intfd)
- `tcsendbreak`: int(* tcsendbreak)(intfd, intduration)
- `tcsendbreak without context pointer`: int(* tcsendbreak)(intfd, intduration)
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 (‘’, LF) passed into stdin:

• ESP_LINE_ENDINGS_CRLF: convert CRLF to LF
• ESP_LINE_ENDINGS_CR: convert CR to LF
• ESP_LINE_ENDINGS_LF: no modification

Note this function is not thread safe w.r.t. reading from UART

Parameters

• mode: line endings expected on UART
void \textbf{esp\_vfs\_dev\_uart\_set\_tx\_line\_endings}(\textbf{esp\_line\_endings\_t} \textit{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:

- \textbf{ESP\_LINE\_ENDINGS\_CRLF}: convert LF to CRLF
- \textbf{ESP\_LINE\_ENDINGS\_CR}: convert LF to CR
- \textbf{ESP\_LINE\_ENDINGS\_LF}: no modification

\textbf{Note} this function is not thread safe w.r.t. writing to UART

\textbf{Parameters}
- \textbf{mode}: line endings to send to UART

int \textbf{esp\_vfs\_dev\_uart\_port\_set\_rx\_line\_endings}(\textbf{int} \textit{uart\_num}, \textbf{esp\_line\_endings\_t} \textit{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:

- \textbf{ESP\_LINE\_ENDINGS\_CRLF}: convert CRLF to LF
- \textbf{ESP\_LINE\_ENDINGS\_CR}: convert CR to LF
- \textbf{ESP\_LINE\_ENDINGS\_LF}: no modification

\textbf{Note} this function is not thread safe w.r.t. reading from UART

\textbf{Return} 0 if succeeded, or -1 when an error (specified by errno) have occurred.

\textbf{Parameters}
- \textbf{uart\_num}: the UART number
- \textbf{mode}: line endings to send to UART

int \textbf{esp\_vfs\_dev\_uart\_port\_set\_tx\_line\_endings}(\textbf{int} \textit{uart\_num}, \textbf{esp\_line\_endings\_t} \textit{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:

- \textbf{ESP\_LINE\_ENDINGS\_CRLF}: convert LF to CRLF
- \textbf{ESP\_LINE\_ENDINGS\_CR}: convert LF to CR
- \textbf{ESP\_LINE\_ENDINGS\_LF}: no modification

\textbf{Note} this function is not thread safe w.r.t. writing to UART

\textbf{Return} 0 if succeeded, or -1 when an error (specified by errno) have occurred.

\textbf{Parameters}
- \textbf{uart\_num}: the UART number
- \textbf{mode}: line endings to send to UART

\textbf{void} \textbf{esp\_vfs\_dev\_uart\_use\_nonblocking}(\textbf{int} \textit{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.

\textbf{Parameters}
- \textbf{uart\_num}: UART peripheral number

\textbf{void} \textbf{esp\_vfs\_dev\_uart\_use\_driver}(\textbf{int} \textit{uart\_num})
set VFS to use UART driver for reading and writing

\textbf{Note} application must configure UART driver before calling these functions
With these functions, read and write are blocking and interrupt-driven.

\textbf{Parameters}
- \textbf{uart\_num}: UART peripheral number

\textbf{void} \textbf{esp\_vfs\_usb\_serial\_jtag\_use\_driver}(\textbf{void})
set VFS to use USB-SERIAL-JTAG driver for reading and writing

\textbf{Note} application must configure USB-SERIAL-JTAG driver before calling these functions
With these functions, 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 initial, 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 has a sector-based organization and also has a limited number of erase/modification cycles per memory sector. The wear levelling component helps to distribute wear and tear among sectors more evenly without requiring any attention from the user.

The wear levelling component provides API functions related to reading, writing, erasing, and memory mapping of data in external SPI flash through the partition component. The component also has higher-level API functions which work with the FAT filesystem defined in FAT filesystem.

The wear levelling component, together with the FAT FS component, uses FAT FS sectors of 4096 bytes, which is a standard size for flash memory. With this size, the component shows the best performance but needs additional memory in RAM.

To save internal memory, the component has two additional modes which both use sectors of 512 bytes:

- **Performance mode.** Erase sector operation data is stored in RAM, the sector is erased, and then data is copied back to flash memory. However, if a device is powered off for any reason, all 4096 bytes of data is lost.
- **Safety mode.** The data is first saved to flash memory, and after the sector is erased, the data is saved back. If a device is powered off, the data can be recovered as soon as the device boots up.
The default settings are as follows: - Sector size is 512 bytes - Performance mode

You can change the settings through the configuration menu.

The wear levelling component does not cache data in RAM. The write and erase functions modify flash directly, and flash contents are consistent when the function returns.

### Wear Levelling access API functions

This is the set of API functions for working with data in flash:

- `wl_mount` - initializes the wear levelling module and mounts the specified partition
- `wlUnmount` - unmounts the partition and deinitializes the wear levelling module
- `wl_erase_range` - erases a range of addresses in flash
- `wl_write` - writes data to a partition
- `wl_read` - reads data from a partition
- `wl_size` - returns the size of available memory in bytes
- `wl_sector_size` - returns the size of one sector

As a rule, try to avoid using raw wear levelling functions and use filesystem-specific functions instead.

### Memory Size

The memory size is calculated in the wear levelling module based on partition parameters. The module uses some sectors of flash for internal data.

### See also

- FAT Filesystem
- 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_t *mount_config, wl_handle_t *wl_handle)
```

Convenience function to initialize FAT filesystem in SPI flash and register it in VFS.

This is an all-in-one function which does the following:

- finds the partition with defined partition_label. Partition label should be configured in the partition table.
- initializes flash wear levelling library on top of the given partition
- mounts FAT partition using FATFS library on top of flash wear levelling library
- registers FATFS library with VFS, with prefix given by base_prefix variable

This function is intended to make example code more compact.
**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] wI_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 wI_handle)**

Unmount FAT filesystem and release resources acquired using esp_vfs_fat_spiflash_mount.

**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**

- `base_path`: path where partition should be registered (e.g. “/spiflash” )
- `wI_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
Chapter 2. API Reference

- out_handle: handle of the WL instance

**esp_err_t wl_unmount (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 wl_erase_range (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 wl_write (wl_handle_t handle, size_t dest_addr, const void *src, size_t size)**

Write data to the WL storage.

Before writing data to flash, corresponding region of flash needs to be erased. This can be done using `wl_erase_range` function.

**Note** Prior to writing to WL storage, make sure it has been erased with `wl_erase_range` call.

**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 wl_read (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.
- size: Size of data to be read, in bytes.

**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

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’s memory, followed by the data with a length of `data_len`. The data offset for each segment in the image is calculated in the following way:

   • offset for 0 Segment = `sizeof(esp_image_header_t) + sizeof(esp_image_segment_header_t)`.
   • offset for 1 Segment = offset for 0 Segment + length of 0 Segment + `sizeof(esp_image_segment_header_t)`.
   • offset for 2 Segment = offset for 1 Segment + length of 1 Segment + `sizeof(esp_image_segment_header_t)`.
   - ...

The count of each segment is defined in the `segment_count` field that is stored in `esp_image_header_t`. The count cannot be more than ESP_IMAGE_MAX_SEGMENTS.

To get the list of your image segments, please run the following command:

```
esptool.py --chip esp32 image_info build/app.bin
```

<table>
<thead>
<tr>
<th>Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 segments</td>
</tr>
<tr>
<td>Segment 1: len 0x13ce0 load 0x3f400020 file_offs 0x00000018 SOC_DROM</td>
</tr>
<tr>
<td>Segment 2: len 0x00000 load 0x3f80000 file_offs 0x00013d00 SOC_RTC_DRAM</td>
</tr>
<tr>
<td>Segment 3: len 0x00000 load 0x3f80000 file_offs 0x00013d08 SOC_RTC_DRAM</td>
</tr>
<tr>
<td>Segment 4: len 0x028e0 load 0x3ff0000 file_offs 0x00013d10 DRAM</td>
</tr>
<tr>
<td>Segment 5: len 0x00000 load 0x3ff028e0 file_offs 0x000165f8 DRAM</td>
</tr>
<tr>
<td>Segment 6: len 0x00000 load 0x40080000 file_offs 0x00016000 SOC_IRAM</td>
</tr>
<tr>
<td>Segment 7: len 0x00000 load 0x40080400 file_offs 0x00016a00 SOC_IRAM</td>
</tr>
<tr>
<td>Segment 8: len 0x00000 load 0x400d0018 file_offs 0x00020010 SOC_IRAM</td>
</tr>
<tr>
<td>Segment 9: len 0x06ec0 load 0x40089a00 file_offs 0x00082e64 SOC_IRAM</td>
</tr>
<tr>
<td>Segment 10: len 0x00000 load 0x400c0000 file_offs 0x00089b58 SOC_RTC_IRAM</td>
</tr>
<tr>
<td>Segment 11: len 0x00000 load 0x50000000 file_offs 0x00089b60 SOC_RTC_DATA</td>
</tr>
</tbody>
</table>

(continues on next page)
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=0x00000 (0)
I (530) esp_image: segment 2: paddr=0x00033d10 vaddr=0x3ff80000 size=0x00000 (0)
I (571) esp_image: segment 3: paddr=0x00033d18 vaddr=0x3ffbe000 size=0x028e0 ...
I (612) esp_image: segment 4: paddr=0x00036600 vaddr=0x3ff28e0 size=0x00000 (0)
I (654) esp_image: segment 5: paddr=0x00036608 vaddr=0x40080000 size=0x00400 ...
I (695) esp_image: segment 6: paddr=0x000366a0 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=0x06ce0 ...
I (888) esp_image: segment 9: paddr=0x000a9b60 vaddr=0x400c0000 size=0x00000 (0)
I (929) esp_image: segment 10: paddr=0x000a9b68 vaddr=0x50000000 size=0x00004 (4)
I (971) esp_image: segment 11: paddr=0x000a9b74 vaddr=0x50000004 size=0x00000 (0)
I (1012) esp_image: segment 12: paddr=0x000a9b7c vaddr=0x50000004 size=0x00000 (0)
```

For more details on the type of memory segments and their address ranges, see ESP32 Technical Reference Manual > System and Memory > Embedded Memory [PDF].

3. The image has a single checksum byte after the last segment. This byte is written on a sixteen byte padded boundary, so the application image might need padding.

4. If the hash_appended field from esp_image_header_t is set then a SHA256 checksum will be appended. The value of 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 - see 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 = \texttt{sizeof(esp_image_header_t)} + \texttt{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 \texttt{sizeof(esp_image_header_t)} + \texttt{sizeof(esp_image_segment_header_t)} + \texttt{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_options(${COMPONENT_TARGET} "-u custom_app_desc")` into `CMakeLists.txt`.

**API Reference**

**Header File**

- `components/bootloader_support/include/esp_app_format.h`

**Structures**

```c
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)
### Chapter 2. API Reference

`esp_chip_id_t 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).

### struct esp_image_segment_header_t
- Header of binary image segment.

#### Public Members

`uint32_t load_addr`
- Address of segment

`uint32_t data_len`
- Length of data

### struct esp_app_desc_t
- Description about application.

#### Public Members

`uint32_t magic_word`
- Magic word ESP_APP_DESC_MAGIC_WORD

`uint32_t secure_version`
- Secure version

`uint32_t reserv1[2]`
- reserv1

`char version[32]`
- Application version

`char project_name[32]`
- Project name

`char time[16]`
- Compile time

`char date[16]`
- Compile date

`char idf_ver[32]`
- Version IDF

`uint8_t app_elf_sha256[32]`
- sha256 of elf file

`uint32_t reserv2[20]`
- reserv2
Macros

ESP_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_ESP8684 = 0x000C
chip ID: ESP32-8684

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

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 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.

- **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_apprtrac_buffer_get (esp_apprtrac_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_apprtrac_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_apprtrac_buffer_put (esp_apprtrac_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_apprtrac_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_apprtrac_buffer_get.
- ptr: Address of trace buffer to release. Should be the value returned by call to esp_apprtrac_buffer_get.
- tmo: Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

esp_err_t esp_apprtrac_write (esp_apprtrac_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_apprtrac_vprintf_to (esp_apprtrac_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_apprtrac_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_apprtrac_flush (esp_apprtrac_dest_t dest, uint32_t tmo)
Flushes remaining data in trace buffer to host.

Return ESP_OK on success, otherwise see esp_err_t

Parameters
- dest: Indicates HW interface to flush data on.
- tmo: Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

esp_err_t esp_apprtrac_flush_nolock (esp_apprtrac_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_apprtrac_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_APPTRACE_TMO_INFINITE to wait indefinitely.

*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_APPTRACE_TMO_INFINITE to wait indefinitely.

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_APPTRACE_TMO_INFINITE to wait indefinitely.

*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_APPTRACE_TMO_INFINITE to wait indefinitely.

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.

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.

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.
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.

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.

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.

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.

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.

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**

```c
definition

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.
```

```c
definition

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 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.
• 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.

```c
linenoiseClearScreen()
```

Clear terminal screen using an escape sequence and position the cursor at the top left corner.

```c
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.

```c
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.

```c
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"` → `[abc, 123 456]`
• `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.
Chapter 2. API Reference

In a typical application, you only need to call `esp_console_new_repl_uart()` to initialize the REPL environment based on UART device, including driver install, basic console configuration, spawning a thread to do REPL task and register several useful commands (e.g. `help`).

After that, you can register your own commands with `esp_console_cmd_register()`. The REPL environment keeps in init state until you call `esp_console_start_repl()`.

Application Example

Example application illustrating usage of the console component is available in `system/console` directory. This example shows how to initialize UART and VFS functions, set up linenoise library, read and handle commands from UART, and store command history in Flash. See README.md in the example directory for more details.

Besides that, ESP-IDF contains several useful examples which based on console component and can be treated as “tools” when developing applications. For example, `peripherals/i2c/i2c_tools`, `wifi/iperf`.

API Reference

Header File

- components/console/esp_console.h

Functions

`esp_err_t esp_console_init(const esp_console_config_t *config)`

initialize console module

**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
Chapter 2. API Reference

### Parameters

- **cmdline**: command line (command name followed by a number of arguments)
- **cmd_ret**: return code from the command (set if command was run)

```c
size_t esp_console_split_argv(char* line, char** argv, size_t argv_size)
```

Split command line into arguments in place.

- This function finds whitespace-separated arguments in the given input line.
- 'abc def 1 20 .3' -> ['abc', 'def', '1', '20', '.3']
- Argument which include spaces may be surrounded with quotes. In this case, spaces are preserved and quotes are stripped.
- 'abc "123 456" def' -> ['abc', '123 456', 'def']
- Escape sequences may be used to produce backslash, double quote, and space:
  - 'a\ b\c"' -> ['a b\c"']

**Note**

Pointers to at most `argv_size - 1` arguments are returned in `argv` array. The pointer after the last one (i.e., `argv[argc]`) is set to NULL.

**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)

```c
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

```c
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. `linenoiseSetFreeHintsCallback` should not be used).

**Parameters**

- **buf**: line typed by the user
- **color**: ANSI color code to be used when displaying the hint
- **bold**: set to 1 if hint has to be displayed in bold

```c
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 a 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**

```c
struct esp_console_config_t
Parameters for console initialization.
```

**Public Members**

```c
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.

2.7.4 eFuse Manager

Introduction

The eFuse Manager library is designed to structure access to eFuse bits and make using these easy. This library operates eFuse bits by a structure name which is assigned in eFuse table. This sections introduces some concepts used by eFuse Manager.
Hardware description

The ESP32 has a number of eFuses which can store system and user parameters. Each eFuse is a one-bit field which can be programmed to 1 after which it cannot be reverted back to 0. Some of system parameters are using these eFuse bits directly by hardware modules and have special place (for example EFUSE_BLK0).

For more details, see ESP32 Technical Reference Manual > eFuse Controller (eFuse) [PDF]. Some eFuse bits are available for user applications.

ESP32 has 4 eFuse blocks each of the size of 256 bits (not all bits are available):

• EFUSE_BLK0 is used entirely for system purposes;
• EFUSE_BLK1 is used for flash encrypt key. If not using that Flash Encryption feature, they can be used for another purpose;
• EFUSE_BLK2 is used for security boot key. If not using that Secure Boot feature, they can be used for another purpose;
• EFUSE_BLK3 can be partially reserved for the custom MAC address, or used entirely for user application. Note that some bits are already used in IDF.

Each block is divided into 8 32-bits registers.

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_BLK3), bit_start(0..255), bit_ count(1..256), comment |

Individual params in CSV file the following meanings:

field_name Name of field. The prefix ESP_EFUSE_ will be added to the name, and this field name will be available in the code. This name will be used to access the fields. The name must be unique for all fields. If the line has an empty name, then this line is combined with the previous field. This allows you to set an arbitrary order of bits in the field, and expand the field as well (see MAC_FACTORY field in the common table). The field_name supports structured format using . to show that the field belongs to another field (see WR_DIS and RD_DIS in the common table).

efuse_block Block number. It determines where the eFuse bits will be placed for this field. Available EFUSE_BLK0..EFUSE_BLK3.

bit_start Start bit number (0..255). The bit_start field can be omitted. In this case, it will be set to bit_start + bit_count from the previous record, if it has the same efuse_block. Otherwise (if efuse_block is different, or this is the first entry), an error will be generated.
Chapter 2. API Reference

**bit_count** The number of bits to use in this field (1.-). This parameter can not be omitted. This field also may be MAX_BLK_LEN in this case, the field length will have the maximum block length, taking into account the coding scheme (applicable for ESP_EFUSE_SECURE_BOOT_KEY and ESP_EFUSE_ENCRYPT_FLASH_KEY fields). The value MAX_BLK_LEN depends on CONFIG_EFUSE_CODE_SCHEME_SELECTOR, will be replaced with “None” - 256, “3/4” - 192, “REPEAT” - 128.

**comment** This param is using for comment field, it also move to C-header file. The comment field can be omitted.

If a non-sequential bit order is required to describe a field, then the field description in the following lines should be continued without specifying a name, this will indicate that it belongs to one field. For example two fields MAC_FACTORY and MAC_FACTORY_CRC:

```
# Factory MAC address #
#######################
MAC_FACTORY,     EFUSE_BLK0, 72, 8, Factory MAC addr [0]
,               EFUSE_BLK0, 64, 8, Factory MAC addr [1]
,               EFUSE_BLK0, 56, 8, Factory MAC addr [2]
,               EFUSE_BLK0, 48, 8, Factory MAC addr [3]
,               EFUSE_BLK0, 40, 8, Factory MAC addr [4]
,               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, EFUSE_BLK0,  0, 1, Write protection for...
->RD_DIS
WR_DIS.FIELD_1, EFUSE_BLK0,  1, 1, Write protection for...
->FIELD_1
WR_DIS.FIELD_2, EFUSE_BLK0,  2, 4, Write protection for...
->FIELD_2 (includes B1 and B2)
->FIELD_2.B1
WR_DIS.FIELD_2.B2, EFUSE_BLK0,  2, 2, Write protection for...
->FIELD_2.B2
WR_DIS.FIELD_3, EFUSE_BLK0,  5, 1, Write protection for...
->FIELD_3
WR_DIS.FIELD_3.ALIAS, EFUSE_BLK0,  5, 1, Write protection for...
->FIELD_3 (just a alias for WR_DIS.FIELD_3)
WR_DIS.FIELD_4, EFUSE_BLK0,  7, 1, Write protection for...
->FIELD_4
```

The structured eFuse field looks like WR_DIS.RD_DIS where the dot points that this field belongs to the parent field - WR_DIS and can not be out of the parent’s range.

It is possible to use some levels of structured fields as WR_DIS.FIELD_2.B1 and B2. These fields should not be crossed each other and should be in the range of two fields: WR_DIS and WR_DIS.FIELD_2.

It is possible to create aliases for fields with the same range, see WR_DIS.FIELD_3 and WR_DIS.FIELD_3.ALIAS.

The IDF names for structured eFuse fields should be unique. The efuse_table_gen tool will generate the final names where the dot will be replaced by _. The names for using in IDF are ESP_EFUSE_WR_DIS, ESP_EFUSE_WR_DIS_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:

```bash
cd $IDF_PATH/components/efuse/ ./efuse_table_gen.py esp32/esp_efuse_table.csv
```

After generation in the folder $IDF_PATH/components/efuse/esp32 create:

- esp_efuse_table.c file.
- In include folder esp_efuse_table.c file.

To generate a custom files, use the following command idf.py efuse-custom-table or:

```bash
cd $IDF_PATH/components/efuse/ ./efuse_table_gen.py esp32/esp_efuse_table.csv PROJECT_PATH/main/esp_efuse_custom_table.csv
```

After generation in the folder PROJECT_PATH/main create:

- esp_efuse_custom_table.c file.
- In include folder esp_efuse_custom_table.c file.

To use the generated fields, you need to include two files:

```c
#include "esp_efuse.h"
#include "esp_efuse_table.h" or "esp_efuse_custom_table.h"
```

Supported coding scheme

eFuse have three coding schemes:

- None (value 0).
- 3/4 (value 1).
- Repeat (value 2).

The coding scheme affects only EFUSE_BLK1, EFUSE_BLK2 and EFUSE_BLK3 blocks. EUSE_BLK0 block always has a coding scheme None. Coding changes the number of bits that can be written into a block, the block length is constant 256, some of these bits are used for encoding and not available for the user.

When using a coding scheme, the length of the payload that can be written is limited (for more details 20.3.1.3 System Parameter coding_scheme):

- None 256 bits.
- 3/4 192 bits.
- Repeat 128 bits.

You can find out the coding scheme of your chip:

- run a `espefuse.py -p PORT summary` command.
- from esptool utility logs (during flashing).
- calling the function in the code `esp_efuse_get_coding_scheme()` for the EFUSE_BLK3 block.

eFuse tables must always comply with the coding scheme in the chip. There is an CONFIG_EFUSE_CODE_SCHEME_SELECTOR option to select the coding type for tables in a Kconfig. When generating source files, if your tables do not follow the coding scheme, an error message will be displayed. Adjust the length or offset fields. If your program was compiled with None encoding and 3/4 is used in the chip, then the ESP_ERR_CODING error may occur when calling the eFuse API (the field is outside the block boundaries). If the field matches the new block boundaries, then the API will work without errors.
Also, 3/4 coding scheme imposes restrictions on writing bits belonging to one coding unit. The whole block with a length of 256 bits is divided into 4 coding units, and in each coding unit there are 6 bytes of useful data and 2 service bytes. These 2 service bytes contain the checksum of the previous 6 data bytes.

It turns out that only one field can be written into one coding unit. Repeated rewriting in one coding unit is prohibited. But if the record was made in advance or through a \texttt{esp_efuse_write_block()} function, then reading the fields belonging to one coding unit is possible.

In case 3/4 coding scheme, the writing process is divided into the coding units and we can not use the usual mode of writing fields. We can prepare all the data for writing and burn it in one time. You can also use this mode for None coding scheme but it is not necessary. It is important for 3/4 coding scheme. The batch writing mode blocks \texttt{esp_efuse_read...} operations.

After changing the coding scheme, run \texttt{efuse_common_table} and \texttt{efuse_custom_table} commands to check the tables of the new coding scheme.

To write some fields into one block, or different blocks in one time, you need to use the batch writing mode. Firstly set this mode through \texttt{esp_efuse_batch_write_begin()} function then write some fields as usual using the \texttt{esp_efuse_write...} functions. At the end to burn them, call the \texttt{esp_efuse_batch_write_commit()} function. It burns prepared data to the eFuse blocks and disables the batch recording mode.

**eFuse API**

Access to the fields is via a pointer to the description structure. API functions have some basic operation:

- \texttt{esp_efuse_read_field_blob()} - returns an array of read eFuse bits.
- \texttt{esp_efuse_read_field_cnt()} - returns the number of bits programmed as “1”.
- \texttt{esp_efuse_write_field_blob()} - writes an array.
- \texttt{esp_efuse_write_field_cnt()} - writes a required count of bits as “1”.
- \texttt{esp_efuse_get_field_size()} - returns the number of bits by the field name.
- \texttt{esp_efuse_read_reg()} - returns value of eFuse register.
- \texttt{esp_efuse_write_reg()} - writes value to eFuse register.
- \texttt{esp_efuse_get_coding_scheme()} - returns eFuse coding scheme for blocks.
- \texttt{esp_efuse_read_block()} - reads key to eFuse block starting at the offset and the required size.
- \texttt{esp_efuse_write_block()} - writes key to eFuse block starting at the offset and the required size.
- \texttt{esp_efuse_batch_write_begin()} - set the batch mode of writing fields.
- \texttt{esp_efuse_batch_write_commit()} - writes all prepared data for batch writing mode and reset the batch writing mode.
- \texttt{esp_efuse_batch_write_cancel()} - reset the batch writing mode and prepared data.
- \texttt{esp_efuse_get_key_dis_read()} - Returns a read protection for the key block.
- \texttt{esp_efuse_set_key_dis_read()} - Sets a read protection for the key block.
- \texttt{esp_efuse_get_key_dis_write()} - Returns a write protection for the key block.
- \texttt{esp_efuse_set_key_dis_write()} - Sets a write protection for the key block.
- \texttt{esp_efuse_get_key_purpose()} - Returns the current purpose set for an eFuse key block.
- \texttt{esp_efuse_write_key()} - Programs a block of key data to an eFuse block
- \texttt{esp_efuse_write_keys()} - Programs keys to unused eFuse blocks
- \texttt{esp_efuse_find_purpose()} - Finds a key block with the particular purpose set.
- \texttt{esp_efuse_get_keypurpose_dis_write()} - Returns a write protection of the key purpose field for an eFuse key block (for esp32 always true).
- \texttt{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 \texttt{esp_efuse_get_chip_ver()}, \texttt{esp_efuse_get_pkg_ver()}.

**How to add a new field**

1. Find a free bits for field. Show \texttt{esp_efuse_table.csv} file or run \texttt{idf.py show-efuse-table} or the next command:
```
$ ./efuse_table_gen.py esp32/esp_efuse_table.csv --info

eFuse coding scheme: NONE

<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>
</tr>
<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>
</tr>
<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>
</tr>
<tr>
<td>9</td>
<td>MAC_FACTORY</td>
<td>EFUSE_BLK0</td>
<td>32</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>MAC_FACTORY</td>
<td>EFUSE_BLK0</td>
<td>40</td>
<td>8</td>
</tr>
<tr>
<td>11</td>
<td>MAC_FACTORY</td>
<td>EFUSE_BLK0</td>
<td>48</td>
<td>8</td>
</tr>
<tr>
<td>12</td>
<td>MAC_FACTORY</td>
<td>EFUSE_BLK0</td>
<td>56</td>
<td>8</td>
</tr>
<tr>
<td>13</td>
<td>MAC_FACTORY</td>
<td>EFUSE_BLK0</td>
<td>64</td>
<td>8</td>
</tr>
<tr>
<td>14</td>
<td>MAC_FACTORY</td>
<td>EFUSE_BLK0</td>
<td>72</td>
<td>8</td>
</tr>
<tr>
<td>15</td>
<td>MAC_FACTORY_CRC</td>
<td>EFUSE_BLK0</td>
<td>80</td>
<td>8</td>
</tr>
<tr>
<td>16</td>
<td>CHIP_VER_DIS_APP_CPU</td>
<td>EFUSE_BLK0</td>
<td>96</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>CHIP_VER_DIS_BT</td>
<td>EFUSE_BLK0</td>
<td>97</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>CHIP_VER_PKG</td>
<td>EFUSE_BLK0</td>
<td>105</td>
<td>3</td>
</tr>
<tr>
<td>19</td>
<td>CHIP_CPU_FREQ_LOW</td>
<td>EFUSE_BLK0</td>
<td>108</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>CHIP_CPU_FREQ_RATED</td>
<td>EFUSE_BLK0</td>
<td>109</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>CHIP_VER_REVI</td>
<td>EFUSE_BLK0</td>
<td>111</td>
<td>1</td>
</tr>
<tr>
<td>22</td>
<td>ADC_VREF_AND_SDIO_DREF</td>
<td>EFUSE_BLK0</td>
<td>136</td>
<td>6</td>
</tr>
<tr>
<td>23</td>
<td>XPD_SDIO_REG</td>
<td>EFUSE_BLK0</td>
<td>142</td>
<td>1</td>
</tr>
<tr>
<td>24</td>
<td>SDIO_TIEH</td>
<td>EFUSE_BLK0</td>
<td>143</td>
<td>1</td>
</tr>
<tr>
<td>25</td>
<td>SDIO_FORCE</td>
<td>EFUSE_BLK0</td>
<td>144</td>
<td>1</td>
</tr>
<tr>
<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>
<td>194</td>
<td>1</td>
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<tr>
<td>28</td>
<td>ABS_DONE_0</td>
<td>EFUSE_BLK0</td>
<td>196</td>
<td>1</td>
</tr>
<tr>
<td>29</td>
<td>DISABLE_JTAG</td>
<td>EFUSE_BLK0</td>
<td>198</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>DISABLE_DL_ENCRYPT</td>
<td>EFUSE_BLK0</td>
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<td>1</td>
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<tr>
<td>31</td>
<td>DISABLE_DL_DECRYPT</td>
<td>EFUSE_BLK0</td>
<td>200</td>
<td>1</td>
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<tr>
<td>32</td>
<td>DISABLE_DL_CACHE</td>
<td>EFUSE_BLK0</td>
<td>201</td>
<td>1</td>
</tr>
<tr>
<td>33</td>
<td>ENCRYPT_FLASH_KEY</td>
<td>EFUSE_BLK1</td>
<td>0</td>
<td>256</td>
</tr>
<tr>
<td>34</td>
<td>SECURE_BOOT_KEY</td>
<td>EFUSE_BLK2</td>
<td>0</td>
<td>256</td>
</tr>
<tr>
<td>35</td>
<td>MAC_CUSTOM_CRC</td>
<td>EFUSE_BLK3</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>36</td>
<td>MAC_CUSTOM</td>
<td>EFUSE_BLK3</td>
<td>8</td>
<td>48</td>
</tr>
<tr>
<td>37</td>
<td>ADC1_TP_LOW</td>
<td>EFUSE_BLK3</td>
<td>96</td>
<td>7</td>
</tr>
<tr>
<td>38</td>
<td>ADC1_TP_HIGH</td>
<td>EFUSE_BLK3</td>
<td>103</td>
<td>9</td>
</tr>
<tr>
<td>39</td>
<td>ADC2_TP_LOW</td>
<td>EFUSE_BLK3</td>
<td>112</td>
<td>7</td>
</tr>
<tr>
<td>40</td>
<td>ADC2_TP_HIGH</td>
<td>EFUSE_BLK3</td>
<td>119</td>
<td>9</td>
</tr>
<tr>
<td>41</td>
<td>SECURE_VERSION</td>
<td>EFUSE_BLK3</td>
<td>128</td>
<td>32</td>
</tr>
<tr>
<td>42</td>
<td>MAC_CUSTOM_VER</td>
<td>EFUSE_BLK3</td>
<td>184</td>
<td>8</td>
</tr>
</tbody>
</table>

Used bits in eFuse table:
EFUSE_BLK0
[2 2] [7 9] [16 18] [20 27] [32 87] [96 97] [105 109] [111 111] [136 144] [188…
191] [194 194] [196 196] [198 201]

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/esp32/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 eFuse bits - espefuse.py.

espefuse.py -p PORT summary

Connecting........__
Detecting chip type... ESP32
espefuse.py v3.1-dev
EFUSE_NAME (Block) Description = [Meaningful_ _Value] [Readable/Writeable] (Hex Value)
---------------------------------------------------------------------

Calibration fuses:
BLK3_PART_RESERVE (BLOCK0): BLOCK3 partially served for ADC... 
---calibration data = True R/W (0b1)
ADC_VOLT (BLOCK0): Voltage reference calibration
--- = 1114 R/W (0b00010)
ADC1_TP_LOW (BLOCK3): ADC1 150mV reading
--- = 346 R/W (0b0010001)
ADC1_TP_HIGH (BLOCK3): ADC1 850mV reading
--- = 3285 R/W (0b0000000101)
ADC2_TP_LOW (BLOCK3): ADC2 150mV reading
--- = 449 R/W (0b00000111)
ADC2_TP_HIGH (BLOCK3): ADC2 850mV reading
--- = 3362 R/W (0b111110101)

Config fuses:
XPD_SDIO_FORCE (BLOCK0): Ignore MTDI pin (GPIO12) for VDD_
---SDIO on reset = False R/W (0b0)
XPD_SDIO_REG (BLOCK0): If XPD_SDIO_FORCE, enable VDD_
---SDIO reg on reset = False R/W (0b0)
XPD_SDIO_TIEH (BLOCK0): If XPD_SDIO_FORCE & XPD_SDIO_REG_
--- = 1.8V R/W (0b0)
CLK8M_FREQ (BLOCK0): 8MHz clock freq override
--- = 53 R/W (0x35)

(continues on next page)
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Value</th>
<th>Read/Write</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPI_PAD_CONFIG_CLK (BLOCK0)</td>
<td>Override SD_CLK pad (GPIO6/SPICLK)</td>
<td>0 R/W</td>
<td>0b00000</td>
<td></td>
</tr>
<tr>
<td>SPI_PAD_CONFIG_Q (BLOCK0)</td>
<td>Override SD_DATA_0 pad (GPIO7/SPIQ)</td>
<td>0 R/W</td>
<td>0b00000</td>
<td></td>
</tr>
<tr>
<td>SPI_PAD_CONFIG_D (BLOCK0)</td>
<td>Override SD_DATA_1 pad (GPIO8/SPID)</td>
<td>0 R/W</td>
<td>0b00000</td>
<td></td>
</tr>
<tr>
<td>SPI_PAD_CONFIG_HD (BLOCK0)</td>
<td>Override SD_DATA_2 pad (GPIO9/SPID)</td>
<td>0 R/W</td>
<td>0b00000</td>
<td></td>
</tr>
<tr>
<td>SPI_PAD_CONFIG_CS0 (BLOCK0)</td>
<td>Override SD_CMD pad (GPIO11/SPICS0)</td>
<td>0 R/W</td>
<td>0b00000</td>
<td></td>
</tr>
<tr>
<td>DISABLE_SDIO_HOST (BLOCK0)</td>
<td>Disable SDIO host</td>
<td></td>
<td>False</td>
<td></td>
</tr>
<tr>
<td>Efuse fuses:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WR_DIS (BLOCK0)</td>
<td>Efuse write disable mask</td>
<td>0 R/W</td>
<td>0x00000</td>
<td></td>
</tr>
<tr>
<td>RD_DIS (BLOCK0)</td>
<td>Efuse read disable mask</td>
<td>0 R/W</td>
<td>0x0</td>
<td></td>
</tr>
<tr>
<td>CODING_SCHEME (BLOCK0)</td>
<td>Efuse variable block length scheme</td>
<td>3/4</td>
<td></td>
<td>(BLK1-3 len=192 bits)</td>
</tr>
<tr>
<td>KEY_STATUS (BLOCK0)</td>
<td>Usage of efuse block 3</td>
<td>(reserved)</td>
<td>False</td>
<td>R/W (0b0)</td>
</tr>
<tr>
<td>Identity fuses:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAC (BLOCK0)</td>
<td>Factory MAC Address</td>
<td>84:0d:8e:18:8e:44 (CRC 0xad OK) R/W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAC_CRC (BLOCK0)</td>
<td>CRC8 for factory MAC address</td>
<td>173</td>
<td>R/W (0xad)</td>
<td></td>
</tr>
<tr>
<td>CHIP_VER_REV1 (BLOCK0)</td>
<td>Silicon Revision 1</td>
<td>True</td>
<td>R/W (0b1)</td>
<td></td>
</tr>
<tr>
<td>CHIP_VER_REV2 (BLOCK0)</td>
<td>Silicon Revision 2</td>
<td>False</td>
<td>R/W (0b0)</td>
<td></td>
</tr>
<tr>
<td>CHIP_VERSION (BLOCK0)</td>
<td>Reserved for future chip versions</td>
<td>2</td>
<td>R/W (0b10)</td>
<td></td>
</tr>
<tr>
<td>CHIP_PACKAGE (BLOCK0)</td>
<td>Chip package identifier</td>
<td>0 R/W</td>
<td>0b00000</td>
<td></td>
</tr>
<tr>
<td>MAC_VERSION (BLOCK3)</td>
<td>Version of the MAC field</td>
<td>0 R/W</td>
<td>0x000</td>
<td></td>
</tr>
<tr>
<td>Security fuses:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLASH_CRYPT_CNT (BLOCK0)</td>
<td>Flash encryption mode counter</td>
<td>0 R/W</td>
<td>0b00000000</td>
<td></td>
</tr>
<tr>
<td>UART_DOWNLOAD_DIS (BLOCK0)</td>
<td>Disable UART download mode</td>
<td>(ESP32 rev3 only)</td>
<td>False R/W (0b0)</td>
<td></td>
</tr>
<tr>
<td>FLASH_CRYPT_CONFIG (BLOCK0)</td>
<td>Flash encryption config (key tweak bits)</td>
<td>0 R/W</td>
<td>0x0</td>
<td></td>
</tr>
<tr>
<td>CONSOLE_DEBUG_DISABLE (BLOCK0)</td>
<td>Disable ROM BASIC interpreter</td>
<td>True</td>
<td>R/W (0b1)</td>
<td></td>
</tr>
<tr>
<td>ABS_DONE_0 (BLOCK0)</td>
<td>Secure boot V1 is enabled for bootloader image</td>
<td>False</td>
<td>R/W (0b0)</td>
<td></td>
</tr>
<tr>
<td>ABS_DONE_1 (BLOCK0)</td>
<td>Secure boot V2 is enabled for bootloader image</td>
<td>False</td>
<td>R/W (0b0)</td>
<td></td>
</tr>
<tr>
<td>JTAG_DISABLE (BLOCK0)</td>
<td>Disable JTAG</td>
<td></td>
<td>False</td>
<td>R/W (0b0)</td>
</tr>
<tr>
<td>DISABLE_DL_ENCRYPT (BLOCK0)</td>
<td>Disable flash encryption in UART</td>
<td>False</td>
<td>R/W (0b0)</td>
<td></td>
</tr>
<tr>
<td>DISABLE_DL_DECRYPT (BLOCK0)</td>
<td>Disable flash decryption in UART</td>
<td>False</td>
<td>R/W (0b0)</td>
<td></td>
</tr>
<tr>
<td>DISABLE_DL_CACHE (BLOCK0)</td>
<td>Disable flash cache in UART</td>
<td>False</td>
<td>R/W (0b0)</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 2. API Reference

(continued from previous page)

<table>
<thead>
<tr>
<th>BLOCK1 (BLOCK1): Flash encryption key</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00</td>
</tr>
<tr>
<td>\textendash;R/W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BLOCK2 (BLOCK2): Secure boot key</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00</td>
</tr>
<tr>
<td>\textendash;R/W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BLOCK3 (BLOCK3): Variable Block 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 00 00 00 00 00 00 00 00 00 00 00 00 91 02 87 fa 00 00 00 00 00 00 00 00</td>
</tr>
<tr>
<td>\textendash;R/W</td>
</tr>
</tbody>
</table>

Flash voltage (VDD_SDIO) determined by GPIO12 on reset (High for 1.8V, \textdash;Low/NC for 3.3V).

To get a dump for all eFuse registers.

```bash
espefuse.py -p PORT dump
```

<table>
<thead>
<tr>
<th>Connecting...........</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detecting chip type... ESP32</td>
</tr>
<tr>
<td>BLOCK0 ( ) [0 ] read_regs: 00000000 8e188e44...</td>
</tr>
<tr>
<td>\textdash;00ad840d 0000e000 00000235 00000000 00000005</td>
</tr>
<tr>
<td>BLOCK1 (flash_encryption) [1 ] read_regs: 00000000 00000000...</td>
</tr>
<tr>
<td>\textdash;00000000 00000000 00000000 00000000</td>
</tr>
<tr>
<td>BLOCK2 (secure_boot_v1 s) [2 ] read_regs: 00000000 00000000...</td>
</tr>
<tr>
<td>\textdash;00000000 00000000 00000000 00000000</td>
</tr>
<tr>
<td>BLOCK3 ( ) [3 ] read_regs: 00000000 00000000...</td>
</tr>
<tr>
<td>\textdash;00000000 fa870291 00000000 00000000</td>
</tr>
<tr>
<td>espefuse.py v3.1-dev</td>
</tr>
</tbody>
</table>

**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.

esp_err_t esp_efuse_read_field_cnt(const esp_efuse_desc_t *field[], size_t *out_cnt)
Reads bits from EFUSE field and returns number of bits programmed as “1”.

If the bits are set not sequentially, they will still be counted.

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.

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

- 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_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.

`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] val: Value to write.

`esp Efuse_coding_scheme_t esp Efuse_get_coding_scheme (esp Efuse_block_t blk)`
Return efuse coding scheme for blocks.
Note: The coding scheme is applicable only to 1, 2 and 3 blocks. For 0 block, the coding scheme is always NONE.

**Return**
Return efuse coding scheme for blocks

**Parameters**
- **[in] blk**: Block number of eFuse.

```c
esp_err_t esp_efuse_read_block(esp_efuse_block_t blk, void *dst_key, size_t offset_in_bits, size_t size_bits)
```

Read key to efuse block starting at the offset and the required size.

**Note**
Please note that reading in the batch mode does not show uncommitted changes.

**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.

**Parameters**
- **[in] blk**: Block number of eFuse.
- **[in] dst_key**: A pointer to array that will contain the result of reading.
- **[in] offset_in_bits**: Start bit in block.
- **[in] size_bits**: The number of bits required to read.

```c
esp_err_t esp_efuse_write_block(esp_efuse_block_t blk, const void *src_key, size_t offset_in_bits, size_t size_bits)
```

Write key to efuse block starting at the offset and the required size.

**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] offset_in_bits**: Start bit in block.
- **[in] size_bits**: The number of bits required to write.

```c
uint8_t esp_efuse_get_chip_ver(void)
```

Returns chip version from efuse.

**Return**
chip version

```c
uint32_t esp_efuse_get(pkg_ver(void)
```

Returns chip package from efuse.

**Return**
chip package

```c
void esp_efuse_reset(void)
```

Reset efuse write registers.

Efuse write registers are written to zero, to negate any changes that have been staged here.

**Note**
This function is not threadsafe, if calling code updates efuse values from multiple tasks then this is caller’s responsibility to serialise.

```c
void esp_efuse_disable_basic_rom_console(void)
```

Disable BASIC ROM Console via efuse.

By default, if booting from flash fails the ESP32 will boot a BASIC console in ROM.

Call this function (from bootloader or app) to permanently disable the console on this chip.

```c
esp_err_t esp_efuse_disable_rom_download_mode(void)
```

Disable ROM Download Mode via eFuse.

Permanently disables the ROM Download Mode feature. Once disabled, if the SoC is booted with strapping pins set for ROM Download Mode then an error is printed instead.
Note Not all SoCs support this option. An error will be returned if called on an ESP32 with a silicon revision lower than 3, as these revisions do not support this option.

Note If ROM Download Mode is already disabled, this function does nothing and returns success.

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

`uint32_t esp_efuse_read_secure_version(void)`
Return secure_version from eFuse field.

Return Secure version from eFuse field

`bool esp_efuse_check_secure_version(uint32_t secure_version)`
Check secure_version from app and secure_version and from eFuse field.

Return
- True: If version of app is equal or more then 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
- `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.
// set the batch writing mode
esp_efuse_batch_write_begin();

// use any writing functions as usual
esp_efuse_write_field_blob(ESP_EFUSE_1);
esp_efuse_write_field_cnt(ESP_EFUSE_1);
esp_efuse_set_write_protect(EFUSE_BLKx);
esp_efuse_write_reg(EFUSE_BLKx);
esp_efuse_write_field(ESP_EFUSE_1, 3); // ESP_EFUSE_1 == 1, here we write a new
--value = 3. The changes will be burn by the commit() function.
esp_efuse_read...(ESP_EFUSE_1); // this function returns ESP_EFUSE_1 == 1...
--because uncommitted changes are not readable, it will be available only...
--after commit.
...

// esp_efuse_batch_write APIs can be called recursively.
esp_efuse_batch_write_begin();
esp_efuse_set_write_protect(EFUSE_BLKx);
esp_efuse_batch_write_commit(); // the burn will be skipped here, it will be...
--done in the last commit().
...

// Write all of these fields to the efuse registers
esp_efuse_batch_write_commit();
esp_efuse_read...(ESP_EFUSE_1); // this function returns ESP_EFUSE_1 == 3.

Return

- ESP_OK: Successful.

esp_err_t esp_efuse_batch_write_cancel (void)
Reset the batch mode of writing fields.
It will reset the batch writing mode and any written changes.

Return

- ESP_OK: Successful.
- ESP_ERR_INVALID_STATE: Tha batch mode was not set.

esp_err_t esp_efuse_batch_write_commit (void)
Writes all prepared data for the batch mode.
Must be called to ensure changes are written to the efuse registers. After this the batch writing mode will be reset.

Return

- ESP_OK: Successful.
- ESP_ERR_INVALID_STATE: The deferred writing mode was not set.

bool esp_efuse_block_is_empty (esp_efuse_block_t block)
Checks that the given block is empty.

Return

- True: The block is empty.
- False: The block is not empty or was an error.

bool esp_efuse_get_key_dis_read (esp_efuse_block_t block)
Returns a read protection for the key block.

Return True: The key block is read protected False: The key block is readable.

Parameters
- [in] block: A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX
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

- [in] block: A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

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 keypurpose, 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

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 eFuse 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 eFuse state, unused block not found.
• ESP_ERR_NOT_ENOUGH_UNUSED_KEY_BLOCKS: Error not enough unused key blocks available
• ESP_ERR_EFUSE_REPEATED_PROG: Error repeated programming of programmed bits is strictly forbidden.
• ESP_ERR_CODING: Error range of data does not match the coding scheme.

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).

Structures

struct esp_efuse_desc_t
Type definition for an eFuse field.

Public Members

esp_efuse_block_t esp_efuse_block: 8
  Block of eFuse

uint8_t bit_start
  Start bit [0..255]

uint16_t bit_count
  Length of bit field [1..-]
Chapter 2. API Reference

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

enum esp_efuse_rom_log_scheme_t
Type definition for ROM log scheme.

Values:

**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

2.7.5 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

```c
const char* esp_err_to_name_r (esp_err_t code, char* buf, size_t buflen)
```

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**

```c
ESP_OK
esp_err_t value indicating success (no error)
```

```c
ESP_FAIL
Generic esp_err_t code indicating failure
```

```c
ESP_ERR_NO_MEM
Out of memory
```

```c
ESP_ERR_INVALID_ARG
Invalid argument
```

```c
ESP_ERR_INVALID_STATE
Invalid state
```

```c
ESP_ERR_INVALID_SIZE
Invalid size
```

```c
ESP_ERR_NOT_FOUND
Requested resource not found
```

```c
ESP_ERR_NOT_SUPPORTED
Operation or feature not supported
```

```c
ESP_ERR_TIMEOUT
Operation timed out
```

```c
ESP_ERR_INVALID_RESPONSE
Received response was invalid
```

```c
ESP_ERR_INVALID_CRC
CRC or checksum was invalid
```

```c
ESP_ERR_INVALID_VERSION
Version was invalid
```

```c
ESP_ERR_INVALID_MAC
MAC address was invalid
```

```c
ESP_ERR_NOT_FINISHED
There are items remained to retrieve
```

```c
ESP_ERR_WIFI_BASE
Starting number of WiFi error codes
```

```c
ESP_ERR_MESH_BASE
Starting number of MESH error codes
```
Chapter 2. API Reference

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(x)
Macro which can be used to check the error code, and terminate the program in case the code is not ESP_OK. Prints the error code, error location, and the failed statement to serial output.

Disabled if assertions are disabled.

ESP_ERROR_CHECK_WITHOUT_ABORT(x)
Macro which can be used to check the error code. Prints the error code, error location, and the failed statement to serial output. In comparison with ESP_ERROR_CHECK(), this prints the same error message but isn’t terminating the program.

Type Definitions
typedef int esp_err_t

2.7.6 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 (CONFIGMBEDTLS_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
- 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.

```c
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
Chapter 2. API Reference

• [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_HTTPS_INVALID_OP: Invalid app image
• ESP_ERR_HTTPS_VALIDATE_FAILED: 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_HTTPS_INVALID_STATE
• ESP_ERR_HTTPS_INVALID_ARG: Invalid app image
• ESP_ERR_HTTPS_VALIDATE_FAILED: Invalid image

Parameters
• [in] https_ota_handle: pointer to esp_https_ota_handle_t structure

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_HTTPS_INVALID_STATE: Invalid ESP HTTPS OTA state
• ESP_FAIL: OTA not started
• ESP_ERR_HTTPS_VALIDATE_FAILED: OTA handle not found
• ESP_ERR_HTTPS_VALIDATE_FAILED: Invalid argument

Parameters
• [in] https_ota_handle: pointer to esp_https_ota_handle_t structure
**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_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

**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

**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**

**struct esp_https_ota_config_t**

ESP HTTPS OTA configuration.

**Public Members**

**const esp_http_client_config_t *http_config**

ESP HTTP client configuration

**http_client_init_cb / http_client_init_cb**

Callback after ESP HTTP client is initialised

**bool bulk_flash_erase**

Erase entire flash partition during initialization. By default flash partition is erased during write operation and in chunk of 4K sector size

**bool partial_http_download**

Enable Firmware image to be downloaded over multiple HTTP requests

**int max_http_request_size**

Maximum request size for partial HTTP download
Chapter 2. API Reference

 Macros

ESP_ERR_HTTPS_OTA_BASE
ESP_ERR_HTTPS_OTA_IN_PROGRESS

 Type Definitions

typedef void *esp_https_ota_handle_t
typedef esp_err_t (*http_client_init_cb_t)(esp_http_client_handle_t)

2.7.7 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()
Chapter 2. API Reference

- sched_yield()
- pthread_self() - An assert will fail if this function is called from a FreeRTOS task which is not a pthread.
- pthread_equal()

**Thread Attributes**

- pthread_attr_init()
- pthread_attr_destroy() - This function doesn’t need to free any resources and instead resets the attr structure to defaults (implementation is same as pthread_attr_init()).
- pthread_attr_getstacksize() / pthread_attr_setstacksize()
- pthread_attr_getdetachstate() / pthread_attr_setdetachstate()

**Once**

- pthread_once()

Static initializer constant PTHREAD_ONCE_INIT is supported.

---

**Note:** This function can be called from tasks created using either pthread or FreeRTOS APIs

**Mutexes** POSIX Mutexes are implemented as FreeRTOS Mutex Semaphores (normal type for “fast” or “error check” mutexes, and Recursive type for “recursive” mutexes). This means that they have the same priority inheritance behaviour as mutexes created with xSemaphoreCreateMutex().

- pthread_mutex_init()
- pthread_mutex_destroy()
- pthread_mutex_lock()
- pthread_mutex_timedlock()
- pthread_mutex_trylock()
- pthread_mutex_unlock()
- pthread_mutexattr_init()
- pthread_mutexattr_destroy()
- pthread_mutexattr_gettype() / pthread_mutexattr_settype()

Static initializer constant PTHREAD_MUTEX_INITIALIZER is supported, but the non-standard static initializer constants for other mutex types are not supported.

---

**Note:** These functions can be called from tasks created using either pthread or FreeRTOS APIs

**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
Chapter 2. API Reference

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

**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](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.
Chapter 2. API Reference

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

`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

`esp_err_t esp_pthread_init(void)`
Initialize pthread library.

Structures

`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.
null

## 2.7.8 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 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()`. Components wanting to remove their handlers from being called can do so by unregistering from the loop using `esp_event_handler_unregister_with()`.
5. 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. Just create a default loop for simplicity.
    esp_event_loop_args_t loop_args;
    esp_event_loop_create_with(&loop_args, NULL);
}
```

(continues on next page)
// created. A handle of type esp_event_loop_handle_t is obtained, which is
// needed by the other APIs to reference the loop
// to perform their operations on.

esp_event_loop_args_t loop_args = {
    .queue_size = ...,  
    .task_name = ...,   
    .task_priority = ..., 
    .task_stack_size = ..., 
    .task_core_id = ..., 
};

esp_event_loop_handle_t loop_handle;

esp_event_loop_create(&loop_args, &loop_handle);

// 3. Register event handler defined in (1). MY_EVENT_BASE and MY_EVENT_ID
// specifies a hypothetical 
// event that handler run_on_event should execute on when it gets posted to
// the loop.

esp_event_handler_register_with(loop_handle, MY_EVENT_BASE, MY_EVENT_ID, run_on_event, ...);

...

// 4. Post events to the loop. This queues the event on the event loop. At
// some point in time
// the event loop executes the event handler registered to the posted event,
// in this case run_on_event.
// For simplicity sake this example calls esp_event_post_to from app_main, but
// posting can be done from
// any other tasks (which is the more interesting use case).

esp_event_post_to(loop_handle, MY_EVENT_BASE, MY_EVENT_ID, ...);

...

// 5. Unregistering an unneeded handler

esp_event_handler_unregister_with(loop_handle, MY_EVENT_BASE, MY_EVENT_ID, run_on_event);

...

// 6. Deleting an unneeded event loop

esp_event_loop_delete(loop_handle);

}

Declaring and defining events

As mentioned previously, events consists of two-part identifiers: the event base and the event ID. The event base identifies an independent group of events; the event ID identifies the event within that group. Think of the event base and event ID as a person’s last name and first name, respectively. A last name identifies a family, and the first name identifies a person within that family.

The event loop library provides macros to declare and define the event base easily.

Event base declaration:

```
ESP_EVENT_DECLARE_BASE(EVENT_BASE)
```

Event base definition:


Chapter 2. API Reference

Note: In IDF, the base identifiers for system events are uppercase and are postfixed with \_EVENT. For example, the base for Wi-Fi events is declared and defined as WIFI\_EVENT, the ethernet event base ETHERNET\_EVENT, and so on. The purpose is to have event bases look like constants (although they are global variables considering the definitions of macros ESP\_EVENT\_DECLARE\_BASE and ESP\_EVENT\_DEFINE\_BASE).

For event ID’s, declaring them as enumerations is recommended. Once again, for visibility, these are typically placed in public header files.

Event ID:

```c
enum {
    EVENT_ID_1,
    EVENT_ID_2,
    EVENT_ID_3,
    ...
}
```

Default Event Loop

The default event loop is a special type of loop used for system events (Wi-Fi events, for example). The handle for this loop is hidden from the user. The creation, deletion, handler registration/unregistration and posting of events is done through a variant of the APIs for user event loops. The table below enumerates those variants, and the user event loops equivalent.

<table>
<thead>
<tr>
<th>User Event Loops</th>
<th>Default Event Loops</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_event_loop_create()</td>
<td>esp_event_loop_create_default()</td>
</tr>
<tr>
<td>esp_event_loop_delete()</td>
<td>esp_event_loop_delete_default()</td>
</tr>
<tr>
<td>esp_event_handler_register_with()</td>
<td>esp_event_handler_register()</td>
</tr>
<tr>
<td>esp_event_handler_unregister_with()</td>
<td>esp_event_handler_unregister()</td>
</tr>
<tr>
<td>esp_event_post_to()</td>
<td>esp_event_post()</td>
</tr>
</tbody>
</table>

If you compare the signatures for both, they are mostly similar except the 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. \(<\text{event base}>, <\text{event ID}>\) - handler executes when the event with base \(<\text{event base}>\) and event ID \(<\text{event ID}>\) gets posted to the loop
2. \(<\text{event base}>, \text{ESP\_EVENT\_ANY\_ID}>\) - handler executes when any event with base \(<\text{event base}>\) 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 get 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**

```c
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 ()
```
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 ()
```
Delete the default event loop.

Return
• ESP_OK: Success
• Others: Fail

```
esp_err_t esp_event_loop_run (esp_event_loop_handle_t event_loop, TickType_t ticks_to_run)
```
Dispatch events posted to an event loop.

This function is used to dispatch events posted to a loop with no dedicated task, i.e. task name was set to NULL in event_loop_args argument during loop creation. This function includes an argument to limit the amount of time it runs, returning control to the caller when that time expires (or some time afterwards). There is no guarantee that a call to this function will exit at exactly the time of expiry. There is also no guarantee that events have been dispatched during the call, as the function might have spent all the allotted time waiting on the event queue. Once an event has been dequeued, however, it is guaranteed to be dispatched. This guarantee contributes to not being able to exit exactly at time of expiry as (1) blocking on internal mutexes is necessary for dispatching the dequeued event, and (2) during dispatch of the dequeued event there is no way to control the time occupied by handler code execution. The guaranteed time of exit is therefore the allotted time + amount of time required to dispatch the last dequeued event.

In cases where waiting on the queue times out, ESP_OK is returned and not ESP_ERR_TIMEOUT, since it is normal behavior.

Note encountering an unknown event that has been posted to the loop will only generate a warning, not an error.

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_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

```c
esp_err_t esp_event_handler_register_with(esp_event_loop_t event_loop, esp_event_base_t event_base, int32_t event_id, esp_event_handler_t event_handler, void *event_handler_arg)
```

Register an event handler to a specific loop (legacy).

This function behaves in the same manner as `esp_event_handler_register`, except the additional specification of the event loop to register the handler to.

**Note** 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

```c
esp_err_t esp_event_handler_instance_register_with(esp_event_loop_t event_loop, 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 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.

```c
esp_err_t esp_event_handler_instance_register(esp_event_base_t event_base, int32_t event_id, esp_event_handler_t event_handler, void *event_handler_arg, esp_event_handler_instance_t *instance)
```

Register an instance of event handler to the default loop.

This function does the same as esp_event_handler_instance_register_with, except that it registers the handler to the default event loop.

**Note** the event loop library does not maintain a copy of event_handler_arg, therefore the user should ensure that event_handler_arg still points to a valid location by the time the handler gets called.

**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.

```c
esp_err_t esp_event_handler_unregister(esp_event_base_t event_base, int32_t event_id, esp_event_handler_t event_handler)
```

Unregister a handler with the system event loop (legacy).

Unregisters a handler, so it will no longer be called during dispatch. Handlers can be unregistered for any combination of event_base and event_id which were previously registered. To unregister a handler, the event_base and event_id arguments must match exactly the arguments passed to esp_event_handler_register() when that handler was registered. Passing ESP_EVENT_ANY_BASE and/or ESP_EVENT_ANY_ID will only unregister handlers that were registered with the same wildcard arguments.

**Note** 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
- 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]** `event_handler`: the handler to unregister

```c
esp_err_t esp_event_handler_unregister_with(esp_event_loop_handle_t event_loop, esp_event_base_t event_base, int32_t event_id, esp_event_handler_t event_handler)
```

Unregister a handler from a specific event loop (legacy).

This function behaves in the same manner as esp_event_handler_unregister, except the additional specification of the event loop to unregister the handler with.

**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

```c
esp_err_t esp_event_handler_instance_unregister_with(esp_event_loop_handle_t event_loop, esp_event_base_t event_base, int32_t event_id, esp_event_handler_instance_t instance)
```

Unregister a handler instance from a specific event loop.

Unregisters a handler instance, so it will no longer be called during dispatch. Handler instances can be unregistered for any combination of event_base and event_id which were previously registered. To unregister a handler instance, the event_base and event_id arguments must match exactly the arguments passed to esp_event_handler_instance_register() when that handler instance was registered. Passing ESP_EVENT_ANY_BASE and/or ESP_EVENT_ANY_ID will only unregister handler instances that were registered with the same wildcard arguments.
Note  When using ESP_EVENT_ANY_ID, handlers registered to specific event IDs using the same base will not be unregistered. When using ESP_EVENT_ANY_BASE, events registered to specific bases will also not be unregistered. This avoids accidental unregistration of handlers registered by other users or components.

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

```c
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, 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

```c
esp_err_t esp_event_post(esp_event_base_t event_base, int32_t event_id, 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 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
• [in] ticks_to_wait: number of ticks to block on a full event queue

```c
esp_err_t esp_event_post_to(esp_event_loop_handle_t event_loop, esp_event_base_t event_base, int32_t event_id, 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 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
• [in] ticks_to_wait: number of ticks to block on a full event queue

```c
esp_err_t esp_event_isr_post(esp_event_base_t event_base, int32_t event_id, 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
• [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, 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:

```plaintext
event loop
   handler
   handler
...
event loop
   handler
   handler
...
```

where:

```plaintext
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
```

```plaintext
handler
   format: address ev:base,id inv:total_invoked run:total_runtime
where:
   address - address of the handler function
   base,id - the event specified by event base and ID this handler executes
   total_invoked - number of times this handler has been invoked
   total_runtime - total amount of time used for invoking this handler
```

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:

```plaintext
struct esp_event_loop_args_t
Configuration for creating event loops.
```

Public Members:

```plaintext
int32_t queue_size
size of the event loop queue
```

```plaintext
const char *task_name
name of the event loop task; if NULL, a dedicated task is not created for event loop
```

```plaintext
UBaseType_t task_priority
priority of the event loop task, ignored if task name is NULL
```

```plaintext
uint32_t task_stack_size
stack size of the event loop task, ignored if task name is NULL
```

```plaintext
BaseType_t task_core_id
core to which the event loop task is pinned to, ignored if task name is NULL
```
Chapter 2. API Reference

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 const char *esp_event_base_t
  unique pointer to a subsystem that exposes events

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(esp_event_base_t event_base, int32_t event_id, void *event_data, size_t event_data_size, TickType_t ticks_to_wait)
  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

- [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
- [in] ticks_to_wait: number of ticks to block on a full event queue

```c
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

```c
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

```c
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

```c
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

```c
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 don’t need to handle If cb is not NULL, it will be call 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

```c
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
Chapter 2. API Reference

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_fail_reason_t sta_er_fail_reason
ESP32 station WPS enrollee mode failed reason code received

system_event_sta_wps_er_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_probereqrecv
ESP32 soft-AP receive probe request packet

system_event_ftm_report_t ftm_report
Report of FTM procedure

system_event_ap_stapassassigned_t ap_stapasssigned
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_PIN 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_ap_probe_req_rx_t system_event_ap_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

define 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

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
Chapter 2. API Reference

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

2.7.9 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 Additions.

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
Chapter 2. API Reference

ESP-IDF FreeRTOS Applications

Unlike Vanilla FreeRTOS, users must not call \texttt{vTaskStartScheduler()}. Instead, ESP-IDF FreeRTOS is started automatically. The entry point is a user defined \texttt{void app\_main(void)} function.

- Typically, users would spawn the rest of their applications task from \texttt{app\_main}.
- The \texttt{app\_main} function is allowed to return at any point (i.e., before the application terminates).
- The \texttt{app\_main} function is called from the \texttt{main} task.

The \texttt{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 \texttt{app_main}. This task will self delete when \texttt{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 (ipcx)</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 \textit{Inter-Processor Call} for more details.</td>
</tr>
</tbody>
</table>

### Task API

#### Header File

- \texttt{components/freertos/FreeRTOS-Kernel/include/freertos/task.h}

#### Functions

\texttt{BaseType_t xTaskCreatePinnedToCore(TaskFunction_t pvTaskCode, const char *const pcName, const uint32_t usStackDepth, void *const pvParameters, UBaseType_t uxPriority, TaskHandle_t *const pvCreatedTask, const BaseType_t xCoreID)}

Create a new task with a specified affinity.

This function is similar to \texttt{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**

- \texttt{pvTaskCode}: Pointer to the task entry function. Tasks must be implemented to never return (i.e. continuous loop), or should be terminated using \texttt{vTaskDelete} function.
- \texttt{pcName}: A descriptive name for the task. This is mainly used to facilitate debugging. Max length defined by \texttt{configMAX\_TASK\_NAME\_LEN} - default is 16.
- \texttt{usStackDepth}: The size of the task stack specified as the number of bytes. Note that this differs from vanilla FreeRTOS.
- \texttt{pvParameters}: Pointer that will be used as the parameter for the task being created.
- \texttt{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 \texttt{uxPriority} parameter should be set to (2 | portPRIVILEGE\_BIT).
- \texttt{pvCreatedTask}: Used to pass back a handle by which the created task can be referenced.
- \texttt{xCoreID}: If the value is \texttt{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 (\texttt{portNUM\_PROCESSORS} - 1) will cause the function to fail.

\texttt{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;

    // Create the task, storing the handle. Note that the passed parameter...
    xTaskCreate( vTaskCode, "NAME", STACK_SIZE, &ucParameterToPass, tskIDLE_PRIORITY, &xHandle );
    configASSERT( xHandle );

    // Use the handle to delete the task.
    if( xHandle != NULL )
    {
        vTaskDelete( xHandle );
    }
}
```

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.

### `TaskHandle_t xTaskCreateStaticPinnedToCore` (TaskFunction_t `pvTaskCode`, const char *`pcName`, const uint32_t `ulStackDepth`, void *`pvParameters`, UBaseType_t `uxPriority`, StaticTask_t *`pxStackBuffer`, StaticTask_t *`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.

### `static TaskHandle_t xTaskCreateStatic` (TaskFunction_t `pvTaskCode`, const char *`pcName`, const uint32_t `ulStackDepth`, void *`pvParameters`, UBaseType_t `uxPriority`, StaticTask_t *`pxStackBuffer`, StaticTask_t *`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`). 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
#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 `StackType_t`
```

(continues on next page)
// 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.
        tskIDLE_PRIORITY, // Priority at which the task is created.
        &xStack,        // Array to use as the task's stack.
        &xTaskBuffer ); // Variable to hold the task's data structure.

    // puxStackBuffer and pxTaskBuffer were not NULL, so the task will have
    // been created, and xHandle will be the task's handle. Use the handle
    // to suspend the task.
    vTaskSuspend( xHandle );
}

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.

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,     // usStackDepth - the stack size DEFINED IN WORDS.
    NULL,    // pvParameters - passed into the task function as the function...
    // parameters.
    1U | 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
// 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 =
{   // pvTaskCode - the function that implements the task.
    vATask,   // pcName - just a text name for the task to assist debugging.
    "ATask",   // usStackDepth - the stack size DEFINED IN BYTES.
    100,   // pxParameters - passed into the task function as the function...
    NULL,   // parameters.
    portPRIVILEGE_BIT,   // uxPriority - task priority, set the...
    portPRIVILEGE_BIT if the task should run in a privileged state.
    cStackBuffer, // pxStackBuffer - 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 );

(continues on next page)
Memory regions are assigned to a restricted task when the task is created by a call to xTaskCreateRestricted(). These regions can be redefined using vTaskAllocateMPURegions().

Example usage:

```c
// 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 },
    { 0, 0, 0 }
};

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)`

INCLUDE_vTaskDelete must be defined as 1 for this function to be available. See the configuration section for more information.

Remove a task from the RTOS real time kernel’s management. The task being deleted will be removed from all ready, blocked, suspended and event lists.

**NOTE:** The idle task is responsible for freeing the kernel allocated memory from tasks that have been deleted. It is therefore important that the idle task is not starved of microcontroller processing time if your application makes any calls to vTaskDelete(). Memory allocated by the task code is not automatically freed, and should be freed before the task is deleted.

See the demo application file death.c for sample code that utilises vTaskDelete().

Example usage:
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.

INCLUDE_vTaskDelay must be defined as 1 for this function to be available. See the configuration section for more information.

vTaskDelay() specifies a time at which the task wishes to unblock relative to the time at which vTaskDelay() is called. For example, specifying a block period of 100 ticks will cause the task to unblock 100 ticks after vTaskDelay() is called. vTaskDelay() does not therefore provide a good method of controlling the frequency of a periodic task as the path taken through the code, as well as other task and interrupt activity, will affect 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:

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.

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

- xPreviousWakeTime: 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 *xPreviousWakeTime + 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 call placed the task into the Blocked state.

There is no ‘FromISR’ version of this function as an interrupt would need to know which object a task was blocked on in order to know which actions to take. For example, if the task was blocked on a queue the interrupt handler would then need to know if the queue was locked.

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:
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_eTaskGetState must be defined as 1 for this function to be available. See the configuration section for more information.

Obtain the state of any task. States are encoded by the eTaskState enumerated type.

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)
configUSE_TRACE_FACILITY must be defined as 1 for this function to be available. See the configuration section for more information.

Populates a TaskStatus_t structure with information about a task.

Example usage:

(continues on next page)
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:

    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.

    Set the task into a suspended state.

    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 resume the suspended task.
        vTaskResume( xHandle );

        // ...

        // Use a NULL handle to resume a suspended task.
        vTaskResume( NULL );
    }
```
for more information.

Suspend any task. When suspended a task will never get any microcontroller processing time, no matter what its priority.

Calls to vTaskSuspend are not accumulative - i.e. calling vTaskSuspend () twice on the same task still only requires one call to vTaskResume () to ready the suspended task.

Example usage:

```c
void vAFunction( void )
{
    TaskHandle_t xHandle;

    // Create a task, storing the handle.
    xTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, &xHandle );

    // ...

    // Use the handle to suspend the created task.
    vTaskSuspend( xHandle );

    // ...

    // The created task will **not** run during this period, unless
    // another task calls vTaskResume( xHandle ).

    //...

    // Suspend ourselves.
    vTaskSuspend( NULL );

    // We cannot get here unless another task calls vTaskResume
    // **with** our handle as the parameter.
}
```

**Parameters**

- **xTaskToSuspend**: Handle to the task being suspended. Passing a NULL handle will cause the calling task to be suspended.

**void vTaskResume**(TaskHandle_t xTaskToResume)

INCLUDE_vTaskSuspend must be defined as 1 for this function to be available. See the configuration section for more information.

Resumes a suspended task.

A task that has been suspended by one or more calls to vTaskSuspend () will be made available for running again by a single call to vTaskResume ()

Example usage:

```c
void vAFunction( void )
{
    TaskHandle_t xHandle;

    // Create a task, storing the handle.
    xTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, &xHandle );

    // ...

    // Use the handle to suspend the created task.
}
```

(continues on next page)
vTaskSuspend( xHandle );

// ...

// The created task will not run during this period, unless
// another task calls vTaskResume( xHandle ).

//....

// Resume the suspended task ourselves.
vTaskResume( xHandle );

// The created task will once again get microcontroller processing
// time in accordance with its priority within the system.

Parameters
• xTaskToResume: Handle to the task being readied.

BaseType_t xTaskResumeFromISR( TaskHandle_t xTaskToResume )
INCLUDE_xTaskResumeFromISR must be defined as 1 for this function to be available. See the configuration section for more information.

An implementation of vTaskResume() that can be called from within an ISR.

A task that has been suspended by one or more calls to vTaskSuspend () will be made available for running again by a single call to xTaskResumeFromISR ()

xTaskResumeFromISR() should not be used to synchronise a task with an interrupt if there is a chance that the interrupt could arrive prior to the task being suspended - as this can lead to interrupts being missed. Use of a semaphore as a synchronisation mechanism would avoid this eventuality.

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.

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:

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 ()
}

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.
Chapter 2. API Reference

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 ();
    }
}

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
    // vTaskEndScheduler (). When we get here we are back to single task
    // execution.
}
```

void vTaskSuspendAll (void)
Suspends the scheduler without disabling interrupts. Context switches will not occur while the scheduler is suspended.

After calling vTaskSuspendAll () the calling task will continue to execute without risk of being swapped out until a call to xTaskResumeAll () has been made.

API functions that have the potential to cause a context switch (for example, vTaskDelayUntil(), xQueueSend(), etc.) must not be called while the scheduler is suspended.

Example usage:

```c
void vTask1( void * pvParameters )
{
    for( ;; )
    {
        // Task code goes here.
        // ...
        // At some point the task wants to perform a long operation during
        // which it does not want to get swapped out. It cannot use
        // taskENTER_CRITICAL ()/taskEXIT_CRITICAL () as the length of the
        // operation may cause interrupts to be missed - including the
    }
}
```

(continues on next page)
// 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();

}
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 uxTaskNumberofTasks (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 re-
turn 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 re-
turn 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.

```c
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.

```c
void vTaskSetApplicationTaskTag(TaskHandle_t xTask, TaskHookFunction_t pxHookFunction)
```

Sets `pxHookFunction` to be the task hook function used by the task `xTask`.

**Parameters**

• **xTask**: Handle of the task to set the hook function for. Passing `xTask` as NULL has the effect of setting the calling tasks hook function.

• **pxHookFunction**: Pointer to the hook function.

```c
TaskHookFunction_t xTaskGetApplicationTaskTag(TaskHandle_t xTask)
```

Returns the `pxHookFunction` value assigned to the task `xTask`. Do not call from an interrupt service routine - call `xTaskGetApplicationTaskTagFromISR()` instead.

```c
TaskHookFunction_t xTaskGetApplicationTaskTagFromISR(TaskHandle_t xTask)
```

Returns the `pxHookFunction` value assigned to the task `xTask`. Can be called from an interrupt service routine.

```c
void vTaskSetThreadLocalStoragePointer(TaskHandle_t xTaskToSet, BaseType_t xIndex, void* pvValue)
```

Set local storage pointer specific to the given task.

Each task contains an array of pointers that is dimensioned by the config `NUM_THREAD_LOCAL_STORAGE_POINTERS` setting in `FreeRTOSConfig.h`. The kernel does not use the pointers itself, so the application writer can use the pointers for any purpose they wish.

**Parameters**

• **xTaskToSet**: Task to set thread local storage pointer for

• **xIndex**: The index of the pointer to set, from 0 to `configNUM_THREAD_LOCAL_STORAGE_POINTERS` - 1.

• **pvValue**: Pointer value to set.

```c
void* pvTaskGetThreadLocalStoragePointer(TaskHandle_t xTaskToQuery, BaseType_t xIndex)
```

Get local storage pointer specific to the given task.

Each task contains an array of pointers that is dimensioned by the config `NUM_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.

```c
void vTaskSetThreadLocalStoragePointerAndDelCallback(TaskHandle_t xTaskToSet, BaseType_t xIndex, void* pvValue, TlsDeleteCallbackFunction_t pvDelCallback)
```

Set local storage pointer and deletion callback.

Each task contains an array of pointers that is dimensioned by the config `NUM_THREAD_LOCAL_STORAGE_POINTERS` setting in `FreeRTOSConfig.h`. The kernel does not use the pointers itself, so the application writer can use the pointers for any purpose they wish.
Local storage pointers set for a task can reference dynamically allocated resources. This function is similar to vTaskSetThreadLocalStoragePointer, but provides a way to release these resources when the task gets deleted. For each pointer, a callback function can be set. This function will be called when task is deleted, with the local storage pointer index and value as arguments.

**Parameters**
- `xTaskToSet`: Task to set thread local storage pointer for
- `xIndex`: The index of the pointer to set, from 0 to configNUM_THREAD_LOCAL_STORAGE_POINTERS - 1.
- `pvValue`: Pointer value to set.
- `pvDelCallback`: Function to call to dispose of the local storage pointer when the task is deleted.

```c
void vApplicationGetIdleTaskMemory( StaticTask_t **pxIdleTaskTCBBuffer, StackType_t **pxIdleTaskStackBuffer, uint32_t *pulIdleTaskStackSize )
```

This function is used to provide a statically allocated block of memory to FreeRTOS to hold the Idle Task TCB. This function is required when configSUPPORT_STATIC_ALLOCATION is set. For more information see this URI: [https://www.FreeRTOS.org/a00110.html#configSUPPORT_STATIC_ALLOCATION](https://www.FreeRTOS.org/a00110.html#configSUPPORT_STATIC_ALLOCATION)

**Parameters**
- `pxIdleTaskTCBBuffer`: A handle to a statically allocated TCB buffer
- `pxIdleTaskStackBuffer`: A handle to a statically allocated Stack buffer for the idle task
- `pulIdleTaskStackSize`: A pointer to the number of elements that will fit in the allocated stack buffer

```c
BaseType_t xTaskCallApplicationTaskHook( TaskHandle_t xTask, void *pvParameter )
```

Calls the hook function associated with `xTask`. Passing `xTask` as NULL has the effect of calling the Running tasks (the calling task) hook function.

**Parameters**
- `xTask`: Handle of the task to call the hook for.
- `pvParameter`: Parameter passed to the hook function for the task to interpret as it wants. The return value is the value returned by the task hook function registered by the user.

```c
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.

```c
UBaseType_t uxTaskGetSystemState ( TaskStatus_t *pxTaskStatusArray, const UBaseType_t uxArraySize, uint32_t *const pulTotalRunTime )
```

`uxTaskGetSystemState()` must be defined as 1 in FreeRTOSConfig.h for `uxTaskGetSystemState()` to be available.

`uxTaskGetSystemState()` populates an `TaskStatus_t` structure for each task in the system. `TaskStatus_t` structures contain, among other things, members for the task handle, task name, task priority, task state, and total amount of run time consumed by the task. See the `TaskStatus_t` structure definition in this file for the full member list.

**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;
    // (continues on next page)
```
// Make sure the write buffer does not contain a string.
*pcWriteBuffer = 0x00;

// Take a snapshot of the number of tasks in case it changes while this
// function is executing.
uxArraySize = uxTaskGetNumberOfTasks();

// Allocate a TaskStatus_t structure for each task. An array could be
// allocated statically at compile time.
pxTaskStatusArray = pvPortMalloc( uxArraySize * sizeof( TaskStatus_t ) );

if( pxTaskStatusArray != NULL )
{
    // Generate raw status information about each task.
    uxArraySize = uxTaskGetSystemState( pxTaskStatusArray, uxArraySize, &
    ulTotalRunTime );

    // For percentage calculations.
    ulTotalRunTime /= 100UL;

    // Avoid divide by zero errors.
    if( ulTotalRunTime > 0 )
    {
        // For each populated position in the pxTaskStatusArray array,
        // format the raw data as human readable ASCII data
        for( x = 0; x < uxArraySize; x++ )
        {
            // What percentage of the total run time has the task used?
            // This will always be rounded down to the nearest integer.
            // ulTotalRunTimeDiv100 has already been divided by 100.
            ulStatsAsPercentage = pxTaskStatusArray[ x ].ulRunTimeCounter / ulTotalRunTime;

            if( ulStatsAsPercentage > 0UL )
            {
                sprintf( pcWriteBuffer, "%s\t\t%lu\t\t%lu%%\r\n",
                pxTaskStatusArray[ x ].pcTaskName, pxTaskStatusArray[ x ].ulRunTimeCounter,
                ulStatsAsPercentage );
            }
            else
            {
                // If the percentage is zero here then the task has
                // consumed less than 1% of the total run time.
                sprintf( pcWriteBuffer, "%s\t\t%lu\t\t<1%%\r\n",
                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

(continued from previous page)
Chapter 2. API Reference

- **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.

```c
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/Demosub-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)
```


configUSE_TASK_NOTIFICATIONS must be undefined or defined as 1 for these functions to be available.

Sends a direct to task notification to a task, with an optional value and action.

Each task has a private array of “notification values” (or ‘notifications’), each of which is a 32-bit unsigned integer (uint32_t). The constant 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. xTaskNotify() is the original API function, and remains backward compatible by always operating on the notification value at index 0 in the array. Calling xTaskNotify() is equivalent to calling xTaskNotifyIndexed() with the uxIndexToNotify parameter set to 0.

eSetBits - The target notification value is bitwise ORed with ulValue. xTaskNotifyIndexed() always returns pdPASS in this case.

**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. 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 `vTaskNotifyWaitIndexed()` to [optionally] block to wait for a notification to be pending, or `xTaskNotifyTakeIndexed()` 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 `vTaskNotifyWaitIndexed()` or `xTaskNotifyTakeIndexed()` (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 `vTaskNotifyIndexedFromISR()` 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 `configTASK_NOTIFICATION_ARRAY_ENTRIES`. `xTaskNotifyFromISR()` does not have this parameter and always sends notifications to index 0.
- `xTaskToNotify`: The handle of the task being notified. The handle to a task can be returned from the `xTaskCreate()` API function used to create the task, and the handle of the currently running task can be obtained by calling `xTaskGetCurrentTaskHandle()`.
- `ulValue`: Data that can be sent with the notification. How the data is used depends on the value of the `eAction` parameter.
- `eAction`: Specifies how the notification updates the task’s notification value, if at all. Valid values for `eAction` are as follows:

  - `eSetBits`: The task’s notification value is bitwise ORed with `ulValue`. `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 `pFAIL` 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 `pTRUE` 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 `pTRUE` 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.
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 light weight and fast binary or counting semaphores.

A notification sent to a task will remain pending until it is cleared by the task calling xTaskNotifyWaitIndexed() or ulTaskNotifyTakeIndexed() (or their un-indexed equivalents). If the task was already in the Blocked state to wait for a notification when the notification arrives then the task will automatically be removed from the Blocked state (unblocked) and the notification cleared.

A task can use xTaskNotifyWaitIndexed() to [optionally] block to wait for a notification to be pending, or ulTaskNotifyTakeIndexed() to [optionally] block to wait for a notification value to have a non-zero value. The task does not consume any CPU time while it is in the Blocked state.

NOTE Each notification within the array operates independently - a task can only block on one notification within the array at a time and will not be unblocked by a notification sent to any other array index.

Backward compatibility information: Prior to FreeRTOS V10.4.0 each task had a single “notification value” , and all task notification API functions operated on that value. Replacing the single notification value with an array of notification values necessitated a new set of API functions that could address specific notifications within the array. xTaskNotifyWait() is the original API function, and remains backward compatible by always operating on the notification value at index 0 in the array. Calling xTaskNotifyWait() is equivalent to calling xTaskNotifyWaitIndexed() with the uxIndexToWaitOn parameter set to 0.

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). See [https://www.FreeRTOS.org/RTOS-task-notifications.html](https://www.FreeRTOS.org/RTOS-task-notifications.html) for more details.

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.

vTaskNotifyGiveIndexedFromISR() is intended for use when task notifications are used as light weight and faster binary or counting semaphore equivalents. Actual FreeRTOS semaphores are given from an ISR using the xSemaphoreGiveFromISR() API function, the equivalent action that instead uses a task notification is vTaskNotifyGiveIndexedFromISR().

When task notifications are being used as a binary or counting semaphore equivalent then the task being notified should wait for the notification using the xTaskNotificationTakeIndexed() API function rather than the xTaskNotifyWaitIndexed() API function.

**NOTE** Each notification within the array operates independently - a task can only block on one notification within the array at a time and will not be unblocked by a notification sent to any other array index.

Backward compatibility information: Prior to FreeRTOS V10.4.0 each task had a single “notification value”, and all task notification API functions operated on that value. Replacing the single notification value with an array of notification values necessitated a new set of API functions that could address specific notifications within the array. xTaskNotifyFromISR() is the original API function, and remains backward compatible by always operating on the notification value at index 0 within the array. Calling xTaskNotifyGiveFromISR() is equivalent to calling xTaskNotifyGiveIndexedFromISR() with the uxIndexToNotify parameter set to 0.

**Parameters**

- xTaskToNotify: The handle of the task being notified. The handle to a task can be returned from the xTaskCreate() API function used to create the task, and the handle of the currently running task can be obtained by calling xTaskGetCurrentTaskHandle().
- uxIndexToNotify: The index within the target task’s array of notification values to which the notification is to be sent. uxIndexToNotify must be less than configTASK_NOTIFICATION_ARRAY_ENTRIES. xTaskNotifyGiveFromISR() does not have this parameter and always sends notifications to index 0.
- pxHigherPriorityTaskWoken: vTaskNotifyGiveFromISR() will set *pxHigherPriorityTaskWoken to pdTRUE if sending the notification caused the task to which the notification was sent to leave the Blocked state, and the unblocked task has a priority higher than the currently running task. If vTaskNotifyGiveFromISR() sets this value to pdTRUE then a context switch should be requested before the interrupt is exited. How a context switch is requested from an ISR is dependent on the port - see the documentation page for the port in use.
uint32_t ulTaskGenericNotifyTake(UBaseType_t uxIndexToWaitOn, BaseType_t xClearCountOnExit, TickType_t xTicksToWait)

Waits for a direct to task notification on a particular index in the calling task’s notification array in a manner similar to taking a counting semaphore.


configUSE_TASK_NOTIFICATIONS must be undefined or defined as 1 for this function to be available.

Each task has a private array of “notification values” (or ‘notifications’), each of which is a 32-bit unsigned integer (uint32_t). The constant configTASK_NOTIFICATION_ARRAY_ENTRIES sets the number of indexes in the array, and (for backward compatibility) defaults to 1 if left undefined. Prior to FreeRTOS V10.4.0 there was only one notification value per task.

Events can be sent to a task using an intermediary object. Examples of such objects are queues, semaphores, mutexes and event groups. Task notifications are a method of sending an event directly to a task without the need for such an intermediary object.

A notification sent to a task can optionally perform an action, such as update, overwrite or increment one of the task’s notification values. In that way task notifications can be used to send data to a task, or be used as light weight and fast binary or counting semaphores.

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(\text{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.

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.

```c
void vTaskSetTimeOutState( TimeOut_t *const pxTimeOut )
```

```c
BaseType_t xTaskCheckForTimeOut( TimeOut_t *const pxTimeOut, TickType_t *const pxTicksToWait )
```

Determines if `pxTicksToWait` ticks has passed since a time was captured using a call to `vTaskSetTimeOutState()`. The captured time includes the tick count and the number of times the tick count has overflowed.

Example Usage:

```c
size_t xUART_Receive( uint8_t *pucBuffer, size_t uxWantedBytes )
{
    size_t uxReceived = 0;
    TickType_t xTicksToWait = MAX_TIME_TO_WAIT;
    TimeOut_t xTimeOut;

    // Initialize xTimeOut. This records the time at which this function
    // was entered.
    vTaskSetTimeOutState( &xTimeOut );

    // Loop until the buffer contains the wanted number of bytes, or a
    // timeout occurs.
    while( UART_bytes_in_rx_buffer( pxUARTInstance ) < uxWantedBytes )
    {
        // The buffer didn't contain enough data so this task is going to
        // enter the Blocked state. Adjusting xTicksToWait to account for
        // any time that has been spent in the Blocked state within this
        // function so far to ensure the total amount of time spent in the
        // Blocked state does not exceed MAX_TIME_TO_WAIT.
        if( xTaskCheckForTimeOut( &xTimeOut, &xTicksToWait ) != pdFALSE )
        {
            // Timed out before the wanted number of bytes were available,
            // exit the loop.
            break;
        }

        // Wait for a maximum of xTicksToWait ticks to be notified that the
        // receive interrupt has placed more data into the buffer.
        ulTaskNotifyTake( pdTRUE, xTicksToWait );
    }
}
```

(continues on next page)
// 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.

**BaseType_t**  **xTaskCatchUpTicks** *(TickType_t xTicksToCatchUp)*

**Macros**
- **tskKERNEL_VERSION_NUMBER**
- **tskKERNEL_VERSION_MAJOR**
- **tskKERNEL_VERSION_MINOR**
- **tskKERNEL_VERSION_BUILD**
- **tskMPU_REGION_READ_ONLY**
- **tskMPU_REGION_READ_WRITE**
- **tskMPU_REGION_EXECUTE_NEVER**
- **tskMPU_REGION_NORMAL_MEMORY**
- **tskMPU_REGION_DEVICE_MEMORY**
- **tskDEFAULT_INDEX_TO_NOTIFY**
- **tskNO_AFFINITY**
- **tskIDLE_PRIORITY**

- Defines the priority used by the idle task. This must not be modified.

**taskYIELD()**
- Macro for forcing a context switch.

**taskENTER_CRITICAL()**
- Macro to mark the start of a critical code region. Preemptive context switches cannot occur when in a critical region.

  **Note**  This may alter the stack (depending on the portable implementation) so must be used with care!

**taskENTER_CRITICAL_FROM_ISR()**

**taskENTER_CRITICAL_ISR()**

**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!
taskEXIT_CRITICAL_FROM_ISR(x)

taskDISABLE_INTERRUPTS()
Macro to disable all maskable interrupts.

taskENABLE_INTERRUPTS()
Macro to enable microcontroller interrupts.

taskSCHEDULER_SUSPENDED

taskSCHEDULER_NOT_STARTED

taskSCHEDULER_RUNNING

taskEXIT_CRITICAL_ISR(x)

taskDISABLE_INTERRUPTS()

vTaskDelayUntil(pxPreviousWakeTime, xTimeIncrement)

xTaskNotify(xTaskToNotify, ulValue, eAction)

xTaskNotifyIndexed(xTaskToNotify, uxIndexToNotify, ulValue, eAction)

xTaskNotifyAndQuery(xTaskToNotify, ulValue, eAction, pulPreviousNotifyValue)
	xTaskNotifyAndQueryIndexed() performs the same operation as xTaskNotifyIndexed() with the addition that it also returns the subject task’s prior notification value (the notification value at the time the function is called rather than when the function returns) in the additional pulPreviousNotifyValue parameter.

xTaskNotifyAndQuery() performs the same operation as xTaskNotify() with the addition that it also returns the subject task’s prior notification value (the notification value as it was at the time the function is called, rather than when the function returns) in the additional pulPreviousNotifyValue parameter.

xTaskNotifyAndQueryIndexed(xTaskToNotify, uxIndexToNotify, ulValue, eAction, pulPreviousNotifyValue)

xTaskNotifyFromISR(xTaskToNotify, ulValue, eAction, pxHigherPriorityTaskWoken)

xTaskNotifyIndexedFromISR(xTaskToNotify, uxIndexToNotify, ulValue, eAction, pxHigherPriorityTaskWoken)

xTaskNotifyAndQueryIndexedFromISR(xTaskToNotify, uxIndexToNotify, ulValue, eAction, pulPreviousNotificationValue, pxHigherPriorityTaskWoken)

xTaskNotifyAndQueryIndexedFromISR() performs the same operation as xTaskNotifyIndexedFromISR() with the addition that it also returns the subject task’s prior notification value (the notification value at the time the function is called rather than at the time the function returns) in the additional pulPreviousNotificationValue parameter.

xTaskNotifyAndQueryFromISR() performs the same operation as xTaskNotifyFromISR() with the addition that it also returns the subject task’s prior notification value (the notification value at the time the function is called rather than at the time the function returns) in the additional pulPreviousNotificationValue 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 pdPASS 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.

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

typedef struct tskTaskControlBlock *TaskHandle_t

typedef BaseType_t (*TaskHookFunction_t) (void *)
typedef void (*TlsDeleteCallbackFunction_t)(int, void *)

Prototype of local storage pointer deletion callback.

Enumerations
enum eTaskState
    Task states returned by eTaskGetState.
    Values:
    eRunning = 0
    eReady
    eBlocked
    eSuspended
    eDeleted
    eInvalid
enum eNotifyAction
    Values:
    eNoAction = 0
    eSetBits
    eIncrement
    eSetValueWithOverwrite
    eSetValueWithoutOverwrite
enum eSleepModeStatus
    Possible return values for eTaskConfirmSleepModeStatus().
    Values:
    eAbortSleep = 0
    eStandardSleep
    eNoTasksWaitingTimeout

Queue API

Header File
    • components/freertos/FreeRTOS-Kernel/include/freertos/queue.h

Functions
BaseType_t xQueueGenericSend (QueueHandle_t xQueue, const *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;
```

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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( 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.
    if( xQueueCreate( 10, sizeof( struct AMessage * ) ) != 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 );
    // ...
}

// Task to peek the data from the queue.
void vADifferentTask( void *pvParameters )
{
    struct AMessage *pxRxedMessage;
    if( xQueue != 0 )
    {
        // Peek a message on the created queue. Block for 10 ticks if a
        // message is not immediately available.
        if( xQueuePeek( xQueue, & pxRxedMessage, ( TickType_t ) 10 ) )
        {
            // pcRxedMessage now points to the struct AMessage variable posted
            // by vATask, but the item still remains on the queue.
        }
    }
    // ...
}
```

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.
Chapter 2. API Reference

**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 const 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 const pvParameters)
{
    struct AMessage *pxRxedMessage;

    // Task to receive from the queue.
    if( xQueue != 0 )
    {
        // ... Rest of task code.
    }
}
```

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Receive a message on the created queue. Block for 10 ticks if a message is not immediately available.

```c
if ( xQueueReceive( xQueue, & pxRxedMessage, ( TickType_t ) 10 ) ) {
    // pcRxedMessage 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.

**ReturnValue** 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.

**ReturnValue** 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;

    // ... Rest of ISR code...
}
```
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();
}

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 un-
  blocked 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).

BaseType_t xQueueGiveFromISR(QueueHandle_t xQueue, BaseType_t *const pxHigherPriorityTaskWoken)

BaseType_t xQueueReceiveFromISR(QueueHandle_t xQueue, void *const pvBuffer, BaseType_t *const pxHigherPriorityTaskWoken)

Receive an item from a queue. It is safe to use this function from within an interrupt service routine.

Example usage:

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 == NULL )
    {
        // Failed to create the queue.
    }
    // ...

    // 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();
    }
}
// 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;
  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.

```c
void vQueueUnregisterQueue (QueueHandle_t xQueue)
```

The registry is provided as a means for kernel aware debuggers to locate queues, semaphores and mutexes. Call `vQueueAddToRegistry()` to add a queue, semaphore or mutex handle to the registry if you want the handle to be available to a kernel aware debugger, and `vQueueUnregisterQueue()` to remove the queue, semaphore or mutex from the register. If you are not using a kernel aware debugger then this function can be ignored.

### Parameters

- **xQueue**: The handle of the queue being removed from the registry.

```c
const char* pcQueueGetName (QueueHandle_t xQueue)
```

The queue registry is provided as a means for kernel aware debuggers to locate queues, semaphores and mutexes. Call `pcQueueGetName()` to look up and return the name of a queue in the queue registry from the queue’s handle.

**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.

```c
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.

```c
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.

```c
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](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
Chapter 2. API Reference

- **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.

```c
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.

**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.

```c
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.

```c
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(QueueHandle_t xQueueSet)  
A version of xQueueSelectFromSet() that can be used from an ISR.

Macros  
**xQueueCreate** (uxQueueLength, uxItemSize)  
Creates a new queue instance, and returns a handle by which the new queue can be referenced.

Internally, within the FreeRTOS implementation, queues use two blocks of memory. The first block is used to hold the queue’s data structures. The second block is used to hold items placed into the queue. If a queue is created using xQueueCreate() then both blocks of memory are automatically dynamically allocated inside the xQueueCreate() function. (see [https://www.FreeRTOS.org/a00111.html](https://www.FreeRTOS.org/a00111.html). If a queue is created using xQueueCreateStatic() then the application writer must provide the memory that will get used by the queue. xQueueCreateStatic() therefore allows a queue to be created without using any dynamic memory allocation.


Example usage:

```c
struct AMessage  
{  
    char ucMessageID;  
    char ucData[20];  
};

void vATask( void *pvParameters )  
{  
    QueueHandle_t xQueue1, xQueue2;  
    // Create a queue capable of containing 10 uint32_t values.  
    xQueue1 = xQueueCreate( 10, sizeof( uint32_t ) );  
    if( xQueue1 == 0 )  
    {  
        // Queue was not created and must not be used.  
    }  
    // Create a queue capable of containing 10 pointers to AMessage structures.  
    // These should be passed by pointer as they contain a lot of data.  
    xQueue2 = xQueueCreate( 10, sizeof( struct AMessage * ) );  
    if( xQueue2 == 0 )  
    {  
        // Queue was not created and must not be used.  
    }  
    // ... Rest of task code.  
}
```

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.

\textbf{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 \url{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.

\url{https://www.FreeRTOS.org/Embedded-RTOS-Queues.html}

Example usage:

```c
struct AMessage  
{  
    char ucMessageID;  
    char ucData[ 20 ];  
};

#define QUEUE_LENGTH 10  
#define ITEM_SIZE sizeof( uint32_t )

// xQueueBuffer will hold the queue structure.  
StaticQueue_t xQueueBuffer;

// ucQueueStorage will hold the items posted to the queue. Must be at least  
// [(queue length) * ( queue item size)] bytes long.  
uint8_t ucQueueStorage[ QUEUE_LENGTH * ITEM_SIZE ];

void vATask( void *pvParameters )
{
    QueueHandle_t xQueue1;
    
    // Create a queue capable of containing 10 uint32_t values.  
    xQueue1 = xQueueCreate( QUEUE_LENGTH, // The number of items the queue can...  
        ITEM_SIZE // The size of each item in the queue  
        & ucQueueStorage[ 0 ] ), // The buffer that will...  
        // hold the items in the queue.  
        &xQueueBuffer ); // The buffer that will hold the...  
        // queue structure.

    // The queue \textbf{is} guaranteed to be created successfully \textbf{as} no dynamic memory  
    // allocation \textbf{is} used. Therefore xQueue1 \textbf{is} now a handle to a valid queue.  
    // ... Rest of task code. 
}
```

\textbf{Return} If the queue is created then a handle to the created queue is returned. If pxQueueBuffer is NULL then NULL is returned.

\textbf{Parameters}

- \textbf{uxQueueLength}: The maximum number of items that the queue can contain.
- \textbf{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.
- \textbf{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.
- \textbf{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:

```c
struct AMessage
{
    char ucMessageID;
    char ucData[20];
} xMessage;

uint32_t ulVar = 10UL;

void vATask( void *pvParameters )
{
    QueueHandle_t xQueue1, xQueue2;
    struct AMessage *pxMessage;

    // Create a queue capable of containing 10 uint32_t values.
    xQueue1 = xQueueCreate( 10, sizeof( uint32_t ) );

    // Create a queue capable of containing 10 pointers to AMessage structures.
    // These should be passed by pointer as they contain a lot of data.
    xQueue2 = xQueueCreate( 10, sizeof( struct AMessage * ) );

    // ...

    if( xQueue1 != 0 )
    {
        // Send an uint32_t. Wait for 10 ticks for space to become available if necessary.
        if( xQueueSendToFront( xQueue1, ( void * ) &ulVar, ( TickType_t ) 10 ) != pdPASS )
        {
            // Failed to post the message, even after 10 ticks.
        }
    }

    if( xQueue2 != 0 )
    {
        // Send a pointer to a struct AMessage object. Don't block if the queue is already full.
        pxMessage = &xMessage;
        xQueueSendToFront( xQueue2, ( void * ) &pxMessage, ( TickType_t ) 0 );
    }

    // ... 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:

```c
struct AMessage
{
    char ucMessageID;
    char ucData[20];
} xMessage;
uint32_t ulVar = 10UL;
void vATask( void *pvParameters )
{
    QueueHandle_t xQueue1, xQueue2;
    struct AMessage *pxMessage;
    // Create a queue capable of containing 10 uint32_t values.
    xQueue1 = xQueueCreate( 10, sizeof( uint32_t ) );
    // Create a queue capable of containing 10 pointers to AMessage structures.
    // These should be passed by pointer as they contain a lot of data.
    xQueue2 = xQueueCreate( 10, sizeof( struct AMessage * ) );
    ...
    if( xQueue1 != 0 )
    {
        // Send an uint32_t. Wait for 10 ticks for space to become available if necessary.
        if( xQueueSendToBack( xQueue1, (void *) &ulVar, (TickType_t) 10 ) != pdPASS )
        {
            // Failed to post the message, even after 10 ticks.
        }
    }
    if( xQueue2 != 0 )
    {
        // 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:

```c
struct AMessage
{
    char ucMessageID;
    char ucData[20];
} xMessage;

uint32_t ulVar = 10UL;

void vATask( void *pvParameters )
{
    QueueHandle_t xQueue1, xQueue2;
    struct AMessage *pxMessage;

    // Create a queue capable of containing 10 uint32_t values.
    xQueue1 = xQueueCreate( 10, sizeof( uint32_t ) );

    // Create a queue capable of containing 10 pointers to AMessage structures.
    // These should be passed by pointer as they contain a lot of data.
    xQueue2 = xQueueCreate( 10, sizeof( struct AMessage * ) );

    if( xQueue1 != 0 )
    {
        // Send an uint32_t. Wait for 10 ticks for space to become available if necessary.
        if( xQueueSend( xQueue1, ( void * ) &ulVar, ( TickType_t ) 10 ) != pdPASS )
        {
            // 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, pItemToQueue)**

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.
- `pItemToQueue`: 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.

\textbf{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();
    }
}
```

\textbf{Return} pdTRUE if the data was successfully sent to the queue, otherwise errQUEUE_FULL.

\textbf{Parameters}

- \texttt{xQueue}: The handle to the queue on which the item is to be posted.
- \texttt{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.
- \texttt{[out] pxHigherPriorityTaskWoken}: xQueueSendToFrontFromISR() 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.

\textbf{xQueueSendToBackFromISR (xQueue, pvItemToQueue, pxHigherPriorityTaskWoken)}

This is a macro that calls xQueueGenericSendFromISR().

Post an item to the back of a queue. It is safe to use this macro from within an interrupt service routine.

Items are queued by copy not reference so it is preferable to only queue small items, especially when called from an ISR. In most cases it would be preferable to store a pointer to the item being queued.

Example usage for buffered IO (where the ISR can obtain more than one value per call):

```c
void vBufferISR( void )
{
    char cIn;
    BaseType_t xHigherPriorityTaskWoken;

    // We have not woken a task at the start of the ISR.
    xHigherPriorityTaskWoken = pdFALSE;

    // Loop until the buffer is empty.
    do
    {
        // Obtain a byte from the buffer.
        cIn = portINPUT_BYTE( RX_REGISTER_ADDRESS );

        // Post the byte.
        xQueueSendToBackFromISR( xRxQueue, &cIn, &xHigherPriorityTaskWoken );
    } while( portINPUT_BYTE( BUFFER_COUNT ) );

    // Now the buffer is empty we can switch context if necessary.
    if( xHigherPriorityTaskWoken )
    {
        portYIELD_FROM_ISR();
    }
}```
We have not woken a task at the start of the ISR.

xHigherPriorityTaskWoken = pdFALSE;

// Loop until the buffer is empty.
do{
   // Obtain a byte from the buffer.
cIn = portINPUT_BYTE( RX_REGISTER_ADDRESS );
   // Post the byte.
xQueueSendToBackFromISR( xRxQueue, &cIn, &xHigherPriorityTaskWoken );
}while( portINPUT_BYTE( BUFFER_COUNT ) );

// Now the buffer is empty we can switch context if necessary.
if( xHigherPriorityTaskWoken ){
   portYIELD_FROM_ISR ( );
}

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 unblocked task has a priority higher than the currently
  running task. If xQueueSendToBackFromISR() sets this value to pdTRUE then a context switch should be requested
  before the interrupt is exited.

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 *not* to use xQueueOverwriteFromISR() on queues that can
   // contain more than one value, and doing so will trigger an assertion
   // if configASSERT() is defined.
   xQueue = xQueueCreate( 1, sizeof( uint32_t ) );
}

void vAnInterruptHandler( void )
{
   // xHigherPriorityTaskWoken must be set to pdFALSE before it is used.
   BaseType_t xHigherPriorityTaskWoken = pdFALSE;
   uint32_t ulVarToSend, ulValReceived;

   // Write the value 10 to the queue using xQueueOverwriteFromISR().
   ulVarToSend = 10;
   }
xQueueOverwriteFromISR( xQueue, &ulVarToSend, &xHigherPriorityTaskWoken );

// The queue is full, but calling xQueueOverwriteFromISR() again will still pass because the value held in the queue will be overwritten with the new value.
ulVarToSend = 100;
xQueueOverwriteFromISR( xQueue, &ulVarToSend, &xHigherPriorityTaskWoken );

// Reading from the queue will now return 100.

//
// if( xHigherPriorityTaskWoken == pdTRUE )
{ 
   // Writing to the queue caused a task to unblock and the unblocked task has a priority higher than or equal to the priority of the currently executing task (the task this interrupt interrupted). Perform 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 *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 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 xQueueSendToBackFromISR() and xQueueSendToFrontFromISR() macros.

Post an item to the back of a queue. It is safe to use this function from within an interrupt service routine.

Items are queued by copy not reference so it is preferable to only queue small items, especially when called from an ISR. In most cases it would be preferable to store a pointer to the item being queued.

Example usage for buffered IO (where the ISR can obtain more than one value per call):

```c
void vBufferISR( void )
{
    char cIn;
    BaseType_t xHigherPriorityTaskWoken;

    // We have not woken a task at the start of the ISR.
    xHigherPriorityTaskWoken = pdFALSE;

    // Loop until the buffer is empty.
    do 
    { 
        // Obtain a byte from the buffer.
```
cIn = portINPUT_BYTE(RX_REGISTER_ADDRESS);

// Post the byte.
xQueueSendFromISR(xRxQueue, &cIn, &xHigherPriorityTaskWoken);
}
while (portINPUT_BYTE(BUFFER_COUNT));

// Now the buffer is empty we can switch context if necessary.
if (xHigherPriorityTaskWoken)
{
    // Actual macro used here is port specific.
    portYIELD_FROM_ISR();
}

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: xQueueSendFromISR() will set *pxHigherPriori-
  tyTaskWoken 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

ttypedef struct QueueDefinition *QueueHandle_t

ttypedef 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.

nttypedef struct QueueDefinition *QueueSetMemberHandle_t

Queue sets can contain both queues and semaphores, so the QueueSetMemberHandle_t is defined as a type to
be used where a parameter or return value can be either an QueueHandle_t or an SemaphoreHandle_t.

Semaphore API

Header File

- components/freertos/FreeRTOS-Kernel/include/freertos/semphr.h

Macros

semBINARY_SEMAPHORE_QUEUE_LENGTH
semSEMAPHORE_QUEUE_ITEM_LENGTH
semGIVE_BLOCK_TIME
vSemaphoreCreateBinary(xSemaphore)
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 \texttt{xSemaphoreCreateBinary()} then the required memory is automatically dynamically allocated inside the \texttt{xSemaphoreCreateBinary()} function. (see \url{https://www.FreeRTOS.org/a00111.html}). If a binary semaphore is created using \texttt{xSemaphoreCreateBinaryStatic()} then the application writer must provide the memory. \texttt{xSemaphoreCreateBinaryStatic()} therefore allows a binary semaphore to be created without using any dynamic memory allocation.

The old \texttt{vSemaphoreCreateBinary()} macro is now deprecated in favour of this \texttt{xSemaphoreCreateBinary()} function. Note that binary semaphores created using the \texttt{vSemaphoreCreateBinary()} macro are created in a state such that the first call to ‘take’ the semaphore would pass, whereas binary semaphores created using \texttt{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 \texttt{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 \texttt{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** (\texttt{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! \url{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 \texttt{xSemaphoreCreateBinary()} then the required memory is automatically dynamically allocated inside the \texttt{xSemaphoreCreateBinary()} function. (see \url{https://www.FreeRTOS.org/a00111.html}). If a binary semaphore is created using \texttt{xSemaphoreCreateBinaryStatic()} then the application writer must provide the memory. \texttt{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 \texttt{xSemaphoreCreateMutex()}.

Example usage:

```c
SemaphoreHandle_t xSemaphore = NULL;
StaticSemaphore_t xSemaphoreBuffer;
```

(continues on next page)
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
    // return NULL.
    xSemaphore = xSemaphoreCreateBinaryStatic( &xSemaphoreBuffer );
    // 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 xSemaphoreCre-
ateBinary(), 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 IN-
CLUDE_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.

**xSemaphoreTakeRecursive** (xMutex, xBlockTime)

*Macro* to recursively obtain, or ‘take’, a mutex type semaphore. The mutex must have previously been created using a call to xSemaphoreCreateRecursiveMutex();

configUSE_RECURSIVE_MUTEXES must be set to 1 in FreeRTOSConfig.h for this macro to be available.

This macro must not be used on mutexes created using xSemaphoreCreateMutex().

A mutex used recursively can be ‘taken’ repeatedly by the owner. The mutex doesn’t become available again until the owner has called xSemaphoreGiveRecursive() for each successful ‘take’ request. For example, if a task successfully ‘takes’ the same mutex 5 times then the mutex will not be available to any other task until it has also ‘given’ the mutex back exactly five times.

Example usage:

```c
SemaphoreHandle_t xMutex = NULL;

// A task that creates a mutex.
void vATask( void * pvParameters )
{
    // Create the mutex to guard a shared resource.
    xMutex = xSemaphoreCreateRecursiveMutex();
}

// A task that uses the mutex.
void vAnotherTask( void * pvParameters )
{
    // ... Do other things.

    if( xMutex != NULL )
    {
        // See if we can obtain the mutex. If the mutex is not available
        // wait 10 ticks to see if it becomes free.
        if( xSemaphoreTakeRecursive( xSemaphore, ( TickType_t ) 10 ) == pdTRUE )
        {
            // We were able to obtain the mutex and can now access the
            // shared resource.

            // ...
            // For some reason due to the nature of the code further calls to
            // xSemaphoreTakeRecursive() are made on the same mutex. In real
            // code these would not be just sequential calls as this would make
            // no sense. Instead the calls are likely to be buried inside
            // a more complex call structure.
            xSemaphoreTakeRecursive( xMutex, ( TickType_t ) 10 );
            xSemaphoreTakeRecursive( xMutex, ( TickType_t ) 10 );

            // The mutex has now been 'taken' three times, so will not be
            // available to another task until it has also been given back
            // three times. Again it is unlikely that real code would have
```

(continues on next page)
// these calls sequentially, but instead buried in a more complex
// call structure. This is just for illustrative purposes.
xSemaphoreGiveRecursive(xMutex);
xSemaphoreGiveRecursive(xMutex);
xSemaphoreGiveRecursive(xMutex);

    // Now the mutex can be taken by other tasks.
}
else{
    // We could not obtain the mutex and can therefore not access
    // the shared resource safely.
}
}

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:

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:

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.

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Chapter 2. API Reference

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```c
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.
```c
xSemaphoreGiveRecursive( xMutex );
xSemaphoreGiveRecursive( xMutex );
xSemaphoreGiveRecursive( xMutex );
```

// Now the mutex can be taken by other tasks.
```c
} 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.
        }
    }
}
```

(continues on next page)
// Timer ISR
void vTimerISR( void * pvParameters )
{
static uint8_t ucLocalTickCount = 0;
static BaseType_t xHigherPriorityTaskWoken;

    // A timer tick has occurred.
    // ... Do other time functions.
    // Is it time for vATask () to run?
    xHigherPriorityTaskWoken = pdFALSE;
    ucLocalTickCount++;
    if( ucLocalTickCount >= TICKS_TO_WAIT )
    {
        // Unblock the task by releasing the semaphore.
        xSemaphoreGiveFromISR( xSemaphore, &xHigherPriorityTaskWoken );

        // Reset the count so we release the semaphore again in 10 ticks time.
        ucLocalTickCount = 0;
    }
    if( xHigherPriorityTaskWoken != pdFALSE )
    {
        // We can force a context switch here. Context switching from an
        // ISR uses port specific syntax. Check the demo task for your port
        // to find the syntax required.
    }
}

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 *pxHigherPriorityTaskWoken to pdTRUE if giving the
  semaphore caused a task to unblock, and the unblocked task has a priority higher than the currently running task. If
  xSemaphoreGiveFromISR() sets this value to pdTRUE then a context switch should be requested before the interrupt is exited.

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 *pxHigherPriorityTaskWoken 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 provide the memory. xSemaphoreCreateMutexStatic() therefore allows a mutex to be created without using any dynamic memory allocation.

Mutexes created using this function can be accessed using the xSemaphoreTake() and xSemaphoreGive() macros. The xSemaphoreTakeRecursive() and xSemaphoreGiveRecursive() macros must not be used.

This type of semaphore uses a priority inheritance mechanism so a task ‘taking’ a semaphore MUST ALWAYS ‘give’ the semaphore back once the semaphore it is no longer required.

Mutex type semaphores cannot be used from within interrupt service routines.

See xSemaphoreCreateBinary() for an alternative implementation that can be used for pure synchronisation (where one task or interrupt always ‘gives’ the semaphore and another always ‘takes’ the semaphore) and from within interrupt service routines.

Example usage:

```
SemaphoreHandle_t xSemaphore;

void vATask( void * pvParameters )
{
    // Semaphore cannot be used before a call to xSemaphoreCreateMutex().
    // This is a macro so pass the variable in directly.
    xSemaphore = xSemaphoreCreateMutex();

    if( xSemaphore != NULL )
    {
        // The semaphore was created successfully.
        // The semaphore can now be used.
    }
}
```

**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.

xSemaphoreCreateMutexStatic(pxMutexBuffer)

Creates a new mutex type semaphore instance, and returns a handle by which the new mutex can be referenced.

Internally, within the FreeRTOS implementation, mutex semaphores use a block of memory, in which the mutex structure is stored. If a mutex is created using xSemaphoreCreateMutex() then the required memory is automatically dynamically allocated inside the xSemaphoreCreateMutex() function. (see https://www.FreeRTOS.org/a00111.html). If a mutex is created using xSemaphoreCreateMutexStatic() then the application writer must provide the memory. xSemaphoreCreateMutexStatic() therefore allows a mutex to be created without using any dynamic memory allocation.

Mutexes created using this function can be accessed using the xSemaphoreTake() and xSemaphoreGive() macros. The xSemaphoreTakeRecursive() and xSemaphoreGiveRecursive() macros must not be used.

This type of semaphore uses a priority inheritance mechanism so a task ‘taking’ a semaphore MUST ALWAYS ‘give’ the semaphore back once the semaphore it is no longer required.

Mutex type semaphores cannot be used from within interrupt service routines.

See xSemaphoreCreateBinary() for an alternative implementation that can be used for pure synchronisation (where one task or interrupt always ‘gives’ the semaphore and another always ‘takes’ the semaphore) and from within interrupt service routines.

Example usage:
SemaphoreHandle_t xSemaphore;
StaticSemaphore_t xMutexBuffer;

void vATask( void * pvParameters )
{
    // A mutex cannot be used before it has been created. xMutexBuffer is
    // into xSemaphoreCreateMutexStatic() so no dynamic memory allocation is
    // attempted.
xSemaphore = xSemaphoreCreateMutexStatic( &xMutexBuffer );

    // As no dynamic memory allocation was performed, xSemaphore cannot be NULL,
    // so there is no need to check it.
}

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.

xSemaphoreCreateRecursiveMutex()
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 mu-
tex structure is stored. If a recursive mutex is created using xSemaphoreCreateRecursiveMutex() then the
required memory is automatically dynamically allocated inside the xSemaphoreCreateRecursiveMutex() func-
tion. (see http://www.freertos.org/a00111.html). If a recursive mutex is created using xSemaphoreCreateRe-
cursiveMutexStatic() 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 xSemaphore-
GiveRecursive() 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:

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.
    }
}
Return xSemaphore Handle to the created mutex semaphore. Should be of type SemaphoreHandle_t.

xSemaphoreCreateRecursiveMutexStatic (pxStaticSemaphore)

Creates a new recursive mutex type semaphore instance, and returns a handle by which the new recursive mutex can be referenced.

Internally, within the FreeRTOS implementation, recursive mutexes use a block of memory, in which the mutex structure is stored. If a recursive mutex is created using xSemaphoreCreateRecursiveMutex() then the required memory is automatically dynamically allocated inside the xSemaphoreCreateRecursiveMutex() function. (see https://www.FreeRTOS.org/a00111.html). If a recursive mutex is created using xSemaphoreCreateRecursiveMutexStatic() then the application writer must provide the memory that will get used by the mutex. xSemaphoreCreateRecursiveMutexStatic() therefore allows a recursive mutex to be created without using any dynamic memory allocation.

Mutexes created using this macro can be accessed using the xSemaphoreTakeRecursive() and xSemaphoreGiveRecursive() macros. The xSemaphoreTake() and xSemaphoreGive() macros must not be used.

A mutex used recursively can be ‘taken’ repeatedly by the owner. The mutex doesn’t become available again until the owner has called xSemaphoreGiveRecursive() for each successful ‘take’ request. For example, if a task successfully ‘takes’ the same mutex 5 times then the mutex will not be available to any other task until it has also ‘given’ the mutex back exactly five times.

This type of semaphore uses a priority inheritance mechanism so a task ‘taking’ a semaphore MUST ALWAYS ‘give’ the semaphore back once the semaphore it is no longer required.

Mutex type semaphores cannot be used from within interrupt service routines.

See xSemaphoreCreateBinary() for an alternative implementation that can be used for pure synchronisation (where one task or interrupt always ‘gives’ the semaphore and another always ‘takes’ the semaphore) and from within interrupt service routines.

Example usage:

```c
SemaphoreHandle_t xSemaphore;
StaticSemaphore_t xMutexBuffer;

void vATask( void * pvParameters )
{
    // A recursive semaphore cannot be used before it is created. Here a
    // recursive mutex is created using xSemaphoreCreateRecursiveMutexStatic().
    // The address of xMutexBuffer is passed into the function, and will hold
    // the mutexes data structures - so no dynamic memory allocation will be
    // attempted.
    xSemaphore = xSemaphoreCreateRecursiveMutexStatic( &xMutexBuffer );

    // As no dynamic memory allocation was performed, xSemaphore cannot be NULL,
    // so there is no need to check it.
}
```

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.

xSemaphoreCreateCounting (uxMaxCount, uxInitialCount)

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 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`-
Chapter 2. API Reference

The `xSemaphoreCreateCountingStatic()` function. (see https://www.FreeRTOS.org/a00111.html). If a counting semaphore is created using `xSemaphoreCreateCountingStatic()` then the application writer must provide the memory. `xSemaphoreCreateCountingStatic()` therefore allows a counting semaphore to be created without using any dynamic memory allocation.

Counting semaphores are typically used for two things:

1) Counting events.

In this usage scenario an event handler will ‘give’ a semaphore each time an event occurs (incrementing the semaphore count value), and a handler task will ‘take’ a semaphore each time it processes an event (decrementing the semaphore count value). The count value is therefore the difference between the number of events that have occurred and the number that have been processed. In this case it is desirable for the initial count value to be zero.

2) Resource management.

In this usage scenario the count value indicates the number of resources available. To obtain control of a resource a task must first obtain a semaphore - decrementing the semaphore count value. When the count value reaches zero there are no free resources. When a task finishes with the resource it ‘gives’ the semaphore back - incrementing the semaphore count value. In this case it is desirable for the initial count value to be equal to the maximum count value, indicating that all resources are free.

Example usage:

```c
SemaphoreHandle_t xSemaphore;
StaticSemaphore_t xSemaphoreBuffer;

void vATask( void *pvParameters )
{
    SemaphoreHandle_t xSemaphore = NULL;

    // Counting semaphore cannot be used before they have been created. Create
    // a counting semaphore using xSemaphoreCreateCountingStatic(). The max
    // value to which the semaphore can count is 10, and the initial value
    // assigned to the count will be 0. The address of xSemaphoreBuffer is
    // passed in and will be used to hold the semaphore structure, so no dynamic
    // memory allocation will be used.
    xSemaphore = xSemaphoreCreateCounting( 10, 0, &xSemaphoreBuffer );

    // No memory allocation was attempted so xSemaphore cannot be NULL, so there
    // is no need to check its value.
}
```

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/FreeRTOS-Kernel/include/freertos/timers.h

**Functions**
```c
TimerHandle_t xTimerCreate( const char * const pcTimerName, TickType_t xTimerPeriodInTicks, UBaseType_t uxAutoReload, void *const pvTimerID, TimerCallbackFunction_t pxCallbackFunction);
```
Creates a new software timer instance, and returns a handle by which the created software timer can be referenced.

Internally, within the FreeRTOS implementation, software timers use a block of memory, in which the timer data structure is stored. If a software timer is created using xTimerCreate() then the required memory is automatically dynamically allocated inside the xTimerCreate() function. (see [https://www.FreeRTOS.org/a00111.html](https://www.FreeRTOS.org/a00111.html)). If a software timer is created using xTimerCreateStatic() then the application writer must provide the memory that will get used by the software timer. xTimerCreateStatic() therefore allows a software timer to be created without using any dynamic memory allocation.

Timers are created in the dormant state. The xTimerStart(), xTimerReset(), xTimerStartFromISR(), xTimerResetFromISR(), xTimerChangePeriod() and xTimerChangePeriodFromISR() API functions can all be used to transition a timer into the active state.

**Example usage:**
```c
* #define NUM_TIMERS 5
  *
  * // An array to hold handles to the created timers.
  * TimerHandle_t xTimers[ NUM_TIMERS ];
  *
  * // An array to hold a count of the number of times each timer expires.
  * int32_t lExpireCounters[ NUM_TIMERS ] = { 0 };
  *
  * // Define a callback function that will be used by multiple timer instances.
  * // The callback function does nothing but count the number of times the
  * // associated timer expires, and stop the timer once the has expired
  * // 10 times.
  * void vTimerCallback( TimerHandle_t pxTimer )
  * {
  *    int32_t lArrayIndex;
  * }
```
(continues on next page)
* const int32_t xMaxExpiryCountBeforeStopping = 10;
* 
* // Optionally do something if the pxTimer parameter is NULL.
* configASSERT( pxTimer );
* 
* // Which timer expired?
* lArrayIndex = ( int32_t ) pvTimerGetTimerID( pxTimer );
* 
* // Increment the number of times that pxTimer has expired.
* lExpireCounters[ lArrayIndex ] += 1;
* 
* // If the timer has expired 10 times then stop it from running.
* if( lExpireCounters[ lArrayIndex ] == xMaxExpiryCountBeforeStopping )
* {
*     // Do not use a block time if calling a timer API function from a
*     // timer callback function, as doing so could cause a deadlock!
*     xTimerStop( pxTimer, 0 );
* }
* 
* void main( void )
* {
*     int32_t x;
*     
*     // Create then start some timers. Starting the timers before the
*     // scheduler
*     // has been started means the timers will start running immediately that
*     // the scheduler starts.
*     for( x = 0; x < NUM_TIMERS; x++ )
*     {
*         xTimers[ x ] = xTimerCreate( "Timer", // Just a text name,
*             ( 100 * x ), // The timer period
*             pdTRUE, // The timers will
*             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.
*         }
*     }
* }
* }
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);”.

```c
TimerHandle_t xTimerCreateStatic(const char *const pcTimerName, TickType_t xTimerPeriodInTicks, const UBaseType_t uxAutoReload, void *const 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 )
* {
* 
* // Obtain the address of the variable to increment from the timer ID.
* puxVariableToIncrement = ( UBaseType_t * ) pvTimerGetTimerID(xExpiredTimer);
* 
* // Increment the variable to show the timer callback has executed.
* ( *puxVariableToIncrement )++;
* 
* // If this callback has executed the required number of times, stop the timer.
* if( *puxVariableToIncrement == 5 )
* {
* // This is called from a timer callback so must not block.
* xTimerStop( xExpiredTimer, staticDONT_BLOCK );
* }
* }
* 
* void main( void )
* {
* 
* // Create the software time. xTimerCreateStatic() has an extra parameter than the normal xTimerCreate() API function. The parameter is a 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
* 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
* 
* (continues on next page)
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 \( \frac{500}{\text{portTICK_PERIOD_MS}} \) 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)
void *pvTimerGetTimerID(TimerHandle_t xTimer);

Returns the ID assigned to the timer.

IDs are assigned to timers using the pvTimerID parameter of the call to xTimerCreated() that was used to create the timer, and by calling the vTimerSetTimerID() API function.

If the same callback function is assigned to multiple timers then the timer ID can be used as time specific (timer local) storage.

Example usage:

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)
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:
Chapter 2. API Reference

Parameters

• xTimer: The timer being updated.
• pvNewID: The ID to assign to the timer.

See the xTimerCreate() API function example usage scenario.

```c
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:

```c
void vAFunction( TimerHandle_t xTimer ) {
  if( xTimerIsTimerActive( xTimer ) != pdFALSE ) // or more simply and equivalently
    "if( xTimerIsTimerActive( xTimer ) )"
  {
    // xTimer is active, do something.
  }
  else
  {
    // xTimer is not active, do something else.
  }
}
```

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.

```c
TaskHandle_t xTimerGetTimerDaemonTaskHandle();
```

xTimerGetTimerDaemonTaskHandle() is only available if INCLUDE_xTimerGetTimerDaemonTaskHandle is set to 1 in FreeRTOSConfig.h.

Simply returns the handle of the timer service/daemon task. It it not valid to call xTimerGetTimerDaemonTaskHandle() before the scheduler has been started.

```c
BaseType_t xTimerPendFunctionCallFromISR( PendedFunction_t xFunctionToPend, void *pvParameter1, uint32_t ulParameter2, BaseType_t *pxHigherPriorityTaskWoken );
```

Used from application interrupt service routines to defer the execution of a function to the RTOS daemon task (the timer service task, hence this function is implemented in timers.c and is prefixed with ‘Timer’).

Ideally an interrupt service routine (ISR) is kept as short as possible, but sometimes an ISR either has a lot of processing to do, or needs to perform processing that is not deterministic. In these cases xTimerPendFunctionCallFromISR() can be used to defer processing of a function to the RTOS daemon task.

A mechanism is provided that allows the interrupt to return directly to the task that will subsequently execute the pended callback function. This allows the callback function to execute contiguously in time with the interrupt - just as if the callback had executed in the interrupt itself.

Example usage:

```c
// This function assumes xTimer has already been created.
void vAFunction( TimerHandle_t xTimer ) {
  if( xTimerIsTimerActive( xTimer ) != pdFALSE ) // or more simply and equivalently "if( xTimerIsTimerActive( xTimer ) )"
    {
      // xTimer is active, do something.
    }
  else
    {
      // xTimer is not active, do something else.
    }
}
The callback function that will execute in the context of the daemon task.

Note callback functions must all use this same prototype.

```c
void vProcessInterface( void *pvParameter1, uint32_t ulParameter2 ) {
    BaseType_t xInterfaceToService;

    // The interface that requires servicing is passed in the second parameter. The first parameter is not used in this case.
    xInterfaceToService = ( BaseType_t ) ulParameter2;

    // ...Perform the processing here...
}
```

An ISR that receives data packets from multiple interfaces

```c
void vAnISR( void ) {
    BaseType_t xInterfaceToService, xHigherPriorityTaskWoken;

    // Query the hardware to determine which interface needs processing.
    xInterfaceToService = prvCheckInterfaces();

    // The actual processing is to be deferred to a task. Request the vProcessInterface() callback function is executed, passing in the number of the interface that needs processing. The 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.

```c
BaseType_t xTimerPendFunctionCall( PendedFunction_t xFunctionToPend, void *pvParameter1, uint32_t ulParameter2, TickType_t xTicksToWait)
```

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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);

Returns the name that was assigned to a timer when the timer was created.

Return The name assigned to the timer specified by the xTimer parameter.

Parameters
- xTimer: The handle of the timer being queried.

void vTimerSetReloadMode(TimerHandle_t xTimer, const UBaseType_t uxAutoReload)
void vTimerSetReloadMode(TimerHandle_t xTimer, const UBaseType_t uxAutoReload);

Updates a timer to be either an auto-reload timer, in which case the timer automatically resets itself each time it expires, or a one-shot timer, in which case the timer will only expire once unless it is manually restarted.

Parameters
- xTimer: The handle of the timer being updated.
- uxAutoReload: If uxAutoReload is set to pdTRUE then the timer will expire repeatedly with a frequency set by the timer’s period (see the xTimerPeriodInTicks parameter of the xTimerCreate() API function). If uxAutoReload is set to pdFALSE then the timer will be a one-shot timer and enter the dormant state after it expires.

UBaseType_t uxTimerGetReloadMode(TimerHandle_t xTimer)
UBaseType_t uxTimerGetReloadMode(TimerHandle_t xTimer);

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.

Return If the timer is an auto-reload timer then pdTRUE is returned, otherwise pdFALSE is returned.

Parameters
- xTimer: The handle of the timer being queried.

TickType_t xTimerGetPeriod(TimerHandle_t xTimer)
TickType_t xTimerGetPeriod(TimerHandle_t xTimer);

Returns the period of a timer.

Return The period of the timer in ticks.

Parameters
- xTimer: The handle of the timer being queried.

TickType_t xTimerGetExpiryTime(TimerHandle_t xTimer)
TickType_t xTimerGetExpiryTime(TimerHandle_t xTimer);

Returns the time in ticks at which the timer will expire. If this is less than the current tick count then the expiry time has overflowed from the current time.
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.

Parameters

- **xTimer**: The handle of the timer being queried.

```c
void vApplicationGetTimerTaskMemory(StaticTask_t **ppxTimerTaskTCBBuffer, StackType_t **ppxTimerTaskStackBuffer, uint32_t *pulTimerTaskStackSize)
```

This function is used to provide a statically allocated block of memory to FreeRTOS to hold the Timer Task TCB. This function is required when **configSUPPORT_STATIC_ALLOCATION** is set. For more information see this URI: https://www.FreeRTOS.org/a00110.html#configSUPPORT_STATIC_ALLOCATION

Parameters

- **ppxTimerTaskTCBBuffer**: A handle to a statically allocated TCB buffer
- **ppxTimerTaskStackBuffer**: A handle to a statically allocated Stack buffer for thie idle task
- **pulTimerTaskStackSize**: A pointer to the number of elements that will fit in the allocated stack buffer

Macros

- `tmrCOMMAND_EXECUTE_CALLBACK_FROM_ISR`
- `tmrCOMMAND_EXECUTE_CALLBACK`
- `tmrCOMMAND_START_DONT_TRACE`
- `tmrCOMMAND_START`
- `tmrCOMMAND_RESET`
- `tmrCOMMAND_STOP`
- `tmrCOMMAND_CHANGE_PERIOD`
- `tmrCOMMAND_DELETE`
- `tmrFIRST_FROM_ISR_COMMAND`
- `tmrCOMMAND_START_FROM_ISR`
- `tmrCOMMAND_RESET_FROM_ISR`
- `tmrCOMMAND_STOP_FROM_ISR`
- `tmrCOMMAND_CHANGE_PERIOD_FROM_ISR`

```c
void xTimerStart(xTimer, 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 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.

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 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)

BaseType_t xTimerChangePeriod( TimerHandle_t xTimer, TickType_t xNewPeriod, TickType_t xTicksToWait );

Timer functionality is provided by a timer service/daemon task. Many of the public FreeRTOS timer API functions send commands to the timer service task through a queue called the timer command queue. The timer command queue is private to the kernel itself and is not directly accessible to application code. The length of the timer command queue is set by the 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:
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.

```c
void vAFunction( TimerHandle_t xTimer )
{
    if( xTimerIsTimerActive( xTimer ) != pdFALSE ) // or more simply and equivalently "if( xTimerIsTimerActive( xTimer ) )"
    {
        // xTimer is already active - delete it.
        xTimerDelete( xTimer );
    }
    else
    {
        // xTimer is not active, change its period to 500ms. This will also cause the timer to start. Block for a maximum of 100 ticks if the change period command cannot immediately be sent to the timer command queue.
        if( xTimerChangePeriod( xTimer, 500 / portTICK_PERIOD_MS, 100 ) == pdPASS )
        {
            // The command was successfully sent.
        }
        else
        {
            // The command could not be sent, even after waiting for 100 ticks
            // to pass. Take appropriate action here.
        }
    }
}
```

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 ‘n’ ticks after xTimerReset() was called, where ‘n’ is the timers defined period.

It is valid to call xTimerReset() before the scheduler has been started, but when this is done the timer will not actually start until the scheduler is started, and the timers expiry time will be relative to when the scheduler is started, not relative to when xTimerReset() was called.

The configUSE_TIMERS configuration constant must be set to 1 for xTimerReset() to be available.

Example usage:

```c
* // When a key 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.
* * 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.
* (continues on next page)
```
vSetBacklightState( BACKLIGHT_ON );

if( xTimerReset( xBacklightTimer, 100 ) != pdPASS )
{
    // The reset command was not executed successfully. Take appropriate
    // action here.
}

// Perform the rest of the key processing here.

void main( void )
{
    int32_t x;

    // Create then start the one-shot timer that is responsible for turning
    // the back-light off if no keys are pressed within a 5 second period.
    xBacklightTimer = xTimerCreate( "BacklightTimer", // Just a...
        ( 5000 / portTICK_PERIOD_MS), // The...
        // timer period in ticks.
        pdFALSE, // The timer...
        // is a one-shot timer.
        0, // The id 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:

```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 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
```
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 performed 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:

```
* // 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 compiler to
*   // compiler. Inspect the demos for the port you are using to find the
*   // actual syntax required.
*   if( xHigherPriorityTaskWoken != pdFALSE )
*   {
*     // Call the interrupt safe yield function here (actual function
*     // depends on the FreeRTOS port being used).
*   }
* }
```
Parameters

- **xTimer**: The handle of the timer that is having its period changed.
- **xNewPeriod**: The new period for xTimer. Timer periods are specified in tick periods, so the constant portTICK_PERIOD_MS can be used to convert a time that has been specified in milliseconds. For example, if the timer must expire after 100 ticks, then xNewPeriod should be set to 100. Alternatively, if the timer must expire after 500ms, then xNewPeriod can be set to (500 / portTICK_PERIOD_MS) provided configTICK_RATE_HZ is less than or equal to 1000.
- **pxHigherPriorityTaskWoken**: The timer service/daemon task spends most of its time in the Blocked state, waiting for messages to arrive on the timer command queue. Calling xTimerChangePeriodFromISR() writes a message to the timer command queue, so has the potential to transition the timer service/daemon task out of the Blocked state. If calling xTimerChangePeriodFromISR() causes the timer service/daemon task to leave the Blocked state, and the timer service/daemon task has a priority equal to or greater than the currently executing task (the task that was interrupted), then *pxHigherPriorityTaskWoken will get set to pdTRUE internally within the xTimerChangePeriodFromISR() function. If xTimerChangePeriodFromISR() sets this value to pdTRUE then a context switch should be performed before the interrupt exits.

**xTimerResetFromISR** (xTimer, pxHigherPriorityTaskWoken)

```
BaseType_t xTimerResetFromISR( TimerHandle_t xTimer, BaseType_t *pxHigherPriorityTaskWoken );
```

A version of xTimerReset() 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
* // 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.
*     }
* }
```
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
typedef struct tmrTimerControl *TimerHandle_t
typedef void (*TimerCallbackFunction_t)(TimerHandle_t xTimer)
typedef void (*PendedFunction_t)(void *, uint32_t)

Event Group API

Header File
- components/freertos/FreeRTOS-Kernel/include/freertos/event_groups.h

Functions
EventGroupHandle_t xEventGroupCreate (void)
Create a new event group.

Internally, within the FreeRTOS implementation, event groups use a [small] block of memory, in which the event group’s structure is stored. If an event groups is created using xEventGroupCreate() then the required memory is automatically dynamically allocated inside the xEventGroupCreate() function. (see https://www.FreeRTOS.org/a00111.html). 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](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](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, 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, BIT_0 | BIT_4, pdTRUE, BIT_0 | BIT_4);

  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 the bits it was waiting for were set then the returned value is the event group value before any bits were automatically cleared in the case that xClearOnExit parameter was set to pdTRUE.

**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().
- **xBitsToWaitFor**: 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, the bits are not cleared before the function returns (if the function returns for a reason other than a timeout). If xClearOnExit is set to pdFALSE, the bits are cleared before the function returns (if the function returns for a reason other than a timeout).
pdFALSE then the bits set in the event group are not altered when the call to xEventGroupWaitBits() returns.

- **xWaitForAllBits**: If xWaitForAllBits is set to pdTRUE then xEventGroupWaitBits() will return when either all the bits in uxBitsToWaitFor are set or the specified block time expires. If xWaitForAllBits is set to pdFALSE then xEventGroupWaitBits() will return when any one of the bits set in uxBitsToWaitFor is set or the specified block time expires. The block time is specified by the xTicksToWait parameter.

- **xTicksToWait**: The maximum amount of time (specified in ‘ticks’) to wait for one/all (depending on the xWaitForAllBits value) of the bits specified by uxBitsToWaitFor to become set.

### EventBits_t xEventGroupClearBits

**EventBits_t xEventGroupClearBits (EventGroupHandle_t xEventGroup, const EventBits_t uxBitsToClear)**

Clear bits within an event group. This function cannot be called from an interrupt.

**Example usage:**

```c
#define BIT_0 ( 1 << 0 )
#define BIT_4 ( 1 << 4 )

void aFunction( EventGroupHandle_t xEventGroup )
{
    EventBits_t uxBits;

    // Clear bit 0 and bit 4 in xEventGroup.
    uxBits = xEventGroupClearBits(
        xEventGroup, // The event group being updated.
        BIT_0 | BIT_4 ); // The bits being cleared.

    if( ( uxBits & ( BIT_0 | BIT_4 ) ) == ( BIT_0 | BIT_4 ) )
    {
        // Both bit 0 and bit 4 were set before xEventGroupClearBits() was called. Both will now be clear (not set).
    }
    else if( ( uxBits & BIT_0 ) != 0 )
    {
        // Bit 0 was set before xEventGroupClearBits() was called. It will now be clear.
    }
    else if( ( uxBits & BIT_4 ) != 0 )
    {
        // Bit 4 was set before xEventGroupClearBits() was called. It will now be clear.
    }
    else
    {
        // Neither bit 0 nor bit 4 were set in the first place.
    }
}
```

**Return**  The value of the event group before the specified bits were cleared.

**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 in the event group. For example, to clear bit 3 only, set uxBitsToClear to 0x08. To clear bit 3 and bit 0 set uxBitsToClear to 0x09.

### EventBits_t xEventGroupSetBits

**EventBits_t xEventGroupSetBits (EventGroupHandle_t xEventGroup, const EventBits_t uxBitsToSet)**

Set bits within an event group. This function cannot be called from an interrupt. xEventGroupSetBitsFromISR() 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:**
#define BIT_0 ( 1 << 0 )
#define BIT_4 ( 1 << 4 )

void aFunction( EventGroupHandle_t xEventGroup )
{
    EventBits_t uxBits;
    // Set bit 0 and bit 4 in xEventGroup.
    uxBits = xEventGroupSetBits( xEventGroup, bit_0 | bit_4 );
    // The bits being set.

    if( ( uxBits & ( BIT_0 | BIT_4 ) ) == ( BIT_0 | BIT_4 ) )
    {
        // Both bit 0 and bit 4 remained set when the function returned.
    }
    else if( ( uxBits & BIT_0 ) != 0 )
    {
        // Bit 0 remained set when the function returned, but bit 4 was cleared. It might be that bit 4 was cleared automatically as a task that was waiting for bit 4 was removed from the Blocked state.
    }
    else if( ( uxBits & BIT_4 ) != 0 )
    {
        // Bit 4 remained set when the function returned, but bit 0 was cleared. It might be that bit 0 was cleared automatically as a task that was waiting for bit 0 was removed from the Blocked state.
    }
    else
    {
        // Neither bit 0 nor bit 4 remained set. It might be that a task was waiting for both of the bits to be set, and the bits were cleared as the task left the Blocked state.
    }
}

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 uxBitsToWaitFor, TickType_t xTicksToWait )
```

Atomically set bits within an event group, then wait for a combination of bits to be set within the same event group. This functionality is typically used to synchronise multiple tasks, where each task has to wait for the other tasks to reach a synchronisation point before proceeding.

This function cannot be used from an interrupt.

The function will return before its block time expires if the bits specified by the uxBitsToWait parameter are set, or become set within that time. In this case all the bits specified by uxBitsToWait will be automatically cleared before the function returns.

Example usage:
// Bits used by the three tasks.
#define TASK_0_BIT ( 1 << 0 )
#define TASK_1_BIT ( 1 << 1 )
#define TASK_2_BIT ( 1 << 2 )

#define ALL_SYNC_BITS ( TASK_0_BIT | TASK_1_BIT | TASK_2_BIT )

// Use an event group to synchronise three tasks. It is assumed this event
// group has already been created elsewhere.
EventGroupHandle_t xEventBits;

void vTask0( void *pvParameters )
{
    EventBits_t uxReturn;
    TickType_t xTicksToWait = 100 / portTICK_PERIOD_MS;

    for( ;; )
    {
        // Perform task functionality here.

        // Set bit 0 in the event flag to note this task has reached the
        // sync point. The other two tasks will set the other two bits defined
        // by ALL_SYNC_BITS. All three tasks have reached the synchronisation
        // point when all the ALL_SYNC_BITS are set. Wait a maximum of 100ms
        // for this to happen.
        uxReturn = xEventGroupSync( xEventBits, TASK_0_BIT, ALL_SYNC_BITS,
                                    xTicksToWait );

        if( ( uxReturn & ALL_SYNC_BITS ) == ALL_SYNC_BITS )
        {
            // All three tasks reached the synchronisation point before the call
            // to xEventGroupSync() timed out.
        }
    }
}

void vTask1( void *pvParameters )
{
    for( ;; )
    {
        // Perform task functionality here.

        // Set bit 1 in the event flag to note this task has reached the
        // synchronisation point. The other two tasks will set the other two
        // bits defined by ALL_SYNC_BITS. All three tasks have reached the
        // synchronisation point when all the ALL_SYNC_BITS are set. Wait
        // indefinitely for this to happen.
        xEventGroupSync( xEventBits, TASK_1_BIT, ALL_SYNC_BITS, portMAX_DELAY );

        // xEventGroupSync() was called with an indefinite block time, so
        // this task will only reach here if the synchronisation was made by all
        // three tasks, so there is no need to test the return value.
    }
}

void vTask2( void *pvParameters )
{
    for( ;; )
    {
        // 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.
    }
}
The other two tasks will set the other two bits defined by \texttt{ALL\_SYNC\_BITS}. All three tasks have reached the synchronisation point when all the \texttt{ALL\_SYNC\_BITS} are set. Wait indefinitely for this to happen.

```c
xEventGroupSync( \texttt{xEventBits}, \texttt{TASK\_2\_BIT}, \texttt{ALL\_SYNC\_BITS}, \texttt{portMAX\_DELAY} );
```

\texttt{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 \texttt{return} value.

\textbf{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 \texttt{xEventGroupSync()} returned because its timeout expired then not all the bits being waited for will be set. If \texttt{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.

\textbf{Parameters}
- \texttt{xEventGroup}: The event group in which the bits are being tested. The event group must have previously been created using a call to \texttt{xEventGroupCreate()}.
- \texttt{uxBitsToSet}: The bits to set in the event group before determining if, and possibly waiting for, all the bits specified by the \texttt{uxBitsToWait} parameter are set.
- \texttt{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 \texttt{uxBitsToWaitFor} to \texttt{0x05}. To wait for bits 0 and bit 1 and bit 2 set \texttt{uxBitsToWaitFor} to \texttt{0x07}. Etc.
- \texttt{xTicksToWait}: The maximum amount of time (specified in \texttt{\texttt{m}} \texttt{\texttt{ticks}}) to wait for all of the bits specified by \texttt{uxBitsToWaitFor} to become set.

\begin{verbatim}
EventBits_t xEventGroupGetBitsFromISR( EventGroupHandle_t xEventGroup )
\end{verbatim}

A version of \texttt{xEventGroupGetBits()} that can be called from an ISR.

\textbf{Return} The event group bits at the time \texttt{xEventGroupGetBitsFromISR()} was called.

\textbf{Parameters}
- \texttt{xEventGroup}: The event group being queried.

\begin{verbatim}
void vEventGroupDelete( EventGroupHandle_t xEventGroup )
\end{verbatim}

Delete an event group that was previously created by a call to \texttt{xEventGroupCreate()}. Tasks that are blocked on the event group will be unblocked and obtain 0 as the event group’s value.

\textbf{Parameters}
- \texttt{xEventGroup}: The event group being deleted.

\textbf{Macros}
\begin{verbatim}
xEventGroupClearBitsFromISR( xEventGroup, uxBitsToClear )
\end{verbatim}

A version of \texttt{xEventGroupClear Bits()} 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 \texttt{xEventGroupClearBitsFromISR()} sends a message to the timer task to have the clear operation performed in the context of the timer task.

\textbf{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().
```

(continues on next page)
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:

#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
- xEventGroup: The event group being queried.

Type Definitions
typedef struct EventGroupDef_t *EventGroupHandle_t
typedef TickType_t EventBits_t

Stream Buffer API

Header File
- components/freertos/FreeRTOS-Kernel/include/freertos/stream_buffer.h

Functions
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.

***NOTE***: Uniquely among FreeRTOS objects, the stream buffer implementation (so also the message buffer implementation, as message buffers are built on top of stream buffers) assumes there is only one task or interrupt that will write to the buffer (the writer), and only one task or interrupt that will read from the buffer (the reader). It is safe for the writer and reader to be different tasks or interrupts, but, unlike other FreeRTOS objects, it is not safe to have multiple different writers or multiple different readers. If there are to be multiple different writers then the application writer must place each call to a writing API function (such as xStreamBufferSend()) inside a critical section and set the send block time to 0. Likewise, if there are to be multiple different readers then the application writer must place each call to a reading API function (such as xStreamBufferReceive()) inside a critical section and set the receive block time to 0.

Use xStreamBufferSend() to write to a stream buffer from a task. Use xStreamBufferSendFromISR() to write to a stream buffer from an interrupt service routine (ISR).

Example use:

```c
void vAFunction( StreamBufferHandle_t xStreamBuffer )
{
    size_t xBytesSent;
    uint8_t ucArrayToSend[] = { 0, 1, 2, 3 };
    char *pcStringToSend = "String to send";
    const TickType_t x100ms = pdMS_TO_TICKS( 100 );
...}
```
Send an array to the stream buffer, blocking for a maximum of 100ms to wait for enough space to be available in the stream buffer.

```c
uint16_t xBytesSent = xStreamBufferSend( xStreamBuffer, ( void * ) ucArrayToSend, sizeof( ucArrayToSend ), x100ms );
if( xBytesSent != sizeof( ucArrayToSend ) ) {
    // The call to xStreamBufferSend() times out before there was enough space in the buffer for the data to be written, but it did successfully write xBytesSent bytes.
}
```

Send the string to the stream buffer. Return immediately if there is not enough space in the buffer.

```c
uint16_t xBytesSent = xStreamBufferSend( xStreamBuffer, ( void * ) pcStringToSend, strlen( pcStringToSend ), 0 );
if( xBytesSent != strlen( pcStringToSend ) ) {
    // The entire string could not be added to the stream buffer because there was not enough free space in the buffer, but xBytesSent bytes were sent. Could try again to send the remaining bytes.
}
```

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.

```c
size_t xStreamBufferSendFromISR( StreamBufferHandle_t xStreamBuffer, const void *pvTxData, size_t xDataLengthBytes, BaseType_t *pxHigherPriorityTaskWoken )
```

Interrupt safe version of the API function that sends a stream of bytes to the stream buffer.

***NOTE***: 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:
// 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.
    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 Blocke state, and the unblocked task has a priority higher than the cur-
  rently 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. *pxHigherPri-
orityTaskWoken should be set to pdFALSE before it is passed into the function. See the example
code below for an example.

size_t xStreamBufferReceive( StreamBufferHandle_t xStreamBuffer, void *pvRxData, size_t xBuffer-
LengthBytes, TickType_t xTicksToWait)

Receives bytes from a stream buffer.

***NOTE***: 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
Chapter 2. API Reference

multiple different readers then the application writer must place each call to a reading API function (such as `xStreamBufferReceive()`) inside a critical section and set the receive block time to 0.

Use `xStreamBufferReceive()` to read from a stream buffer from a task. Use `xStreamBufferReceiveFromISR()` to read from a stream buffer from an interrupt service routine (ISR).

Example use:

```c
void vAFunction( StreamBuffer_t xStreamBuffer )
{
  uint8_t ucRxData[ 20 ];
  size_t xReceivedBytes;
  const TickType_t xBlockTime = pdMS_TO_TICKS( 20 );

  // Receive up to another sizeof( ucRxData ) bytes from the stream buffer.
  // Wait in the Blocked state (so not using any CPU processing time) for a
  // maximum of 100ms for the full sizeof( ucRxData ) number of bytes to be
  // available.
  xReceivedBytes = xStreamBufferReceive( xStreamBuffer,
                             ( void * ) ucRxData,
                             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.

```c
size_t xStreamBufferReceiveFromISR( StreamBufferHandle_t xStreamBuffer, void *pvRxData,
                                     size_t xBufferLengthBytes, BaseType_t *const pxHigherPriorityTaskWoken )
```

An interrupt safe version of the API function that receives bytes from a stream buffer.

Use `xStreamBufferReceive()` to read bytes from a stream buffer from a task. Use `xStreamBufferReceiveFromISR()` to read bytes from a stream buffer from an interrupt service routine (ISR).

Example use:

```c
// A stream buffer that has already been created.
StreamBuffer_t xStreamBuffer;

void vAInterruptServiceRoutine( void )
{
  uint8_t ucRxData[ 20 ];
}
```

(continues on next page)
size_t xReceivedBytes;
BaseType_t xHigherPriorityTaskWoken = pdFALSE; // Initialised to pdFALSE.

// Receive the next stream from the stream buffer.
xReceivedBytes = xStreamBufferReceiveFromISR( xStreamBuffer,
( void * ) ucRxData,
sizeof( ucRxData ),
&xHigherPriorityTaskWoken );

if( xReceivedBytes > 0 )
{
    // ucRxData contains xReceivedBytes read from the stream buffer.
    // Process the stream here....
}

// If xHigherPriorityTaskWoken was set to pdTRUE inside
// xStreamBufferReceiveFromISR() then a task that has a priority above the
// priority of the currently executing task was unblocked and a context
// switch should be performed to ensure the ISR returns to the unblocked
// task. In most FreeRTOS ports this is done by simply passing
// xHigherPriorityTaskWoken into taskYIELD_FROM_ISR(), which will test the
// variables value, and perform the context switch if necessary. Check the
// documentation for the port in use for port specific instructions.
taskYIELD_FROM_ISR( xHigherPriorityTaskWoken );

Return  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.

void vStreamBufferDelete( StreamBufferHandle_t xStreamBuffer )
Deletes a stream buffer that was previously created using a call to xStreamBufferCreate() or xStreamBuffer-
CreateStatic(). 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.

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.
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.

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
    {
        // (continues on next page)
    }
}
```
// 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. 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. 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.

```c
xStreamBufferCreateStatic(xBufferSizeBytes, xTriggerLevelBytes, pucStreamBufferStorageArea, pxStaticStreamBuffer)
```

Creates a new stream buffer using statically allocated memory. See `xStreamBufferCreate()` for a version that uses dynamically allocated memory.

```c
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;

// 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.
Chapter 2. API Reference

Parameters

- `xBufferSizeBytes`: The size, in bytes, of the buffer pointed to by the `pucStreamBufferStorageArea` parameter.
- `xTriggerLevelBytes`: The number of bytes that must be in the stream buffer before a task that is blocked on the stream buffer to wait for data is moved out of the blocked state. For example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 1 then the task will be unblocked when a single byte is written to the buffer or the task’s block time expires. As another example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 10 then the task will not be unblocked until the stream buffer contains at least 10 bytes or the task’s block time expires. If a reading task’s block time expires before the trigger level is reached then the task will still receive however many bytes are actually available. Setting a trigger level of 0 will result in a trigger level of 1 being used. It is not valid to specify a trigger level that is greater than the buffer size.
- `pucStreamBufferStorageArea`: Must point to a uint8_t array that is at least `xBufferSizeBytes + 1` big. This is the array to which streams are copied when they are written to the stream buffer.
- `pxStaticStreamBuffer`: Must point to a variable of type StaticStreamBuffer_t, which will be used to hold the stream buffer’s data structure.

Type Definitions

```c
typedef struct StreamBufferDef_t *StreamBufferHandle_t
```

Message Buffer API

Header File

- `components.freertos.FreeRTOS-Kernel/include/freertos/message_buffer.h`

Macros

```c
#define 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.
    }
```

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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:

```c
// Used to dimension the array used to hold the messages. The available space will actually be one less than this, so 999.
#define STORAGE_SIZE_BYTES 1000

// Defines the memory that will actually hold the messages within the 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 architectures a 10 byte message will take up 14 bytes of message buffer space. The maximum number of bytes that can be stored in the message buffer is actually (xBufferSizeBytes - 1).
- `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.
***NOTE***: 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
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**

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.

***NOTE***: 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 example below for an example.

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 )
    {
        // 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 im-
mediately 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.

xBMessageBufferReceiveFromISR (xBMessageBuffer, pvRxData, xBufferLengthBytes, pxHigherPri-
orityTaskWoken)

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.

***NOTE***: 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
xBMessageBufferSend()) 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
xBMessageBufferRead()) inside a critical section and set the receive block time to 0.

Use xMessageBufferReceive() to read from a message buffer from a task. Use xMessageBufferReceive-
FromISR() to read from a message buffer from an interrupt service routine (ISR).

Example use:

// A message buffer that has already been created.
xBMessageBuffer_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 unblocked task has a priority higher than the currently executing task (the task that was interrupted), then, internally, `xMessageBufferReceiveFromISR()` will set `pxHigherPriorityTaskWoken` to `pdTRUE`. If `xMessageBufferReceiveFromISR()` sets this value to `pdTRUE`, then normally a context switch should be performed before the interrupt is exited. That will ensure the interrupt returns directly to the highest priority Ready state task. `pxHigherPriorityTaskWoken` should be set to `pdFALSE` before it is passed into the function. See the code example below for an example.

`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.

`vMessageBufferIsFull`(`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.

`vMessageBufferIsEmpty`(`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.

`vMessageBufferReset`(`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 message to be available, then `pdFAIL` is returned.

Parameters
- `xMessageBuffer`: The handle of the message buffer being reset.

`vMessageBufferSpaceAvailable`(`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 size of `size_t` bytes are also written to store the message length. `sizeof(size_t)` is typically 4 bytes on a 32-bit architecture, so if `vMessageBufferSpaceAvailable()` 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.

#### xMessageBufferSpacesAvailable (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.

#### 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.
2.7.10 FreeRTOS Additions

This document describes the additional features added to ESP-IDF FreeRTOS. This document is split into the following parts:

Contents

- FreeRTOS Additions
  - Overview
  - Ring Buffers
  - Hooks
  - TLSP Deletion Callbacks
  - Component Specific Properties
  - API Reference

Overview

ESP-IDF FreeRTOS is a modified version 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.
- **Hooks**: ESP-IDF FreeRTOS hooks provide support for registering extra Idle and Tick hooks at run time. Moreover, the hooks can be asymmetric among both CPUs.
- **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 APIs to send an item, or to allocate space for an item in the ring buffer to be filled manually by the user. For efficiency reasons, **items are always retrieved from the ring buffer by reference**. As a result, all retrieved items **must also be returned** to the ring buffer by using `vRingbufferReturnItem()` or `vRingbufferReturnItemFromISR()`, in order for them to be removed from the ring buffer completely. The ring buffers are split into the three following types:

- **No-Split buffers** will guarantee that an item is stored in contiguous memory and will not attempt to split an item under any circumstances. Use No-Split buffers when items must occupy contiguous memory. **Only this buffer type allows you to get the data item address and write to the item by yourself.** Refer the documentation of the functions `xRingbufferSendAcquire()` and `xRingbufferSendComplete()` for more details.

- **Allow-Split buffers** will allow an item to be split in two parts when wrapping around the end of the buffer if there is enough space at the tail and the head of the buffer combined to store the item. Allow-Split buffers are more memory efficient than No-Split buffers but can return an item in two parts when retrieving.

- **Byte buffers** do not store data as separate items. All data is stored as a sequence of bytes, and any number of bytes can be sent or retrieved each time. Use byte buffers when separate items do not need to be maintained (e.g. a byte stream).

**Note**: No-Split buffers and Allow-Split buffers will always store items at 32-bit aligned addresses. Therefore, when retrieving an item, the item pointer is guaranteed to be 32-bit aligned. This is useful especially when you need to send some data to the DMA.
**Note:** Each item stored in No-Split or Allow-Split buffers will **require an additional 8 bytes for a header.** Item sizes will also be rounded up to a 32-bit aligned size (multiple of 4 bytes), however the true item size is recorded within the header. The sizes of No-Split and Allow-Split buffers will also be rounded up when created.

**Usage** The following example demonstrates the usage of `xRingbufferCreate()` and `xRingbufferSend()` to create a ring buffer and then send an item to it.

```c
#include "freertos/ringbuf.h"
static char tx_item[] = "test_item";
...

//Create ring buffer
RingbufHandle_t buf_handle;
buf_handle = xRingbufferCreate(1028, RINGBUF_TYPE_NOSPLIT);
if (buf_handle == NULL) {
    printf("Failed to create ring buffer\n");
}

//Send an item
UBaseType_t res = xRingbufferSend(buf_handle, tx_item, sizeof(tx_item), pdMS_TO_TICKS(1000));
if (res != pdTRUE) {
    printf("Failed to send item\n");
}
```

The following example demonstrates the usage of `xRingbufferSendAcquire()` and `xRingbufferSendComplete()` instead of `xRingbufferSend()` to acquire memory on the ring buffer (of type `RINGBUF_TYPE_NOSPLIT`) and then send an item to it. This adds one more step, but allows getting the address of the memory to write to, and writing to the memory yourself.

```c
#include "freertos/ringbuf.h"
#include "soc/lldesc.h"

typedef struct {
    lldesc_t dma_desc;
    uint8_t buf[1];
} dma_item_t;

#define DMA_ITEM_SIZE(N) (sizeof(lldesc_t)+((N)+3)&(~3))
...

//Retrieve space for DMA descriptor and corresponding data buffer
//This has to be done with SendAcquire, or the address may be different when we copy
da_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,
};
```

(continues on next page)


```c
//Actually send to the ring buffer for consumer to use
res = xRingbufferSendComplete(buf_handle, &item);
if (res != pdTRUE) {
    printf("Failed to send item\n");
}
```

The following example demonstrates retrieving and returning an item from a **No-Split ring buffer** using `xRingbufferReceive()` and `vRingbufferReturnItem()`

```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()`
...  

//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.

![Diagram of Sending items to No-Split or Allow-Split ring buffers](image)

Fig. 31: Sending items to No-Split or Allow-Split ring buffers

For No-Split and Allow-Split buffers, a header of 8 bytes precedes every data item. Furthermore, the space occupied by each item is rounded up to the nearest 32-bit aligned size in order to maintain overall 32-bit alignment. However, the true size of the item is recorded inside the header which will be returned when the item is retrieved.

Referring to the diagram above, the 18, 3, and 27 byte items are rounded up to 20, 4, and 28 bytes respectively. An 8 byte header is then added in front of each item.

Byte buffers treat data as a sequence of bytes and does not incur any overhead (no headers). As a result, all data sent to a byte buffer is merged into a single item.

Referring to the diagram above, the 18, 3, and 27 byte items are sequentially written to the byte buffer and merged into a single item of 48 bytes.

Using SendAcquire and SendComplete  Items in No-Split buffers are acquired (by SendAcquire) in strict FIFO order and must be sent to the buffer by SendComplete for the data to be accessible by the consumer.
Multiple items can be sent or acquired without calling `SendComplete`, and the items do not necessarily need to be completed in the order they were acquired. However, the receiving of data items must occur in FIFO order, therefore not calling `SendComplete` for the earliest acquired item will prevent the subsequent items from being received.

The following diagrams illustrate what will happen when `SendAcquire` and `SendComplete` don’t happen in the same order. At the beginning, there is already a data item of 16 bytes sent to the ring buffer. Then `SendAcquire` is called to acquire space of 20, 8, 24 bytes on the ring buffer.

After that, we fill (use) the buffers, and send them to the ring buffer by `SendComplete` in the order of 8, 24, 20. When 8 bytes and 24 bytes data are sent, the consumer still can only get the 16 bytes data item. Hence, if `SendComplete` is not called for the 20 bytes, it will not be available, nor will the data items following the 20 bytes item.

When the 20 bytes item is finally completed, all the 3 data items can be received now, in the order of 20, 8, 24 bytes, right after the 16 bytes item existing in the buffer at the beginning.

Allow-Split buffers and byte buffers do not allow using `SendAcquire` or `SendComplete` since acquired buffers are required to be complete (not wrapped).

**Wrap around** The following diagrams illustrate the differences between No-Split, Allow-Split, and byte buffers when a sent item requires a wrap around. The diagrams assume a buffer of 128 bytes with 56 bytes of free space that wraps around and a sent item of 28 bytes.
No-Split buffers will only store an item in continuous free space and will not split an item under any circumstances. When the free space at the tail of the buffer is insufficient to completely store the item and its header, the free space at the tail will be marked as dummy data. The buffer will then wrap around and store the item in the free space at the head of the buffer.

Referring to the diagram above, the 16 bytes of free space at the tail of the buffer is insufficient to store the 28 byte item. Therefore, the 16 bytes is marked as dummy data and the item is written to the free space at the head of the buffer instead.

![Fig. 35: Wrap around in Allow-Split buffers](image)

Allow-Split buffers will attempt to split the item into two parts when the free space at the tail of the buffer is insufficient to store the item data and its header. Both parts of the split item will have their own headers (therefore incurring an extra 8 bytes of overhead).

Referring to the diagram above, the 16 bytes of free space at the tail of the buffer is insufficient to store the 28 byte item. Therefore, the item is split into two parts (8 and 20 bytes) and written as two parts to the buffer.

Note: Allow-Split buffers treat both parts of the split item as two separate items, therefore call xRingbufferReceiveSplit() instead of xRingbufferReceive() to receive both parts of a split item in a thread safe manner.

![Fig. 36: Wrap around in byte buffers](image)

Byte buffers will store as much data as possible into the free space at the tail of buffer. The remaining data will then be stored in the free space at the head of the buffer. No overhead is incurred when wrapping around in byte buffers.

Referring to the diagram above, the 16 bytes of free space at the tail of the buffer is insufficient to completely store the 28 bytes of data. Therefore, the 16 bytes of free space is filled with data, and the remaining 12 bytes are written to the free space at the head of the buffer. The buffer now contains data in two separate continuous parts, and each continuous part will be treated as a separate item by the byte buffer.

Retrieving/Returning The following diagrams illustrate the differences between No-Split and Allow-Split buffers as compared to byte buffers in retrieving and returning data.

Items in No-Split buffers and Allow-Split buffers are retrieved in strict FIFO order and must be returned for the occupied space to be freed. Multiple items can be retrieved before returning, and the items do not necessarily need to be returned in the order they were retrieved. However, the freeing of space must occur in FIFO order, therefore not returning the earliest retrieved item will prevent the space of subsequent items from being freed.
Referring to the diagram above, the **16, 20, and 8 byte items are retrieved in FIFO order**. However, the items are not returned in the order they were retrieved. First, the 20 byte item is returned followed by the 8 byte and the 16 byte items. The space is not freed until the first item, i.e., the 16 byte item is returned.

**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);
```

(continues on next page)
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
xQueueSetMemberHandle member = xQueueSelectFromSet(queue_set, pdMS_TO_TICKS(1000));

//Check if member is ring buffer
if (member != NULL && xRingbufferCanRead(buf_handle, member) == pdTRUE) {
  //Member is ring buffer, receive item from ring buffer
  size_t item_size;
  char *item = (char *)xRingbufferReceive(buf_handle, &item_size, 0);

  //Handle item
  ...

  } else {
...
}

Ring Buffers with Static Allocation  The xRingbufferCreateStatic() can be used to create ring buffers with specific memory requirements (such as a ring buffer being allocated in external RAM). All blocks of memory used by a ring buffer must be manually allocated beforehand then passed to the xRingbufferCreateStatic() to be initialized as a ring buffer. These blocks include the following:

- The ring buffer’s data structure of type StaticRingbuffer_t
- The ring buffer’s storage area of size xBufferSize. Note that xBufferSize must be 32-bit aligned for No-Split and Allow-Split buffers.

The manner in which these blocks are allocated will depend on the users requirements (e.g. all blocks being statically declared, or dynamically allocated with specific capabilities such as external RAM).

Note:  When deleting a ring buffer created via xRingbufferCreateStatic(), the function vRingbufferDelete() will not free any of the memory blocks. This must be done manually by the user after vRingbufferDelete() is called.

The code snippet below demonstrates a ring buffer being allocated entirely in external RAM.

```c
#include "freertos/ringbuf.h"
#include "freertos/semphr.h"
#include "esp_heap_caps.h"

#define BUFFER_SIZE 400    //32-bit aligned size
#define BUFFER_TYPE RINGBUF_TYPE_NOSPLIT
...

//Allocate ring buffer data structure and storage area into external RAM
StaticRingbuffer_t *buffer_struct = (StaticRingbuffer_t *)heap_caps_malloc(sizeof(StaticRingbuffer_t), MALLOC_CAP_SPIRAM);
uint8_t *buffer_storage = (uint8_t *)heap_caps_malloc(sizeof(uint8_t) * BUFFER_SIZE, ...

```

(continues on next page)
//Create a ring buffer with manually allocated memory
RingbufHandle_t handle = xRingbufferCreateStatic(BUFFER_SIZE, BUFFER_TYPE, buffer_storage, buffer_struct);
...
//Delete the ring buffer after used
vRingbufferDelete(handle);
//Manually free all blocks of memory
free(buffer_struct);
free(buffer_storage);

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.

Hooks

FreeRTOS consists of Idle Hooks and Tick Hooks which allow for application specific functionality to be added to the Idle Task and Tick Interrupt. ESP-IDF provides its own Idle and Tick Hook API in addition to the hooks provided by vanilla FreeRTOS. ESP-IDF hooks have the added benefit of being run time configurable and asymmetrical.

Vanilla FreeRTOS Hooks  Idle and Tick Hooks in vanilla FreeRTOS are implemented by the user defining the functions vApplicationIdleHook() and vApplicationTickHook() respectively somewhere in the application. Vanilla FreeRTOS will run the user defined Idle Hook and Tick Hook on every iteration of the Idle Task and Tick Interrupt respectively.

Vanilla FreeRTOS hooks are referred to as Legacy Hooks in ESP-IDF FreeRTOS. To enable legacy hooks, CONFIG_FREERTOS_LEGACY_HOOKS should be enabled in project configuration menu.

Due to vanilla FreeRTOS being designed for single core, vApplicationIdleHook() and vApplicationTickHook() can only be defined once. However, the ESP32 is dual-core in nature, therefore same Idle Hook and Tick Hook are used for both cores (in other words, the hooks are symmetrical for both cores).

ESP-IDF Idle and Tick Hooks  For some use-cases it may be necessary for the Idle Tasks or Tick Interrupts to execute multiple hooks that are configurable at run time.

Furthermore, due to the dual-core nature of the ESP32, it may be necessary for some applications to have separate hooks for each core.

Therefore, ESP-IDF provides its own hooks API in addition to the legacy hooks provided by vanilla FreeRTOS.
The ESP-IDF tick and idle hooks are registered at run time. Each tick hook and idle hook must be registered to a specific CPU. When the idle task runs or a tick interrupt occurs on a particular CPU, the CPU will run each of its registered idle hook and tick hook in turn.

**Note:** Tick interrupt stays active whilst cache is disabled and hence `vApplicationTickHook()` (legacy case) or ESP-IDF tick hooks must be placed in internal RAM. Please refer to the [SPI flash API documentation](#) for more details.

### TLSP Deletion Callbacks

Vanilla FreeRTOS provides a Thread Local Storage Pointers (TLSP) feature. These are pointers stored directly in the Task Control Block (TCB) of a particular task. TLSPs allow each task to have its own unique set of pointers to data structures. Vanilla FreeRTOS expects users to…

- set a task’s TLSPs by calling `vTaskSetThreadLocalStoragePointer()` after the task has been created.
- get a task’s TLSPs by calling `pvTaskGetThreadLocalStoragePointer()` during the task’s lifetime.
- free the memory pointed to by the TLSPs before the task is deleted.

However, there can be instances where users may want the freeing of TLSP memory to be automatic. Therefore, ESP-IDF 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 every task.

The TLSP deletion callbacks are set in a similar fashion to the TLSPs themselves.

- `vTaskSetThreadLocalStoragePointerAndDelCallback()` sets both a particular TLSP and its associated callback.
- Calling the Vanilla FreeRTOS function `vTaskSetThreadLocalStoragePointer()` will simply set the TLSP’s associated Deletion Callback to `NULL` meaning that no callback will be called for that TLSP during task deletion.

When implementing TLSP callbacks, users should note the following:

- The callback must never attempt to block or yield and critical sections should be kept as short as possible.
- The callback is called shortly before a deleted task’s memory is freed. Thus, the callback can either be called from `vTaskDelete()` itself, or from the idle task.

### Component Specific Properties

Besides standard component variables that are available with basic cmake build properties, FreeRTOS component also provides arguments (only one so far) for simpler integration with other modules:

- `ORIG_INCLUDE_PATH` - contains an absolute path to freertos root include folder. Thus instead of `#include "freertos/FreeRTOS.h"` you can refer to headers directly: `#include "FreeRTOS.h"`.

### API Reference

### Ring Buffer API

#### Header File

- `components/esp_ringbuf/include/freertos/ringbuf.h`
Functions

**RingbufHandle_t xRingbufferCreate** (size_t xBufferSize, RingbufferType_t xBufferType)
Create a ring buffer.

**Note** xBufferSize of no-split/allow-split buffers will be rounded up to the nearest 32-bit aligned size.

**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.

Attempt to insert an item into the ring buffer. This function will block until enough free space is available or until it times out.

**Note** For no-split/allow-split ring buffers, the actual size of memory that the item will occupy will be rounded up to the nearest 32-bit aligned size. This is done to ensure all items are always stored in 32-bit aligned fashion.

**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.

Attempt to insert an item into the ring buffer from an ISR. This function will return immediately if there is insufficient free space in the buffer.

**Note** For no-split/allow-split ring buffers, the actual size of memory that the item will occupy will be rounded up to the nearest 32-bit aligned size. This is done to ensure all items are always stored in 32-bit aligned fashion.
Chapter 2. API Reference

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** Calls 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)
- `[in]` xTicksToWait: Ticks to wait for items in the ring buffer.

```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.

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.

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

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.

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

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, UBaseType_t *uxFree, UBaseType_t *uxRead, UBaseType_t *uxWrite, UBaseType_t *uxAcquire, UBaseType_t *uxItemsWaiting)
```

Get information about ring buffer status.
Get information of a ring buffer’s current status such as free/read/write/acquire pointer positions, and number of items waiting to be retrieved. Arguments can be set to NULL if they are not required.

**Parameters**
- [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_ALLOWSSPLIT` = 0
  
  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.

**Hooks API**
Header File

- components/esp_system/include/esp_freertos_hooks.h

Functions

```c
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

```c
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

```c
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

```c
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

```c
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
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

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

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)

2.7.11 Heap Memory Allocation

Stack and Heap

ESP-IDF applications use the common computer architecture patterns of stack (dynamic memory allocated by program control flow) and heap (dynamic memory allocated by function calls), as well as statically allocated memory (allocated at compile time).

Because ESP-IDF is a multi-threaded RTOS environment, each RTOS task has its own stack. By default, each of these stacks is allocated from the heap when the task is created. (See xTaskCreateStatic() for the alternative where stacks are statically allocated.)

Because ESP32 uses multiple types of RAM, it also contains multiple heaps with different capabilities. A capabilities-based memory allocator allows apps to make heap allocations for different purposes.

For most purposes, the standard libc malloc() and free() functions can be used for heap allocation without any special consideration.

However, in order to fully make use of all of the memory types and their characteristics, ESP-IDF also has a capabilities-based heap memory allocator. If you want to have memory with certain properties (for example, DMA-Capable Memory or executable-memory), you can create an OR-mask of the required capabilities and pass that to heap_caps_malloc().

Memory Capabilities

The ESP32 contains multiple types of RAM:

- DRAM (Data RAM) is memory used to hold data. This is the most common kind of memory accessed as heap.
- IRAM (Instruction RAM) usually holds executable data only. If accessed as generic memory, all accesses must be 32-bit aligned.
- D/IRAM is RAM which can be used as either Instruction or Data RAM.
For more details on these internal memory types, see Memory Types.

It’s also possible to connect external SPI RAM to the ESP32 - external RAM can be integrated into the ESP32’s memory map using the flash cache, and accessed similarly to DRAM.

DRAM uses capability MALLOC_CAP_8BIT (accessible in single byte reads and writes). When calling malloc(), the ESP-IDF malloc() implementation internally calls heap_caps_malloc(size, MALLOC_CAP_8BIT) in order to allocate DRAM that is byte-addressable. To test the free DRAM heap size at runtime, call cpp:func:heap_caps_get_free_size(MALLOC_CAP_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:** Due to a technical limitation, the maximum statically allocated DRAM usage is 160KB. The remaining 160KB (for a total of 320KB of DRAM) can only be allocated at runtime as heap.

**Note:** At runtime, the available heap DRAM may be less than calculated at compile time, because at startup some memory is allocated from the heap before the FreeRTOS scheduler is started (including memory for the stacks of initial FreeRTOS tasks).

**IRAM**  At startup, the IRAM heap contains all instruction memory which is not used by the app executable code.

The idf.py size command can be used to find the amount of IRAM used by the app.

**D/IRAM**  Some memory in the ESP32 is available as either DRAM or IRAM. If memory is allocated from a D/IRAM region, the free heap size for both types of memory will decrease.

**Heap Sizes**  At startup, all ESP-IDF apps log a summary of all heap addresses (and sizes) at level Info:

```
I (252) heap_init: Initializing. RAM available for dynamic allocation:
I (259) heap_init: At 3FFAE6E0 len 00001920 (6 KiB): DRAM
I (265) heap_init: At 3FFB2EC8 len 0002D138 (180 KiB): DRAM
I (272) heap_init: At 3FFE0440 len 00003AE0 (14 KiB): D/IRAM
I (278) heap_init: At 3FFE4350 len 0001BCB0 (111 KiB): D/IRAM
I (284) heap_init: At 4008944C len 00016BB4 (90 KiB): IRAM
```

**Finding available heap**  See Heap Information.

**Special Capabilities**

**DMA-Capable Memory**  Use the MALLOC_CAP_DMA flag to allocate memory which is suitable for use with hardware DMA engines (for example SPI and I2S). This capability flag excludes any external PSRAM.
32-Bit Accessible Memory If a certain memory structure is only addressed in 32-bit units, for example an array of ints or pointers, it can be useful to allocate it with the MALLOC_CAP_32BIT flag. This also allows the allocator to give out IRAM memory; something which it can’t do for a normal malloc() call. This can help to use all the available memory in the ESP32.

Memory allocated with MALLOC_CAP_32BIT can only be accessed via 32-bit reads and writes, any other type of access will generate a fatal LoadStoreError exception.

External SPI Memory When external RAM is enabled, external SPI RAM under 4MiB in size can be allocated using standard malloc calls, or via heap_caps_malloc(MALLOC_CAP_SPIRAM), depending on configuration. See Configuring External RAM for more details.

To use the region above the 4MiB limit, you can use the himem API.

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 previously allocated memory, or 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.

```c
void *heap_caps_aligned_alloc (size_t alignment, size_t size, uint32_t caps)
```

Allocate an aligned chunk of memory which has the given capabilities.

**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 calloc(), 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
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.

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.
Chapter 2. API Reference

**MALLOCS_CON Pháp TEB**

**MALLOCS_CON Pháp TEB**

Memory must be in RTC fast memory.

**MALLOCS_CON Pháp TEB**

Memory can’t be used / list end marker.

**Type Definitions**

```c
typedef void (*esp_alloc_failed_hook_t)(size_t size, summer_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**

```c
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.

```c
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.

```c
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.

```c
esp_err_t heap_caps_add_region_with_caps (const uint32_t caps[], intptr_t start, intptr_t end)
```

Add a region of memory to the collection of heaps at runtime, with custom capabilities.

Similar to heap_caps_add_region(), only custom memory capabilities are specified by the caller.

**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_heap_aligned_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, defined in multi_heap_platform.h.

The lock in question must be recursive.

When the heap is first registered, the associated lock is NULL.

Parameters
- heap: Handle to a registered heap.
- lock: Optional pointer to a locking structure to associate with this heap.

void multi_heap_dump (multi_heap_handle_t heap)

Dump heap information to stdout.

For debugging purposes, this function dumps information about every block in the heap to stdout.

Parameters
- heap: Handle to a registered heap.

bool multi_heap_check (multi_heap_handle_t heap, bool print_errors)

Check heap integrity.

Walks the heap and checks all heap data structures are valid. If any errors are detected, an error-specific message can be optionally printed to stderr. Print behaviour can be overridden at compile time by defining MULTI_CHECK_FAIL_PRINTF in multi_heap_platform.h.

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 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.

**Structures**

```c
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**

```c
typedef struct multi_heap_info *multi_heap_handle_t
```
Opaque handle to a registered heap.

### 2.7.12 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 that the corruption happened. You can move these checks around to “close in on” the section of code that corrupted the heap.
- Based on the memory address which is being corrupted, you can use JTAG debugging to set a watchpoint on this address and have the CPU halt when it is written to.
- If you don’t have JTAG, but you do know roughly when the corruption happens, then you can set a watchpoint in software just beforehand via esp_cpu_set_watchpoint(). A fatal exception will occur when the watchpoint triggers. The following is an example of how to use the function - esp_cpu_set_watchpoint(0, (void *)addr, 4, ESP_WATCHPOINT_STORE). Note that watchpoints are per-CPU and are set on the current running CPU only, so if you don’t know which CPU is corrupting memory then you will need to call this function on both CPUs.
- For buffer overflows, heap tracing in HEAP_TRACE_ALL mode lets you see which callers are allocating which addresses from the heap. See Heap Tracing To Find Heap Corruption for more details. If you can find the function which allocates memory with an address immediately before the address which is corrupted, this will probably be the function which overflows the buffer.
- Calling heap_caps_dump() or heap_caps_dump_all() can give an indication of what heap blocks are surrounding the corrupted region and may have overflowed/underflowed/etc.

Configuration

Temporarily increasing the heap corruption detection level can give more detailed information about heap corruption errors.

In the project configuration menu, under Component config there is a menu Heap memory debugging. The setting CONFIG_HEAP_CORRUPTION_DETECTION can be set to one of three levels:

Basic (no poisoning) This is the default level. No special heap corruption features are enabled, but provided assertions are enabled (the default configuration) then a heap corruption error will be printed if any of the heap’s internal data structures appear overwritten or corrupted. This usually indicates a buffer overrun or out of bounds write.

If assertions are enabled, an assertion will also trigger if a double-free occurs (the same memory is freed twice).

Calling heap_caps_check_integrity() in Basic mode will check the integrity of all heap structures, and print errors if any appear to be corrupted.

Light Impact At this level, heap memory is additionally “poisoned” with head and tail “canary bytes” before and after each block which is allocated. If an application writes outside the bounds of allocated buffers, the canary bytes will be corrupted and the integrity check will fail.

The head canary word is 0xABBA1234 (3412BAAB in byte order), and the tail canary word is 0xBAAD5678 (7856ADBA in byte order).

“Basic” heap corruption checks can also detect most out of bounds writes, but this setting is more precise as even a single byte overrun can be detected. With Basic heap checks, the number of overrun bytes before a failure is detected will depend on the properties of the heap.

Enabling “Light Impact” checking increases memory usage, each individual allocation will use 9 to 12 additional bytes of memory (depending on alignment).

Each time free() is called in Light Impact mode, the head and tail canary bytes of the buffer being freed are checked against the expected values.
When `heap_caps_check_integrity()` is called, all allocated blocks of heap memory have their canary bytes checked against the expected values.

In both cases, the check is that the first 4 bytes of an allocated block (before the buffer returned to the user) should be the word 0xABBA1234. Then the last 4 bytes of the allocated block (after the buffer returned to the user) should be the word 0xBAAD5678.

Different values usually indicate buffer underrun or overrun, respectively.

**Comprehensive** This level incorporates the “light impact” detection features plus additional checks for uninitialised-access and use-after-free bugs. In this mode, all freshly allocated memory is filled with the pattern 0xCE, and all freed memory is filled with the pattern 0xFE.

Enabling “Comprehensive” detection has a substantial runtime performance impact (as all memory needs to be set to the allocation patterns each time a malloc/free completes, and the memory also needs to be checked each time.) However, it allows easier detection of memory corruption bugs which are much more subtle to find otherwise. It is recommended to only enable this mode when debugging, not in production.

**Crashes in Comprehensive Mode** If an application crashes reading/writing an address related to 0xCECECECE in Comprehensive mode, this indicates it has read uninitialized memory. The application should be changed to either use calloc() (which zeroes memory), or initialize the memory before using it. The value 0xCECECECE may also be seen in stack-allocated automatic variables, because in IDF most task stacks are originally allocated from the heap and in C stack memory is uninitialized by default.

If an application crashes and the exception register dump indicates that some addresses or values were 0xFEFEFEFE, this indicates it is reading heap memory after it has been freed (a “use after free bug”). The application should be changed to not access heap memory after it has been freed.

If a call to malloc() or realloc() causes a crash because it expected to find the pattern 0xFEFEFEFE in free memory and a different pattern was found, then this indicates the app has a use-after-free bug where it is writing to memory which has already been freed.

**Manual Heap Checks in Comprehensive Mode** Calls to `heap_caps_check_integrity()` may print errors relating to 0xFEFEFEFE, 0xABBA1234 or 0xBAAD5678. In each case the checker is expecting to find a given pattern, and will error out if this is not found:

- For free heap blocks, the checker expects to find all bytes set to 0xFE. Any other values indicate a use-after-free bug where free memory has been incorrectly overwritten.
- For allocated heap blocks, the behaviour is the same as for Light Impact mode. The canary bytes 0xABBA1234 and 0xBAAD5678 are checked at the head and tail of each allocated buffer, and any variation indicates a buffer overrun/underrun.

**Heap Task Tracking**

Heap Task Tracking can be used to get per task info for heap memory allocation. Application has to specify the heap capabilities for which the heap allocation is to be tracked.

Example code is provided in `system/heap_task_tracking`

**Heap Tracing**

Heap Tracing allows tracing of code which allocates/frees memory. Two tracing modes are supported:

- Standalone. In this mode trace data are kept on-board, so the size of gathered information is limited by the buffer assigned for that purposes. Analysis is done by the on-board code. There are a couple of APIs available for accessing and dumping collected info.
- Host-based. This mode does not have the limitation of the standalone mode, because trace data are sent to the host over JTAG connection using app_trace library. Later on they can be analysed using special tools.
Heap tracing can perform two functions:

- Leak checking: find memory which is allocated and never freed.
- Heap use analysis: show all functions that are allocating/freeing memory while the trace is running.

**How To Diagnose Memory Leaks**

If you suspect a memory leak, the first step is to figure out which part of the program is leaking memory. Use the `xPortGetFreeHeapSize()`, `heap_caps_get_free_size()`, or related functions to track memory use over the life of the application. Try to narrow the leak down to a single function or sequence of functions where free memory always decreases and never recovers.

**Standalone Mode**

Once you’ve identified the code which you think is leaking:

- In the project configuration menu, navigate to Component settings -> Heap Memory Debugging -> Heap tracing and select Standalone option (see `CONFIG_HEAP_TRACING_DEST`).
- Call the function `heap_trace_init_standalone()` early in the program, to register a buffer which can be used to record the memory trace.
- Call the function `heap_trace_start()` to begin recording all mallocs/frees in the system. Call this immediately before the piece of code which you suspect is leaking memory.
- Call the function `heap_trace_stop()` to stop the trace once the suspect piece of code has finished executing.
- Call the function `heap_trace_dump()` to dump the results of the heap trace.

An example:

```c
#include "esp_heap_trace.h"
#define NUM_RECORDS 100
static heap_trace_record_t trace_record[NUM_RECORDS]; // This buffer must be in ...
...
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/./
-0x400d27c1: 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
```

(continues on next page)
Chapter 2. API Reference

(continued from previous page)

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.
• cc0unt 0x... is the CCOUNT (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:

```
#include "esp_heap_trace.h"
...

void app_main()
{
  ...
  ESP_ERROR_CHECK( heap_trace_init_tohost() );
```

(continues on next page)
To gather and analyze heap trace do the following on the host:

1. Build the program and download it to the target as described in *Getting Started Guide.*
2. Run OpenOCD (see *JTAG Debugging*).

**Note:** In order to use this feature you need OpenOCD version v0.10.0-esp32-20181105 or later.

3. You can use GDB to start and/or stop tracing automatically. To do this you need to prepare special `gdbinit` file:

```
target remote :3333
mon reset halt
flushregs
tb heap_trace_start
commands
mon esp sysview start file:///tmp/heap.svdat
c
end
tb heap_trace_stop
commands
mon esp sysview stop
c
```

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.svdat`. Tracing will be stopped when program hits breakpoint at `heap_trace_stop()`.

4. Run GDB using the following command: `xtensa-esp32-elf-gdb -x gdbinit </path/to/program/elf>`
5. Quit GDB when program stops at `heap_trace_stop()`. Trace data are saved in `/tmp/heap.svdat`
6. Run processing script `$IDF_PATH/tools/esp_app_trace/sysviewtrace_proc.py -p -b </path/to/program/elf> /tmp/heap_log.svdat`

The output from the heap trace will look something like this:

```
Parse trace from '/tmp/heap.svdat'...
Stop parsing trace. (Timeout 0.000000 sec while reading 1 bytes!)
Process events from '[/tmp/heap.svdat]'...
[0.002244575] HEAP: Allocated 1 bytes @ 0x3ffaffd8 from task "alloc" on core 0 by:
/home/user/projects/esp/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

[0.002798700] HEAP: Freed bytes @ 0x3ffb50bc 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)

[0.202436200] 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)

[0.202451725] 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)

[0.202667500] 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 @ 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:47
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)

[0.302451475] HEAP: Allocated 8 bytes @ 0x3ffbb40b8 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: Freed bytes @ 0x3ffbb40b8 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)

(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)
[0.102436025] 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)
[0.202436200] 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)
[0.302436000] HEAP: Allocated 4 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:47
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)
Found 10 leaked bytes in 4 blocks.

**Heap Tracing To Find Heap Corruption**  Heap tracing can also be used to help track down heap corruption. When a region in heap is corrupted, it may be from some other part of the program which allocated memory at a nearby address.

If you have some idea at what time the corruption occurred, enabling heap tracing in **HEAP_TRACE_ALL** mode allows you to record all the functions which allocated memory, and the addresses of the allocations.

Using heap tracing in this way is very similar to memory leak detection as described above. For memory which is allocated and not freed, the output is the same. However, records will also be shown for memory which has been freed.

**Performance Impact**  Enabling heap tracing in menuconfig increases the code size of your program, and has a very small negative impact on performance of heap allocation/free operations even when heap tracing is not running.

When heap tracing is running, heap allocation/free operations are substantially slower than when heap tracing is stopped. Increasing the depth of stack frames recorded for each allocation (see above) will also increase this performance impact.

**False-Positive Memory Leaks**  Not everything printed by `heap_trace_dump()` is necessarily a memory leak. Among things which may show up here, but are not memory leaks:

- Any memory which is allocated after `heap_trace_start()` but then freed after `heap_trace_stop()` will appear in the leak dump.
- Allocations may be made by other tasks in the system. Depending on the timing of these tasks, it’s quite possible this memory is freed after `heap_trace_stop()` is called.
- The first time a task uses 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**

*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.

*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.

*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.)

*esp_err_t heap_trace_stop*(void)

Stop heap tracing.

**Return**

- ESP_ERR_NOT_SUPPORTED Project was compiled without heap tracing enabled in menuconfig.
Chapter 2. API Reference

- ESP_ERR_INVALID_STATE Heap tracing was not in progress.
- ESP_OK Heap tracing stopped.

`esp_err_t heap_trace_resume (void)`
Resume heap tracing which was previously stopped.
Unlike heap_trace_start(), this function does not clear the buffer of any pre-existing trace records.
The heap trace mode is the same as when heap_trace_start() was last called (or HEAP_TRACE_ALL if heap_trace_start() was never called).

**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.

`size_t heap_trace_get_count (void)`
Return number of records in the heap trace buffer.
It is safe to call this function while heap tracing is running.

`esp_err_t heap_trace_get (size_t index, heap_trace_record_t *record)`
Return a raw record from the heap trace buffer.

**Note** It is safe to call this function while heap tracing is running, however in HEAP_TRACE_LEAK mode record indexing may skip entries unless heap tracing is stopped first.

**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.

`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**

`struct heap_trace_record_t`  
Trace record data type. Stores information about an allocated region of memory.

**Public Members**

`uint32_t` ecount  
CCOUNT of the CPU when the allocation was made. LSB (bit value 1) is the CPU number (0 or 1).

`void *` address  
Address which was allocated.

`size_t` size  
Size of the allocation.

`void *` allocated_by[CONFIG_HEAP_TRACING_STACK_DEPTH]  
Call stack of the caller which allocated the memory.

`void *` freed_by[CONFIG_HEAP_TRACING_STACK_DEPTH]  
Call stack of the caller which freed the memory (all zero if not freed.)
### Macros

`CONFIG_HEAP_TRACING_STACK_DEPTH`

### Enumerations

```c
enum heap_trace_mode_t
{
  HEAP_TRACE_ALL,
  HEAP_TRACE_LEAKS
};
```

### 2.7.13 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 `CONFIG_ESP_TIMER_IMPL`. Available options are:

- LAC timer
- (legacy) FRC2 timer

**Note:** The FRC2 is a legacy option for ESP32 until v4.2, a 32-bit hardware timer was used. Starting at v4.2, use the new LAC timer option instead, it has a simpler implementation, and has smaller run time overhead because software handling of timer overflow is not needed.

#### 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**

- components/esp_timer/include/esp_timer.h

**Functions**

- `esp_err_t esp_timer_early_init (void)`
  
  **Minimal initialization of esp_timer.**

  This function can be called very early in startup process, after this call only `esp_timer_get_time` function can be used.

  **Note** This function is called from startup code. Applications do not need to call this function before using other `esp_timer` APIs.

  **Return**

  • ESP_OK on success

- `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

- `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

- `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

```c
esp_err_t esp_timer_start_periodic(esp_timer_handle_t timer, uint64_t period)
```

Start a periodic timer.

Timer should not be running when this function is called. This function will start the timer which will trigger every ‘period’ microseconds.

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

```c
esp_err_t esp_timer_stop(esp_timer_handle_t timer)
```

Stop the timer.

This function stops the timer previously started using esp_timer_start_once or esp_timer_start_periodic.

Return

- ESP_OK on success
- ESP_ERR_INVALID_STATE if the timer is not running

Parameters

- timer: timer handle created using esp_timer_create

```c
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

```c
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

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 can not allocate temporary buffer for the output

Parameters
Chapter 2. API Reference

- 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

esp_timer_cb_t callback
Function to call when timer expires.

void *arg
Argument to pass to the callback.

esp_timer_dispatch_t dispatch_method
Call the callback from task or from ISR.

const char *name
Timer name, used in esp_timer_dump function.

bool skip_unhandled_events
Skip unhandled events for periodic timers.

Type Definitions
typedef struct esp_timer *esp_timer_handle_t
Opaque type representing a single esp_timer.
typedef void (*esp_timer_cb_t)(void *arg)
Timer callback function type.

Parameters
• arg: pointer to opaque user-specific data

Enumerations
typedef 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.

2.7.14 The himem allocation API
Overview

The ESP32 can access external SPI RAM transparently, so you can use it as normal memory in your program code. However, because the address space for external memory is limited in size, only the first 4MiB can be used as such. Access to the remaining memory is still possible, however this needs to go through a bankswitching scheme controlled by the himem API.

Specifically, what is implemented by the himem API is a bankswitching scheme. Hardware-wise, the 4MiB region for external SPI RAM is mapped into the CPU address space by a MMU, which maps a configurable 32K bank/page of external SPI RAM into each of the 32K pages in the 4MiB region accessed by the CPU. For external memories that are <=4MiB, this MMU is configured to unity mapping, effectively mapping each CPU address 1-to-1 to the external SPI RAM address.

In order to use the himem API, you have to enable it in the menuconfig using CONFIG_SPIRAM_BANKSWITCH_ENABLE, as well as set the amount of banks reserved for this in CONFIG_SPIRAM_BANKSWITCH_RESERVE. This decreases the amount of external memory allocated by functions like malloc(), but it allows you to use the himem api to map any of the remaining memory into the reserved banks.

The himem API is more-or-less an abstraction of the bankswitching scheme: it allows you to claim one or more banks of address space (called ‘regions’ in the API) as well as one or more of banks of memory to map into the ranges.

Example

An example doing a simple memory test of the high memory range is available in esp-idf: system/himem

API Reference

Header File

- components/esp_hw_support/include/soc/esp32/himem.h

Functions

esp_err_t esp_himem_alloc(size_t size, esp_himem_handle_t *handle_out)

Allocate a block in high memory.

Return - ESP_OK if successful
- ESP_ERR_NO_MEM if out of memory
- ESP_ERR_INVALID_SIZE if size is not a multiple of 32K

Parameters
- size: Size of the to-be-allocated block, in bytes. Note that this needs to be a multiple of the external RAM mmu block size (32K).
- [out] handle_out: Handle to be returned

esp_err_t esp_himem_alloc_map_range(size_t size, esp_himem_rangehandle_t *handle_out)

Allocate a memory region to map blocks into.

This allocates a contiguous CPU memory region that can be used to map blocks of physical memory into.

Return - ESP_OK if successful
- ESP_ERR_NO_MEM if out of memory or address space
- ESP_ERR_INVALID_SIZE if size is not a multiple of 32K

Parameters
- size: Size of the range to be allocated. Note this needs to be a multiple of the external RAM mmu block size (32K).
- [out] handle_out: Handle to be returned

esp_err_t esp_himem_map(esp_himem_handle_t handle, esp_himem_rangehandle_t range, size_t ram_offset, size_t range_offset, size_t len, int flags, void **out_ptr)

Map a block of high memory into the CPUs address space.

This effectively makes the block available for read/write operations.
Note  The region to be mapped needs to have offsets and sizes that are aligned to the SPI RAM MMU block size (32K)

Return - ESP_OK if the memory could be mapped
  • ESP_ERR_INVALID_ARG if offset, range or len aren’t MMU-block-aligned (32K)
  • ESP_ERR_INVALID_SIZE if the offsets/lengths don’t fit in the allocated memory or range
  • ESP_ERR_INVALID_STATE if a block in the selected ram offset/length is already mapped, or if a block in the selected range offset/length already has a mapping.

Parameters
  • handle: Handle to the block of memory, as given by esp_himem_alloc
  • range: Range handle to map the memory in
  • ram_offset: Offset into the block of physical memory of the block to map
  • range_offset: Offset into the address range where the block will be mapped
  • len: Length of region to map
  • flags: One of ESP_HIMEM_MAPFLAG_*
  • [out] out_ptr: Pointer to variable to store resulting memory pointer in

`esp_err_t esp_himem_free(esp_himem_handle_t handle)`
Free a block of physical memory.
This clears out the associated handle making the memory available for re-allocation again. This will only succeed if none of the memory blocks currently have a mapping.

Return - ESP_OK if the memory is successfully freed
  • ESP_ERR_INVALID_ARG if the handle still is (partially) mapped

Parameters
  • handle: Handle to the block of memory, as given by esp_himem_alloc

`esp_err_t esp_himem_free_map_range(esp_himem_rangehandle_t handle)`
Free a mapping range.
This clears out the associated handle making the range available for re-allocation again. This will only succeed if none of the range blocks currently are used for a mapping.

Return - ESP_OK if the memory is successfully freed
  • ESP_ERR_INVALID_ARG if the handle still is (partially) mapped to

Parameters
  • handle: Handle to the range block, as given by esp_himem_alloc_map_range

`esp_err_t esp_himem_unmap(esp_himem_rangehandle_t range, void *ptr, size_t len)`
Unmap a region.
Return - ESP_OK if the memory is successfully unmapped,
  • ESP_ERR_INVALID_ARG if ptr or len are invalid.

Parameters
  • range: Range handle
  • ptr: Pointer returned by esp_himem_map
  • len: Length of the block to be unmapped. Must be aligned to the SPI RAM MMU blocksize (32K)

`size_t esp_himem_get_phys_size(void)`
Get total amount of memory under control of himem API.

Return Amount of memory, in bytes

`size_t esp_himem_get_free_size(void)`
Get free amount of memory under control of himem API.

Return Amount of free memory, in bytes

`size_t esp_himem_reserved_area_size(void)`
Get amount of SPI memory address space needed for bankswitching.

Note This is also weakly defined in esp32/spiram.c and returns 0 there, so if no other function in this file is used, no memory is reserved.

Return Amount of reserved area, in bytes
Macros

ESP_HIMEM_BLKSZ
ESP_HIMEM_MAPFLAG_RO

Indicates that a mapping will only be read from. Note that this is unused for now.

Type Definitions

typedef struct esp_himem_ramdata_t *esp_himem_handle_t

typedef struct esp_himem_rangedata_t *esp_himem_rangehandle_t

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, 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 \texttt{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.

- \texttt{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.
- \texttt{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 \texttt{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 \texttt{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 \texttt{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 \texttt{void func(void *arg)} but implemented entirely in assembly
- The callback is invoked via the \texttt{CALLX0} instruction with register windowing disabled, thus the callback:
  - Must not call any register window related instructions (e.g., \texttt{entry} and \texttt{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 \texttt{a2}, \texttt{a3}, \texttt{a4} are (saved/restored) automatically thus
  - \texttt{a2} will contain the \texttt{void *arg} of the callback
  - \texttt{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.

- \texttt{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.
- \texttt{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.

```c
/* 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"
```

(continues on next page)
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

---

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`
```c
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)
```

IPC Callback.

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_init(void)**

Initialize the IPC ISR feature.

This function initializes the IPC ISR feature and must be called before any other esp_ipc_isr····() functions.

The IPC ISR feature allows for callbacks (written in assembly) to be run on a particular CPU in the context of a High Priority Interrupt.

- This function will register a High Priority Interrupt on each CPU. The priority of the interrupts is dependent on the CONFIG_ESP_SYSTEM_CHECK_INT_LEVEL option.
- Callbacks written in assembly can then run in context of the registered High Priority Interrupts
- Callbacks can be executed by calling esp_ipc_isr_asm_call() or esp_ipc_isr_asm_call_blocking()

**void esp_ipc_isr_asm_call(esp_ipc_isr_func_t func, void *arg)**

Execute an assembly callback on the other CPU.

Execute a given callback on the other CPU in the context of a High Priority Interrupt.

- This function will busy-wait in a critical section until the other CPU has started execution of the callback
- The callback must be written in assembly, is invoked using a CALLX0 instruction, and has a2, a3, a4 as scratch registers. See docs for more details

**Note** This function is not available in single-core mode.

**Parameters**

- [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_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
Chapter 2. API Reference

• [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()
    • 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

\texttt{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 \texttt{esp\_execute\_shared\_stack\_function} (\textit{SemaphoreHandle\_t lock}, \textit{void \*stack}, \textit{size\_t stack\_size}, \textit{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

- \texttt{lock}: Mutex object to protect in case of shared stack
- \texttt{stack}: Pointer to user allocated stack
- \texttt{stack\_size}: Size of current stack in bytes
- \texttt{function}: pointer to the shared stack function to be executed

Macros

\texttt{ESP\_EXECUTE\_EXPRESSION\_WITH\_STACK} (\textit{lock}, \textit{stack}, \textit{stack\_size}, \textit{expression})
Typedef Definitions

typedef void (*shared_stack_function)(void)

2.7.17 Interrupt allocation

Overview

The ESP32 has two cores, with 32 interrupts each. Each interrupt has a certain priority level, most (but not all) interrupts are connected to the interrupt mux.

Because there are more interrupt sources than interrupts, sometimes it makes sense to share an interrupt in multiple drivers. The esp_intr_alloc() abstraction exists to hide all these implementation details.

A driver can allocate an interrupt for a certain peripheral by calling esp_intr_alloc() (or esp_intr_alloc_intrstatus()). It can use the flags passed to this function to set the type of 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

Peripheralsthat can generate interrupts can be divided in two types:

- External peripherals, within the ESP32 but outside the Xtensa cores themselves. Most ESP32 peripherals are of this type.
- Internal peripherals, part of the Xtensa CPU cores themselves.

Interrupt handling differs slightly between these two types of peripherals.

Internal peripheral interrupts Each Xtensa CPU core has its own set of six internal peripherals:

- Three timer comparators
- A performance monitor
- Two software interrupts.

Internal interrupt sources are defined in esp_intr_alloc.h as ETS_INTERNAL_*.INTERRUPT_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.
### esp_intr_reserve

Reserve an interrupt to be used outside of this framework.

**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.

```c
esp_err_t esp_intr_reserve(int intno, int cpu)
```

### esp_intr_alloc

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 if no free interrupt found with the specified flags.

**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.
- 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_handler_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.

```c
esp_err_t esp_intr_alloc(int source, int flags, intr_handler_t handler, void *arg, intr_handle_t *ret_handle)
```

### esp_intr_alloc_intrstatus

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.

**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.

```c
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

```c
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

```c
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

```c
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

```c
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.

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
typedef void (*intr_handler_t)(void *arg)
Function prototype for interrupt handler function

typedef struct intr_handle_data_t intr_handle_data_t
Interrupt handler associated data structure

typedef intr_handle_data_t *intr_handle_t
Handle to an interrupt handler

2.7.18 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, "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` macros. 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 can not raise log level above the level set using CONFIG_LOG_MAXIMUM_LEVEL setting in menuconfig. To raise log level above the default one for a given file, define LOG_LOCAL_LEVEL to one of the ESP_LOG_* values, before including esp_log.h in this file.

**Parameters**  
- `tag`: Tag of the log entries to enable. Must be a non-NULL zero terminated string. Value "*" resets log level for all tags to the given value.
- `level`: Selects log level to enable. Only logs at this and lower verbosity levels will be shown.

```c
esp_log_level_t esp_log_level_get(const char *tag)
```

Get log level for a given tag, can be used to avoid expensive log statements.

**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_vprintf(vprintf_like_t func)
```

Set function used to output log entries.

By default, log output goes to UART0. This function can be used to redirect log output to some other destination, such as file or network. Returns the original log handler, which may be necessary to return output to the previous destination.
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 start 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 system 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.
```

```c
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 logsink.
```

See esp_log_write()

Macros

```c
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

```c
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
Chapter 2. API Reference

- **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 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 ...
   74 68 |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

**portGET_ARGUMENT_COUNT_INNER** (zero, one, count, ...)

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**

**ESP_EARLY_LOGE** (tag, format, ...)

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)  

ESP_LOG_EARLY_IMPL (tag, format, ...)  

ESP_LOGE (tag, format, ...)  

ESP_LOGW (tag, format, ...)  

ESP_LOGI (tag, format, ...)  

ESP_LOGD (tag, format, ...)  

ESP_LOGV (tag, format, ...)  

ESP_LOG_LEVEL (level, tag, format, ...)  
runtime macro to output logs at a specified level.

See printf

Parameters

• tag: tag of the log, which can be used to change the log level by esp_log_level_set at runtime.
• level: level of the output log.
• format: format of the output log. See printf
• ...: variables to be replaced into the log. See printf

ESP_LOG_LEVEL_LOCAL (level, tag, format, ...)  
runtime macro to output logs at a specified level. Also check the level with LOG_LOCAL_LEVEL.

See 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

enum esp_log_level_t
Log level.

Values:

ESP_LOG_NONE
No log output

ESP_LOG_ERROR
Critical errors, software module can not 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 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 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>base_mac</td>
<td>base_mac</td>
</tr>
<tr>
<td>Wi-Fi SoftAP</td>
<td>base_mac, +1 to the last octet</td>
<td><em>Local MAC</em> derived from Wi-Fi Station MAC</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>base_mac, +2 to the last octet</td>
<td>base_mac, +1 to the last octet</td>
</tr>
<tr>
<td>Ethernet</td>
<td>base_mac, +3 to the last octet</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.

**Custom Base MAC**  The default Base MAC is pre-programmed by Espressif in eFuse BLK0. To set a custom Base MAC instead, call the function `esp_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).

The custom base MAC addresses should be allocated such that derived MAC addresses will not overlap. Configure the option `CONFIG_ESP32_UNIVERSAL_MAC_ADDRESSES` to set the number of valid universal MAC addresses that can be derived from the custom base MAC, 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>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version</td>
<td>8</td>
<td>191:184</td>
<td>0: invalid, others — valid</td>
</tr>
<tr>
<td>Reserved</td>
<td>128</td>
<td>183:56</td>
<td></td>
</tr>
<tr>
<td>MAC address</td>
<td>48</td>
<td>55:8</td>
<td></td>
</tr>
<tr>
<td>MAC address CRC</td>
<td>8</td>
<td>7:0</td>
<td>CRC-8-CCITT, polynomial 0x07</td>
</tr>
</tbody>
</table>

**Note:** If the 3/4 coding scheme is enabled, all eFuse fields in this block must be burnt at the same time.
Once 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 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:

  ```
  #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 “1”. 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.

**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

```c
typedef void (*shutdown_handler_t)(void)
    Shutdown handler type
```

Enumerations

```c
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

```c
const char *esp_get_idf_version(void)
    Return full IDF version string, same as ‘git describe’ output.

Note: If you are printing the ESP-IDF version in a log file or other information, this function provides more information than using the numerical version macros. For example, numerical version macros don’t differentiate between development, pre-release and release versions, but the output of this function does.

Return: constant string from IDF_VER
```

Macros

```c
ESP_IDF_VERSION_MAJOR
    Major version number (X.x.x)

ESP_IDF_VERSION_MINOR
    Minor version number (X.X.x)
```
Chapter 2. API Reference

**ESP_IDF_VERSION_PATCH**
- Patch version number (x.x.X)

**ESP_IDF_VERSION_VAL** (major, minor, patch)
- Macro to convert IDF version number into an integer
  - To be used in comparisons, such as ESP_IDF_VERSION >= ESP_IDF_VERSION_VAL(4, 0, 0)

**ESP_IDF_VERSION**
- Current IDF version, as an integer
  - To be used in comparisons, such as ESP_IDF_VERSION >= ESP_IDF_VERSION_VAL(4, 0, 0)

**Header File**
- components/esp_hw_support/include/esp_mac.h

**Functions**

- **esp_err_t esp_base_mac_addr_set(const uint8_t* mac)**
  - Set base MAC address with the MAC address which is stored in BLK3 of EFUSE or external storage e.g. flash and EEPROM.
  - Base MAC address is used to generate the MAC addresses used by network interfaces.
  - If using a custom base MAC address, call this API before initializing any network interfaces. Refer to the ESP-IDF Programming Guide for details about how the Base MAC is used.
  - Note: Base MAC must be a unicast MAC (least significant bit of first byte must be zero).
  - Note: If not using a valid OUI, set the "locally administered" bit (bit value 0x02 in the first byte) to avoid collisions.
  - Return: ESP_OK on success ESP_ERR_INVALID_ARG if mac is NULL or is not a unicast MAC

**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_base_mac_addr_get(uint8_t* mac)**
  - Return base MAC address which is set using esp_base_mac_addr_set.
  - Note: If no custom Base MAC has been set, this returns the pre-programmed Espressif base MAC address.
  - 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 CUSTOM_MAC address has not been set, all zeros (for esp32-xx) ESP_ERR_INVALID_VERSION An invalid MAC version field was read from BLK3 of EFUSE (for esp32) ESP_ERR_INVALID_CRC An invalid MAC CRC was read from BLK3 of EFUSE (for esp32)

**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.

Enumerations
enum esp_mac_type_t
Values:
  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 app slot” partitions (i.e. ota_0 and ota_1) and an “OTA Data Partition”.

The OTA operation functions write a new app firmware image to whichever OTA app slot that is currently not selected for booting. Once the image is verified, the OTA Data partition is updated to specify that this image should be used for the next boot.
OTA Data Partition

An OTA data partition (type data, subtype ota) must be included in the *Partition Table* of any project which uses the OTA functions.

For factory boot settings, the OTA data partition should contain no data (all bytes erased to 0xFF). In this case the esp-idf software bootloader will boot the factory app if it is present in the partition table. If no factory app is included in the partition table, the first available OTA slot (usually ota_0) is booted.

After the first OTA update, the OTA data partition is updated to specify which OTA app slot partition should be booted next.

The OTA data partition is two flash sectors (0x2000 bytes) in size, to prevent problems if there is a power failure while it is being written. Sectors are independently erased and written with matching data, and if they disagree a counter field is used to determine which sector was written more recently.

App rollback

The main purpose of the application rollback is to keep the device working after the update. This feature allows you to roll back to the previous working application in case a new application has critical errors. When the rollback process is enabled and an OTA update provides a new version of the app, one of three things can happen:

- The application works fine, *esp_ota_mark_app_valid_cancel_rollback()* marks the running application with the state ESP_OTA_IMG_VALID. There are no restrictions on booting this application.
- The application has critical errors and further work is not possible, a rollback to the previous application is required, *esp_ota_mark_app_invalid_rollback_and_reboot()* marks the running application with the state ESP_OTA_IMG_INVALID and reset. This application will not be selected by the bootloader for boot and will boot the previously working application.
- If the *CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE* option is set, and a reset occurs without calling either function then the application is rolled back.

**Note:** The state is not written to the binary image of the application but rather to the otadata partition. The partition contains a ota_seq counter which is a pointer to the slot (ota_0, ota_1, ...) from which the application will be selected for boot.

App OTA State

States control the process of selecting a boot app:

<table>
<thead>
<tr>
<th>States</th>
<th>Restriction of selecting a boot app in bootloader</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_OTA_IMG_VALID</td>
<td>Non 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><em>CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE</em> 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><em>CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE</em> 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 odata.
- Restart `esp_restart()`. The bootloader will boot the specified application.

To determine if self-tests should be run during startup of an application, call the `esp_ota_get_state_partition()` function. If result is `ESP_OTA_IMG_PENDING_VERIFY` then self-testing and subsequent confirmation of operability is required.

**Where the states are set** A brief description of where the states are set:

- `ESP_OTA_IMG_VALID` state is set by `esp_ota_mark_app_valid_cancel_rollback()` function.
- `ESP_OTA_IMG_UNDEFINED` state is set by `esp_ota_set_boot_partition()` function if `CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE` option is not enabled.
- `ESP_OTA_IMG_NEW` state is set by `esp_ota_set_boot_partition()` function if `CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE` option is enabled.
- `ESP_OTA_IMG_INVALID` state is set by `esp_ota_mark_app_invalid_rollback_and_reboot()` function.
• ESP_OTA_IMG_ABORTED state is set if there was no confirmation of the application operability and occurs reboots (if CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE option is enabled).
• ESP_OTA_IMG_PENDING_VERIFY state is set in a bootloader if CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE option is enabled and selected app has ESP_OTA_IMG_NEW state.

**Anti-rollback**

Anti-rollback prevents rollback to application with security version lower than one programmed in eFuse of chip.

This function works if set CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK option. In the bootloader, when selecting a bootable application, an additional security version check is added which is on the chip and in the application image. The version in the bootable firmware must be greater than or equal to the version in the chip.

CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK and CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE options are used together. In this case, rollback is possible only on the security version which is equal or higher than the version in the chip.

**A typical anti-rollback scheme is**

- New firmware released with the elimination of vulnerabilities with the previous version of security.
- After the developer makes sure that this firmware is working. He can increase the security version and release a new firmware.
- Download new application.
- To make it bootable, run the function esp_ota_set_boot_partition(). If the security version of the new application is smaller than the version in the chip, the new application will be erased. Update to new firmware is not possible.
- Reboot.
- In the bootloader, an application with a security version greater than or equal to the version in the chip will be selected. If otadata is in the initial state, and one firmware was loaded via a serial channel, whose secure version is higher than the chip, then the secure version of efuse will be immediately updated in the bootloader.
- New application booted. Then the application should perform diagnostics of the operation and if it is completed successfully, you should call esp_ota_mark_app_valid_cancel_rollback() function to mark the running application with the ESP_OTA_IMG_VALID state and update the secure version on chip. Note that if was called esp_ota_mark_app_invalid_rollback_and_reboot() function a rollback may not happen as the device may not have any bootable apps. It will then return ESP_ERR_OTA_ROLLBACK_FAILED error and stay in the ESP_OTA_IMG_PENDING_VERIFY state.

The next update of app is possible if a running app is in the ESP_OTA_IMG_VALID state.

**Recommendation:**

If you want to avoid the download/erase overhead in case of the app from the server has security version lower than the running app, you have to get new_app_info.secure_version from the first package of an image and compare it with the secure version of efuse. Use esp_efuse_check_secure_version(new_app_info.secure_version) function if it is true then continue downloading otherwise abort.

```c
bool image_header_was_checked = false;
while (1) {
    int data_read = esp_http_client_read(client, ota_write_data, BUFFSIZE);
    ...
    if (data_read > 0) {
        if (image_header_was_checked == false) {
            esp_app_desc_t new_app_info;
            if (data_read > sizeof(esp_image_header_t) + sizeof(esp_image_segment_header_t) + sizeof(esp_app_desc_t)) {
                // check current version with downloading
                if (esp_efuse_check_secure_version(new_app_info.secure_version) == false) {
                    ESP_LOGE(TAG, "This a new app can not be downloaded due to a..."
                                "secure version is lower than stored in efuse.");
                }
            }
        }
    }
}(continues on next page)
```
Restrictions:

- The number of bits in the `secure_version` field is limited to 32 bits. This means that only 32 times you can do an anti-rollback. You can reduce the length of this efuse field using `CONFIG_BOOTLOADER_APP_SEC_VER_SIZE_EFUSE_FIELD` option.
- Anti-rollback works only if the encoding scheme for efuse is set to `NONE`.
- Factory and Test partitions are not supported in anti rollback scheme and hence partition table should not have partition with SubType set to `factory` or `test`.

`security_version`:

- In application image it is stored in `esp_app_desc` structure. The number is set `CONFIG_BOOTLOADER_APP_SECURE_VERSION`.
- In ESP32 it is stored in efuse `EFUSE_BLK3_RDATA4_REG` (when a eFuse bit is programmed to 1, it can never be reverted to 0). The number of bits set in this register is the `security_version` from app.

Secure OTA Updates Without Secure boot

The verification of signed OTA updates can be performed even without enabling hardware secure boot. This can be achieved by setting `CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT` and `CONFIG_SECURE_SIGNED_ON_UPDATE_NO_SECURE_BOOT`

For more information refer to `Signed App Verification Without Hardware Secure Boot`

OTA Tool (otatool.py)

The component `app_update` provides a tool `otatool.py` for performing OTA partition-related operations on a target device. The following operations can be performed using the tool:

- read contents of otadata partition (read_otadata)
- erase otadata partition, effectively resetting device to factory app (erase_otadata)
- switch OTA partitions (switch_ota_partition)
- erasing OTA partition (erase_ota_partition)
- write to OTA partition (write_ota_partition)
- read contents of OTA partition (read_ota_partition)

The tool can either be imported and used from another Python script or invoked from shell script for users wanting to perform operation programmatically. This is facilitated by the tool’s Python API and command-line interface, respectively.

Python API  Before anything else, make sure that the `otatool` module is imported.
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(notatool_dir)  # this enables Python to find otatool module
from otatool import *  # import all names inside otatool module

The starting point for using the tool’s Python API to do is create a **OtatoolTarget** object:

```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 **otatool.py** has the following structure:

```
otatool.py [command-args] [subcommand] [subcommand-args]
```

- `command-args` - these are arguments that are needed for executing the main command (parttool.py), mostly pertaining to the target device
- `subcommand` - this is the operation to be performed
- `subcommand-args` - these are arguments that are specific to the chosen operation

```bash
# Erase 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:

```bash
# Display possible subcommands and show main command argument descriptions
otatool.py --help

# Show descriptions for specific subcommand arguments
otatool.py [subcommand] --help
```
Chapter 2. API Reference

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

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.

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

esp_err_t esp_ota_begin(const esp_partition_t *partition, size_t image_size, esp_ota_handle_t *out_handle)

Commence an OTA update writing to the specified partition.

The specified partition is erased to the specified image size.

If image size is not yet known, pass OTA_SIZE_UNKNOWN which will cause the entire partition to be erased.

On success, this function allocates memory that remains in use until esp_ota_end() is called with the returned handle.

Note: If the rollback option is enabled and the running application has the ESP_OTA_IMG_PENDINGVERIFY state then it will lead to the ESP_ERR_OTA_ROLLBACK_INVALIDSTATE 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.

Returns a description for the requested app partition.

- **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 void esp_ota_mark_app_valid_cancel_rollback()
```

This function is called to indicate that the running app is working well.

Return

- **ESP_OK**: if successful.

```
c void esp_ota_mark_app_invalid_rollback_and_reboot()
```

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 *esp_partition_t *esp_ota_get_last_invalid_partition()
```

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_INVALID_ARG**: partition or ota_state arguments were NULL.
- **ESP_ERR_INVALID_ARG**: partition is not ota.
- **ESP_ERR_INVALID_SIZERead would go out of bounds of the partition.**
- **ESP_ERR_INVALID_SIZERead would go out of bounds of the partition.**
- **ESP_ERR_INVALID_ARG**: partition is not ota.
- **ESP_ERR_INVALID_ARG**: partition is not ota.
- **ESP_ERR_INVALID_ARG**: partition is not ota.

Parameters

- **[in]** partition: Pointer to partition.
• [out] ota_state: state of partition (if this partition has a record in odata).

`esp_err_t esp_ota_erase_last_boot_app_partition(void)`
Erase previous boot app partition and corresponding ota data 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.

`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 odata 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.

**Macros**

OTA_SIZE_UNKNOWN
Used for esp_ota_begin() if new image size is unknown

OTA_WITH_SEQUENTIAL_WRITES
Used for esp_ota_begin() if new image size is unknown and erase can be done in incremental manner (assuming write operation is in continuous sequence)

ESP_ERR_OTA_BASE
Base error code for ota_ops api

ESP_ERR_OTA_PARTITION_CONFLICT
Error if request was to write or erase the current running partition

ESP_ERR_OTA_SELECT_INFO_INVALID
Error if OTA data partition contains invalid content

ESP_ERR_OTA_VALIDATE_FAILED
Error if OTA app image is invalid

ESP_ERR_OTA_SMALL_SEC_VER
Error if the firmware has a secure version less than the running firmware.

ESP_ERR_OTA_ROLLBACK_FAILED
Error if flash does not have valid firmware in passive partition and hence rollback is not possible

ESP_ERR_OTA_ROLLBACK_INVALID_STATE
Error if current active firmware is still marked in pending validation state (ESP_OTA_IMG_PENDING_VERIFY), essentially first boot of firmware image post upgrade and hence firmware upgrade is not possible

**Type Definitions**

typedef uint32_t esp_ota_handle_t
Opaque handle for an application OTA update.

esp_ota_begin() returns a handle which is then used for subsequent calls to esp_ota_write() and esp_ota_end().

**Debugging OTA Failure**

**2.7.21 Performance Monitor**

The Performance Monitor component provides APIs to use ESP32 internal performance counters to profile functions and applications.
Fig. 39: How to Debug When OTA Fails (click to enlarge)
Chapter 2. API Reference

Application Example

An example which combines performance monitor is provided in examples/system/perfmon directory. This example initializes the performance monitor structure and execute them with printing the statistics.

High level API Reference

Header Files

• perfmon/include/perfmon.h

API Reference

Header File

• components/perfmon/include/xtensa_perfmon_access.h

Functions

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

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

global xtensa_perfmon_start (void)

Start PM counters.

Start all PM counters synchronously. Write 1 to the PGM register

void xtensa_perfmon_stop (void)

Stop PM counters.

Stop all PM counters synchronously. Write 0 to the PGM register

uint32_t xtensa_perfmon_value (int id)

Read PM counter.

Read value of defined PM counter.

Return

• Performance counter value

Parameters

• [in] id: performance counter number
**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 occurred (overflow = 1)

- **Parameters**
  - **[in]** id: performance counter number

**xtensa_perfmon_dump** (void)

Dump PM values.

Dump all PM registers to the console.

**Header File**

- components/perfmon/include/xtensa_perfmon_apis.h

**Functions**

**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

**xtensa_perfmon_view_cb** (void *params, uint32_t select, uint32_t mask, uint32_t value)

Dump PM results.

Callback to dump perfmon result to a FILE* stream specified in perfmon_config_t::callback_params. If callback_params is set to NULL, will print to stdout

- **Parameters**
  - **[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**

**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_esp32_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_ESP32_DEFAULT_CPU_FREQ_MHZ` setting, and the minimum
  CPU frequency will be locked to the XTAL frequency.

**Note:** Automatic light sleep is based on FreeRTOS Tickless Idle functionality. If automatic light
  sleep is requested while the option `CONFIG_FREERTOS_USE_TICKLESS_IDLE` is not enabled in menuconfig,
  `esp_pm_configure()` will return the error `ESP_ERR_NOT_SUPPORTED`.

**Note:** In light sleep, peripherals are clock gated, and interrupts (from GPIOs and internal peripherals) will not be
  generated. A wakeup source described in the Sleep Modes documentation can be used to trigger wakeup from the
  light sleep state.

For example, the EXT0 and EXT1 wakeup sources can be used to wake up the chip via a GPIO.

**Power Management Locks**

Applications have the ability to acquire/release locks in order to control the power management algorithm. When an
  application acquires a lock, the power management algorithm operation is restricted in a way described below. When
  the lock is released, such restrictions are removed.

Power management locks have acquire/release counters. If the lock has been acquired a number of times, it needs to
  be released the same number of times to remove associated restrictions.

ESP32 supports three types of locks described in the table below.

<table>
<thead>
<tr>
<th>Lock</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_PM_CPU_FREQ_MAX</td>
<td>Requests CPU frequency to be at the maximum value set with <code>esp_pm_configure()</code>. For ESP32, this value can be set to 80 MHz, 160 MHz, or 240 MHz.</td>
</tr>
<tr>
<td>ESP_PM_APB_FREQ_MAX</td>
<td>Requests the APB frequency to be at the maximum supported value. For ESP32, this is 80 MHz.</td>
</tr>
<tr>
<td>ESP_PM_NO_LIGHT_SLEEP</td>
<td>Disables automatic switching to light sleep.</td>
</tr>
</tbody>
</table>

**ESP32 Power Management Algorithm**

The table below shows how CPU and APB frequencies will be switched if dynamic frequency scaling is enabled. You can specify the maximum CPU frequency with either `esp_pm_configure()` or `CONFIG_ESP32_DEFAULT_CPU_FREQ_MHZ`. 
<table>
<thead>
<tr>
<th>Max CPU Frequency Set</th>
<th>Lock Acquisition</th>
<th>CPU and APB Frequencies</th>
</tr>
</thead>
</table>
| 240                   | Any of ESP_PM_CPU_FREQ_MAX or ESP_PM_APB_FREQ_MAX acquired | CPU: 240 MHz  
APB: 80 MHz |
|                       | None             | Min values for both frequencies set with \texttt{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 \texttt{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 \texttt{esp_pm_configure()} |

If none of the locks are acquired, and light sleep is enabled in a call to \texttt{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 \textit{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 \textit{skip_unhandled_events} option as true. Timers with this flag will not wake up the system and it helps to reduce consumption.

**Dynamic Frequency Scaling and Peripheral Drivers**

When DFS is enabled, the APB frequency can be changed multiple times within a single RTOS tick. The APB frequency change does not affect the operation of some peripherals, while other peripherals may have issues. For example, Timer Group peripheral timers will keep counting, however, the speed at which they count will change proportionally to the APB frequency.

The following peripherals work normally even when the APB frequency is changing:

- **UART**: if REF_TICK is used as a clock source. See \texttt{use_ref_tick} member of \texttt{uart_config_t}.
- **LEDC**: if REF_TICK is used as a clock source. See \texttt{ledc_timer_config()} function.
- **RMT**: if REF_TICK or XTAL is used as a clock source. See \texttt{flags} member of \texttt{rmt_config_t} and macro \textit{RMT_CHANNEL_FLAGS_AWARE_DFS}.
- **GPTimer**: if APB is used as the clock source. See \texttt{clk_src} member of \texttt{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, unless CONFIG_BTDM_CTRL_LOW_POWER_CLOCK option is set to “External 32kHz crystal”.

The following peripheral drivers are not aware of DFS yet. Applications need to acquire/release locks themselves, when necessary:

- PCNT
- Sigma-delta
- The legacy timer group driver (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

```c
esp_err_t esp_pm_configure(const void *config)
```

Set implementation-specific power management configuration.

**Return**

- ESP_OK on success
- ESP_ERR_INVAL_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)

```c
esp_err_t esp_pm_get_configuration(void *config)
```

Get implementation-specific power management configuration.

**Return**

- ESP_OK on success
- ESP_ERR_INVAL_ARG if the pointer is null

**Parameters**

- `config`: pointer to implementation-specific configuration structure (e.g. esp_pm_config_esp32)

```c
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 `m_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
typedef struct esp_pm_lock *esp_pm_lock_handle_t
Opaque handle to the power management lock.

Enumerations
enum esp_pm_lock_type_t
Power management constraints.

Values:

ESP_PM_CPU_FREQ_MAX
Require CPU frequency to be at the maximum value set via esp_pm_configure. Argument is unused and
should be set to 0.

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/esp32/pm.h

Structures
struct esp_pm_config_esp32_t
Power management config for ESP32.
Pass a pointer to this structure as an argument to esp_pm_configure function.

Public Members

int max_freq_mhz
Maximum CPU frequency, in MHz

int min_freq_mhz
Minimum CPU frequency to use when no locks are taken, in MHz

bool light_sleep_enable
Enter light sleep when no locks are taken
2.7.23 Random Number Generation

ESP32 contains a hardware random number generator, values from it can be obtained using the APIs `esp_random()` and `esp_fill_random()`.

The hardware RNG produces true random numbers under any of the following conditions:

- RF subsystem is enabled (i.e. Wi-Fi or Bluetooth are enabled).
- An internal entropy source has been enabled by calling `bootloader_random_enable()` and not yet disabled by calling `bootloader_random_disable()`.
- While the ESP-IDF Second stage bootloader is running. This is because the default ESP-IDF bootloader implementation calls `bootloader_random_enable()` when the bootloader starts, and `bootloader_random_disable()` before executing the app.

When any of these conditions are true, samples of physical noise are continuously mixed into the internal hardware RNG state to provide entropy. Consult the ESP32 Technical Reference Manual > Random Number Generator (RNG) [PDF] chapter for more details.

If none of the above conditions are true, the output of the RNG should be considered pseudo-random only.

Startup

During startup, ESP-IDF bootloader temporarily enables a non-RF entropy source (internal reference voltage noise) that provides entropy for any first boot key generation. However, after the app starts executing then normally only pseudo-random numbers are available until Wi-Fi or Bluetooth are initialized.

To re-enable the entropy source temporarily during app startup, or for an application that does not use Wi-Fi or Bluetooth, call the function `bootloader_random_enable()` to re-enable the internal entropy source. The function `bootloader_random_disable()` must be called to disable the entropy source again before using ADC, I2S, Wi-Fi or Bluetooth.

**Note:** The entropy source enabled during the boot process by the ESP-IDF Second Stage Bootloader will seed the internal RNG state with some entropy. However, the internal hardware RNG state is not large enough to provide a continuous stream of true random numbers. This is why a continuous entropy source must be enabled whenever true random numbers are required.

**Note:** If an application requires a source of true random numbers but it is not possible to permanently enable a hardware entropy source, consider using a strong software DRBG implementation such as the mbedTLS CTR-DRBG or HMAC-DRBG, with an initial seed of entropy from hardware RNG true random numbers.

API Reference

**Header File**

- `components/esp_hw_support/include/esp_random.h`

**Functions**

```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

void esp_fill_random (void *buf, size_t len)
 Fill a buffer with random bytes from hardware RNG.

Note  This function is implemented via calls to esp_random(), so the same constraints apply.

Parameters
• buf: Pointer to buffer to fill with random numbers.
• len: Length of buffer in bytes

Header File
• components/bootloader_support/include/bootloader_random.h

Functions
void bootloader_random_enable (void)
 Enable an entropy source for RNG if RF 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.

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.

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 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 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.

Revisions 0 and 1 of the ESP32 only support this wakeup mode when RTC peripherals are not forced to be powered on (i.e. ESP_PD_DOMAIN_RTC_PERIPH should be set to ESP_PD_OPTION_AUTO). `esp_sleep_enable_touchpad_wakeup()` function can be used to enable this wakeup source.

**External wakeup (ext0)**  
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 deep 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()`.

In revisions 0 and 1 of the ESP32, this wakeup source is incompatible with ULP and touch wakeup sources. `esp_sleep_enable_ext0_wakeup()` function can be used to enable this wakeup source.

**Warning:** After 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.

Revisions 0 and 1 of the ESP32 only support this wakeup mode when RTC peripherals are not forced to be powered on (i.e. `ESP_PD_DOMAIN_RTC_PERIPH` should be set to `ESP_PD_OPTION_AUTO`).

`esp_sleep_enable_ulp_wakeup()` function can be used to enable this wakeup source.

### GPIO wakeup (light sleep only)

In addition to EXT0 and EXT1 wakeup sources described above, one more method of wakeup from external inputs is available in light sleep mode. With this wakeup source, each pin can be individually configured to trigger wakeup on high or low level using `gpio_wakeup_enable()` function. Unlike EXT0 and EXT1 wakeup sources, which can only be used with RTC IOs, this wakeup source can be used with any IO (RTC or digital).

`esp_sleep_enable_gpio_wakeup()` function can be used to enable this wakeup source.

**Warning:** Before entering light sleep mode, check if any GPIO pin to be driven is part of the VDD_SDIO power domain. If so, this power domain must be configured to remain ON during sleep.
For example, on ESP32-WROOM-32 board, GPIO16 and GPIO17 are linked to VDD_SDIO power domain. If they are configured to remain high during light sleep, the power domain should be configured to remain powered ON. This can be done with `esp_sleep_pd_config()`:

```c
esp_sleep_pd_config(ESP_PD_DOMAIN_VDDSDIO, ESP_PD_OPTION_ON);
```

**UART wakeup (light sleep only)** When ESP32 receives UART input from external devices, it is often 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 to trigger wakeup, before sending the data. `esp_sleep_enable_uart_wakeup()` function can be used to enable this wakeup source.

**Power-down of RTC peripherals and memories**

By default, `esp_deep_sleep_start()` and `esp_light_sleep_start()` functions will power down all RTC power domains which are not needed by the enabled wakeup sources. To override this behaviour, `esp_sleep_pd_config()` function is provided.

Note: in revision 0 of the ESP32, RTC fast memory will always be kept enabled in deep sleep, so that the deep sleep stub can run after reset. This can be overridden, if the application doesn’t need clean reset behaviour after deep sleep.

If some variables in the program are placed into RTC slow memory (for example, using `RTC_DATA_ATTR` attribute), RTC slow memory will be kept powered on by default. This can be overridden using `esp_sleep_pd_config()` function, if desired.

**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 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:

```c
rtc_gpio_isolate(GPIO_NUM_12);
```
UART output handling

Before entering sleep mode, \texttt{esp\_deep\_sleep\_start()} will flush the contents of UART FIFOs. When entering light sleep mode using \texttt{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

\texttt{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 \texttt{esp\_sleep\_get\_touchpad\_wakeup\_status()} functions.

For ext1 wakeup sources, it is possible to identify pin which has caused wakeup using \texttt{esp\_sleep\_get\_ext1\_wakeup\_status()} functions.

Disable sleep wakeup source

Previously configured wakeup source can be disabled later using \texttt{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 \texttt{ESP\_SLEEP\_WAKEUP\_ALL}.

Application Example

Implementation of basic functionality of deep sleep is shown in \texttt{protocols/sntp} example, where ESP module is periodically waken up to retrieve time from NTP server.

More extensive example in \texttt{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

\texttt{esp\_err\_t esp\_sleep\_disable\_wakeup\_source}(\texttt{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.

\textbf{Note} This function does not modify wake up configuration in RTC. It will be performed in \texttt{esp\_sleep\_start()} function.

\textbf{Return}

- ESP\_OK on success
- ESP\_ERR\_INVALID\_STATE if trigger was not active

\textbf{Parameters}

- \texttt{source}: - number of source to disable of type \texttt{esp\_sleep\_source\_t}

\texttt{esp\_err\_t esp\_sleep\_enable\_ulp\_wakeup} (\texttt{void})

Enable wakeup by ULP coprocessor.

\textbf{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

```c
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

```c
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

```c
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

```c
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

```c
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)
**esp_err_t esp_sleep_enable_ext1_wakeup** (uint64_t mask, esp_sleep_ext1_wakeup_mode_t mode)

Enable wakeup using multiple pins.

This function uses external wakeup feature of RTC controller. It will work even if RTC peripherals are shut down during sleep.

This feature can monitor any number of pins which are in RTC IOs. Once any of the selected pins goes into the state given by mode argument, the chip will be woken up.

**Note** This function does not modify pin configuration. The pins are configured in esp_sleep_start, immediately before entering sleep mode.

**Note** Internal pullups and pulldowns don’t work when RTC peripherals are shut down. In this case, external resistors need to be added. Alternatively, RTC peripherals (and pullups/pulldowns) may be kept enabled using esp_sleep_pd_config function.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if any of the selected GPIOs is not an RTC GPIO, or mode is invalid

**Parameters**
- **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.
- **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

**esp_err_t esp_sleep_enable_gpio_wakeup** (void)

Enable wakeup from light sleep using GPIOs.

Each GPIO supports wakeup function, which can be triggered on either low level or high level. Unlike EXT0 and EXT1 wakeup sources, this method can be used both for all IOs: RTC IOs and digital IOs. It can only be used to wakeup from light sleep though.

To enable wakeup, first call gpio_wakeup_enable, specifying gpio number and wakeup level, for each GPIO which is used for wakeup. Then call this function to enable wakeup feature.

**Note** In revisions 0 and 1 of the ESP32, GPIO wakeup source can not be used together with touch or ULP wakeup sources.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if wakeup triggers conflict

**Parameters**
- **uart_num**: UART port to wake up from

**esp_err_t esp_sleep_enable_uart_wakeup** (int uart_num)

Enable wakeup from light sleep using UART.

Use uart_set_wakeup_threshold function to configure UART wakeup threshold.

Wakeup from light sleep takes some time, so not every character sent to the UART can be received by the application.

**Note** ESP32 does not support wakeup from UART2.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if wakeup from given UART is not supported

**Parameters**
- **uart_num**: UART port to wake up from

**esp_err_t esp_sleep_enable_wifi_wakeup** (void)

Enable wakeup by WiFi MAC.

**Return**
- ESP_OK on success

**esp_err_t esp_sleep_disable_wifi_wakeup** (void)

Disable wakeup by WiFi MAC.

**Return**
- ESP_OK on success
Chapter 2. API Reference

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 GPIO caused wakeup, BIT(n) will be set

esp_err_t esp_sleep_pd_config (esp_sleep_pd_domain_t domain, esp_sleep_pd_option_t option)
Set power down mode for an RTC power domain in sleep mode.

If not set set using this API, all power domains default to ESP_PD_OPTION_AUTO.

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
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:

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_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)
  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 watchdog timeout on CPU0” or “Interrupt watchdog 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 loop going 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 Tasks of each CPU, 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().

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 is connected to OpenOCD via JTAG.

Interrupt Watchdog API Reference

Header File

- esp_system/include/esp_int_wdt.h

Functions

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

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

`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)`
Unsubscribes 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_INVALID_ARG: 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_ESP32_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_ESP32_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 Hardware Design Guidelines.

Get Current Time

To get the current time, use the POSIX function gettimeofday(). Additionally, you can use the following standard C library functions to obtain time and manipulate it:

```c
gettimeofday
time
asctime
clock
difftime
gmtime
localtime
mktime
strftime
adjtime*
```

* To stop smooth time adjustment and update the current time immediately, use the POSIX function settimeofday().

If you need to obtain time with one second resolution, use the following 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.

### API Reference

#### Header File

- `components/lwip/include/apps/esp_sntp.h`

#### Functions

**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 sntp_set_sync_mode(sntp_sync_mode_t sync_mode)**

Set the sync mode.

Modes allowed: `SNTP_SYNC_MODE_IMMED` and `SNTP_SYNC_MODE_SMOOTH`.

**Parameters**

- `sync_mode`: Sync mode.

**sntp_sync_mode_t sntp_get_sync_mode(void)**

Get set sync mode.
### Return SNTP_SYNC_MODE_IMMED: Update time immediately. SNTP_SYNC_MODE_SMOOTH: Smooth time updating.

```c
sntp_sync_status_t sntp_get_sync_status (void)
```

Get status of time sync.

After the update is completed, the status will be returned as SNTP_SYNC_STATUS_COMPLETED. After that, the status will be reset to SNTP_SYNC_STATUS_RESET. If the update operation is not completed yet, the status will be SNTP_SYNC_STATUS_RESET. If a smooth mode was chosen and the synchronization is still continuing (adjtime works), then it will be SNTP_SYNC_STATUS_IN_PROGRESS.

### Return SNTP_SYNC_STATUS_RESET: Reset status. SNTP_SYNC_STATUS_COMPLETED: Time is synchronized. SNTP_SYNC_STATUS_IN_PROGRESS: Smooth time sync in progress.

```c
void sntp_set_sync_status (sntp_sync_status_t sync_status)
```

Set status of time sync.

#### Parameters
- `sync_status`: status of time sync (see sntp_sync_status_t)

```c
void sntp_set_time_sync_notification_cb (sntp_sync_time_cb_t callback)
```

Set a callback function for time synchronization notification.

#### Parameters
- `callback`: a callback function

```c
void sntp_set_sync_interval (uint32_t interval_ms)
```

Set the sync interval of SNTP operation.

**Note:** SNTPv4 RFC 4330 enforces a minimum sync interval of 15 seconds. This sync interval will be used in the next attempt update time throught 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.

```c
uint32_t sntp_get_sync_interval (void)
```

Get the sync interval of SNTP operation.

#### Return the sync interval

```c
bool sntp_restart (void)
```

Restart SNTP.

#### Return True - Restart False - SNTP was not initialized yet

### Type Definitions

```c
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

```c
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.
Chapter 2. API Reference

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_putchar(int channel, void (*)(char) 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_putchar(void) 
Install UART1 as the default console channel, equivalent to esp_rom_install_channel_putchar(1, 
esp_rom_uart_putchar)

soc_reset_reason_t esp_rom_get_reset_reason(int cpu_no) 
Get reset reason of CPU.
Return Reset reason code (see in soc/reset_reasons.h)
Parameters
• cpu_no: CPU number

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++ 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:

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

```
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:

```
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.
- 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 save-defconfig 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.
- 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. configen.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.

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 to 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.

**SDK tool configuration**

Contains:

- `CONFIG_SDK_TOOLPREFIX`
- `CONFIG_SDK_TOOLCHAIN_SUPPORTS_TIME_WIDE_64_BITS`

**CONFIG_SDK_TOOLPREFIX**

Compiler toolchain path/prefix

*Found in: SDK tool configuration*

The prefix/path that is used to call the toolchain. The default setting assumes a crosstool-ng gcc setup that is in your PATH.

*Default value:*

- “xtensa-esp32-elf-“

**CONFIG_SDK_TOOLCHAIN_SUPPORTS_TIME_WIDE_64_BITS**

Toolchain supports time_t wide 64-bits

*Found in: SDK tool configuration*

Enable this option in case you have a custom toolchain which supports time_t wide 64-bits. This option checks time_t is 64-bits and disables ROM time functions to use the time functions from the toolchain instead. This option allows resolving the Y2K38 problem. See “Setup Linux Toolchain from Scratch” to build a custom toolchain which supports 64-bits time_t.

Note: ESP-IDF does not currently come with any pre-compiled toolchain that supports 64-bit wide time_t. This will change in a future major release, but currently 64-bit time_t requires a custom built toolchain.

*Default value:*

- No (disabled)
Build type

Contains:

- \texttt{CONFIG\_APP\_BUILD\_TYPE}
- \texttt{CONFIG\_APP\_REPRODUCIBLE\_BUILD}

\textbf{CONFIG\_APP\_BUILD\_TYPE}

Application build type

\textit{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 IRAM 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
# Load the application into RAM
load
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=
CONFIG\_NEWLIB\_NANO\_FORMAT=y CONFIG\_ESP\_SYSTEM\_PANIC\_PRINT\_HALT=y
CONFIG\_ESP\_DEBUG\_STUBS\_ENABLE=CONFIG\_ESP\_ERR\_TO\_NAME\_LOOKUP=
```

\textbf{Available options:}

- Default (binary application + 2nd stage bootloader) (\texttt{APP\_BUILD\_TYPE\_APP\_2NDBOOT})
- ELF file, loadable into RAM (EXPERIMENTAL) (\texttt{APP\_BUILD\_TYPE\_ELF\_RAM})

\textbf{CONFIG\_APP\_REPRODUCIBLE\_BUILD}

Enable reproducible build

\textit{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)

\textbf{Default value:}

- No (disabled)
Chapter 2. API Reference

Application manager

Contains:

- CONFIG_APP_COMPILE_TIME_DATE
- 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.

**Range:**

- from 8 to 64

**Default value:**

- 16

**Bootloader config**

Contains:

- CONFIG_BOOTLOADER_LOG_LEVEL
- CONFIG_BOOTLOADER_COMPILER_OPTIMIZATION
- CONFIG_BOOTLOADER_SPI_WP_PIN
- 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_SPI_CUSTOM_WP_PIN
- 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_SPI_CUSTOM_WP_PIN

Use custom SPI Flash WP Pin when flash pins set in eFuse (read help)

*Found in: Bootloader config*

This setting is only used if the SPI flash pins have been overridden by setting the eFuses SPI_PAD_CONFIG_xxx, and the SPI flash mode is QIO or QOUT.

When this is the case, the eFuse config only defines 3 of the 4 Quad I/O data pins. The WP pin (aka ESP32 pin “SD_DATA_3” or SPI flash pin “IO2”) is not specified in eFuse. The same pin is also used for external SPIRAM if it is enabled.

If this config item is set to N (default), the correct WP pin will be automatically used for any Espressif chip or module with integrated flash. If a custom setting is needed, set this config item to Y and specify the GPIO number connected to the WP.

**Default value:**

- No (disabled) if ESPTOOLPY_FLASHMODE_QIO || ESPTOOLPY_FLASHMODE_QOUT

CONFIG_BOOTLOADER_SPI_WP_PIN

Custom SPI Flash WP Pin

*Found in: Bootloader config*

The option “Use custom SPI Flash WP Pin” must be set or this value is ignored.

If burning a customized set of SPI flash pins in eFuse and using QIO or QOUT mode for flash, set this value to the GPIO number of the SPI flash WP pin.

**Range:**

- from 0 to 33 if ESPTOOLPY_FLASHMODE_QIO || ESPTOOLPY_FLASHMODE_QOUT

**Default value:**

- 7 if ESPTOOLPY_FLASHMODE_QIO || ESPTOOLPY_FLASHMODE_QOUT
**CONFIG_BOOTLOADER_VDDSDIO_BOOST**

VDDSDIO LDO voltage

*Found in: Bootloader config*

If this option is enabled, and VDDSDIO LDO is set to 1.8V (using eFuse or MTDI bootstrapping pin), bootloader will change LDO settings to output 1.9V instead. This helps prevent flash chip from browning out during flash programming operations.

This option has no effect if VDDSDIO is set to 3.3V, or if the internal VDDSDIO regulator is disabled via eFuse.

**Available options:**
- 1.8V (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.

**Range:**
- from 0 to 39 if CONFIG_BOOTLOADER_FACTORY_RESET

**Default value:**
- 4 if CONFIG_BOOTLOADER_FACTORY_RESET

**CONFIG_BOOTLOADER_FACTORY_RESET_PIN_LEVEL**

Factory reset GPIO level

*Found in: Bootloader config > CONFIG_BOOTLOADER_FACTORY_RESET*

Pin level for factory reset, can be triggered on low or high.

**Available options:**
- Reset on GPIO low (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.
Chapter 2. API Reference

CONFIGBOOTLOADER_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 EXTERNALCRYSTAL).

Default value:
- Yes (enabled)

**CONFIG_BOOTLOADER_WDT_DISABLE_IN_USER_CODE**

Allows RTC watchdog disable in user code

*Found in: Bootloader config > CONFIG_BOOTLOADER_WDT_ENABLE*

If this option is set, the ESP-IDF app must explicitly reset, feed, or disable the rtc_wdt in the app’s
own code. If this option is not set (default), then rtc_wdt will be disabled by ESP-IDF before calling the
app_main() function.

Use function rtc_wdt_feed() for resetting counter of rtc_wdt. Use function rtc_wdt_disable() for 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_OTA_IMG_PENDING_VERIFY” state set. This state prevents the re-run of this app.
After the first boot of the new app in the user code, the function should be called to confirm the
operability of the app or vice versa about its non-operability. If the app is working, then it is marked
as valid. Otherwise, it is marked as not valid and rolls back to the previous working app. A reboot is
performed, and the app is booted before the software update. Note: If during the first boot a new app
the power goes out or the WDT works, then roll back will happen. Rollback is possible only between
the apps with the same security versions.

Default value:
- No (disabled)

**CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK**

Enable app anti-rollback support

*Found in: Bootloader config > CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE*

This option prevents rollback to previous firmware/application image with lower security version.

Default value:
• No (disabled) if `CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE`

**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 have a scheme with `ota_0 + ota_1` (without factory).

*Default value:*

• 0 if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`

**CONFIG_BOOTLOADER_APP_SEC_VER_SIZE_EFUSE_FIELD**

Size of the eFuse secure version field

*Found in:* `Bootloader config > CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE > CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`

The size of the eFuse secure version field. Its length is limited to 32 bits for ESP32 and 16 bits for ESP32-S2. This determines how many times the security version can be increased.

*Range:*

• from 1 to 32 if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`
• from 1 to 16 if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`

*Default value:*

• 32 if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`
• 16 if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`

**CONFIG_BOOTLOADER_EFUSE_SECURE_VERSION_EMULATE**

Emulate operations with eFuse secure version (only test)

*Found in:* `Bootloader config > CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE > CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`

This option allows to emulate read/write operations with all eFuses and eFuse secure version. It allows to test anti-rollback implementation without permanent write eFuse bits. There should be an entry in partition table with following details: `emul_eFuse, data, eFuse, 0x2000`.

This option enables: `EFUSE_VIRTUAL` and `EFUSE_VIRTUAL_KEEP_IN_FLASH`.

*Default value:*

• No (disabled) if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`

**CONFIG_BOOTLOADER_SKIP_VALIDATE_IN_DEEP_SLEEP**

Skip image validation when exiting deep sleep

*Found in:* `Bootloader config`
This option disables the normal validation of an image coming out of deep sleep (checksums, SHA256, and signature). This is a trade-off between wakeup performance from deep sleep, and image integrity checks.

Only enable this if you know what you are doing. It should not be used in conjunction with using deep_sleep() entry and changing the active OTA partition as this would skip the validation upon first load of the new OTA partition.

It is possible to enable this option with Secure Boot if “allow insecure options” is enabled, however it’s strongly recommended to NOT enable it as it may allow a Secure Boot bypass.

**Default value:**
- No (disabled) if `CONFIG_SECURE_BOOT && CONFIG_SECURE_BOOT_INSECURE` || `CONFIG_SECURE_BOOT`

**CONFIG_BOOTLOADER_SKIP_VALIDATE_ON_POWER_ON**

Skip image validation from power on reset (READ HELP FIRST)

*Found in:* Bootloader config

Some applications need to boot very quickly from power on. By default, the entire app binary is read from flash and verified which takes up a significant portion of the boot time.

Enabling this option will skip validation of the app when the SoC boots from power on. Note that in this case it’s not possible for the bootloader to detect if an app image is corrupted in the flash, therefore it’s not possible to safely fall back to a different app partition. Flash corruption of this kind is unlikely but can happen if there is a serious firmware bug or physical damage.

Following other reset types, the bootloader will still validate the app image. This increases the chances that flash corruption resulting in a crash can be detected following soft reset, and the bootloader will fall back to a valid app image. To increase the chances of successfully recovering from a flash corruption event, keep the option `BOOTLOADER_WDT_ENABLE` enabled and consider also enabling `BOOTLOADER_WDT_DISABLE_IN_USER_CODE` - then manually disable the RTC Watchdog once the app is running. In addition, enable both the Task and Interrupt watchdog timers with reset options set.

**Default value:**
- No (disabled)

**CONFIG_BOOTLOADER_SKIP_VALIDATE_ALWAYS**

Skip image validation always (READ HELP FIRST)

*Found in:* Bootloader config

Selecting this option prevents the bootloader from ever validating the app image before booting it. Any flash corruption of the selected app partition will make the entire SoC unbootable.

Although flash corruption is a very rare case, it is not recommended to select this option. Consider selecting “Skip image validation from power on reset” instead. However, if boot time is the only important factor then it can be enabled.

**Default value:**
- No (disabled)

**CONFIG_BOOTLOADER_CUSTOM_RESERVE_RTC**

Reserve RTC FAST memory for custom purposes

*Found in:* Bootloader config

This option allows the customer to place data in the RTC FAST memory, this area remains valid when rebooted, except for power loss. This memory is located at a fixed address and is available for both the bootloader and the application. (The application and bootloader must be compiled with the same option). The RTC FAST memory has access only through PRO_CPU.
**Default value:**
- No (disabled)

**CONFIG_BOOTLOADER_CUSTOM_RESERVE_RTC_SIZE**

Size in bytes for custom purposes

*Found in: Bootloader config > CONFIG_BOOTLOADER_CUSTOM_RESERVE_RTC*

This option reserves in RTC FAST memory the area for custom purposes. If you want to create your own bootloader and save more information in this area of memory, you can increase it. It must be a multiple of 4 bytes. This area (rtc_retain_mem_t) is reserved and has access from the bootloader and an application.

**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_SIGNED_ON_BOOT_NO_SECURE_BOOT
- CONFIG_SECURE_FLASH_CHECK_ENC_EN_IN_APP
- CONFIG_SECURE_FLASH_ENC_ENABLED
- CONFIG_SECURE_BOOT
- CONFIG_SECURE_BOOTLOADER_KEY_ENCODING
- Potentially insecure options
  - CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT
  - CONFIG_SECURE_BOOT_VERIFICATION_KEY
  - CONFIG_SECURE_BOOTLOADER_MODE
  - CONFIG_SECURE_BOOT_BUILD_SIGNED_BINARIES
  - CONFIG_SECURE_UART_ROM_DL_MODE
  - CONFIG_SECURE_SIGNED_ON_UPDATE_NO_SECURE_BOOT

**CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT**

Require signed app images

*Found in: Security features*

Require apps to be signed to verify their integrity.

This option uses the same app signature scheme as hardware secure boot, but unlike hardware secure boot it does not prevent the bootloader from being physically updated. This means that the device can...
be secured against remote network access, but not physical access. Compared to using hardware Secure Boot this option is much simpler to implement.

CONFIG_SECURE_SIGNED_APPS_SCHEME

App Signing Scheme

*Found in: Security features*


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_BOOT_NO_SECURE_BOOT

Bootloader verifies app signatures

*Found in: Security features*

If this option is set, the bootloader will be compiled with code to verify that an app is signed before booting it.

If hardware secure boot is enabled, this option is always enabled and cannot be disabled. If hardware secure boot is not enabled, this option doesn’t add significant security by itself so most users will want to leave it disabled.

*Default value:*

- No (disabled) if CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT
  
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_BOOTLOADER_MODE**

Secure bootloader mode

*Found in: Security features*

**Available options:**
- One-time flash (SECURE_BOOTLOADER_ONE_TIME_FLASH)
  On first boot, the bootloader will generate a key which is not readable externally or by software. A digest is generated from the bootloader image itself. This digest will be verified on each subsequent boot.
  Enabling this option means that the bootloader cannot be changed after the first time it is booted.
- Reflashable (SECURE_BOOTLOADER_REFLASHABLE)
  Generate a reusable secure bootloader key, derived (via SHA-256) from the secure boot signing key.
  This allows the secure bootloader to be re-flashed by anyone with access to the secure boot signing key.
  This option is less secure than one-time flash, because a leak of the digest key from one device allows reflash of any device that uses it.

**CONFIG_SECURE_BOOT_BUILD_SIGNED_BINARIES**

Sign binaries during build

*Found in: Security features*

Once secure boot or signed app requirement is enabled, app images are required to be signed.

If enabled (default), these binary files are signed as part of the build process. The file named “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_BOOTLOADER_KEY_ENCODING**

Hardware Key Encoding

*Found in: Security features*

In reflashable secure bootloader mode, a hardware key is derived from the signing key (with SHA-256) and can be written to eFuse with espfuse.py.

Normally this is a 256-bit key, but if 3/4 Coding Scheme is used on the device then the eFuse key is truncated to 192 bits.

This configuration item doesn’t change any firmware code, it only changes the size of key binary which is generated at build time.

*Available options:*
  - No encoding (256 bit key) (SECURE_BOOTLOADER_KEY_ENCODING_256BIT)
  - 3/4 encoding (192 bit key) (SECURE_BOOTLOADER_KEY_ENCODING_192BIT)

**CONFIG_SECURE_BOOT_INSECURE**

Allow potentially insecure options

*Found in: Security features*
You can disable some of the default protections offered by secure boot, in order to enable testing or a custom combination of security features.

Only enable these options if you are very sure.

Refer to the Secure Boot section of the ESP-IDF Programmer’s Guide for this version before enabling.

**Default value:**
- No (disabled) if `CONFIG_SECURE_BOOT`

**CONFIG_SECURE_FLASH_ENC_ENABLED**

Enable flash encryption on boot (READ DOCS FIRST)

*Found in: Security features*

If this option is set, flash contents will be encrypted by the bootloader on first boot.

*Note: After first boot, the system will be permanently encrypted. Re-flashing an encrypted system is complicated and not always possible.*

Read *Flash Encryption* before enabling.

**Default value:**
- No (disabled)

**CONFIG_SECURE_FLASH_ENCRYPTION_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_BOOT_ALLOW_ROM_BASIC`
- `CONFIG_SECURE_FLASH_UART_BOOTLOADER_ALLOW_DEC`
- `CONFIG_SECURE_FLASH_UART_BOOTLOADER_ALLOW_ENC`
- `CONFIG_SECURE_FLASH_UART_BOOTLOADER_ALLOW_CACHE`
- `CONFIG_SECURE_FLASH_REQUIRE_ALREADY_ENABLED`

**CONFIG_SECURE_BOOT_ALLOW_ROM_BASIC**

Leave ROM BASIC Interpreter available on reset

*Found in: Security features > Potentially insecure options*

By default, the BASIC ROM Console starts on reset if no valid bootloader is read from the flash.
When either flash encryption or secure boot are enabled, the default is to disable this BASIC fallback mode permanently via eFuse.

If this option is set, this eFuse is not burned and the BASIC ROM Console may remain accessible. Only set this option in testing environments.

**Default value:**

- No (disabled) if \(\text{CONFIG\_SECURE\_BOOT\_INSECURE} \ || \ \text{SECURE\_FLASH\_ENCRYPTION\_MODE\_DEVELOPMENT} \)

**CONFIG\_SECURE\_BOOT\_ALLOW\_JTAG**

Allow JTAG Debugging

*Found in: Security features > Potentially insecure options*

If not set (default), the bootloader will permanently disable JTAG (across entire chip) on first boot when either secure boot or flash encryption is enabled.

Setting this option leaves JTAG on for debugging, which negates all protections of flash encryption and some of the protections of secure boot.

Only set this option in testing environments.

**Default value:**

- No (disabled) if \(\text{CONFIG\_SECURE\_BOOT\_INSECURE} \ || \ \text{SECURE\_FLASH\_ENCRYPTION\_MODE\_DEVELOPMENT} \)

**CONFIG\_SECURE\_BOOT\_ALLOW\_SHORT\_APP\_PARTITION**

Allow app partition length not 64KB aligned

*Found in: Security features > Potentially insecure options*

If not set (default), app partition size must be a multiple of 64KB. App images are padded to 64KB length, and the bootloader checks any trailing bytes after the signature (before the next 64KB boundary) have not been written. This is because flash cache maps entire 64KB pages into the address space. This prevents an attacker from appending unverified data after the app image in the flash, causing it to be mapped into the address space.

Setting this option allows the app partition length to be unaligned, and disables padding of the app image to this length. It is generally not recommended to set this option, unless you have a legacy partitioning scheme which doesn’t support 64KB aligned partition lengths.

**CONFIG\_SECURE\_BOOT\_V2\_ALLOW\_EFUSE\_RD\_DIS**

Allow additional read protecting of efuses

*Found in: Security features > Potentially insecure options*

If not set (default, recommended), on first boot the bootloader will burn the WR\_DIS\_RD\_DIS efuse when Secure Boot is enabled. This prevents any more efuses from being read protected.

If this option is set, it will remain possible to write the EFUSE\_RD\_DIS efuse field after Secure Boot is enabled. This may allow an attacker to read-protect the BLK2 efuse (for ESP32) and BLOCK4-BLOCK10 (i.e. BLOCK\_KEY0-BLOCK\_KEY5) (for other chips) holding the public key digest, causing an immediate denial of service and possibly allowing an additional fault injection attack to bypass the signature protection.

NOTE: Once a BLOCK is read-protected, the application will read all zeros from that block.

NOTE: If “UART ROM download mode (Permanently disabled (recommended))” or “UART ROM download mode (Permanently switch to Secure mode (recommended))” is set, then it is _NOT_ possible to read/write efuses using espefuse.py utility. However, efuse can be read/written from the application.
**CONFIG_SECURE_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_DEC**

Leave UART bootloader decryption enabled

*Found in:* Security features > Potentially insecure options

If not set (default), the bootloader will permanently disable UART bootloader decryption access on first boot. If set, the UART bootloader will still be able to access hardware decryption.

Only set this option in testing environments. Setting this option allows complete bypass of flash encryption.

**Default value:**
- No (disabled) if 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.

**Serial flasher config**

Contains:
- `CONFIG_ESPTOOLPY_MONITOR_BAUD`
- `CONFIG_ESPTOOLPY_AFTER`
- `CONFIG_ESPTOOLPY_BEFORE`
- `CONFIG_ESPTOOLPY_MONITOR_BAUD_OTHER_VAL`
- `CONFIG_ESPTOOLPY_FLASHSIZE_DETECT`
- `CONFIG_ESPTOOLPY_NO_STUB`
- `CONFIG_ESPTOOLPY_FLASH_SAMPLE_MODE`
Chapter 2. API Reference

- `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_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)
- 8 MB (ESPTOOLPY_FLASHSIZE_8MB)
- 16 MB (ESPTOOLPY_FLASHSIZE_16MB)

**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)

**CONFIG_ESPTOOLPY_MONITOR_BAUD**

`idf.py monitor` baud rate

*Found in: Serial flasher config*

Baud rate to use when running `idf.py monitor` or `make monitor` to view serial output from a running chip.

If “Same as UART Console baud rate” is chosen then the value will follow the “UART Console baud rate” config item.

Can override by setting the MONITORBAUD environment variable.

*Available options:*

- Same as UART console baud rate (ESPTOOLPY_MONITOR_BAUD_CONSOLE)
Chapter 2. API Reference

- **9600 bps (ESPTOOLPY_MONITOR_BAUD_9600B)**
- **57600 bps (ESPTOOLPY_MONITOR_BAUD_57600B)**
- **115200 bps (ESPTOOLPY_MONITOR_BAUD_115200B)**
- **230400 bps (ESPTOOLPY_MONITOR_BAUD_230400B)**
- **921600 bps (ESPTOOLPY_MONITOR_BAUD_921600B)**
- **2 Mbps (ESPTOOLPY_MONITOR_BAUD_2MB)**
- Custom baud rate (ESPTOOLPY_MONITOR_BAUD_OTHER)

**CONFIG_ESPTOOLPY_MONITOR_BAUD_OTHER_VAL**

Custom baud rate value

*Found in: Serial flasher config*

**Default value:**

- 115200

**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_NVS)
  This is a variation of the default “Single factory app, no OTA” partition table that supports encrypted NVS when using flash encryption. See the Flash Encryption section in the ESP-IDF Programmers Guide for more information.
  The corresponding CSV file in the IDF directory is components/partition_table/partitions_singleapp_encr_nvs.csv

- Single factory app (large), no OTA, encrypted NVS (PARTITION_TABLE_SINGLE_APP_LARGE_ENC_NVS)
  This is a variation of the “Single factory app (large), no OTA” partition table that supports encrypted NVS when using flash encryption. See the Flash Encryption section in the ESP-IDF Programmers Guide for more information.
  The corresponding CSV file in the IDF directory is components/partition_table/partitions_singleapp_large_encr_nvs.csv

- Factory app, two OTA definitions, encrypted NVS (PARTITION_TABLE_TWO_OTA_ENCRYPTED_NVS)
  This is a variation of the “Factory app, two OTA definitions” partition table that supports encrypted NVS when using flash encryption. See the Flash Encryption section in the ESP-IDF Programmers Guide for more information.
  The corresponding CSV file in the IDF directory is components/partition_table/partitions_two_ota_encr_nvs.csv

**CONFIG_PARTITION_TABLE_CUSTOM_FILENAME**

Custom partition CSV file

*Found in: Partition Table*

Name of the custom partition CSV filename. This path is evaluated relative to the project root directory.

*Default value:*
  - “partitions.csv”

**CONFIG_PARTITION_TABLE_OFFSET**

Offset of partition table

*Found in: Partition Table*

The address of partition table (by default 0x8000). Allows you to move the partition table, it gives more space for the bootloader. Note that the bootloader and app will both need to be compiled with the same PARTITION_TABLE_OFFSET value.

This number should be a multiple of 0x1000.

Note that partition offsets in the partition table CSV file may need to be changed if this value is set to a higher value. To have each partition offset adapt to the configured partition table offset, leave all partition offsets blank in the CSV file.

*Default value:*
  - “0x8000”

**CONFIG_PARTITION_TABLE_MD5**

Generate an MD5 checksum for the partition table

*Found in: Partition Table*

Generate an MD5 checksum for the partition table for protecting the integrity of the table. The generation should be turned off for legacy bootloaders which cannot recognize the MD5 checksum in the partition table.

*Default value:*
Chapter 2. API Reference

• Yes (enabled) if CONFIG_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 -0g flag to CFLAGS.
• The “Size” setting will add the -0s flag to CFLAGS.
• The “Performance” setting will add the -O2 flag to CFLAGS.
• The “None” setting will add the -00 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 -00 produces compiled code without optimization.

Note that custom optimization levels may be unsupported.

Compiler optimization for the IDF bootloader is set separately, see the BOOT-LOADER_COMPILER_OPTIMIZATION setting.

Available options:

• Debug (-Og) (COMPILER_OPTIMIZATION_DEFAULT)
• Optimize for size (-Os) (COMPILER_OPTIMIZATION_SIZE)
• Optimize for performance (-O2) (COMPILER_OPTIMIZATION_PERF)
• Debug without optimization (-00) (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 -ffile-prefix-map options to the GCC command line. To replace additional paths in
your binaries, modify the project CMakeLists.txt file to pass custom -ffile-prefix-map arguments.

*Default value:*
- Yes (enabled)

**CONFIG_COMPILER_CXX_EXCEPTIONS**

Enable C++ exceptions

*Found in: Compiler options*

Enabling this option compiles all IDF C++ files with exception support enabled.

Disabling this option disables C++ exception support in all compiled files, and any libstdc++ code which
throws an exception will abort instead.

Enabling this option currently adds an additional ~500 bytes of heap overhead when an exception is
thrown in user code for the first time.

*Default value:*
- No (disabled)

Contains:

- **CONFIG_COMPILER_CXX_EXCEPTIONS_EMG_POOL_SIZE**
CONFIG_COMPILER_CXX_EXCEPTIONS_EMG_POOL_SIZE

Emergency Pool Size

*Found in: Compiler options > CONFIG_COMPILER_CXX_EXCEPTIONS*

Size (in bytes) of the emergency memory pool for C++ exceptions. This pool will be used to allocate memory for thrown exceptions when there is not enough memory on the heap.

**Default value:**
- 0 if `CONFIG_COMPILER_CXX_EXCEPTIONS`

CONFIG_COMPILER_CXX_RTTI

Enable C++ run-time type info (RTTI)

*Found in: Compiler options*

Enabling this option compiles all C++ files with RTTI support enabled. This increases binary size (typically by tens of kB) but allows using `dynamic_cast` conversion and `typeid` operator.

**Default value:**
- No (disabled)

CONFIG_COMPILER_STACK_CHECK_MODE

Stack smashing protection mode

*Found in: Compiler options*

Stack smashing protection mode. Emit extra code to check for buffer overflows, such as stack smashing attacks. This is done by adding a guard variable to functions with vulnerable objects. The guards are initialized when a function is entered and then checked when the function exits. If a guard check fails, program is halted. Protection has the following modes:

- In NORMAL mode (GCC flag: `-fstack-protector`) only functions that call `alloca`, and functions with buffers larger than 8 bytes are protected.
- STRONG mode (GCC flag: `-fstack-protector-strong`) is like NORMAL, but includes additional functions to be protected — those that have local array definitions, or have references to local frame addresses.
- In OVERALL mode (GCC flag: `-fstack-protector-all`) all functions are protected.

Modes have the following impact on code performance and coverage:

- performance: NORMAL > STRONG > OVERALL
- coverage: NORMAL < STRONG < OVERALL

The performance impact includes increasing the amount of stack memory required for each task.

**Available options:**
- None (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
- 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
- ESP32-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
Chapter 2. API Reference

- Log output
- LWIP
- mbedTLS
- mDNS
- Modbus configuration
- Newlib
- NVS
- OpenSSL
- OpenThread
- PHY
- Power Management
- PThreads
- SPI Flash driver
- SPIFFS Configuration
- Supplicant
- TCP Transport
- Unity unit testing library
- 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
- 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 (APPTRACE_DEST_JTAG)
- None (APPTRACE_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) (APPTRACE_SV_TS_SOURCE_CCOUNT)
- General Purpose Timer (Timer Group) (APPTRACE_SV_TS_SOURCE_GPTIMER)
- esp_timer high resolution timer (APPTRACE_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.
Chapter 2. API Reference

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_BTDM_CTRL_AUTO_LATENCY
  • CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP
  • CONFIG_BTDM_CTRL_FULL_SCAN_SUPPORTED
  • CONFIG_BTDM_CTRL_BLE_MAX_CONN
  • CONFIG_BTDM_BLE_SCAN_DUPL
  • CONFIG_BTDM_BLE_SLEEP_CLOCK_ACCURACY
  • CONFIG_BTDM_CTRL_MODE
  • CONFIG_BTDM_CTRL_BR_EDR_MAX_ACL_CONN
  • CONFIG_BTDM_CTRL_BR_EDR_SCO_DATA_PATH
  • CONFIG_BTDM_CTRL_BR_EDR_MAX_SYNC_CONN
  • CONFIG_BTDM_CTRL_HCI_MODE_CHOICE
  • HCI UART(H4) Options
  • CONFIG_BTDM_CTRL_HLI
  • CONFIG_BTDM_CTRL_LEGACY_AUTH_VENDOR_EVT
  • MODEM SLEEP Options
  • CONFIG_BTDM_CTRL_PCM_ROLE_EDGE_CONFIG
  • CONFIG_BTDM_CTRL_PINNED_TO_CORE_CHOICE

CONFIG_BTDM_CTRL_MODE

Bluetooth controller mode (BR/EDR/BLE/DUALMODE)

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller

Specify the bluetooth controller mode (BR/EDR, BLE or dual mode).

Available options:
  • BLE Only (BTDM_CTRL_MODE_BLE_ONLY)
  • BR/EDR Only (BTDM_CTRL_MODE_BR_EDR_ONLY)
  • Bluetooth Dual Mode (BTDM_CTRL_MODE_BTDM)

CONFIG_BTDM_CTRL_BLE_MAX_CONN

BLE Max Connections

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller

BLE maximum connections of bluetooth controller. Each connection uses 1 KB static DRAM whenever the BT controller is enabled.

Range:
  • from 1 to 9 if (BTDM_CTRL_MODE_BLE_ONLY || BTDM_CTRL_MODE_BTDM) && CONFIG_BT_ENABLED

Default value:
  • 3 if (BTDM_CTRL_MODE_BLE_ONLY || BTDM_CTRL_MODE_BTDM) && CONFIG_BT_ENABLED

CONFIG_BTDM_CTRL_BR_EDR_MAX_ACL_CONN

BR/EDR ACL Max Connections

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller

BR/EDR ACL maximum connections of bluetooth controller. Each connection uses 1.2 KB DRAM whenever the BT controller is enabled.

Range:
  • from 1 to 7 if (BTDM_CTRL_MODE_BR_EDR_ONLY || BTDM_CTRL_MODE_BTDM) && CONFIG_BT_ENABLED

Default value:
CONFIG_BTDM_CTRL_BR_EDR_MAX_SYNC_CONN

BR/EDR Sync(SCO/eSCO) Max Connections

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller

BR/EDR Synchronize maximum connections of bluetooth controller. Each connection uses 2 KB DRAM whenever the BT controller is enabled.

Range:
- from 0 to 3 if (BTDM_CTRL_MODE_BR_EDR_ONLY || BTDM_CTRL_MODE_BTDM) && CONFIG_BT_ENABLED

Default value:
- 0 if (BTDM_CTRL_MODE_BR_EDR_ONLY || BTDM_CTRL_MODE_BTDM) && CONFIG_BT_ENABLED

CONFIG_BTDM_CTRL_BR_EDR_SCO_DATA_PATH

BR/EDR Sync(SCO/eSCO) default data path

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller

SCO data path, i.e. HCI or PCM. SCO data can be sent/received through HCI synchronous packets, or the data can be routed to on-chip PCM module on ESP32. PCM input/output signals can be “matrixed” to GPIOs. The default data path can also be set using API “esp_bredr_sco_datapath_set”

Available options:
- HCI (BTDM_CTRL_BR_EDR_SCO_DATA_PATH_HCI)
- PCM (BTDM_CTRL_BR_EDR_SCO_DATA_PATH_PCM)

CONFIG_BTDM_CTRL_PCM_ROLE_EDGE_CONFIG

PCM Signal Config (Role and Polar)

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller

Default value:
- Yes (enabled) if BTDM_CTRL_BR_EDR_SCO_DATA_PATH_PCM && CONFIG_BT_ENABLED

Contains:
- CONFIG_BTDM_CTRL_PCM_POLAR
- CONFIG_BTDM_CTRL_PCM_ROLE

CONFIG_BTDM_CTRL_PCM_ROLE

PCM Role

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > CONFIG_BTDM_CTRL_PCM_ROLE_EDGE_CONFIG

PCM role can be configured as PCM master or PCM slave

Available options:
- PCM Master (BTDM_CTRL_PCM_ROLE_MASTER)
- PCM Slave (BTDM_CTRL_PCM_ROLE_SLAVE)
**CONFIG_BTDM_CTRL_PCM_POLAR**

PCM Polar

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > CONFIG_BTDM_CTRL_PCM_ROLE_EDGE_CONFIG*

PCM polarity can be configured as Falling Edge or Rising Edge

**Available options:**
- Falling Edge (BTDM_CTRL_PCM_POLAR_FALLING_EDGE)
- Rising Edge (BTDM_CTRL_PCM_POLAR_RISING_EDGE)

**CONFIG_BTDM_CTRL_AUTO_LATENCY**

Auto latency

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

BLE auto latency, used to enhance classic BT performance while classic BT and BLE are enabled at the same time.

**Default value:**
- No (disabled) if BTDM_CTRL_MODE_BTDM && CONFIG_BT_ENABLED

**CONFIG_BTDM_CTRL_LEGACY_AUTH_VENDOR_EVT**

Legacy Authentication Vendor Specific Event Enable

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

To protect from BIAS attack during Legacy authentication, Legacy authentication Vendor specific event should be enabled

**Default value:**
- Yes (enabled) if (BTDM_CTRL_MODE_BR_EDR_ONLY || BTDM_CTRL_MODE_BTDM) && CONFIG_BT_ENABLED

**CONFIG_BTDM_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) (BTDM_CTRL_PINNED_TO_CORE_0)
- Core 1 (APP CPU) (BTDM_CTRL_PINNED_TO_CORE_1)

**CONFIG_BTDM_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 (BTDM_CTRL_HCI_MODE_VHCI)  
  Normal option. Mostly, choose this VHCI when bluetooth host run on ESP32, too.
- UART(H4) (BTDM_CTRL_HCI_MODE_UART_H4)  
  If use external bluetooth host which run on other hardware and use UART as the HCI interface, choose this option.
**HCI UART(H4) Options**  
Contains:

- `CONFIG_BTDM_CTRL_HCI_UART_BAUDRATE`
- `CONFIG_BTDM_CTRL_HCI_UART_NO`

**CONFIG_BTDM_CTRL_HCI_UART_NO**

UART Number for HCI

*Found in:* Component config > Bluetooth > `CONFIG_BT_ENABLED` > Bluetooth controller > HCI UART(H4) Options

Uart number for HCI. The available uart is UART1 and UART2.

*Range:*
- from 1 to 2 if `BTDM_CTRL_HCI_MODE_UART_H4` & `CONFIG_BT_ENABLED`

*Default value:*
- 1 if `BTDM_CTRL_HCI_MODE_UART_H4` & `CONFIG_BT_ENABLED`

**CONFIG_BTDM_CTRL_HCI_UART_BAUDRATE**

UART Baudrate for HCI

*Found in:* Component config > Bluetooth > `CONFIG_BT_ENABLED` > Bluetooth controller > HCI UART(H4) Options

UART Baudrate for HCI. Please use standard baudrate.

*Range:*
- from 115200 to 921600 if `BTDM_CTRL_HCI_MODE_UART_H4` & `CONFIG_BT_ENABLED`

*Default value:*
- 921600 if `BTDM_CTRL_HCI_MODE_UART_H4` & `CONFIG_BT_ENABLED`

**MODEM SLEEP Options**  
Contains:

- `CONFIG_BTDM_CTRL_LOW_POWER_CLOCK`
- `CONFIG_BTDM_CTRL_MODEM_SLEEP`

**CONFIG_BTDM_CTRL_MODEM_SLEEP**

Bluetooth modem sleep

*Found in:* Component config > Bluetooth > `CONFIG_BT_ENABLED` > Bluetooth controller > MODEM SLEEP Options

Enable/disable bluetooth controller low power mode.

*Default value:*
- Yes (enabled) if `CONFIG_BT_ENABLED`

**CONFIG_BTDM_CTRL_MODEM_SLEEP_MODE**

Bluetooth Modem sleep mode

*Found in:* Component config > Bluetooth > `CONFIG_BT_ENABLED` > Bluetooth controller > MODEM SLEEP Options > `CONFIG_BTDM_CTRL_MODEM_SLEEP`

To select which strategy to use for modem sleep

*Available options:*

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Espressif Systems  1503  Release v5.0-dev-1077-g397639d

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• ORIG Mode (sleep with low power clock) (BTDM_CTRL_MODEM_SLEEP_MODE_ORIG)
  ORIG mode is a bluetooth sleep mode that can be used for dual mode controller. In this mode, bluetooth controller sleeps between BR/EDR frames and BLE events. A low power clock is used to maintain bluetooth reference clock.
• EVED Mode (For internal test only) (BTDM_CTRL_MODEM_SLEEP_MODE_EVED)
  EVED mode is for BLE only and is only for internal test. Do not use it for production. This mode is not compatible with DFS nor light sleep

**CONFIG_BTDM_CTRL_LOW_POWER_CLOCK**

Bluetooth low power clock

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > MODEM SLEEP Options*

Select the low power clock source for bluetooth controller. Bluetooth low power clock is the clock source to maintain time in sleep mode.

- “Main crystal” option provides good accuracy and can support Dynamic Frequency Scaling to be used with Bluetooth modem sleep. Light sleep is not supported.
- “External 32kHz crystal” option allows user to use a 32.768kHz crystal as Bluetooth low power clock. This option is allowed as long as External 32kHz crystal is configured as the system RTC clock source. This option provides good accuracy and supports Bluetooth modem sleep to be used alongside Dynamic Frequency Scaling or light sleep.

**Available options:**

- **Main crystal (BTDM_CTRL_LPCLK_SEL_MAIN_XTAL)**
  Main crystal can be used as low power clock for bluetooth modem sleep. If this option is selected, bluetooth modem sleep can work under Dynamic Frequency Scaling (DFS) enabled, but cannot work when light sleep is enabled. Main crystal has a good performance in accuracy as the bluetooth low power clock source.
- **External 32kHz crystal (BTDM_CTRL_LPCLK_SEL_EXT_32K_XTAL)**
  External 32kHz crystal has a nominal frequency of 32.768kHz and provides good frequency stability. If used as Bluetooth low power clock, External 32kHz can support Bluetooth modem sleep to be used with both DFS and light sleep.

**CONFIG_BTDM_BLE_SLEEP_CLOCK_ACCURACY**

BLE Sleep Clock Accuracy

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

BLE Sleep Clock Accuracy (SCA) for the local device is used to estimate window widening in BLE connection events. With a lower level of clock accuracy (e.g. 500ppm over 250ppm), the slave needs a larger RX window to synchronize with master in each anchor point, thus resulting in an increase of power consumption but a higher level of robustness in keeping connected. According to the requirements of Bluetooth Core specification 4.2, the worst-case accuracy of Classic Bluetooth low power oscillator (LPO) is +/-250ppm in STANDBY and in low power modes such as sniff. For BLE the worst-case SCA is +/-500ppm.

- “151ppm to 250ppm” option is the default value for Bluetooth Dual mode
- **“251ppm to 500ppm” option can be used in BLE only mode when using external 32kHz crystal as low power clock.** This option is provided in case that BLE sleep clock has a lower level of accuracy, or other error sources contribute to the inaccurate timing during sleep.

**Available options:**

- 251ppm to 500ppm (BTDM_BLE_DEFAULT_SCA_500PPM)
- 151ppm to 250ppm (BTDM_BLE_DEFAULT_SCA_250PPM)

**CONFIG_BTDM_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 (BTDM_CTRL_MODE_BTDM || BTDM_CTRL_MODE_BLE_ONLY) && CONFIG_BT_ENABLED

**CONFIG_BTDM_SCAN_DUPL_TYPE**

Scan Duplicate Type

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > CONFIG_BTDM_BLE_SCAN_DUPL

Scan duplicate have three ways. one is “Scan Duplicate By Device Address”. This way is to use advertiser address filtering. The adv packet of the same address is only allowed to be reported once. Another way is “Scan Duplicate By Device Address And Advertising Data”. This way is to use advertising data and device address filtering. All different adv packets with the same address are allowed to be reported. The last way is “Scan Duplicate By Advertising Data”. This way is to use advertising data filtering. All same advertising data only allow to be reported once even though they are from different devices.

**Available options:**
- Scan Duplicate By Device Address (BTDM_SCAN_DUPL_TYPE_DEVICE)
  This way is to use advertiser address filtering. The adv packet of the same address is only allowed to be reported once
- Scan Duplicate By Advertising Data (BTDM_SCAN_DUPL_TYPE_DATA)
  This way is to use advertising data filtering. All same advertising data only allow to be reported once even though they are from different devices.
- Scan Duplicate By Device Address And Advertising Data (BTDM_SCAN_DUPL_TYPE_DATA_DEVICE)
  This way is to use advertising data and device address filtering. All different adv packets with the same address are allowed to be reported.

**CONFIG_BTDM_SCAN_DUPL_CACHE_SIZE**

Maximum number of devices in scan duplicate filter

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > CONFIG_BTDM_BLE_SCAN_DUPL

Maximum number of devices which can be recorded in scan duplicate filter. When the maximum amount of device in the filter is reached, the cache will be refreshed.

**Range:**
- from 10 to 1000 if CONFIG_BTDM_BLE_SCAN_DUPL && CONFIG_BT_ENABLED

**Default value:**
- 200 if CONFIG_BTDM_BLE_SCAN_DUPL && CONFIG_BT_ENABLED

**CONFIG_BTDM_BLE_MESH_SCAN_DUPL_EN**

Special duplicate scan mechanism for BLE Mesh scan

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > CONFIG_BTDM_BLE_SCAN_DUPL

This enables the BLE scan duplicate for special BLE Mesh scan.

**Default value:**
- No (disabled) if CONFIG_BTDM_BLE_SCAN_DUPL && CONFIG_BT_ENABLED
**CONFIG_BTDM_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_BTDM_BLE_SCAN_DUPL > CONFIG_BTDM_BLE_MESH_SCAN_DUPL_EN*

Maximum number of adv packets which can be recorded in duplicate scan cache for BLE Mesh. When the maximum amount of device in the filter is reached, the cache will be refreshed.

**Range:**
- from 10 to 1000 if CONFIG_BTDM_BLE_MESH_SCAN_DUPL_EN && CONFIG_BT_ENABLED

**Default value:**
- 200 if CONFIG_BTDM_BLE_MESH_SCAN_DUPL_EN && CONFIG_BT_ENABLED

**CONFIG_BTDM_CTRL_FULL_SCAN_SUPPORTED**

BLE full scan feature supported

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

The full scan function is mainly used to provide BLE scan performance. This is required for scenes with high scan performance requirements, such as BLE Mesh scenes.

**Default value:**
- Yes (enabled) if (BTDM_CTRL_MODE_BLE_ONLY || BTDM_CTRL_MODE_BTDM) && CONFIG_BT_ENABLED

**CONFIG_BTDM_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 (BTDM_CTRL_MODE_BTDM || BTDM_CTRL_MODE_BLE_ONLY) && CONFIG_BT_ENABLED

**CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_NUM**

BLE adv report flow control number

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > CONFIG_BTDM_BLE_ADV REPORT_FLOW_CTRL SUPP*

The number of unprocessed advertising report that Bluedroid can save. If you set BTDM_BLE_ADV_REPORT_FLOW_CTRL_NUM to a small value, this may cause adv packets lost. If you set BTDM_BLE_ADV_REPORT_FLOW_CTRL_NUM to a large value, Bluedroid may cache a lot of adv packets and this may cause system memory run out. For example, if you set it to 50, the maximum memory consumed by host is 35 * 50 bytes. Please set BTDM_BLE_ADV_REPORT_FLOW_CTRL_NUM according to your system free memory and handle adv packets as fast as possible, otherwise it will cause adv packets lost.

**Range:**
- from 50 to 1000 if CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP && CONFIG_BT_ENABLED

**Default value:**
- 100 if CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP && CONFIG_BT_ENABLED
CONFIG_BTDM_BLE_ADV_REPORT_DISCARD_THRESHOLD

BLE adv lost event threshold value

*Found in*: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP

When adv report flow control is enabled, the ADV lost event will be generated when the number of ADV packets lost in the controller reaches this threshold. It is better to set a larger value. If you set BTDM_BLE_ADV_REPORT_DISCARD_THRESHOLD to a small value or printf every adv lost event, it may cause adv packets lost more.

*Range*: from 1 to 1000 if CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP && CONFIG_BT_ENABLED

*Default value*: 20 if CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP && CONFIG_BT_ENABLED

CONFIG_BTDM_CTRL_HLI

High level interrupt

*Found in*: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller

Using Level 4 interrupt for Bluetooth.

*Default value*: Yes (enabled) if CONFIG_BT_ENABLED && 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_BTC_TASK_STACK_SIZE
- CONFIG_BT_BLE_ENABLED
- BT_DEBUG_LOG_LEVEL
- CONFIG_BT_ACL_CONNECTIONS
- CONFIG_BT_ALLOCATION_FROM_SPIRAM_FIRST
- CONFIG_BT_CLASSIC_ENABLED
- CONFIG_BT_HID_ENABLED
- CONFIG_BT_STACK_NO_LOG
- CONFIG_BT_MULTI_CONNECTION_ENABLE
**CONFIG_BT_MAX_DEVICE_NAME_LEN**

- CONFIG_BT_MAX_DEVICE_NAME_LEN

**CONFIG_BT_BLE_ACT_SCAN_REP_ADV_SCAN**

- CONFIG_BT_BLE_ACT_SCAN_REP_ADV_SCAN

**CONFIG_BT_SSP_ENABLED**

- CONFIG_BT_SSP_ENABLED

**CONFIG_BT_BLUEDROID_PINNED_TO_CORE_CHOICE**

- CONFIG_BT_BLUEDROID_PINNED_TO_CORE_CHOICE

**CONFIG_BT_BLE_ESTAB_LINK_CONN_TOUT**

- CONFIG_BT_BLE_ESTAB_LINK_CONN_TOUT

**CONFIG_BT_BLE_RPA_SUPPORTED**

- CONFIG_BT_BLE_RPA_SUPPORTED

**CONFIG_BT_BLE_DYNAMIC_ENV_MEMORY**

- CONFIG_BT_BLE_DYNAMIC_ENV_MEMORY

**CONFIG_BT_HFP_WBS_ENABLE**

- CONFIG_BT_HFP_WBS_ENABLE

**CONFIG_BT_BTU_TASK_STACK_SIZE**

Bluetooth event (callback to application) task stack size

*Found in:* Component config > Bluetooth > Bluedroid Options

This select btu 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_BLUEDROID_MEM_DEBUG**

Bluedroid memory debug

*Found in:* Component config > Bluetooth > Bluedroid Options

Bluedroid memory debug

**Default value:**

- No (disabled) if BT_BLUEDROID_ENABLED && BT_BLUEDROID_ENABLED

**CONFIG_BT_CLASSIC_ENABLED**

Classic Bluetooth

*Found in:* Component config > Bluetooth > Bluedroid Options

For now this option needs “SMP_ENABLE” to be set to yes

**Default value:**

- No (disabled) if BT_BLUEDROID_ENABLED && BT_BLUEDROID_ENABLED
CONFIG_BT_A2DP_ENABLE

A2DP

Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED

Advanced Audio Distribution Profile

Default value:
• No (disabled) if CONFIG_BT_CLASSIC_ENABLED && BT_BLUEDROID_ENABLED

CONFIG_BT_SPP_ENABLED

SPP

Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED

This enables the Serial Port Profile

Default value:
• No (disabled) if CONFIG_BT_CLASSIC_ENABLED && BT_BLUEDROID_ENABLED

CONFIG_BT_HFP_ENABLE

Hands Free/Handset Profile

Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED

Default value:
• No (disabled) if CONFIG_BT_CLASSIC_ENABLED && BT_BLUEDROID_ENABLED

CONFIG_BT_HFP_ROLE

Hands-free Profile Role configuration

Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED > CONFIG_BT_HFP_ENABLE

Available options:
• Hands Free Unit (BT_HFP_CLIENT_ENABLE)
• Audio Gateway (BT_HFP_AG_ENABLE)

CONFIG_BT_HFP_AUDIO_DATA_PATH

audio(SCO) data path

Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED > CONFIG_BT_HFP_ENABLE

SCO data path, i.e. HCI or PCM. This option is set using API esp_bredr_sco_datapath_set in Bluetooth host. Default SCO data path can also be set in Bluetooth Controller.

Available options:
• PCM (BT_HFP_AUDIO_DATA_PATH_PCM)
• HCI (BT_HFP_AUDIO_DATA_PATH_HCI)

CONFIG_BT_HFP_WBS_ENABLE

Wide Band Speech

Found in: Component config > Bluetooth > Bluedroid Options

This enables Wide Band Speech. Should disable it when SCO data path is PCM. Otherwise there will be no data transmitted via GPIOs.

Default value:
Chapter 2. API Reference

- Yes (enabled) if `BT_HFP_AUDIO_DATA_PATH_HCI` && `BT_BLUEDROID_ENABLED`

**CONFIG_BT_HID_ENABLED**

Classic BT HID

*Found in: Component config > Bluetooth > Bluedroid Options*

This enables the BT HID Host

**Default value:**
- No (disabled) if `CONFIG_BT_CLASSIC_ENABLED` && `BT_BLUEDROID_ENABLED`

**CONFIG_BT_HID_ROLE**

Profile Role configuration

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_HID_ENABLED*

**Available options:**
- Classic BT HID Host (BT_HID_HOST_ENABLED)
  This enables the BT HID Host
- Classic BT HID Device (BT_HID_DEVICE_ENABLED)
  This enables the BT HID Device

**CONFIG_BT_SSP_ENABLED**

Secure Simple Pairing

*Found in: Component config > Bluetooth > Bluedroid Options*

This enables the Secure Simple Pairing. If disable this option, Bluedroid will only support Legacy Pairing

**Default value:**
- Yes (enabled) if `CONFIG_BT_CLASSIC_ENABLED` && `BT_BLUEDROID_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_BLUEDROID_ENABLED` && `BT_BLUEDROID_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_BLUEDROID_ENABLED`
CONFIG_BT_GATTS_PPCP_CHAR_GAP

Enable Peripheral Preferred Connection Parameters characteristic in GAP service

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTS_ENABLE*

This enables “Peripheral Preferred Connection Parameters” characteristic (UUID: 0x2A04) in GAP service that has connection parameters like min/max connection interval, slave latency and supervision timeout multiplier

**Default value:**
- No (disabled) if `CONFIG_BT_GATTS_ENABLE` && `BT_BLUEDROID_ENABLED`

CONFIG_BT_BLE_BLUFI_ENABLE

Include blufi function

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTS_ENABLE*

This option can be close when the app does not require blufi function.

**Default value:**
- No (disabled) if `CONFIG_BT_GATTS_ENABLE` && `BT_BLUEDROID_ENABLED`

CONFIG_BT_GATT_MAX_SR_PROFILES

Max GATT Server Profiles

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTS_ENABLE*

Maximum GATT Server Profiles Count

**Range:**
- from 1 to 32 if `CONFIG_BT_GATTS_ENABLE` && `BT_BLUEDROID_ENABLED` && `BT_BLUEDROID_ENABLED`

**Default value:**
- 8 if `CONFIG_BT_GATTS_ENABLE` && `BT_BLUEDROID_ENABLED` && `BT_BLUEDROID_ENABLED`

CONFIG_BT_GATTS_SEND_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_GATTS_SEND_SERVICE_CHANGE_MANUAL)
  Manually send service change indication through API `esp_ble_gatts_send_service_change_indication()`
- GATTs automatically send service change indication (BT_GATTS_SEND_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_NVS_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

Range:
  • from 0 to 7 if CONFIG_BT_GATTC_ENABLE && BT_BLUEDROID_ENABLED

Default value:
  • 3 if CONFIG_BT_GATTC_ENABLE && BT_BLUEDROID_ENABLED

CONFIG_BT_BLE_SMP_ENABLE

Include BLE security module (SMP)

Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED

This option can be close when the app not used the ble security connect.

Default value:
  • Yes (enabled) if CONFIG_BT_BLE_ENABLED && BT_BLUEDROID_ENABLED

CONFIG_BT_SMP_SLAVE_CON_PARAMS_UPD_ENABLE

Slave enable connection parameters update during pairing

Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_BLE_SMP_ENABLE

In order to reduce the pairing time, slave actively initiates connection parameters update during pairing.

Default value:
  • No (disabled) if CONFIG_BT_BLE_SMP_ENABLE && 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_APLI_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_BTIF_TRACE_LEVEL
  • CONFIG_BT_LOG_BTM_TRACE_LEVEL
  • CONFIG_BT_LOG_GAP_TRACE_LEVEL
  • CONFIG_BT_LOG_GATT_TRACE_LEVEL
  • CONFIG_BT_LOG_HCI_TRACE_LEVEL
  • CONFIG_BT_LOG_HID_TRACE_LEVEL
  • CONFIG_BT_LOG_L2CAP_TRACE_LEVEL
  • CONFIG_BT_LOG_MCA_TRACE_LEVEL
  • CONFIG_BT_LOG_OSI_TRACE_LEVEL
  • CONFIG_BT_LOG_PAN_TRACE_LEVEL
  • CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL
  • CONFIG_BT_LOG_SDP_TRACE_LEVEL
  • CONFIG_BT_LOG_SMP_TRACE_LEVEL

**CONFIG_BT_LOG_HCI_TRACE_LEVEL**

HCI layer

*Found in:* Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL

Define BT trace level for HCI layer

**Available options:**

  • NONE (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 > Bluedroid 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 > Bluedroid 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 > Bluedroid 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)
- 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 > Bluez 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 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 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 > Bluedroid 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 > Bluedroid 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_ENBALE**

Enable BLE multi-conections

*Found in: Component config > Bluetooth > Bluedroid Options*

Enable this option if there are multiple connections

**Default value:**
- Yes (enabled) if 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:
- No (disabled) if BT_BLUE_DROID_ENABLED && BT_BLUE_DROID_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_CENTER
- CONFIG_BT_NIMBLE_MESH
- CONFIG_BT_NIMBLE_ROLE_OBSERVER
- CONFIG_BT_NIMBLE_ROLE_PERIPHERAL
- CONFIG_BT_NIMBLE_BLEBLE_ENABLE
- CONFIG_BT_NIMBLE_ENABLE_CONN_REALTEMP
- CONFIG_BT_NIMBLE_REQ_ESP_TIMER
- CONFIG_BT_NIMBLE_DEBUG
- 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_NV1_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 9 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:**
• 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
• CONFIG_BT_NIMBLE_MESH_RELAY
• CONFIG_BT_NIMBLE_MESH_DEVICE_NAME
• CONFIG_BT_NIMBLE_MESH_NODE_COUNT

CONFIG_BT_NIMBLE_MESH_PROXY
Enable mesh proxy functionality

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH*

Enable proxy. This is automatically set whenever NIMBLE_MESH_PB_GATT or NIMBLE_MESH_GATT_PROXY is set

*Default value:*
  • No (disabled) if CONFIG_BT_NIMBLE_MESH && BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_MESH_PROV
Enable BLE mesh provisioning

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH*

Enable mesh provisioning

*Default value:*
  • Yes (enabled) if CONFIG_BT_NIMBLE_MESH && BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_MESH_PB_ADV
Enable mesh provisioning over advertising bearer

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH > CONFIG_BT_NIMBLE_MESH_PROV*

Enable this option to allow the device to be provisioned over the advertising bearer

*Default value:*
  • Yes (enabled) if CONFIG_BT_NIMBLE_MESH_PROV && BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_MESH_PB_GATT
Enable mesh provisioning over GATT bearer

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH > CONFIG_BT_NIMBLE_MESH_PROV*

Enable this option to allow the device to be provisioned over the GATT bearer

*Default value:*
  • Yes (enabled) if CONFIG_BT_NIMBLE_MESH_PROV && BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_MESH_GATT_PROXY
Enable GATT Proxy functionality

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH*

This option enables support for the Mesh GATT Proxy Service, i.e. the ability to act as a proxy between a Mesh GATT Client and a Mesh network

*Default value:*
  • Yes (enabled) if CONFIG_BT_NIMBLE_MESH && BT_NIMBLE_ENABLED
**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_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:**
- No (disabled) 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_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 (CONFIG_ESP32_SPIRAM_SUPPORT || CONFIG_ESP32_IRAM_AS_8BIT_ACCESSIBLE_MEMORY) && CONFIG_BLE_MESH

**CONFIG_BLE_MESH_FREERTOS_STATIC_ALLOC_MODE**

Memory allocation for FreeRTOS objects

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_FREERTOS_STATIC_ALLOC*

Choose the memory to be used for FreeRTOS objects.

**Available options:**
- External SPIRAM (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 \( \text{CONFIG_BLE_MESH_PROVISIONER} \) && \( \text{CONFIG_BLE_MESH} \)

**Default value:**
- 10 if \( \text{CONFIG_BLE_MESH_PROVISIONER} \) && \( \text{CONFIG_BLE_MESH} \)

**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 \( \text{CONFIG_BLE_MESH_PROVISIONER} \) && \( \text{CONFIG_BLE_MESH} \)

**Default value:**
- 10 if \( \text{CONFIG_BLE_MESH_PROVISIONER} \) && \( \text{CONFIG_BLE_MESH} \)

**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 example, 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 \( \text{CONFIG_BLE_MESH_PB_ADV} \) && \( \text{CONFIG_BLE_MESH_PROVISIONER} \) && \( \text{CONFIG_BLE_MESH} \)

**Default value:**
- 2 if \( \text{CONFIG_BLE_MESH_PB_ADV} \) && \( \text{CONFIG_BLE_MESH_PROVISIONER} \) && \( \text{CONFIG_BLE_MESH} \)

**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 \( \text{CONFIG_BLE_MESH_PB_GATT} \) && \( \text{CONFIG_BLE_MESH_PROVISIONER} \) && \( \text{CONFIG_BLE_MESH} \)

**Default value:**
• 1 if `CONFIG_BLE_MESH_PB_GATT` & `CONFIG_BLE_MESH_PROVISIONER` & `CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_PROVISIONER_SUBNET_COUNT**

Maximum number of mesh subnets that can be created by Provisoner

*Found in: Component config*> `CONFIG_BLE_MESH` > `CONFIG_BLE_MESH_PROVISIONER`

This option specifies how many subnets per network a Provisioner can create. Indeed, this value decides the number of network keys which can be added by a Provisioner.

*Range:*
  - from 1 to 4096 if `CONFIG_BLE_MESH_PROVISIONER` & `CONFIG_BLE_MESH`

*Default value:*
  - 3 if `CONFIG_BLE_MESH_PROVISIONER` & `CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_PROVISIONER_APP_KEY_COUNT**

Maximum number of application keys that can be owned by Provisioner

*Found in: Component config*> `CONFIG_BLE_MESH` > `CONFIG_BLE_MESH_PROVISIONER`

This option specifies how many application keys the Provisioner can have. Indeed, this value decides the number of the application keys which can be added by a Provisioner.

*Range:*
  - from 1 to 4096 if `CONFIG_BLE_MESH_PROVISIONER` & `CONFIG_BLE_MESH`

*Default value:*
  - 3 if `CONFIG_BLE_MESH_PROVISIONER` & `CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_PROVISIONER_RECV_HB**

Support receiving Heartbeat messages

*Found in: Component config*> `CONFIG_BLE_MESH` > `CONFIG_BLE_MESH_PROVISIONER`

When this option is enabled, Provisioner can call specific functions to enable or disable receiving Heartbeat messages and notify them to the application layer.

*Default value:*
  - No (disabled) if `CONFIG_BLE_MESH_PROVISIONER` & `CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_PROVISIONER_RECV_HB_FILTER_SIZE**

Maximum number of filter entries for receiving Heartbeat messages

*Found in: Component config*> `CONFIG_BLE_MESH` > `CONFIG_BLE_MESH_PROVISIONER` > `CONFIG_BLE_MESH_PROVISIONER_RECV_HB`

This option specifies how many heartbeat filter entries Provisioner supports. The heartbeat filter (acceptlist or rejectlist) entries are used to store a list of SRC and DST which can be used to decide if a heartbeat message will be processed and notified to the application layer by Provisioner. Note: The filter is an empty rejectlist by default.

*Range:*
  - from 1 to 1000 if `CONFIG_BLE_MESH_PROVISIONER_RECV_HB` & `CONFIG_BLE_MESH_PROVISIONER` & `CONFIG_BLE_MESH`

*Default value:*
  - 3 if `CONFIG_BLE_MESH_PROVISIONER_RECV_HB` & `CONFIG_BLE_MESH_PROVISIONER` & `CONFIG_BLE_MESH`
CONFIG_BLE_MESH_PROV

BLE Mesh Provisioning support

*Found in: Component config > CONFIG_BLE_MESH*

Enable this option to support BLE Mesh Provisioning functionality. For BLE Mesh, this option should be always enabled.

**Default value:**
- Yes (enabled) if CONFIG_BLE_MESH

CONFIG_BLE_MESH_PB_ADV

Provisioning support using the advertising bearer (PB-ADV)

*Found in: Component config > CONFIG_BLE_MESH*

Enable this option to allow the device to be provisioned over the advertising bearer. This option should be enabled if PB-ADV is going to be used during provisioning procedure.

**Default value:**
- Yes (enabled) if CONFIG_BLE_MESH

CONFIG_BLE_MESH_UNPROVISIONED_BEACON_INTERVAL

Interval between two consecutive Unprovisioned Device Beacon

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_PB_ADV*

This option specifies the interval of sending two consecutive unprovisioned device beacon, users can use this option to change the frequency of sending unprovisioned device beacon. For example, if the value is 5, it means the unprovisioned device beacon will send every 5 seconds. When the option of BLE_MESH_FAST_PROV is selected, the value is better to be 3 seconds, or less.

**Range:**
- from 1 to 100 if CONFIG_BLE_MESH_NODE & CONFIG_BLE_MESH_PB_ADV & CONFIG_BLE_MESH

**Default value:**
- 5 if CONFIG_BLE_MESH_NODE & CONFIG_BLE_MESH_PB_ADV & CONFIG_BLE_MESH
- 3 if CONFIG_BLE_MESH_FAST_PROV & CONFIG_BLE_MESH_NODE & CONFIG_BLE_MESH_PB_ADV & CONFIG_BLE_MESH

CONFIG_BLE_MESH_PB_GATT

Provisioning support using GATT (PB-GATT)

*Found in: Component config > CONFIG_BLE_MESH*

Enable this option to allow the device to be provisioned over GATT. This option should be enabled if PB-GATT is going to be used during provisioning procedure.

# Virtual option enabled whenever any Proxy protocol is needed

CONFIG_BLE_MESH_PROXY

BLE Mesh Proxy protocol support

*Found in: Component config > CONFIG_BLE_MESH*

Enable this option to support BLE Mesh Proxy protocol used by PB-GATT and other proxy pdu transmission.

**Default value:**
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_NVSM_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 \texttt{CONFIG\_BLE\_MESH}

\textbf{CONFIG\_BLE\_MESH\_ADV\_BUF\_COUNT}

Number of advertising buffers

\textit{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.

\textbf{Range:}
• from 6 to 256 if \texttt{CONFIG\_BLE\_MESH}

\textbf{Default value:}
• 60 if \texttt{CONFIG\_BLE\_MESH}

\textbf{CONFIG\_BLE\_MESH\_IVU\_DIVIDER}

Divider for IV Update state refresh timer

\textit{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).

\textbf{Range:}
• from 2 to 96 if \texttt{CONFIG\_BLE\_MESH}

\textbf{Default value:}
• 4 if \texttt{CONFIG\_BLE\_MESH}

\textbf{CONFIG\_BLE\_MESH\_TX\_SEG\_MSG\_COUNT}

Maximum number of simultaneous outgoing segmented messages

\textit{Found in: Component config > CONFIG\_BLE\_MESH}

Maximum number of simultaneous outgoing multi-segment and/or reliable messages. The default value is 1, which means the device can only send one segmented message at a time. And if another segmented message is going to be sent, it should wait for the completion of the previous one. If users are going to send multiple segmented messages at the same time, this value should be configured properly.

\textbf{Range:}
• from 1 to if \texttt{CONFIG\_BLE\_MESH}

\textbf{Default value:}
• 1 if \texttt{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 starts 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`
**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 Friendship 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 Friend’s 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*

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 

**Support for BLE Mesh Client/Server models**

Contains:

- CONFIG_BLE_MESH_GENERIC_BATTERY_CLI
- CONFIG_BLE_MESH_GENERIC_DEF_TRANS_TIME_CLI
- CONFIG_BLE_MESH_GENERIC_LEVEL_CLI
- CONFIG_BLE_MESH_GENERIC_LOCATION_CLI
- CONFIG_BLE_MESH_GENERIC_ONOFF_CLI
- CONFIG_BLE_MESH_GENERIC_POWER_LEVEL_CLI
- CONFIG_BLE_MESH_GENERIC_POWER_ONOFF_CLI
- CONFIG_BLE_MESH_GENERIC_PROPERTY_CLI
- CONFIG_BLE_MESH_GENERIC_SERVER
- CONFIG_BLE_MESH_LIGHT_CTL_CLI
- CONFIG_BLE_MESH_LIGHT_HSL_CLI
- CONFIG_BLE_MESH_LIGHT_LC_CLI
- CONFIG_BLE_MESH_LIGHT_LIGHTNESS_CLI
- CONFIG_BLE_MESH_LIGHT_XYL_CLI
- CONFIG_BLE_MESH_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 provisioning procedure. And on the Provisioner side, a test function needs to be invoked to add the node information into the mesh stack.

Default value:
• Yes (enabled) if CONFIG_BLE_MESH_SELF_TEST && CONFIG_BLE_MESH

CONFIG_BLE_MESH_TEST_USE_WHITE_LIST

Use white list to filter mesh advertising packets

Found in: Component config > CONFIG_BLE_MESH > BLE Mesh specific test option > 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 debugging level

*Found in:* Component config > CoAP Configuration > CONFIG_COAP_MBEDTLS_DEBUG

Set CoAP debugging level

**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
- GPIO 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*

Also you can forbid the ISR being disabled during flash writing access, by add ESP_INTR_FLAG_IRAM when initializing the driver.

**Default value:**
- Yes (enabled)

**TWAI configuration**  Contains:

- **CONFIG_TWAI_ERRATA_FIX_RX_FRAME_INVALID**
- **CONFIG_TWAI_ERRATA_FIX_BUS_OFF_REC**
- **CONFIG_TWAI_ERRATA_FIX_RX_FIFO_CORRUPT**
- **CONFIG_TWAI_ERRATA_FIX_TX_INTR_LOST**
- **CONFIG_TWAI_ISR_IN_IRAM**

**CONFIG_TWAI_ISR_IN_IRAM**

Place TWAI ISR function into IRAM

*Found in: Component config > Driver configurations > TWAI configuration*

Place the TWAI ISR in to IRAM. This will allow the ISR to avoid cache misses, and also be able to run whilst the cache is disabled (such as when writing to SPI Flash). Note that if this option is enabled: - Users should also set the ESP_INTR_FLAG_IRAM in the driver configuration structure when installing the driver (see docs for specifics). - Alert logging (i.e., setting of the TWAI_ALERT_AND_LOG flag) will have no effect.

**Default value:**
- No (disabled)
**CONFIG_TWAI_ERRATA_FIX_BUS_OFF_REC**

Add SW workaround for REC change during bus-off

*Found in: Component config > Driver configurations > TWAI configuration*

When the bus-off condition is reached, the REC should be reset to 0 and frozen (via LOM) by the driver’s ISR. However on the ESP32, there is an edge case where the REC will increase before the driver’s ISR can respond in time (e.g., due to the rapid occurrence of bus errors), thus causing the REC to be non-zero after bus-off. A non-zero REC can prevent bus-off recovery as the bus-off recovery condition is that both TEC and REC become 0. Enabling this option will add a workaround in the driver to forcibly reset REC to zero on reaching bus-off.

*Default value:*
• No (disabled)

**CONFIG_TWAI_ERRATA_FIX_TX_INTR_LOST**

Add SW workaround for TX interrupt lost errata

*Found in: Component config > Driver configurations > TWAI configuration*

On the ESP32, when a transmit interrupt occurs, and interrupt register is read on the same APB clock cycle, the transmit interrupt could be lost. Enabling this option will add a workaround that checks the transmit buffer status bit to recover any lost transmit interrupt.

*Default value:*
• No (disabled)

**CONFIG_TWAI_ERRATA_FIX_RX_FRAME_INVALID**

Add SW workaround for invalid RX frame errata

*Found in: Component config > Driver configurations > TWAI configuration*

On the ESP32, when receiving a data or remote frame, if a bus error occurs in the data or CRC field, the data of the next received frame could be invalid. Enabling this option will add a workaround that will reset the peripheral on detection of this errata condition. Note that if a frame is transmitted on the bus whilst the reset is ongoing, the message will not be receive by the peripheral sent on the bus during the reset, the message will be lost.

*Default value:*
• No (disabled)

**CONFIG_TWAI_ERRATA_FIX_RX_FIFO_CORRUPT**

Add SW workaround for RX FIFO corruption errata

*Found in: Component config > Driver configurations > TWAI configuration*

On the ESP32, when the RX FIFO overruns and the RX message counter maxes out at 64 messages, the entire RX FIFO is no longer recoverable. Enabling this option will add a workaround that resets the peripheral on detection of this errata condition. Note that if a frame is being sent on the bus during the reset bus during the reset, the message will be lost.

*Default value:*
• No (disabled)

**UART configuration**

Contains:

• **CONFIG_UART_ISR_IN_IRAM**
CONFIG_UART_ISR_IN_IRAM

Place UART ISR function into IRAM

*Found in: Component config > Driver configurations > UART configuration*

If this option is not selected, UART interrupt will be disabled for a long time and may cause data lost when doing spi flash operation.

**Default value:**
- No (disabled)

GPIO Configuration  Contains:

- **CONFIG_GPIO_ESP32_SUPPORT_SWITCH_SLP_PULL**

CONFIG_GPIO_ESP32_SUPPORT_SWITCH_SLP_PULL

Support light sleep GPIO pullup/pulldown configuration for ESP32

*Found in: Component config > Driver configurations > GPIO Configuration*

This option is intended to fix the bug that ESP32 is not able to switch to configured pullup/pulldown mode in sleep. If this option is selected, chip will automatically emulate the behaviour of switching, and about 450B of source codes would be placed into IRAM.

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, allowing 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_CODE_SCHEME_SELECTOR
- CONFIG_EFUSE_VIRTUAL
- CONFIG_EFUSE_CUSTOM_TABLE

CONFIG_EFUSE_CUSTOM_TABLE
Use custom eFuse table

**Found in:** Component config > eFuse Bit Manager

Allows to generate a structure for eFuse from the CSV file.

**Default value:**
- No (disabled)

CONFIG_EFUSE_CUSTOM_TABLE_FILENAME
Custom eFuse CSV file

**Found in:** Component config > eFuse Bit Manager > CONFIG_EFUSE_CUSTOM_TABLE

Name of the custom eFuse CSV filename. This path is evaluated relative to the project root directory.

**Default value:**
- “main/esp_efuse_custom_table.csv” if CONFIG_EFUSE_CUSTOM_TABLE
**CONFIG_EFUSEVIRTUAL**

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_EFUSEVIRTUAL_KEEP_IN_FLASH**

Keep eFuses in flash

*Found in: Component config > eFuse Bit Manager > CONFIG_EFUSE_VIRTUAL*

In addition to the “Simulate eFuse operations in RAM” option, this option just adds a feature to keep eFuses after reboots in flash memory. To use this mode the partition_table should have the efuse partition.

**partition.csv:**
```
efuse_em, data, efuse, , 0x2000,
```

During startup, the eFuses are copied from flash or, in case if flash is empty, from real eFuse to RAM and then update flash. This mode is useful when need to keep changes after reboot (testing secure_boot and flash_encryption).

**CONFIG_EFUSECODESCHEME_SELECTOR**

Coding Scheme Compatibility

*Found in: Component config > eFuse Bit Manager*

Selector eFuse code scheme.

**Available options:**
- None Only (EFUSE_CODE_SCHEME_COMPATNONE)
- 3/4 and None (EFUSE_CODE_SCHEME_COMPAT_3_4)
- Repeat, 3/4 and None (common table does not support it) (EFUSE_CODE_SCHEME_COMPAT_REPEAT)

**ESP-TLS**

Contains:
- **CONFIG_ESP_TLS_INSECURE**
- **CONFIG_ESP_TLS_LIBRARY_CHOOSE**
- **CONFIG_ESP_TLS_CLIENT_SESSION_TICKETS**
- **CONFIG_ESP_DEBUG_WOLFSSL**
- **CONFIG_ESP_TLS_SERVER**
- **CONFIG_ESP_TLS_PSK_VERIFICATION**
- **CONFIG_ESP_TLS_SERVER_SESSION_TICKETS**
- **CONFIG_ESP_WOLFSSL_SMALL_CERT_VERIFY**
- **CONFIG_ESP_TLS_USE_SECURE_ELEMENT**

**CONFIG_ESP_TLS_LIBRARY_CHOOSE**

Choose SSL/TLS library for ESP-TLS (See help for more Info)

*Found in: Component config > ESP-TLS*
The ESP-TLS APIs support multiple backend TLS libraries. Currently mbedTLS and WolfSSL are supported. Different TLS libraries may support different features and have different resource usage. Consult the ESP-TLS documentation in ESP-IDF Programming guide for more details.

Available options:
- mbedTLS (ESP_TLS_USING_MBEDTLS)
- wolfSSL (License info in wolfSSL directory README) (ESP_TLS_USING_WOLFSSL)

**CONFIG_ESP_TLS_USE_SECURE_ELEMENT**
Use Secure Element (ATECC608A) with ESP-TLS

*Found in: Component config > ESP-TLS*

Enable use of Secure Element for ESP-TLS, this enables internal support for ATECC608A peripheral on ESP-WROOM32SE, which can be used for TLS connection.

*Default value:*
- No (disabled)

**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 certificate 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
ESP32-specific Contains:

- `CONFIG_ESP32_RTC_EXT_CRYST_ADDIT_CURRENT_METHOD`
- `CONFIG_ESP32_COMPATIBLE_PRE_V3_1_BOOTLOADERS`
- `CONFIG_ESP32_COMPATIBLE_PRE_V2_1_BOOTLOADERS`
- `CONFIG_ESP32_DEFAULT_CPU_FREQ_MHZ`
- `CONFIG_ESP32_DPORT_DIS_INTERRUPT_LVL`
- `CONFIG_ESP32_IRAM_AS_8BIT_ACCESSIBLE_MEMORY`
- `CONFIG_ESP32_ULP_COPROC_ENABLED`
- `CONFIG_ESP32_DEEP_SLEEP_WAKEUP_DELAY`
- `CONFIG_ESP32_BROWNOUT_DET`
- `CONFIG_ESP32_XTAL_FREQ_SEL`
- `CONFIG_ESP32_DEBUG_OCDAWARE`
- `CONFIG_ESP32_REV_MIN`
- `CONFIG_ESP32_NO_BLOBS`
- `CONFIG_ESP32_RTC_XTAL_CAL_RETRY`
- `CONFIG_ESP32_RTC_CLK_CAL_CYCLES`
- `CONFIG_ESP32_DISABLE_BASIC_ROM_CONSOLE`
- `CONFIG_ESP32_RTCDATA_IN_FAST_MEM`
- `CONFIG_ESP32_RTC_CLK_SRC`
- `CONFIG_ESP32_SPIRAM_SUPPORT`
- `CONFIG_ESP32_TIME_SYSCALL`
- `CONFIG_ESP32_USE_FIXED_STATIC_RAM_SIZE`
- `CONFIG_ESP32_TRAX`

**CONFIG_ESP32_REV_MIN**

Minimum Supported ESP32 Revision

*Found in: Component config > ESP32-specific*

Minimum revision that ESP-IDF would support. ESP-IDF performs different strategy on different esp32 revision.

**Available options:**
- Rev 0 (ESP32_REV_MIN_0)
- Rev 1 (ESP32_REV_MIN_1)
- Rev 2 (ESP32_REV_MIN_2)
- Rev 3 (ESP32_REV_MIN_3)

**CONFIG_ESP32_DEFAULT_CPU_FREQ_MHZ**

CPU frequency

*Found in: Component config > ESP32-specific*

CPU frequency to be set on application startup.

**Available options:**
- 40 MHz (ESP32_DEFAULT_CPU_FREQ_40)
- 80 MHz (ESP32_DEFAULT_CPU_FREQ_80)
- 160 MHz (ESP32_DEFAULT_CPU_FREQ_160)
- 240 MHz (ESP32_DEFAULT_CPU_FREQ_240)

**CONFIG_ESP32_SPIRAM_SUPPORT**

Support for external, SPI-connected RAM

*Found in: Component config > ESP32-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_ALLOW_BSS_SEG_EXTERNAL_MEMORY`
- `CONFIG_SPIRAM_ALLOW_NONINIT_SEG_EXTERNAL_MEMORY`
- `CONFIG_SPIRAM_ALLOW_STACK_EXTERNAL_MEMORY`
- `CONFIG_SPIRAM_SPIWP_SD3_PIN`
- `CONFIG_SPIRAM_BANKSWITCH_ENABLE`
- `CONFIG_SPIRAM_2T_MODE`
- `CONFIG_SPIRAM_CACHE_WORKAROUND`
- `CONFIG_SPIRAM_BOOT_INIT`
- `CONFIG_SPIRAM_MALLOC_ALWAYSINTERNAL`
- `PSRAM clock and cs IO for ESP32-D2WD`
- `PSRAM clock and cs IO for ESP32-DOWD`
- `PSRAM clock and cs IO for ESP32-PICO`
- `CONFIG_SPIRAM_MALLOC_RESERVE_INTERNAL`
- `CONFIG_SPIRAM_MEMTEST`
- `CONFIG_SPIRAM_SPEED`
- `CONFIG_SPIRAM_OCCUPY_SPI_HOST`
- `CONFIG_SPIRAM_USE`
- `SPIRAM clock workaround debugging`
- `SPIRAM workaround libraries placement`
- `CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP`
- `CONFIG_SPIRAM_TYPE`
- `CONFIG_SPIRAM_CUSTOM_SPIWP_SD3_PIN`

**CONFIG_SPIRAM_TYPE**

Type of SPI RAM chip in use

*Found in: Component config > ESP32-specific > CONFIG_ESP32_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 or LY68L6400 (SPIRAM_TYPE_ESPPSRAM64)

**CONFIG_SPIRAM_SPEED**

Set RAM clock speed

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config*

Select the speed for the SPI RAM chip. If SPI RAM is enabled, we only support three combinations of SPI speed mode we supported now:

1. Flash SPI running at 40Mhz and RAM SPI running at 40Mhz
2. Flash SPI running at 80Mhz and RAM SPI running at 40Mhz
3. Flash SPI running at 80Mhz and RAM SPI running at 80Mhz

Note: If the third mode (80Mhz+80Mhz) is enabled for SPI RAM of type 32MBit, one of the HSPI/VSPI host will be occupied by the system. Which SPI host to use can be selected by the config item SPIRAM_OCCUPY_SPI_HOST. Application code should never touch HSPI/VSPI hardware in this case. The option to select 80MHz will only be visible if the flash SPI speed is also 80MHz. (ESP-TOOLPY_FLASHFREQ_80M is true)

**Available options:**

- 40MHz clock speed (SPIRAM_SPEED_40M)
• 80MHz clock speed (SPIRAM_SPEED_80M)

**CONFIG_SPIRAM_BOOT_INIT**

Initialize SPI RAM during startup

*Found in: Component config > ESP32-specific > CONFIG_ESP32_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_ESP32_SPIRAM_SUPPORT**

**CONFIG_SPIRAM_IGNORE_NOTFOUND**

Ignore PSRAM when not found

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > CONFIG_SPIRAM_BOOT_INIT*

Normally, if psram initialization is enabled during compile time but not found at runtime, it is seen as an error making the CPU panic. If this is enabled, booting will complete but no PSRAM will be available.

**Default value:**

• No (disabled) if **CONFIG_SPIRAM_BOOT_INIT** && **CONFIG_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY** && **CONFIG_ESP32_SPIRAM_SUPPORT**

**CONFIG_SPIRAM_USE**

SPI RAM access method

*Found in: Component config > ESP32-specific > CONFIG_ESP32_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.

**Available options:**

• Integrate RAM into memory map (SPIRAM_USE_MEMMAP)
• Make RAM allocatable using heap_caps_malloc (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 > ESP32-specific > CONFIG_ESP32_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_ESP32_SPIRAM_SUPPORT**
CONFIG_SPIRAM_MALLOC_ALWAYSINTERNAL

Maximum malloc() size, in bytes, to always put in internal memory

*Found in: Component config > ESP32-specific > CONFIG_ESP32_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_ESP32_SPIRAM_SUPPORT

**Default value:**
- 16384 if SPIRAM_USE_MALLOC && CONFIG_ESP32_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 > ESP32-specific > CONFIG_ESP32_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_ESP32_SPIRAM_SUPPORT

CONFIG_SPIRAM_MALLOC_RESERVE_INTERNAL

Reservethis amount of bytes for data that specifically needstobe in DMA or internal memory

*Found in: Component config > ESP32-specific > CONFIG_ESP32_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.

Setthis 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_ESP32_SPIRAM_SUPPORT

**Default value:**
- 32768 if SPIRAM_USE_MALLOC && CONFIG_ESP32_SPIRAM_SUPPORT

CONFIG_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY

Allow .bss segment placed in external memory

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config*

If enabled, variables with EXT_RAM_ATTR attribute will be placed in SPIRAM instead of internal DRAM. BSS section of lwip, net80211, pp, bt libraries will be automatically placed in SPIRAM. BSS sections from other object files and libraries can also be placed in SPIRAM through linker fragment scheme extram_bss.

Note that the variables placed in SPIRAM using EXT_RAM_ATTR will be zero initialized.
CONFIG_SPIRAM_ALLOW_NOINIT_SEG_EXTERNAL_MEMORY

Allow .noinit segment placed in external memory

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config*

If enabled, noinit variables can be placed in PSRAM using EXT_RAM_NOINIT_ATTR.

Note the values placed into this section will not be initialized at startup and should keep its value after software restart.

CONFIG_SPIRAM_CACHE_WORKAROUND

Enable workaround for bug in SPI RAM cache for Rev1 ESP32s

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config*

Revision 1 of the ESP32 has a bug that can cause a write to PSRAM not to take place in some situations when the cache line needs to be fetched from external RAM and an interrupt occurs. This enables a fix in the compiler (-mfix-esp32-psram-cache-issue) that makes sure the specific code that is vulnerable to this will not be emitted.

This will also not use any bits of newlib that are located in ROM, opting for a version that is compiled with the workaround and located in flash instead.

The workaround is not required for ESP32 revision 3 and above.

**Default value:**

- Yes (enabled) if (SPIRAM_USE_MEMMAP || SPIRAM_USE_CAPS_ALLOC || SPIRAM_USE_MALLOC) && CONFIG_ESP32_SPIRAM_SUPPORT

SPIRAM cache workaround debugging  Contains:

- CONFIG_SPIRAM_CACHE_WORKAROUND_STRATEGY

CONFIG_SPIRAM_CACHE_WORKAROUND_STRATEGY

Workaround strategy

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > SPIRAM cache workaround debugging*

Select the workaround strategy. Note that the strategy for precompiled libraries (libgcc, newlib, bt, wifi) is not affected by this selection.

Unless you know you need a different strategy, it’s suggested you stay with the default MEMW strategy. Note that DUPLDST can interfere with hardware encryption and this will be automatically disabled if this workaround is selected. ‘Insert nops’ is the workaround that was used in older esp-idf versions. This workaround still can cause faulty data transfers from/to SPI RAM in some situation.

**Available options:**

- Insert memw after vulnerable instructions (default) (SPIRAM_CACHE_WORKAROUND_STRATEGY_MEMW)
- Duplicate LD/ST for 32-bit, memw for 8/16 bit (SPIRAM_CACHE_WORKAROUND_STRATEGY_DUPLDST)
- Insert nops between vulnerable loads/stores (old strategy, obsolete) (SPIRAM_CACHE_WORKAROUND_STRATEGY_NOPS)

SPIRAM workaround libraries placement  Contains:

- CONFIG_SPIRAM_CACHE_LIBCHAR_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBENV_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBFILE_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBIO_IN_IRAM
Chapter 2. API Reference

- `CONFIG_SPIRAM_CACHE_LIBJMP_IN_IRAM`
- `CONFIG_SPIRAM_CACHE_LIBMATH_IN_IRAM`
- `CONFIG_SPIRAM_CACHE_LIBMEM_IN_IRAM`
- `CONFIG_SPIRAM_CACHE_LIBMISC_IN_IRAM`
- `CONFIG_SPIRAM_CACHE_LIBNUMPARSER_IN_IRAM`
- `CONFIG_SPIRAM_CACHE_LIBRAND_IN_IRAM`
- `CONFIG_SPIRAM_CACHE_LIBSTR_IN_IRAM`
- `CONFIG_SPIRAM_CACHE_LIBTIME_IN_IRAM`

**CONFIG_SPIRAM_CACHE_LIBJMP_IN_IRAM**

Put libc’s jump related functions in IRAM

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: `longjmp` and `setjmp`. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_SPIRAM_CACHE_LIBMATH_IN_IRAM**

Put libc’s math related functions in IRAM

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: `abs`, `div`, `labs`, `ldiv`, `quorem`, `fpclassify`, and `isnan`. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_SPIRAM_CACHE_LIBNUMPARSER_IN_IRAM**

Put libc’s number parsing related functions in IRAM

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: `utoa`, `itoa`, `atoi`, `atol`, `strtol`, and `strtoul`. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_SPIRAM_CACHE_LIBIO_IN_IRAM**

Put libc’s I/O related functions in IRAM

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > SPIRAM workaround libraries placement*
The functions affected by this option are: wcrtomb, fvwrite, wbuf, wsetup, fputwc, wcrtomb_r, ungetc, makebuf, fflush, refill, and sccl. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

Default value:
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_SPIRAM_CACHE_LIBTIME_IN_IRAM**

Put libc’s time related functions in IRAM

*Found in:* `Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > SPIRAM workaround libraries placement`

The functions affected by this option are: asctime, asctime_r, ctime, ctime_r, localtime, localtime_r, gmtime, gmtime_r, strftime, mktime, tzset_r, tzset, time, getzinfo, systimes, month_lengths, timelocal, tzvars, tzlock, tzcalc_limits, and strptime. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

Default value:
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_SPIRAM_CACHE_LIBCHAR_IN_IRAM**

Put libc’s characters related functions in IRAM

*Found in:* `Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > SPIRAM workaround libraries placement`

The functions affected by this option are: ctype_, toupper, tolower, toascii,strupr, bzero, isalnum, isalpha, isascii, isblank, iscntrl, isdigit, isgraph, islower, ispunct, isspace, and isupper. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

Default value:
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_SPIRAM_CACHE_LIBMEM_IN_IRAM**

Put libc’s memory related functions in IRAM

*Found in:* `Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > SPIRAM workaround libraries placement`

The functions affected by this option are: memccpy, memchr, memmove, and memrchr. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

Default value:
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_SPIRAM_CACHE_LIBSTR_IN_IRAM**

Put libc’s string related functions in IRAM

*Found in:* `Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > SPIRAM workaround libraries placement`
The functions affected by this option are: strcasecmp, strcasestr, strchr, strcoll, strcpy, strcsn, strdup, strdup_r, strcat, strcpcy, strlen, strlwr, strncasecmp, strncat, strncmp, strncpy, strndup, strndup_r, strchr, strsep, strspn, strsr, strtok_r, andstrup. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_SPIRAM_CACHE_LIBRAND_IN_IRAM**

Put libc’s random related functions in IRAM

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: srand, rand, and rand_r. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_SPIRAM_CACHE_LIBENV_IN_IRAM**

Put libc’s environment related functions in IRAM

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: environ, envlock, and getenv_r. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_SPIRAM_CACHE_LIBFILE_IN_IRAM**

Put libc’s file related functions in IRAM

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: lock, isatty, fclose, open, close, creat, read, rshift, sbrk, stdio, syscall, sysopen, creat, sysread, syswrite, impure, fwalk, and findfp. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_SPIRAM_CACHE_LIBMISC_IN_IRAM**

Put libc’s miscellaneous functions in IRAM, see help

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > SPIRAM workaround libraries placement*
The functions affected by this option are: raise and system. Putting these functions in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_ESP32_SPIRAM_SUPPORT`

---

**CONFIG_SPIRAM_BANKSWITCH_ENABLE**

Enable bank switching for >4MiB external RAM

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config*

The ESP32 only supports 4MiB of external RAM in its address space. The hardware does support larger memories, but these have to be bank-switched in and out of this address space. Enabling this allows you to reserve some MMU pages for this, which allows the use of the esp_himem api to manage these banks.

#Note that this is limited to 62 banks, as esp_spiram_writeback_cache needs some kind of mapping of some banks below that mark to work. We cannot at this moment guarantee this to exist when himem is #enabled.

If spiram 2T mode is enabled, the size of 64Mbit psram will be changed as 32Mbit, so himem will be unusable.

**Default value:**
- Yes (enabled) if (SPIRAM_USE_MEMMAP || SPIRAM_USE_CAPS_ALLOC || SPIRAM_USE_MALLOC) && `CONFIG_ESP32_SPIRAM_SUPPORT` `CONFIG_SPIRAM_BANKSWITCH_ENABLE`

---

**CONFIG_SPIRAM_BANKSWITCH_RESERVE**

Amount of 32K pages to reserve for bank switching

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > CONFIG_SPIRAM_BANKSWITCH_ENABLE*

Select the amount of banks reserved for bank switching. Note that the amount of RAM allocatable with malloc/esp_heap_alloc_caps will decrease by 32K for each page reserved here.

Note that this reservation is only actually done if your program actually uses the himem API. Without any himem calls, the reservation is not done and the original amount of memory will be available to malloc/esp_heap_alloc_caps.

**Range:**
- from 1 to 62 if `CONFIG_SPIRAM_BANKSWITCH_ENABLE` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**Default value:**
- 8 if `CONFIG_SPIRAM_BANKSWITCH_ENABLE` && `CONFIG_ESP32_SPIRAM_SUPPORT`

---

**CONFIG_SPIRAM_ALLOW_STACK_EXTERNAL_MEMORY**

Allow external memory as an argument to xTaskCreateStatic

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config*

Because some bits of the ESP32 code environment cannot be recompiled with the cache workaround, normally tasks cannot be safely run with their stack residing in external memory; for this reason xTaskCreate (and related task creation functions) always allocate stack in internal memory and xTaskCreateStatic will check if the memory passed to it is in internal memory. If you have a task that needs a large amount of stack and does not call on ROM code in any way (no direct calls, but also no Bluetooth/WiFi), you can try enable this to cause xTaskCreateStatic to allow tasks stack in external memory.

**Default value:**
- No (disabled) if SPIRAM_USE_MALLOC && `CONFIG_ESP32_SPIRAM_SUPPORT`
Chapter 2. API Reference

**CONFIG_SPIRAM_OCCUPY_SPI_HOST**

SPI host to use for 32MBit PSRAM

_Found in:_ Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config

When both flash and PSRAM is working under 80MHz, and the PSRAM is of type 32MBit, one of the HSPI/VSPI host will be used to output the clock. Select which one to use here.

Available options:

- HSPI host (SPI2) (SPIRAM_OCCUPY_HSPI_HOST)
- VSPI host (SPI3) (SPIRAM_OCCUPY_VSPI_HOST)
- Will not try to use any host, will abort if not able to use the PSRAM (SPIRAM_OCCUPY_NO_HOST)

**PSRAM clock and cs IO for ESP32-DOWD**

Contains:

- `CONFIG_D0WD_PSRAM_CLK_IO`
- `CONFIG_D0WD_PSRAM_CS_IO`

**CONFIG_D0WD_PSRAM_CLK_IO**

PSRAM CLK IO number

_Found in:_ Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > PSRAM clock and cs IO for ESP32-DOWD

The PSRAM CLOCK IO can be any unused GPIO, user can config it based on hardware design. If user use 1.8V flash and 1.8V psram, this value can only be one of 6, 7, 8, 9, 10, 11, 16, 17.

Range:

- from 0 to 33 if `CONFIG_ESP32_SPIRAM_SUPPORT` && `CONFIG_ESP32_SPIRAM_SUPPORT`

Default value:

- 17 if `CONFIG_ESP32_SPIRAM_SUPPORT` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_D0WD_PSRAM_CS_IO**

PSRAM CS IO number

_Found in:_ Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > PSRAM clock and cs IO for ESP32-DOWD

The PSRAM CS IO can be any unused GPIO, user can config it based on hardware design. If user use 1.8V flash and 1.8V psram, this value can only be one of 6, 7, 8, 9, 10, 11, 16, 17.

Range:

- from 0 to 33 if `CONFIG_ESP32_SPIRAM_SUPPORT` && `CONFIG_ESP32_SPIRAM_SUPPORT`

Default value:

- 16 if `CONFIG_ESP32_SPIRAM_SUPPORT` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**PSRAM clock and cs IO for ESP32-D2WD**

Contains:

- `CONFIG_D2WD_PSRAM_CLK_IO`
- `CONFIG_D2WD_PSRAM_CS_IO`

**CONFIG_D2WD_PSRAM_CLK_IO**
PSRAM CLK IO number

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > PSRAM clock and cs IO for ESP32-D2WD*

User can config it based on hardware design. For ESP32-D2WD chip, the psram can only be 1.8V psram, so this value can only be one of 6, 7, 8, 9, 10, 11, 16, 17.

**Range:**

- from 0 to 33 if `CONFIG_ESP32_SPIRAM_SUPPORT` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**Default value:**

- 9 if `CONFIG_ESP32_SPIRAM_SUPPORT` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_D2WD_PSRAM_CS_IO**

PSRAM CS IO number

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > PSRAM clock and cs IO for ESP32-D2WD*

User can config it based on hardware design. For ESP32-D2WD chip, the psram can only be 1.8V psram, so this value can only be one of 6, 7, 8, 9, 10, 11, 16, 17.

**Range:**

- from 0 to 33 if `CONFIG_ESP32_SPIRAM_SUPPORT` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**Default value:**

- 10 if `CONFIG_ESP32_SPIRAM_SUPPORT` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**PSRAM clock and cs IO for ESP32-PICO**

Contains:

- `CONFIG_PICO_PSRAM_CS_IO`

**CONFIG_PICO_PSRAM_CS_IO**

PSRAM CS IO number

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config > PSRAM clock and cs IO for ESP32-PICO*

The PSRAM CS IO can be any unused GPIO, user can config it based on hardware design.

For ESP32-PICO chip, the psram share clock with flash, so user do not need to configure the clock IO. For the reference hardware design, please refer to [https://www.espressif.com/sites/default/files/documentation/esp32-pico-d4_datasheet_en.pdf](https://www.espressif.com/sites/default/files/documentation/esp32-pico-d4_datasheet_en.pdf)

**Range:**

- from 0 to 33 if `CONFIG_ESP32_SPIRAM_SUPPORT` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**Default value:**

- 10 if `CONFIG_ESP32_SPIRAM_SUPPORT` && `CONFIG_ESP32_SPIRAM_SUPPORT`

**CONFIG_SPIRAM_CUSTOM_SPIWP_SD3_PIN**

Use custom SPI PSRAM WP(SD3) Pin when flash pins set in eFuse (read help)

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config*

This setting is only used if the SPI flash pins have been overridden by setting the eFuses SPI_PAD_CONFIG_xxx, and the SPI flash mode is DIO or DOUT.
When this is the case, the eFuse config only defines 3 of the 4 Quad I/O data pins. The WP pin (aka ESP32 pin “SD_DATA_3” or SPI flash pin “IO2”) is not specified in eFuse. The psram only has QPI mode, so a WP pin setting is necessary.

If this config item is set to N (default), the correct WP pin will be automatically used for any Espressif chip or module with integrated flash. If a custom setting is needed, set this config item to Y and specify the GPIO number connected to the WP pin.

When flash mode is set to QIO or QOUT, the PSRAM WP pin will be set the same as the SPI Flash WP pin configured in the bootloader.

**Default value:**
- No (disabled) if (ESPTOOLPY_FLASHMODE_DIO || ESPTOOLPY_FLASHMODE_DOUT) && CONFIG_ESP32_SPIRAM_SUPPORT

**CONFIG_SPIRAM_SPIWP_SD3_PIN**

Custom SPI PSRAM WP(SD3) Pin

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config*

The option “Use custom SPI PSRAM WP(SD3) pin” must be set or this value is ignored.

If burning a customized set of SPI flash pins in eFuse and using DIO or DOUT mode for flash, set this value to the GPIO number of the SPIRAM WP pin.

**Range:**
- from 0 to 33 if (ESPTOOLPY_FLASHMODE_DIO || ESPTOOLPY_FLASHMODE_DOUT) && CONFIG_ESP32_SPIRAM_SUPPORT

**Default value:**
- 7 if (ESPTOOLPY_FLASHMODE_DIO || ESPTOOLPY_FLASHMODE_DOUT) && CONFIG_ESP32_SPIRAM_SUPPORT

**CONFIG_SPIRAM_2T_MODE**

Enable SPI PSRAM 2T mode

*Found in: Component config > ESP32-specific > CONFIG_ESP32_SPIRAM_SUPPORT > SPI RAM config*

Enable this option to fix single bit errors inside 64Mbit PSRAM.

Some 64Mbit PSRAM chips have a hardware issue in the RAM which causes bit errors at multiple fixed bit positions.

Note: If this option is enabled, the 64Mbit PSRAM chip will appear to be 32Mbit in size. Applications will not be affected unless the use the esp_himem APIs, which are not supported in 2T mode.

**Default value:**
- No (disabled) if CONFIG_ESP32_SPIRAM_SUPPORT && CONFIG_ESP32_SPIRAM_SUPPORT

**CONFIG_ESP32_TRAX**

Use TRAX tracing feature

*Found in: Component config > ESP32-specific*

The ESP32 contains a feature which allows you to trace the execution path the processor has taken through the program. This is stored in a chunk of 32K (16K for single-processor) of memory that can’t be used for general purposes anymore. Disable this if you do not know what this is.

**Default value:**
- No (disabled)
CONFIG_ESP32_TRAX_TWOBANKS

Reserve memory for tracing both pro as well as app cpu execution

*Found in: Component config > ESP32-specific > CONFIG_ESP32_TRAX*

The ESP32 contains a feature which allows you to trace the execution path the processor has taken through the program. This is stored in a chunk of 32K (16K for single-processor) of memory that can’t be used for general purposes anymore. Disable this if you do not know what this is.

# Memory to reverse for trace, used in linker script

**Default value:**

- No (disabled) if `CONFIG_ESP32_TRAX` & `CONFIG_FREERTOS_UNICORE`

CONFIG_ESP32_ULP_COPROC_ENABLED

Enable Ultra Low Power (ULP) Coprocessor

*Found in: Component config > ESP32-specific*

Set to ‘y’ if you plan to load a firmware for the coprocessor.

If this option is enabled, further coprocessor configuration will appear in the Components menu.

**Default value:**

- No (disabled)

CONFIG_ESP32_ULP_COPROC_RESERVE_MEM

RTC slow memory reserved for coprocessor

*Found in: Component config > ESP32-specific > CONFIG_ESP32_ULP_COPROC_ENABLED*

Bytes of memory to reserve for ULP coprocessor firmware & data.

Data is reserved at the beginning of RTC slow memory.

**Range:**

- from 32 to 8176 if `CONFIG_ESP32_ULP_COPROC_ENABLED`
- from 0 to 0 if `CONFIG_ESP32_ULP_COPROC_ENABLED`

**Default value:**

- 512 if `CONFIG_ESP32_ULP_COPROC_ENABLED`
- 0 if `CONFIG_ESP32_ULP_COPROC_ENABLED`

CONFIG_ESP32_DEBUG_OCDAWARE

Make exception and panic handlers JTAG/OCD aware

*Found in: Component config > ESP32-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_ESP32_BROWNOUT_DET

Hardware brownout detect & reset

*Found in: Component config > ESP32-specific*

The ESP32 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:**
Chapter 2. API Reference

• Yes (enabled)

CONFIG_ESP32_BROWNOUT_DET_LVL_SEL
Brownout voltage level

Found in: Component config > ESP32-specific > CONFIG_ESP32_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 ESP32 chip.

# The voltage levels here are estimates, more work needs to be done to figure out the exact voltages of the brownout threshold levels.

Available options:
• 2.43V +/- 0.05 (ESP32_BROWNOUT_DET_LVL_SEL_0)
• 2.48V +/- 0.05 (ESP32_BROWNOUT_DET_LVL_SEL_1)
• 2.58V +/- 0.05 (ESP32_BROWNOUT_DET_LVL_SEL_2)
• 2.62V +/- 0.05 (ESP32_BROWNOUT_DET_LVL_SEL_3)
• 2.67V +/- 0.05 (ESP32_BROWNOUT_DET_LVL_SEL_4)
• 2.70V +/- 0.05 (ESP32_BROWNOUT_DET_LVL_SEL_5)
• 2.77V +/- 0.05 (ESP32_BROWNOUT_DET_LVL_SEL_6)
• 2.80V +/- 0.05 (ESP32_BROWNOUT_DET_LVL_SEL_7)

CONFIG_ESP32_TIME_SYSCALL
Timers used for gettimeofday function

Found in: Component config > ESP32-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(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 (ESP32_TIME_SYSCALL_USE_RTC_FRC1)
• RTC (ESP32_TIME_SYSCALL_USE_RTC)
• High-resolution timer (ESP32_TIME_SYSCALL_USE_FRC1)
• None (ESP32_TIME_SYSCALL_USE_NONE)

CONFIG_ESP32_RTC_CLK_SRC
RTC clock source

Found in: Component config > ESP32-specific

Choose which clock is used as RTC clock source.

• “Internal 150kHz oscillator” option provides lowest deep sleep current consumption, and does not require extra external components. However frequency stability with respect to temperature is poor, so time may drift in deep/light sleep modes.
• “External 32kHz crystal” provides better frequency stability, at the expense of slightly higher (1uA) deep sleep current consumption.
• “External 32kHz oscillator” allows using 32kHz clock generated by an external circuit. In this case, external clock signal must be connected to 32K_XN pin. Amplitude should be <1.2V in case of sine wave signal, and <1V in case of square wave signal. Common mode voltage should be 0.1 < Vcm < 0.5Vamp, where Vamp is the signal amplitude. Additionally, 1nF capacitor must be connected between 32K_XP pin and ground. 32K_XP pin cannot be used as a GPIO in this case.

• “Internal 8.5MHz oscillator divided by 256” option results in higher deep sleep current (by 5uA) but has better frequency stability than the internal 150kHz oscillator. It does not require external components.

Available options:
• Internal 150kHz RC oscillator (ESP32_RTC_CLK_SRC_INT_RC)
• External 32kHz crystal (ESP32_RTC_CLK_SRC_EXT_CRYST)
• External 32kHz oscillator at 32K_XN pin (ESP32_RTC_CLK_SRC_EXT_OSC)
• Internal 8.5MHz oscillator, divided by 256 (~33kHz) (ESP32_RTC_CLK_SRC_INT_8MD256)

CONFIG_ESP32_RTC_EXT_CRYST_ADDIT_CURRENT_METHOD

Additional current for external 32kHz crystal

Found in: Component config > ESP32-specific

With some 32kHz crystal configurations, the X32N and X32P pins may not have enough drive strength to keep the crystal oscillating. Choose the method to provide additional current from touchpad 9 to the external 32kHz crystal. Note that the deep sleep current is slightly high (4-5uA) and the touchpad and the wakeup sources of both touchpad and ULP are not available in method 1 and method 2.

This problem is fixed in ESP32 ECO 3, so this workaround is not needed. Setting the project configuration to minimum revision ECO3 will disable this option, allow all wakeup sources, and save some code size.

• “None” option will not provide additional current to external crystal
• “Method 1” option can’t ensure 100% to solve the external 32k crystal start failed issue, but the touchpad can work in this method.
• “Method 2” option can solve the external 32k issue, but the touchpad can’t work in this method.

Available options:
• None (ESP32_RTC_EXT_CRYST_ADDIT_CURRENT_NONE)
• Method 1 (ESP32_RTC_EXT_CRYST_ADDIT_CURRENT)
• Method 2 (ESP32_RTC_EXT_CRYST_ADDIT_CURRENT_V2)

CONFIG_ESP32_RTC_CLK_CAL_CYCLES

Number of cycles for RTC_SLOW_CLK calibration

Found in: Component config > ESP32-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:
Chapter 2. API Reference

• from 0 to 27000 if ESP32_RTC_CLK_SRC_EXT_CRYST or ESP32_RTC_CLK_SRC_EXT_OSC or ESP32_RTC_CLK_SRC_INT_8MD256
• from 0 to 32766

**Default value:**
• 3000 if ESP32_RTC_CLK_SRC_EXT_CRYST or ESP32_RTC_CLK_SRC_EXT_OSC or ESP32_RTC_CLK_SRC_INT_8MD256
• 1024

**CONFIG_ESP32_RTC_XTAL_CAL_RETRY**

Number of attempts to repeat 32k XTAL calibration

*Found in: Component config > ESP32-specific*

Number of attempts to repeat 32k XTAL calibration before giving up and switching to the internal RC. Increase this option if the 32k crystal oscillator does not start and switches to internal RC.

**Default value:**
• 1 if ESP32_RTC_CLK_SRC_EXT_CRYST

**CONFIG_ESP32_DEEP_SLEEP_WAKEUP_DELAY**

Extra delay in deep sleep wake stub (in us)

*Found in: Component config > ESP32-specific*

When ESP32 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_ESP32_XTAL_FREQ_SEL**

Main XTAL frequency

*Found in: Component config > ESP32-specific*

ESP32 currently supports the following XTAL frequencies:

• 26 MHz
• 40 MHz

Startup code can automatically estimate XTAL frequency. This feature uses the internal 8MHz oscillator as a reference. Because the internal oscillator frequency is temperature dependent, it is not recommended to use automatic XTAL frequency detection in applications which need to work at high ambient temperatures and use high-temperature qualified chips and modules.

**Available options:**
• 40 MHz (ESP32_XTAL_FREQ_40)
• 26 MHz (ESP32_XTAL_FREQ_26)
• Autodetect (ESP32_XTAL_FREQ_AUTO)
Chapter 2. API Reference

**CONFIG_ESP32_DISABLE_BASIC_ROM_CONSOLE**
Permanently disable BASIC ROM Console

*Found in: Component config > ESP32-specific*

If set, the first time the app boots it will disable the BASIC ROM Console permanently (by burning an eFuse).

Otherwise, the BASIC ROM Console starts on reset if no valid bootloader is read from the flash.

(Enabling secure boot also disables the BASIC ROM Console by default.)

**Default value:**
- No (disabled)

**CONFIG_ESP32_NO_BLOBS**
No Binary Blobs

*Found in: Component config > ESP32-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_ESP32_COMPATIBLE_PRE_V2_1_BOOTLOADERS**
App compatible with bootloader before ESP-IDF v2.1

*Found in: Component config > ESP32-specific*

Bootloaders before ESP-IDF v2.1 did less initialisation of the system clock. This setting needs to be enabled to build an app which can be booted by these older bootloaders.

If this setting is enabled, the app can be booted by any bootloader from IDF v1.0 up to the current version.

If this setting is disabled, the app can only be booted by bootloaders from IDF v2.1 or newer.

Enabling this setting adds approximately 1KB to the app’s IRAM usage.

**Default value:**
- No (disabled)

**CONFIG_ESP32_COMPATIBLE_PRE_V3_1_BOOTLOADERS**
App compatible with bootloader and partition table before ESP-IDF v3.1

*Found in: Component config > ESP32-specific*

Partition tables before ESP-IDF V3.1 do not contain an MD5 checksum field, and the bootloader before ESP-IDF v3.1 cannot read a partition table that contains an MD5 checksum field.

Enable this option only if your app needs to boot on a bootloader and/or partition table that was generated from a version *before* ESP-IDF v3.1.

If this option and Flash Encryption are enabled at the same time, and any data partitions in the partition table are marked Encrypted, then the partition encrypted flag should be manually verified in the app before accessing the partition (see CVE-2021-27926).

**Default value:**
- No (disabled)
CONFIG_ESP32_RTCDATA_IN_FAST_MEM

Place RTC_DATA_ATTR and RTC_RODATA_ATTR variables into RTC fast memory segment

*Found in: Component config > ESP32-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. This option depends on the CONFIG_FREERTOS_UNICORE option because RTC fast memory can be accessed only by PRO_CPU core.

**Default value:**
- No (disabled) if CONFIG_FREERTOS_UNICORE

CONFIG_ESP32_USE_FIXED_STATIC_RAM_SIZE

Use fixed static RAM size

*Found in: Component config > ESP32-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 ESP32_FIXED_STATIC_RAM_SIZE

**Default value:**
- No (disabled)

CONFIG_ESP32_FIXED_STATIC_RAM_SIZE

Fixed Static RAM size

*Found in: Component config > ESP32-specific > CONFIG_ESP32_USE_FIXED_STATIC_RAM_SIZE*

RAM size dedicated for static variables (.data & .bss sections). Please note that the actual length will be reduced by BTDM_reserve_DRAM if Bluetooth controller is enabled.

**Range:**
- from 0 to 0x2c200 if CONFIG_ESP32_USE_FIXED_STATIC_RAM_SIZE

**Default value:**
- “0x1E000” if CONFIG_ESP32_USE_FIXED_STATIC_RAM_SIZE

CONFIG_ESP32_DPORT_DIS_INTERRUPT_LVL

Disable the interrupt level for the DPORT workarounds

*Found in: Component config > ESP32-specific*

To prevent interrupting DPORT workarounds, need to disable interrupt with a maximum used level in the system.

**Default value:**
- 5

CONFIG_ESP32_IRAM_AS_8BIT_ACCESSIBLE_MEMORY

Enable IRAM as 8 bit accessible memory

*Found in: Component config > ESP32-specific*

If enabled, application can use IRAM as byte accessible region for storing data (Note: IRAM region cannot be used as task stack)

This is possible due to handling of exceptions LoadStoreError (3) and LoadStoreAlignmentError (9) Each unaligned read/write access will incur a penalty of maximum of 167 CPU cycles.
**ADC-Calibration**  Contains:

- `CONFIG_ADC_CAL_EFUSE_VREF_ENABLE`
- `CONFIG_ADC_CAL_LUT_ENABLE`
- `CONFIG_ADC_CAL_EFUSE_TP_ENABLE`

**CONFIG_ADC_CAL_EFUSE_TP_ENABLE**

Use Two Point Values

*Found in: Component config > ADC-Calibration*

Some ESP32s have Two Point calibration values burned into eFuse BLOCK3. This option will allow the ADC calibration component to characterize the ADC-Voltage curve using Two Point values if they are available.

*Default value:*
  - Yes (enabled)

**CONFIG_ADC_CAL_EFUSE_VREF_ENABLE**

Use eFuse Vref

*Found in: Component config > ADC-Calibration*

Some ESP32s have Vref burned into eFuse BLOCK0. This option will allow the ADC calibration component to characterize the ADC-Voltage curve using eFuse Vref if it is available.

*Default value:*
  - Yes (enabled)

**CONFIG_ADC_CAL_LUT_ENABLE**

Use Lookup Tables

*Found in: Component config > ADC-Calibration*

This option will allow the ADC calibration component to use Lookup Tables to correct for non-linear behavior in 11db attenuation. Other attenuations do not exhibit non-linear behavior hence will not be affected by this option.

*Default value:*
  - Yes (enabled)

**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)
Chapter 2. API Reference

Ethernet Contains:

- `CONFIG_ETH_USE_ESP32_EMAC`
- `CONFIG_ETH_USE_OPENETH`
- `CONFIG_ETH_USE_SPI_ETHERNET`

`CONFIG_ETH_USE_ESP32_EMAC`
Support ESP32 internal EMAC controller

Found in: `Component config > Ethernet`

ESP32 integrates a 10/100M Ethernet MAC controller.

Default value:
- Yes (enabled)

Contains:

- `CONFIG_ETH_DMA_RX_BUFFER_NUM`
- `CONFIG_ETH_DMA_TX_BUFFER_NUM`
- `CONFIG_ETH_SOFT_FLOW_CONTROL`
- `CONFIG_ETH_DMA_BUFFER_SIZE`
- `CONFIG_ETH_RMII_CLK_OUTPUT_GPIO0`
- `CONFIG_ETH_PHY_INTERFACE`
- `CONFIG_ETH_RMII_CLK_OUT_GPIO`
- `CONFIG_ETH_RMII_CLK_MODE`

`CONFIG_ETH_PHY_INTERFACE`
PHY interface

Found in: `Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC`

Select the communication interface between MAC and PHY chip.

Available options:
- Reduced Media Independent Interface (RMII) (ETH_PHY_INTERFACE_RMII)

`CONFIG_ETH_RMII_CLK_MODE`
RMII clock mode

Found in: `Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC`

Select external or internal RMII clock.

Available options:
- Input RMII clock from external (ETH_RMII_CLK_INPUT)
  MAC will get RMII clock from outside. Note that ESP32 only supports GPIO0 to input the
  RMII clock
- Output RMII clock from internal (ETH_RMII_CLK_OUTPUT)
  ESP32 can generate RMII clock by internal APLL. This clock can be routed to the external
  PHY device. ESP32 supports to route the RMII clock to GPIO0/16/17.

`CONFIG_ETH_RMII_CLK_OUTPUT_GPIO0`
Output RMII clock from GPIO0 (Experimental!)

Found in: `Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC`

GPIO0 can be set to output a pre-divided PLL clock (test only!). Enabling this option will configure
GPIO0 to output a 50MHz clock. In fact this clock doesn’t have directly relationship with EMAC
peripheral. Sometimes this clock won’t work well with your PHY chip. You might need to add some
extra devices after GPIO0 (e.g. inverter). Note that outputting RMII clock on GPIO0 is an experimental practice. If you want the Ethernet to work with WiFi, don’t select GPIO0 output mode for stability.

**Default value:**
- No (disabled) if `ETH_RMII_CLK_OUTPUT && CONFIG_ETH_USE_ESP32_EMAC`

**CONFIG_ETH_RMII_CLK_OUT_GPIO**
RMII clock GPIO number

*Found in: Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC*

Set the GPIO number to output RMII Clock.

**Range:**
- from 16 to 17 if `CONFIG_ETH_RMII_CLK_OUTPUT_GPIO0 && ETH_RMII_CLK_OUTPUT && CONFIG_ETH_USE_ESP32_EMAC`

**Default value:**
- 17 if `CONFIG_ETH_RMII_CLK_OUTPUT_GPIO0 && ETH_RMII_CLK_OUTPUT && CONFIG_ETH_USE_ESP32_EMAC`

**CONFIG_ETH_DMA_BUFFER_SIZE**
Ethernet DMA buffer size (Byte)

*Found in: Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC*

Set the size of each buffer used by Ethernet MAC DMA.

**Range:**
- from 256 to 1600

**Default value:**
- 512

**CONFIG_ETH_DMA_RX_BUFFER_NUM**
Amount of Ethernet DMA Rx buffers

*Found in: Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC*

Number of DMA receive buffers. Each buffer’s size is `ETH_DMA_BUFFER_SIZE`. Larger number of buffers could increase throughput somehow.

**Range:**
- from 3 to 30

**Default value:**
- 10

**CONFIG_ETH_DMA_TX_BUFFER_NUM**
Amount of Ethernet DMA Tx buffers

*Found in: Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC*

Number of DMA transmit buffers. Each buffer’s size is `ETH_DMA_BUFFER_SIZE`. Larger number of buffers could increase throughput somehow.

**Range:**
- from 3 to 30

**Default value:**
- 10
CONFIG_ETH_SOFT_FLOW_CONTROL

Enable software flow control

*Found in:* Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC

Ethernet MAC engine on ESP32 doesn’t feature a flow control logic. The MAC driver can perform a software flow control if you enable this option. Note that, if the RX buffer number is small, enabling software flow control will cause obvious performance loss.

**Default value:**
- No (disabled) if `CONFIG_ETH_DMA_RX_BUFFER_NUM > 15` && `CONFIG_ETH_USE_ESP32_EMAC`

CONFIG_ETH_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.
Chapter 2. API Reference

**CONFIG_ETH_USE_OPENETH**

Support OpenCores Ethernet MAC (for use with QEMU)

*Found in: Component config > Ethernet*

OpenCores Ethernet MAC driver can be used when an ESP-IDF application is executed in QEMU. This driver is not supported when running on a real chip.

**Default value:**

- No (disabled)

Contains:

- `CONFIG_ETH_OPENETH_DMA_RX_BUFFER_NUM`
- `CONFIG_ETH_OPENETH_DMA_TX_BUFFER_NUM`

**CONFIG_ETH_OPENETH_DMA_RX_BUFFER_NUM**

Number of Ethernet DMA Rx buffers

*Found in: Component config > Ethernet > CONFIG_ETH_USE_OPENETH*

Number of DMA receive buffers, each buffer is 1600 bytes.

**Range:**

- from 1 to 64 if `CONFIG_ETH_USE_OPENETH`

**Default value:**

- 4 if `CONFIG_ETH_USE_OPENETH`

**CONFIG_ETH_OPENETH_DMA_TX_BUFFER_NUM**

Number of Ethernet DMA Tx buffers

*Found in: Component config > Ethernet > CONFIG_ETH_USE_OPENETH*

Number of DMA transmit buffers, each buffer is 1600 bytes.

**Range:**

- from 1 to 64 if `CONFIG_ETH_USE_OPENETH`

**Default value:**

- 1 if `CONFIG_ETH_USE_OPENETH`

**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_OTA_ALLOW_HTTP**

**CONFIG_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_ESP32_UNIVERSAL_MAC_ADDRESSES*

**CONFIG_ESP32_UNIVERSAL_MAC_ADDRESSES**
Number of universally administered (by IEEE) MAC address

*Found in: Component config > Hardware Settings > MAC Config*
Configure the number of universally administered (by IEEE) MAC addresses. During initialization, MAC addresses for each network interface are generated or derived from a single base MAC address. If the number of universal MAC addresses is four, all four interfaces (WiFi station, WiFi softap, Bluetooth and Ethernet) receive a universally administered MAC address. These are generated sequentially by adding 0, 1, 2 and 3 (respectively) to the final octet of the base MAC address. If the number of universal MAC addresses is two, only two interfaces (WiFi station and Bluetooth) receive a universally administered MAC address. These are generated sequentially by adding 0 and 1 (respectively) to the base MAC address. The remaining two interfaces (WiFi softap and Ethernet) receive local MAC addresses. These are derived from the universal WiFi station and Bluetooth MAC addresses, respectively. When using the default (Espressif-assigned) base MAC address, either setting can be used. When using a custom universal MAC address range, the correct setting will depend on the allocation of MAC addresses in this range (either 2 or 4 per device.)

**Available options:**
- Two (ESP32_UNIVERSAL_MAC_ADDRESSES_TWO)
- Four (ESP32_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.

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

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_MAX_WIFI_TX_POWER
- CONFIG_ESP_PHY_REDUCE_TX_POWER
- CONFIG_ESP_PHY_CALIBRATION_AND_DATA_STORAGE
- CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION

CONFIG_ESP_PHY_CALIBRATION_AND_DATA_STORAGE

Store phy calibration data in NVS

*Found in: Component config > PHY*

If this option is enabled, NVS will be initialized and calibration data will be loaded from there. PHY calibration will be skipped on deep sleep wakeup. If calibration data is not found, full calibration will be performed and stored in NVS. Normally, only partial calibration will be performed. If this option is disabled, full calibration will be performed.

If it’s easy that your board calibrate bad data, choose ‘n’. Two cases for example, you should choose ‘n’: 1. If your board is easy to be booted up with antenna disconnected. 2. Because of your board design, each time when you do calibration, the result are too unstable. If unsure, choose ‘y’.

**Default value:**
- Yes (enabled)

CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION

Use a partition to store PHY init data

*Found in: Component config > PHY*

If enabled, PHY init data will be loaded from a partition. When using a custom partition table, make sure that PHY data partition is included (type: ‘data’, subtype: ‘phy’). With default partition tables,
this is done automatically. If PHY init data is stored in a partition, it has to be flashed there, otherwise runtime error will occur.

If this option is not enabled, PHY init data will be embedded into the application binary.

If unsure, choose ‘n’.

**Default value:**
- No (disabled)

Contains:
- `CONFIG_ESP_PHY_DEFAULT_INIT_IF_INVALID`
- `CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN`

**CONFIG_ESP_PHY_DEFAULT_INIT_IF_INVALID**
Reset default PHY init data if invalid

*Found in: Component config > PHY > CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION*

If enabled, PHY init data will be restored to default if it cannot be verified successfully to avoid endless bootloops.

If unsure, choose ‘n’.

**Default value:**
- No (disabled) if `CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION`

**CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN**
Support multiple PHY init data bin

*Found in: Component config > PHY > CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION*

If enabled, the corresponding PHY init data type can be automatically switched according to the country code. China’s PHY init data bin is used by default. Can be modified by country information in API `esp_wifi_set_country()`. The priority of switching the PHY init data type is: 1. Country configured by API `esp_wifi_set_country()` and the parameter policy is `WIFI_COUNTRY_POLICY_MANUAL`. 2. Country notified by the connected AP. 3. Country configured by API `esp_wifi_set_country()` and the parameter policy is `WIFI_COUNTRY_POLICY_AUTO`.

**Default value:**
- No (disabled) if `CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION` & `CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN`

**CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN_EMBED**
Support embedded multiple phy init data bin to app bin

*Found in: Component config > PHY > CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION > CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN*

If enabled, multiple phy init data bin will 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_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)

**Power Management** Contains:
- CONFIG_PM_SLP_DISABLE_GPIO
- 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_USE_RTC_TIMER_REF

Use RTC timer to prevent time drift (EXPERIMENTAL)

Found in: Component config > Power Management > CONFIG_PM_ENABLE

When APB clock frequency changes, high-resolution timer (esp_timer) scale and base value need to be adjusted. Each adjustment may cause small error, and over time such small errors may cause time drift. If this option is enabled, RTC timer will be used as a reference to compensate for the drift. It is recommended that this option is only used if 32k XTAL is selected as RTC clock source.

Default value:
• No (disabled) if CONFIG_PM_ENABLE && ESP_TIMER_IMPL_FRC2

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_sel_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.

ESP System Settings  Contains:

- CONFIG_ESP_SYSTEM_RTC_EXT_XTAL_BOOTSTRAP_CYCLES
- CONFIG_ESP_CONSOLE_UART
- CONFIG_ESP_SYSTEM_ALLOW_RTC_FAST_MEM_AS_HEAP
- CONFIG_ESP_SYSTEM_EVENT_TASK_STACK_SIZE
- CONFIG_ESP_TASK_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_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 and 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 do a debug on runtime. This feature will switch system to single core mode.

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**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).

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**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.

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**Memory protection**

Contains:

- **CONFIG_ESP_SYSTEM_MEMPROT_FEATURE**

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**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.

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**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 \texttt{CONFIG\_ESP\_SYSTEM\_MEMPROT\_FEATURE}

\textbf{CONFIG\_ESP\_SYSTEM\_EVENT\_QUEUE\_SIZE}

System event queue size

\textit{Found in: Component config > ESP System Settings}

Config system event queue size in different application.

\textbf{Default value:}

• 32

\textbf{CONFIG\_ESP\_SYSTEM\_EVENT\_TASK\_STACK\_SIZE}

Event loop task stack size

\textit{Found in: Component config > ESP System Settings}

Config system event task stack size in different application.

\textbf{Default value:}

• 2304

\textbf{CONFIG\_ESP\_MAIN\_TASK\_STACK\_SIZE}

Main task stack size

\textit{Found in: Component config > ESP System Settings}

Configure the “main task” stack size. This is the stack of the task which calls \texttt{app\_main()}. If \texttt{app\_main()} returns then this task is deleted and its stack memory is freed.

\textbf{Default value:}

• 3584

\textbf{CONFIG\_ESP\_MAIN\_TASK\_AFFINITY}

Main task core affinity

\textit{Found in: Component config > ESP System Settings}

Configure the “main task” core affinity. This is the used core of the task which calls \texttt{app\_main()}. If \texttt{app\_main()} returns then this task is deleted.

\textbf{Available options:}

• CPU0 (ESP\_MAIN\_TASK\_AFFINITY\_CPU0)
• CPU1 (ESP\_MAIN\_TASK\_AFFINITY\_CPU1)
• No affinity (ESP\_MAIN\_TASK\_AFFINITY\_NO\_AFFINITY)

\textbf{CONFIG\_ESP\_MINIMAL\_SHARED\_STACK\_SIZE}

Minimal allowed size for shared stack

\textit{Found in: Component config > ESP System Settings}

Minimal value of size, in bytes, accepted to execute a expression with shared stack.

\textbf{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_UART_NUM

UART peripheral to use for console output (0-1)

*Found in: Component config > ESP System Settings*

This UART peripheral is used for console output from the ESP-IDF Bootloader and the app.

If the configuration is different in the Bootloader binary compared to the app binary, UART is reconfigured after the bootloader exits and the app starts.

Due to an ESP32 ROM bug, UART2 is not supported for console output via esp_rom_printf.

**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:**
- 1 if ESP_CONSOLE_UART_CUSTOM
- 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_CONSOLED_UART_CUSTOM

**Default value:**
- 3 if ESP_CONSOLED_UART_CUSTOM
- 44 if ESP_CONSOLED_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_INT_WDT**

Interrupt watchdog

**Found in:** Component config > ESP System Settings

This watchdog timer can detect if the FreeRTOS tick interrupt has not been called for a certain time, either because a task turned off interrupts and did not turn them on for a long time, or because an interrupt handler did not return. It will try to invoke the panic handler first and failing that reset the SoC.

**Default value:**
- Yes (enabled)

**CONFIG_ESP_INT_WDT_TIMEOUT_MS**

Interrupt watchdog timeout (ms)

**Found in:** Component config > ESP System Settings > CONFIG_ESP_INT_WDT

The timeout of the watchdog, in milliseconds. Make this higher than the FreeRTOS tick rate.

**Range:**
- from 10 to 10000
Default value:
- 300 if `CONFIG_ESP32_SPIRAM_SUPPORT` && `CONFIG_ESP_INT_WDT`
- 800 if `CONFIG_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.
Chapter 2. API Reference

**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:**
- Yes (enabled) if `CONFIG_ESP_TASK_WDT` && `CONFIG_FREERTOS_UNICORE`

**CONFIG_ESP_PANIC_HANDLER_IRAM**

Place panic handler code in IRAM

*Found in: Component config > ESP System Settings*

If this option is disabled (default), the panic handler code is placed in flash not IRAM. This means that if ESP-IDF crashes while flash cache is disabled, the panic handler will automatically re-enable flash cache before running GDB Stub or Core Dump. This adds some minor risk, if the flash cache status is also corrupted during the crash.

If this option is enabled, the panic handler code (including required UART functions) is placed in IRAM. This may be necessary to debug some complex issues with crashes while flash cache is disabled (for example, when writing to SPI flash) or when flash cache is corrupted when an exception is triggered.

**Default value:**
- No (disabled)

**CONFIG_ESP_DEBUG_STUBS_ENABLE**

OpenOCD debug stubs

*Found in: Component config > ESP System Settings*

Debug stubs are used by OpenOCD to execute pre-compiled onboard code which does some useful debugging stuff, e.g. GCOV data dump.

**Default value:**
- “COMPILER_OPTIMIZATION_LEVEL_DEBUG” if `CONFIG_ESP32_TRAX` && ESP32S2_TRAX && ESP32S3_TRAX

**CONFIG_ESP_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_IPCUSES_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_IMPL**
- **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 seing 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:**

Espressif Systems 1607 Release v5.0-dev-1077-g397639d

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• from 2048 to 65536

Default value:
• 3584

**CONFIG_ESP_TIMER_INTERRUPT_LEVEL**

Interrupt level

*Found in: Component config > High resolution timer (esp_timer)*

It sets the interrupt level for esp_timer ISR in range 1..3. A higher level (3) helps to decrease the ISR esp_timer latency.

**Range:**
• from 1 to 3
• from 1 to 1

**Default value:**
• 1

**CONFIG_ESP_TIMER_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)

**CONFIG_ESP_TIMER_IMPL**

Hardware timer to use for esp_timer

*Found in: Component config > High resolution timer (esp_timer)*

esp_timer APIs can be implemented using different hardware timers.

• “FRC2 (legacy)” implementation has been used in ESP-IDF v2.x - v4.1.
• “LAC timer of Timer Group 0” implementation is simpler, and has smaller run time overhead because software handling of timer overflow is not needed.
• “SYSTIMER” implementation is similar to “LAC timer of Timer Group 0” but for non ESP32 chips.

**Available options:**
• FRC2 (legacy) timer (ESP_TIMER_IMPL_FRC2)
• LAC timer of Timer Group 0 (ESP_TIMER_IMPL_TG0_LAC)
• SYSTIMER (ESP_TIMER_IMPL_SYSTIMER)

**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_GMAC_SUPPORT
• CONFIG_ESP32_WIFI_IRAM_OPT
• CONFIG_ESP32_WIFI_MGMT_SBUF_NUM
• CONFIG_ESP32_WIFI_NVS_ENABLED
• CONFIG_ESP_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 CONFIG_ESP32_SPIRAM_SUPPORT || ESP32S2_SPIRAM_SUPPORT || ESP32S3_SPIRAM_SUPPORT

Default value:
- 32 if CONFIG_ESP32_SPIRAM_SUPPORT || ESP32S2_SPIRAM_SUPPORT || 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 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 preferred 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 `CONFIG_ESP32_SPIRAM_SUPPORT` || `ESP32S2_SPIRAM_SUPPORT` || `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 && CONFIG_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:*

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Chapter 2. API Reference

- No (disabled) if `CONFIG_BT_ENABLED` && `CONFIG_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_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_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)
**Chapter 2. API Reference**

- 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_LONG_FILENAMES
- CONFIG_FATFS_MAX_LFN
- CONFIG_FATFS_FS_LOCK
Chapter 2. API Reference

• `CONFIG_FATFS_VOLUME_COUNT`
• `CONFIG_FATFS_CHOOSE_CODEPAGE`
• `CONFIG_FATFS_ALLOC_PREFER_EXTRAM`
• `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_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_LONG_FILENAMES`

Long filename support

*Found in: Component config > FAT Filesystem support*

Support long filenames in FAT. Long filename data increases memory usage. FATFS can be configured to store the buffer for long filename data in stack or heap.
### Available options:
- No long filenames (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:**
- 255

### CONFIG_FATFS_API_ENCODING

API character encoding

*Found in: Component config > FAT Filesystem support*

Choose encoding for character and string arguments/returns when using FATFS APIs. The encoding of arguments will usually depend on text editor settings.

**Available options:**
- API uses ANSI/OEM encoding (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 to the open objects.
* >0: Enable file lock function. The value defines how many files/sub-directories can be opened simultaneously under file lock control.

Note that the file lock control is independent of re-entrancy.

**Range:**
- from 0 to 65535

**Default value:**
- 0

### CONFIG_FATFS_TIMEOUT_MS

Timeout for acquiring a file lock, ms

*Found in: Component config > FAT Filesystem support*

This option sets FATFS configuration value _FS_TIMEOUT, scaled to milliseconds. Sets the number of milliseconds FATFS will wait to acquire a mutex when operating on an open file. For example, if one task is performing a lengthy operation, another task will wait for the first task to release the lock, and time out after amount of time set by this option.
Chapter 2. API Reference

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**

Prefer 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_CAPS_ALLOC || SPIRAM_USE_MALLOC

**CONFIG_FATFS_USE_FASTSEEK**

Enable fast seek algorithm when using lseek function through VFS FAT

*Found in: Component config > FAT Filesystem support*

The fast seek feature enables fast backward/long seek operations without FAT access by using an in-memory CLMT (cluster link map table). Please note, fast-seek is only allowed for read-mode files, if a file is opened in write-mode, the seek mechanism will automatically fallback to the default implementation.

Default value:
- No (disabled)

**CONFIG_FATFS_FASTSEEK_BUFFER_SIZE**

Fast seek CLMT buffer size

*Found in: Component config > FAT Filesystem support > CONFIG_FATFS_USE_FASTSEEK*

If fast seek algorithm is enabled, this defines the size of CLMT buffer used by this algorithm in 32-bit word units. This value should be chosen based on prior knowledge of maximum elements of each file entry would store.

Default value:
- 64 if CONFIG_FATFS_USE_FASTSEEK
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`
- `CONFIG_FMB_TIMER_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.
**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).

**Range:**
- from 3 to 23

**Default value:**
- 10

**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 task stack size. The Stack size may be adjusted when debug mode is used which requires more stack size (for example).

*Found in: Component config > Modbus configuration*

**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:
  • No (disabled)

**FreeRTOS** Contains:

- `CONFIG_FREERTOS_FPU_IN_ISR`
- `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_ENABLE_TASK_SNAPSHOT`
- `CONFIG_FREERTOS_TASK_FUNCTION_WRAPPER`
- `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_CHECK_PORT_CRITICAL_COMPLIANCE`
- `CONFIG_FREERTOS_HZ`
- `CONFIG_FREERTOS_USE_TICKLESS_IDLE`
- `CONFIG_FREERTOS_LEGACY_HOOKS`
- `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
- SYSTIMER 0 (level 1) (FREERTOS_CORETIMER_SYSTIMER_LVL1)
  Select this to use systimer with the 1 interrupt priority.
- SYSTIMER 0 (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 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_LEGACY_HOOKS**

Use FreeRTOS legacy hooks

*Found in: Component config > FreeRTOS*

FreeRTOS offers a number of hooks/callback functions that are called when a timer tick happens, the idle thread runs etc. esp-idf replaces these by runtime registerable hooks using the esp_register_freertos_xxx_hook system, but for legacy reasons the old hooks can also still be enabled. Please enable this only if you have code that for some reason can’t be migrated to the esp_register_freertos_xxx_hook system.

**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_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 > CON-
FIG_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_FPU_IN_ISR
Allow use of float inside Level 1 ISR (EXPERIMENTAL)

Found in: Component config > FreeRTOS

When enabled, the usage of float type is allowed inside Level 1 ISRs.

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 assertion level. e.g. If the system assertion is disabled, then the HAL assertion can’t be enabled either. If the system assertion is enable, then the HAL assertion can still be disabled by this Kconfig option.

Available options:

• Same as system assertion level (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:
Chapter 2. API Reference

- 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 ESP32’s RTC and FRC1 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_ETHARP_TRUST_IP_MAC
- 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_MSBCHAP_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_GRPRTUOUS_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_TCPIP_CORE_LOCKING**

Enable tcpip core locking

*Found in: Component config > LWIP*

If Enable tcpip core locking, creates a global mutex that is held during TCPIP thread operations. Can be locked by client code to perform lwIP operations without changing into TCPIP thread using callbacks. See LOCK_TCPIP_CORE() and UNLOCK_TCPIP_CORE().

If disable tcpip core locking, 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.
Chapter 2. API Reference

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. Use VFS_SUPPORT_SELECT instead, which is the inverse of this option. The virtual filesystem layer of select() redirects sockets to lwip_select() and non-socket file descriptors to their respective driver implementations. If this option is enabled then all calls of select() will be redirected to lwip_select(), therefore, select can be used for sockets only.

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)
Chapter 2. API Reference

CONFIG_LWIP_SO_RCVBUF
Enable SO_RCVBUF option

*Found in: Component config > LWIP*

Enabling this option allows checking for available data on a netconn.

**Default value:**
- No (disabled)

CONFIG_LWIP_NETBUF_RECVINFO
Enable IP_PKTINFO option

*Found in: Component config > LWIP*

Enabling this option allows checking for the destination address of a received IPv4 Packet.

**Default value:**
- No (disabled)

CONFIG_LWIP_IP4_FRAG
Enable fragment outgoing IP4 packets

*Found in: Component config > LWIP*

Enabling this option allows fragmenting outgoing IP4 packets if their size exceeds MTU.

**Default value:**
- Yes (enabled)

CONFIG_LWIP_IP6_FRAG
Enable fragment outgoing IP6 packets

*Found in: Component config > LWIP*

Enabling this option allows fragmenting outgoing IP6 packets if their size exceeds MTU.

**Default value:**
- Yes (enabled)

CONFIG_LWIP_IP4_REASSEMBLY
Enable reassembly incoming fragmented IP4 packets

*Found in: Component config > LWIP*

Enabling this option allows reassembling incoming fragmented IP4 packets.

**Default value:**
- No (disabled)

CONFIG_LWIP_IP6_REASSEMBLY
Enable reassembly incoming fragmented IP6 packets

*Found in: Component config > LWIP*

Enabling this option allows reassembling incoming fragmented IP6 packets.

**Default value:**
- No (disabled)
CONFIG_LWIP_IP_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_ETHARP_TRUST_IP_MAC
Enable LWIP ARP trust

*Found in: Component config > LWIP*

Enabling this option allows ARP table to be updated.

If this option is enabled, the incoming IP packets cause the ARP table to be updated with the source MAC and IP addresses supplied in the packet. You may want to disable this if you do not trust LAN peers to have the correct addresses, or as a limited approach to attempt to handle spoofing. If disabled, LWIP will need to make a new ARP request if the peer is not already in the ARP table, adding a little latency. The peer *is* in the ARP table if it requested our address before. Also notice that this slows down input processing of every IP packet!

There are two known issues in real application if this feature is enabled: - The LAN peer may have bug to update the ARP table after the ARP entry is aged out. If the ARP entry on the LAN peer is aged out but failed to be updated, all IP packets sent from LWIP to the LAN peer will be dropped by LAN peer.
- The LAN peer may not be trustful, the LAN peer may send IP packets to LWIP with two different MACs, but the same IP address. If this happens, the LWIP has problem to receive IP packets from LAN peer.

So the recommendation is to disable this option. Here the LAN peer means the other side to which the ESP station or soft-AP is connected.

**Default value:**
- No (disabled)
CONFIG_LWIP_ESP_GRATUITOUS_ARP

Send gratuitous ARP periodically

*Found in: Component config > LWIP*

Enable this option allows to send gratuitous ARP periodically. This option solve the compatibility issues. If the ARP table of the AP is old, and the AP doesn’t send ARP request to update it’s ARP table, this will lead to the STA sending IP packet fail. Thus we send gratuitous ARP periodically to let AP update it’s ARP table.

*Default value:*
  - Yes (enabled)

CONFIG_LWIP_GARP_TMR_INTERVAL

GARP timer interval(seconds)

*Found in: Component config > LWIP > CONFIG_LWIP_ESP_GRATUITOUS_ARP*

Set the timer interval for gratuitous ARP. The default value is 60s

*Default value:*
  - 60

CONFIG_LWIP_TCPIP_RECVMBOX_SIZE

TCPIP task receive mail box size

*Found in: Component config > LWIP*

Set TCPIP task receive mail box size. Generally bigger value means higher throughput but more memory. The value should be bigger than UDP/TCP mail box size.

*Range:*
  - from 6 to 64 if CONFIG_LWIP_WND_SCALE
  - from 6 to 1024 if CONFIG_LWIP_WND_SCALE

*Default value:*
  - 32

CONFIG_LWIP_DHCP_DOES_ARP_CHECK

DHCP: Perform ARP check on any offered address

*Found in: Component config > LWIP*

Enabling this option performs a check (via ARP request) if the offered IP address is not already in use by another host on the network.

*Default value:*
  - Yes (enabled)

CONFIG_LWIP_DHCP_DISABLE_CLIENT_ID

DHCP: Disable Use of HW address as client identification

*Found in: Component config > LWIP*

This option could be used to disable DHCP client identification with its MAC address. (Client id is used by DHCP servers to uniquely identify clients and are included in the DHCP packets as an option 61) Set this option to “y” in order to exclude option 61 from DHCP packets.

*Default value:*
  - No (disabled)
**CONFIG_LWIP_DHCP_DISABLE_VENDOR_CLASS_ID**

DHCP: Disable Use of vendor class identification

*Found in: Component config > LWIP*

This option could be used to disable DHCP client vendor class identification. Set this option to “y” in order to exclude option 60 from DHCP packets.

**Default value:**
- Yes (enabled)

**CONFIG_LWIP_DHCP_RESTORE_LAST_IP**

DHCP: Restore last IP obtained from DHCP server

*Found in: Component config > LWIP*

When this option is enabled, DHCP client tries to re-obtain last valid IP address obtained from DHCP server. Last valid DHCP configuration is stored in nvs and restored after reset/power-up. If IP is still available, there is no need for sending discovery message to DHCP server and save some time.

**Default value:**
- No (disabled)

**CONFIG_LWIP_DHCP_OPTIONS_LEN**

DHCP total option length

*Found in: Component config > LWIP*

Set total length of outgoing DHCP option msg. Generally bigger value means it can carry more options and values. If your code meets LWIP_ASSERT due to option value is too long. Please increase the LWIP_DHCP_OPTIONS_LEN value.

**Range:**
- from 68 to 255

**Default value:**
- 68
- 108

**DHCP server**

Contains:
- **CONFIG_LWIP_DHCP**

**CONFIG_LWIP_DHCP**

DHCP: 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_DHCPLEASE_UNIT**

Multiplier for lease time, in seconds

*Found in: Component config > LWIP > DHCP server > CONFIG_LWIP_DHCP*

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.
Chapter 2. API Reference

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.

**Default value:**
- Yes (enabled)

Contains:
- CONFIG_LWIP_LOOPBACK_MAX_PBUFS

CONFIG_LWIP_LOOPBACK_MAX_PBUFS

Max queued loopback packets per interface

*Found in: Component config > LWIP > CONFIG_LWIP_NETIF_LOOPBACK*

Configure the maximum number of packets which can be queued for loopback on a given interface. Reducing this number may cause packets to be dropped, but will avoid filling memory with queued packet data.

**Range:**
- from 0 to 16

**Default value:**
**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_TCP_KEEP_CONNECTION_WHEN_IP_CHANGES`
- `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_TCP_SACK_OUT`
- `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*
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_RECVMBBOX_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_RECVMBBOX_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*

TCP will support sending selective acknowledgements (SACKs).

**Default value:**

- No (disabled)

**CONFIG_LWIP_TCP_KEEP_CONNECTION_WHEN_IP_CHANGES**

Keep TCP connections when IP changed

*Found in: Component config > LWIP > TCP*

This option is enabled when the following scenario happen: network dropped and reconnected, IP changes is like: 192.168.0.2->0.0.0.0->192.168.0.2

Disable this option to keep consistent with the original LWIP code behavior.

**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_RECCVMBOX_SIZE packets for each UDP socket, so the maximum possible cached UDP packets for all UDP sockets is UDP_RECCVMBOX_SIZE multiples the maximum UDP socket number. In other words, the bigger UDP_RECCVMBOX_SIZE means more memory. On the other hand, if the receive mail box is too small, the mail box may be full. If the mail box is full, the LWIP drops the packets. So generally we need to make sure the UDP receive mail box is big enough to avoid packet drop between LWIP core and application.

**Range:**
- from 6 to 64

**Default value:**
- 6

**Checksums**
Contains:
- CONFIG_LWIP_CHECKSUM_CHECK_ICMP
- CONFIG_LWIP_CHECKSUM_CHECK_IP
- CONFIG_LWIP_CHECKSUM_CHECK_UDP

CONFIG_LWIP_CHECKSUM_CHECK_IP

Enable LWIP IP checksums

*Found in: Component config > LWIP > Checksums*

Enable checksum checking for received IP messages

**Default value:**
- No (disabled)

CONFIG_LWIP_CHECKSUM_CHECK_UDP

Enable LWIP UDP checksums

*Found in: Component config > LWIP > Checksums*

Enable checksum checking for received UDP messages

**Default value:**
- No (disabled)

CONFIG_LWIP_CHECKSUM_CHECK_ICMP

Enable LWIP ICMP checksums

*Found in: Component config > LWIP > Checksums*

Enable checksum checking for received ICMP messages

**Default value:**
- Yes (enabled)
**CONFIG_LWIP_TCPIP_TASK_STACK_SIZE**

TCP/IP Task Stack Size

 FOUND in: Component config > LWIP

Configure TCP/IP task stack size, used by LWIP to process multi-threaded TCP/IP operations. Setting this stack too small will result in stack overflow crashes.

 Range: 
  - from 2048 to 65536

 Default value: 
  - 3072

**CONFIG_LWIP_TCPIP_TASK_AFFINITY**

TCP/IP task affinity

 FOUND in: Component config > LWIP

Allows setting LwIP tasks affinity, i.e. whether the task is pinned to CPU0, pinned to CPU1, or allowed to run on any CPU. Currently this applies to “TCP/IP” task and “Ping” task.

 Available options: 
  - No affinity (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.
Chapter 2. API Reference

**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 20

**Default value:**
- 3

**CONFIG_LWIP_PPP_NOTIFY_PHASE_SUPPORT**
Enable Notify Phase Callback

*Found in: Component config > LWIP*

Enable to set a callback which is called on change of the internal PPP state machine.

**Default value:**
- No (disabled) if `CONFIG_LWIP_PPP_SUPPORT`

**CONFIG_LWIP_PPP_PAP_SUPPORT**
Enable PAP support

*Found in: Component config > LWIP*

Enable Password Authentication Protocol (PAP) support

**Default value:**
- No (disabled) if `CONFIG_LWIP_PPP_SUPPORT`

**CONFIG_LWIP_PPP_CHAP_SUPPORT**
Enable CHAP support

*Found in: Component config > LWIP*

Enable Challenge Handshake Authentication Protocol (CHAP) support

**Default value:**
- No (disabled) if `CONFIG_LWIP_PPP_SUPPORT`

**CONFIG_LWIP_PPP_MSCHAP_SUPPORT**
Enable MSCHAP support

*Found in: Component config > LWIP*

Enable Microsoft version of the Challenge-Handshake Authentication Protocol (MSCHAP) support

**Default value:**
- No (disabled) if `CONFIG_LWIP_PPP_SUPPORT`
CONFIG_LWIP_PPP_MPPE_SUPPORT
Enable MPPE support

*Found in: Component config > LWIP*
Enable Microsoft Point-to-Point Encryption (MPPE) support

**Default value:**
- No (disabled) if `CONFIG_LWIP_PPP_SUPPORT`

CONFIG_LWIP_ENABLE_LCP_ECHO
Enable LCP ECHO

*Found in: Component config > LWIP*
Enable LCP echo keepalive requests

**Default value:**
- No (disabled) if `CONFIG_LWIP_PPP_SUPPORT`

CONFIG_LWIP_LCP_ECHOINTERVAL
Echo interval (s)

*Found in: Component config > LWIP > CONFIG_LWIP_ENABLE_LCP_ECHO*
Interval in seconds between keepalive LCP echo requests, 0 to disable.

**Range:**
- from 0 to 1000000 if `CONFIG_LWIP_ENABLE_LCP_ECHO`

**Default value:**
- 3 if `CONFIG_LWIP_ENABLE_LCP_ECHO`

CONFIG_LWIP_LCP_MAXECHOFAILS
Maximum echo failures

*Found in: Component config > LWIP > CONFIG_LWIP_ENABLE_LCP_ECHO*
Number of consecutive unanswered echo requests before failure is indicated.

**Range:**
- from 0 to 100000 if `CONFIG_LWIP_ENABLE_LCP_ECHO`

**Default value:**
- 3 if `CONFIG_LWIP_ENABLE_LCP_ECHO`

CONFIG_LWIP_PPP_DEBUG_ON
Enable PPP debug log output

*Found in: Component config > LWIP*
Enable PPP debug log output

**Default value:**
- No (disabled) if `CONFIG_LWIP_PPP_SUPPORT`
CONFIG_LWIP_SLIP_SUPPORT

Enable SLIP support (new/experimental)

*Found in: Component config > LWIP*

Enable SLIP stack. Now only SLIP over serial is possible. SLIP over serial support is experimental and unsupported.

*Default value:*
  - No (disabled)

Contains:
  - CONFIG_LWIP_SLIP_DEBUG_ON

CONFIG_LWIP_SLIP_DEBUG_ON

Enable SLIP debug log output

*Found in: Component config > LWIP > CONFIG_LWIP_SLIP_SUPPORT*

Enable SLIP debug log output

*Default value:*
  - No (disabled) if CONFIG_LWIP_SLIP_SUPPORT

ICMP

Contains:
  - CONFIG_LWIP_ICMP
  - CONFIG_LWIP_BROADCAST_PING
  - CONFIG_LWIP_MULTICAST_PING

CONFIG_LWIP_ICMP

ICMP: Enable ICMP

*Found in: Component config > LWIP > ICMP*

Enable ICMP module for check network stability

*Default value:*
  - Yes (enabled)

CONFIG_LWIP_MULTICAST_PING

Respond to multicast pings

*Found in: Component config > LWIP > ICMP*

*Default value:*
  - No (disabled)

CONFIG_LWIP_BROADCAST_PING

Respond to broadcast pings

*Found in: Component config > LWIP > ICMP*

*Default value:*
  - No (disabled)
LWIP RAW API  Contains:
  • CONFIG_LWIP_MAX_RAW_PCBS

CONFIG_LWIP_MAX_RAW_PCBS

Maximum LWIP RAW PCBs

*Found in: Component config > LWIP > LWIP RAW API*

The maximum number of simultaneously active LWIP RAW protocol control blocks. The practical maximum limit is determined by available heap memory at runtime.

*Range:*
  • from 1 to 1024

*Default value:*
  • 16

SNTP  Contains:
  • CONFIG_LWIP_SNTP_MAX_SERVERS
  • CONFIG_LWIP_SNTP_UPDATE_DELAY
  • CONFIG_LWIP_DHCP_GET_NTP_SRV

CONFIG_LWIP_SNTP_MAX_SERVERS

Maximum number of NTP servers

*Found in: Component config > LWIP > SNTP*

Set maximum number of NTP servers used by LwIP SNTP module. First argument of sntp_setserver/sntp_setservername 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_SNTP_UPDATE_DELAY

Request interval to update time (ms)

*Found in: Component config > LWIP > SNTP*

This option allows you to set the time update period via SNTP. Default is 1 hour. Must not be below 15 seconds by specification. (SNTPv4 RFC 4330 enforces a minimum update time of 15 seconds).

Range:
- from 15000 to 4294967295

**Default value:**
- 3600000

CONFIG_LWIP_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_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_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

Default value:
• No (disabled) if CONFIG_LWIP_DEBUG

CONFIG_LWIP_DHCP_DEBUG

Enable DHCP debug messages

Default value:
• No (disabled) if CONFIG_LWIP_DEBUG

CONFIG_LWIP_IP6_DEBUG

Enable IP6 debug messages

Default value:
• No (disabled) if CONFIG_LWIP_DEBUG

CONFIG_LWIP_ICMP6_DEBUG

Enable ICMP6 debug messages

Default value:
• No (disabled) if CONFIG_LWIP_DEBUG

CONFIG_LWIP_TCP_DEBUG

Enable TCP debug messages

Default value:
• No (disabled) if CONFIG_LWIP_DEBUG

CONFIG_LWIP_Sntp_DEBUG

Enable SNTP debug messages

Default value:
• No (disabled) if CONFIG_LWIP_DEBUG

mbedTLS Contains:

• CONFIGMBEDTLSASYMMETRICCONTENTLEN
• Certificate Bundle
• Certificates
• CONFIGMBEDTLSCHACHA20_C
• CONFIGMBEDTSLDHM_C
• CONFIGMBEDTLS_ECP_C
• CONFIGMBEDTLS_ECDH_C
Chapter 2. API Reference

- `CONFIG_MBEDTLS_ECPAKE_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_ECDSA_DETERMINISTIC`
- `CONFIG_MBEDTLS_HARDWARE_AES`
- `CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN`
- `CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY`
- `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`
- `CONFIG_MBEDTLS_MEM_ALLOC_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 malloc()/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_MBEDTLSASYMMETRICCONTENT_LEN

Asymmetric in/out fragment length

Found in: Component config > mbedTLS

If enabled, this option allows customizing TLS in/out fragment length in asymmetric way. Please note that enabling this with default values saves 12KB of dynamic memory per TLS connection.

Default value:
• Yes (enabled)

CONFIG_MBEDTLS_SSL_IN_CONTENT_LEN
TLS maximum incoming fragment length

*Found in: Component config > mbedTLS > CONFIG_MBEDTLSASYMMETRICCONTENT_LEN*

This defines maximum incoming fragment length, overriding default maximum content length (MBEDTLS_SSL_MAXCONTENT_LEN).

**Range:**
- from 512 to 16384

**Default value:**
- 16384

**CONFIG_MBEDTLS_SSL_OUT_CONTENT_LEN**

TLS maximum outgoing fragment length

*Found in: Component config > mbedTLS > CONFIG_MBEDTLSASYMMETRICCONTENT_LEN*

This defines maximum outgoing fragment length, overriding default maximum content length (MBEDTLS_SSL_MAXCONTENT_LEN).

**Range:**
- from 512 to 16384

**Default value:**
- 4096

**CONFIG_MBEDTLS_DYNAMIC_BUFFER**

Using dynamic TX/RX buffer

*Found in: Component config > mbedTLS*

Using dynamic TX/RX buffer. After enabling this option, mbedTLS will allocate TX buffer when need to send data and then free it if all data is sent, allocate RX buffer when need to receive data and then free it when all data is used or read by upper layer.

By default, when SSL is initialized, mbedTLS also allocate TX and RX buffer with the default value of “MBEDTLS_SSL_OUTCONTENT_LEN” or “MBEDTLS_SSL_INCONTENT_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_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_CA_CERT*

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)

**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_DEFAULT_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_DEFAULT_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_DEFAULT_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_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_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:**
Chapter 2. API Reference

• 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_PSK_MODES
• 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` && `CONFIG_MBEDTLS_DHM_C`

**CONFIG_MBEDTLS_KEY_EXCHANGE_ECDHE_PSK**

Enable ECDHE-PSK based ciphersuite modes

*Found in: Component config > mbedTLS > TLS Key Exchange Methods > CONFIG_MBEDTLS_PSK_MODES*

Enable to support Elliptic-Curve-Diffie-Hellman PSK (pre-shared-key) TLS authentication modes.

**Default value:**

- Yes (enabled) if `CONFIG_MBEDTLS_PSK_MODES` && `CONFIG_MBEDTLS_ECDH_C`

**CONFIG_MBEDTLS_KEY_EXCHANGE_RSA_PSK**

Enable RSA-PSK based ciphersuite modes

*Found in: Component config > mbedTLS > TLS Key Exchange Methods > CONFIG_MBEDTLS_PSK_MODES*

Enable to support RSA PSK (pre-shared-key) TLS authentication modes.

**Default value:**

- Yes (enabled) if `CONFIG_MBEDTLS_PSK_MODES`

**CONFIG_MBEDTLS_KEY_EXCHANGE_RSA**

Enable RSA-only based ciphersuite modes

*Found in: Component config > mbedTLS > TLS Key Exchange Methods*

Enable to support ciphersuites with prefix TLS-RSA-WITH-

**Default value:**

- Yes (enabled)

**CONFIG_MBEDTLS_KEY_EXCHANGE_DHE_RSA**

Enable DHE-RSA based ciphersuite modes

*Found in: Component config > mbedTLS > TLS Key Exchange Methods*

Enable to support ciphersuites with prefix TLS-DHE-RSA-WITH-

**Default value:**

- Yes (enabled) if `CONFIG_MBEDTLS_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)

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)
Chapter 2. API Reference

**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_CRLPARSE_C
- CONFIG_MBEDTLS_X509_CSRPARSE_C

CONFIG_MBEDTLS_PEMPARSE_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_PEMWRITE_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_CRLPARSE_C
X.509 CRL parsing
*Found in: Component config > mbedTLS > Certificates*
**Default value:**
- Yes (enabled)

CONFIG_MBEDTLS_X509_CSRPARSE_C
X.509 CSR parsing
*Found in: Component config > mbedTLS > Certificates*
Support for parsing X.509 Certificate Signing Requests
**Default value:**
- Yes (enabled)
CONFIG_MBEDTLS_ECP_C
Elliptic Curve Ciphers

*Found in: Component config > mbedTLS*

**Default value:**
- Yes (enabled)

CONFIG_MBEDTLS_DHM_C
Diffie-Hellman-Merkle key exchange (DHM)

*Found in: Component config > mbedTLS*

Enable DHM. Needed to use DHE-xxx TLS ciphersuites.

Note that the security of Diffie-Hellman key exchanges depends on a suitable prime being used for the exchange. Please see detailed warning text about this in file `mbedtls/dhm.h` file.

**Default value:**
- No (disabled)

CONFIG_MBEDTLS_ECDH_C
Elliptic Curve Diffie-Hellman (ECDH)

*Found in: Component config > mbedTLS*

Enable ECDH. Needed to use ECDHE-xxx TLS ciphersuites.

**Default value:**
- Yes (enabled)

CONFIG_MBEDTLS_ECDSA_C
Elliptic Curve DSA

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECDH_C*

Enable ECDSA. Needed to use ECDSA-xxx TLS ciphersuites.

**Default value:**
- Yes (enabled)

CONFIG_MBEDTLS_ECJPAKE_C
Elliptic curve J-PAKE

*Found in: Component config > mbedTLS*

Enable ECJPAKE. Needed to use ECJPAKE-xxx TLS ciphersuites.

**Default value:**
- No (disabled)

CONFIG_MBEDTLS_ECP_DP_SECP192R1_ENABLED
Enable SECP192R1 curve

*Found in: Component config > mbedTLS*

Enable support for SECP192R1 Elliptic Curve.

**Default value:**
- Yes (enabled) if \((CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN || CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY) && CONFIG_MBEDTLS_ECP_C\)
CONFIG_MBEDTLS_ECP_DP_SECP224R1_ENABLED
Enable SECP224R1 curve

Found in: Component config > mbedTLS
Enable support for SECP224R1 Elliptic Curve.

Default value:
- Yes (enabled) if (CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN || CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY) && CONFIG_MBEDTLS_ECP_C

CONFIG_MBEDTLS_ECP_DP_SECP256R1_ENABLED
Enable SECP256R1 curve

Found in: Component config > mbedTLS
Enable support for SECP256R1 Elliptic Curve.

Default value:
- Yes (enabled)

CONFIG_MBEDTLS_ECP_DP_SECP384R1_ENABLED
Enable SECP384R1 curve

Found in: Component config > mbedTLS
Enable support for SECP384R1 Elliptic Curve.

Default value:
- Yes (enabled) if (CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN || CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY) && CONFIG_MBEDTLS_ECP_C

CONFIG_MBEDTLS_ECP_DP_SECP521R1_ENABLED
Enable SECP521R1 curve

Found in: Component config > mbedTLS
Enable support for SECP521R1 Elliptic Curve.

Default value:
- Yes (enabled) if (CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN || CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY) && CONFIG_MBEDTLS_ECP_C

CONFIG_MBEDTLS_ECP_DP_SECP192K1_ENABLED
Enable SECP192K1 curve

Found in: Component config > mbedTLS
Enable support for SECP192K1 Elliptic Curve.

Default value:
- Yes (enabled) if (CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN || CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY) && CONFIG_MBEDTLS_ECP_C

CONFIG_MBEDTLS_ECP_DP_SECP224K1_ENABLED
Enable SECP224K1 curve

Found in: Component config > mbedTLS
Enable support for SECP224K1 Elliptic Curve.
Default value:
• Yes (enabled) if (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 (CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN || CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY) && CONFIG_MBEDTLS_ECP_C
CONFIG_MBEDTLS_ECP_NIST_OPTIM

NIST ‘modulo p’ optimisations

*Found in: Component config > mbedTLS*

NIST ‘modulo p’ optimisations increase Elliptic Curve operation performance.
Disabling this option saves some code size.

# end of Elliptic Curve options

**Default value:**
- Yes (enabled)

CONFIG_MBEDTLS_POLY1305_C

Poly1305 MAC algorithm

*Found in: Component config > mbedTLS*

Enable support for Poly1305 MAC algorithm.

**Default value:**
- No (disabled)

CONFIG_MBEDTLS_CHACHA20_C

Chacha20 stream cipher

*Found in: Component config > mbedTLS*

Enable support for Chacha20 stream cipher.

**Default value:**
- No (disabled)

CONFIG_MBEDTLS_CHACHAPOLY_C

ChaCha20-Poly1305 AEAD algorithm

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_CHACHA20_C*

Enable support for ChaCha20-Poly1305 AEAD algorithm.

**Default value:**
- No (disabled) if `CONFIG_MBEDTLS_CHACHA20_C` && `CONFIG_MBEDTLS_POLY1305_C`

CONFIG_MBEDTLS_HKDF_C

HKDF algorithm (RFC 5869)

*Found in: Component config > mbedTLS*

Enable support for the Hashed Message Authentication Code (HMAC)-based key derivation function (HKDF).

**Default value:**
- No (disabled)
**CONFIG_MBEDTLS_THREADING_C**

Enable the threading abstraction layer

*Found in: Component config > mbedTLS*

If you do intend to use contexts between threads, you will need to enable this layer to prevent race conditions.

**Default value:**
- No (disabled)

**CONFIG_MBEDTLS_THREADING_ALT**

Enable threading alternate implementation

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_THREADING_C*

Enable threading alt to allow your own alternate threading implementation.

**Default value:**
- 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 stack size.

*Default value:*
• 4096

**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)

**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.
**CONFIG_MQTT_MSG_ID_INCREMENTAL**

Use Incremental Message Id

*Found in: Component config > ESP-MQTT Configurations*

Set this to true for the message id (2.3.1 Packet Identifier) to be generated as an incremental number rather then a random value (used by default)

**Default value:**

- No (disabled)

**CONFIG_MQTT_SKIP_PUBLISH_IF_DISCONNECTED**

Skip publish if disconnected

*Found in: Component config > ESP-MQTT Configurations*

Set this to true to avoid publishing (enqueuing 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
Chapter 2. API Reference

**CONFIG_MQTT_SSL_DEFAULT_PORT**
Default MQTT over SSL port

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

Default MQTT over SSL port

**Default value:**
- 8883 if `CONFIG_MQTT_USE_CUSTOM_CONFIG` & `CONFIG_MQTT_TRANSPORT_SSL`

**CONFIG_MQTT_WS_DEFAULT_PORT**
Default MQTT over Websocket port

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

Default MQTT over Websocket port

**Default value:**
- 80 if `CONFIG_MQTT_USE_CUSTOM_CONFIG` & `CONFIG_MQTT_TRANSPORT_WEBSOCKET`

**CONFIG_MQTT_WSS_DEFAULT_PORT**
Default MQTT over Websocket Secure port

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

Default MQTT over Websocket Secure port

**Default value:**
- 443 if `CONFIG_MQTT_USE_CUSTOM_CONFIG` & `CONFIG_MQTT_TRANSPORT_WEBSOCKET_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*

MQTT task stack size

**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:**
**CONFIG_MQTT_TASK_PRIORITY**

MQTT task priority

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

MQTT task priority. Higher number denotes higher priority.

**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).

**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`
Chapter 2. API Reference

**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)
Chapter 2. API Reference

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_COMMISSIONER**

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
Chapter 2. API Reference

**CONFIG_OPENTHREAD_JOINER**

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_SRPL_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)
Chapter 2. API Reference

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_SHORT_BUS
- 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.
Chapter 2. API Reference

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_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.

**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:**
-
Chapter 2. API Reference

• 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 option helps to set individual write chunk size, smaller value here ensures that cache (and non-IRAM resident interrupts) remains disabled for shorter duration.

**Range:**
• from 256 to 8192

**Default value:**
• 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_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:**
**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:**
- No (disabled)
- 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/disables memory read caching of nucleus file system operations.

**Default value:**
- Yes (enabled)

### CONFIG_SPIFFS_CACHE_WR
Enable SPIFFS Write Caching

*Found in: Component config > SPIFFS Configuration > SPIFFS Cache Configuration > CONFIG_SPIFFS_CACHE*

Enables memory write caching for file descriptors in hydrogen.

**Default value:**
- Yes (enabled)

### CONFIG_SPIFFS_CACHE_STATS
Enable SPIFFS Cache Statistics

*Found in: Component config > SPIFFS Configuration > SPIFFS Cache Configuration > CONFIG_SPIFFS_CACHE*

Enable/disable statistics on caching. Debug/test purpose only.

**Default value:**
- No (disabled)

### CONFIG_SPIFFS_PAGE_CHECK
Enable SPIFFS Page Check

*Found in: Component config > SPIFFS Configuration*

Always check header of each accessed page to ensure consistent state. If enabled it will increase number of reads from flash, especially if cache is disabled.

**Default value:**
- Yes (enabled)

### CONFIG_SPIFFS_GC_MAX_RUNS
Set Maximum GC Runs

*Found in: Component config > SPIFFS Configuration*

Define maximum number of GC runs to perform to reach desired free pages.

**Range:**
- from 1 to 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)
Chapter 2. API Reference

**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 support time_t 64 bits (see SDK_TOOLCHAIN_SUPPORTS_TIME_WIDE_64BITS).

**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
Chapter 2. API Reference

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

Unity unit testing library Contains:

• CONFIG.Unity_ENABLE_COLOR
• CONFIG.Unity_ENABLE_IDF_TEST_RUNNER
• CONFIG.Unity_ENABLE_FIXTURE
• CONFIG.Unity_ENABLE_BACKTRACE_ON_FAIL
• CONFIG.Unity_ENABLE_64BIT
• CONFIG.Unity_ENABLE_DOUBLE
• CONFIG.Unity_ENABLE_FLOAT

CONFIG.Unity_ENABLE_FLOAT
Support for float type

Found in: Component config > Unity unit testing library
If not set, assertions on float arguments will not be available.

Default value:
• Yes (enabled)

CONFIG.Unity_ENABLE_DOUBLE
Support for double type

Found in: Component config > Unity unit testing library
If not set, assertions on double arguments will not be available.

Default value:
• Yes (enabled)
**CONFIGUNITY_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 \texttt{UNITY\_ASSERT\_EQUAL}, as that will cause pointer-to-int- cast warnings.

**Default value:**
- No (disabled)

**CONFIGUNITY_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)

**CONFIGUNITY_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)

**CONFIGUNITY_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)
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 de-
  scriptors (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 unconventionally 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.
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_A2DP_ENABLE` (*CONFIG_BT_A2DP_ENABLE*)
- `CONFIG_A2D_INITIAL_TRACE_LEVEL` (*CONFIG_BT_LOG_A2D_TRACE_LEVEL*)
  - `CONFIG_A2D_TRACE_LEVEL_NONE`
  - `CONFIG_A2D_TRACE_LEVEL_ERROR`
  - `CONFIG_A2D_TRACE_LEVEL_WARNING`
  - `CONFIG_A2D_TRACE_LEVEL_API`
  - `CONFIG_A2D_TRACE_LEVEL_EVENT`
  - `CONFIG_A2D_TRACE_LEVEL_DEBUG`
  - `CONFIG_A2D_TRACE_LEVEL_VERBOSE`
- `CONFIG_ADC2_DISABLE_DAC` (*CONFIG_ADC_DISABLE_DAC*)
- `CONFIG_APPL_INITIAL_TRACE_LEVEL` (*CONFIG_BT_LOG_APPL_TRACE_LEVEL*)
  - `CONFIG_APPL_TRACE_LEVEL_NONE`
  - `CONFIG_APPL_TRACE_LEVEL_ERROR`
  - `CONFIG_APPL_TRACE_LEVEL_WARNING`
  - `CONFIG_APPL_TRACE_LEVEL_API`
  - `CONFIG_APPL_TRACE_LEVEL_EVENT`
  - `CONFIG_APPL_TRACE_LEVEL_DEBUG`
  - `CONFIG_APPL_TRACE_LEVEL_VERBOSE`
- `CONFIG_APP_ANTI_ROLLBACK` (*CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK*)
- `CONFIG_APP_ROLLBACK_ENABLE` (*CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE*)
- `CONFIG_APP_SECURE_VERSION` (*CONFIG_BOOTLOADER_APP_SECURE_VERSION*)
- `CONFIG_APP_SECURE_VERSION_SIZE_EFUSE_FIELD` (*CONFIG_BOOTLOADER_APP_SEC_VER_SIZE_EFUSE_FIELD*)
- `CONFIG_AVCT_INITIAL_TRACE_LEVEL` (*CONFIG_BT_LOG_AVCT_TRACE_LEVEL*)
  - `CONFIG_AVCT_TRACE_LEVEL_NONE`
  - `CONFIG_AVCT_TRACE_LEVEL_ERROR`
  - `CONFIG_AVCT_TRACE_LEVEL_WARNING`
  - `CONFIG_AVCT_TRACE_LEVEL_API`
  - `CONFIG_AVCT_TRACE_LEVEL_EVENT`
  - `CONFIG_AVCT_TRACE_LEVEL_DEBUG`
  - `CONFIG_AVCT_TRACE_LEVEL_VERBOSE`
- `CONFIG_AVDT.Initial_trace_level` (*CONFIG_BT_LOG_AVDT_TRACE_LEVEL*)
  - `CONFIG_AVDT_TRACE_LEVEL_NONE`
  - `CONFIG_AVDT_TRACE_LEVEL_ERROR`
  - `CONFIG_AVDT_TRACE_LEVEL_WARNING`
  - `CONFIG_AVDT_TRACE_LEVEL_API`
  - `CONFIG_AVDT_TRACE_LEVEL_EVENT`
  - `CONFIG_AVDT_TRACE_LEVEL_DEBUG`
  - `CONFIG_AVDT_TRACE_LEVEL_VERBOSE`
- CONFIG_AVDT_TRACE_LEVEL_VERBOSE

- CONFIG_AVRC_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_AVRC_TRACE_LEVEL)
  - CONFIG_AVRC_TRACE_LEVEL_NONE
  - CONFIG_AVRC_TRACE_LEVEL_ERROR
  - CONFIG_AVRC_TRACE_LEVEL_WARNING
  - CONFIG_AVRC_TRACE_LEVEL_API
  - CONFIG_AVRC_TRACE_LEVEL_EVENT
  - CONFIG_AVRC_TRACE_LEVEL_DEBUG
  - CONFIG_AVRC_TRACE_LEVEL_VERBOSE

- CONFIG_BLE_ACTIVE_SCAN_REPORT_ADV_SCAN_RSP_INDIVIDUALLY (CONFIG_BT_BLE_ACT_SCAN_REP_ADV_SCAN)

- CONFIG_BLE_ADV_REPORT_DISCARD_THRESHOLD (CONFIG_BTDM_BLE_ADV_REPORT_DISCARD_THRESHOLD)

- CONFIG_BLE_ADV_REPORT_FLOW_CONTROL_NUM (CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_NUM)

- CONFIG_BLE_ADV_REPORT_FLOW_CONTROL_SUPPORTED (CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP)

- CONFIG_BLE_ESTABLISH_LINK_CONNECTION_TIMEOUT (CONFIG_BT_BLE_ESTAB_LINK_CONN_TOUT)

- CONFIG_BLE_HOST_QUEUE_CONGESTION_CHECK (CONFIG_BT_BLE_HOST_QUEUE_CONG_CHECK)

- CONFIG_BLE_MESH_GATT_PROXY (CONFIG_BLE_MESH_GATT_PROXY_SERVER)

- CONFIG_BLE_MESH_SCAN_DUPLICATE_EN (CONFIG_BTDM_BLE_MESH_SCAN_DUPL_EN)

- CONFIG_BLE_SCAN_DUPLICATE (CONFIG_BTDM_BLE_SCAN_DUPL)

- CONFIG_BLE_SMP_ENABLE (CONFIG_BT_BLE_SMP_ENABLE)

- 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_BROWNOUT_DET (CONFIG_ESP32_BROWNOUT_DET)

- CONFIG_BROWNOUT_DET_LVL_SEL (CONFIG_ESP32_BROWNOUT_DET_LVL_SEL)
  - CONFIG_BROWNOUT_DET_LVL_SEL_0
  - CONFIG_BROWNOUT_DET_LVL_SEL_1
  - CONFIG_BROWNOUT_DET_LVL_SEL_2
  - CONFIG_BROWNOUT_DET_LVL_SEL_3
  - CONFIG_BROWNOUT_DET_LVL_SEL_4
  - CONFIG_BROWNOUT_DET_LVL_SEL_5
  - CONFIG_BROWNOUT_DET_LVL_SEL_6
  - CONFIG_BROWNOUT_DET_LVL_SEL_7

- CONFIG_BTC_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_BTC_TRACE_LEVEL)
  - CONFIG_BTC_TRACE_LEVEL_NONE
  - CONFIG_BTC_TRACE_LEVEL_ERROR
  - CONFIG_BTC_TRACE_LEVEL_WARNING
  - CONFIG_BTC_TRACE_LEVEL_API
  - CONFIG_BTC_TRACE_LEVEL_EVENT
  - CONFIG_BTC_TRACE_LEVEL_DEBUG
  - CONFIG_BTC_TRACE_LEVEL_VERBOSE

- CONFIG_BTC_TASK_STACK_SIZE (CONFIG_BT_BTC_TASK_STACK_SIZE)

- CONFIG_BTDM_CONTROLLER_BLE_MAX_CONN (CONFIG_BTDM_CTRL_BLE_MAX_CONN)

- CONFIG_BTDM_CONTROLLER_BR_EDR_MAX_ACL_CONN (CONFIG_BTDM_CTRL_BR_EDR_MAX_ACL_CONN)
Chapter 2. API Reference

- **CONFIG_BTDM_CONTROLLER_BR_EDR_MAX_SYNC_CONN**
  - **CONFIG_BTDM_CTRL_BR_EDR_MAX_SYNC_CONN**
- **CONFIG_BTDM_CONTROLLER_FULL_SCAN_SUPPORTED**
  - **CONFIG_BTDM_CTRL_FULL_SCAN_SUPPORTED**
- **CONFIG_BTDM_CONTROLLER_HCI_MODE_CHOICE**
  - **CONFIG_BTDM_CTRL_HCI_MODE_CHOICE**
    - CONFIG_BTDM_CONTROLLER_HCI_MODE_VHCI
    - CONFIG_BTDM_CONTROLLER_HCI_MODE_UART_H4
- **CONFIG_BTDM_CONTROLLER_MODE**
  - **CONFIG_BTDM_CTRL_MODE**
    - **CONFIG_BTDM_CONTROLLER_MODE_BLE_ONLY**
    - **CONFIG_BTDM_CONTROLLER_MODE_BR_EDR_ONLY**
    - **CONFIG_BTDM_CONTROLLER_MODE_BTDM**
- **CONFIG_BTDM_CONTROLLER_MODEM_SLEEP**
  - **CONFIG_BTDM_CTRL_MODEM_SLEEP**
- **CONFIG_BTDM_CONTROLLER_PINNED_TO_CORE_CHOICE**
  - **CONFIG_BTDM_CTRL_PINNED_TO_CORE_CHOICE**
- **CONFIG_BTH_LOG_SDP_INITIAL_TRACE_LEVEL**
  - **CONFIG_BT_LOG_SDP_TRACE_LEVEL**
    - **CONFIG_SDP_TRACE_LEVEL_NONE**
    - **CONFIG_SDP_TRACE_LEVEL_ERROR**
    - **CONFIG_SDP_TRACE_LEVEL_WARNING**
    - **CONFIG_SDP_TRACE_LEVEL_API**
    - **CONFIG_SDP_TRACE_LEVEL_EVENT**
    - **CONFIG_SDP_TRACE_LEVEL_DEBUG**
    - **CONFIG_SDP_TRACE_LEVEL_VERBOSE**
- **CONFIG_BTIF_INITIAL_TRACE_LEVEL**
  - **CONFIG_BT_LOG_BTIF_TRACE_LEVEL**
    - **CONFIG_BTIF_TRACE_LEVEL_NONE**
    - **CONFIG_BTIF_TRACE_LEVEL_ERROR**
    - **CONFIG_BTIF_TRACE_LEVEL_WARNING**
    - **CONFIG_BTIF_TRACE_LEVEL_API**
    - **CONFIG_BTIF_TRACE_LEVEL_EVENT**
    - **CONFIG_BTIF_TRACE_LEVEL_DEBUG**
    - **CONFIG_BTIF_TRACE_LEVEL_VERBOSE**
- **CONFIG_BTM_INITIAL_TRACE_LEVEL**
  - **CONFIG_BT_LOG_BTM_TRACE_LEVEL**
    - **CONFIG_BTM_TRACE_LEVEL_NONE**
    - **CONFIG_BTM_TRACE_LEVEL_ERROR**
    - **CONFIG_BTM_TRACE_LEVEL_WARNING**
    - **CONFIG_BTM_TRACE_LEVEL_API**
    - **CONFIG_BTM_TRACE_LEVEL_EVENT**
    - **CONFIG_BTM_TRACE_LEVEL_DEBUG**
    - **CONFIG_BTM_TRACE_LEVEL_VERBOSE**
- **CONFIG_BTU_TASK_STACK_SIZE**
  - **CONFIG_BT_BTU_TASK_STACK_SIZE**
- **CONFIG_CLASSIC_BT_ENABLED**
  - **CONFIG_BT_CLASSIC_ENABLED**
- **CONFIG_COMPATIBLE_PRE_V2_1_BOOTLOADERS**
  - **CONFIG_ESP32_COMPATIBLE_PRE_V2_1_BOOTLOADERS**
- **CONFIG_CONSOLE_UART**
  - **CONFIG_ESP_CONSOLE_UART**
    - **CONFIG_CONSOLE_UART_DEFAULT**
    - **CONFIG_CONSOLE_UART_CUSTOM**
    - **CONFIG_ESP_CONSOLE_UART_NONE**
- **CONFIG_CONSOLE_UART_BAUDRATE**
  - **CONFIG_ESP_CONSOLE_UART_BAUDRATE**
- **CONFIG_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_BASIC_ROM_CONSole**
  - **CONFIG_ESP32_DISABLE_BASIC_ROM_CONSole**
- **CONFIG_DISABLE_GCC8_WARNINGS**
  - **CONFIG_COMPILER_DISABLE_GCC8_WARNINGS**
- **CONFIG_DUPLICATE_SCAN_CACHE_SIZE**
  - **CONFIG_BTDM_SCAN_DUPL_CACHE_SIZE**
- **CONFIG_EFUSE_SECURE_VERSION_EMULATE**
  - **CONFIG_BOOTLOADER_EFUSE_SECURE_VERSION_EMULATE**
• CONFIG_ENABLE_STATIC_TASK_CLEAN_UP_HOOK (CONFIG_FREERTOS_ENABLE_STATIC_TASK_CLEAN_UP_HOOK)
• CONFIG_ESP32C3_LIGHTSLEEP_GPIO_RESET_WORKAROUND (CONFIG_ESP_SLEEP_GPIO_RESET_WORKAROUND)
• CONFIG_ESP32C3_MEMPROT_FEATURE (CONFIG_ESP_SYSTEM_MEMPROT_FEATURE)
• CONFIG_ESP32C3_MEMPROT_FEATURE_LOCK (CONFIG_ESP_SYSTEM_MEMPROT_FEATURE_LOCK)
• CONFIG_ESP32H2_MEMPROT_FEATURE (CONFIG_ESP_SYSTEM_MEMPROT_FEATURE)
• CONFIG_ESP32H2_MEMPROT_FEATURE_LOCK (CONFIG_ESP_SYSTEM_MEMPROT_FEATURE_LOCK)
• CONFIG_ESP32S2_ALLOW_RTC_FAST_MEM_AS_HEAP (CONFIG_ESP_SYSTEM_ALLOW_RTC_FAST_MEM_AS_HEAP)
• CONFIG_ESP32S2_MEMPROT_FEATURE (CONFIG_ESP_SYSTEM_MEMPROT_FEATURE)
• CONFIG_ESP32S2_MEMPROT_FEATURE_LOCK (CONFIG_ESP_SYSTEM_MEMPROT_FEATURE_LOCK)
• CONFIG_ESP32S2_PANIC (CONFIG_ESP_SYSTEM_PANIC)
  – CONFIG_ESP32S2_PANIC_PRINT_HALT
  – CONFIG_ESP32S2_PANIC_PRINT_REBOOT
  – CONFIG_ESP32S2_PANIC_SILENT_REBOOT
  – CONFIG_ESP32S2_PANIC_GDBSTUB
• CONFIG_ESP32S2_PANIC_PRINT_HALT
• CONFIG_ESP32S2_PANIC_PRINT_REBOOT
• CONFIG_ESP32S2_PANIC_SILENT_REBOOT
• CONFIG_ESP32S2_PANIC_GDBSTUB
• CONFIG_ESP32_ALLOW_RTC_FAST_MEM_AS_HEAP (CONFIG_ESP_SYSTEM_ALLOW_RTC_FAST_MEM_AS_HEAP)
• 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_CODECINFO
  – CONFIG_ESP32_CORE_DUMP_CODEC_DISABLE
• CONFIG_ESP32_CORE_DUMP_MAX_TASKS_NUM (CONFIG_ESP_COREDUMP_MAX_TASKS_NUM)
• CONFIG_ESP32_CORE_DUMP_UART_DELAY (CONFIG_ESP_COREDUMP_UART_DELAY)
• CONFIG_ESP32_DEBUG_STUBS_ENABLE (CONFIG_ESP_DEBUG_STUBS_ENABLE)
• CONFIG_ESP32_GCOV_ENABLE (CONFIG_APPTRACE_GCOV_ENABLE)
• CONFIG_ESP32_RTC_CLOCK_SOURCE (CONFIG_ESP32_RTC_CLK_SRC)
  – CONFIG_ESP32_RTC_CLOCK_SOURCE_INTERNAL_RC
  – CONFIG_ESP32_RTC_CLOCK_SOURCE_EXTERNAL_CRYSTAL
  – CONFIG_ESP32_RTC_CLOCK_SOURCE_EXTERNAL_OSC
  – CONFIG_ESP32_RTC_CLOCK_SOURCE_INTERNAL_8MD256
• 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_ESP_GRRATUITOUS_ARP (CONFIG_LWIP_ESP_GRRATUITOUS_ARP)
• CONFIG_ESP_SYSTEM_PD_FLASH (CONFIG_ESP_SLEEP_POWER_DOWN_FLASH)
• CONFIG_ESP_TCP_KEEP_CONNECTION_WHEN_IP_CHANGES
  (CONFIG_LWIP_TCP_KEEP_CONNECTION_WHEN_IP_CHANGES)
• 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_DECRYPT
  (CONFIG_SECURE_FLASH_UART_BOOTLOADER_ALLOW_DEC)
• CONFIG_FLASH_ENCRYPTION_UART_BOOTLOADER_ALLOW_ENCRYPT
  (CONFIG_SECURE_FLASH_UART_BOOTLOADER_ALLOW_ENC)
• 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_GARP_TMR_INTERVAL (CONFIG_LWIP_GARP_TMR_INTERVAL)
• CONFIG_GATTC_CACHE_NVS_FLASH (CONFIG_BT_GATTC_CACHE_NVS_FLASH)
• CONFIG_GATTC_ENABLE (CONFIG_BT_GATTC_ENABLE)
• 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_GATT_SEND_SERVICE_CHANGE_MODE (CONFIG_BT_GATTS_SEND_SERVICE_CHANGE_MODE)
  – CONFIG_GATTS_SEND_SERVICE_CHANGE_MANUAL
  – CONFIG_GATTS_SEND_SERVICE_CHANGE_AUTO
• CONFIG_GATT_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_GATT_TRACE_LEVEL)
  – CONFIG_GATT_TRACE_LEVEL_NONE
  – CONFIG_GATT_TRACE_LEVEL_ERROR
  – CONFIG_GATT_TRACE_LEVEL.WARNING
  – CONFIG_GATT_TRACE_LEVEL_API
  – CONFIG_GATT_TRACE_LEVEL_EVENT
  – CONFIG_GATT_TRACE_LEVEL_DEBUG
  – CONFIG_GATT_TRACE_LEVEL_VERBOSE
• CONFIG_GDBSTUB_MAX_TASKS (CONFIG_ESP_GDBSTUB_MAX_TASKS)
• CONFIG_GDBSTUB_SUPPORT_TASKS (CONFIG_ESP_GDBSTUB_SUPPORT_TASKS)
• CONFIG_HCI_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_HCI_TRACE_LEVEL)
  – CONFIG_HCI_TRACE_LEVEL_NONE
  – CONFIG_HCI_TRACE_LEVEL_ERROR
  – CONFIG_HCI_TRACE_LEVEL_WARNING
  – CONFIG_HCI_TRACE_LEVEL_API
  – CONFIG_HCI_TRACE_LEVEL_EVENT
  – CONFIG_HCI_TRACE_LEVEL_DEBUG
  – CONFIG_HCI_TRACE_LEVEL_VERBOSE
• CONFIG_HFP_AUDIO_DATA_PATH (CONFIG_BT_HFP_AUDIO_DATA_PATH)
  – CONFIG_HFP_AUDIO_DATA_PATH_PCM
  – CONFIG_HFP_AUDIO_DATA_PATH_HCI
• CONFIG_HFP_ENABLE (CONFIG_BT_HFP_ENABLE)
• CONFIG_HFP_ROLE (CONFIG_BT_HFP_ROLE)
  – CONFIG_HFP_CLIENT_ENABLE
  – CONFIG_HFP_AG_ENABLE
• CONFIG_HID_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_HID_TRACE_LEVEL)
  – CONFIG_HID_TRACE_LEVEL_NONE
  – CONFIG_HID_TRACE_LEVEL_ERROR
- CONFIG_HID_TRACE_LEVEL_WARNING
- CONFIG_HID_TRACE_LEVEL_API
- CONFIG_HID_TRACE_LEVEL_EVENT
- CONFIG_HID_TRACE_LEVEL_DEBUG
- CONFIG_HID_TRACE_LEVEL_VERBOSE

• CONFIG_INT_WDT (CONFIG_ESP_INT_WDT)
• CONFIG_INT_WDT_CHECK_CPU1 (CONFIG_ESP_INT_WDT_CHECK_CPU1)
• CONFIG_INT_WDT_TIMEOUT_MS (CONFIG_ESP_INT_WDT_TIMEOUT_MS)
• CONFIG_IPC_TASK_STACK_SIZE (CONFIG_ESP_IPC_TASK_STACK_SIZE)

- CONFIG_L2CAP_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_L2CAP_TRACE_LEVEL)
  - CONFIG_L2CAP_TRACE_LEVEL_NONE
  - CONFIG_L2CAP_TRACE_LEVEL_ERROR
  - CONFIG_L2CAP_TRACE_LEVEL_WARNING
  - CONFIG_L2CAP_TRACE_LEVEL_API
  - CONFIG_L2CAP_TRACE_LEVEL_EVENT
  - CONFIG_L2CAP_TRACE_LEVEL_DEBUG
  - CONFIG_L2CAP_TRACE_LEVEL_VERBOSE

• CONFIG_L2_TO_L3_COPY (CONFIG_LWIP_L2_TO_L3_COPY)

- CONFIG_LOG_BOOTLOADER_LEVEL (CONFIG_BOOTLOADER_LOG_LEVEL)
  - CONFIG_LOG_BOOTLOADER_LEVEL_NONE
  - CONFIG_LOG_BOOTLOADER_LEVEL_ERROR
  - CONFIG_LOG_BOOTLOADER_LEVEL_WARN
  - CONFIG_LOG_BOOTLOADER_LEVEL_INFO
  - CONFIG_LOG_BOOTLOADER_LEVEL_DEBUG
  - CONFIG_LOG_BOOTLOADER_LEVEL_VERBOSE

• CONFIG_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_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_MESH_DUPLICATE_SCAN_CACHE_SIZE (CONFIG_BTDM_MESH_DUPL_SCAN_CACHE_SIZE)

- CONFIG_MONITOR_BAUD (CONFIG_ESPTOOLPY_MONITOR_BAUD)
  - CONFIG_MONITOR_BAUD_9600B
  - CONFIG_MONITOR_BAUD_57600B
  - CONFIG_MONITOR_BAUD_115200B
  - CONFIG_MONITOR_BAUD_230400B
  - CONFIG_MONITOR_BAUD_921600B
  - CONFIG_MONITOR_BAUD_2MB
  - CONFIG_MONITOR_BAUD_OTHER

• CONFIG_MONITOR_BAUD_OTHER_VAL (CONFIG_ESPTOOLPY_MONITOR_BAUD_OTHER_VAL)
• 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_NIMBLE_HS_FLOW_CTRL_ITVL (CONFIG_BT_NIMBLE_HS_FLOW_CTRL_ITVL)
• CONFIG_NIMBLE_HS_FLOW_CTRL_THRESH (CONFIG_BT_NIMBLE_HS_FLOW_CTRL_THRESH)
• CONFIG_NIMBLE_HS_FLOW_CTRL_TX_ON_DISCONNECT (CONFIG_BT_NIMBLE_HS_FLOW_CTRL_TX_ON_DISCONNECT)
• CONFIG_NIMBLE_L2CAP_COC_MAX_NUM (CONFIG_BT_NIMBLE_L2CAP_COC_MAX_NUM)
• CONFIG_NIMBLE_MAX_BONDS (CONFIG_BT_NIMBLE_MAX_BONDS)
• CONFIG_NIMBLE_MAX_CCCDS (CONFIG_BT_NIMBLE_MAX_CCCDS)
• CONFIG_NIMBLE_MAX_CONNECTIONS (CONFIG_BT_NIMBLE_MAX_CONNECTIONS)
• CONFIG_NIMBLE_MEM_ALLOC_MODE (CONFIG_BT_NIMBLE_MEM_ALLOC_MODE)
  – CONFIG_NIMBLE_MEM_ALLOC_MODE_INTERNAL
  – CONFIG_NIMBLE_MEM_ALLOC_MODE_EXTERNAL
  – CONFIG_NIMBLE_MEM_ALLOC_MODE_DEFAULT
• CONFIG_NIMBLE_MESH (CONFIG_BT_NIMBLE_MESH)
• CONFIG_NIMBLE_MESH_DEVICE_NAME (CONFIG_BT_NIMBLE_MESH_DEVICE_NAME)
• CONFIG_NIMBLE_MESH_FRIEND (CONFIG_BT_NIMBLE_MESH_FRIEND)
• CONFIG_NIMBLE_MESH_GATT_PROXY (CONFIG_BT_NIMBLE_MESH_GATT_PROXY)
• CONFIG_NIMBLE_MESH_LOW_POWER (CONFIG_BT_NIMBLE_MESH_LOW_POWER)
• CONFIG_NIMBLE_MESH_PB_ADV (CONFIG_BT_NIMBLE_MESH_PB_ADV)
• CONFIG_NIMBLE_MESH_PB_GATT (CONFIG_BT_NIMBLE_MESH_PB_GATT)
• CONFIG_NIMBLE_MESH_PROXY (CONFIG_BT_NIMBLE_MESH_PROXY)
• CONFIG_NIMBLE_MESH_RELAY (CONFIG_BT_NIMBLE_MESH_RELAY)
• CONFIG_NIMBLE_MSYS1_BLOCK_COUNT (CONFIG_BT_NIMBLE_MSYS1_BLOCK_COUNT)
• CONFIG_NIMBLE_NVS_PERSIST (CONFIG_BT_NIMBLE_NVS_PERSIST)
• CONFIG_NIMBLE_PINNED_TO_CORE_CHOICE (CONFIG_BT_NIMBLE_PINNED_TO_CORE_CHOICE)
  – CONFIG_NIMBLE_PINNED_TO_CORE_0
  – CONFIG_NIMBLE_PINNED_TO_CORE_1
• CONFIG_NIMBLE_ROLE_BROADCASTER (CONFIG_BT_NIMBLE_ROLE_BROADCASTER)
• CONFIG_NIMBLE_ROLE_CENTRAL (CONFIG_BT_NIMBLE_ROLE_CENTRAL)
• CONFIG_NIMBLE_ROLE_OBSERVER (CONFIG_BT_NIMBLE_ROLE_OBSERVER)
• CONFIG_NIMBLE_ROLE_PERIPHERAL (CONFIG_BT_NIMBLE_ROLE_PERIPHERAL)
• CONFIG_NIMBLE_RPA_TIMEOUT (CONFIG_BT_NIMBLE_RPA_TIMEOUT)
• CONFIG_NIMBLE_SM_LEGACY (CONFIG_BT_NIMBLE_SM_LEGACY)
• CONFIG_NIMBLE_SM_SC (CONFIG_BT_NIMBLE_SM_SC)
• CONFIG_NIMBLE_SM_SC_DEBUG_KEYS (CONFIG_BT_NIMBLE_SM_SC_DEBUG_KEYS)
• CONFIG_NIMBLE_SVC_GAP_APPEARANCE (CONFIG_BT_NIMBLE_SVC_GAP_APPEARANCE)
• CONFIG_NIMBLE_SVC_GAP_DEVICE_NAME (CONFIG_BT_NIMBLE_SVC_GAP_DEVICE_NAME)
• CONFIG_NIMBLE_TASK_STACK_SIZE (CONFIG_BT_NIMBLE_TASK_STACK_SIZE)
• CONFIG_NO_BLOBS (CONFIG_ESP32_NO_BLOBS)
• CONFIG_NUMBER_OF_UNIVERSAL_MAC_ADDRESS (CONFIG_ESP32_UNIVERSAL_MAC_ADDRESSES)
  – CONFIG_TWO_UNIVERSAL_MAC_ADDRESS
  – CONFIG_FOUR_UNIVERSAL_MAC_ADDRESS
• CONFIG_OPTIMIZATION_ASSERTION_LEVEL (CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL)
  – CONFIG_OPTIMIZATION_ASSERTIONS_ENABLED
  – CONFIG_OPTIMIZATION_ASSERTIONS_SILENT
  – CONFIG_OPTIMIZATION_ASSERTIONS_DISABLED
• **CONFIG_OPTIMIZATION_COMPILER** (*CONFIG_COMPILER_OPTIMIZATION*)  
  - CONFIG_COMPILER_OPTIMIZATION_LEVEL_DEBUG  
  - CONFIG_COMPILER_OPTIMIZATION_LEVEL_RELEASE

• **CONFIG_OSI_INITIAL_TRACE_LEVEL** (*CONFIG_BT_LOG_OSI_TRACE_LEVEL*)  
  - CONFIG_OSI_TRACE_LEVEL_NONE  
  - CONFIG_OSI_TRACE_LEVEL_ERROR  
  - CONFIG_OSI_TRACE_LEVEL_WARNING  
  - CONFIG_OSI_TRACE_LEVEL_API  
  - CONFIG_OSI_TRACE_LEVEL_EVENT  
  - CONFIG_OSI_TRACE_LEVEL_DEBUG  
  - CONFIG_OSI_TRACE_LEVEL_VERBOSE

• **CONFIG_PAN_INITIAL_TRACE_LEVEL** (*CONFIG_BT_LOG_PAN_TRACE_LEVEL*)  
  - CONFIG_PAN_TRACE_LEVEL_NONE  
  - CONFIG_PAN_TRACE_LEVEL_ERROR  
  - CONFIG_PAN_TRACE_LEVEL_WARNING  
  - CONFIG_PAN_TRACE_LEVEL_API  
  - CONFIG_PAN_TRACE_LEVEL_EVENT  
  - CONFIG_PAN_TRACE_LEVEL_DEBUG  
  - CONFIG_PAN_TRACE_LEVEL_VERBOSE

• **CONFIG_POST_EVENTS_FROM_IRAM_ISR** (*CONFIG_ESP_EVENT_POST_FROM_IRAM_ISR*)

• **CONFIG_POST_EVENTS_FROM_ISR** (*CONFIG_ESP_EVENT_POST_FROM_ISR*)

• **CONFIG_PPP_CHAP_SUPPORT** (*CONFIG_LWIP_PPP_CHAP_SUPPORT*)

• **CONFIG_PPP_DEBUG_ON** (*CONFIG_LWIP_PPP_DEBUG_ON*)

• **CONFIG_PPP_MPPE_SUPPORT** (*CONFIG_LWIP_PPP_MPPE_SUPPORT*)

• **CONFIG_PPP_MSCHAP_SUPPORT** (*CONFIG_LWIP_PPP_MSCHAP_SUPPORT*)

• **CONFIG_PPP_NOTIFY_PHASE_SUPPORT** (*CONFIG_LWIP_PPP_NOTIFY_PHASE_SUPPORT*)

• **CONFIG_PPP_PAP_SUPPORT** (*CONFIG_LWIP_PPP_PAP_SUPPORT*)

• **CONFIG_PPP_SUPPORT** (*CONFIG_LWIP_PPP_SUPPORT*)

• **CONFIG_PPP_MPPE_SUPPORT** (*CONFIG_LWIP_PPP_MPPE_SUPPORT*)

• **CONFIG_PPP_MSCHAP_SUPPORT** (*CONFIG_LWIP_PPP_MSCHAP_SUPPORT*)

• **CONFIG_PPP_NOTIFY_PHASE_SUPPORT** (*CONFIG_LWIP_PPP_NOTIFY_PHASE_SUPPORT*)

• **CONFIG_PPP_PAP_SUPPORT** (*CONFIG_LWIP_PPP_PAP_SUPPORT*)

• **CONFIG_PPP_SUPPORT** (*CONFIG_LWIP_PPP_SUPPORT*)

• **CONFIG_REDUCE_PHY_TX_POWER** (*CONFIG_ESP_PHY_REDUCE_TX_POWER*)

• **CONFIG_RFCOMM_INITIAL_TRACE_LEVEL** (*CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL*)  
  - CONFIG_RFCOMM_TRACE_LEVEL_NONE  
  - CONFIG_RFCOMM_TRACE_LEVEL_ERROR  
  - CONFIG_RFCOMM_TRACE_LEVEL_WARNING  
  - CONFIG_RFCOMM_TRACE_LEVEL_API  
  - CONFIG_RFCOMM_TRACE_LEVEL_EVENT  
  - CONFIG_RFCOMM_TRACE_LEVEL_DEBUG  
  - CONFIG_RFCOMM_TRACE_LEVEL_VERBOSE

• **CONFIG_SCAN_DUPLICATE_TYPE** (*CONFIG_BTDM_SCAN_DUPL_TYPE*)  
  - CONFIG_SCAN_DUPLICATE_BY_DEVICE_ADDR  
  - CONFIG_SCAN_DUPLICATE_BY_ADV_DATA  
  - CONFIG_SCAN_DUPLICATE_BY_ADV_DATA_AND_DEVICE_ADDR

• **CONFIG_SEMIHOSTFS_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_SMP_SLAVE_CON_PARAMS_UPD_ENABLE** (*CONFIG_BT_SMP_SLAVE_CON_PARAMS_UPD_ENABLE*)

• **CONFIG_SPIRAM_SUPPORT** (*CONFIG_ESP32_SPIRAM_SUPPORT*)

• **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_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_START_READY_ENABLE** *(CONFIG_APPTRACE_SV_EVT_TASK_START_READY_ENABLE)*
• **CONFIG_SYSVIEW_EVT_TASK_STOP_EXEC_ENABLE** *(CONFIG_APPTRACE_SV_EVT_TASK_STOP_EXEC_ENABLE)*
• **CONFIG_SYSVIEW_EVT_TASK_STOP_READY_ENABLE** *(CONFIG_APPTRACE_SV_EVT_TASK_STOP_READY_ENABLE)*
• **CONFIG_SYSVIEW_EVT_TASK_TERMINATE_ENABLE** *(CONFIG_APPTRACE_SV_EVT_TASK_TERMINATE_ENABLE)*
• **CONFIG_SYSVIEW_EVT_TIMER_ENTER_ENABLE** *(CONFIG_APPTRACE_SV_EVT_TIMER_ENTER_ENABLE)*
• **CONFIG_SYSVIEW_EVT_TIMER_EXIT_ENABLE** *(CONFIG_APPTRACE_SV_EVT_TIMER_EXIT_ENABLE)*
• **CONFIG_SYSVIEW_MAX_TASKS** *(CONFIG_APPTRACE_SV_MAX_TASKS)*
• **CONFIG_SYSVIEW_TS_SOURCE** *(CONFIG_APPTRACE_SV_TS_SOURCE)*
  - CONFIG_SYSVIEW_TS_SOURCE_CCOUNT
  - CONFIG_SYSVIEW_TS_SOURCE_ESP_TIMER
• **CONFIG_TASK_WDT** *(CONFIG_ESP_TASK_WDT)*
• **CONFIG_TASK_WDT_CHECK_IDLE_TASK_CPU0** *(CONFIG_ESP_TASK_WDT_CHECK_IDLE_TASK_CPU0)*
• **CONFIG_TASK_WDT_CHECK_IDLE_TASK_CPU1** *(CONFIG_ESP_TASK_WDT_CHECK_IDLE_TASK_CPU1)*
• **CONFIG_TASK_WDT_PANIC** *(CONFIG_ESP_TASK_WDT_PANIC)*
• **CONFIG_TASK_WDT_TIMEOUT_S** *(CONFIG_ESP_TASK_WDT_TIMEOUT_S)*
• **CONFIG_TCPIP_RECVMBOX_SIZE** *(CONFIG_LWIP_TCPIP_RECVMBOX_SIZE)*
• **CONFIG_TCPIP_TASK_AFFINITY** *(CONFIG_LWIP_TCPIP_TASK_AFFINITY)*
  - CONFIG_TCPIP_TASK_AFFINITY_NO_AFFINITY
  - CONFIG_TCPIP_TASK_AFFINITY_CPU0
  - CONFIG_TCPIP_TASK_AFFINITY_CPU1
• **CONFIG_TCPIP_TASK_STACK_SIZE** *(CONFIG_LWIP_TCPIP_TASK_STACK_SIZE)*
• **CONFIG_TCP_MAXRTX** *(CONFIG_LWIP_TCP_MAXRTX)*
• **CONFIG_TCP_MSL** *(CONFIG_LWIP_TCP_MSL)*
• **CONFIG_TCP_MSS** *(CONFIG_LWIP_TCP_MSS)*
• **CONFIG_TCP_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_SYNMAXRTX** *(CONFIG_LWIP_TCP_SYNMAXRTX)*
• **CONFIG_TCP_WND_DEFAULT** *(CONFIG_LWIP_TCP_WND_DEFAULT)*
• **CONFIG_TIMER_QUEUE_LENGTH** *(CONFIG_FREERTOS_TIMER_QUEUE_LENGTH)*
• **CONFIG_TIMER_TASK_PRIORITY** *(CONFIG_FREERTOS_TIMER_TASK_PRIORITY)*
• **CONFIG_TIMER_TASK_STACK_DEPTH** *(CONFIG_FREERTOS_TIMER_TASK_STACK_DEPTH)*
• **CONFIG_TIMER_TASK_STACK_SIZE** *(CONFIG_ESP_TIMER_TASK_STACK_SIZE)*
• **CONFIG_TOOLPREFIX** *(CONFIG_SDK_TOOLPREFIX)*
• **CONFIG_UDP_RECVMBOX_SIZE** *(CONFIG_LWIP_UDP_RECVMBOX_SIZE)*
• CONFIG_ULP_COPROC_ENABLED (CONFIG_ESP32_ULP_COPROC_ENABLED)
• CONFIG_ULP_COPROC_RESERVE_MEM (CONFIG_ESP32_ULP_COPROC_RESERVE_MEM)
• CONFIG_USE_ONLY_LWIP_SELECT (CONFIG_LWIP_USE_ONLY_LWIP_SELECT)
• CONFIG_WARN_WRITE_STRINGS (CONFIG_COMPILER_WARN_WRITE_STRINGS)
• CONFIG_WIFI_LWIP_ALLOCATION_FROM_SPIRAM_FIRST (CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP)

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

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_INVALIDHANDLE (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_XTS_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_DIFFERS** (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_UNDEFINDED_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 encoding operation.

**ESP_ERR_NOT_ENOUGH_UNUSED_KEY_BLOCKS (0x1605):** Error, not enough unused key blocks available

**ESP_ERR_DAMAGED_READING (0x1606):** Error. Burn or reset was done during a reading operation leads to damage read data. This error is internal to the efuse component and not returned by any public API.

**ESP_ERR_IMAGE_BASE (0x2000):**

**ESP_ERR_IMAGE_FLASH_FAIL (0x2001):**

**ESP_ERR_IMAGE_INVALID (0x2002):**

**ESP_ERR_WIFI_BASE (0x3000):** Starting number of WiFi error codes

**ESP_ERR_WIFI_NOT_INIT (0x3001):** WiFi driver was not installed by esp_wifi_init

**ESP_ERR_WIFI_NOT_STARTED (0x3002):** WiFi driver was not started by esp_wifi_start

**ESP_ERR_WIFI_NOT_STOPPED (0x3003):** WiFi driver was not stopped by esp_wifi_stop

**ESP_ERR_WIFI_IF (0x3004):** WiFi interface error

**ESP_ERR_WIFI_MODE (0x3005):** WiFi mode error

**ESP_ERR_WIFI_STATE (0x3006):** WiFi internal state error

**ESP_ERR_WIFI_CONN (0x3007):** WiFi internal control block of station or soft-AP error

**ESP_ERR_WIFI_NVS (0x3008):** WiFi internal NVS module error

**ESP_ERR_WIFI_MAC (0x3009):** MAC address is invalid

**ESP_ERR_WIFI_SSID (0x300a):** SSID is invalid

**ESP_ERR_WIFI_PASSWORD (0x300b):** Password is invalid

**ESP_ERR_WIFI_TIMEOUT (0x300c):** Timeout error

**ESP_ERR_WIFI_WAKE_FAIL (0x300d):** WiFi is in sleep state (RF closed) and wake 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_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
<table>
<thead>
<tr>
<th>Error Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_ERR_ESPNOW_EXIST (0x306b)</td>
<td>ESPNOW peer has existed</td>
</tr>
<tr>
<td>ESP_ERR_ESPNOW_IF (0x306c)</td>
<td>Interface error</td>
</tr>
<tr>
<td>ESP_ERR_DPP_FAILURE (0x3097)</td>
<td>Generic failure during DPP Operation</td>
</tr>
<tr>
<td>ESP_ERR_DPP_TX_FAILURE (0x3098)</td>
<td>DPP Frame Tx failed OR not Acked</td>
</tr>
<tr>
<td>ESP_ERR_DPP_INVALID_ATTR (0x3099)</td>
<td>Encountered invalid DPP Attribute</td>
</tr>
<tr>
<td>ESP_ERR_MESH_BASE (0x4000)</td>
<td>Starting number of MESH error codes</td>
</tr>
<tr>
<td>ESP_ERR_MESH_WIFI_NOT_START (0x4001)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_NOT_INIT (0x4002)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_NOT_CONFIG (0x4003)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_NOT_START (0x4004)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_NOT_SUPPORT (0x4005)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_NOT_ALLOWED (0x4006)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_NO_MEMORY (0x4007)</td>
<td></td>
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<tr>
<td>ESP_ERR_MESH_ARGUMENT (0x4008)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_EXCEED_MTU (0x4009)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_TIMEOUT (0x400a)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_DISCONNECTED (0x400b)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_QUEUE_FAIL (0x400c)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_QUEUE_FULL (0x400d)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_NO_PARENT_FOUND (0x400e)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_NO_ROUTE_FOUND (0x400f)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_OPTION_NULL (0x4010)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_OPTION_UNKNOWN (0x4011)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_XON_NO_WINDOW (0x4012)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_INTERFACE (0x4013)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_MESH_DISCARD_DUPLICATE (0x4014)</td>
<td></td>
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<tr>
<td>ESP_ERR_MESH_DISCARD (0x4015)</td>
<td></td>
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<tr>
<td>ESP_ERR_MESH_VOTING (0x4016)</td>
<td></td>
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<tr>
<td>ESP_ERR_MESH_XMIT (0x4017)</td>
<td></td>
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<tr>
<td>ESP_ERR_MESH_QUEUE_READ (0x4018)</td>
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<tr>
<td>ESP_ERR_MESH_PS (0x4019)</td>
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</tr>
<tr>
<td>ESP_ERR_MESH_RECV_RELEASE (0x401a)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_ESP_NETIF_BASE (0x5000)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_ESP_NETIF_INVALID_PARAMS (0x5001)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_ESP_NETIF_IF_NOT_READY (0x5002)</td>
<td></td>
</tr>
<tr>
<td>ESP_ERR_ESP_NETIF_DHCP_INIT_FAILED (0x5003)</td>
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</tr>
<tr>
<td>ESP_ERR_ESP_NETIF_DHCPC_ALREADY_STARTED (0x5004)</td>
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</tr>
<tr>
<td>ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED (0x5005)</td>
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</tr>
<tr>
<td>ESP_ERR_ESP_NETIF_NO_MEM (0x5006)</td>
<td></td>
</tr>
</tbody>
</table>
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
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_KEY_VERIFY_SETUP_FAILED (0x8034): wolfSSL api returned error
ESP_ERR_WOLFSSL_CTX_SETUP_FAILED (0x8035): wolfSSL api returned failed
ESP_ERR_WOLFSSL_SSL_WRITE_FAILED (0x8038): wolfSSL api returned failed
ESP_ERR_HTTPS_OTA_BASE (0x9000)
ESP_ERR_HTTPS_OTA_IN_PROGRESS (0x9001)
ESP_ERR_PING_BASE (0xa000)
ESP_ERR_PING_INVALID_PARAMS (0xa001)
ESP_ERR_PING_NO_MEM (0xa002)
ESP_ERR_HTTPD_BASE (0xb000): Starting number of HTTPD error codes
ESP_ERR_HTTPD_HANDLERS_FULL (0xb001): All slots for registering URI handlers have been consumed
ESP_ERR_HTTPD_HANDLER_EXISTS (0xb002): URI handler with same method and target URI already registered
ESP_ERR_HTTPD_INVALID_REQ (0xb003): Invalid request pointer
ESP_ERR_HTTPD_RESULT_TRUNC (0xb004): Result string truncated
ESP_ERR_HTTPD_RESP_HDR (0xb005): Response header field larger than supported
ESP_ERR_HTTPD_RESP_SEND (0xb006): Error occurred while sending response packet
ESP_ERR_HTTPD_ALLOC_MEM (0xb007): Failed to dynamically allocate memory for resource
ESP_ERR_HTTPD_TASK (0xb008): Failed to launch server task/thread
ESP_ERR_HW_CRYPTO_BASE (0xc000): Starting number of HW cryptography module error codes
ESP_ERR_HW_CRYPTO_DS_HMAC_FAIL (0xc001): HMAC peripheral problem
ESP_ERR_HW_CRYPTO_DS_INVALID_KEY (0xc002)
ESP_ERR_HW_CRYPTO_DS_INVALID_DIGEST (0xc004)
ESP_ERR_HW_CRYPTO_DS_INVALID_PADDING (0xc005)
ESP_ERR_MEMPROT_BASE (0xd000): Starting number of Memory Protection API error codes
ESP_ERR_MEMPROT_MEMORY_TYPE_INVALID (0xd001)
ESP_ERR_MEMPROT_SPLIT_ADDR_INVALID (0xd002)
ESP_ERR_MEMPROT_SPLIT_ADDR_OUT_OF_RANGE (0xd003)
ESP_ERR_MEMPROT_SPLIT_ADDR_UNALIGNED (0xd004)
Chapter 2. API Reference

ESP_ERR_MEMMGT_UNIMGMT_BLOCK_INVALID (0xd005)
ESP_ERR_MEMPROT_WORLD_INVALID (0xd006)
ESP_ERR_MEMPROT_AREA_INVALID (0xd007)
# Chapter 3

## ESP32 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 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>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>1</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 (^{1})</td>
<td>2 (^{1})</td>
<td>3</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, SDIO slave, 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>✗</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/SDIO/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>1</td>
<td>✗</td>
</tr>
<tr>
<td><strong>Security</strong></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><strong>Other</strong></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 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. 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 (ISR, OS scheduler 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 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. When enabled in menuconfig, 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 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;
}
```

The `esp_apptrace_write()` function uses `memcpy` to copy user data to the internal buffer. In some cases it can be more optimal to use `esp_apptrace_buffer_get()` and `esp_apptrace_buffer_put()` functions. They allow developers to allocate buffer and fill it themselves. The following piece of code shows how to do this.

```c
#include "esp_app_trace.h"
...
int number = 10;
char *ptr = (char *)esp_apptrace_buffer_get(ESP_APPTRACE_DEST_TRAX, 32, 100/
   "tmo in us");
if (ptr == NULL) {
    ESP_LOGE(TAG, "Failed to get buffer!");
    return ESP_FAIL;
}
sprintf(ptr, "Here is the number %d", number);
esp_err_t res = esp_apptrace_buffer_put(ESP_APPTRACE_DEST_TRAX, ptr, 100/
   "tmo in us");
if (res != ESP_OK) {
    /* in case of error host tracing tool (e.g. OpenOCD) will report..."incomplete user buffer */
    ESP_LOGE(TAG, "Failed to put buffer!");
    return res;
}
```

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_apptrace_read() function uses memcpy to copy host data to user buffer. In some cases it can be more optimal to use esp_apptrace_down_buffer_get() and esp_apptrace_down_buffer_put() functions. They allow developers to occupy chunk of read buffer and process it in-place. The following piece of code shows how to do this.

```c
#include "esp_app_trace.h"
...
char down_buf[32];
uint32_t *number;
size_t sz = 32;

/* config down buffer */
esp_apptrace_down_buffer_config(down_buf, sizeof(down_buf));
char *ptr = (char *)esp_apptrace_down_buffer_get(ESP_APPTRACE_DEST_TRAX, &sz, ...
    --100/*tmo in us*/);
if (ptr == NULL) {
    ESP_LOGE(TAG, "Failed to get buffer!");
    return ESP_FAIL;
}
if (sz > 4) {
    number = (uint32_t *)ptr;
    printf("Here is the number %d", *number);
} else {
    printf("No data");
}

esp_err_t res = esp_apptrace_down_buffer_put(ESP_APPTRACE_DEST_TRAX, ptr, 100/
    --"tmo in us");
if (res != ESP_OK) {
    /* in case of error host tracing tool (e.g. OpenOCD) will report ...
    incomplete user buffer */
    ESP_LOGE(TAG, "Failed to put buffer!");
    return res;
}
```

2. The next step is to build the program image and download it to the target as described in the Getting Started Guide.
3. Run OpenOCD (see JTAG Debugging).
4. Connect to OpenOCD telnet server. It can be done using the following command in terminal telnet <oocd_host> 4444. If telnet session is opened on the same machine which runs OpenOCD you can use localhost as <oocd_host> in the command above.
5. Start trace data collection using special OpenOCD command. This command will transfer tracing data and redirect them to 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.
Chapter 4. API Guides

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:

```
esp aptrace [start <options>] | [stop] | [status] | [dump <cores_num> <outfile>]
```

Sub-commands:

- `start` Start tracing (continuous streaming).
- `stop` Stop tracing.
- `status` Get tracing status.
- `dump` Dump all data from (post-mortem dump).

Start command syntax:

```
start <outfile> [poll_period [trace_size [stop_tmo [wait4halt [skip_size]]]]]
```

- `outfile` Path to file to save data from both CPUs. This argument should have the following format: file://path/to/file.
- `poll_period` Data polling period (in ms) for available trace data. If greater than 0 then command runs in non-blocking mode. By default, 1 ms.
- `trace_size` Maximum size of data to collect (in bytes). Tracing is stopped after specified amount of data is received. By default-1 (tracesizetostoptriggerisdisabled).
- `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.
   
   ```
   esp aptrace start file://trace.log 1 2048 5 0 0
   ```

   The tracing data will be retrieved and saved in non-blocking mode. This process will stop automatically after 2048 bytes are collected, or if no data are available for more than 5 seconds.

   Note: Tracing data is buffered before it is made available to OpenOCD. If you see 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.
Chapter 4. API Guides

```plaintext
esp apptrace 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 apptrace stop` command on OpenOCD telnet prompt, or by pressing Ctrl+C in
OpenOCD window.

3. Retrieve tracing data and save them indefinitely.

```plaintext
esp apptrace 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:

```plaintext
esp apptrace 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_apptrace_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_apptrace_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`.  

Espressif Systems  1736  Release v5.0-dev-1077-g397639d
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 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 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.
Chapter 4. API Guides

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.

   ```
   esp sysview start file://pro-cpu.SVDat file://app-cpu.SVDat
   ```

   The tracing data will be retrieved and saved in non-blocking mode. To stop 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.

   ```
   esp sysview start file://pro-cpu.SVDat file://app-cpu.SVDat 0 -1 -1
   ```

   OpenOCD telnet command line prompt will not be available until tracing is stopped. To stop tracing, press Ctrl+C in 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 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:
Chapter 4. API Guides


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)

Basic 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.

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 `--coverage` option, you can add `set_source_files_properties(source1.c source2.c PROPERTIES COMPIL_FLAGS --coverage)` to the `CMakeLists.txt` file of the component.

When a source file is compiled with the `--coverage` option (e.g. `gcov_example.c`), the compiler will generate the `gcov_example.gcno` file in the project’s build directory.

**Project Configuration** Before building a project with source code coverage, ensure that the following project configuration options are enabled by running `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 `--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 `telnet localhost 4444`). Note that GDB could be used instead of telnet to issue commands to OpenOCD, however all commands issued from GDB will need to be prefixed as `mon <oocd_command>`.

When the target dumps code coverage data, the `.gcda` files are stored in the project’s build directory. For example, if `gcov_example_main.c` of the main component was compiled with the `--coverage` option, then dumping the code coverage data would generate a `gcov_example_main.gcda` in `build/esp-idf/main/CMakeFiles/__idf_main.dir/gcov_example_main.c.gcda`. Note that the `.gcno` files produced during compilation are also placed in the same directory.

The dumping of code coverage data can be done multiple times throughout an application’s lifetime. Each dump will simply update the `.gcda` file with the newest code coverage information. Code coverage data is accumulative, thus the newest data will contain the total execution count of each code path over the application’s entire lifetime.

ESP-IDF supports two methods of dumping code coverage data form the target to the host:

- **Instant Run-Time Dump**
- **Hard-coded Dump**

**Instant Run-Time Dump** An Instant Run-Time Dump is triggered by calling the `ESP32 gcov OpenOCD` command (via a telnet session). Once called, OpenOCD will immediately preempt the ESP32’s current state and execute a built-in IDF Gcov debug stub function. The debug stub function will handle the dumping of data to the Host. Upon completion, the ESP32 will resume its current state.

**Hard-coded Dump** A Hard-coded Dump is triggered by the application itself by calling `esp_gcov_dump()` from somewhere within the application. When called, the application will halt and wait for OpenOCD to connect and retrieve the code coverage data. Once `esp_gcov_dump()` is called, the Host must execute the `esp gcov dump` OpenOCD command (via a telnet session). The `esp gcov dump` command will cause OpenOCD to connect to the ESP32, retrieve the code coverage data, then disconnect from the ESP32 thus allowing the application to resume. Hard-coded Dumps can also be triggered multiple times throughout an application’s lifetime.

Hard-coded dumps are useful if code coverage data is required at certain points of an application’s lifetime by placing `esp_gcov_dump()` where necessary (e.g., after application initialization, during each iteration of an application’s main loop).

GDB can be used to set a breakpoint on `esp_gcov_dump()`, then call `mon esp gcov dump` automatically via the use a `gdbinit` script (see Using GDB from *Command Line*).

The following GDB script is will add a breakpoint at `esp_gcov_dump()`, then call the `mon esp gcov dump` OpenOCD command.
Chapter 4. API Guides

```
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 0x1000.
2. **Second stage bootloader** loads partition table and main app image from flash. Main app incorporates both RAM segments and read-only segments mapped via flash cache.
3. **Application startup** executes. At this point the second CPU and RTOS scheduler are started.

This process is explained in detail in the following sections.

---

#### 4.2.1 First stage bootloader

After SoC reset, PRO CPU will start running immediately, executing reset vector code, while APP CPU will be held in reset. During startup process, PRO CPU does all the initialization. APP CPU reset is de-asserted in the `call_start_cpu0` function of application startup code. Reset vector code is located in the mask ROM of the ESP32 chip and cannot be modified.

Startup code called from the reset vector determines the boot mode by checking `GPIO_STRAP_REG` register for bootstrap pin states. Depending on the reset reason, the following takes place:
1. Reset from deep sleep: if the value in `RTC_CNTL_STORE6_REG` is non-zero, and CRC value of RTC memory in `RTC_CNTL_STORE7_REG` is valid, use `RTC_CNTL_STORE6_REG` as an entry point address and jump immediately to it. If `RTC_CNTL_STORE6_REG` is zero, or `RTC_CNTL_STORE7_REG` contains invalid CRC, or once the code called via `RTC_CNTL_STORE6_REG` returns, proceed with boot as if it was a power-on reset. **Note:** to run customized code at this point, a deep sleep stub mechanism is provided. Please see deep sleep documentation for this.

2. For power-on reset, software SOC reset, and watchdog SOC reset: check the `GPIO_STRAP_REG` register if a custom boot mode (such as UART Download Mode) is requested. If this is the case, this custom loader mode is executed from ROM. Otherwise, proceed with boot as if it was due to software CPU reset. Consult ESP32 datasheet for a description of SoC boot modes and how to execute them.

3. For software CPU reset and watchdog CPU reset: configure SPI flash based on EFUSE values, and attempt to load the code from flash. This step is described in more detail in the next paragraphs.

**Note:** During normal boot modes the RTC watchdog is enabled when this happens, so if the process is interrupted or stalled then the watchdog will reset the SOC automatically and repeat the boot process. This may cause the SoC to strap into a new boot mode, if the strapping GPIOs have changed.

Second stage bootloader binary image is loaded from flash starting at address 0x1000. If **Secure Boot** is in use then the first 4 kB sector of flash is used to store secure boot IV and digest of the bootloader image. Otherwise, this sector is unused.

### 4.2.2 Second stage bootloader

In ESP-IDF, the binary image which resides at offset 0x1000 in flash is the second stage bootloader. Second stage bootloader source code is available in the `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.
Chapter 4. API Guides

- Running the main task and calling `app_main`.

**Note:** Understanding all stages of ESP-IDF app initialization is often not necessary. To understand initialization from the application developer’s perspective only, skip forward to Running the main task.

### Port Initialization

ESP-IDF application entry point is `call_start_cpu0` function found in `components/esp_system/port/cpu_start.c`. This function is executed by the second stage bootloader, and never returns.

This port-layer initialization function initializes the basic C Runtime Environment (CRT) and performs initial configuration of the SoC’s internal hardware:

- Reconfigure CPU exceptions for the app (allowing app interrupt handlers to run, and causing Fatal Errors to be handled using the options configured for the app rather than the simpler error handler provided by ROM).
- If the option `CONFIG_BOOTLOADER_WDT_ENABLE` is not set then the RTC watchdog timer is disabled.
- Initialize internal memory (data & bss).
- Finish configuring the MMU cache.
- Enable PSRAM if configured.
- Set the CPU clocks to the frequencies configured for the project.
- Reconfigure the main SPI flash based on the app header settings (necessary for compatibility with bootloader versions before ESP-IDF V4.0, see *Bootloader compatibility*).
- If the app is configured to run on multiple cores, start the other core and wait for it to initialize as well (inside the similar “port layer” initialization function `call_start_cpu1`).

Once `call_start_cpu0` completes running, it calls the “system layer” initialization function `start_cpu0` found in `components/esp_system/startup.c`. Other cores will also complete port-layer initialization and call `start_other_cores` found in the same file.

### System Initialization

The main system initialization function is `start_cpu0`. By default, this function is weak-linked to the function `start_cpu0_default`. This means that it’s possible to override this function to add some additional initialization steps.

The primary system initialization stage includes:

- Log information about this application (project name, App version, etc.) if default log level enables this.
- Initialize the heap allocator (before this point all allocations must be static or on the stack).
- Initialize newlib component syscalls and time functions.
- Configure the brownout detector.
- Setup libc stdin, stdout, and stderr according to the serial console configuration.
- Perform any security-related checks, including burning efuses that should be burned for this configuration (including disabling ROM download mode on ESP32 V3, `CONFIG_ESP32_DISABLE_BASIC_ROM_CONSOLE`).
- Initialize SPI flash API support.
- Call global C++ constructors and any C functions marked with `__attribute__((constructor))`.

Secondary system initialization allows individual components to be initialized. If a component has an initialization function annotated with the `ESP_SYSTEM_INIT_FN` macro, it will be called as part of secondary initialization.

### 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 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. Using this information ESP32 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 into GATT Server mode and then it will send broadcasts with specific advertising data. You can customize this broadcast as needed, which is not a part of the BluFi Profile.
2. Use the App installed on the mobile phone to search for this particular broadcast. The mobile phone will connect to ESP32 as the GATT Client once the broadcast is confirmed. The App used during this part is up to you.
3. After the GATT connection is successfully established, the mobile phone will send a data frame for key negotiation to ESP32 (see the section *The Frame Formats Defined in BluFi* for details).
4. After ESP32 receives the data frame of key negotiation, it will parse the content according to the user-defined negotiation method.
5. The mobile phone works with ESP32 for key negotiation using the encryption algorithms such as DH, RSA or ECC.
6. After the negotiation process is completed, the mobile phone will send a control frame for security-mode setup to ESP32.
7. When receiving this control frame, ESP32 will be able to encrypt and decrypt the communication data using the shared key and the security configuration.
8. The mobile phone sends the data frame defined in the section of The Frame Formats Defined in BluFi, with the Wi-Fi configuration information to ESP32, including SSID, password, etc.
9. The mobile phone sends a control frame of Wi-Fi connection request to ESP32. When receiving this control frame, ESP32 will regard the communication of essential information as done and get ready to connect to the Wi-Fi.
10. After connecting to the Wi-Fi, ESP32 will send a control frame of Wi-Fi connection status report to the mobile phone, to report the connection status. At this point the networking procedure is completed.

Note:
1. After ESP32 receives the control frame of security-mode configuration, it will execute the operations in accordance with the defined security mode.
2. The data lengths before and after symmetric encryption/decryption must stay the same. It also supports in-place encryption and decryption.

4.3.3 The Flow Chart of BluFi

4.3.4 The Frame Formats Defined in BluFi

The frame formats for the communication between the mobile phone App and ESP32 are defined as follows:

The frame format with no fragment (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>
<tr>
<td>Data</td>
<td>• Total Content Length: 2</td>
</tr>
<tr>
<td></td>
<td>• Content: {Data Length} - 2</td>
</tr>
<tr>
<td>CheckSum (Most Significant Bit)</td>
<td>2</td>
</tr>
</tbody>
</table>

Normally, the control frame does not contain data bits, except for ACK Frame.
Fig. 2: BluFi Flow Chart
Chapter 4. API Guides

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. • b’ 0000: no checksum and no encryption; • b’ 0001: with checksum but no encryption; • b’ 0010: no checksum but with encryption; • b’ 0011: with both checksum and encryption.</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: • 0x00: NULL • 0x01: STA • 0x02: SoftAP • 0x03: SoftAP &amp; STA Please set the SSID/Password/Max Connection Number of the AP mode in the first place if an AP gets involved.</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. • 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[0~5] is taken as the MAC address for the STA device. If there is a second STA device, then it uses data[6-11] and the rest can be done in the same manner.</td>
</tr>
<tr>
<td>0x7 (b’ 000111)</td>
<td>Get the version information.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x8 (b’ 001000)</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’ 001001)</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: 0x1 b’01)
<table>
<thead>
<tr>
<th>Data Frame</th>
<th>Implication</th>
<th>Explanation</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0 000001</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 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 000001</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 000001</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 000010</td>
<td>Send the SSID for SoftAP mode.</td>
<td></td>
<td>Please refer to Note 1 below.</td>
</tr>
<tr>
<td>0x5 000010</td>
<td>Send the password for SoftAP mode.</td>
<td></td>
<td>Please refer to Note 1 below.</td>
</tr>
<tr>
<td>0x6 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 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 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 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 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 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 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 011000</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 011010</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 the DATA field is encrypted (no checksum). Control frame is not 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 as SHA1, MD5, CRC, etc.) for the end of the frame. Data field includes sequence + data length + clear text. Both the control frame and the 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 frame;</td>
</tr>
<tr>
<td></td>
<td>• 1 indicates that there are subsequent data fragments and used to transmit longer data. In the case of a frag frame, the total length of the current content section + subsequent content section is given, in the first 2 bytes of 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

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 a 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, you can determine and develop the security processing, such as key negotiation. The mobile application sends the negotiation data to ESP32 and then the data will be sent to the application layer for processing. If the application layer does not process it, you can use the DH encryption algorithm provided by BluFi to negotiate the key.

   The application layer needs to register several security-related functions to BluFi:

   ```c
   typedef void (*esp_blufi_negotiate_data_handler_t)(uint8_t *data, int len, uint8_t *output_data, int *output_len, bool *need_free)
   ```

   This function is for ESP32 to receive normal data during negotiation, 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): 0xFF01, writable

   BluFi (ESP32 -> the mobile phone): 0xFF02, readable and callable

   **4.4 Bootloader**

   The ESP-IDF Software Bootloader performs the following functions:

   1. Minimal initial configuration of internal modules;
   2. Initialize Flash Encryption and/or Secure features, if configured;
   3. Select the application partition to boot, based on the partition table and ota_data (if any);
   4. Load this image to RAM (IRAM & DRAM) and transfer management to the image that was just loaded.
Bootloader is located at the address 0x1000 in the flash.

For a full description of the startup process including the the ESP-IDF bootloader, see Application Startup Flow.

### 4.4.1 Bootloader compatibility

It is recommended to update to newer versions of ESP-IDF: when they are released. The OTA (over the air) update process can flash new apps in the field but cannot flash a new bootloader. For this reason, the bootloader supports booting apps built from newer versions of ESP-IDF.

The bootloader does not support booting apps from older versions of ESP-IDF. When updating ESP-IDF manually on an existing product that might need to downgrade the app to an older version, keep using the older ESP-IDF bootloader binary as well.

**Note:** If testing an OTA update for an existing product in production, always test it using the same ESP-IDF bootloader binary that is deployed in production.

#### Before ESP-IDF V2.1

Bootloaders built from very old versions of ESP-IDF (before ESP-IDF V2.1) perform less hardware configuration than newer versions. When using a bootloader from these early ESP-IDF versions and building a new app, enable the config option `CONFIG_ESP32_COMPATIBLE_PRE_V2_1_BOOTLOADERS`.

#### Before ESP-IDF V3.1

Bootloaders built from versions of ESP-IDF before V3.1 do not support MD5 checksums in the partition table binary. When using a bootloader from these ESP-IDF versions and building a new app, enable the config option `CONFIG_ESP32_COMPATIBLE_PRE_V3_1_BOOTLOADERS`.

#### SPI Flash Configuration

Each ESP-IDF application or bootloader .bin file contains a header with `CONFIG_ESPTOOLPY_FLASHMODE, CONFIG_ESPTOOLPY_FLASHFREQ, CONFIG_ESPTOOLPY_FLASHSIZE` embedded in it. These are used to configure the SPI flash during boot.

The *First stage bootloader* in ROM reads the *Second stage bootloader* header information from flash and uses this information to load the rest of the *Second stage bootloader* from flash. However, at this time the system clock speed is lower than configured and not all flash modes are supported. When the *Second stage bootloader* then runs, it will reconfigure the flash using values read from the currently selected app binary’s header (and NOT from the *Second stage bootloader* header). This allows an OTA update to change the SPI flash settings in use.

Bootloaders prior to ESP-IDF V4.0 used the bootloader’s own header to configure the SPI flash, meaning these values could not be changed in an update. To maintain compatibility with older bootloaders, the app re-initializes the flash settings during app startup using the configuration found in the app header.

### 4.4.2 Log Level

The default bootloader log level is “Info”. By setting the `CONFIG_BOOTLOADER_LOG_LEVEL` option, it’s possible to increase or decrease this level. This log level is separate from the log level used in the app (see Logging library).

Reducing bootloader log verbosity can improve the overall project boot time by a small amount.
4.4.3 Factory reset

Sometimes it is desirable to have a way for the device to fall back to a known-good state, in case of some problem with an update.

To roll back to the original “factory” device configuration and clear any user settings, configure the config item CONFIG_BOOTLOADER_FACTORY_RESET in the bootloader.

The factory reset mechanism allows the device to be factory reset in two ways:

- Clear one or more data partitions. The CONFIG_BOOTLOADER_DATA_FACTORY_RESET option allows users to specify which data partitions will be erased when the factory reset is executed. Users can specify the names of partitions as a comma-delimited list with optional spaces for readability. (Like this: nvs, phy_init, nvs_custom). Make sure that the names of partitions specified in the option are the same as those found in the partition table. Partitions of type “app” cannot be specified here.
- Boot from “factory” app partition. Enabling the CONFIG_BOOTLOADER_OTA_DATA_ERASE option will cause the device to boot from the default “factory” app partition after a factory reset (or if there is no factory app partition in the partition table then the default ota app partition is selected instead). This reset process involves erasing the OTA data partition which holds the currently selected OTA partition slot. The “factory” app partition slot (if it exists) is never updated via OTA, so resetting to this allows reverting to a “known good” firmware application.

Either or both of these configuration options can be enabled independently.

In addition, the following configuration options control the reset condition:

- CONFIG_BOOTLOADER_NUM_PIN_FACTORY_RESET - The input GPIO number used to trigger a factory reset. This GPIO must be pulled low or high (configurable) on reset to trigger this.
- CONFIG_BOOTLOADER_HOLD_TIME_GPIO - this is hold time of GPIO for reset/test mode (by default 5 seconds). The GPIO must be held continuously for this period of time after reset before a factory reset or test partition boot (as applicable) is performed.
- CONFIG_BOOTLOADER_FACTORY_RESET_PIN_LEVEL - configure whether a factory reset should trigger on a high or low level of the GPIO. If the GPIO has an internal pullup then this is enabled before the pin is sampled, consult the ESP32 datasheet for details on pin internal pullups.

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 0x7000 (28672) bytes.

If the bootloader binary is too large, then the bootloader build will fail with an error “Bootloader binary size [...] is too large for partition table offset”. If the bootloader binary is flashed anyhow then the ESP32 will fail to boot - errors will be logged about either invalid partition table or invalid bootloader checksum.

Options to work around this are:

- Set bootloader compiler optimization back to “Size” if it has been changed from this default value.
- Reduce bootloader log level. Setting log level to Warning, Error or None all significantly reduce the final binary size (but may make it harder to debug).
- Set `CONFIG_PARTITION_TABLE_OFFSET` to a higher value than 0x8000, to place the partition table later in the flash. This increases the space available for the bootloader. If the partition table CSV file contains explicit partition offsets, they will need changing so no partition has an offset lower than `CONFIG_PARTITION_TABLE_OFFSET + 0x1000`. (This includes the default partition CSV files supplied with ESP-IDF.)

When Secure Boot V2 is enabled, there is also an absolute binary size limit of 48KB (0xC000 bytes) (excluding the 4 KB signature), because the bootloader is first loaded into a fixed size buffer for verification.

4.4.8 Fast boot from Deep Sleep

The bootloader has the `CONFIG_BOOTLOADER_SKIP_VALIDATE_IN_DEEP_SLEEP` option which allows the wake-up time from deep sleep to be reduced (useful for reducing power consumption). This option is available when `CONFIG_SECURE_BOOT` option is disabled. Reduction of time is achieved due to the lack of image verification. During the first boot, the bootloader stores the address of the application being launched in the RTC FAST memory. And during the awakening, this address is used for booting without any checks, thus fast loading is achieved.

4.4.9 Custom bootloader

The current bootloader implementation allows a project to extend it or modify it. There are two ways of doing it: by implementing hooks or by overriding it. Both ways are presented in `custom_bootloader` folder in ESP-IDF examples:
• `bootloader_hooks` which presents how to connect some hooks to the bootloader initialization
• `bootloader_override` which presents how to override the bootloader implementation

In the bootloader space, you cannot use the drivers and functions from other components. If necessary, then the required functionality should be placed in the project’s `bootloader_components` directory (note that this will increase its size).

If the bootloader grows too large then it can collide with the partition table, which is flashed at offset 0x8000 by default. Increase the `partition table offset` value to place the partition table later in the flash. This increases the space available for the bootloader.

### 4.5 Build System

This document explains the implementation of the ESP-IDF build system and the concept of “components”. Read this document if you want to know how to organize and build a new ESP-IDF project or component.

#### 4.5.1 Overview

An ESP-IDF project can be seen as an amalgamation of a number of components. For example, for a webserver that shows the current humidity, there could be:

- The ESP-IDF base libraries (libc, ROM bindings, etc)
- The Wi-Fi drivers
- A TCP/IP stack
- The FreeRTOS operating system
- A 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, ie 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 if 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 `OUTPUT_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` 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):
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.

**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 CMake-Lists.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 all supported Python versions. It should work out-of-box even if you have a legacy system where the default python interpreter is still Python 2.7, however, it is advised to switch to Python 3 if possible.

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.

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 <module>
    import kconfiglib
ImportError: bad magic number in 'kconfiglib': b'\x03\xf3\r
'
```

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.
Chapter 4. API Guides

- 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_minimum_required(VERSION 3.5)
included($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 - ie `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.
Chapter 4. API Guides

• 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.
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-error, 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 (ie they contain a CMakeLists.txt file), or they can be top-level directories whose sub-directories are components.

When CMake runs to configure the project, it logs the components included in the build. This list can be useful for debugging the inclusion/exclusion of certain components.
Multiple components with the same name

When ESP-IDF is collecting all the components to compile, it will do this in the order specified by COMPO-
ONENT_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:

```bash
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**.
  – 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:

```
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:

```
set_source_files_properties(mysrc.c
  PROPERTIES COMPILER_FLAGS
  -Wno-unused-variable)
```

This can be useful if there is upstream code that emits warnings.

When using these commands, place them after the call to `idf_component_register` in the component CMakeLists file.
4.5.6 Component Configuration

Each component can also have a Kconfig file, alongside CMakeLists.txt. This contains configuration settings to add to the configuration menu for this component. These settings are found under the “Component Settings” menu when menuconfig is run. To create a component Kconfig file, it is easiest to start with one of the Kconfig files distributed with ESP-IDF. For an example, see Adding conditional configuration.

4.5.7 Preprocessor Definitions

The ESP-IDF build system adds the following C preprocessor definitions on the command line:

- **ESP_PLATFORM**: Can be used to detect that build happens within ESP-IDF.
- **IDF_VER**: Defined to a git version string. E.g. v2.0 for a tagged release or v1.0-275-g0efaa4f for an arbitrary commit.

4.5.8 Component Requirements

When compiling each component, the ESP-IDF build system recursively evaluates its dependencies. This means each component needs to declare the components that it depends on ("requires").

**When writing a component**

```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 components 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:
**Car component**  The `car.h` header file is the public interface for the `car` component. This header includes `engine.h` directly because it uses some declarations from this header:

```c
/* car.h */
#include "engine.h"

#ifdef ENGINE_IS_HYBRID
#define CAR_MODEL "Hybrid"
#endif
```

And `car.c` includes `car.h` as well:

```c
/* car.c */
#include "car.h"
```

This means the `car/CMakeLists.txt` file needs to declare that `car` requires `engine`:

```cmake
idf_component_register(
  SRCS "car.c"
  INCLUDE_DIRS "."
  REQUIRES engine)
```

- `SRCS` gives the list of source files in the `car` component.
- `INCLUDE_DIRS` gives the list of public include directories for this component. Because the public interface is `car.h`, the directory containing `car.h` is listed here.
- `REQUIRES` gives the list of components required by the public interface of this component. Because `car.h` is a public header and includes a header from `engine`, we include `engine` here. This makes sure that any other component which includes `car.h` will be able to recursively include the required `engine.h` also.

**Engine component**  The `engine` component also has a public header file `include/engine.h`, but this header is simpler:

```c
/* engine.h */
#define ENGINE_IS_HYBRID

void engine_start (void);
```

The implementation is in `engine.c`:

```c
/* engine.c */
#include "engine.h"
#include "spark_plug.h"

...
```

In this component, `engine` depends on `spark_plug` but this is a private dependency. `spark_plug.h` is needed to compile `engine.c`, but not needed to include `engine.h`.

This means that the `engine/CMakeLists.txt` file can use `PRIV_REQUIRES`:
idf_component_register(SRCS "engine.c"
    INCLUDE_DIRS "include"
    PRIV_REQUIRES spark_plug)

As a result, source files in the car component don’t need the spark_plug include directories added to their compiler search path. This can speed up compilation, and stops compiler command lines from becoming longer than necessary.

**Spark Plug Component**  The spark_plug component doesn’t depend on anything else. It has a public header file spark_plug.h, but this doesn’t include headers from any other components.

This means that the spark_plug/CMakeLists.txt file doesn’t need any REQUIRES or PRIV_REQUIRES clauses:

idf_component_register(SRCS "spark_plug.c"
    INCLUDE_DIRS ".")

**Source File Include Directories**

Each component’s source file is compiled with these include path directories, as specified in the passed arguments to idf_component_register:

idf_component_register(.
    INCLUDE_DIRS "include"
    PRIV_INCLUDE_DIRS "other")

- The current component’s INCLUDE_DIRS and PRIV_INCLUDE_DIRS.
- The INCLUDE_DIRS belonging to all other components listed in the REQUIRES and PRIV_REQUIRES parameters (ie all the current component’s public and private dependencies).
- Recursively, all of the INCLUDE_DIRS of those components REQUIRES lists (ie all public dependencies of this component’s dependencies, recursively expanded).

**Main component requirements**

The component named main is special because it automatically requires all other components in the build. So it’s not necessary to pass REQUIRES or PRIV_REQUIRES to this component. See renaming main for a description of what needs to be changed if no longer using the main component.

**Common component requirements**

To avoid duplication, every component automatically requires some “common” IDF components even if they are not mentioned explicitly. Headers from these components can always be included.

The list of common components is: cxx, newlib, freertos, esp_hw_support, heap, log, 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 twice on the linker command line.

For example:

```cmake
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 (`MAKE_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 -DDEBUG=1` will produce more verbose diagnostic output from the IDF build system.
- Running `cmake` with the `--trace` or `--trace-expand` options will give a lot of information about control flow. See the `cmake` command line documentation.

When included from a project CMakeLists file, the `project.cmake` file defines some utility modules and global variables and then sets `IDF_PATH` if it was not set in the system environment.

It also defines an overridden custom version of the built-in `CMake` project function. This function is overridden to add all of the ESP-IDF specific project functionality.

**Warning On Undefined Variables**

By default, `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:

```
config FOO_ENABLE_BAR
  bool "Enable the BAR feature."
  help
    This enables the BAR feature of the FOO component.
```

CMakeLists.txt:

```
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:

```cpp
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:

```cpp
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 can not 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 our 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`:

```cpp
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)
```

(continues on next page)
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:

```cpp
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:

```cpp
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:

```cpp
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:

```cpp
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:
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:

```
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`.

Submit Document Feedback
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.)

**Note:** When using an external build process with PSRAM, remember to add -mfix-esp32-psram-cache-issue to the C compiler arguments. See CONFIG_SPIRAM_CACHE_WORKAROUND for details of this flag.

### ExternalProject dependencies, 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 (i.e 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_ALWAY 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 CMake-Lists.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 if 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`:

```cmake
add_library(json STATIC cJSON/cJSON.c cJSON/cJSON_Utils.c)
target_include_directories(json PUBLIC cJSON)
```

- This is actually an equivalent declaration to the IDF json component /components/json/CMakeLists.txt.
- This file is quite simple as there are not a lot of source files. For components with a large number of files, the globbing 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.

### 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 req1 req2 ...])
```

where:

- **target_name**- name that can be used to reference the imported library, such as when linking to other targets
- **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
cmake_minimum_required(VERSION 3.5)
project(my_custom_app C)

# Include CMake file that provides ESP-IDF CMake build system APIs.
include($ENV{IDF_PATH}/tools/cmake/idf.cmake)

# Include ESP-IDF components in the build, may be thought as an equivalent of
# add_subdirectory() but with some additional processing and magic for ESP-IDF_
# specific build processes.
idf_build_process(esp32)

# Create the project executable and plainly link the newlib component to it using
```
The example in build_system/cmake/idf_as_lib demonstrates the creation of an application equivalent to hello world application using a custom CMake project.

**Note:** The IDF build system can only set compiler flags for source files that it builds. When an external CMakeLists.txt file is used and PSRAM is enabled, remember to add -mfix-esp32-psram-cache-issue to the C compiler arguments. See CONFIG_SPIRAM_CACHE_WORKAROUND for details of this flag.

### 4.5.21 ESP-IDF CMake Build System API

**idf-build-commands**

```
idf_build_get_property(var property [GENERATOR_EXPRESSION])
```

Retrieve a build property `property` and store it in `var` accessible from the current scope. Specifying `GENERATOR_EXPRESSION` will retrieve the generator expression string for that property, instead of the actual value, which can be used with CMake commands that support generator expressions.

```
idf_build_set_property(property val [APPEND])
```

Set a build property `property` with value `val`. Specifying `APPEND` will append the specified value to the current value of the property. If the property does not previously exist or it is currently empty, the specified value becomes the first element/member instead.

```
idf_build_component(component_dir)
```

Present a directory `component_dir` that contains a component to the build system. Relative paths are converted to absolute paths with respect to current directory. All calls to this command must be performed before `idf_build_process`.

This command does not guarantee that the component will be processed during build (see the `COMPONENTS` argument description for `idf_build_process`)

```
idf_build_process(target
                [PROJECT_DIR project_dir]
                [PROJECT_VER project_ver]
                [PROJECT_NAME project_name]
                [SDKCONFIG sdkconfig]
                [SDKCONFIG_DEFAULTS sdkconfig_defaults]
                [BUILD_DIR build_dir]
                [COMPONENTS component1 component2 ...])
```

Performs the bulk of the behind-the-scenes magic for including ESP-IDF components such as component configuration, libraries creation, dependency expansion and resolution. Among these functions, perhaps the most important from a user’s perspective is the libraries creation by calling each component’s `idf_component_register`. This command creates the libraries for each component, which are accessible using aliases in the form `idf::component_name`. These aliases can be used to link the components to the user’s own targets, either libraries or executables.

The call requires the target chip to be specified with `target` argument. Optional arguments for the call include:

- `PROJECT_DIR` - directory of the project; defaults to CMAKE_SOURCE_DIR
• PROJECT_NAME - name of the project; defaults to CMAKE_PROJECT_NAME
• PROJECT_VER - version/revision of the project; defaults to “1”
• SDKCONFIG - output path of generated sdkconfig file; defaults to PROJECT_DIR/sdkconfig or CMAKE_SOURCE_DIR/sdkconfig depending if PROJECT_DIR is set
• SDKCONFIG_DEFAULTS - list of files containing default config to use in the build (list must contain full paths); defaults to empty. For each value filename in the list, the config from file filename.target, if it exists, is also loaded.
• BUILD_DIR - directory to place ESP-IDF build-related artifacts, such as generated binaries, text files, components; defaults to CMAKE_BINARY_DIR
• COMPONENTS - select components to process among the components known by the build system (added via idf_build_component). This argument is used to trim the build. Other components are automatically added if they are required in the dependency chain, i.e. the public and private requirements of the components in this list are automatically added, and in turn the public and private requirements of those requirements, so on and so forth. If not specified, all components known to the build system are processed.

```cmake
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.

```cmake
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:

```cmake
idf_build_get_property(python PYTHON)
message(STATUS "The Python interpreter is: \${python}\")
```

---

- BUILD_DIR - build directory; set from idf_build_process BUILD_DIR argument
- BUILD_COMPONENTS - list of components included in the build; set by idf_build_process
- BUILD_COMPONENT_ALIASES - list of library alias of components included in the build; set by idf_build_process
- C_COMPILE_OPTIONS - compile options applied to all components’ C source files
- COMPILE_OPTIONS - compile options applied to all components’ source files, regardless of it being C or C++
- COMPILE_DEFINITIONS - compile definitions applied to all component source files
- 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_VER - ESP-IDF version; set from either a version file or the Git revision of the IDF_PATH repository
- INCLUDE_DIRECTORIES - include directories for all component source files
- KCONFIGS - list of Kconfig files found in components in build; set by idf_build_process
- KCONFIG_PROJBUILDS - list of Kconfig.projobuild files found in components in build; set by idf_build_process
- PROJECT_NAME - name of the project; set from idf_build_process PROJECT_NAME argument
- PROJECT_DIR - directory of the project; set from idf_build_process PROJECT_DIR argument
• PROJECT_VER - version of the project; set from \texttt{idf\_build\_process PROJECT\_VER} argument
• PYTHON - Python interpreter used for the build; set from PYTHON environment variable if available, if not “python” is used
• SDKCONFIG - full path to output config file; set from \texttt{idf\_build\_process} SDKCONFIG argument
• SDKCONFIG_DEFAULTS - list of files containing default config to use in the build; set from \texttt{idf\_build\_process} SDKCONFIG_DEFAULTS argument
• SDKCONFIG_HEADER - full path to C/C++ header file containing component configuration; set by \texttt{idf\_build\_process}
• SDKCONFIG_CMAKE - full path to CMake file containing component configuration; set by \texttt{idf\_build\_process}
• SDKCONFIG_JSON - full path to JSON file containing component configuration; set by \texttt{idf\_build\_process}
• SDKCONFIG_JSON_MENUS - full path to JSON file containing config menus; set by \texttt{idf\_build\_process}

\textbf{idf-component-commands}

\begin{verbatim}
idf_component_get_property(var component property [GENERATOR\_EXPRESSION])
\end{verbatim}

Retrieve a specified component’s component property, property and store it in \texttt{var} accessible from the current scope. Specifying \texttt{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.

\begin{verbatim}
idf_component_set_property(component property val [APPEND])
\end{verbatim}

Set a specified component’s component property, property with value \texttt{val}. Specifying \texttt{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.

\begin{verbatim}
idf_component_register([[SRCS src1 src2 ...] | [[SRC\_DIRS dir1 dir2 ...] [EXCLUDE_ 
\_SRCS src1 src2 ...]]) 
[INCLUDE\_DIRS dir1 dir2 ...] 
[PRIV\_INCLUDE\_DIRS dir1 dir2 ...] 
[REQUIRES component1 component2 ...] 
[PRIV\_REQUIRES component1 component2 ...] 
[LDFRAGMENTS ldfragment1 ldfragment2 ...] 
[REQUIRED\_IDF\_TARGETS target1 target2 ...] 
[EMBED\_FILES file1 file2 ...] 
[EMBED\_TXTFILES file1 file2 ...] 
[KCONFIG kconfig] 
[KCONFIG\_PROJBUILD kconfig\_projbuidl]]
\end{verbatim}

Register a component to the build system. Much like the \texttt{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 \texttt{idf_component_register}:

• commands that are not valid in CMake script mode
• custom commands defined in \texttt{project\_include\_cmake}
• build system API commands except \texttt{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 \texttt{idf_component_register}.

The arguments for \texttt{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 \textbf{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 the current component
• PRIV_INCLUDE_DIRS - directory paths, must be relative to the component directory, which will be added to the include search path for this component’s source files only
• REQUIRED - 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.projbuild 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:

```c
idf_component_get_property(dir freertos COMPONENT_DIR)
message(STATUS "The 'freertos' component directory is: ${dir}")
```

• COMPONENT_ALIAS - alias for COMPONENT_LIB used for linking the component to external targets; set by `idf_build_component` and alias library itself is created by `idf_component_register`
• COMPONENT_DIR - component directory; set by `idf_build_component`
• COMPONENT_OVERRIDEN_DIR - contains the directory of the original component if this component overrides another component
• COMPONENT_LIB - name for created component static/interface library; set by `idf_build_component` and library itself is created by `idf_component_register`
• COMPONENT_NAME - name of the component; set by `idf_build_component` based on the component directory name
• COMPONENT_TYPE - type of the component, whether LIBRARY or CONFIG_ONLY. A component is of type LIBRARY if it specifies source files or embeds a file
• EMBED_FILES - list of files to embed in component; set from `idf_component_register EMBED_FILES` argument
• EMBED_TXTFILES - list of text files to embed in component; set from `idf_component_register EMBED_TXTFILES` argument
• INCLUDE_DIRS - list of component include directories; set from `idf_component_register INCLUDE_DIRS` argument
• KCONFIG - component Kconfig file; set by `idf_build_component`
• KCONFIG_PROJBUILD - component Kconfig.projbuild; set by `idf_build_component`
• LDFFRAGMENTS - list of component linker fragment files; set from `idf_component_register LDFFRAGMENTS` argument
• 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 REQUIRED_IDF_TARGETS` argument
• REQUIRES - list of public component dependencies; set from `idf_component_register REQUIRED` 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.
- CMakeCache.txt is the CMake cache file which contains other information about the CMake process, toolchain, etc.
- config/sdkconfig.json is a JSON-formatted version of the project configuration values.
- config/kconfig_menus.json is a JSON-formatted version of the menus shown in menuconfig, for use in external IDE UIs.
JSON Configuration Server

A tool called `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 CMakescripts 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:

![ESP-IDF Build System Process](image)

**Initialization**   This phase sets up necessary parameters for the build.

- Upon inclusion of `idf.cmake` in `project.cmake`, the following steps are performed:
  - Set `IDF_PATH` from environment variable or inferred from path to `project.cmake` included in the top-level CMakeLists.txt.
  - Add `/tools/cmake` to `CMAKE_MODULE_PATH` and include core modules plus the various helper/third-party scripts.
– Set build tools/executables such as default Python interpreter.
– Get ESP-IDF git revision and store as IDF_VER.
– Set global build specifications i.e. compile options, compile definitions, include directories for all components in the build.
– Add components in components to the build.
  • The initial part of the custom project() command performs the following steps:
    – Set IDF_TARGET from environment variable or CMake cache and the corresponding CMAKE_TOOLCHAIN_FILE to be used.
    – Add components in EXTRA_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.

Processing

This phase processes the components in the build, and is the second half of idf_build_process().

• Load project configuration from sdkconfig file and generate an sdkconfig.cmake and sdkconfig.h header. These define configuration variables/macros that are accessible from the build scripts and C/C++ source/header files, respectively.
• Include each component’s project_include.cmake.
• Add each component as a subdirectory, processing its CMakeLists.txt. The component CMakeLists.txt calls the registration command, idf_component_register which adds source files, include directories, creates component library, links dependencies, etc.

Finalization

This phase is everything after idf_build_process().

• Create executable and link the component libraries to it.
• Generate project metadata files such as project_description.json and display relevant information about the project built.

Browse /tools/cmake/project.cmake for more details.

4.5.25 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_IDFLAGS**: Used to override linker flags. Use the CMake `target_link_libraries` command instead.
- **COMPONENT_ADD_LINKER_DEPS**: List of files that linking should depend on. `target_link_libraries` will usually infer these dependencies automatically. For linker scripts, use the provided custom CMake function `target_linker_scripts`.
- **COMPONENT_SUBMODULES**: No longer used, the build system will automatically enumerate all submodules in the ESP-IDF repository.
- **COMPONENT_EXTRA_INCLUDES**: Used to be an alternative to `COMPONENT_PRIV_INCLUDEDIRS` for absolute paths. Use `PRIV_INCLUDE_DIRS` argument to `idf_component_register` for all cases now (can be relative or absolute).
- **COMPONENT_OBJS**: Previously, component sources could be specified as a list of object files. Now they can be specified as a list of source files via `SRCS` argument to `idf_component_register`.
- **COMPONENT_OBJEXCLUDE**: Has been replaced with `EXCLUDE_SRCS` argument to `idf_component_register`. Specify source files (as absolute paths or relative to component directory), instead.
- **COMPONENT_EXTRA_CLEAN**: Set property `ADDITIONAL_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 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 unintialised 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 does should be to call esp_default_wake_deep_sleep(). It is not necessary to implement esp_wake_deep_sleep() in your app in order to use deep sleep. It is only necessary if you want to have special behaviour immediately on wake.

If you want to swap between different deep sleep stubs at runtime, it is also possible to do this by calling the esp_set_deep_sleep_wake_stub() function. This is not necessary if you only use the default esp_wake_deep_sleep() function.

All of these functions are declared in the esp_sleep.h header under components/esp32.

4.6.3 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\n";
    esp_rom_printf(fmt_str, wake_count + 1);
}
```

The RTC memory area where this data will be placed can be configured via menuconfig option named `CONFIG_ESP32_RTCDATA_IN_FAST_MEM`. This option allows to keep slow memory area for ULP programs and once it is enabled the data marked with `RTC_DATA_ATTR` and `RTC_RODATA_ATTR` are placed in the RTC fast memory segment otherwise it goes to RTC slow memory (default option). This option depends on the `CONFIG_FREERTOS_UNICORE` because RTC fast memory can be accessed only by PRO_CPU.

The attributes `RTC_FAST_ATTR` and `RTC_SLOW_ATTR` can be used to specify data that will be force placed into RTC_FAST and RTC_SLOW memory respectively. Any access to data marked with `RTC_FAST_ATTR` is allowed by PRO_CPU only and it is responsibility of user to make sure about it.

Unfortunately, any string constants used in this way must be declared as arrays and marked with `RTC_RODATA_ATTR`, as shown in the example above.

The second way is to place the data into any source file whose name starts with `rtc_wake_stub`.

For example, the equivalent example in `rtc_wake_stub_counter.c`:

```c
int wake_count;

void RTC_IRAM_ATTR esp_wake_deep_sleep(void) {
    esp_default_wake_deep_sleep();
    esp_rom_printf("Wake count $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, all RTC Fast memory areas will be validated with CRC. When ESP32 wakes up from deep sleep, the RTC fast memory will be validated with CRC again. If the validation passes, the wake stubs code will be executed. Otherwise, the normal initialization, bootloader and esp-idf codes will be executed.

**Note:** When the `CONFIG_ESP_SYSTEM_ALLOW_RTC_FAST_MEM_AS_HEAP` option is enabled, all the RTC fast memory except the wake stubs area is added to the heap.

4.7 Error Handling
4.7.1 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.

4.7.2 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.

4.7.3 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.

4.7.4 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:0x3ff85030
 0x400d0816:0x3ff85050

Note: If IDF monitor is used, addresses in the backtrace will be converted to file names and line numbers.

- The first line mentions the error code as a hexadecimal value, and the identifier used for this error in source code. The latter depends on CONFIG_ESP_ERR_TO_NAME_LOOKUP option being set. Address in the program where error has occurred is printed as well.
- Subsequent lines show the location in the program where ESP_ERROR_CHECK() macro was called, and the expression which was passed to the macro as an argument.
- Finally, backtrace is printed. This is part of panic handler output common to all fatal errors. See Fatal Errors for more information about the backtrace.

### 4.7.5 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().

### 4.7.6 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.

### 4.7.7 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.

### 4.7.8 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.

### 4.7.9 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.

### 4.7.10 CHECK MACROS Examples

Some examples:
static const char* TAG = "Test";

esp_err_t test_func(void)
{
    esp_err_t ret = ESP_OK;

    ESP_ERROR_CHECK(x);            // err message -
    ESP_ERROR_CHECK WITHOUT_ABORT(x);    // err message -
    ESP_RETURN_ON_ERROR(x, TAG, "fail reason 1");    // err message -
    ESP_RETURN_ON_FALSE(a, err_code, TAG, "fail reason 3");    // err message -
}

Note: If the option CONFIG_COMPILER_OPTIMIZATIONCHECKS_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.

4.7.11 Error handling patterns

1. Attempt to recover. Depending on the situation, this might mean to retry the call after some time, or attempt to de-initialize the driver and re-initialize it again, or 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);
```
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 behaviour 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));
```

### 4.7.12 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.

### 4.8 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, please check another product by Espressif called ESP-WIF-MESH. For more information and documentation see ESP-WIFI-MESH.
4.8.1 Getting Started with ESP-BLE-MESH

This section is intended to help you get started with ESP-BLE-MESH for the hardware based on the ESP32 chip by Espressif.

We are going to demonstrate process of setting and operation of a small ESP-BLE-MESH network of three nodes. This process will cover device provisioning and node configuration, and then sending on/off commands to Generic OnOff Server Models on specific nodes.

If you are new to ESP-IDF, please first set up development environment, compile, flash and run example application following top level ESP-IDF Get Started documentation.

What You Need

Hardware:

- Three ESP32 boards, see options.
- USB cables to connect the boards.
- Computer configured with ESP-IDF.
- Mobile phone or tablet running Android or iOS.

Software:

- Example application bluetooth/esp_ble_mesh/ble_mesh_node/onoff_server code to load to the ESP32 boards.
- Mobile App: nRF Mesh for Android or iOS. Optionally you can use some other Apps:
  - EspBleMesh Android App
  - Silicon Labs Android or iOS App

Installation Step by Step

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

**Step 1. Check Hardware**  Both ESP32-DevKitC and ESP-WROVER-KIT development boards are supported for ESP-BLE-MESH implementation. You can choose particular board through menuconfig: idf.py menuconfig

> Example Configuration > Board selection for ESP-BLE-MESH

**Note:** If you plan to use ESP32-DevKitC, connect a RGB LED to GPIO pins 25, 26 and 27.

**Step 2. Configure Software**  Enter the bluetooth/esp_ble_mesh/ble_mesh_node/onoff_server example directory, run idf.py menuconfig to select your board and then run idf.py build to compile the example.

**Step 3. Upload Application to Nodes**  After the bluetooth/esp_ble_mesh/ble_mesh_node/onoff_server example is compiled successfully, users can run idf.py flash to upload the same generated binary files into each of the three development boards.

Once boards are powered on, the RGB LED on each board should turn GREEN.

**Step 4. Provision Nodes**  In this section, we will use the nRF Mesh Android App to demonstrate how to provision an unprovisioned device. Users can also get its iOS version from the App Store.

**4.1 Scanner**  The Scanner is App’s functionality to search for unprovisioned devices in range. Open the App, press Scanner at the bottom and the search will start. After a short while we should see three unprovisioned devices displayed.
Fig. 4: ESP-BLE-MESH Devices Power On

Fig. 5: nRF Mesh - Scanner
4.2 Identify  Users can select any unprovisioned device, then the App will try to set up a connection with the selected device. After the BLE connection is established successfully (sometimes users need to try multiple times to get connected), and proper ESP-BLE-MESH GATT Service is discovered, users can see the IDENTIFY interface button on the screen. The IDENTIFY operation can be used to tell users which device is going to be provisioned.

Note: The IDENTIFY operation also needs some cooperation on the device side, then users can see which device is in the provisioning process. Currently when pressing the IDENTIFY interface button, no signs can be seen from the device except from the log on the serial monitor.

After the IDENTIFY interface button is pressed, users can see the PROVISION interface button.

![Diagram of IDENTIFY and PROVISION interfaces]

After the IDENTIFY interface button is pressed, users can see the PROVISION interface button.

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.
Chapter 4. API Guides

Fig. 7: nRF Mesh - Configuration Complete

Fig. 8: nRF Mesh - Initial Configuration Failed
Chapter 4. API Guides

Here an example of three devices listed.

- The left picture shows that the third device is provisioned successfully, but the App failed to connect with it. When it tries to reconnect with the third node, three nodes are displayed on the App.
- The right picture shows that after connecting with any node successfully, the App displays the information of the three nodes. Users can see that the App has got the Composition Data of the first and the second nodes, but for the third one, only the unicast address has been assigned to it while the Composition Data is unknown.

4.4 Configuration When provisioning and initial configuration are finished, users can start to configure the node, such as binding AppKey with each model with the elements, setting publication information to it, etc.

Example below shows how to bind AppKey with Generic OnOff Server Model within the Primary Element.

Note: No need to bind AppKey with the Configuration Server Model, since it only uses the DevKey to encrypt messages in the Upper Transport Layer.

Step 5. Operate Network After all the Generic OnOff Server Models within the three elements are bound with proper AppKey, users can use the App to turn on/off the RGB LED.

In the bluetooth/esp_ble_mesh/ble_mesh_node/onoff_server example, the first Generic OnOff Server Model is used to control the RED color, the second one is used to control the GREEN color and the third one is used to control the BLUE color.

The following screenshot shows different board with different color on.

Note: For nRF Mesh iOS App [version 1.0.4], when the node contains more than one element, the App is not behaving correctly. If users try to turn on/off the second or the third Generic OnOff Server Model, the message sent by the App is destined to the first Generic OnOff Server Model within the Primary Element.
Chapter 4. API Guides

Fig. 10: nRF Mesh - Reconnect - Three Nodes

Fig. 11: nRF Mesh - Model Bind AppKey
Chapter 4. API Guides

Fig. 12: nRF Mesh - Generic OnOff Control

Fig. 13: Three ESP-BLE-MESH Nodes On
4.8.2 ESP-BLE-MESH Examples

- **ESP-BLE-MESH Node OnOff Server** - shows the use of ESP-BLE-MESH as a node having a Configuration Server model and a Generic OnOff Server model. A ESP-BLE-MESH Provisioner can then provision the unprovisioned device and control a RGB LED representing on/off state, see example code.
- **ESP-BLE-MESH Node OnOff Client** - shows how a Generic OnOff Client model works within a node. The node has a Configuration Server model and a Generic OnOff Client model, see example code.
- **ESP-BLE-MESH Provisioner** - shows how a device can act as an ESP-BLE-MESH Provisioner to provision devices. The Provisioner has a Configuration Server model, a Configuration Client model and a Generic OnOff Client model, see example code.
- **ESP-BLE-MESH Fast Provisioning - Client and Server** - this example is used for showing how fast provisioning can be used in order to create a mesh network. It takes no more than 60 seconds to provision 100 devices, see example client code and example server code.
- **ESP-BLE-MESH and Wi-Fi Coexistence** - an example that demonstrates the Wi-Fi and Bluetooth (BLE/BR/EDR) coexistence feature of ESP32. Simply put, users can use the Wi-Fi while operating Bluetooth, see example code.
- **ESP-BLE-MESH Console** - an example that implements BLE Mesh basic features. Within this example a node can be scanned and provisioned by Provisioner and reply to get/set message from Provisioner, see example node code.

4.8.3 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

4.8.4 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

4.8.5 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
Chapter 4. API Guides

- 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 OnOff Setup Server
  - Generic Power Level Server
  - Generic Power Level Setup Server
  - Generic Battery Server
  - Generic Location Server
  - Generic Location Setup Server
  - Generic User Property Server
  - Generic Admin Property Server
  - Generic Manufacturer Property Server
  - Generic Client Property Server

- **Sensor server models**
  - Sensor Server
  - Sensor Setup Server

- **Time and Scenes server models**
  - Time Server
Chapter 4. API Guides

- Time Setup Server
- Scene Server
- Scene Setup Server
- Scheduler Server
- Scheduler Setup Server

• **Lighting server models**
  - Light Lightness Server
  - Light Lightness Setup Server
  - Light CTL Server
  - Light CTL Temperature Server
  - Light CTL Setup Server
  - Light HSL Server
  - Light HSL Hue Server
  - Light HSL Saturation Server
  - Light HSL Setup Server
  - Light xyL Server
  - Light xyL Setup Server
  - Light LC Server
  - Light LC Setup Server

**Mesh Applications**

• **ESP-BLE-MESH Node**
  - Tutorial
  - Tutorial
  - Example

• **ESP-BLE-MESH Provisioner**
  - Tutorial
  - Example

• **ESP-BLE-MESH Fast Provisioning**
  - Fast Provisioning Client Model Tutorial
  - Fast Provisioning Server Model Tutorial
  - Example
  - Demo Video

• **ESP-BLE-MESH and Wi-Fi Coexistence**
  - Tutorial
  - Example
  - Demo Video

• **ESP-BLE-MESH Console Commands**
  - Example

**Future Release Features**

**Mesh Core**

- Provisioner NVS Storage

**Mesh Applications**

- Fast OTA
- Friendship

**ESP-BLE-MESH Architecture**

This document introduces ESP-BLE-MESH architecture overview, ESP-BLE-MESH architecture implementation as well as ESP-BLE-MESH auxiliary routines.
• ESP-BLE-MESH Architecture Overview
  – Describes the five major parts of ESP-BLE-MESH architecture and the functionality of each part.
• ESP-BLE-MESH Architecture Implementation
  – Describes the basic functions of ESP-BLE-MESH files, the correspondence between files and ESP-BLE-MESH architecture, and the interface for calling among files.
• ESP-BLE-MESH Auxiliary Routines
  – Describe the auxiliary routines of ESP-BLE-MESH, such as Mesh network management, Mesh features, etc.

1. ESP-BLE-MESH Architecture Overview  Currently ESP-BLE-MESH has implemented most functions of Mesh Profile and all the Client Models defined in Mesh Model specification. Those missing functions/models are under development and will be provided soon. ESP-BLE-MESH architecture has been granted the official Bluetooth certification.

ESP-BLE-MESH architecture includes five key parts:

• Mesh Protocol Stack
  – Mesh Networking is responsible for processing of messages of ESP-BLE-MESH nodes.
  – Mesh Provisioning is responsible for provisioning flow of ESP-BLE-MESH devices.
  – Mesh Models is responsible for the implementation of SIG-defined models.
• Network Management
  – Implements several network management procedures, including node removal procedure, IV Index recovery procedure, etc.
• Features
  – Include several ESP-BLE-MESH features, e.g. Low Power feature, Friend feature, Relay feature, etc.
• Mesh Bearer Layer
  – Includes Advertising Bearer and GATT Bearer. The bearer layer is crucial to ESP-BLE-MESH protocol stack which is built on Bluetooth Low-Energy technology, because the protocol stack must make use of the bearer layer to transmit data via the BLE advertising channel and connection channel.
• Applications
  – Based on ESP-BLE-MESH protocol stack and Mesh Models.
  – By calling API and handling Event, Applications interact with Mesh Networking and Mesh Provisioning in ESP-BLE-MESH protocol stack, as well as a series of Models provided by Mesh Models.

1.1 Mesh Protocol Stack

1.1.1 Mesh Networking  Mesh Networking in the protocol stack architecture implements the following functions:

• The communication between nodes in the Mesh network.
• Encryption and decryption of messages in the Mesh network.
• Management of Mesh network resources (Network Key, IV Index, etc.).
• Segmentation and reassembly of Mesh network messages.
• Model mapping of messages between different models.
• For more features, please see ESP-BLE-MESH Feature List.

The implementation of Mesh Networking functions is based on hierarchy structure. Functions of each layer are shown in Table 1.1:
Fig. 14: Figure 1.1 ESP-BLE-MESH Architecture Diagram
Table 1: Table 1.1 Mesh Networking Architecture Description

<table>
<thead>
<tr>
<th>Layer</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access Layer</td>
<td>Access Layer not only defines the format of application data, but also defines and controls the encryption and decryption of the data packets conducted by Upper Transport Layer.</td>
</tr>
<tr>
<td>Upper Transport Layer</td>
<td>Upper Transport Layer encrypts, decrypts, and authenticates application data to and from the access layer; it also handles special messages called “transport control messages”, including messages related to “friendship” and heartbeat messages.</td>
</tr>
<tr>
<td>Lower Transport Layer</td>
<td>Lower Transport Layer handles segmentation and reassembly of PDU.</td>
</tr>
<tr>
<td>Network Layer</td>
<td>Network Layer defines the address type and format of the network messages, and implements the relay function of the device.</td>
</tr>
</tbody>
</table>

1.1.2 Mesh Provisioning  

Mesh Provisioning in the protocol stack architecture implements the following functions:

- Provisioning of unprovisioned devices.
- Allocation of Mesh network resources (unicast address, IV Index, NetKey, etc.).
- Four authentication methods support during provisioning.
- For more features, please see ESP-BLE-MESH Feature List.

The implementation of Mesh Provisioning functions is based on hierarchy structure. Functions of each layer are shown in Table 1.2:

Table 2: Table 1.2 Mesh Provisioning Architecture Description

<table>
<thead>
<tr>
<th>Layer</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provisioning PDUs</td>
<td>Provisioning PDUs from different layers are handled using provisioning protocol.</td>
</tr>
<tr>
<td>Generic Provisioning PDU/Proxy PDU</td>
<td>The Provisioning PDUs are transmitted to an unprovisioned device using a Generic Provisioning layer or Proxy protocol layer.</td>
</tr>
<tr>
<td>PB-ADV/PB-GATT</td>
<td>These layers define how the Provisioning PDUs are transmitted as transactions that can be segmented and reassembled.</td>
</tr>
<tr>
<td>Advertising/Provisioning Service</td>
<td>The provisioning bearers define how sessions are established such that the transactions from the generic provisioning layer can be delivered to a single device.</td>
</tr>
</tbody>
</table>

1.1.3 Mesh Models  

Mesh Models in the protocol stack architecture implements the following functions:

- Configuration Client/Server Models
- Health Client/Server Models
- Generic Client/Server Models
- Sensor Client/Server Models
- Time and Scenes Client/Server Models
- Lighting Client/Server Models

Functions of each layer are shown in Table 1.3:

Table 3: Table 1.3 Mesh Models Architecture Description

<table>
<thead>
<tr>
<th>Layer</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Layer</td>
<td>Model Layer implements models used to standardize the operation of typical user scenarios, including Generic Client/Server Models, Sensor Client/Server Models, Time and Scenes Client/Server Models, Lighting Client/Server Models and several vendor models.</td>
</tr>
<tr>
<td>Foundation Model Layer</td>
<td>Foundation Model Layer implements models related to ESP-BLE-MESH configuration, management, self diagnosis, etc.</td>
</tr>
</tbody>
</table>

1.2 Mesh Network Management  

Network Management implements the following functions:

- 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 4: Table 1.3 Mesh Bearers Description

<table>
<thead>
<tr>
<th>Layer</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>GATT Bearer</td>
<td>The GATT Bearer uses the Proxy protocol to transmit and receive Proxy PDUs between two devices over a GATT connection.</td>
</tr>
<tr>
<td>Advertising Bearer</td>
<td>When using the Advertising Bearer, a mesh packet shall be sent in the Advertising Data of a Bluetooth Low Energy advertising PDU using the Mesh Message AD Type.</td>
</tr>
</tbody>
</table>

1.5 Mesh Applications The Applications in the protocol stack architecture implement the corresponding functions by calling the API provided by the ESP-BLE-MESH protocol stack and processing the Event reported by the protocol stack. There are some common applications, such as gateway, lighting and etc.

Interaction between application layer (Applications) and API / Event
• Application layer calls API
  – Call the provisioning-related API for provisioning.
  – Call the model-related API to send messages.
  – Call the device-attributes-related API to get local information about the device.
• Application layer processes Event
  The application layer is designed based on events, which take parameters to the application layer. Events are mainly divided into two categories.
  – The events completed by calling API.
    * Such as nodes sending messages.
  – The events that the protocol stack actively reports to the application layer.
    * The Event that the protocol stack actively reports.
    * The Event that Model actively reports.
  The event is reported by the callback function registered by the application layer, and the callback function also contains the corresponding processing of the event.

Interaction between API / Event and ESP-BLE-MESH protocol stack
• API used by user mainly calls functions provided by Mesh Networking, Mesh Provisioning and Mesh Models.
• The interaction between API / Event and the protocol stack does not operate across the hierarchy of the protocol stack. For example, API does not call functions related to Network Layer.
2. ESP-BLE-MESH Architecture Implementation  The design and implementation of ESP-BLE-MESH architecture is based on layers and modules. In details, Section 2.1 (Mesh Networking Implementation), Section 2.2 (Mesh Provisioning Implementation) and Section 2.3 (Mesh Bearers Implementation) are based on layers, and Section 2.4 (Mesh Models Implementation) is on modules.

- **Layer-based Approach**: With Layer-based approach, the architecture is designed according to the layers specified in the Mesh Profile Specification. Each layer has its unique files which include APIs of this layer and etc. The specific design is shown in Figure 2.1.

- **Module-based Approach**: Every file implements an independent function that can be called by other programs.

The design of ESP-BLE-MESH architecture uses layer-based approach. The sequence of layers which data packets are processed through is fixed, i.e., the processing of packets will form a message flow. Thus, we could see flows of messages from the Protocol Stack Interface Diagram in Figure 2.1.

2.1 Mesh Protocol Stack Implementation

2.1.1 Mesh Networking Implementation  The list of files and the functions implemented in each file in Mesh Networking are shown in Table 2.1:

<table>
<thead>
<tr>
<th>File</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>access.c</td>
<td>ESP-BLE-MESH Access Layer</td>
</tr>
<tr>
<td>transport.c</td>
<td>ESP-BLE-MESH Lower/Upper Transport Layer</td>
</tr>
<tr>
<td>net.c</td>
<td>ESP-BLE-MESH Network Layer</td>
</tr>
<tr>
<td>adv.c</td>
<td>A task used to send ESP-BLE-MESH advertising packets, a callback used to handle received advertising packets and APIs used to allocate adv buffers</td>
</tr>
</tbody>
</table>

2.1.2 Mesh Provisioning Implementation  The implementation of Mesh Provisioning is divided into two chunks due to the Node/Provisioner coexistence.

Specific files that provide implementation of provisioning of Node are shown in Table 2.2:

<table>
<thead>
<tr>
<th>File</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>prov.c</td>
<td>ESP-BLE-MESH Node provisioning (PB-ADV &amp; PB-GATT)</td>
</tr>
<tr>
<td>proxy_server.c</td>
<td>ESP-BLE-MESH Proxy Server related functionalities</td>
</tr>
<tr>
<td>beacon.c</td>
<td>APIs used to handle ESP-BLE-MESH Beacons</td>
</tr>
</tbody>
</table>

Specific files that implement functions of Provisioner are shown in Table 2.3:

<table>
<thead>
<tr>
<th>File</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>provisioner_prov.c</td>
<td>ESP-BLE-MESH Provisioner provisioning (PB-ADV &amp; PB-GATT)</td>
</tr>
<tr>
<td>proxy_client.c</td>
<td>ESP-BLE-MESH Proxy Client related functionalities</td>
</tr>
<tr>
<td>provisioner_main.c</td>
<td>ESP-BLE-MESH Provisioner networking related functionalities</td>
</tr>
</tbody>
</table>

2.1.3 Mesh Models Implementation  Mesh Models are used to implement the specific functions of model in nodes. Server model is used to maintain node status. Client model is used to obtain and modify node state.
<table>
<thead>
<tr>
<th>File</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>cfg_cli.c</td>
<td>Send Configuration Client messages and receive corresponding response messages</td>
</tr>
<tr>
<td>cfg_srv.c</td>
<td>Receive Configuration Client messages and send proper response messages</td>
</tr>
<tr>
<td>health_cli.c</td>
<td>Send Health Client messages and receive corresponding response messages</td>
</tr>
<tr>
<td>health_srv.c</td>
<td>Receive Health Client messages and send proper response messages</td>
</tr>
<tr>
<td>client_common.c</td>
<td>ESP-BLE-MESH model related operations</td>
</tr>
<tr>
<td>generic_client.c</td>
<td>Send ESP-BLE-MESH Generic Client messages and receive corresponding response messages</td>
</tr>
<tr>
<td>lighting_client.c</td>
<td>Send ESP-BLE-MESH Lighting Client messages and receive corresponding response messages</td>
</tr>
<tr>
<td>sensor_client.c</td>
<td>Send ESP-BLE-MESH Sensor Client messages and receive corresponding response messages</td>
</tr>
<tr>
<td>time_scene_client.c</td>
<td>Send ESP-BLE-MESH Time Scene Client messages and receive corresponding response messages</td>
</tr>
<tr>
<td>generic_server.c</td>
<td>Receive ESP-BLE-MESH Generic Client messages and send corresponding response messages</td>
</tr>
<tr>
<td>lighting_server.c</td>
<td>Receive ESP-BLE-MESH Lighting Client messages and send corresponding response messages</td>
</tr>
<tr>
<td>sensor_server.c</td>
<td>Receive ESP-BLE-MESH Sensor Client messages and send corresponding response messages</td>
</tr>
<tr>
<td>time_scene_server.c</td>
<td>Receive ESP-BLE-MESH Time Scene Client messages and send corresponding response messages</td>
</tr>
</tbody>
</table>

2.2 Mesh Bearers Implementation Portability is fully considered in the implementation of Mesh Bearers. When the ESP-BLE-MESH protocol stack is being ported to other platforms, users only need to modify mesh_bearer_adapt.c (example of NimBLE version).

<table>
<thead>
<tr>
<th>File</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>mesh_bearer_adapt.c</td>
<td>ESP-BLE-MESH Bearer Layer adapter, This file provides the interfaces used to receive and send ESP-BLE-MESH ADV &amp; GATT related packets.</td>
</tr>
</tbody>
</table>

Note: mesh_bearer_adapt.c is the implementation of Advertising Bearer and GATT Bearer in Mesh Networking framework.

2.3 Mesh Applications Implementation We have provided a series of application examples for customer development, and users can develop products based on ESP-BLE-MESH Examples.

3. Auxiliary Routine Auxiliary routine refers to optional functions in the ESP-BLE-MESH protocol stack. The design of the auxiliary routine generally implement the truncation of code through CONFIG_BLE_MESH.

3.1 Features

- Low Power
- Friend
- Relay
- Proxy Client/Server
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 can not 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.
The phase of configuration is to add AppKeys to the node and bind AppKeys to corresponding models. And some items are optional during configuration, including adding subscription addresses to the node, set publication information, etc. By configuration, the node can actually transmit messages to a Provisioner and receive messages from it.

1.2 If a Provisioner wants to change states of a node, what requirements should be met for a Provisioner?

- Client model that corresponds to server model of the node is required.
- NetKey and AppKey used to encrypt messages shall be owned by both the node and the Provisioner.
- The address owned by the node shall be known, which could be its unicast address or subscription address.

1.3 How can NetKey and AppKey be used?

- NetKey is used for encryption of messages in Network Layer. Nodes with the same NetKey are assumed to be in the same subnet while those with different NetKeys cannot communicate with each other.
- AppKey is used for encryption of messages in Upper Transport Layer. If client model and server model are bound to different AppKeys, the communication cannot be achieved.

1.4 How to generate a NetKey or AppKey for Provisioner? Can we use a fixed NetKey or AppKey?

- The API `esp_ble_mesh_provisioner_add_local_net_key()` can be used to add a NetKey with a fixed or random value.
- The API `esp_ble_mesh_provisioner_add_local_app_key()` can be used to add an AppKey with a fixed or random value.

1.5 Is the unicast address of Provisioner fixed?

The value of `prov_unicast_addr` in `esp_ble_mesh_prov_t` is used to set the unicast address of Provisioner, it can be set only once during initialization and can’t be changed afterwards.

1.6 Can the address of Provisioner serve as destination address of the node-reporting-status message?

The unicast address of Provisioner can be set only once during initialization and can’t be changed afterwards. In theory, it can serve as the destination address of the node-reporting-status message, provided that the unicast address of the Provisioner is known by nodes. Nodes can know the unicast address of Provisioner during configuration since Provisioner sends messages to them with its unicast address used as the source address.

Subscription address can also be used. Provisioner subscribes to a group address or virtual address, and nodes send messages to the subscription address.

1.7 Is the unicast address of the node that is firstly provisioned by Provisioner to ESP-BLE-MESH network fixed?

The value of `prov_start_address` in `esp_ble_mesh_prov_t` is used to set the starting address when the Provisioner provisions unprovisioned devices, i.e. the unicast address of the node it firstly provisioned. It can be set only once during initialization and can’t be changed afterwards.

1.8 Is the unicast address of the node that mobile App firstly provisioned fixed?

The App will decide the unicast address, and currently most of them are fixed.
1.9 How to know which unprovisioned device is the Provisioner that is provisioning currently?

The value of `prov_attention` in `esp_ble_mesh_prov_t` is used by Provisioner set to unprovisioned device during provisioning. It can be set only once during initialization and can’t be changed afterwards. When the unprovisioned device is joining the mesh network, it can display in a specific way like flashing light to notify Provisioner that it is being provisioned.

1.10 How many ways to authenticate the devices during provisioning? Which way was used in the provided examples?

There are four authentication methods, i.e. No OOB, Static OOB, Output OOB and Input OOB. In the provided examples, No OOB is used.

1.11 What information can be carried by the advertising packets of the unprovisioned device before provisioning into the network?

- Device UUID
- OOB Info
- URL Hash (optional)

1.12 Can such information be used for device identification?

For example, each unprovisioned device contains a unique Device UUID, which can be used for device identification.

1.13 How is the unicast address assigned when the node provisioned by Provisioner contains multiple elements?

- Provisioner will assign an unicast address for the primary element of the node, and unicast address of the remaining elements are incremented one by one.
- For example: If an unprovisioned device has three elements, i.e. the primary element, the second element and the third element. After provisioning, the primary element address of the node is 0x0002 while the second element address is 0x0003, and the third element address is 0x0004.

1.14 How can Provisioner get and parse the Composition Data of nodes through Configuration Client Model?

- Provisioner can get the Composition Data of nodes using the `Configuration Client Model` API `esp_ble_mesh_config_client_set_state()` with `comp_data_get` in the parameter `esp_ble_mesh_cfg_client_get_state_t` set properly.
- Users can refer to the following code to parse the Composition Data:

```c
#include <stdio.h>
#include <string.h>
#include <stdint.h>

//test date: 0C001A000800000105010000000000001000003103F002A00
//0C00 1A00 0100 0800 0300 0001 05 01 0000 0000 0010 0031 03F002A00
// 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 * 4) {
        return -1;
    }

    pos_sig_base = sizeof(*head) - 1;

    for(i = 1; i < head->sig_models * 2; i = i + 2) {
        data->SIG_models[i/2] = mystr[i + pos_sig_base] | (mystr[i + pos_sig_base + 1] << 8);
        printf("%d: %4.4x\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);
    }
}
1.15 How can Provisioner further configure nodes through obtained Composition Data?

Provisioner do the following configuration by calling the Configuration Client Model API `esp_ble_mesh_config_client_set_state()`.

- Add AppKey to nodes with `app_key_add` in the parameter `esp_ble_mesh_cfg_client_set_state_t` set properly.
- Add subscription address to the models of nodes with `model_sub_add` in the parameter `esp_ble_mesh_cfg_client_set_state_t` set properly.
- Set publication information to the models of nodes with `model_pub_set` in the parameter `esp_ble_mesh_cfg_client_set_state_t` set properly.

1.16 Can nodes add corresponding configurations for themselves?

This method can be used in special cases like testing period.

- Here is an example to show nodes add new group addresses for their models.

```c
esp_err_t example_add_fast_prov_group_address(uint16_t model_id, uint16_t group_addr)
{
    const esp_ble_mesh_comp_t *comp = NULL;
    esp_ble_mesh_elem_t *element = NULL;
    esp_ble_mesh_model_t *model = NULL;
    int i, j;

    if (!ESP_BLE_MESH_ADDR_IS_GROUP(group_addr)) {
        return ESP_ERR_INVALID_ARG;
    }

    comp = esp_ble_mesh_get_composition_data();
    if (!comp) {
        return ESP_FAIL;
    }

    for (i = 0; i < comp->element_count; i++) {
```
element = &comp->elements[i];
model = esp_ble_mesh_find_sig_model(element, model_id);
if (!model) {
    continue;
}
for (j = 0; j < ARRAY_SIZE(model->groups); j++) {
    if (model->groups[j] == group_addr) {
        break;
    }
}
if (j != ARRAY_SIZE(model->groups)) {
    ESP_LOGW(TAG, "%s: Group address already exists, element_index: %d", __func__, i);
    continue;
}
for (j = 0; j < ARRAY_SIZE(model->groups); j++) {
    if (model->groups[j] == ESP_BLE_MESH_ADDR_UNASSIGNED) {
        model->groups[j] = group_addr;
        break;
    }
}
if (j != ARRAY_SIZE(model->groups)) {
    ESP_LOGE(TAG, "%s: Model is full of group addresses, element_index: %d", __func__, i);
}
return ESP_OK;

**Note:** When the NVS storage of the node is enabled, group address added and AppKey bound by this method will not be saved in the NVS when the device is powered off currently. These configuration information can only be saved if they are configured by Configuration Client Model.

### 1.17 How does Provisioner control nodes by grouping?

Generally there are two approaches to implement group control in ESP-BLE-MESH network, group address approach and virtual address approach. And supposing there are 10 devices, i.e., five devices with blue lights and five devices with red lights.

- Method 1: 5 blue lights can subscribe to a group address, 5 red lights subscribe to another one. By sending messages to different group addresses, Provisioner can realize group control.
- Method 2: 5 blue lights can subscribe to a virtual address, 5 red lights subscribe to another one. By sending messages to different virtual addresses, Provisioner can realize group control.

### 1.18 How does Provisioner add nodes to multiple subnets?

Provisioner can add multiple NetKeys to nodes during configuration, and nodes sharing the same NetKey belong to the same subnet. Provisioner can communicate with nodes on different subnets by using different NetKeys.

### 1.19 How does Provisioner know if a node in the mesh network is offline?

Node offline is usually defined as: the condition that the node cannot be properly communicated with other nodes in the mesh network due to power failure or some other reasons.

There is no connection between nodes and nodes in the ESP-BLE-MESH network. They communicate with each other through advertising channels.
Chapter 4. API Guides

An example is given here to show how to detect a node is offline by Provisioner.

- The node can periodically send heartbeat messages to Provisioner. And if Provisioner failed to receive heartbeat messages in a certain period, the node is considered to be offline.

**Note:** The heartbeat message should be designed into a single package (less than 11 bytes), so the transmission and reception of it can be more efficient.

1.20 What operations should be performed when Provisioner removes nodes from the network?

Usually when Provisioner tries to remove node from the mesh network, the procedure includes three main steps:

- Firstly, Provisioner adds the node that need to be removed to the “blacklist”.
- Secondly, Provisioner performs the **Key Refresh procedure**.
- Lastly, the node performs node reset procedure, and switches itself to an unprovisioned device.

1.21 In the Key Refresh procedure, how does Provisioner update the Netkey owned by nodes?

- Provisioner updates the NetKey of nodes using the **Configuration Client Model** API `esp_ble_mesh_config_client_set_state()` with `net_key_update` in the parameter `esp_ble_mesh_cfg_client_set_state_t` set properly.
- Provisioner updates the AppKey of nodes using the **Configuration Client Model** API `esp_ble_mesh_config_client_set_state()` with `app_key_update` in the parameter `esp_ble_mesh_cfg_client_set_state_t` set properly.

1.22 How does Provisioner manage nodes in the mesh network?

ESP-BLE-MESH implements several functions related to basic node management in the example, such as `esp_ble_mesh_store_node_info()`. And ESP-BLE-MESH also provides the API `esp_ble_mesh_provisioner_set_node_name()` which can be used to set the node’s local name and the API `esp_ble_mesh_provisioner_get_node_name()` which can be used to get the node’s local name.

1.23 What does Provisioner need when trying to control the server model of nodes?

Provisioner must include corresponding client model before controlling the server model of nodes.

Provisioner shall add its local NetKey and AppKey.

- Provisioner add NetKey by calling the API `esp_ble_mesh_provisioner_add_local_net_key()`.
- Provisioner add AppKey by calling the API `esp_ble_mesh_provisioner_add_local_app_key()`.

Provisioner shall configure its own client model.

- Provisioner bind AppKey to its own client model by calling the API `esp_ble_mesh_provisioner_bind_app_key_to_local_model()`.

1.24 How does Provisioner control the server model of nodes?

ESP-BLE-MESH supports all SIG-defined client models. Provisioner can use these client models to control the server models of nodes. And the client models are divided into 6 categories with each category has the corresponding functions.

- **Configuration Client Model**
  - The API `esp_ble_mesh_config_client_get_state()` can be used to get the `esp_ble_mesh_cfg_client_get_state_t` values of Configuration Server Model.
  - The API `esp_ble_mesh_config_client_set_state()` can be used to set the `esp_ble_mesh_cfg_client_set_state_t` values of Configuration Server Model.
**Health Client Model**
- The API `esp_ble_mesh_health_client_get_state()` can be used to get the `esp_ble_mesh_health_client_get_state_t` values of Health Server Model.
- The API `esp_ble_mesh_health_client_set_state()` can be used to set the `esp_ble_mesh_health_client_set_state_t` values of Health Server Model.

**Generic Client Models**
- The API `esp_ble_mesh_generic_client_get_state()` can be used to get the `esp_ble_mesh_generic_client_get_state_t` values of Generic Server Models.
- The API `esp_ble_mesh_generic_client_set_state()` can be used to set the `esp_ble_mesh_generic_client_set_state_t` values of Generic Server Models.

**Lighting Client Models**
- The API `esp_ble_mesh_light_client_get_state()` can be used to get the `esp_ble_mesh_light_client_get_state_t` values of Lighting Server Models.
- The API `esp_ble_mesh_light_client_set_state()` can be used to set the `esp_ble_mesh_light_client_set_state_t` values of Lighting Server Models.

**Sensor Client Models**
- The API `esp_ble_mesh_sensor_client_get_state()` can be used to get the `esp_ble_mesh_sensor_client_get_state_t` values of Sensor Server Model.
- The API `esp_ble_mesh_sensor_client_set_state()` can be used to set the `esp_ble_mesh_sensor_client_set_state_t` values of Sensor Server Model.

**Time and Scenes Client Models**
- The API `esp_ble_mesh_time_scene_client_get_state()` can be used to get the `esp_ble_mesh_time_scene_client_get_state_t` values of Time and Scenes Server Models.
- The API `esp_ble_mesh_time_scene_client_set_state()` can be used to set the `esp_ble_mesh_time_scene_client_set_state_t` values of Time and Scenes Server Models.

---

**2. Node Development**

**2.1 What kind of models are included by nodes?**

- In ESP-BLE-MESH, nodes are all composed of a series of models with each model implements some functions of the node.
- Model has two types, client model and server model. Client model can get and set the states of server model.
- Model can also be divided into SIG model and vendor model. All behaviors of SIG models are officially defined while behaviors of vendor models are defined by users.

**2.2 Is the format of messages corresponding to each model fixed?**

- Messages, which consist of opcode and payload, are divided by opcode.
- The type and the format of the messages corresponding to models are both fixed, which means the messages transmitted between models are fixed.

**2.3 Which functions can be used to send messages with the models of nodes?**

- For client models, users can use the API `esp_ble_mesh_client_model_send_msg()` to send messages.
- For server models, users can use the API `esp_ble_mesh_server_model_send_msg()` to send messages.
- For publication, users call the API `esp_ble_mesh_model_publish()` to publish messages.

**2.4 How to achieve the transmission of messages without packet loss?**
Chapter 4. API Guides

Acknowledged message is needed if users want to transmit messages without packet loss. The default time to wait for corresponding response is set in `CONFIG_BLE_MESH_CLIENT_MSG_TIMEOUT`. If the sender waits for the response until the timer expires, the corresponding timeout event would be triggered.

**Note:** Response timeout can be set in the API `esp_ble_mesh_client_model_send_msg()`. The default value (4 seconds) would be applied if the parameter `msg_timeout` is set to 0.

### 2.5 How to send unacknowledged messages?

For client models, users can use the API `esp_ble_mesh_client_model_send_msg()` with the parameter `need_rsp` set to `false` to send unacknowledged messages.

For server models, the messages sent by using the API `esp_ble_mesh_server_model_send_msg()` are always unacknowledged messages.

### 2.6 How to add subscription address to models?

Subscription address can be added through Configuration Client Model.

### 2.7 What is the difference between messages sent and published by models?

Messages sent by calling the API `esp_ble_mesh_client_model_send_msg()` or `esp_ble_mesh_server_model_send_msg()` will be sent in the duration determined by the Network Transmit state.

Messages published by calling the API `esp_ble_mesh_model_publish()` will be published determined by the Model Publication state. And the publication of messages is generally periodic or with a fixed number of counts. The publication period and publication count are controlled by the Model Publication state, and can be configured through Configuration Client Model.

### 2.8 How many bytes can be carried when sending unsegmented messages?

The total payload length (which can be set by users) of unsegmented message is 11 octets, so if the opcode of the message is 2 octets, then the message can carry 9-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.
• The API `esp_ble_mesh_register_health_client_callback()` is used to register callback function used to handle Health Client Model related events.
• The API `esp_ble_mesh_register_health_server_callback()` is used to register callback function used to handle Health Server Model related events.
• The API `esp_ble_mesh_register_generic_client_callback()` is used to register callback function used to handle Generic Client Models related events.
• The API `esp_ble_mesh_register_light_client_callback()` is used to register callback function used to handle Lighting Client Models related events.
• The API `esp_ble_mesh_register_sensor_client_callback()` is used to register callback function used to handle Sensor Client Model related events.
• The API `esp_ble_mesh_register_time_scene_client_callback()` is used to register callback function used to handle Time and Scenes Client Models related events.
• The API `esp_ble_mesh_register_custom_model_callback()` is used to register callback function used to handle vendor model and unrealized server models related events.

7. Others

7.1 How to print the message context?

The examples use `ESP_LOG_BUFFER_HEX()` to print the message context while the ESP-BLE-MESH protocol stack uses `bt_hex()`.

7.2 Which API can be used to restart ESP32?

The API `esp_restart()`.

7.3 How to monitor the remaining space of the stack of a task?

The API `vTaskList()` can be used to print the remaining space of the task stack periodically.

7.4 How to change the level of log without changing the menuconfig output level?

The API `esp_log_level_set()` can be used to change the log output level rather than using menu-config to change it.
# ESP-BLE-MESH Terminology

<table>
<thead>
<tr>
<th>Term</th>
<th>Official Definition</th>
<th>Detailed Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unprovisioned Device</td>
<td>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 an ESP-BLE-MESH network has an independent set of state values that indicate certain states of the device, like brightness, and color of lighting device. Change of state value will lead to change of the physical state of devices. For example, changing the on/off state of a device is actually turning on/off the device.</td>
</tr>
<tr>
<td>Model</td>
<td>A model defines the basic functionality of a node.</td>
<td>A node may contain multiple models, and each model defines basic functionalities of nodes, like the states needed by the nodes, the messages controlling the states, and actions resulted from messages handling. The function implementation of the nodes is based on models, which can be divided into SIG Model and Vendor Model, with the former defined by SIG and latter defined by users.</td>
</tr>
<tr>
<td>Element</td>
<td>An addressable entity within a device.</td>
<td>A node can contain one or more elements, with each having a unicast address and one or more models, and the models contained by the same element must not be the same.</td>
</tr>
<tr>
<td>Composition Data State</td>
<td>The Composition Data state contains information about a node, the elements it includes, and the supported models.</td>
<td>By reading the value of the Composition Data state, users can know basic information of the node, such as the number of elements, and the models in each element. Provisioner gets this message to further provision the device, such as configuring subscription address and publishing address of nodes.</td>
</tr>
</tbody>
</table>

### Table 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>
<tr>
<td>Term</td>
<td>Official Definition</td>
<td>Detailed Explanation</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>PB-ADV</td>
<td>PB-ADV is a provisioning bearer used to provision a device using Generic Provisioning PDUs over the advertising channels.</td>
<td>PB-ADV transfers packets generated during the provisioning process over the advertising channels. This way can only be used for provisioning when provisioner and unprovisioned device both support PB-ADV.</td>
</tr>
<tr>
<td>PB-GATT</td>
<td>PB-GATT is a provisioning bearer used to provision a device using Proxy PDUs to encapsulate Provisioning PDUs within the Mesh Provisioning Service.</td>
<td>PB-GATT uses connection channels to transfer packets generated during the provisioning process. If an unprovisioned device wants to be provisioned through this method, it needs to implement the related Mesh Provisioning Service. Unprovisioned devices which don’t implement such service cannot be provisioned into mesh network through PB-GATT bearer.</td>
</tr>
<tr>
<td>Provisioning</td>
<td>Provisioning is a process of adding an unprovisioned device to a mesh network, managed by a Provisioner.</td>
<td>The process of provisioning turns the “unprovisioned device” into a “node”, making it a member of the ESP-BLE-MESH network.</td>
</tr>
<tr>
<td>Authentication Method</td>
<td>Authentication is a step during the provisioning of nodes.</td>
<td>There are four authentication methods for unprovisioned devices: Output OOB, Input OOB, Static OOB, and No OOB.</td>
</tr>
<tr>
<td>Input OOB</td>
<td>Input Out-of-Band</td>
<td>For example, a Provisioner generates and displays a random number, and then prompts users to take appropriate actions to input the random number into the unprovisioned device. Taking lighting switch as an example, users can press the button for several times in a certain period of time to input the random number displayed on the Provisioner. Authentication method of the Input OOB is similar to that of Output OOB, but the role of the device is reversed.</td>
</tr>
<tr>
<td>Output OOB</td>
<td>Output Out-of-Band</td>
<td>For example, an unprovisioned device will choose a random number and output the number in a way that is compatible with its functionality. If the unprovisioned device is a bulb, it can flash a specified number of times. If the unprovisioned device has an LCD screen, the random number can display as a multi-digit value. Users who start provisioning should input the observed number to authenticate the unprovisioned device.</td>
</tr>
<tr>
<td>Static OOB</td>
<td>Static Out-of-Band</td>
<td>Authentication method of Static OOB: use Static OOB information. Use 0 as Static OOB information if No OOB information is needed. Use Static OOB information to authenticate devices which are going through provisioning if OOB information is needed.</td>
</tr>
<tr>
<td>No OOB</td>
<td>No Out-of-Band</td>
<td>Authentication method of No OOB: Set the value of the Static OOB field to 0. Using this way is like not authenticating the unprovisioned devices.</td>
</tr>
<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 15: Table 5 ESP-BLE-MESH Terminology - Address
### 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
4.9 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.

4.9.1 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

4.9.2 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.

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 other's 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.

4.9.3 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 <strong>is</strong> or <strong>can be</strong> 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 <strong>single-hop</strong> whereas traversing multiple connections is known as <strong>multi-hop</strong>.</td>
</tr>
<tr>
<td>Subnetwork</td>
<td>A subnetwork is subdivision of an ESP-WIFI-MESH network which consists of a node and all of its descendant nodes. Therefore the subnetwork of the root node consists of all nodes in an ESP-WIFI-MESH network.</td>
</tr>
<tr>
<td>MAC Address</td>
<td>Media Access Control Address used to uniquely identify each node or router within an ESP-WIFI-MESH network.</td>
</tr>
<tr>
<td>DS</td>
<td>Distribution System (External IP Network)</td>
</tr>
</tbody>
</table>

Tree Topology

ESP-WIFI-MESH is built atop the infrastructure Wi-Fi protocol and can be thought of as a networking protocol that combines many individual Wi-Fi networks into a single WLAN. In Wi-Fi, stations are limited to a single connection with an AP (upstream connection) at any time, whilst an AP can be simultaneously connected to multiple stations (downstream connections). However ESP-WIFI-MESH allows nodes to simultaneously act as a station and an AP. Therefore a node in ESP-WIFI-MESH can have **multiple downstream connections using its softAP interface**, whilst simultaneously having a **single upstream connection using its station interface**. This naturally results in a tree network topology with a parent-child hierarchy consisting of multiple layers.

ESP-WIFI-MESH is a multiple hop (multi-hop) network meaning nodes can transmit packets to other nodes in the network through one or more wireless hops. Therefore, nodes in ESP-WIFI-MESH not only transmit their own packets, but simultaneously serve as relays for other nodes. Provided that a path exists between any two nodes on the physical layer (via one or more wireless hops), any pair of nodes within an ESP-WIFI-MESH network can communicate.

**Note:** The size (total number of nodes) in an ESP-WIFI-MESH network is dependent on the maximum number of layers permitted in the network, and the maximum number of downstream connections each node can have. Both of these variables can be configured to limit the size of the network.

Node Types

**Root Node:** The root node is the top node in the network and serves as the only interface between the ESP-WIFI-MESH network and an external IP network. The root node is connected to a conventional Wi-Fi router and relays packets to/from the external IP network to nodes within the ESP-WIFI-MESH network. **There can only be one root node within an ESP-WIFI-MESH network** and the root node’s upstream connection may only be with the router. Referring to the diagram above, node A is the root node of the network.
Chapter 4. API Guides

Fig. 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
- Current number of child nodes
- Maximum number of downstream connections to accept

The signal strength of a potential upstream connection is represented by RSSI (Received Signal Strength Indication) of the beacon frames of the potential parent node. To prevent nodes from forming a weak upstream connection, ESP-WIFI-MESH implements an RSSI threshold mechanism for beacon frames. If a node detects a beacon frame with an RSSI below a preconfigured threshold, the transmitting node will be disregarded when forming an upstream connection.

**Panel A** of the illustration above demonstrates how the RSSI threshold affects the number of parent node candidates an idle node has.

**Panel B** of the illustration above demonstrates how an RF shielding object can lower the RSSI of a potential parent node. Due to the RF shielding object, the area in which the RSSI of node X is above the threshold is significantly reduced. This causes the idle node to disregard node X even though node X is physically adjacent. The idle node will instead form an upstream connection with the physically distant node Y due to a stronger RSSI.

**Note:** Nodes technically still receive all beacon frames on the MAC layer. The RSSI threshold is an ESP-WIFI-MESH feature that simply filters out all received beacon frames that are below the preconfigured threshold.

**Preferred Parent Node**

When an idle node has multiple parent nodes candidates (potential parent nodes), the idle node will form an upstream connection with the **preferred parent node**. The preferred parent node is determined based on the following criteria:

- Which layer the parent node candidate is situated on
- The number of downstream connections (child nodes) the parent node candidate currently has
The selection of the preferred parent node will always prioritize the parent node candidate on the shallowest layer of the network (including the root node). This helps minimize the total number of layers in an ESP-WIFI-MESH network when upstream connections are formed. For example, given a second layer node and a third layer node, the second layer node will always be preferred.

If there are multiple parent node candidates within the same layer, the parent node candidate with the least child nodes will be preferred. This criteria has the effect of balancing the number of downstream connections amongst nodes of the same layer.

Panel A of the illustration above demonstrates an example of how the idle node G selects a preferred parent node given the five parent node candidates B/C/D/E/F. Nodes on the shallowest layer are preferred, hence nodes B/C are prioritized since they are second layer nodes whereas nodes D/E/F are on the third layer. Node C is selected as the preferred parent node due it having fewer downstream connections (fewer child nodes) compared to node B.

Panel B of the illustration above demonstrates the case where the root node is within range of the idle node G. In
other words, the root node’s beacon frames are above the RSSI threshold when received by node G. The root node is always the shallowest node in an ESP-WIFI-MESH network hence is always the preferred parent node given multiple parent node candidates.

**Note:** Users may also define their own algorithm for selecting a preferred parent node, or force a node to only connect with a specific parent node (see the Mesh Manual Networking Example).

## Routing Tables

Each node within an ESP-WIFI-MESH network will maintain its individual routing table used to correctly route ESP-WIFI-MESH packets (see ESP-WIFI-MESH Packet) to the correct destination node. The routing table of a particular node will **consist of the MAC addresses of all nodes within the particular node’s subnetwork** (including the MAC address of the particular node itself). Each routing table is internally partitioned into multiple subtables with each subtable corresponding to the subnetwork of each child node.

![Routing Tables Example](image)

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
4.9.4 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, the 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 idle 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 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 from 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.

![Diagram](image)

**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.
Fig. 26: Network Building with Asynchronous Power On Example
**Synchronous Power-On:** Had all nodes powered-on synchronously, node E would have become the root node as it has the strongest router RSSI (-10 dB). This would result in a significantly different network layout compared to the network formed under the conditions of asynchronous power-on. **However the synchronous power-on network layout can still be reached if the user manually switches the root node** (see `esp_mesh_waive_root()`).

**Note:** Differences in parent node selection caused by asynchronous power-on are autonomously corrected for to some extent in ESP-WIFI-MESH (see Parent Node Switching)

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**Loop-back Avoidance, Detection, and Handling**

A loop-back is the situation where a particular node forms an upstream connection with one of its descendant nodes (a node within the particular node’s subnetwork). This results in a circular connection path thereby breaking the tree topology. ESP-WIFI-MESH prevents loop-back during parent selection by excluding nodes already present in the selecting node’s routing table (see Routing Tables) thus prevents a particular node from attempting to connect to any node within its subnetwork.

In the event that a loop-back occurs, ESP-WIFI-MESH utilizes a path verification mechanism and energy transfer mechanism to detect the loop-back occurrence. The parent node of the upstream connection that caused the loop-back will then inform the child node of the loop-back and initiate a disconnection.

**4.9.5 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.
Chapter 4. API Guides

Fig. 27: Self Healing From Root Node Failure

**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.

Fig. 28: Self Healing From Intermediate Parent Node Failure

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.

![Diagram of a root node switch example](image)

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.
Chapter 4. API Guides

**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.

### 4.9.6 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.

![ESP-WIFI-MESH Packet](image)

**Fig. 30: ESP-WIFI-MESH Packet**

The **header** of an ESP-WIFI-MESH packet contains the MAC addresses of the source and destination nodes. The options field contains information pertaining to the special types of ESP-WIFI-MESH packets such as a group transmission or a packet originating from the external IP network (see `MESH_OPT_SEND_GROUP` and `MESH_OPT_RECV_DS_ADDR`).

The **payload** of an ESP-WIFI-MESH packet contains the actual application data. This data can be raw binary data, or encoded under an application layer protocol such as HTTP, MQTT, and JSON (see `mesh_proto_t`).

**Note:** When sending an ESP-WIFI-MESH packet to the external IP network, the destination address field of the header will contain the IP address and port of the target server rather than the MAC address of a node (see `mesh_addr_t`). Furthermore the root node will handle the formation of the outgoing TCP/IP packet.

### Group Control & Multicasting

Multicasting is a feature that allows a single ESP-WIFI-MESH packet to be transmitted simultaneously to multiple nodes within the network. Multicasting in ESP-WIFI-MESH can be achieved by either specifying a list
of target nodes, or specifying a preconfigured group of nodes. Both methods of multicasting are called via 
`esp_mesh_send()`.

To multicast by specifying a list of target nodes, users must first set the ESP-WIFI-MESH packet’s destination
address to the Multicast-Group Address (01:00:5E:xx:xx:xx). This signifies that the ESP-WIFI-MESH packet is a multicast packet with a group of addresses, and that the address should be obtained from the header options. Users must then list the MAC addresses of the target nodes as options (see `mesh_opt_t` and `MESH_OPT_SEND_GROUP`). This method of multicasting requires no prior setup but can incur a large amount of overhead data as each target node’s MAC address must be listed in the options field of the header.

Multicasting by group allows an ESP-WIFI-MESH packet to be transmitted to a preconfigured group of nodes. Each grouping is identified by a unique ID, and a node can be placed into a group via `esp_mesh_set_group_id()`. Multicasting to a group involves setting the destination address of the ESP-WIFI-MESH packet to the target group ID. Furthermore, the `MESH_DATA_GROUP` flag must set. Using groups to multicast incurs less overhead, but requires nodes to previously added into groups.

**Note:** During a multicast, all nodes within the network still receive the ESP-WIFI-MESH packet on the MAC layer. However, nodes not included in the MAC address list or the target group will simply filter out the packet.

**Broadcasting**

Broadcasting is a feature that allows a single ESP-WIFI-MESH packet to be transmitted simultaneously to all nodes within the network. Each node essentially forwards a broadcast packet to all of its upstream and downstream connections such that the packet propagates 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.

**Upstream Flow Control**

ESP-WIFI-MESH relies on parent nodes to control the upstream data flow of their immediate child nodes. To prevent a parent node’s message buffer from overflowing due to an overload of upstream transmissions, a parent node will allocate a quota for upstream transmissions known as a receiving window for each of its child nodes. Each child node must apply for a receiving window before it is permitted to transmit upstream. The size of a receiving window can be dynamically adjusted. An upstream transmission from a child node to the parent node consists of the following steps:

1. Before each transmission, the child node sends a window request to its parent node. The window request consists of a sequence number which corresponds to the child node’s data packet that is pending transmission.
2. The parent node receives the window request and compares the sequence number with the sequence number of the previous packet sent by the child node. The comparison is used to calculate the size of the receiving window which is transmitted back to the child node.

3. The child node transmits the data packet in accordance with the window size specified by the parent node. If the child node depletes its receiving window, it must obtain another receiving windows by sending a request before it is permitted to continue transmitting.

**Note:** ESP-WIFI-MESH does not support any downstream flow control.

**Warning:** Due to *Parent Node Switching*, packet loss may occur during upstream transmissions.

Due to the fact that the root node acts as the sole interface to an external IP network, it is critical that downstream nodes are aware of the root node’s connection status with the external IP network. Failing to do so can lead to nodes attempting to pass data upstream to the root node whilst it is disconnected from the IP network. This results in unnecessary transmissions and packet loss. ESP-WIFI-MESH address this issue by providing a mechanism to stabilize the throughput of outgoing data based on the connection status between the root node and the external IP network. The root node can broadcast its external IP network connection status to all other nodes by calling `esp_mesh_post_toDS_state()`.

### Bi-Directional Data Stream

The following diagram illustrates the various network layers involved in an ESP-WIFI-MESH Bidirectional Data Stream.

![Bi-Directional Data Stream Diagram](image)

Due to the use of *Routing Tables*, ESP-WIFI-MESH is able to handle pack forwarding entirely on the mesh layer. A TCP/IP layer is only required on the root node when it transmits/receives a packet to/from an external IP network.

### 4.9.7 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 indicates the number of beacon frame intervals (TBTTs) remaining until the network channel switch occurs. Therefore, the Channel Switch Count is decremented every beacon frame and allows connected stations to synchronize their channel switch with the AP.

ESP-WIFI-MESH Network Channel Switching

ESP-WIFI-MESH Network Channel Switching also utilize beacon frames that contain a CSA element. However, being a multi-hop network makes the switching process in ESP-WIFI-MESH is more complex due to the fact that a beacon frame might not be able to reach all nodes within the network (i.e. in a single hop). Therefore, an ESP-WIFI-MESH network relies on nodes to forward the CSA element so that it is propagated throughout the network.

When an intermediate parent node with one or more child nodes receives a beacon frame containing a CSA, the node will forward the CSA element by including the element in its next transmitted beacon frame (i.e. with the same New Channel Number and Channel Switch Count). Given that all nodes within an ESP-WIFI-MESH network receive the same CSA, the nodes can synchronize their channel switches using the Channel Switch Count, albeit with a short delay due to CSA element forwarding.

An ESP-WIFI-MESH network channel switch can be triggered by either the router or the root node.

Root Node Triggered  A root node triggered channel switch can only occur when the ESP-WIFI-MESH network is not connected to a router. By calling esp_mesh_switch_channel(), the root node will set an initial Channel Switch Count value and begin including a CSA element in its beacon frames. Each CSA element is then received by second layer nodes, and forwarded downstream in 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 channel change).**
  - 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.
### 4.9.8 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 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>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>N</td>
</tr>
<tr>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Channel Only</td>
</tr>
<tr>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>X</td>
<td>Channel and Router</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>

- **Network Building Time**: <60 seconds
- **Healing time**:
  - Root node break down: <10 seconds
  - Child node break down: <5 seconds
- **Per-hop latency**: 10 to 30 milliseconds

**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.
4.9.9 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

4.10 Core Dump

4.10.1 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

4.10.2 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
• Use SHA256 for core dump integrity verification (only work in ELF format)

The CRC32 option provides better calculation performance and consumes less memory for storage.

The SHA256 hash algorithm provides greater probability of detecting corruption than a CRC32 with multiple bit errors.

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

4.10.3 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:

<table>
<thead>
<tr>
<th>Name, Type, SubType, Offset, Size</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>coredump, data, coredump, , 64K</td>
</tr>
</tbody>
</table>

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>

4.10.4 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 <target_chip_type> info_corefile -t b64 -c </path/to/saved/base64/text> </path/to/program/elf/file> or espcoredump.py --chip <target_chip_type> 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:

```
CORE DUMP START

<body of base64-encoded core dump, save it to file on disk>

CORE DUMP END
```

The CORE DUMP START and CORE DUMP END lines must not be included in core dump text file.
4.10.5 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/esp32_rom.elf) and pass it to ‘espcoredump.py’.

4.10.6 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:

```bash
(gdb) p global_var
$1 = 25 '\031'
```

4.10.7 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
Chapter 4. API Guides

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 partitio-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_core file.
<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.

4.11  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.

4.11.1  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 (SYSTEM_EVENT_WIFI_READY)</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_SCAN_DONE (SYSTEM_EVENT_SCAN_DONE)</td>
<td>wifi_event_sta_scan_done_t</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_START (SYSTEM_EVENT_STA_START)</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_STOP (SYSTEM_EVENT_STA_STOP)</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_CONNECTED (SYSTEM_EVENT_STA_CONNECTED)</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_DISCONNECTED (SYSTEM_EVENT_STA_DISCONNECTED)</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_AUTHMODE_CHANGE (SYSTEM_EVENT_STA_AUTHMODE_CHANGE)</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_WPS_ER_SUCCESS (SYSTEM_EVENT_STA_WPS_ER_SUCCESS)</td>
<td>wifi_event_sta_connected_t</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_WPS_ER_FAILED (SYSTEM_EVENT_STA_WPS_ER_FAILED)</td>
<td>wifi_event_sta_disconnected_t</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_WPS_ER_TIMEOUT (SYSTEM_EVENT_STA_WPS_ER_TIMEOUT)</td>
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</tr>
<tr>
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</tr>
<tr>
<td>WIFI_EVENT_AP_START (SYSTEM_EVENT_AP_START)</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_AP_STOP (SYSTEM_EVENT_AP_STOP)</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_AP_STACONNECTED (SYSTEM_EVENT_AP_STACONNECTED)</td>
<td>n/a</td>
</tr>
<tr>
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</tr>
<tr>
<td>WIFI_EVENT_AP_PROBEREQRECVED (SYSTEM_EVENT_AP_PROBEREQRECVED)</td>
<td>n/a</td>
</tr>
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<td><strong>Ethernet</strong></td>
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<td>ETHERNET_EVENT_START (SYSTEM_EVENT_ETH_START)</td>
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<tr>
<td>ETHERNET_EVENT_STOP (SYSTEM_EVENT_ETH_STOP)</td>
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</tr>
<tr>
<td>ETHERNET_EVENT_CONNECTED (SYSTEM_EVENT_ETH_CONNECTED)</td>
<td>n/a</td>
</tr>
<tr>
<td>ETHERNET_EVENT_DISCONNECTED (SYSTEM_EVENT_ETH_DISCONNECTED)</td>
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</tr>
<tr>
<td><strong>IP</strong></td>
<td></td>
</tr>
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<td>ip_event_got_ip_t</td>
</tr>
<tr>
<td>IP_EVENT_STA_LOST_IP (SYSTEM_EVENT_STA_LOST_IP)</td>
<td>n/a</td>
</tr>
<tr>
<td>IP_EVENT_AP_STAIPASSIGNED (SYSTEM_EVENT_AP_STAIPASSIGNED)</td>
<td>n/a</td>
</tr>
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<td>IP_EVENT_ETH_GOT_IP6 (SYSTEM_EVENT_ETH_GOT_IP6)</td>
<td>ip_event_got_ip6_t</td>
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<td>ip_event_got_ip_t</td>
</tr>
<tr>
<td>IP_EVENT_ETH_LOST_IP (SYSTEM_EVENT_ETH_LOST_IP)</td>
<td>n/a</td>
</tr>
</tbody>
</table>

#### 4.11.2 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.
4.11.3 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 parameters 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_gatts_register_callback(), esp_gattc_cb_event_t, esp_ble_gap_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.

4.12 Support for External RAM

4.12.1 Introduction

ESP32 has a few hundred kilobytes of internal RAM, residing on the same die as the rest of the chip components. It can be insufficient for some purposes, so ESP32 has the ability to also use up to 4 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.

4.12.2 Hardware

ESP32 supports SPI PSRAM (Psuedostatic RAM) connected in parallel with the SPI flash chip. While ESP32 is capable of supporting several types of RAM chips, ESP-IDF currently only supports Espressif branded PSRAM chips (e.g., ESP-PSRAM32, ESP-PSRAM64, etc).

**Note:** Some PSRAM chips are 1.8 V devices and some are 3.3 V. The working voltage of the PSRAM chip must match the working voltage of the flash component. Consult the datasheet for your PSRAM chip and ESP32 device to find out the working voltages. For a 1.8 V PSRAM chip, make sure to either set the MTDI pin to a high signal level on bootup, or program ESP32 eFuses to always use the VDD_SIO level of 1.8 V. Not doing this can damage the PSRAM and/or flash chip.

**Note:** Espressif produces both modules and system-in-package chips that integrate compatible PSRAM and flash and are ready to mount on a product PCB. Consult the Espressif website for more information.

For specific details about connecting the SoC or module pins to an external PSRAM chip, consult the SoC or module datasheet.
4.12.3 Configuring External RAM

ESP-IDF fully supports the use of external RAM in applications. Once the external RAM is initialized at startup, ESP-IDF can be configured to integrate the external RAM in several ways:

- Integrate RAM into the ESP32 Memory Map
- Add External RAM to the Capability Allocator
- Provide External RAM via malloc() (default)
- Allow .bss Segment to be Placed in External Memory
- Allow .noinit Segment to be Placed in External Memory

Integrate RAM into the ESP32 Memory Map

Select this option by choosing “Integrate RAM into memory map” from CONFIG_SPIRAM_USE.

This is the most basic option for external SPI RAM integration. Most likely, you will need another, more advanced option.

During the ESP-IDF startup, external RAM is mapped into the data address space, starting at address 0x3F800000 (byte-accessible). The length of this region is the same as the SPI RAM size (up to the limit of 4 MB).

Applications can manually place data in external memory by creating pointers to this region. So if an application uses external memory, it is responsible for all management of the external SPI RAM: coordinating buffer usage, preventing corruption, etc.

Add External RAM to the Capability Allocator

Select this option by choosing “Make RAM allocatable using heap_caps_malloc(...)” from CONFIG_SPIRAM_USE.

When enabled, memory is mapped to address 0x3F800000 and also added to the capabilities-based heap memory allocator using MALLOC_CAP_SPIRAM.

To allocate memory from external RAM, a program should call heap_caps_malloc(size, MALLOC_CAP_SPIRAM). After use, this memory can be freed by calling the normal free() function.

Provide External RAM via malloc()

Select this option by choosing “Make RAM allocatable using malloc() as well” from CONFIG_SPIRAM_USE. This is the default option.

In this case, memory is added to the capability allocator as described for the previous option. However, it is also added to the pool of RAM that can be returned by the standard malloc() function.

This allows any application to use the external RAM without having to rewrite the code to use heap_caps_malloc(..., MALLOC_CAP_SPIRAM).

An additional configuration item, CONFIG_SPIRAM_MALLOC_ALWAYSINTERNAL, can be used to set the size threshold when a single allocation should prefer external memory:

- When allocating a size less than the threshold, the allocator will try internal memory first.
- When allocating a size equal to or larger than the threshold, the allocator will try external memory first.

If a suitable block of preferred internal/external memory is not available, the allocator will try the other type of memory.

Because some buffers can only be allocated in internal memory, a second configuration item CONFIG_SPIRAM_MALLOC_reserve_INTERNAL defines a pool of internal memory which is reserved for only explicitly internal allocations (such as memory for DMA use). Regular malloc() will not allocate from this pool. The MALLOC_CAP_DMA and MALLOC_CAP_INTERNAL flags can be used to allocate memory from this pool.
Allow .bss Segment to be Placed in External Memory

Enable this option by checking `CONFIG_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY`. This configuration setting is independent of the other three.

If enabled, a region of the address space starting from 0x3F800000 will be used to store zero-initialized data (BSS segment) from the lwIP, net80211, libpp, and bluedroid ESP-IDF libraries.

Additional data can be moved from the internal BSS segment to external RAM by applying the macro `EXT_RAM_ATTR` to any static declaration (which is not initialized to a non-zero value).

It is also possible to place the BSS section of a component or a library to external RAM using linker fragment scheme `extram_bss`.

This option reduces the internal static memory used by the BSS segment.

Remaining external RAM can also be added to the capability heap allocator using the method shown above.

Allow .noinit Segment to be Placed in External Memory

Enable this option by checking `CONFIG_SPIRAM_ALLOW_NOINIT_SEG_EXTERNAL_MEMORY`. If enabled, a region of the address space provided in external RAM will be used to store non-initialized data. The values placed in this segment will not be initialized or modified even during startup or restart.

By applying the macro `EXT_RAM_NOINIT_ATTR`, data could be moved from the internal NOINIT segment to external RAM. Remaining external RAM can still be added to the capability heap allocator using the method shown above, `Add External RAM to the Capability Allocator`.

4.12.4 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.

The option `CONFIG_SPIRAM_ALLOW_STACK_EXTERNAL_MEMORY` can be used to place task stacks into external memory. In these cases `xTaskCreateStatic()` must be used to specify a task stack buffer allocated from external memory, otherwise task stacks will still be allocated from internal memory.

4.12.5 Failure to initialize

By default, failure to initialize external RAM will cause the ESP-IDF startup to abort. This can be disabled by enabling the config item `CONFIG_SPIRAM_IGNORE_NOTFOUND`.

If `CONFIG_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY` is enabled, the option to ignore failure is not available as the linker will have assigned symbols to external memory addresses at link time.
• Regarding stacks in PSRAM: For tasks not calling on code in ROM in any way, directly or indirectly, the menuconfig option `CONFIG_SPIRAM_ALLOW_STACK_EXTERNAL_MEMORY` will eliminate the check in `xTaskCreateStatic`, allowing a task’s stack to be in external RAM. Using this is not advised, however.
• When used at 80 MHz clock speed, external RAM must also occupy either the HSPI or VSPI bus. Select which SPI host will be used by `CONFIG_SPIRAM_OCCUPY_SPI_HOST`.

### 4.12.6 Chip revisions

There are some issues with certain revisions of ESP32 that have repercussions for use with external RAM. The issues are documented in the ESP32 ECO document. In particular, ESP-IDF handles the bugs mentioned in the following ways:

**ESP32 rev v0**

ESP-IDF has no workaround for the bugs in this revision of silicon, and it cannot be used to map external PSRAM into ESP32’s main memory map.

**ESP32 rev v1**

The bugs in this revision of silicon cause issues if certain sequences of machine instructions operate on external memory. (ESP32 ECO 3.2). As a workaround, the GCC compiler received the flag `-mfix-esp32-psram-cache-issue` to filter these sequences and only output the code that can safely be executed. Enable this flag by checking `CONFIG_SPIRAM_CACHE_WORKAROUND`.

Aside from linking to a recompiled version of Newlib with the additional flag, ESP-IDF also does the following:

• Avoids using some ROM functions
• Allocates static memory for the WiFi stack

**ESP32 rev v3**

ESP32 revision 3 (“ECO V3”) fixes the PSRAM cache issue found in rev. 1. When `CONFIG_ESP32_REV_MIN` option is set to rev. 3, compiler workarounds related to PSRAM will be disabled. For more information about ESP32 ECO V3, see ESP32 ECO V3 User Guide.

### 4.13 Fatal Errors

#### 4.13.1 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.

### 4.13.2 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_ESP32_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_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:

### 4.13.3 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.
Chapter 4. API Guides

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.

### 4.13.4 GDB Stub

If the CONFIG_ESP_SYSTEM_PANIC_GDBSTUB option is enabled, the panic handler will not reset the chip when a fatal error happens. Instead, it will start a GDB remote protocol server, commonly referred to as GDB Stub. When this happens, a GDB instance running on the host computer can be instructed to connect to the ESP32 UART port.
If *IDF Monitor* is used, GDB is started automatically when a GDB Stub prompt is detected on the UART. The output looks like this:

```plaintext
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-
!esp32-elf".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
Find the GDB manual and other documentation resources online at:
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from /Users/user/esp/example/build/example.elf...done.
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.

### 4.13.5 Guru Meditation Errors

This section explains the meaning of different error causes, printed in parenthes after the Guru Meditation Error: Core panic’ed message.

**Note:** See the [Guru Meditation Wikipedia article](https://en.wikipedia.org/wiki/Guru_Meditation) for historical origins of “Guru Meditation”.

**IllegalInstruction**

This CPU exception indicates that the instruction which was executed was not a valid instruction. Most common reasons for this error include:

- FreeRTOS task function has returned. In FreeRTOS, if a task function needs to terminate, it should call `vTaskDelete()` and delete itself, instead of returning.
- Failure to read next instruction from SPI flash. This usually happens if:
  - Application has reconfigured the SPI flash pins as some other function (GPIO, UART, etc.). Consult the Hardware Design Guidelines and the datasheet for the chip or module for details about the SPI flash pins.
  - Some external device has accidentally been connected to the SPI flash pins, and has interfered with communication between ESP32 and SPI flash.

**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.

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.
4.13.6 Other Fatal Errors

Brownout

ESP32 has a built-in brownout detector, which is enabled by default. The brownout detector can trigger a system reset if the supply voltage goes below a safe level. The brownout detector can be configured using CONFIG_ESP32_BROWNOUT_DET and CONFIG_ESP32_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 0x4008e8b7:0x3ffc17a0 0x400d2138:0x3ffc17c0
  0x400e79d5:0x3ffc180 0x400e79a7:0x3ffc1840 0x400e79df:0x3ffc18a0
  0x400e2235:0x3ffc18c0 0x400e1916:0x3ffc18f0 0x400e19cd:0x3ffc1910
  0x400e1a11:0x3ffc1930 0x400e1bb2:0x3ffc1950 0x400d2c44:0x3ffe1a80
```

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:

```cpp
cidf_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:

```cpp
cidf_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:

```cpp
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: panic_abort at /path/to/esp-idf/components/esp_system/panic.c:367
- 0x4008c791: esp_system_abort at /path/to/esp-idf/components/esp_system/system_api.c:106
- 0x4008c587: __ubsan_default_handler at /path/to/esp-idf/components/esp_system/ubsan.c:152
- 0x4008c6be: __ubsan_handle_out_of_bounds at /path/to/esp-idf/components/esp_system/ubsan.c:223
- 0x400db74f: test_ub at main.c:128
- 0x400db99c: app_main at main.c:56 (discriminator 1)
```

The types of errors reported by UBSAN can be as follows:
<table>
<thead>
<tr>
<th>Name</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>type_mismatch, type_mismatch_v1</td>
<td>Incorrect pointer value: null, unaligned, not compatible with the given type.</td>
</tr>
<tr>
<td>add_overflow, sub_overflow, mul_overflow, negate_overflow</td>
<td>Integer overflow during addition, subtraction, multiplication, negation.</td>
</tr>
<tr>
<td>divrem_overflow</td>
<td>Integer division by 0 or INT_MIN.</td>
</tr>
<tr>
<td>shift_out_of_bounds</td>
<td>Overflow in left or right shift operators.</td>
</tr>
<tr>
<td>out_of_bounds</td>
<td>Access outside of bounds of an array.</td>
</tr>
<tr>
<td>unreachable</td>
<td>Unreachable code executed.</td>
</tr>
<tr>
<td>missing_return</td>
<td>Non-void function has reached its end without returning a value (C++ only).</td>
</tr>
<tr>
<td>vla_bound_not_positive</td>
<td>Size of variable length array is not positive.</td>
</tr>
<tr>
<td>load_invalid_value</td>
<td>Value of bool or enum (C++ only) variable is invalid (out of bounds).</td>
</tr>
<tr>
<td>nonnull_arg</td>
<td>Null argument passed to a function which is declared with a non-null attribute.</td>
</tr>
<tr>
<td>nonnull_return</td>
<td>Null value returned from a function which is declared with returns_nonnull 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>

### 4.14 Flash Encryption

This is a quick start guide to ESP32’s flash encryption feature. Using an application code example, it demonstrates how to test and verify flash encryption operations during development and production.

#### 4.14.1 Introduction

Flash encryption is intended for encrypting the contents of the ESP32’s off-chip flash memory. Once this feature is enabled, firmware is flashed as plaintext, and then the data is encrypted in place on the first boot. As a result, physical readout of flash will not be sufficient to recover most flash contents.

With flash encryption enabled, the following types of data are encrypted by default:

- Firmware bootloader
- Partition Table
- All “app” type partitions

Other types of data can be encrypted conditionally:

- Any partition marked with the `encrypted` flag in the partition table. For details, see [Encrypted Partition Flag](#).
- SecureBoot bootloader digest if SecureBoot is enabled (see below).

**Secure Boot** is a separate feature which can be used together with flash encryption to create an even more secure environment.

**Important:** For production use, flash encryption should be enabled in the “Release” mode only.

**Important:** Enabling flash encryption limits the options for further updates of ESP32. Before using this feature, read the document and make sure to understand the implications.
## 4.14.2 Relevant eFuses

The flash encryption operation is controlled by various eFuses available on ESP32. The list of eFuses and their descriptions is given in the table below. The names in eFuse column are also used by 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>CODING_SCHEME</td>
<td>Controls actual number of block1 bits used to derive final 256-bit AES key. Possible values: 0 for 256 bits, 1 for 192 bits, 2 for 128 bits. Final AES key is derived based on the FLASH_CRYPT_CONFIG value.</td>
<td>2</td>
</tr>
<tr>
<td>flash_encryption (block1)</td>
<td>AES key storage.</td>
<td>256 bit key block</td>
</tr>
<tr>
<td>FLASH_CRYPT_CONFIG</td>
<td>Controls the AES encryption process.</td>
<td>4</td>
</tr>
<tr>
<td>DISABLE_DL_ENCRYPT</td>
<td>If set, disables flash encryption operation while running in Firmware Download mode.</td>
<td>1</td>
</tr>
<tr>
<td>DISABLE_DL_DECRYPT</td>
<td>If set, disables flash decryption while running in UART Firmware Download mode.</td>
<td>1</td>
</tr>
<tr>
<td>FLASH_CRYPT_CNT</td>
<td>Enables/disables encryption at boot time. If even number of bits set (0, 2, 4, 6) - encrypt flash at boot time. If odd number of bits set (1, 3, 5, 7) - do not encrypt flash at boot time.</td>
<td>7</td>
</tr>
</tbody>
</table>

### Note:

- R/W access control is available for all the eFuse bits listed in the table above.
- The default value of these bits is 0 after manufacturing.

Read and write access to eFuse bits is controlled by appropriate fields in the registers WR_DIS and RD_DIS. For more information on ESP32 eFuses, see eFuse manager. To change protection bits of eFuse field using espefuse.py, use these two commands: read_protect_efuse and write_protect_efuse. Example espefuse.py write_protect_efuse DISABLE_DL_ENCRYPT.

### 4.14.3 Flash Encryption Process

Assuming that the eFuse values are in their default states and the firmware bootloader is compiled to support flash encryption, the flash encryption process executes as shown below:

1. On the first power-on reset, all data in flash is un-encrypted (plaintext). The ROM bootloader loads the firmware bootloader.
2. Firmware bootloader reads the FLASH_CRYPT_CNT eFuse value (0b00000000). Since the value is 0 (even number of bits set), it configures and enables the flash encryption block. It also sets the FLASH_CRYPT_CONFIG eFuse to 0xF. For more information on the flash encryption block, see ESP32 Technical Reference Manual > eFuse Controller (eFuse) > Flash Encryption Block [PDF].
3. Firmware bootloader uses RNG (random) module to generate an AES-256 bit key and then writes it into the flash_encryption eFuse. The key cannot be accessed via software as the write and read protection bits for the flash_encryption eFuse are set. The flash encryption operations happen entirely by hardware, and the key cannot be accessed via software.
4. Flash encryption block encrypts the flash contents - the firmware bootloader, applications and partitions marked as encrypted. Encrypting in-place can take time, up to a minute for large partitions.
5. Firmware bootloader sets the first available bit in FLASH_CRYPT_CNT (0b00000001) to mark the flash contents as encrypted. Odd number of bits is set.
6. For **Development Mode**, the firmware bootloader sets only the eFuse bits `DISABLE_DL_DECRYPT` and `DISABLE_DL_CACHE` to allow the UART bootloader to re-flash encrypted binaries. Also, the `FLASH_CRYPT_CNT` eFuse bits are NOT write-protected.

7. For **Release Mode**, the firmware bootloader sets the eFuse bits `DISABLE_DL_ENCRYPT`, `DISABLE_DL_DECRYPT`, and `DISABLE_DL_CACHE` to 1 to prevent the UART bootloader from decrypting the flash contents. It also write-protects the `FLASH_CRYPT_CNT` eFuse bits. To modify this behavior, see **Enabling UART Bootloader Encryption/Decryption**.

8. The device is then rebooted to start executing the encrypted image. The firmware bootloader calls the flash decryption block to decrypt the flash contents and then loads the decrypted contents into IRAM.

During the development stage, there is a frequent need to program different plaintext flash images and test the flash encryption process. This requires that Firmware Download mode is able to load new plaintext images as many times as it might be needed. However, during manufacturing or production stages, Firmware Download mode should not be allowed to access flash contents for security reasons.

Hence, two different flash encryption configurations were created: for development and for production. For details on these configurations, see Section **Flash Encryption Configuration**.

### 4.14.4 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 generated key or external host-generated key.

**Using ESP32 Generated Key** Development mode allows you to download multiple plaintext images using Firmware Download mode.

To test flash encryption process, take the following steps:

1. Ensure that you have an ESP32 device with default flash encryption eFuse settings as shown in **Relevant eFuses**. See how to check ESP32 Flash Encryption Status.

2. In **Project Configuration Menu**, do the following:
   
   - **Enable flash encryption on boot**
   - **Select encryption mode** (**Development mode** by default)
   - **Select UART ROM download mode** (**enabled** by default. Note that for the esp32 target, the choice is only available when `CONFIG_ESP32_REV_MIN` level is set to 3 (ESP32 V3)).
   - **Select the appropriate bootloader log verbosity**
   - **Save the configuration and exit.**

   Enabling flash encryption will increase the size of bootloader, which might require updating partition table offset. See **Bootloader Size**.

3. Run the command given below to build and flash the complete images.

   ```
   idf.py flash monitor
   ```
Note: This command does not include any user files which should be written to the partitions on the flash memory. Please write them manually before running this command otherwise the files should be encrypted separately before writing.

This command will write to flash memory unencrypted images: the firmware bootloader, the partition table and applications. Once the flashing is complete, ESP32 will reset. On the next boot, the firmware bootloader encrypts: the firmware bootloader, application partitions and partitions marked as encrypted then resets. Encrypting in-place can take time, up to a minute for large partitions. After that, the application is decrypted at runtime and executed.

A sample output of the first ESP32 boot after enabling flash encryption is given below:

```
--- idf_monitor on /dev/cu.SLAB_USBtoUART 115200 ---
--- Quit: Ctrl+| | Menu: Ctrl+T | Help: Ctrl+T followed by Ctrl+H ---

ets Jun 8 2016 00:22:57
rst:0x1 (POWERON_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configskip: 0, SPIWP:0xee
clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:2
load:0x3fff0018,len:4
load:0x3fff001c,len:8452
load:0x40078000,len:13608
load:0x40080400,len:6664
entry 0x40080764
I (28) boot: ESP-IDF v4.0-dev-850-gc4447462d-dirty 2nd stage bootloader
I (29) boot: compile time 15:37:14
I (30) boot: Enabling RNG early entropy source...
I (35) boot: SPI Speed : 40MHz
I (39) boot: SPI Mode : DIO
I (43) boot: SPI Flash Size : 4MB
I (47) boot: Partition Table:
I (51) boot: # Label Usage Type ST Offset Length
I (58) boot:  0 nvs WiFi data 01 02 0000a000 00006000
I (66) boot:  1 phy_init RF data 01 01 00010000 00010000
I (73) boot:  2 factory factory app 00 00 00020000 00100000
I (81) boot: End of partition table
I (85) esp_image: segment 0: paddr=0x00020020 vaddr=0x3f400020 size=0x0808c (---32908) map
I (105) esp_image: segment 1: paddr=0x000280b4 vaddr=0x3ffb0000 size=0x01ea4 (---7844) load
I (109) esp_image: segment 2: paddr=0x00029f60 vaddr=0x40080000 size=0x00400 (---1024) load
0x40080000: _WindowOverflow4 at esp-idf/esp-idf/components/freertos/xtensa_vectors.
S:S:1778
I (114) esp_image: segment 3: paddr=0x0002a368 vaddr=0x40080400 size=0x05ca8 (---23720) load
I (132) esp_image: segment 4: paddr=0x00030018 vaddr=0x400d0018 size=0x126a8 (---75432) map
0x400d0018: __flash_cache_start at ???:
I (159) esp_image: segment 5: paddr=0x000426c8 vaddr=0x400860a8 size=0x01f4c (---8012) load
0x400860a8: prvAddNewTaskToReadyList at esp-idf/esp-idf/components/freertos/tasks.
c:c:4561
I (168) boot: Loaded app from partition at offset 0x20000
I (168) boot: Checking flash encryption...
I (168) flash_encrypt: Generating new flash encryption key...
I (187) flash_encrypt: Read & write protecting new key...
```
Chapter 4. API Guides

I (187) flash_encrypt: Setting CRYPT_CONFIG efuse to 0xF
W (188) flash_encrypt: Not disabling UART bootloader encryption
I (195) flash_encrypt: Disable UART bootloader decryption...
I (201) flash_encrypt: Disable UART bootloader MMU cache...
I (208) flash_encrypt: Disable JTAG...
I (212) flash_encrypt: Disable ROM BASIC interpreter fallback...
I (219) esp_image: segment 0: paddr=0x00001020 vaddr=0x3fff0018 size=0x00004 ( _
--4)
I (227) esp_image: segment 1: paddr=0x0000102c vaddr=0x3fff001c size=0x02104 ( _
--8452)
I (239) esp_image: segment 2: paddr=0x00003138 vaddr=0x40078000 size=0x03528 ( _
--13608)
I (249) esp_image: segment 3: paddr=0x00006668 vaddr=0x40080400 size=0x01a08 ( _
--6664)
I (657) esp_image: segment 0: paddr=0x00020020 vaddr=0x3f400020 size=0x0808c ( _
--32908) map
I (669) esp_image: segment 1: paddr=0x000280b4 vaddr=0x3ffb0000 size=0x01ea4 ( _
--7844)
I (672) esp_image: segment 2: paddr=0x00029f60 vaddr=0x40080000 size=0x00400 ( _
--1024)
0x40080000: _WindowOverflow4 at esp-idf/esp-idf/components/freertos/xtensa_vectors.
--S:1778
I (676) esp_image: segment 3: paddr=0x0002a368 vaddr=0x40080400 size=0x05ca8 ( _
--23720)
I (692) esp_image: segment 4: paddr=0x00030018 vaddr=0x400d0018 size=0x126a8 ( _
--75432) map
0x400d0018: _flash_cache_start at ???:?
I (719) esp_image: segment 5: paddr=0x000426c8 vaddr=0x400860a8 size=0x01f4c ( _
--8012)
0x400860a8: prvAddNewTaskToReadyList at esp-idf/esp-idf/components/freertos/tasks.
--c:4561
I (722) flash_encrypt: Encrypting partition 2 at offset 0x20000...
I (13229) flash_encrypt: Flash encryption completed
I (13229) boot: Resetting with flash encryption enabled...

A sample output of subsequent ESP32 boots just mentions that flash encryption is already enabled:

rst:0x1 (POWERON_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configspir: 0, SPIWP:0xee
clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:2
load:0x3fff0018,len:4
load:0x3fff001c,len:8452
load:0x40078000,len:13652
ho 0 tail 12 room 4
load:0x40080400,len:6664
entry 0x40080764
I (30) boot: ESP-IDF v4.0-dev-850-gc4447462d-dirty 2nd stage bootloader
I (30) boot: compile time 16:32:53
I (31) boot: Enabling RNG early entropy source...
I (37) boot: SPI Speed : 40MHz
I (41) boot: SPI Mode : DIO
I (45) boot: SPI Flash Size : 4MB
I (49) boot: Partition Table:
I (52) boot: ## Label Usage Type ST Offset Length
I (60) boot: 0 nvs WiFi data 01 02 00000a000 00006000
I (67) boot: 1 phy_init RF data 01 01 00010000 00010000
I (75) boot: 2 factory factory app 00 00 00020000 00100000

(continues on next page)
At this stage, if you need to update and re-flash binaries, see Re-flashing Updated Partitions.

Using Host Generated Key It is possible to pre-generate a flash encryption key on the host computer and burn it into the eFuse. This allows you to pre-encrypt data on the host and flash already encrypted data without needing a plaintext flash update. This feature can be used in both Development Mode and Release Mode. Without a pre-generated key, data is flashed in plaintext and then ESP32 encrypts the data in-place.
Chapter 4. API Guides

**Note:** This option is not recommended for production, unless a separate key is generated for each individual device.

To use a host generated key, take the following steps:

1. Ensure that you have an ESP32 device with default flash encryption eFuse settings as shown in Relevant eFuses. See how to check ESP32 Flash Encryption Status.
2. Generate a random key by running:
   
   `espsecure.py generate_flash_encryption_key my_flash_encryption_key.bin`

3. **Before the first encrypted boot**, burn the key into your device’s eFuse using the command below. This action can be done only once.
   
   `espefuse.py --port PORT burn_key flash_encryption my_flash_encryption_key.bin`

   If the key is not burned and the device is started after enabling flash encryption, the ESP32 will generate a random key that software cannot access or modify.

4. In Project Configuration Menu, do the following:
   - **Enable flash encryption on boot**
   - **Select encryption mode** (Development mode by default)
   - **Select the appropriate bootloader log verbosity**
   - **Save the configuration and exit.**

   Enabling flash encryption will increase the size of bootloader, which might require updating partition table offset. See Bootloader Size.

5. Run the command given below to build and flash the complete images.
   
   `idf.py flash monitor`

   **Note:** This command does not include any user files which should be written to the partitions on the flash memory. Please write them manually before running this command otherwise the files should be encrypted separately before writing.

   This command will write to flash memory unencrypted images: the firmware bootloader, the partition table and applications. Once the flashing is complete, ESP32 will reset. On the next boot, the firmware bootloader encrypts: the firmware bootloader, application partitions and partitions marked as encrypted then resets. Encrypting in-place can take time, up to a minute for large partitions. After that, the application is decrypted at runtime and executed.

   If using Development Mode, then the easiest way to update and re-flash binaries is **Re-flashing Updated Partitions**.

   If using Release Mode, then it is possible to pre-encrypt the binaries on the host and then flash them as ciphertext. See Manually Encrypting Files.

**Re-flashing Updated Partitions** If you update your application code (done in plaintext) and want to re-flash it, you will need to encrypt it before flashing. To encrypt the application and flash it in one step, run:

`idf.py encrypted-app-flash monitor`

If all partitions needs to be updated in encrypted format, run:

`idf.py encrypted-flash monitor`
Release Mode

In Release mode, UART bootloader cannot perform flash encryption operations. New plaintext images can ONLY be downloaded using the over-the-air (OTA) scheme which will encrypt the plaintext image before writing to flash.

To use this mode, take the following steps:

1. Ensure that you have an ESP32 device with default flash encryption eFuse settings as shown in Relevant eFuses. See how to check ESP32 Flash Encryption Status.

2. In Project Configuration Menu, do the following:
   - Enable flash encryption on boot
   - Select Release mode (Note that once Release mode is selected, the DISABLE_DL_ENCRYPT and DISABLE_DL_DECRYPT eFuse bits will be burned to disable flash encryption hardware in ROM Download Mode.)
   - Select UART ROM download mode (Permanently disabled (recommended)) (Note that this option is only available when CONFIG_ESP32_REV_MIN is set to 3 (ESP32 V3).) The default choice is to keep UART ROM download mode enabled, however it’s recommended to permanently disable this mode to reduce the options available to an attacker.
   - Select the appropriate bootloader log verbosity
   - Save the configuration and exit.

Enabling flash encryption will increase the size of bootloader, which might require updating partition table offset. See Bootloader Size.

3. Run the command given below to build and flash the complete images.

   \[\text{idf.py flash monitor}\]

   **Note:** This command does not include any user files which should be written to the partitions on the flash memory. Please write them manually before running this command otherwise the files should be encrypted separately before writing.

   This command will write to flash memory unencrypted images: the firmware bootloader, the partition table and applications. Once the flashing is complete, ESP32 will reset. On the next boot, the firmware bootloader encrypts: the firmware bootloader, application partitions and partitions marked as encrypted then resets. Encrypting in-place can take time, up to a minute for large partitions. After that, the application is decrypted at runtime and executed.

   Once the flash encryption is enabled in Release mode, the bootloader will write-protect the FLASH_CRYPT_CNT eFuse.

   For subsequent plaintext field updates, use OTA scheme.

   **Note:** If you have pre-generated the flash encryption key and stored a copy, and the UART download mode is not permanently disabled via CONFIG_SECURE_UART_ROM_DL_MODE (ESP32 V3 only), then it is possible to update the flash locally by pre-encrypting the files and then flashing the ciphertext. See Manually Encrypting Files.

Best Practices

When using Flash Encryption in production:

- Do not reuse the same flash encryption key between multiple devices. This means that an attacker who copies encrypted data from one device cannot transfer it to a second device.
- When using ESP32 V3, if the UART ROM Download Mode is not needed for a production device then it should be disabled to provide an extra level of protection. Do this by calling
esp_efuse_disable_rom_download_mode() during application startup. Alternatively, configure the project `CONFIG_ESP32_REV_MIN` level to 3 (targeting ESP32 V3 only) and select the `CONFIG_SECURE_UART_ROM_DL_MODE` to “Permanently disable ROM Download Mode (recommended)”.

The ability to disable ROM Download Mode is not available on earlier ESP32 versions.

- Enable Secure Boot as an extra layer of protection, and to prevent an attacker from selectively corrupting any part of the flash before boot.

### 4.14.5 Possible Failures

Once flash encryption is enabled, the `FLASH_CRYPT_CNT` eFuse value will have an odd number of bits set. It means that all the partitions marked with the encryption flag are expected to contain encrypted ciphertext. Below are the three typical failure cases if the ESP32 is erroneously loaded with plaintext data:

1. If the bootloader partition is re-flashed with a plaintext firmware bootloader image, the ROM bootloader will fail to load the firmware bootloader resulting in the following failure:

   ```
   rst:0x3 (SW_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
   flash read err, 1000
   ets_main.c 371
   ets Jun 8 2016 00:22:57
   
   rst:0x7 (TG0WDT_SYS_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
   flash read err, 1000
   ets_main.c 371
   ets Jun 8 2016 00:22:57
   
   rst:0x7 (TG0WDT_SYS_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
   flash read err, 1000
   ets_main.c 371
   ets Jun 8 2016 00:22:57
   
   rst:0x7 (TG0WDT_SYS_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
   flash read err, 1000
   ets_main.c 371
   ets Jun 8 2016 00:22:57
   ```

   **Note:** This error also appears if the flash contents are erased or corrupted.

2. If the firmware bootloader is encrypted, but the partition table is re-flashed with a plaintext partition table image, the bootloader will fail to read the partition table resulting in the following failure:

   ```
   rst:0x3 (SW_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
   configsip: 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
   ho 0 tail 12 room 4
   load:0x40078000,len:19168
   entry 0x40080764
   I (60) boot: ESP-IDF v4.0-dev-763-g2c55fae6c-dirty 2nd stage bootloader
   I (60) boot: compile time 19:15:54
   I (62) boot: Enabling RNG early entropy source...
   ```

(continues on next page)
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
code:0x3fff001c,len:8452
load:0x40078000,len:13616
code:0x40080400,len:6664
entry 0x40080764
```

4.14.6 ESP32 Flash Encryption Status

1. Ensure that you have an ESP32 device with default flash encryption eFuse settings as shown in Relevant eFuses.

To check if flash encryption on your ESP32 device is enabled, do one of the following:

- flash the application example security/flash_encryption onto your device. This application prints the FLASH_CRYPT_CNT eFuse value and if flash encryption is enabled or disabled.
- Find the serial port name under which your ESP32 device is connected, replace PORT with your port name in the following command, and run it:

```
espefuse.py -p PORT summary
```

4.14.7 Reading and Writing Data in Encrypted Flash

ESP32 application code can check if flash encryption is currently enabled by calling `esp_flash_encryption_enabled()`. Also, a device can identify the flash encryption mode by calling `esp_get_flash_encryption_mode()`.

Once flash encryption is enabled, be more careful with accessing flash contents from code.
Scope of Flash Encryption

Whenever the `FLASH_CRYPT_CNT` eFuse is set to a value with an odd number of bits, all flash content accessed via the MMU’s flash cache is transparently decrypted. It includes:

- Executable application code in flash (IROM).
- All read-only data stored in flash (DROM).
- Any data accessed via `spi_flash_mmap()`.
- The firmware bootloader image when it is read by the ROM bootloader.

**Important:** The MMU flash cache unconditionally decrypts all existing data. Data which is stored unencrypted in flash memory will also be “transparently decrypted” via the flash cache and will appear to software as random garbage.

Reading from Encrypted Flash

To read data without using a flash cache MMU mapping, you can use the partition read function `esp_partition_read()`. This function will only decrypt data when it is read from an encrypted partition. Data read from unencrypted partitions will not be decrypted. In this way, software can access encrypted and non-encrypted flash in the same way.

You can also use the following SPI flash API functions:

- `esp_flash_read()` to read raw (encrypted) data which will not be decrypted
- `esp_flash_read_encrypted()` to read and decrypt data

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.

4.14.8 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.
Chapter 4. API Guides

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.

4.14.9 Disabling Flash Encryption

If flash encryption was enabled accidentally, flashing of plaintext data will soft-brick the ESP32. The device will reboot continuously, printing the error flash read err, 1000 or invalid header: 0xXXXXXX.

For flash encryption in Development mode, encryption can be disabled by burning the FLASH_CRYPT_CNT eFuse. It can only be done three times per chip by taking the following steps:

1. In Project Configuration Menu, disable Enable flash encryption on boot, then save and exit.
2. Open project configuration menu again and double-check that you have disabled this option! If this option is left enabled, the bootloader will immediately re-enable encryption when it boots.
3. With flash encryption disabled, build and flash the new bootloader and application by running idf.py flash.
4. Use espefuse.py (in components/esptool_py/esptool) to disable the FLASH_CRYPT_CNT by running:

   espefuse.py burn_efuse FLASH_CRYPT_CNT

Reset the ESP32. Flash encryption will be disabled, and the bootloader will boot as usual.

4.14.10 Key Points About Flash Encryption

- Flash memory contents is encrypted using AES-256. The flash encryption key is stored in the flash_encryption eFuse internal to the chip and, by default, is protected from software access.
- The flash encryption algorithm is AES-256, where the key is “tweaked” with the offset address of each 32 byte block of flash. This means that every 32-byte block (two consecutive 16 byte AES blocks) is encrypted with a unique key derived from the flash encryption key.
- Flash access is transparent via the flash cache mapping feature of ESP32 - any flash regions which are mapped to the address space will be transparently decrypted when read. Some data partitions might need to remain unencrypted for ease of access or might require the use of flash-friendly update algorithms which are ineffective if the data is encrypted. NVS partitions for non-volatile storage cannot be encrypted since the NVS library is not directly compatible with flash encryption. For details, refer to NVS Encryption.
- If flash encryption might be used in future, the programmer must keep it in mind and take certain precautions when writing code that uses encrypted flash.
- If secure boot is enabled, re-flashing the bootloader of an encrypted device requires a “Re-flashable” secure boot digest (see Flash Encryption and Secure Boot).

Enabling flash encryption will increase the size of bootloader, which might require updating partition table offset. See Bootloader Size.

**Important:** Do not interrupt power to the ESP32 while the first boot encryption pass is running. If power is interrupted, the flash contents will be corrupted and will require flashing with unencrypted data again. In this case, re-flashing will not count towards the flashing limit.
4.14.11 Limitations of Flash Encryption

Flash encryption protects firmware against unauthorised readout and modification. It is important to understand the limitations of the flash encryption feature:

- Flash encryption is only as strong as the key. For this reason, we recommend keys are generated on the device during first boot (default behaviour). If generating keys off-device, ensure proper procedure is followed and don’t share the same key between all production devices.
- Not all data is stored encrypted. If storing data on flash, check if the method you are using (library, API, etc.) supports flash encryption.
- Flash encryption does not prevent an attacker from understanding the high-level layout of the flash. This is because the same AES key is used for every pair of adjacent 16 byte AES blocks. When these adjacent 16 byte blocks contain identical content (such as empty or padding areas), these blocks will encrypt to produce matching pairs of encrypted blocks. This may allow an attacker to make high-level comparisons between encrypted devices (i.e. to tell if two devices are probably running the same firmware version).
- For the same reason, an attacker can always tell when a pair of adjacent 16 byte blocks (32 byte aligned) contain two identical 16 byte sequences. Keep this in mind if storing sensitive data on the flash, design your flash storage so this doesn’t happen (using a counter byte or some other non-identical value every 16 bytes is sufficient). NVS Encryption deals with this and is suitable for many uses.
- Flash encryption alone may not prevent an attacker from modifying the firmware of the device. To prevent unauthorised firmware from running on the device, use flash encryption in combination with Secure Boot.

4.14.12 Flash Encryption and Secure Boot

It is recommended to use flash encryption in combination with Secure Boot. However, if Secure Boot is enabled, additional restrictions apply to device re-flashing:

- OTA Updates are not restricted, provided that the new app is signed correctly with the Secure Boot signing key.
- Plaintext serial flash updates are only possible if the Re-flashable Secure Boot mode is selected and a Secure Boot key was pre-generated and burned to the ESP32 (refer to Secure Boot). In such configuration, idf.py bootloader will produce a pre-digested bootloader and secure boot digest file for flashing at offset 0x0. When following the plaintext serial re-flashing steps it is necessary to re-flash this file before flashing other plaintext data.
- Re-flashing via Pregenerated Flash Encryption Key is still possible, provided the bootloader is not re-flashed. Re-flashing the bootloader requires the same Re-flashable option to be enabled in the Secure Boot config.

4.14.13 Advanced Features

The following section covers advanced features of flash encryption.

Encrypted Partition Flag

Some partitions are encrypted by default. Other partitions can be marked in the partition table description as requiring encryption by adding the flag encrypted to the partitions’ flag field. As a result, data in these marked partitions will be treated as encrypted in the same manner as an app partition.

<table>
<thead>
<tr>
<th># Name, Type, SubType, Offset, Size, Flags</th>
</tr>
</thead>
<tbody>
<tr>
<td>nvs, data, nvs, 0x9000, 0x6000</td>
</tr>
<tr>
<td>phy_init, data, phy, 0xf000, 0x1000</td>
</tr>
<tr>
<td>factory, app, factory, 0x10000, 1M</td>
</tr>
<tr>
<td>secret_data, 0x40, 0x01, 0x20000, 256K, encrypted</td>
</tr>
</tbody>
</table>

For details on partition table description, see partition table.

Further information about encryption of partitions:

- Default partition tables do not include any encrypted data partitions.
• With flash encryption enabled, the app partition is always treated as encrypted and does not require marking.
• If flash encryption is not enabled, the flag “encrypted” has no effect.
• You can also consider protecting phy_init data from physical access, readout, or modification, by marking the optional phy partition with the flag encrypted.
• The nvs partition cannot be encrypted, because the NVS library is not directly compatible with flash encryption.

Enabling UART Bootloader Encryption/Decryption

On the first boot, the flash encryption process burns by default the following eFuses:

• DISABLE_DL_ENCRYPT which disables flash encryption operation when running in UART bootloader boot mode.
• DISABLE_DL_DECRYPT which disables transparent flash decryption when running in UART bootloader mode, even if the eFuse FLASH_CRYPT_CNT is set to enable it in normal operation.
• DISABLE_DL_CACHE which disables the entire MMU flash cache when running in UART bootloader mode.

However, before the first boot you can choose to keep any of these features enabled by burning only selected eFuses and write-protect the rest of eFuses with unset value 0. For example:

```
espefuse.py --port PORT burn_efuse DISABLE_DL_DECRYPT
espefuse.py --port PORT write_protect_efuse DISABLE_DL_ENCRYPT
```

**Important:** Leaving DISABLE_DL_DECRYPT unset (0) makes flash encryption useless.

An attacker with physical access to the chip can use UART bootloader mode with custom stub code to read out the flash contents.

Setting FLASH_CRYPT_CONFIG

The eFuse FLASH_CRYPT_CONFIG determines the number of bits in the flash encryption key which are “tweaked” with the block offset. For details, see Flash Encryption Algorithm.

On the first boot of the firmware bootloader, this value is set to the maximum 0xF.

It is possible to burn this eFuse manually and write protect it before the first boot in order to select different tweak values. However, this is not recommended.

It is strongly recommended to never write-protect FLASH_CRYPT_CONFIG when it is unset. Otherwise, its value will remain zero permanently, and no bits in the flash encryption key will be tweaked. As a result, the flash encryption algorithm will be equivalent to AES ECB mode.

JTAG Debugging

By default, when Flash Encryption is enabled (in either Development or Release mode) then JTAG debugging is disabled via eFuse. The bootloader does this on first boot, at the same time it enables flash encryption.

See JTAG with Flash Encryption or Secure Boot for more information about using JTAG Debugging with Flash Encryption.

Manually Encrypting Files

Manually encrypting or decrypting files requires the flash encryption key to be pre-burned in eFuse (see Using Host Generated Key) and a copy to be kept on the host. If the flash encryption is configured in Development Mode then it’s not necessary to keep a copy of the key or follow these steps, the simpler Re-flashing Updated Partitions steps can be used.
The key file should be a single raw binary file (example: key.bin).

For example, these are the steps to encrypt the file build/my-app.bin to flash at offset 0x10000. Run espsecure.py as follows:

```bash
espsecure.py encrypt_flash_data --keyfile /path/to/key.bin --address 0x10000 --output my-app-ciphertext.bin build/my-app.bin
```

The file my-app-ciphertext.bin can then be flashed to offset 0x10000 using esptool.py. To see all of the command line options recommended for esptool.py, see the output printed when idf.py build succeeds.

**Note:** If the flashed ciphertext file is not recognized by the ESP32 when it boots, check that the keys match and that the command line arguments match exactly, including the correct offset.

If your ESP32 uses non-default `FLASH_CRYPT_CONFIG value in eFuse` then you will need to pass the `--flash_crypt_conf` argument to espsecure.py to set the matching value. This will not happen if the device configured flash encryption by itself, but may happen if burning eFuses manually to enable flash encryption.

The command `espsecure.py decrypt_flash_data` can be used with the same options (and different input/output files), to decrypt ciphertext flash contents or a previously encrypted file.

### 4.14.14 Technical Details

The following sections provide some reference information about the operation of flash encryption.

**Flash Encryption Algorithm**

- AES-256 operates on 16-byte blocks of data. The flash encryption engine encrypts and decrypts data in 32-byte blocks - two AES blocks in series.
- The main flash encryption key is stored in the `flash_encryption` eFuse and, by default, is protected from further writes or software readout.
- AES-256 key size is 256 bits (32 bytes) read from the `flash_encryption` eFuse. The hardware AES engine uses the key in reversed byte order as compared to the storage order in `flash_encryption`.
  - If the `CODING_SCHEME` eFuse is set to 0 (default, “None” Coding Scheme) then the eFuse key block is 256 bits and the key is stored as-is (in reversed byte order).
  - If the `CODING_SCHEME` eFuse is set to 1 (3/4 Encoding) then the eFuse key block is 192 bits (in reversed byte order), so overall entropy is reduced. The hardware flash encryption still operates on a 256-bit key, after being read (and un-reversed), the key is extended as `key = key[0:255] + key[64:127]`.
- AES algorithm is used inverted in flash encryption, so the flash encryption “encrypt” operation is AES decrypt and the “decrypt” operation is AES encrypt. This is for performance reasons and does not alter the efficiency of the algorithm.
- Each 32-byte block (two adjacent 16-byte AES blocks) is encrypted with a unique key. The key is derived from the main flash encryption key in `flash_encryption`, XORed with the offset of this block in the flash (a “key tweak”).
- The specific tweak depends on the `FLASH_CRYPT_CONFIG` eFuse setting. This is a 4-bit eFuse where each bit enables XORing of a particular range of the key bits:
  - Bit 1, bits 0-66 of the key are XORed.
  - Bit 2, bits 67-131 of the key are XORed.
  - Bit 3, bits 132-194 of the key are XORed.
  - Bit 4, bits 195-256 of the key are XORed.
- It is recommended that `FLASH_CRYPT_CONFIG` is always left at the default value `0xF`, so that all key bits are XORed with the block offset. For details, see Setting `FLASH_CRYPT_CONFIG`.
- The high 19 bits of the block offset (bit 5 to bit 23) are XORed with the main flash encryption key. This range is chosen for two reasons: the maximum flash size is 16MB (24 bits), and each block is 32 bytes so the least significant 5 bits are always zero.
• There is a particular mapping from each of the 19 block offset bits to the 256 bits of the flash encryption key to determine which bit is XORed with which. See the variable `_FLASH_ENCRYPTION_TWEAK_PATTERN` in the `espsecure.py` source code for complete mapping.

• To see the full flash encryption algorithm implemented in Python, refer to the `_flash_encryption_operation()` function in the `espsecure.py` source code.

4.15 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
    * Startup and Termination
  - Critical Sections
    * API Changes
    * Implementation
    * Restrictions and Considerations
  - Misc
    * Floating Point Usage
    * ESP-IDF FreeRTOS Single Core

4.15.1 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:
4.15.2 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).

4.15.3 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.

### 4.15.4 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

<table>
<thead>
<tr>
<th>1. Starting state. None of the ready state tasks have been selected to run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head [ AX, B0, C1, D0 ] Tail</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>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</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core0--</td>
</tr>
<tr>
<td>Head [ AX, B0, C1, D0 ] Tail</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>Head [ B0, C1, D0, AX ] Tail</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>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</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core1------</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>Head [ B0, C1, D0, AX ] Tail</td>
</tr>
<tr>
<td>0 1</td>
</tr>
<tr>
<td>Head [ B0, D0, AX, C1 ] Tail</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>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</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core0--</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>Head [ B0, D0, AX, C1 ] Tail</td>
</tr>
<tr>
<td>1 0</td>
</tr>
</tbody>
</table>

(continues on next page)
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.

### Startup and Termination

ESP-IDF FreeRTOS does not require users to call `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 `void app_main(void)` function. For more details regarding the startup of ESP-IDF FreeRTOS applications, see [ESP-IDF FreeRTOS Applications](#).

ESP-IDF FreeRTOS does not support scheduler termination. Calling `vTaskEndScheduler()` will simply cause the application to abort.

### 4.15.5 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:

- `taskENTER_CRITICAL()` enters a critical section by disabling interrupts
• taskEXIT_CRITICAL()  exits a critical section by reenabling interrupts
• taskENTER_CRITICAL_FROM_ISR()  enters a critical section from an ISR by disabling interrupt nesting
• taskEXIT_CRITICAL_FROM_ISR()  exits a critical section from an ISR by reenabling interrupt nesting

However, in an SMP system, merely disabling interrupts does not constitute a critical section as the presence of other cores means that a shared resource can still be concurrently accessed. Therefore, critical sections in ESP-IDF FreeRTOS are implemented using spinlocks. To accommodate the spinlocks, the ESP-IDF FreeRTOS critical section APIs contain an additional spinlock parameter as shown below:

• Spinlocks are of portMUX_TYPE (not to be confused to FreeRTOS mutexes)
• taskENTER_CRITICAL(&mux) enters a critical from a task context
• taskEXIT_CRITICAL(&mux) exits a critical section from a task context
• taskENTER_CRITICAL_ISR(&mux) enters a critical section from an interrupt context
• taskEXIT_CRITICAL_ISR(&mux) exits a critical section from an interrupt context

Note: The critical section API can be called recursively (i.e., nested critical sections). Entering a critical section multiple times recursively is valid so long as the critical section is exited the same number of times it was entered. However, given that critical sections can target different spinlocks, users should take care to avoid dead locking when entering critical sections recursively.

Implementation

In ESP-IDF FreeRTOS, the process of a particular core entering and exiting a critical section is as follows:

• For taskENTER_CRITICAL(&mux) (or taskENTER_CRITICAL_ISR(&mux))
  1. The core disables its interrupts (or interrupt nesting) up to configMAX_SYSCALL_INTERRUPT_PRIORITY
  2. The core then spins on the spinlock using an atomic compare-and-set instruction until it acquires the lock. 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.
• 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

4.15.6 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 use 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.

4.16 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).

4.16.1 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'</td>
<td>Y</td>
<td>This header contains a list of C macros specifying the various capabilities of the ESP32’s peripheral xxx. Hardware capabilities of a peripheral include things such as the number of channels, DMA support, hardware FIFO/buffer lengths, etc.</td>
</tr>
<tr>
<td>#include &quot;soc/xxx_struct.h&quot;</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_reg.h&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#include &quot;soc/xxx_pins.h&quot;</td>
<td>Y</td>
<td>If certain signals of a peripheral are mapped to a particular pin of the ESP32, their mappings are defined in this header as C macros.</td>
</tr>
<tr>
<td>#include &quot;soc/xxx_periph.h&quot;</td>
<td>N</td>
<td>This header is mainly used as a convenience header file to automatically include xxx_caps.h, xxx_struct.h, and xxx_reg.h.</td>
</tr>
<tr>
<td>#include &quot;hal/xxx_types.h&quot;</td>
<td>N</td>
<td>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:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Protocol related types/macro such as a frames, modes, common bus speeds, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 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.</td>
</tr>
<tr>
<td>#include &quot;hal/xxx_ll.h&quot;</td>
<td>Y</td>
<td>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.</td>
</tr>
<tr>
<td>#include &quot;hal/xxx_hal.h&quot;</td>
<td>Y</td>
<td>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.</td>
</tr>
<tr>
<td>#include &quot;driver/xxx.h&quot;</td>
<td>N</td>
<td>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.</td>
</tr>
</tbody>
</table>

### 4.16.2 LL (Low Level) Layer

The primary purpose of the LL Layer is to abstract away register field access into more easily understandable functions. LL functions essentially translate various in/out arguments into the register fields of a peripheral in the form of get/set functions. All the necessary bit shifting, masking, offsetting, and endianness of the register fields should be handled by the LL functions.

//Inside xxx_ll.h

```c
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)
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.

### 4.16.3 HAL (Hardware Abstraction Layer)

The HAL layer models the operational process of a peripheral as a set of general steps, where each step has an associated function. For each step, the details of a peripheral’s register implementation (i.e., which registers need to be set/read) are hidden (abstracted away) by the HAL. By 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.

4.17 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, 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.

4.17.1 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>Free to use (See 1)</td>
</tr>
<tr>
<td>5</td>
<td>xt_highint5</td>
<td>Normally used by ESP-IDF debug logic (See 1)</td>
</tr>
<tr>
<td>dbg</td>
<td>xt_debugexception</td>
<td>Debug exception. Called on e.g. a BREAK instruction. (See 2)</td>
</tr>
</tbody>
</table>

The following notes give more information about the items in the tables above.

1. ESP-IDF debug logic can be configured to run on `xt_highint4` or `xt_highint5` in `CONFIG_ESP_SYSTEM_CHECK_INT_LEVEL`. Bluetooth’s interrupt can be configured to run on level 4 by enabling `CONFIG_BTDM_CTRL_HLI`. If `CONFIG_BTDM_CTRL_HLI` is enabled, ESP-IDF debug logic must be running on level 5 interrupt.
2. If `CONFIG_BTDM_CTRL_HLI` is enabled, `xt_debugexception` is used to fix live lock issue in ESP32 ECO3.

Using these symbols is done by creating an assembly file (suffix `.S`) and defining the named symbols, like this:

```assembly
.section .iram1, "ax"
.global   xt_highint5
.type     xt_highint5, @function
.align    4
xt_highint5:
... your code here
rsr      a0, EXCSAVE_5
rfi      5
```

For a real-life example, see the `esp_system/port/soc/esp32/highint_hdl.S` file; the panic handler interrupt is implemented there.
4.17.2 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. When `CONFIG_BTDM_CTRL_HLI` is enabled, C code is also called from a high-level interrupt, this is possible thanks to some additional protection added to it.

- Make sure your assembly code gets linked in. Indeed, as the free-to-use symbols are declared as weak, the linker may discard the file containing the symbol. This 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 arguments to `esp_intr_alloc()` must be NULL, however.

- In theory, medium priority interrupts could also be handled in this way. ESP-IDF does not support this yet.

4.18 JTAG Debugging

This document provides a guide to installing OpenOCD for ESP32 and debugging using GDB. The document is structured as follows:

- **Introduction** Introduction to the purpose of this guide.
- **How it Works?** Description how ESP32, JTAG interface, OpenOCD and GDB are interconnected and working together to enable debugging of ESP32.
- **Selecting JTAG Adapter** What are the criteria and options to select JTAG adapter hardware.
- **Setup of OpenOCD** Procedure to install OpenOCD and verify that it is installed.
- **Configuring ESP32 Target** Configuration of OpenOCD software and setting up of JTAG adapter hardware, which together make up the debugging target.
- **Launching Debugger** Steps to start up a debug session with GDB from Eclipse and from Command Line.
- **Debugging Examples** If you are not familiar with GDB, check this section for debugging examples provided from Eclipse as well as from Command Line.
- **Building OpenOCD from Sources** Procedure to build OpenOCD from sources for Windows, Linux and macOS operating systems.
- **Tips and Quirks** This section provides collection of tips and quirks related to JTAG debugging of ESP32 with OpenOCD and GDB.

4.18.1 Introduction

The ESP32 has two powerful Xtensa cores, allowing for a great deal of variety of program architectures. The FreeRTOS OS that comes with ESP-IDF is capable of multi-core preemptive scheduling, allowing for an intuitive way of writing software.
The downside of the ease of programming is that debugging without the right tools is harder: figuring out a bug that is caused by two threads, running even simultaneously on two different CPU cores, can take a long time when all you have are `printf()` statements. A better (and in many cases quicker) way to debug such problems is by using a debugger, connected to the processors over a debug port.

Espressif has ported OpenOCD to support the ESP32 processor and the multi-core FreeRTOS (which is the foundation of most ESP32 apps). Additionally, some extra tools have been written to provide extra features that OpenOCD does not support natively.

This document provides a guide to installing OpenOCD for ESP32 and debugging using GDB under Linux, Windows and macOS. Except for OS specific installation procedures, the s/w user interface and use procedures are the same across all supported operating systems.

**Note:** Screenshots presented in this document have been made for Eclipse Neon 3 running on Ubuntu 16.04 LTS. There may be some small differences in what a particular user interface looks like, depending on whether you are using Windows, macOS or Linux and / or a different release of Eclipse.

### 4.18.2 How it Works?

The key software and hardware components that perform debugging of ESP32 with OpenOCD over JTAG (Joint Test Action Group) interface is presented in the diagram below under the “Debugging With JTAG” label. These components include xtensa-esp32-elf-gdb debugger, OpenOCD on chip debugger, and the JTAG adapter connected to ESP32 target.

Likewise, the “Application Loading and Monitoring” label indicates the key software and hardware components that allow an application to be compiled, built, and flashed to ESP32, as well as to provide means to monitor diagnostic messages from ESP32.

“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.

![Fig. 36: JTAG debugging - overview diagram](image-url)
If the *ESP-WROVER-KIT* is used, then connection from PC to ESP32 is done effectively with a single USB cable. This is made possible by the FT2232H chip, which provides two USB channels, one for JTAG and the other for UART connection.

### 4.18.3 Selecting JTAG Adapter

The quickest and most convenient way to start with JTAG debugging is by using *ESP-WROVER-KIT*. Each version of this development board has JTAG interface already built in. No need for an external JTAG adapter and extra wiring to connect JTAG to ESP32. ESP-WROVER-KIT is using FT2232H JTAG interface operating at 20 MHz clock speed, which is difficult to achieve with an external adapter.

If you decide to use separate JTAG adapter, look for one that is compatible with both the voltage levels on the ESP32 as well as with the OpenOCD software. The JTAG port on the ESP32 is an industry-standard JTAG port which lacks (and does not need) the TRST pin. The JTAG I/O pins all are powered from the VDD_3P3_RTC pin (which normally would be powered by a 3.3 V rail) so the JTAG adapter needs to be able to work with JTAG pins in that voltage range.

On the software side, OpenOCD supports a fair amount of JTAG adapters. See [http://openocd.org/doc/html/Debug-Adapter-Hardware.html](http://openocd.org/doc/html/Debug-Adapter-Hardware.html) for an (unfortunately slightly incomplete) list of the adapters OpenOCD works with. This page lists SWD-compatible adapters as well; take note that the ESP32 does not support SWD. JTAG adapters that are hardcoded to a specific product line, e.g. ST-LINK debugging adapters for STM32 families, will not work.

The minimal signalling to get a working JTAG connection are TDI, TDO, TCK, TMS and GND. Some JTAG debuggers also need a connection from the ESP32 power line to a line called e.g. Vtar to set the working voltage. SRST can optionally be connected to the CH_PD of the ESP32, although for now, support in OpenOCD for that line is pretty minimal.

*ESP-Prog* is an example for using an external board for debugging by connecting it to the JTAG pins of ESP32.

### 4.18.4 Setup of OpenOCD

If you have already set up ESP-IDF with CMak 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.

### 4.18.5 Configuring ESP32 Target

Once OpenOCD is installed, you can proceed to configuring the ESP32 target (i.e ESP32 board with JTAG interface). Configuring the target is split into the following three steps:
Chapter 4. API Guides

- Configure and connect JTAG interface
- Run OpenOCD
- Upload application for debugging

Configure and connect JTAG interface

This step depends on the JTAG and ESP32 board you are using (see the two cases described below).

Configure ESP-WROVER-KIT JTAG Interface

All versions of ESP-WROVER-KIT boards have built-in JTAG functionality. Putting it to work requires setting jumpers or DIP switches to enable JTAG functionality, and configuring USB drivers. Please refer to step by step instructions below.

Configure Hardware

- Enable on-board JTAG functionality by setting JP8 according to ESP-WROVER-KIT V4.1 Getting Started Guide, Section Setup Options.
- Verify if ESP32 pins used for JTAG communication are not connected to some other h/w that may disturb JTAG operation:

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>JTAG Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTDO / GPIO15</td>
<td>TDO</td>
</tr>
<tr>
<td>MTDI / GPIO12</td>
<td>TDI</td>
</tr>
<tr>
<td>MTCK / GPIO13</td>
<td>TCK</td>
</tr>
<tr>
<td>MTMS / GPIO14</td>
<td>TMS</td>
</tr>
<tr>
<td>GND</td>
<td>GND</td>
</tr>
</tbody>
</table>

Configure USB Drivers

Install and configure USB drivers, so OpenOCD is able to communicate with JTAG interface on ESP-WROVER-KIT board as well as with UART interface used to upload application for flash. Follow steps below specific to your operating system.

**Note:** ESP-WROVER-KIT uses an FT2232 adapter. The following instructions can also be used for other FT2232 based JTAG adapters.

**Windows**

2. Wait until USB ports of ESP-WROVER-KIT are recognized by Windows and drives are installed. If they do not install automatically, then download them from https://www.ftdichip.com/Drivers/D2XX.htm and install manually.
3. Download Zadig tool (Zadig_X.X.exe) from https://zadig.akeo.ie/ and run it.
4. In Zadig tool go to “Options” and check “List All Devices”.
5. Check the list of devices that should contain two ESP-WROVER-KIT specific USB entries: “Dual RS232-HS (Interface 0)” and “Dual RS232-HS (Interface 1)” . The driver name would be “FTDIBUS (vxxxx)” and USB ID: 0403 6010.
6. The first device (Dual RS232-HS (Interface 0)) is connected to the JTAG port of the ESP32. Original “FTDIBUS (vxxxx)” driver of this device should be replaced with “WinUSB (v6xxxxx)” . To do so, select “Dual RS232-HS (Interface 0) and reinstall attached driver to the “WinUSB (v6xxxxx)” , see picture above.

**Note:** Do not change the second device “Dual RS232-HS (Interface 1)” . It is routed to ESP32’s serial port (UART) used for upload of application to ESP32’s flash.
Now ESP-WROVER-KIT’s JTAG interface should be available to the OpenOCD. To carry on with debugging environment setup, proceed to section Run OpenOCD.

**Linux**

2. Open a terminal, enter `ls -l /dev/ttyUSB*` command and check, if board’s USB ports are recognized by the OS. You are looking for similar result:

   ```
   user-name@computer-name:~/esp$ ls -l /dev/ttyUSB*
   crw-rw---- 1 root dialout 188, 0 Jul 10 19:04 /dev/ttyUSB0
   crw-rw---- 1 root dialout 188, 1 Jul 10 19:04 /dev/ttyUSB1
   ```

3. Following section “Permissions delegation” in OpenOCD’s README, setup the access permissions to both USB ports.
4. Log off and login, then cycle the power to the board to make the changes effective. In terminal enter again `ls -l /dev/ttyUSB*` command to verify, if group-owner has changed from dialout to plugdev:

   ```
   user-name@computer-name:~/esp$ ls -l /dev/ttyUSB*
   crw-rw-r-- 1 root plugdev 188, 0 Jul 10 19:07 /dev/ttyUSB0
   crw-rw-r-- 1 root plugdev 188, 1 Jul 10 19:07 /dev/ttyUSB1
   ```

   If you see similar result and you are a member of plugdev group, then the setup is complete.

   The /dev/ttyUSB0 interface with lower number is used for JTAG communication. The other interface is routed to ESP32’s serial port (UART) used for upload of application to ESP32’s flash.

Now ESP-WROVER-KIT’s JTAG interface should be available to the OpenOCD. To carry on with debugging environment setup, proceed to section Run OpenOCD.

**MacOS** On macOS, using FT2232 for JTAG and serial port at the same time needs some additional steps. When the OS loads FTDI serial port driver, it does so for both channels of FT2232 chip. However only one of these channels is used as a serial port, while the other is used as JTAG. If the OS has loaded FTDI serial port driver for the channel used for JTAG, OpenOCD will not be able to connect to the chip. There are two ways around this:

1. Manually unload the FTDI serial port driver before starting OpenOCD, start OpenOCD, then load the serial port driver.
2. Modify FTDI driver configuration so that it doesn’t load itself for channel B of FT2232 chip, which is the channel used for JTAG on ESP-WROVER-KIT.
Manually unloading the driver

1. Install FTDI driver from [https://www.ftdichip.com/Drivers/VCP.htm](https://www.ftdichip.com/Drivers/VCP.htm)
2. Connect USB cable to the ESP-WROVER-KIT.
3. Unload the serial port driver:

```sh
sudo kextunload -b com.FTDI.driver.FTDIUSBSerialDriver
```

In some cases you may need to unload Apple’s FTDI driver as well:

- macOS < 10.15:

  ```sh
  sudo kextunload -b com.apple.driver.AppleUSBFTDI
  ```

- macOS 10.15:

  ```sh
  sudo kextunload -b com.apple.DriverKit-AppleUSBFTDI
  ```

**Warning:** Attempting to use serial over the wrong channel with the FTDI driver will cause a kernel panic. The ESP-WROVER-KIT uses channel A for JTAG and channel B for serial.

4. Run OpenOCD:

```sh
openocd -f board/esp32-wrover-kit-3.3v.cfg
```

5. In another terminal window, load FTDI serial port driver again:

```sh
sudo kextload -b com.FTDI.driver.FTDIUSBSerialDriver
```

**Note:** If you need to restart OpenOCD, there is no need to unload FTDI driver again — just stop OpenOCD and start it again. The driver only needs to be unloaded if ESP-WROVER-KIT was reconnected or power was toggled.

This procedure can be wrapped into a shell script, if desired.

Modifying FTDI driver

In a nutshell, this approach requires modification to FTDI driver configuration file, which prevents the driver from being loaded for channel B of FT2232H.

**Note:** Other boards may use channel A for JTAG, so use this option with caution.

**Warning:** This approach also needs signature verification of drivers to be disabled, so may not be acceptable for all users.

1. Open FTDI driver configuration file using a text editor (note `sudo`):

```sh
sudo nano /Library/Extensions/FTDIUSBSerialDriver.kext/Contents/Info.plist
```

2. Find and delete the following lines:

```xml
<key>FT2232H_B</key>
<dict>
  <key>CFBundleIdentifier</key>
  <string>com.FTDI.driver.FTDIUSBSerialDriver</string>
  <key>IOClass</key>
  <string>FTDIUSBSerialDriver</string>
  <key>IOProviderClass</key>
  <string>IOUSBInterface</string>
  <key>bConfigurationValue</key>
  <integer>1</integer>
</dict>
```

(continues on next page)
3. Save and close the file
4. Disable driver signature verification:
   1. Open Apple logo menu, choose “Restart...”
   2. When you hear the chime after reboot, press CMD+R immediately
   3. Once Recovery mode starts up, open Terminal
   4. Run the command:

   ```
csrutil enable --without kext
   ```
   5. Restart again

After these steps, serial port and JTAG can be used at the same time.

To carry on with debugging environment setup, proceed to section Run OpenOCD.

**Configure Other JTAG Interface** Refer to section Selecting JTAG Adapter for guidance what JTAG interface to select, so it is able to operate with OpenOCD and ESP32. Then follow three configuration steps below to get it working.

**Configure Hardware**

1. Identify all pins / signals on JTAG interface and ESP32 board, that should be connected to establish communication.

   Table 23: ESP32 JTAG pins
   
<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>JTAG Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTDO/GPIO15</td>
<td>TDO</td>
</tr>
<tr>
<td>MTDI/GPIO12</td>
<td>TDI</td>
</tr>
<tr>
<td>MTCK/GPIO13</td>
<td>TCK</td>
</tr>
<tr>
<td>MTMS/GPIO14</td>
<td>TMS</td>
</tr>
<tr>
<td>GND</td>
<td>GND</td>
</tr>
</tbody>
</table>

2. Verify if ESP32 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 and JTAG interface.

**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 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/esp32-wrover-kit-3.3v.cfg
```

**Note:** The files provided after `-f` above are specific for ESP-WROVER-KIT with ESP32-WROOM-32 module. You may need to provide different files depending on the hardware that is used. For guidance see *Configuration of OpenOCD for specific target*.

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 ESP-WROVER-KIT with ESP32-WROOM-32 module):

```
user-name@computer-name:~/esp/esp-idf$ openocd -f board/esp32-wrover-kit-3.3v.cfg
Open On-Chip Debugger v0.10.0-esp32-20190708 (2019-07-08-11:04)
Licensed under GNU GPL v2
For bug reports, read
   http://openocd.org/doc/doxygen/bugs.html
none separate
adapter speed: 20000 kHz
force hard breakpoints
Info : ftdi: if you experience problems at higher adapter clocks, try the command
   "ftdi_tdo_sample_edge falling"
Info : clock speed 20000 kHz
Info : JTAG tap: esp32.cpu0 tap/device found: 0x120034e5 (mfg: 0x272 (Tensilica),
   part: 0x2003, ver: 0x1)
Info : JTAG tap: esp32.cpu1 tap/device found: 0x120034e5 (mfg: 0x272 (Tensilica),
   part: 0x2003, ver: 0x1)
Info : esp32: Debug controller was reset (pwrstat=0x5F, after clear 0x0F).
Info : esp32: Core was reset (pwrstat=0x5F, after clear 0x0F).
```

- If there is an error indicating permission problems, please see section on “Permissions delegation” in the OpenOCD README file located in the `~/esp/openocd-esp32` directory.
- In case there is an error in finding the configuration files, e.g. Can’t find board/esp32-wrover-kit-3.3v.cfg, check if the `OPENOCD_SCRIPTS` environment variable is set correctly. This variable is used by OpenOCD to look for the files specified after the `-f` option. See *Setup of OpenOCD* section for details. Also check if the file is indeed under the provided path.
- If you see JTAG errors (e.g., ...all ones or ...all zeroes), please check your JTAG connections, whether other signals are connected to JTAG besides ESP32’s pins, and see if everything is powered on correctly.

### Upload application for debugging

Build and upload your application to ESP32 as usual, see *Step 8. Build the Project*.

Another option is to write application image to flash using OpenOCD via JTAG with commands like this:

```
openocd -f board/esp32-wrover-kit-3.3v.cfg -c "program_esp filename.bin 0x10000 verify exit"
```

OpenOCD flashing command `program_esp` has the following format:

```
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 programing.
- `exit` - Optional. Finally exit OpenOCD.
You are now ready to start application debugging. Follow the steps described in the section below.

### 4.18.6 Launching Debugger

The toolchain for ESP32 features GNU Debugger, in short GDB. It is available with other toolchain programs under filename: xtensa-esp32-elf-gdb. GDB can be called and operated directly from command line in a terminal. Another option is to call it from within IDE (like Eclipse, Visual Studio Code, etc.) and operate indirectly with help of GUI instead of typing commands in a terminal.

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**.

### 4.18.7 Debugging Examples

This section is intended for users not familiar with GDB. It presents example debugging session from **Eclipse** using simple application available under get-started/blink and covers the following debugging actions:

1. Navigating through the code, call stack and threads
2. Setting and clearing breakpoints
3. Halting the target manually
4. Stepping through the code
5. Checking and setting memory
6. Watching and setting program variables
7. Setting conditional breakpoints

Similar debugging actions are provided using GDB from **Command Line**.

Before proceeding to examples, set up your ESP32 target and load it with get-started/blink.

### 4.18.8 Building OpenOCD from Sources

Please refer to separate documents listed below, that describe build process.

**Building OpenOCD from Sources for Windows**

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 runned 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-cross-winpthreads-git \
p7zip
```
Download Sources of OpenOCD   The sources for the ESP32-enabled variant of OpenOCD are available from Espressif GitHub under https://github.com/espressif/openocd-esp32. To download the sources, use the following commands:

```
cd ~/esp
git clone --recursive https://github.com/espressif/openocd-esp32.git
```

The clone of sources should be now saved in ~/esp/openocd-esp32 directory.

**Downloading libusb** 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 -olibusb ./libusb-1.0.22.7z
export CPPFLAGS="-$CPPFLAGS -I$(PWD)/libusb/include/libusb-1.0"
export LDFLAGS="-$LDFLAGS -L$(PWD)/libusb/MinGW32/.libs/dll"
```

**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 `OOCD_INSTALLDIR/bin` from `~/esp/openocd-esp32/src`.

Once `make` process is successfully completed, the executable of OpenOCD will be saved in `~/esp/openocd-esp32/src` directory.

**Full Listing** 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-i686-libtool mingw-w64-i686-pkg-config mingw-w64-i686-cross-winpthreads-gti p7zip
cd ~/esp
git clone --recursive https://github.com/espressif/openocd-esp32.git
```

(continues on next page)
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="
-llibusb -L$PWD/libusb/MinGW32/.libs/dll"
export CPPFLAGS="$CPPFLAGS -D__USE_MINGW_ANSI_STDIO=1 -Wno-error"; export CFLAGS="
-D__USE_MINGW_ANSI_STDIO=1 -Wno-error"
cd ~/esp/openocd-esp32
./bootstrap
./configure --disable-doxygen-pdf --enable-ftdi --enable-jlink --enable-ulink --
-build=i686-w64-mingw32 --host=i686-w64-mingw32
make
cp ../libusb/MinGW32/dll/libusb-1.0.dll ./src
cp /opt/i686-w64-mingw32/bin/libwinpthread-1.dll ./src

# # optional
# export DESTDIR="$PWD"
# make install
# cp ./src/libusb-1.0.dll $DESTDIR/mingw32/bin
# cp ./src/libwinpthread-1.dll $DESTDIR/mingw32/bin

Next Steps  To carry on with debugging environment setup, proceed to section Configuring ESP32 Target.

Building OpenOCD from Sources for Linux

The following instructions are alternative to downloading binary OpenOCD from Espressif GitHub. To quickly set up the binary OpenOCD, instead of compiling it yourself, backup and proceed to section Setup of OpenOCD.

Download Sources of OpenOCD  The sources for the ESP32-enabled variant of OpenOCD are available from Espressif GitHub under https://github.com/espressif/openocd-esp32. To download the sources, use the following commands:

```bash
cd ~/esp
git clone --recursive https://github.com/espressif/openocd-esp32.git
```

The clone of sources should be now saved in ~/esp/openocd-esp32 directory.

Install Dependencies  Install packages that are required to compile OpenOCD.

Note:  Install the following packages one by one, check if installation was successful and then proceed to the next package. Resolve reported problems before moving to the next step.

```
sudo apt-get install make
sudo apt-get install libtool
sudo apt-get install pkg-config
sudo apt-get install autoconf
sudo apt-get install automake
sudo apt-get install texinfo
sudo apt-get install libusb-1.0
```

Note:

- Version of pkg-config should be 0.2.3 or above.
- Version of autoconf should be 2.6.4 or above.
• Version of automake should be 1.9 or above.
• When using USB-Blaster, ASIX Presto, OpenJTAG and FT2232 as adapters, drivers libFTDI and FTD2XX need to be downloaded and installed.
• When using CMSIS-DAP, HIDAPI is needed.

**Build OpenOCD**  Proceed with configuring and building OpenOCD:

```
cd ~/esp/openocd-esp32
./bootstrap
./configure
make
```

Optionally you can add `sudo make install` step at the end. Skip it, if you have an existing OpenOCD (from e.g. another development platform), as it may get overwritten.

**Note:**

• Should an error occur, resolve it and try again until the command `make` works.
• If there is a submodule problem from OpenOCD, please `cd` to the openocd-esp32 directory and input `git submodule update --init`.
• If the `./configure` is successfully run, information of enabled JTAG will be printed under OpenOCD configuration summary.
• If the information of your device is not shown in the log, use `./configure` to enable it as described in `./openocd-esp32/doc/INSTALL.txt`.
• For details concerning compiling OpenOCD, please refer to `openocd-esp32/README`.

Once `make` process is successfully completed, the executable of OpenOCD will be saved in `~/openocd-esp32/bin` directory.

**Next Steps**  To carry on with debugging environment setup, proceed to section *Configuring ESP32 Target.*

**Building OpenOCD from Sources for MacOS**

The following instructions are alternative to downloading binary OpenOCD from Espressif GitHub. To quickly setup the binary OpenOCD, instead of compiling it yourself, backup and proceed to section *Setup of OpenOCD.*

**Download Sources of OpenOCD**  The sources for the ESP32-enabled variant of OpenOCD are available from Espressif GitHub under [https://github.com/espressif/openocd-esp32](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 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/esp32-wrover-kit-3.3v.cfg
```

and Windows:

```
src\openocd -f board\esp32-wrover-kit-3.3v.cfg
```

4.18.9  Tips and Quirks

This section provides collection of links to all tips and quirks referred to from various parts of this guide.

Tips and Quirks

This section provides collection of all tips and quirks referred to from various parts of this guide.
Breakpoints and watchpoints available  ESP32 debugger supports 2 hardware implemented breakpoints and 64 software ones. Hardware breakpoints are implemented by ESP32 chip’s logic and can be set anywhere in the code: either in flash or IRAM program’s regions. Additionally there are 2 types of software breakpoints implemented by OpenOCD: flash (up to 32) and IRAM (up to 32) breakpoints. Currently GDB can not set software breakpoints in flash. So until this limitation is removed those breakpoints have to be emulated by OpenOCD as hardware ones (see below for details). ESP32 also supports 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.

What else should I know about breakpoints?  Emulating part of hardware breakpoints using software flash ones means that the GDB command hb myFunction which is invoked for function in flash will use pure hardware breakpoint if it is available otherwise one of the 32 software flash breakpoints is used. The same rule applies to b myFunction-like commands. In this case GDB will decide what type of breakpoint to set itself. If myFunction is resided in writable region (IRAM) software IRAM breakpoint will be used otherwise hardware or software flash breakpoint is used as it is done for hb command.

Flash Mappings vs SW Flash Breakpoints  In order to set/clear software breakpoints in flash, OpenOCD needs to know their flash addresses. To accomplish conversion from the ESP32 address space to the flash one, OpenOCD uses mappings of program’s code regions resided in flash. Those mappings are kept in the image header which is prepended to program binary data (code and data segments) and is specific to every application image written to the flash. So to support software flash breakpoints OpenOCD should know where application image under debugging is resided in the flash. By default OpenOCD reads partition table at 0x8000 and uses mappings from the first found application image, but there can be the cases when it will not work, e.g. partition table is not at standard flash location or even there can be multiple images: one factory and two OTA and you may want to debug any of them. To cover all possible debugging scenarios OpenOCD supports special command which can be used to set arbitrary location of application image to debug. The command has the following format:

```
esp appimage_offset <offset>
```

Offset should be in hex format. To reset to the default behaviour you can specify -1 as offset.

Note:  Since GDB requests memory map from OpenOCD only once when connecting to it, this command should be specified in one of the TCL configuration files, or passed to OpenOCD via its command line. In the latter case command line should look like below:

```
openocd -f board/esp32-wrover-kit-3.3v.cfg -c "init; halt; esp appimage_offset_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_ESP32_DEBUG_OCD AWARE** is enabled by default. If a panic or unhandled exception is thrown and a JTAG debugger is connected (ie OpenOCD is running), ESP-IDF will break into the debugger.
- **CONFIG_FREERTOS_WATCHPOINT_END_OF_STACK** (disabled by default) sets watchpoint index 1 (the second of two) at the end of any task stack. This is the most accurate way to debug task stack overflows. Click the link for more details.
Please see the project configuration menu menu for more details on setting compile-time options.

**FreeRTOS support**  
OpenOCD has explicit support for the ESP-IDF FreeRTOS. GDB can see FreeRTOS tasks as threads. Viewing them all can be done using the GDB `i threads` command, changing to a certain task is done with `thread n`, with `n` being the number of the thread. FreeRTOS detection can be disabled in target’s configuration. For more details see *Configuration of OpenOCD for specific target*.

**Why to set SPI flash voltage in OpenOCD configuration?**  
The MTDI pin of ESP32, being among four pins used for JTAG communication, is also one of ESP32’s bootstrapping pins. On power up ESP32 is sampling binary level on MTDI to set it’s internal voltage regulator used to supply power to external SPI flash chip. If binary level on MDTI pin on power up is low, the voltage regulator is set to deliver 3.3 V, if it is high, then the voltage is set to 1.8 V. The MTDI pin should have a pull-up or may rely on internal weak pull down resistor (see ESP32 Series Datasheet for details), depending on the type of SPI chip used. Once JTAG is connected, it overrides the pull-up or pull-down resistor that is supposed to do the bootstrapping.

To handle this issue OpenOCD’s board configuration file (e.g. board\esp32-wrover-kit-3.3v.cfg for ESP-WROVER-KIT board) provides `ESP32_FLASH_VOLTAGE` parameter to set the idle state of the TDO line to a specified binary level, therefore reducing the chance of a bad bootup of application due to incorrect flash voltage.

Check specification of ESP32 module connected to JTAG, what is the power supply voltage of SPI flash chip. Then set `ESP32_FLASH_VOLTAGE` accordingly. Most WROOM modules use 3.3 V flash. WROVER earlier than ESP32-WROVER-B use 1.8 V flash, while ESP32-WROVER-B and -E modules use 3.3 V flash.

**Optimize JTAG speed**  
In order to achieve higher data rates and minimize number of dropped packets it is recommended to optimize setting of JTAG clock frequency, so it is at maximum and still provides stable operation of JTAG. To do so use the following tips.

1. The upper limit of JTAG clock frequency is 20 MHz if CPU runs at 80 MHz, or 26 MHz if CPU runs at 160 MHz or 240 MHz.
2. Depending on particular JTAG adapter and the length of connecting cables, you may need to reduce JTAG frequency below 20 / 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 used to pick up at most convenient / appropriate line and start debugging.

- `set remote hardware-watchpoint-limit 2` — Restrict GDB to using two hardware watchpoints supported by the chip, 2 for ESP32. For more information see https://sourceware.org/gdb/onlinedocs/gdb/Remote-Configuration.html.
- `mon reset halt` — reset the chip and keep the CPUs halted
- `flushregs halt` — monitor (mon) command can not inform GDB that the target state has changed. GDB will assume that whatever stack the target had before mon reset halt will still be valid. In fact, after reset the target state will change, and executing flushregs is a way to force GDB to get new state from the target.
- `thb app_main` — insert a temporary hardware breakpoint at `app_main`, put here another function name if required.
- `c` — resume the program. It will then stop at breakpoint inserted at `app_main`.

**Configuration of OpenOCD for specific target**  
There are several kinds of OpenOCD configuration files (* .cfg). All configuration files are located in subdirectories of share/openocd/scripts directory of OpenOCD distribution (or tcl/scripts directory of the source repository). For the purposes of this guide, the most important ones are board, interface and target.

- `interface` configuration files describe the JTAG adapter. Examples of JTAG adapters are ESP-Prog and J-Link.
target configuration files describe specific chips, or in some cases, modules.
board configuration files are provided for development boards with a built-in JTAG adapter. Such files include an interface configuration file to choose the adapter, and target configuration file to choose the chip/module.

The following configuration files are available for ESP32:

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>board/esp32-wrover-kit-3.3v.cfg</td>
<td>Board configuration file for ESP-WROVER-KIT with a 3.3 V ESP32-WROOM-32 module or ESP32-WROVER-B / ESP32-WROVER-E module.</td>
</tr>
<tr>
<td>board/esp32-wrover-kit-1.8v.cfg</td>
<td>Board configuration file for ESP-WROVER-KIT with an 1.8 V ESP32-WROVER module.</td>
</tr>
<tr>
<td>board/esp32-ethernet-kit-3.3v.cfg</td>
<td>Board configuration file for ESP-Ethernet-KIT with a 3.3 V ESP32-WROOM-B / ESP32-WROOM-E module.</td>
</tr>
<tr>
<td>target/esp32.cfg</td>
<td>ESP32 target configuration file. Can be used together with one of the interface/configuration files.</td>
</tr>
<tr>
<td>target/esp32-solo-1.cfg</td>
<td>Target configuration file for ESP32-SOLO-1 module. Different from esp32.cfg in that it only configures one CPU.</td>
</tr>
<tr>
<td>interface/ftdi/esp32_devkitj_v1.cfg</td>
<td>JTAG adapter configuration file for ESP-WROVER-KIT and ESP-Prog boards.</td>
</tr>
</tbody>
</table>

If you are using one of the boards which have a pre-defined configuration file, you only need to pass one -f argument to OpenOCD, specifying that file.
If you are using a board not listed here, you need to specify both the interface configuration file and target configuration file.

Custom configuration files OpenOCD configuration files are written in TCL, and include a variety of choices for customization and scripting. This can be useful for non-standard debugging situations. Please refer to OpenOCD Manual for the TCL scripting reference.

OpenOCD configuration variables The following variables can be optionally set before including the ESP-specific target configuration file. This can be done either in a custom configuration file, or from the command line.

The syntax for setting a variable in TCL is:

```
set VARIABLE_NAME value
```

To set a variable from the command line (replace the name of .cfg file with the correct file for your board):

```
openocd -c 'set VARIABLE_NAME value' -f board/esp-xxxxx-kit.cfg
```

It is important to set the variable before including the ESP-specific configuration file, otherwise the variable will not have effect. You can set multiple variables by repeating the -c option.

<table>
<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_BASED</td>
<td>Set to the path (on the host) which will be the default directory for semihosting functions.</td>
</tr>
</tbody>
</table>
### Table 26: ESP32-specific OpenOCD variables

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32_FLASH_VOLTAGE</td>
<td>When using 1.8 V flash ESP32 based modules, set this variable to 1.8. Refer to <a href="#">Why to set SPI flash voltage in OpenOCD configuration?</a>.</td>
</tr>
<tr>
<td>ESP32_ONLYCPU</td>
<td>For multi-core targets, can be set to 1 to only enable single core debugging.</td>
</tr>
</tbody>
</table>

#### How debugger resets ESP32?

The board can be reset by entering `mon reset` or `mon reset halt` into GDB.

#### 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 module and JTAG adapter. ESP32 JTAG is using the following pins:

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>JTAG Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTDO / GPIO15</td>
<td>TDO</td>
</tr>
<tr>
<td>MTDI / GPIO12</td>
<td>TDI</td>
</tr>
<tr>
<td>MTCK / GPIO13</td>
<td>TCK</td>
</tr>
<tr>
<td>MTMS / GPIO14</td>
<td>TMS</td>
</tr>
<tr>
<td>GND</td>
<td>GND</td>
</tr>
</tbody>
</table>

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 Vtar 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 MTDO pin to be an input:

```
cpu0: xtensa_resume (line 431): DSR (FFFFFFFF) indicates target still busy!
cpu0: xtensa_resume (line 431): DSR (FFFFFFFF) indicates DIR instruction generated_ →an exception!
cpu0: xtensa_resume (line 431): DSR (FFFFFFFF) indicates DIR instruction generated_ →an overrun!
cpu1: xtensa_resume (line 431): DSR (FFFFFFFF) indicates target still busy!
cpu1: xtensa_resume (line 431): DSR (FFFFFFFF) indicates DIR instruction generated_ →an exception!
cpu1: xtensa_resume (line 431): DSR (FFFFFFFF) indicates DIR instruction generated_ →an overrun!
```

#### JTAG with Flash Encryption or Secure Boot

By default, enabling Flash Encryption and/or Secure Boot will disable JTAG debugging. On first boot, the bootloader will burn an eFuse bit to permanently disable JTAG at the same time it enables the other features.

The project configuration option `CONFIG_SECURE_BOOT_ALLOW_JTAG` will keep JTAG enabled at this time, removing all physical security but allowing debugging. (Although the name suggests Secure Boot, this option can be applied even when only Flash Encryption is enabled).

However, OpenOCD may attempt to automatically read and write the flash in order to set software breakpoints. This has two problems:

- Software breakpoints are incompatible with Flash Encryption, OpenOCD currently has no support for encrypting or decrypting flash contents.
- If Secure Boot is enabled, setting a software breakpoint will change the digest of a signed app and make the signature invalid. This means if a software breakpoint is set and then a reset occurs, the signature verification will fail on boot.
To disable software breakpoints while using JTAG, add an extra argument `-c 'set ESP_FLASH_SIZE 0'` to the start of the OpenOCD command line, see OpenOCD configuration variables.

**Note:** For the same reason, the ESP-IDF app may fail bootloader verification of app signatures, when this option is enabled and a software breakpoint is set.

**JTAG and ESP32-WROOM-32 AT firmware Compatibility Issue**  
The ESP32-WROOM series of modules come pre-flashed with AT firmware. This firmware configures the pins GPIO12 to GPIO15 as SPI slave interface, which makes using JTAG impossible.

To make JTAG available, build new firmware that is not using pins GPIO12 to GPIO15 dedicated to JTAG communication. After that, flash the firmware onto your module. See also Do not use JTAG pins for something else.

**Reporting issues with OpenOCD / GDB**  
In case you encounter a problem with OpenOCD or GDB programs itself and do not find a solution searching available resources on the web, open an issue in the OpenOCD issue tracker under https://github.com/espressif/openocd-esp32/issues.

1. In issue report provide details of your configuration:
   a. JTAG adapter type, and the chip/module being debugged.
   b. Release of ESP-IDF used to compile and load application that is being debugged.
   c. Details of OS used for debugging.
   d. Is OS running natively on a PC or on a virtual machine?
2. Create a simple example that is representative to observed issue. Describe steps how to reproduce it. In such an example debugging should not be affected by non-deterministic behaviour introduced by the Wi-Fi stack, so problems will likely be easier to reproduce, if encountered once.
3. Prepare logs from debugging session by adding additional parameters to start up commands.
   OpenOCD:
   
   ```sh
   openocd -l openocd_log.txt -d3 -f board/esp32-wrover-kit-3.3v.cfg
   ```

   Logging to a file this way will prevent information displayed on the terminal. This may be a good thing taken amount of information provided, when increased debug level `-d3` is set. If you still like to see the log on the screen, then use another command instead:

   ```sh
   openocd -d3 -f board/esp32-wrover-kit-3.3v.cfg 2>&1 | tee openocd.log
   ```

   Debugger:
   
   ```sh
   xtensa-esp32-elf-gdb -ex "set remotelogfile gdb_log.txt" <all other options>
   ```

   Optionally add command remotelogfile gdb_log.txt to the gdbinit file.
4. Attach both openocd_log.txt and gdb_log.txt files to your issue report.

### 4.18.10 Related Documents

**Using Debugger**

This section covers configuration and running debugger using several methods:

- from **Eclipse**
- from **Command Line**
- using **idf.py debug targets**

**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 plug-ins like “GDB Hardware Debugging” plug-in. We have found this plug-in quite convenient and decided to use throughout this guide.

To begin with, install “GDB Hardware Debugging” plug-in 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. 38: Configuration of GDB Hardware Debugging - Main tab

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.

8. The last tab 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:
Fig. 39: Configuration of GDB Hardware Debugging - Debugger tab
mon reset halt
flushregs
set remote hardware-watchpoint-limit 2

Note: If you want to update image in the flash automatically before starting new debug session add the following lines of commands at the beginning of “Initialization Commands” textbox:

mon reset halt
mon program_esp ${workspace_loc:blink/build/blink.bin} 0x10000 verify

For description of program_esp command see Upload application for debugging.


10. Further down on the same tab, establish an initial breakpoint to halt CPUs after they are reset by debugger. The plugin will set this breakpoint at the beginning of the function entered under “Set break point at:” . Checkout this option and enter app_main in provided field.

11. Checkout “Resume” option. This will make the program to resume after mon reset halt is invoked per point 8. The program will then stop at breakpoint inserted at app_main.

Configuration described in points 8 - 11 is shown below.

Fig. 40: Configuration of GDB Hardware Debugging - Startup tab

If the “Startup” sequence looks convoluted and respective “Initialization Commands” are not clear to you, check What is the meaning of debugger’s startup commands? for additional explanation.

12. If you previously completed Configuring ESP32 Target steps described above, so the target is running and ready to talk to debugger, go right to debugging by pressing “Debug” button. Otherwise press “Apply” to save changes, go back to Configuring ESP32 Target and return here to start debugging.
Once all 1-12 configuration steps are satisfied, the new Eclipse perspective called “Debug” will open as shown on example picture below.

![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 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
   ```
   Save this file in current directory.
   For more details what’s inside `gdbinit` file, see What is the meaning of debugger’s startup commands?
4. Now you are ready to launch GDB. Type the following in terminal:
xtensa-esp32-elf-gdb -x gdbinit build/blink.elf

5. If previous steps have been done correctly, you will see a similar log concluded with \(\text{(gdb)}\) prompt:

```
user-name@computer-name:~/esp/blink$ xtensa-esp32-elf-gdb -x gdbinit build/
--blink.elf
GNU gdb (crosstool-NG crosstool-ng-1.22.0-61-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-
--esp32-elf".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
Find the GDB manual and other documentation resources online at:
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from build/blink.elf...done.
0x400d10d8 in esp_vApplicationIdleHook () at /home/user-name/esp/esp-idf/
--components/esp32/.freertos_hooks.c:52
52 asm("waiti 0");
JTAG tap: esp32.cpu0 tap/device found: 0x120034e5 (mfg: 0x272 (Tensilica),
--part: 0x2003, ver: 0x1)
JTAG tap: esp32.slave tap/device found: 0x120034e5 (mfg: 0x272 (Tensilica),
--part: 0x2003, ver: 0x1)
esp32: Debug controller was reset (pwrstat=0x5F, after clear 0x0F).
esp32: Core was reset (pwrstat=0x5F, after clear 0x0F).
Target halted. PRO_CPU: PC=0x5000004B (active) APP_CPU: PC=0x00000000
esp32: target state: halted
esp32: Core was reset (pwrstat=0x1F, after clear 0x0F).
Target halted. PRO_CPU: PC=0x40000400 (active) APP_CPU: PC=0x40000400
esp32: target state: halted
Hardware assisted breakpoint 1 at 0x400db717: file /home/user-name/esp/blink/
--main/./blink.c, line 43.
0x0: 0x00000000
Target halted. PRO_CPU: PC=0x400DB717 (active) APP_CPU: PC=0x400D10D8
[New Thread 1073428656]
[New Thread 1073413708]
[New Thread 1073431316]
[New Thread 1073410672]
[New Thread 1073408876]
[New Thread 1073432196]
[New Thread 1073415552]
[Switching to Thread 1073411996]
Temporary breakpoint 1, app_main () at /home/user-name/esp/blink/main/./blink.
--c:43
43 xTaskCreate(&blink_task, "blink_task", 512, NULL, 5, NULL);
(gdb)
```

Note the third line from bottom that shows debugger halting at breakpoint established in gdbinit file at function app_main(). Since the processor is halted, the LED should not be blinking. If this is what you see as well, you are ready to start debugging.

If you are not quite sure how to use GDB, check Command Line example debugging session in section Debugging Examples.
**idf.py debug targets**  It is also possible to execute the described debugging tools conveniently from `idf.py`. These commands are supported:

1. `idf.py openocd`  
   Runs OpenOCD in a console with configuration defined in the environment or via command line. It uses default script directory defined as `OPENOCD_SCRIPTS` environmental variable, which is automatically added from an Export script (export.sh or export.bat). It is possible to override the script location using command line argument `--openocd-scripts`.  
   As for the JTAG configuration of the current board, please use the environmental variable `OPENOCD_COMMANDS` or `--openocd-commands` command line argument. If none of the above is defined, OpenOCD is started with `-f board/esp32-wrover-kit-3.3v.cfg` board definition.

2. `idf.py gdb`  
   Starts the gdb the same way as the Command Line, but generates the initial gdb scripts referring to the current project elf file.

3. `idf.py gdtui`  
   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. 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. 42: Debug Perspective in Eclipse
Fig. 43: 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.

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.
Fig. 45: 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. 46: Three breakpoints are set / maximum two are allowed
You will be also able to see that LED is changing the state after each click to “Resume” program execution.

Read more about breakpoints under Breakpoints and watchpoints available and What else should I know about breakpoints?

**Halting the target manually** When debugging, you may resume application and enter code waiting for some event or staying in infinite loop without any break points defined. In such case, to go back to debugging mode, you can break program execution manually by pressing “Suspend” button.

To check it, delete all breakpoints and click “Resume”. Then click “Suspend”. Application will be halted at some random point and LED will stop blinking. Debugger will expand thread and highlight the line of code where application halted.

![Image of debugger interface](image)

**Fig. 47: 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 subroutines calls, while “Step Over (F6)” steps over the call, treating it as a single source line.

Before being able to demonstrate this functionality, using information discussed in previous paragraph, make sure that you have only one breakpoint defined at line 36 of blink.c.

Resume program by entering pressing F8 and let it halt. Now press “Step Over (F6)”, one by one couple of times, to see how debugger is stepping one program line at a time.

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.
Chapter 4. API Guides

Fig. 48: Stepping through the code with “Step Over (F6)”
Fig. 49: 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 GPIOs.

For more information, see *ESP32 Technical Reference Manual > IO MUX and GPIO Matrix (GPIO, IO_MUX)* [PDF].

Being in the same `blink.c` project as before, set two breakpoints right after `gpio_set_level` instruction. Click "Memory" tab and then "Add Memory Monitor" button. Enter `0x3FF44004` in provided dialog.

Now resume program by pressing F8 and observe "Monitor" tab.

![Fig. 50: 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. 51: 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 task 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.

![Fig. 52: Watching program variable “i”](image)

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. 53: Setting a conditional breakpoint
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 }
```

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-idf/components/
   → esp32/./cpu_start.c:339
```

Line #0 of output provides the last function call before the application halted, i.e. app_main () we have listed previously. The app_main () was in turn called by function main_task from line 339 of code located in file cpu_start.c.

To get to the context of main_task in file cpu_start.c, enter frame N, where N = 1, because the main_task is listed under #1):

```
(gdb) frame 1
#1 0x400d057e in main_task (args=0x0) at /home/user-name/esp-idf/components/
   → esp32/./cpu_start.c:339
339  app_main();
```

Enter l and this will reveal the piece of code that called app_main() (in line 339):

```
(gdb) l
334 ;
335 }
```
By listing some lines before, you will see the function name `main_task` we have been looking for:

```c
static void main_task(void* args) {
    // Now that the application is about to start, disable boot watchdogs
    REG_CLR_BIT(TIMG_WDTCONFIG0_REG(0), TIMG_WDT_FLASHBOOT_MOD_EN_S);
    REG_CLR_BIT(RTC_CNTL_WDTCONFIG0_REG, RTC_CNTL_WDT_FLASHBOOT_MOD_EN);
    #if !CONFIG_FREERTOS_UNICORE
      while (port_xSchedulerRunning[1] == 0) {
        ;
      }
    #endif
    // Enable allocation in region where the startup stacks were located.
    heap_caps_enable_nonos_stack_heaps();
    app_main();
    vTaskDelete(NULL);
}
```

To see the other code, enter `i threads`. This will show the list of threads running on target:

```plaintext
(gdb) i threads
Id  Target Id  Frame
  8  Thread 1073411336  0x400d0848 in dport_access_init_core (arg=0x0)
       at /home/user-name/esp/esp-idf/components/esp32/./dport_access.c:170
  7  Thread 1073408744  0x3ffae694 in xQueueGenericReceive (xQueue=0x3ffae694,
       pvBuffer=0x0, xTicksToWait=1644638200, xJustPeeking=0) at /home/user-name/esp/esp-idf/components/freertos/./queue.c:1452
  6  Thread 1073431096  0x4000bfe9 in ?? ()
       at /home/user-name/esp/esp-idf/components/esp32/.idfcomponents/freertos/.timers.c:445
  5  Thread 1073410208  0x4000bf08 in ?? ()
       at /home/user-name/esp/esp-idf/components/esp32/.dport_access_init.c:150
  3  Thread 1073413512 (IDLE) prvIdleTask (pvParameters=0x0)
       at /home/user-name/esp/esp-idf/components/freertos/.tasks.c:3282
  2  Thread 1073413512 (IDLE) prvIdleTask (pvParameters=0x0)
       at /home/user-name/esp/esp-idf/components/freertos/.tasks.c:3282
  1  Thread 1073411772 (main : Running) app_main () at /home/user-name/esp/blink/main/.blink.c:43
```

The thread list shows the last function calls per each thread together with the name of C source file if available. You can navigate to specific thread by entering `thread N`, where N is the thread Id. To see how it works go to thread 5:

```plaintext
(gdb) thread 5
```
Then check the backtrace:

```plaintext
(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 0x4008532b 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:

```plaintext
(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:

```plaintext
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB6F6 (active) APP_CPU: PC=0x400D10D8
Breakpoint 2, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/./blink.c:33
 33 gpio_set_level(BLINK_GPIO, 0);
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB6F8 (active) APP_CPU: PC=0x400D10D8
Target halted. PRO_CPU: PC=0x400DB704 (active) APP_CPU: PC=0x400D10D8
Breakpoint 3, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/./blink.c:36
 36 gpio_set_level(BLINK_GPIO, 1);
```

(continues on next page)
You will also be 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
-- 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
-- blink/main/./blink.c:36
breakpoint already hit 1 time
(gdb)
```

Please note that breakpoint numbers (listed under `Num`) start with 2. This is because first breakpoint has been already established at function `app_main()` by running command `thb app_main` on debugger launch. As it was a temporary breakpoint, it has been automatically deleted and now is not listed anymore.

To remove breakpoints enter `delete N` command (in short `d N`), where `N` is the breakpoint number:

```
(gdb) delete 1
No breakpoint number 1.
(gdb) delete 2
(gdb)
```

Read more about breakpoints under *Breakpoints and watchpoints available* and *What else should I know about breakpoints?*

**Halting and resuming the application** When debugging, you may resume application and enter code waiting for some event or staying in infinite loop without any breakpoints defined. In such case, to go back to debugging mode, you can break program execution manually by entering Ctrl+C.

To check it delete all breakpoints and enter `c` to resume application. Then enter Ctrl+C. Application will be halted at some random point and LED will stop blinking. Debugger will print the following:

```
(gdb) c
Continuing.
^CTarget halted. PRO_CPU: PC=0x400D0C00 APP_CPU: PC=0x400D0C00 (active)
[New Thread 1073433352]
Program received signal SIGINT, Interrupt.
[Switching to Thread 1073413512]
0x400d0c00 in esp_vApplicationIdleHook () at /home/user-name/esp/esp-idf/components/esp32/./freertos_hooks.c:52
 52    asm("waiti 0");
(gdb)
```

In particular case above, the application has been halted in line 52 of code in file `freertos_hooks.c`. Now you can resume it again by enter `c` or do some debugging as discussed below.

**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](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.
Chapter 4. API Guides

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.
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=0x400DB754 (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DB758 (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DC04C (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DB75B (active) APP_CPU: PC=0x400D1128
37 vTaskDelay(1000 / portTICK_PERIOD_MS);
(gdb) n
Target halted. PRO_CPU: PC=0x400DB75E (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400846FC (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DB761 (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DB766 (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=0x400DB74B (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DC04C (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DC04F (active) APP_CPU: PC=0x400D1128
gpio_set_level (gpio_num=GPIO_NUM_4, level=0) at /home/user-name/esp/esp-idf/
   \-components/driver/.\-gpio.c:183
183   GPIO_CHECK(GPIO_IS_VALID_OUTPUT_GPIO(gpio_num), "GPIO output gpio_num error
   \-", ESP_ERR_INVALID_ARG);
(gdb)
```

In this particular case debugger stepped inside `gpio_set_level(BLINK_GPIO, 0)` and effectively moved to `gpio.c` driver code.

See *Why stepping with “next” does not bypass subroutine calls?* for potential limitation of using `next` command.

**Checking and setting memory**  Displaying the contents of memory is done with command `x`. With additional parameters you may vary the format and count of memory locations displayed. Run `help x` to see more details. Companion command to `x` is `set` that let you write values to the memory.

We will demonstrate how `x` and `set` work by reading from and writing to the memory location `0x3FF44004` labeled as `GPIO_OUT_REG` used to set and clear individual GPIO’ s.

For more information, see *ESP32 Technical Reference Manual > IO MUX and GPIO Matrix (GPIO, IO_MUX)* [PDF].
Chapter 4. API Guides

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
Target halted. PRO_CPU: PC=0x400DB74E (active) APP_CPU: PC=0x400D1128

Breakpoint 2, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/.
    ^blink.c:34
34 vTaskDelay(1000 / portTICK_PERIOD_MS);
(gdb) x /1wx 0x3FF44004
0x3ff44004: 0x00000000
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB751 (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DB75B (active) APP_CPU: PC=0x400D1128

Breakpoint 3, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/.
    ^blink.c:37
37 vTaskDelay(1000 / portTICK_PERIOD_MS);
(gdb) x /1wx 0x3FF44004
0x3ff44004: 0x00000010
(gdb)
```

If your are blinking LED connected to GPIO4, then you should see fourth bit being flipped each time the LED changes the state:

```
0x3ff44004: 0x00000000
... 0x3ff44004: 0x00000000
0x3ff44004: 0x00000010
```

Now, when the LED is off, that corresponds to 0x3ff44004: 0x00000000 being displayed, try using set command to set this bit by writting 0x00000010 to the same memory location:

```
(gdb) x /1wx 0x3FF44004
0x3ff44004: 0x00000000
(gdb) set {unsigned int}0x3FF44004=0x000010
```

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
```

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) p i
$1 = 3
(gdb)
```

To modify the value of i use `set` command as below (you can then print it out to check if it has been indeed changed):

```
(gdb) set var i = 0
(gdb) p i
$3 = 0
(gdb)
```

You may have up to two watchpoints, see Breakpoints and watchpoints available.

**Setting conditional breakpoints**  Here comes more interesting part. You may set a breakpoint to halt the program execution, if certain condition is satisfied. Delete existing breakpoints and try this:

```
(gdb) break blink.c:34 if (i == 2)
Breakpoint 3 at 0x400db753: file /home/user-name/esp/blink/main/./blink.c, line 34.
(gdb)
```

Above command sets conditional breakpoint to halt program execution in line 34 of `blink.c` if i == 2.

If current value of i is less than 2 and program is resumed, it will blink LED in a loop until condition i == 2 gets true and then finally halt:

```
(gdb) set var i = 0
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB755 (active) APP_CPU: PC=0x400D112C
Target halted. PRO_CPU: PC=0x400DB753 (active) APP_CPU: PC=0x400D112C
Target halted. PRO_CPU: PC=0x400DB755 (active) APP_CPU: PC=0x400D112C
Target halted. PRO_CPU: PC=0x400DB753 (active) APP_CPU: PC=0x400D112C
Breakpoint 3, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/./
  → blink.c:34
34    gpio_set_level(BLINK_GPIO, 0);
(gdb)
```

**Obtaining help on commands**  Commands presented so for 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:
4.19 Linker Script Generation

4.19.1 Overview

There are several memory regions where code and data can be placed. Code and read-only data are placed by default in flash, writable data in RAM, etc. However, it is sometimes necessary to change these default placements.

For example, it may be necessary to place critical code in RAM for performance reasons 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.

4.19.2 Quick Start

This section presents a guide for quickly placing code/data to RAM and RTC memory - placements ESP-IDF provides out-of-the-box.

For this guide, suppose we have the following:

- components/
  - my_component/
    - CMakeLists.txt
    - component.mk
    - Kconfig

(continues on next page)
Chapter 4. API Guides

(continued from previous page)

- src/
  - my_src1.c
  - my_src2.c
  - my_src3.c
  - my_linker_fragment_file.lf

- a component named `my_component` that is archived as library `libmy_component.a` during build
- three source files archived under the library, `my_src1.c`, `my_src2.c` and `my_src3.c` which are compiled as `my_src1.o`, `my_src2.o` and `my_src3.o`, respectively
- under `my_src1.o`, the function `my_function1` is defined; under `my_src2.o`, the function `my_function2` is defined
- there is bool-type config `PERFORMANCE_MODE` (y/n) and int type config `PERFORMANCE_LEVEL` (with range 0-3) in `my_component`’s Kconfig

Creating and Specifying a Linker Fragment File

Before anything else, a linker fragment file needs to be created. A linker fragment file is simply a text file with a .lf extension upon which the desired placements will be written. After creating the file, it is then necessary to present it to the build system. The instructions for the build systems supported by ESP-IDF are as follows:

In the component’s CMakeLists.txt file, specify argument `LDFRAGMENTS` in the `idf_component_register` call. The value of `LDFRAGMENTS` can either be an absolute path or a relative path from the component directory to the created linker fragment file.

```bash
# file paths relative to CMakeLists.txt
idf_component_register(...
  LDFRAGMENTS "path/to/linker_fragment_file.lf" "path/to/
  "another_linker_fragment_file.lf"
  ...)
```

Specifying placements

It is possible to specify placements at the following levels of granularity:

- object file (.obj or .o files)
- symbol (function/variable)
- archive (.a files)

Placing object files Suppose the entirety of `my_src1.o` is performance-critical, so it is desirable to place it in RAM. On the other hand, the entirety of `my_src2.o` contains symbols needed coming out of deep sleep, so it needs to be put under RTC memory. In the the linker fragment file, we can write:

```bash
[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)
  else:
    * (default)
```

(continues on next page)
my_src2 (noflash)
eelif PERFORMANCE_LEVEL = 3:
    my_src1 (noflash)
    my_src2 (noflash)
    my_src3 (noflash)
else:
    * (rtc)

Nesting condition-checking is also possible. The following is equivalent to the snippet above:

[mapping:my_component]
archive: libmy_component.a
entries:
    if PERFORMANCE_LEVEL <= 3 && PERFORMANCE_LEVEL > 0:
        if PERFORMANCE_LEVEL >= 1:
            object1 (noflash)
            if PERFORMANCE_LEVEL >= 2:
                object2 (noflash)
                if PERFORMANCE_LEVEL >= 3:
                    object2 (noflash)
        else:
            * (rtc)

The ‘default’ placements

Up until this point, the term ‘default placements’ has been mentioned as fallback placements when the placement rules rtc and noflash are not specified. It is important to note that the tokens noflash or rtc are not merely keywords, but are actually entities called fragments, specifically schemes.

In the same manner as rtc and noflash are schemes, there exists a default scheme which defines what the default placement rules should be. As the name suggests, it is where code and data are usually placed, i.e. code/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.

### 4.19.3 Linker Script Generation Internals

Linking is the last step in the process of turning C/C++ source files into an executable. It is performed by the toolchain’s linker, and accepts linker scripts which specify code/data placements, among other things. With the linker script generation mechanism, this process is no different, except that the linker script passed to the linker is dynamically generated from: (1) the collected linker fragment files and (2) linker script template.

**Note:** The tool that implements the linker script generation mechanism lives under tools/ldgen.

**Linker Fragment Files**

As mentioned in the quick start guide, fragment files are simple text files with the .lf extension containing the desired placements. This is a simplified description of what fragment files contain, however. What fragment files actually contain are ‘fragments’. Fragments are entities which contain pieces of information which, when put
together, form placement rules that tell where to place sections of object files in the output binary. There are three types of fragments: \textit{sections}, \textit{scheme} and \textit{mapping}.

**Grammar** The three fragment types share a common grammar:

```
[type:name]
key: value
key:
  value
  value
  value...
```

- \textit{type}: Corresponds to the fragment type, can either be \textit{sections}, \textit{scheme} or \textit{mapping}.
- \textit{name}: The name of the fragment, should be unique for the specified fragment type.
- \textit{key, value}: Contents of the fragment; each fragment type may support different keys and different grammars for the key values.

**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 \texttt{eval\_string} from \texttt{kconfiglib} package and adheres to its required syntax and limitations. Supported operators are as follows:

- \textbf{comparison} – LessThan $<$
  - LessThanOrEqualTo $\leq$
  - MoreThan $>$
  - MoreThanOrEqualTo $\geq$
  - Equal $=$
  - NotEqual $\neq$
- \textbf{logical} – Or $\mid$
  - And $\&$
  - Negation $!$
- \textbf{grouping} – Parenthesis $()$

Condition checking behaves as you would expect an \texttt{if...elseif/elif...else} block in other languages. Condition-checking is possible for both key values and entire fragments. The two sample fragments below are equivalent:

```
# Value for keys is dependent on config
[type:name]
key_1:
  if CONDITION = y:
    value_1
  else:
    value_2
key_2:
  if CONDITION = y:
    value_a
```
else:
    value_b

# 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.

Compatibility with ESP-IDF v3.x Linker Script Fragment Files  ESP-IDF v4.0 brings some changes to the linker script fragment file grammar:

- indentation is enforced and improperly indented fragment files generate a parse exception; this was not enforced in the old version but previous documentation and examples demonstrates properly indented grammar
- move to if...elif...else structure for conditionals, with the ability to nest checks and place entire fragments themselves inside conditionals
- mapping fragments now requires a name like other fragment types

Linker script generator should be able to parse ESP-IDF v3.x linker fragment files that are indented properly (as demonstrated by the ESP-IDF v3.x version of this document). Backward compatibility with the previous mapping fragment grammar (optional name and the old grammar for conditionals) has also been retained but with a deprecation warning. Users should switch to the newer grammar discussed in this document as support for the old grammar is planned to be removed in the future.

Note that linker fragment files using the new ESP-IDF v4.0 grammar is not supported on ESP-IDF v3.x, however.

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.*

(continues on next page)
Scheme

Scheme fragments define what target a sections fragment is assigned to.

```
[scheme:name]
entries:
  sections -> target
  sections -> target
  ...
```

Example:

```
[scheme:noflash]
entries:
  text -> iram0_text # the entries under the sections fragment named... 
  -> text will go to iram0_text 
  rodata -> dram0_data # the entries under the sections fragment named...
  -> rodata will go to dram0_data
```

The default scheme

There exists a special scheme with the name default. This scheme is special because catch-all placement rules are generated from its entries. This means that, if one of its entries is `text -> flash_text`, the placement rule will be generated for the target `flash_text`.

```
.*( .literal .literal.* .text .text.* )
```

These catch-all rules then effectively serve as fallback rules for those whose mappings were not specified.

The default scheme is defined in `esp_system/app.lf`. The noflash and rtc scheme fragments which are built-in schemes referenced in the quick start guide are also defined in this file.

Mapping

Mapping fragments define what scheme fragment to use for mappable entities, i.e. object files, function names, variable names, archives.

```
[mapping:name]
archive: archive # output archive file name, as built (i.e. libxxx.
  
  a)
entries:
  object:symbol (scheme) # symbol granularity
  object (scheme) # object granularity
  * (scheme) # archive granularity
```

There are three levels of placement granularity:

- symbol: The object file name and symbol name are specified. The symbol name can be a function name or a variable name.
- object: Only the object file name is specified.
- archive: * is specified, which is a short-hand for all the object files under the archive.

To know what an entry means, let us expand a sample object-granularity placement:
Chapter 4. API Guides

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 ...

Example:

```
[mapping:map]
archive: libfreertos.a
entries:
* (noflash)
```

Aside from the entity and scheme, flags can also be specified in an entry. The following flags are supported (note: <> = argument name, [] = optional):

1. ALIGN(<alignment>[, pre, post])
   Align the placement by the amount specified in alignment. Generates

2. SORT([<sort_by_first>,<sort_by_second>])
   Emits SORT_BY_NAME, SORT_BY_ALIGNMENT, SORT_BY_INIT_PRIORITY or SORT in the input section description.
   Possible values for sort_by_first and sort_by_second are: name, alignment, init_priority.
   If both sort_by_first and sort_by_second are not specified, the input sections are sorted by name. If both are specified, then the nested sorting follows the same rules discussed in https://sourceware.org/binutils/docs/ld/Input-Section-Wildcards.html.

3. KEEP()
   Prevent the linker from discarding the placement by surrounding the input section description with KEEP command. See https://sourceware.org/binutils/docs/ld/Input-Section-Keep.html for more details.

4. SURROUND(<name>)
   Generate symbols before and after the placement. The generated symbols follow the naming _<name>_start and _<name>_end. For example, if name == sym1,

When adding flags, the specific section -> target in the scheme needs to be specified. For multiple section -> target, use a comma as a separator. For example,

```
# Notes:
# A. semicolon after entity-scheme
# B. comma before section2 -> target2
# C. section1 -> target1 and section2 -> target2 should be defined in entries of
#   scheme1
entity1 (scheme1);
   section1 -> target1 KEEP() ALIGN(4, pre, post),
   section2 -> target2 SURROUND(sym) ALIGN(4, post) SORT()
```
Putting it all together, the following mapping fragment, for example,

```plaintext
[mapping:name]
archive: lib1.a
entries:
  obj1 (noflash);
      rodata -> dram0_data KEEP() SORT() ALIGN(8) SURROUND(my_sym)
```

generates an output on the linker script:

```plaintext
_. = ALIGN(8)
_my_sym_start = ABSOLUTE(.)
KEEP(lib1.a:obj1.*{ SORT(.rodata) SORT(.rodata.*) })
_my_sym_end = ABSOLUTE(.)
```

Note that ALIGN and SURROUND, as mentioned in the flag descriptions, are order sensitive. Therefore, if for the same mapping fragment these two are switched, the following is generated instead:

```plaintext
_my_sym_start = ABSOLUTE(.)
_. = ALIGN(8)
KEEP(lib1.a:obj1.*{ SORT(.rodata) SORT(.rodata.*) })
_my_sym_end = ABSOLUTE(.)
```

**On Symbol-Granularity Placements** Symbol granularity placements is possible due to compiler flags `-ffunction-sections` and `-fdata-sections`. ESP-IDF compiles with these flags by default. If the user opts to remove these flags, then the symbol-granularity placements will not work. Furthermore, even with the presence of these flags, there are still other limitations to keep in mind due to the dependence on the compiler’s emitted output sections.

For example, with `-ffunction-sections`, separate sections are emitted for each function; with section names predictably constructed i.e. `.text.{func_name}` and `.literal.{func_name}`. This is not the case for string literals within the function, as they go to pooled or generated section names.

With `-fdata-sections`, for global scope data the compiler predictably emits either `.data.{var_name}`, `.rodata.{var_name}` or `.bss.{var_name};` and so Type I mapping entry works for these. However, this is not the case for static data declared in function scope, as the generated section name is a result of mangling the variable name with some other information.

**Linker Script Template**

The linker script template is the skeleton in which the generated placement rules are put into. It is an otherwise ordinary linker script, with a specific marker syntax that indicates where the generated placement rules are placed.

To reference the placement rules collected under a target token, the following syntax is used:

```plaintext
mapping[target]
```

Example:

The example below is an excerpt from a possible linker script template. It defines an output section `.iram0.text`, and inside is a marker referencing the target `iram0_text`.

```plaintext
.iram0.text : 
{  /* Code marked as running out of IRAM */
   _iram_text_start = ABSOLUTE(.);

   /* Marker referencing iram0_text */
   mapping[iram0_text]

(continues on next page)
Suppose the generator collected the fragment definitions below:

```plaintext
[sections:text]
  .text+
  .literal+
[sections:iram]
  .iram1+
[scheme:default]
  entries:
    text -> flash_text
    iram -> iram0_text

[scheme:noflash]
  entries:
    text -> iram0_text

[mapping:freertos]
  archive: libfreertos.a
  entries:
    * (noflash)
```

Then the corresponding excerpt from the generated linker script will be as follows:

```plaintext
.iram0.text :
{
  /* Code marked as running out of IRAM */
  _iram_text_start = ABSOLUTE(.);

  /* Placement rules generated from the processed fragments, placed where the...
  marker was in the template */
  "libfreertos.a: (.literal .text .literal.* .text.*)"

  _iram_text_end = ABSOLUTE(.);
} >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/esp32/sections.ld.in; the generated output script sections.ld is put under its build directory.
4.20 Memory Types

ESP32 chip has multiple memory types and flexible memory mapping features. This section describes how ESP-IDF uses these features by default.

ESP-IDF distinguishes between instruction memory bus (IRAM, IROM, RTC FAST memory) and data memory bus (DRAM, DROM). Instruction memory is executable, and can only be read or written via 4-byte aligned words. Data memory is not executable and can be accessed via individual byte operations. For more information about the different memory buses consult the ESP32 Technical Reference Manual > System and Memory [PDF].

4.20.1 DRAM (Data RAM)

Non-constant static data (.data) and zero-initialized data (.bss) is placed by the linker into Internal SRAM as data memory. Remaining space in this region is used for the runtime heap.

By applying the EXT_RAM_ATTR macro, zero-initialized data can also be placed into external RAM. To use this macro, the CONFIG_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY needs to be enabled. See Allow .bss Segment to be Placed in External Memory.

The available size of the internal DRAM region is reduced by 64kB (by shifting start address to 0x3FFC0000) if Bluetooth stack is used. Length of this region is also reduced by 16 kB or 32kB if trace memory is used. Due to some memory fragmentation issues caused by ROM, it is also not possible to use all available DRAM for static allocations - however the remaining DRAM is still available as heap at runtime.

Constant data may also be placed into DRAM, for example if it is used in an non-flash-safe ISR (see explanation under How to place code in IRAM).

“noinit” DRAM

The macro __NOINIT_ATTR can be used as attribute to place data into .noinit section. The values placed into this section will not be initialized at startup and should keep its value after software restart.

By applying the EXT_RAM_NOINIT_ATTR macro, Non-initialized value could also be placed in external RAM. To do this, the CONFIG_SPIRAM_ALLOW_NOINIT_SEG_EXTERNAL_MEMORY needs to be enabled. See Allow .noinit Segment to be Placed in External Memory. If the CONFIG_SPIRAM_ALLOW_NOINIT_SEG_EXTERNAL_MEMORY is not enabled, EXT_RAM_NOINIT_ATTR will behave just as __NOINIT_ATTR, it will make data to be placed into .noinit segment in internal RAM.

Example:

__NOINIT_ATTR uint32_t noinit_data;

4.20.2 IRAM (Instruction RAM)

ESP-IDF allocates part of Internal SRAM0 region for instruction RAM. The region is defined in ESP32 Technical Reference Manual > System and Memory > Embedded Memory [PDF]. Except for the first 64 kB block which is used for PRO and APP MMU caches, the rest of this memory range (i.e. from 0x40080000 to 0x400A0000) is used to store parts of the application which need to run from RAM.

Why place code in IRAM

Cases when parts of application should be placed into IRAM:

• Interrupt handlers must be placed into IRAM if ESP_INTR_FLAG_IRAM is used when registering the interrupt handler. For more information, see IRAM-Safe Interrupt Handlers.
• Some timing critical code may be placed into IRAM to reduce the penalty associated with loading the code from flash. ESP32 reads code and data from flash via the MMU cache. In some cases, placing a function into IRAM may reduce delays caused by a cache miss and significantly improve that function’s performance.
How to place code in IRAM

Some code is automatically placed into the IRAM region using the linker script.

If some specific application code needs to be placed into IRAM, it can be done by using the Linker Script Generation feature and adding a linker script fragment file to your component that targets entire source files or functions with the noflash placement. See the Linker Script Generation docs for more information.

Alternatively, it’s possible to specify IRAM placement in the source code using the IRAM_ATTR macro:

```c
#include "esp_attr.h"

void IRAM_ATTR gpio_isr_handler(void* arg)
{
    // ...
}
```

There are some possible issues with placement in IRAM, that may cause problems with IRAM-safe interrupt handlers:

- Strings or constants inside an IRAM_ATTR function may not be placed in RAM automatically. It’s possible to use DRAM_ATTR attributes to mark these, or using the linker script method will cause these to be automatically placed correctly.

```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 -fjump-tables -ftree-switch-conversion options when compiling individual source files, see Controlling Component Compilation.

4.20.3 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 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 application 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.

4.20.4 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.

RTC fast memory can only be accessed by the PRO CPU.

In single core mode, remaining RTC fast memory is added to the heap unless the option CONFIG_ESP_SYSTEM_ALLOW_RTC_FAST_MEM_AS_HEAP is disabled. This memory can be used interchangeably with DRAM (Data RAM), but is slightly slower to access and not DMA capable.
### 4.20.5 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.

The DRAM_ATTR attribute can be used to force constants from DROM into the DRAM (Data RAM) section (see above).

### 4.20.6 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;
```

### 4.20.7 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";
```

```c
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.
Chapter 4. API Guides

4.20.8 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 \texttt{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...
    // the buffer will be placed right after stuff.
    // initialization code...
    spi_transaction_t temp = {
        .tx_buffer = buffer,
        .length = 8 * sizeof(buffer),
    };
    spi_device_transmit(spi, &temp);
    // other stuff
}
```

4.21 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.

4.21.1 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 \texttt{ESP\_NETIF} functionality
- Simple Network Time Protocol (SNTP) is supported via the \texttt{lwip/include/apps/snntp/snntp.h} \texttt{lwip/lwip/src/include/lwip/apps/snntp.h} functions (see also \texttt{SNTP Time Synchronization})
- ICMP Ping is supported using a variation on the lwIP ping API. See \texttt{ICMP Echo}.
- NetBIOS lookup is available using the standard lwIP API. \texttt{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 \texttt{mDNS Service}), but lwIP can look up mDNS hosts using standard APIs such as \texttt{gethostbyname()} and the convention \texttt{hostname.local}, provided the \texttt{CONFIG\_LWIP\_DNS\_SUPPORT\_MDNS\_QUERIES} setting is enabled.

4.21.2 BSD Sockets API

The BSD Sockets API is a common cross-platform TCP/IP sockets API that originated in the Berkeley Standard Distribution of UNIX but is now standardized in a section of the POSIX specification. BSD Sockets are sometimes called POSIX Sockets or Berkeley Sockets.

As implemented in ESP-IDF, lwIP supports all of the common usages of the BSD Sockets API.
References

A wide range of BSD Sockets reference material is available, including:

- Single UNIX Specification BSD Sockets page
- Berkeley Sockets Wikipedia page

Examples

A number of ESP-IDF examples show how to use the BSD Sockets APIs:

- protocols/sockets/tcp_server
- protocols/sockets/tcp_client
- protocols/sockets/udp_server
- protocols/sockets/udp_client
- protocols/sockets/udp_multicast
- protocols/http_request (Note: this is a simplified example of using a TCP socket to send an HTTP request. The ESP HTTP Client is a much better option for sending HTTP requests.)

Supported functions

The following BSD socket API functions are supported. For full details see lwip/lwip/src/include/lwip/sockets.h.

- socket()
- bind()
- accept()
- shutdown()
- getpeername()
- getsockopt() & setsockopt() (see Socket Options)
- close() (via Virtual filesystem component)
- read(), readv(), write(), writev() (via Virtual filesystem component)
- recv(), recvmsg(), recvfrom()
- send(), sendmsg(), sendto()
- select() (via Virtual filesystem component)
- poll() (Note: on ESP-IDF, poll() is implemented by calling select internally, so using select() directly is recommended if a choice of methods is available.)
- fcntl() (see fcntl)

Non-standard functions:

- ioctl() (see iocls)

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.
<table>
<thead>
<tr>
<th>Error code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECONNREFUSED</td>
<td>Connection refused</td>
</tr>
<tr>
<td>EADDRINUSE</td>
<td>Address already in use</td>
</tr>
<tr>
<td>ECONNABORTED</td>
<td>Software caused connection abort</td>
</tr>
<tr>
<td>ENETUNREACH</td>
<td>Network is unreachable</td>
</tr>
<tr>
<td>ENETDOWN</td>
<td>Network interface is not configured</td>
</tr>
<tr>
<td>ETIMEDOUT</td>
<td>Connection timed out</td>
</tr>
<tr>
<td>EHOSTDOWN</td>
<td>Host is down</td>
</tr>
<tr>
<td>EHOSTUNREACH</td>
<td>Host is unreachable</td>
</tr>
<tr>
<td>EINPROGRESS</td>
<td>Connection already in progress</td>
</tr>
<tr>
<td>EALREADY</td>
<td>Socket already connected</td>
</tr>
<tr>
<td>EDESTADDRREQ</td>
<td>Destination address required</td>
</tr>
<tr>
<td>EPROTONOSUPPORT</td>
<td>Unknown protocol</td>
</tr>
</tbody>
</table>

**Socket Options**

The `getsockopt()` and `setsockopt()` functions allow getting/setting per-socket options.

Not all standard socket options are supported by lwIP in ESP-IDF. The following socket options are supported:

**Common options**  Used with level argument `SOL_SOCKET`.

- `SO_REUSEADDR` (available if `CONFIG_LWIP_SO_REUSE` is set, behavior can be customized by setting `CONFIG_LWIP_SO_REUSE_RXTOALL`)
- `SO_KEEPALIVE`
- `SO_BROADCAST`
- `SO_ACCEPTCONN`
- `SO_RCVBUF` (available if `CONFIG_LWIP_SO_RCVBUF` is set)
- `SO_SNDFTIMEO / 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_KEEPTIME` (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, ...)`. 

### 4.21.3 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.

### 4.21.4 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`

4.21.5 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

4.21.6 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()

Abort TCP connections when IP changes  CONFIG_LWIP_TCP_KEEP_CONNECTION_WHEN_IP_CHANGES is disabled by default. This disables the default lwIP behaviour of keeping TCP connections open if an interface IP changes, in case the interface IP changes back (for example, if an interface connection goes down and comes back up). Enable this option to keep TCP connections open in this case, until they time out normally. This may increase the number of sockets in use if a network interface goes down temporarily.

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 or Ethernet project configuration (as applicable) may also help.

4.21.7 Performance Optimization

TCP/IP performance is a complex subject, and performance can be optimized towards multiple goals. The default settings of ESP-IDF are tuned for a compromise between throughput, latency, and moderate memory usage.
Maximum throughput

Espressif tests ESP-IDF TCP/IP throughput using the wifi/iperf example in an RF sealed enclosure.

The wifi/iperf/sdkconfig.defaults file for the iperf example contains settings known to maximize TCP/IP throughput, usually at the expense of higher RAM usage. To get maximum TCP/IP throughput in an application at the expense of other factors then suggest applying settings from this file into the project sdkconfig.

**Important:** Suggest applying changes a few at a time and checking the performance each time with a particular application workload.

- If a lot of tasks are competing for CPU time on the system, consider that the lwIP task has configurable CPU affinity (`CONFIG_LWIP_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, setting `CONFIG_LWIP_USE_ONLY_LWIP_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_IP_RECVMBBOX_SIZE`, `CONFIG_LWIP_TCP_RECVMBBOX_SIZE` and `CONFIG_LWIP_UDP_RECVMBBOX_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:

\[
lwip_dynamic_peak_memory = \frac{(lwip_udp_con_num * lwip_udp_conn) + (lwip_tcp_con_num * (lwip_tcp_tx_win_size + lwip_tcp_rx_win_size + lwip_tcp_conn))}{\text{lwip_total_heap_size}}
\]
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).

4.22 OpenThread

OpenThread is a IP stack running on the 802.15.4 MAC layer which features mesh network and low power consumption.

4.22.1 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:

![Diagram of OpenThread device modes](image)
**4.22.2 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.

**4.22.3 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 an 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.
Chapter 4. API Guides

4.23 Partition Tables

4.23.1 Overview

A single ESP32’s flash can contain multiple apps, as well as many different kinds of data (calibration data, filesystems, parameter storage, etc). For this reason a partition table is flashed to (default offset) 0x8000 in the flash.

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.

4.23.2 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,
otadata, 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, 0x210000, 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 “otadata” slot, which holds the data for OTA updates. The bootloader consults this data in order to know which app to execute. If “otadata” is empty, it will execute the factory app.

4.23.3 Creating Custom Tables

If you choose “Custom partition table CSV” in menuconfig then you can also enter the name of a CSV file (in the project directory) to use for your partition table. The CSV file can describe any number of definitions for the table you need.

The CSV format is the same format as printed in the summaries shown above. However, not all fields are required in the CSV. For example, here is the “input” CSV for the OTA partition table:
# 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. 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 file system` (**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.
4.23.4 Generating Binary Partition Table

The partition table which is flashed to the ESP32 is in a binary format, not CSV. The tool `partition_table/gen_esp32part.py` is used to convert between CSV and binary formats.

If you configure the partition table CSV name in the project configuration (`idf.py menuconfig`) and then build the project or run `idf.py partition-table`, this conversion is done as part of the build process.

To convert CSV to Binary manually:

```
python gen_esp32part.py input_partitions.csv binary_partitions.bin
```

To convert binary format back to CSV manually:

```
python gen_esp32part.py binary_partitions.bin input_partitions.csv
```

To display the contents of a binary partition table on stdout (this is how the summaries displayed when running `idf.py partition-table` are generated):

```
python gen_esp32part.py binary_partitions.bin
```

4.23.5 Partition Size Checks

The ESP-IDF build system will automatically check if generated binaries fit in the available partition space, and will fail with an error if a binary is too large.

Currently these checks are performed for the following binaries:

- Bootloader binary must fit in space before partition table (see Bootloader Size).
- App binary should fit in at least one partition of type “app”. If the app binary doesn’t fit in any app partition, the build will fail. If it only fits in some of the app partitions, a warning is printed about this.

**Note:** Although the build process will fail if the size check returns an error, the binary files are still generated and can be flashed (although they may not work if they are too large for the available space.)

MD5 checksum

The binary format of the partition table contains an MD5 checksum computed based on the partition table. This checksum is used for checking the integrity of the partition table during the boot.

The MD5 checksum generation can be disabled by the `--disable-md5sum` option of `gen_esp32part.py` or by the `CONFIG_PARTITION_TABLE_MD5` option. This is useful for example when one uses a bootloader from ESP-IDF before v3.1 which cannot process MD5 checksums and the boot fails with the error message `invalid magic number 0xebeb`.

4.23.6 Flashing the partition table

- `idf.py partition-table-flash`: will flash the partition table with `esptool.py`.
- `idf.py flash`: Will flash everything including the partition table.

A manual flashing command is also printed as part of `idf.py partition-table` output.

**Note:** Note that updating the partition table doesn’t erase data that may have been stored according to the old partition table. You can use `idf.py erase-flash` (or `esptool.py erase_flash`) to erase the entire flash contents.
Chapter 4. API Guides

4.23.7 Partition Tool (parttool.py)

The component partition_table provides a tool parttool.py for performing partition-related operations on a target device. The following operations can be performed using the tool:

- reading a partition and saving the contents to a file (read_partition)
- writing the contents of a file to a partition (write_partition)
- erasing a partition (erase_partition)
- retrieving info such as name, offset, size and flag ("encrypted") of a given partition (get_partition_info)

The tool can either be imported and used from another Python script or invoked from shell script for users wanting to perform operation programmatically. This is facilitated by the tool’s Python API and command-line interface, respectively.

Python API

Before anything else, make sure that the partool 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")  # partool.py lives in $IDF_PATH/components/partition_table
sys.path.append(parttool_dir)  # this enables Python to find partool module
from partool import *  # import all names inside partool module
```

The starting point for using the tool’s Python API to do is create a PartoolTarget object:

```python
# Create a partool.py target device connected on serial port /dev/ttyUSB1
target = PartoolTarget("/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:
Chapter 4. API Guides

parttool.py [command-args] [subcommand] [subcommand-args]

- **command-args** - These are arguments that are needed for executing the main...
- **subcommand** (parttool.py), mostly pertaining to the target device
- **subcommand-args** - These are arguments that are specific to the chosen operation

```python
# 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:

```bash
# Display possible subcommands and show main command argument descriptions
parttool.py --help

# Show descriptions for specific subcommand arguments
parttool.py [subcommand] --help
```

### 4.24 Performance

ESP-IDF ships with default settings that are designed for a trade-off between performance, resource usage, and available functionality.

These guides describe how to optimize a firmware application for a particular aspect of performance. Usually this involves some trade-off in terms of limiting available functions, or swapping one aspect of performance (such as execution speed) for another (such as RAM usage).

#### 4.24.1 How to Optimize Performance

1. Decide what the performance-critical aspects of your application are (for example: a particular response time to a certain network operation, a particular startup time limit, particular peripheral data throughput, etc.).
2. Find a way to measure this performance (some methods are outlined in the guides below).
3. Modify the code and project configuration and compare the new measurement to the old measurement.
4. Repeat step 3 until the performance meets the requirements set out in step 1.

#### 4.24.2 Guides

**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)
", 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_ESP_TOOLS_FLASHFREQ` to 80 MHz. This is double the 40 MHz default value and will double the speed at which code is loaded or executed from flash. You should verify that the board or module that connects the ESP32 to the flash chip is rated for 80 MHz operation at the relevant temperature ranges, before changing this setting. The hardware datasheet(s) will have this information.
- Set `CONFIG_ESP_TOOLS_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 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 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`

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-free-switch-conversion options when compiling individual source files, see Controlling Component Compilation.
Improving Startup Time  
In addition to the overall performance improvements shown above, the following options can be tweaked to specifically reduce startup time:

- Minimizing the `CONFIG_LOG_DEFAULT_LEVEL` and `CONFIG_BOOTLOADER_LOG_LEVEL` has a large impact on startup time. To enable more logging after the app starts up, set the `CONFIG_LOG_MAXIMUM_LEVEL` as well and then call `esp_log_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_ESP32_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.esp32` 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_TCP_IP_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)*.

• **Bluedroid Bluetooth Host** creates multiple tasks when used:
  
  – Stack event callback task ("BTC") has high priority (19).
  – Stack BTU layer task has high priority (20).
  – Host HCI host task has high priority (22).

  All Bluedroid Tasks are pinned to the same core, which is Core 0 by default *(configurable)*.

• The Ethernet driver creates a task for the MAC to receive Ethernet frames. If using the default config ETH_MAC_DEFAULT_CONFIG then the priority is medium-high (15) and the task is not pinned to any core. These settings can be changed by passing a custom eth_mac_config_t struct when initializing the Ethernet MAC.

• If using the **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-empts 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().
Chapter 4. API Guides

- 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 lwIP TCP/IP (Wi-Fi and Ethernet), see *Performance Optimization*
- The `wifi/iperf` example contains a configuration that is heavily optimized for Wi-Fi TCP/IP throughput. Append the contents of the files `wifi/iperf/sdkconfig.defaults`, `wifi/iperf/sdkconfig.defaults.esp32` and `wifi/iperf/sdkconfig.ci.99` to 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: 14956 bytes
  DRAM .bss size: 15808 bytes
Used static DRAM: 30764 bytes (149972 available, 17.0% used)
Used static IRAM: 83918 bytes (47154 available, 64.0% used)
  Flash code: 559943 bytes
  Flash rodata: 176736 bytes
Total image size: 835553 bytes (.bin may be padded larger)
```

This output breaks down the size of all static memory regions in the firmware binary:

- DRAM .data size is statically allocated RAM that is assigned to non-zero values at startup. This uses RAM (DRAM) at runtime and also uses space in the binary file.
- DRAM .bss size is statically allocated RAM that is assigned zero at startup. This uses RAM (DRAM) at runtime but doesn’t use any space in the binary file.
- Used static DRAM is the total DRAM used by .data + .bss. The available size is the estimated amount of DRAM which will be available as heap memory at runtime (due to metadata overhead and implementation constraints, and heap allocations done by ESP-IDF during startup, the actual free heap at startup will be lower than this).
Chapter 4. API Guides

• Used static IRAM is the total size of executable code executed from IRAM. This uses space in the binary file and also reduces IRAM and/or DRAM (depending on sizes) available as heap memory at runtime. See Optimizing IRAM Usage.
• Flash code is the total size of executable code executed from flash cache (IROM). This uses space in the binary file.
• Flash rodata is the total size of read-only data loaded from flash cache (DROM). This uses space in the binary file.
• Total image size is the estimated total binary file size, which is the total of all the used memory types except for .bss.

Component Usage Summary (idf.py size-components)  The summary output provided by idf.py size does not give enough detail to find the main contributor to excessive binary size. To analyze in more detail, use idf.py size-components

```
$ idf.py size-components
[...] Total sizes:
  DRAM .data size:  14956 bytes
  DRAM .bss size:  15808 bytes
Used static DRAM:  30764 bytes ( 149972 available, 17.0% used)
Used static IRAM:  83918 bytes ( 47154 available, 64.0% used)
  Flash code:  559943 bytes
  Flash rodata:  176736 bytes
  Total image size:~ 835553 bytes (bin may be padded larger)
Per-archive contributions to ELF file:
  Archive File  DRAM .data & .bss & other  IRAM  D/IRAM  Flash code &...
  ──rodata  Total
        libnet80211.a  1267  6044  0  5490  0  107445 ...
        liblwip.a  21  3838  0  0  0  97465 ...
        libmbedtls.a  64  81  0  30  0  76645 ...
        libmbedcrypto.a  64  81  0  30  0  76645 ...
        libpp.a  2427 1292 0 20851 0  37208 ...
        libc.a  4  0  0  0  0  50756 ...
        libphy.a  1439 715 0 7798 0  33074 ...
        libwpa_supplicant.a  12  848 0 0 0  35505 ...
        libfreertos.a  3104 740 0 15711 0  367 ...
        libesp_sys}catch.a    0 24 0 0 0  14347 ...
        libgcrypt.a  1562 294 0 8851 0  1840 ...
        libesp_system.a  245 206 0 3078 0  5990 ...
        libesp-tls.a  0 4 0 0 0  5637 ...
        libtcpNSURL_adapter.a  0 17 0 0 0  216 ...
        libcxx.a  36 0 0 0 0  79 ...
        libc.a  2 0 0 0 0  3 ...
```

(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 IRAM that can be dynamically allocated at runtime using `HEAP_CAP_32BIT`.
- **D/IRAM**: Shows IRAM space which, due to occupying D/IRAM space, is also reducing available DRAM available as heap at runtime.
- **Flash code & rodata**: these are the same as the totals above, IROM and DROM space accessed from flash cache that contribute to the binary size.

### Source File Usage Summary (`idf.py size-files`)
For even more detail, run `idf.py size-files` to get a summary of the contribution each object file has made to the final binary size. Each object file corresponds to a single source file.

```bash
$ idf.py size-files
[...]
Total sizes:

<table>
<thead>
<tr>
<th>Section</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRAM .data</td>
<td>14956 bytes</td>
</tr>
<tr>
<td>DRAM .bss</td>
<td>15808 bytes</td>
</tr>
<tr>
<td>Used static DRAM</td>
<td>30764 bytes (149972 available, 17.0% used)</td>
</tr>
<tr>
<td>Used static IRAM</td>
<td>83918 bytes (47154 available, 64.0% used)</td>
</tr>
<tr>
<td>Flash code</td>
<td>559943 bytes</td>
</tr>
<tr>
<td>Flash rodata</td>
<td>176736 bytes</td>
</tr>
<tr>
<td>Total image size:</td>
<td>835553 bytes ( .bin may be padded larger)</td>
</tr>
</tbody>
</table>

Per-file contributions to ELF file:

<table>
<thead>
<tr>
<th>Object File</th>
<th>DRAM .data &amp; .bss &amp; other</th>
<th>IRAM</th>
<th>D/IRAM</th>
<th>Flash code &amp; rodata</th>
</tr>
</thead>
<tbody>
<tr>
<td>x509.crt_bundle.S.o</td>
<td>0 0 0 0 0 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>64212</td>
<td>64212</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wl_cnx.o</td>
<td>2 3183 0 221 0 13119</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>phy_chip_v7.o</td>
<td>721 614 0 1642 0 16820</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 19797</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ieee80211_ioc1.o</td>
<td>740 96 0 437 0 15325</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2627</td>
<td>19225</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pp.o</td>
<td>1142 45 0 8871 0 5030</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

(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>:
---<REFERENCE> Difference
DRAM .data size: 14516 bytes  
14956 -440
DRAM .bss size: 15792 bytes  
15808 -16
Used static DRAM: 30308 bytes (150428 available, 16.8% used)  
30764 -456 ( +456 available, +0 total)
Used static IRAM: 78498 bytes (52574 available, 59.9% used)  
83918 -5420 ( +5420 available, +0 total)
Flash code: 509183 bytes  
559943 -50760
Flash rodata: 170592 bytes  
176736 -6144
Total image size: 772789 bytes (.bin may be padded larger)  
835553 -62764

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.)
Chapter 4. API Guides

The map file argument is <projectname>.map in the build directory

```
$IDF_PATH/tools/idf_size.py build/project_name.map
```

It is also possible to view the equivalent of size-components or size-files output:

```
$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 -fdata-sections and linker option --gc-sections). Items mentioned in this list do not contribute to the final binary.

- **Memory Configuration, Linker script and memory map**  These two parts go together. Some of the output comes directly from the linker command line and the Linker Script, both provided by the Build System. The linker script is partially generated from the ESP-IDF project using the Linker Script Generation feature.

As the output of the Linker script and memory map part of the map unfolds, you can see each symbol (function or static variable) linked into the final binary along with its address (as a 16 digit hex number), its length (also in hex), and the library and object file it was linked from (which can be used to determine the component and the source file).

Following all of the output sections that take up space in the final .bin file, the memory map also includes some sections in the ELF file that are only used for debugging (ELF sections .debug_*, etc.). These don’t contribute to the final binary size. You’ll notice the address of these symbols is a very low number (starting from 0x0000000000000000 and counting up).

- **Cross Reference Table.**  This table shows for each symbol (function or static variable), the list of object file(s) that referred to it. If you’re wondering why a particular thing is included in the binary, this will help determine what included it.

**Note:** Unfortunately, the Cross Reference Table doesn’t only include symbols that made it into the final binary. It also includes symbols in discarded sections. Therefore, just because something is shown here doesn’t mean that it was included in the final binary - this needs to be checked separately.

**Note:** Linker map files are generated by the GNU binutils linker “ld”, not ESP-IDF. You can find additional information online about the linker map file format. This quick summary is written from the perspective of ESP-IDF build system in particular.
Reducing Overall Size  The following configuration options will reduce the final binary size of almost any ESP-IDF project:

- Set `CONFIG_COMPILER_OPTIMIZATION` to “Optimize for size (-Os)” . In some cases, “Optimize for performance (-O2)” will also reduce the binary size compared to the default. Note that if your code contains C or C++ Undefined Behaviour then increasing the compiler optimization level may expose bugs that otherwise don’t happen.
- Reduce the compiled-in log output by lowering the app `CONFIG_LOG_DEFAULT_LEVEL`. If the `CONFIG_LOG_MAXIMUM_LEVEL` is changed from the default then this setting controls the binary size instead. Reducing compiled-in logging reduces the number of strings in the binary, and also the code size of the calls to logging functions.
- Set the `CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL` to “Silent”. This avoids compiling in a dedicated assertion string and source file name for each assert that may fail. It’s still possible to find the failed assert in the code by looking at the memory address where the assertion failed.
- Besides the `CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL`, you can disable or silent the assertion for HAL component separately by setting `CONFIG_HAL_DEFAULT_ASSERTION_LEVEL`.
- Set `CONFIG_COMPILER_OPTIMIZATION_CHECKS_SILENT`. This removes specific error messages for particular internal ESP-IDF error check macros. This may make it harder to debug some error conditions by reading the log output.
- If the binary needs to run on only certain revision(s) of ESP32, increasing `CONFIG_ESP32_REV_MIN` to match can result in a reduced binary size. This will make a large difference if setting ESP32 minimum revision 3, and PSRAM is enabled.
- Don’t enable `CONFIG_COMPILER_CXX.Exceptions`, `CONFIG_COMPILER_CXX.RTTI`, or set the `CONFIG_COMPILER_STACK_CHECK_MODE` to Overall. All of these options are already disabled by default, but they have a large impact on binary size.
- Disabling `CONFIG_ESP.ERR.TO_NAME_LOOKUP` will remove the lookup table to translate user-friendly names for error values (see Error Handling) in error logs, etc. This saves some binary size, but error values will be printed as integers only.
- Setting `CONFIG_ESP.SYSTEM.PANIC` to “Silent reboot” will save a small amount of binary size, however this is only recommended if no one will use UART output to debug the device.

**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_WIFl.SOFTAP_SUPPORT` will save some Wi-Fi binary size if soft-AP support is not needed.

**ADC**
- Disabling ADC calibration features `CONFIG_ADC_CAL.EFUSE_TP_ENABLE`, `CONFIG_ADC_CAL.EFUSE_VREF_ENABLE`, `CONFIG_ADC_CAL.LUT_ENABLE` will save a small amount of binary size if ADC driver is used, at expense of accuracy.

**Bluetooth NimBLE**  If using NimBLE Bluetooth Host then the following modifications can reduce binary size:
- Set `CONFIG_BTDM_CTRL_BLE.MAX_CONN` to 1 if only one BLE connection is needed.
- `CONFIG_BT_NIMBLE_MAX_CONNECTIONS` to 1 if only one BLE connection is needed.
- Disable either `CONFIG_BT_NIMBLE_ROLE.CENTERA` 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 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.
Chapter 4. API Guides

If depending on third party clients or servers, always pay attention to announcements about future changes to supported TLS features. If not, the ESP32 device may become inaccessible if support changes.

**Note:** Not every combination of mbedTLS 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_FILE** — 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 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 but 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 Bluez, setting the option `CONFIG_BT_BLE_DYNAMIC_ENV_MEMORY` will cause Bluez 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_ESP_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** task has stack sizes `CONFIG_BT_BT_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.
• The Ethernet driver allocates DMA buffers for the internal Ethernet MAC when it is initialized - configuration options are \texttt{CONFIG\_ETH\_DMA\_BUFFER\_SIZE, CONFIG\_ETH\_DMA\_RX\_BUFFER\_NUM, CONFIG\_ETH\_DMA\_TX\_BUFFER\_NUM}.
• mbedTLS TLS session memory usage can be minimized by enabling the ESP-IDF feature \texttt{CONFIG\_MBEDTLS\_DYNAMIC\_BUFFER}.
• In single core mode only, it’s possible to use IRAM as byte accessible memory (added to the regular heap) by enabling \texttt{CONFIG\_ESP32\_IRAM\_AS\_8BIT\_ACCESSIBLE\_MEMORY}. Note that this option carries a performance penalty and the risk of security issues caused by executable data. If this option is enabled then it’s possible to set other options to prefer certain buffers be allocated from this memory: mbedTLS, NimBLE.
• Reduce \texttt{CONFIG\_BTDM\_CTRL\_BLE\_MAX\_CONN} if using BLE.
• Reduce \texttt{CONFIG\_BTDM\_CTRL\_BR\_EDR\_MAX\_ACL\_CONN} if using Bluetooth Classic.

\textbf{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.

\textbf{Optimizing 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 \textit{Measuring Static Sizes}. If the firmware failed to link, steps to analyze are shown at \textit{Showing Size When Linker Fails}.

The following options will reduce IRAM usage of some ESP-IDF features:

• Enable \texttt{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 \texttt{CONFIG\_FREERTOS\_PLACE\_SNAPSHOT\_FUNS\_INTO\_FLASH}. Enabling this option will place snapshot-related functions, such as \texttt{vTaskGetSnapshot} or \texttt{uxTaskGetSnapshotAll}, in flash.
• Disable Wi-Fi options \texttt{CONFIG\_ESP32\_WIFI\_IRAM\_OPT} and/or \texttt{CONFIG\_ESP32\_WIFI\_RX\_IRAM\_OPT}. Disabling these options will free available IRAM at the cost of Wi-Fi performance.
• \texttt{CONFIG\_SPI\_FLASH\_ROM\_DRIVER\_PATCH} disabling this option will free some IRAM but is only available in some flash configurations (see the configuration item help text).
• Disabling \texttt{CONFIG\_ESP\_EVENT\_POST\_FROM\_IRAM\_ISR} prevents posting \texttt{esp\_event} events from IRAM-Safe Interrupt Handlers but will save some IRAM.
• Disabling \texttt{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 \texttt{CONFIG\_HAL\_DEFAULT\_ASSERTION\_LEVEL} to disable assertion for HAL component will save some IRAM especially for HAL code who calls \texttt{HAL\_ASSERT} a lot and resides in IRAM.

When compiling for ESP32 revisions older than ECO3 (\texttt{CONFIG\_ESP32\_REV\_MIN}), PSRAM cache bug workaround (\texttt{CONFIG\_SPIRAM\_CACHE\_WORKAROUND}) option is enabled, and the C library functions normally located in ROM are recompiled with the workaround and placed into IRAM instead. For most applications, it is safe to move many of the C library functions into Flash, reclaiming some IRAM. Corresponding options include:

• \texttt{CONFIG\_SPIRAM\_CACHE\_LIBJMP\_IN\_IRAM}: affects the functions longjmp and setjmp.
• \texttt{CONFIG\_SPIRAM\_CACHE\_LIBMATH\_IN\_IRAM}: affects the functions abs, div, labs, idiv, quorem, fpclassify and nan.
• \texttt{CONFIG\_SPIRAM\_CACHE\_LIBNUMPARSER\_IN\_IRAM}: affects the functions utoa, itoa, atoi, atol, strtol, and strttl.
• \texttt{CONFIG\_SPIRAM\_CACHE\_LIBIO\_IN\_IRAM}: affects the functions wctomb, fwrite, wbuf, wsetup, fputwc, wctomb_r, ungetc, makebuf, fflush, refill, and sccl.
• **CONFIG_SPIRAM_CACHE_LIBTIME_IN_IRAM**: affects the functions `asctime`, `asctime_r`, `ctime`, `ctime_r`, `lcltime`, `lcltime_r`, `gmtime`, `gmtime_r`, `strptime`, `mktime`, `tzset_r`, `tzset`, `time`, `gettzinfo`, `sysctimes`, `month_lengths`, `timelocal`, `tzvars`, `tzlock`, `tz_calc_limits`, and `strptime`.

• **CONFIG_SPIRAM_CACHE_LIBCHAR_IN_IRAM**: affects the functions `ctype_`, `toupper`, `tolower`, `toascii`, `strupr`, `bzero`, `isalnum`, `isalpha`, `isascii`, `isblank`, `iscntrl`, `isdigit`, `isgraph`, `islower`, `isprint`, `ispunct`, `isspace`, and `isupper`.

• **CONFIG_SPIRAM_CACHE_LIBMEM_IN_IRAM**: affects the functions `memccpy`, `memchr`, `memmove`, and `memrchr`.

• **CONFIG_SPIRAM_CACHE_LIBSTR_IN_IRAM**: affects the functions `strcasecmp`, `strcasestr`, `strchr`, `strcoll`, `strcpy`, `strcspn`, `strdup`, `strdup_r`, `strlcat`, `strlcpy`, `strlens`, `strlwr`, `strcasecmp`, `strncasecmp`, `strncat`, `strncpy`, `strndup`, `strndup_r`, `strchr`, `strsep`, `strspn`, `strstr`, `strtok_r`, and `strupr`.

• **CONFIG_SPIRAM_CACHE_LIBRAND_IN_IRAM**: affects the functions `srand`, `rand`, and `rand_r`.

• **CONFIG_SPIRAM_CACHE_LIBENV_IN_IRAM**: affects the functions `environ`, `envlock`, and `getenv_r`.

• **CONFIG_SPIRAM_CACHE_LIBFILE_IN_IRAM**: affects the functions `lock`, `isatty`, `fclose`, `open`, `close`, `creat`, `read`, `rshift`, `sbrk`, `stdio`, `sysbfrk`, `sysclose`, `sysopen`, `creat`, `sysread`, `syswrite`, `impure`, `fwalk`, and `findfp`.

• **CONFIG_SPIRAM_CACHE_LIBMISC_IN_IRAM**: affects the functions `raise` and `system`.

The exact amount of IRAM saved will depend on how much C library code is actually used by the application. In addition to these, the following options may be used to move more of the C library code into Flash, however note that this may result in reduced performance. Also take care to not use corresponding C library functions from interrupts which may be called while cache is disabled (allocated with `ESP_INTR_FLAG_IRAM` flag), refer to **IRAM-Safe Interrupt Handlers** for more details. For these reasons, the functions `itoa`, `memcmp`, `memcpy`, `memset`, `strcat`, `strcmp`, and `strlen` are always put in IRAM.

---

**Note:** Moving frequently-called functions from IRAM to flash may increase their execution time.

**Note:** Other configuration options exist that will increase IRAM usage by moving some functionality into IRAM, usually for performance, but the default option is not to do this. These are not listed here. The IRAM size impact of enabling these options is usually noted in the configuration item help text.

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### 4.25 RF calibration

ESP32 supports three RF calibration methods during RF initialization:

1. Partial calibration
2. Full calibration
3. No calibration

#### 4.25.1 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`.

#### 4.25.2 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.

### 4.25.3 No calibration

No calibration method is only used when the device wakes up from deep sleep.

### 4.25.4 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/esp32/include/phy_init_data.h`. It is embedded into the application binary after compiling and then stored into read-only memory (DROM). To use the default initialization data, please go to `menuconfig` and disable `CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION`.

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`.

### 4.26 Secure Boot

**Important:** All references in this document are related to Secure Boot V1 (The AES based Secure Boot Scheme). ESP32 Revision 3 onwards, the preferred secure boot scheme is **Secure Boot V2**. Please refer to Secure Boot V2 document for ESP32 Revision 3 or ESP32-S2.

Secure Boot is a feature for ensuring only your code can run on the chip. Data loaded from flash is verified on each reset.

Secure Boot is separate from the **Flash Encryption** feature, and you can use secure boot without encrypting the flash contents. However, for a secure environment both should be used simultaneously. See **Secure Boot & Flash Encryption** for more details.

**Important:** Enabling secure boot limits your options for further updates of your ESP32. Make sure to read this document throughly and understand the implications of enabling secure boot.
4.26.1 Background

- Most data is stored in flash. Flash access does not need to be protected from physical access in order for secure boot to function, because critical data is stored (non-software-accessible) in Efuses internal to the chip.
- Efuses are used to store the secure bootloader key (in efuse BLOCK2), and also a single Efuse bit (ABS_DONE_0) is burned (written to 1) to permanently enable secure boot on the chip. For more details on Efuses, see ESP32 Technical Reference Manual > eFuse Controller (eFuse) [PDF].
- To understand the secure boot process, first familiarise yourself with the standard ESP-IDF boot process.
- Both stages of the boot process (initial software bootloader load, and subsequent partition & app loading) are verified by the secure boot process, in a “chain of trust” relationship.

4.26.2 Secure Boot Process Overview

This is a high level overview of the secure boot process. Step by step instructions are supplied under How To Enable Secure Boot. Further in-depth details are supplied under Technical Details:

1. The options to enable secure boot are provided in the Project Configuration Menu, under “Secure Boot Configuration”.
2. Secure Boot defaults to signing images and partition table data during the build process. The “Secure boot private signing key” config item is a file path to a ECDSA public/private key pair in a PEM format file.
3. The software bootloader image is built by esp-idf with secure boot support enabled and the public key (signature verification) portion of the secure boot signing key compiled in. This software bootloader image is flashed at offset 0x1000.
4. On first boot, the software bootloader follows the following process to enable secure boot:
   - Hardware secure boot support generates a device secure bootloader key (generated via hardware RNG, then stored read/write protected in efuse), and a secure digest. The digest is derived from the key, an IV, and the bootloader image contents.
   - The secure digest is flashed at offset 0x0 in the flash.
   - Depending on Secure Boot Configuration, efuses are burned to disable JTAG and the ROM BASIC interpreter (it is strongly recommended these options are turned on.)
   - Bootloader permanently enables secure boot by burning the ABS_DONE_0 efuse. The software bootloader then becomes protected (the chip will only boot a bootloader image if the digest matches.)
5. On subsequent boots the ROM bootloader sees that the secure boot efuse is burned, reads the saved digest at 0x0 and uses hardware secure boot support to compare it with a newly calculated digest. If the digest does not match then booting will not continue. The digest and comparison are performed entirely by hardware, and the calculated digest is not readable by software. For technical details see Secure Boot Hardware Support.
6. When running in secure boot mode, the software bootloader uses the secure boot signing key (the public key of which is embedded in the bootloader itself, and therefore validated as part of the bootloader) to verify the signature appended to all subsequent partition tables and app images before they are booted.

4.26.3 Keys

The following keys are used by the secure boot process:

- “secure bootloader key” is a 256-bit AES key that is stored in Efuse block 2. The bootloader can generate this key itself from the internal hardware random number generator, the user does not need to supply it (it is optionally possible to supply this key, see Re-Flashable Software Bootloader). The Efuse holding this key is read & write protected (preventing software access) before secure boot is enabled.
  - By default, the Efuse Block 2 Coding Scheme is “None” and a 256 bit key is stored in this block. On some ESP32s, the Coding Scheme is set to 3/4 Encoding (CODING_SCHEME efuse has value 1) and a 192 bit key must be stored in this block.
For more details, see ESP32 Technical Reference Manual > eFuse Controller (eFuse) > System Parameter coding_scheme [PDF].
The algorithm operates on a 256 bit key in all cases, 192 bit keys are extended by repeating some bits (details).
- “secure boot signing key” is a standard ECDSA public/private key pair (see Image Signing Algorithm) in PEM format.
Chapter 4. API Guides

- The public key from this key pair (for signature verification but not signature creation) is compiled into the software bootloader and used to verify the second stage of booting (partition table, app image) before booting continues. The public key can be freely distributed, it does not need to be kept secret.
- The private key from this key pair must be securely kept private, as anyone who has this key can authenticate to any bootloader that is configured with secure boot and the matching public key.

4.26.4 Bootloader Size

Enabling Secure boot and/or flash encryption will increase the size of bootloader, which might require updating partition table offset. See Bootstrap Size.

4.26.5 How To Enable Secure Boot

1. Open the Project Configuration Menu, navigate to “Secure Boot Configuration” and select the option “One-time Flash”. (To understand the alternative “Reflashable” choice, see Re-Flashable Software Bootloader.)
2. Select a name for the secure boot signing key. This option will appear after secure boot is enabled. The file can be anywhere on your system. A relative path will be evaluated from the project directory. The file does not need to exist yet.
3. Set other menuconfig options (as desired). Pay particular attention to the “Bootloader Config” options, as you can only flash the bootloader once. Then exit menuconfig and save your configuration.
4. The first time you run make, if the signing key is not found then an error message will be printed with a command to generate a signing key via espsecure.py generate_signing_key.

**Important:** A signing key generated this way will use the best random number source available to the OS and its Python installation (/dev/urandom on OS X/Linux and CryptGenRandom() on Windows). If this random number source is weak, then the private key will be weak.

**Important:** For production environments, we recommend generating the keypair using openssl or another industry standard encryption program. See Generating Secure Boot Signing Key for more details.

5. Run idf.py bootloader to build a secure boot enabled bootloader. The build output will include a prompt for a flashing command, using esptool.py write.flash.
6. When you’re ready to flash the bootloader, run the specified command (you have to enter it yourself, this step is not performed by make) and then wait for flashing to complete. **Remember this is a one time flash, you can’t change the bootloader after this!**
7. Run idf.py flash to build and flash the partition table and the just-built app image. The app image will be signed using the signing key you generated in step 4.

**Note:** idf.py flash doesn’t flash the bootloader if secure boot is enabled.

8. Reset the ESP32 and it will boot the software bootloader you flashed. The software bootloader will enable secure boot on the chip, and then it verifies the app image signature and boots the app. You should watch the serial console output from the ESP32 to verify that secure boot is enabled and no errors have occurred due to the build configuration.

**Note:** Secure boot won’t be enabled until after a valid partition table and app image have been flashed. This is to prevent accidents before the system is fully configured.

**Note:** If the ESP32 is reset or powered down during the first boot, it will start the process again on the next boot.
9. On subsequent boots, the secure boot hardware will verify the software bootloader has not changed (using the secure bootloader key) and then the software bootloader will verify the signed partition table and app image (using the public key portion of the secure boot signing key).

### 4.26.6 Re-Flashable Software Bootloader

Configuration “Secure Boot: One-Time Flash” is the recommended configuration for production devices. In this mode, each device gets a unique key that is never stored outside the device.

However, an alternative mode Secure Boot: Reflashable is also available. This mode allows you to supply a binary key file that is used for the secure bootloader key. As you have the key file, you can generate new bootloader images and secure boot digests for them.

In the esp-idf build process, this 256-bit key file is derived from the ECDSA app signing key generated by the user (see the Generating Secure Boot Signing Key step below). This private key’s SHA-256 digest is used as the secure bootloader key in efuse (as-is for Coding Scheme None, or truncate to 192 bytes for 3/4 Encoding). This is a convenience so you only need to generate/protect a single private key.

**Note:** Although it’s possible, we strongly recommend not generating one secure boot key and flashing it to every device in a production environment. The “One-Time Flash” option is recommended for production environments.

To enable a reflashable bootloader:

1. In the Project Configuration Menu, select “Bootloader Config” -> CONFIG_SECURE_BOOT -> CONFIG_SECURE_BOOT_V1_ENABLED -> CONFIG_SECURE_BOOTLOADER_MODE -> Reflashable.
2. If necessary, set the CONFIG_SECURE_BOOTLOADER_KEY_ENCODING based on the coding scheme used by the device. The coding scheme is shown in the Features line when esptool.py connects to the chip, or in the espfuse.py summary output.
3. Follow the steps shown above to choose a signing key file, and generate the key file.
4. Run idf.py bootloader. A binary key file will be created, derived from the private key that is used for signing. Two sets of flashing steps will be printed - the first set of steps includes an espfuse.py burn_key secure_boot_v1 path_to/secure-bootloader-key-xxx.bin command which is used to write the bootloader key to efuse. (Flashing this key is a one-time-only process.) The second set of steps can be used to reflash the bootloader with a pre-calculated digest (generated during the build process).
5. Resume from Step 6 of the one-time flashing process, to flash the bootloader and enable secure boot. Watch the console log output closely to ensure there were no errors in the secure boot configuration.

### 4.26.7 Generating Secure Boot Signing Key

The build system will prompt you with a command to generate a new signing key via espsecure.py generate_signing_key. This uses the python-ecdsa library, which in turn uses Python’s os.urandom() as a random number source.

The strength of the signing key is proportional to (a) the random number source of the system, and (b) the correctness of the algorithm used. For production devices, we recommend generating signing keys from a system with a quality entropy source, and using the best available EC key generation utilities.

For example, to generate a signing key using the openssl command line:

```
` openssl ecparam -name prime256v1 -genkey -noout -out my_secure_boot_signing_key.pem`
```

Remember that the strength of the secure boot system depends on keeping the signing key private.
4.26.8 Remote Signing of Images

For production builds, it can be good practice to use a remote signing server rather than have the signing key on the build machine (which is the default esp-idf secure boot configuration). The espsecure.py command line program can be used to sign app images & partition table data for secure boot, on a remote system.

To use remote signing, disable the option “Sign binaries during build”. The private signing key does not need to be present on the build system. However, the public (signature verification) key is required because it is compiled into the bootloader (and can be used to verify image signatures during OTA updates).

To extract the public key from the private key:

```
$ espsecure.py extract_public_key --keyfile PRIVATE_SIGNING_KEY PUBLIC_VERIFICATION_KEY
```

The path to the public signature verification key needs to be specified in the menuconfig under “Secure boot public signature verification key” in order to build the secure bootloader.

After the app image and partition table are built, the build system will print signing steps using espsecure.py:

```
$ espsecure.py sign_data --keyfile PRIVATE_SIGNING_KEY BINARY_FILE
```

The above command appends the image signature to the existing binary. You can use the `-output` argument to write the signed binary to a separate file:

```
$ espsecure.py sign_data --keyfile PRIVATE_SIGNING_KEY --output SIGNED_BINARY_FILE
```

4.26.9 Secure Boot Best Practices

- Generate the signing key on a system with a quality source of entropy.
- Keep the signing key private at all times. A leak of this key will compromise the secure boot system.
- Do not allow any third party to observe any aspects of the key generation or signing process using espsecure.py. Both processes are vulnerable to timing or other side-channel attacks.
- Enable all secure boot options in the Secure Boot Configuration. These include flash encryption, disabling of JTAG, disabling BASIC ROM interpreter, and disabling the UART bootloader encrypted flash access.
- Use secure boot in combination with flash encryption to prevent local readout of the flash contents.

4.26.10 Technical Details

The following sections contain low-level reference descriptions of various secure boot elements:

**Secure Boot Hardware Support**

The first stage of secure boot verification (checking the software bootloader) is done via hardware. The ESP32’s Secure Boot support hardware can perform three basic operations:

1. Generate a random sequence of bytes from a hardware random number generator.
2. Generate a digest from data (usually the bootloader image from flash) using a key stored in Efuse block 2. The key in Efuse can (& should) be read/write protected, which prevents software access. For full details of this algorithm see Secure Bootloader Digest Algorithm. The digest can only be read back by software if Efuse ABS_DONE_0 is not burned (ie still 0).
3. Generate a digest from data (usually the bootloader image from flash) using the same algorithm as step 2 and compare it to a pre-calculated digest supplied in a buffer (usually read from flash offset 0x0). The hardware returns a true/false comparison without making the digest available to software. This function is available even when Efuse ABS_DONE_0 is burned.
Secure Bootloader Digest Algorithm

Starting with an “image” of binary data as input, this algorithm generates a digest as output. The digest is sometimes referred to as an “abstract” in hardware documentation.

For a Python version of this algorithm, see the espsecure.py tool in the components/esptool_py directory (specifically, the digest_secure_bootloader command).

Items marked with (*) are to fulfill hardware restrictions, as opposed to cryptographic restrictions.

1. Read the AES key from efuse block 2, in reversed byte order. If Coding Scheme is set to 3/4 Encoding, extend the 192 bit key to 256 bits using the same algorithm described in Flash Encryption Algorithm.
2. Prefix the image with a 128 byte randomly generated IV.
3. If the image length is not modulo 128, pad the image to a 128 byte boundary with 0xFF. (*)
4. For each 16 byte plaintext block of the input image:
   - Reverse the byte order of the plaintext input block (*)
   - Apply AES256 in ECB mode to the plaintext block.
   - Reverse the byte order of the ciphertext output block. (*)
   - Append to the overall ciphertext output.
5. Byte-swap each 4 byte word of the ciphertext (*)
6. Calculate SHA-512 of the ciphertext.

Output digest is 192 bytes of data: The 128 byte IV, followed by the 64 byte SHA-512 digest.

Image Signing Algorithm

Deterministic ECDSA as specified by RFC 6979.

- Curve is NIST256p (openssl calls this curve “prime256v1”, it is also sometimes called secp256r1).
- Hash function is SHA256.
- Key format used for storage is PEM.
  - In the bootloader, the public key (for signature verification) is flashed as 64 raw bytes.
- Image signature is 68 bytes - a 4 byte version word (currently zero), followed by a 64 bytes of signature data. These 68 bytes are appended to an app image or partition table data.

Manual Commands

Secure boot is integrated into the esp-idf build system, so make will automatically sign an app image if secure boot is enabled. idf.py bootloader will produce a bootloader digest if menuconfig is configured for it.

However, it is possible to use the espsecure.py tool to make standalone signatures and digests.

To sign a binary image:

```
espsecure.py sign_data --keyfile ./my_signing_key.pem --output ./image_signed.bin
```

Keyfile is the PEM file containing an ECDSA private signing key.

To generate a bootloader digest:

```
espsecure.py digest_secure_bootloader --keyfile ./securebootkey.bin --output ./bootloader-digest.bin build/bootloader/bootloader.bin
```

Keyfile is the 32 byte raw secure boot key for the device.

The output of the espsecure.py digest_secure_bootloader command is a single file which contains both the digest and the bootloader appended to it. To flash the combined digest plus bootloader to the device:

```
esptool.py write_flash 0x0 bootloader-digest.bin
```
4.26.11 Secure Boot & Flash Encryption

If secure boot is used without Flash Encryption, it is possible to launch “time-of-check to time-of-use” attack, where flash contents are swapped after the image is verified and running. Therefore, it is recommended to use both the features together.

4.26.12 Signed App Verification Without Hardware Secure Boot

The integrity of apps can be checked even without enabling the hardware secure boot option. This option uses the same app signature scheme as hardware secure boot, but unlike hardware secure boot it does not prevent the bootloader from being physically updated. This means that the device can be secured against remote network access, but not physical access. Compared to using hardware Secure Boot this option is much simpler to implement. See How To Enable Signed App Verification for step by step instructions.

An app can be verified on update and, optionally, be verified on boot.

- Verification on update: When enabled, the signature is automatically checked whenever the esp_ota_ops.h APIs are used for OTA updates. If hardware secure boot is enabled, this option is always enabled and cannot be disabled. If hardware secure boot is not enabled, this option still adds significant security against network-based attackers by preventing spoofing of OTA updates.
- Verification on boot: When enabled, the bootloader will be compiled with code to verify that an app is signed before booting it. If hardware secure boot is enabled, this option is always enabled and cannot be disabled. If hardware secure boot is not enabled, this option doesn’t add significant security by itself so most users will want to leave it disabled.

How To Enable Signed App Verification

1. Open Project Configuration Menu -> Security features -> Enable CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT
2. “Bootaider verifies app signatures” can be enabled, which verifies app on boot.
3. By default, “Sign binaries during build” will be enabled on selecting “Require signed app images” option, which will sign binary files as a part of build process. The file named in “Secure boot private signing key” will be used to sign the image.
4. If you disable “Sign binaries during build” option then you’ll have to enter path of a public key file used to verify signed images in “Secure boot public signature verification key”. In this case, private signing key should be generated by following instructions in Generating Secure Boot Signing Key; public verification key and signed image should be generated by following instructions in Remote Signing of Images.

4.26.13 Advanced Features

JTAG Debugging

By default, when Secure Boot is enabled then JTAG debugging is disabled via eFuse. The bootloader does this on first boot, at the same time it enables Secure Boot.

See JTAG with Flash Encryption or Secure Boot for more information about using JTAG Debugging with either Secure Boot or signed app verification enabled.

4.27 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.
For ESP32 before ECO3, refer to *Secure Boot*. It is recommended that users use Secure Boot V2 if they have a chip version that supports it. Secure Boot V2 is safer and more flexible than Secure Boot V1.

Secure Boot V2 uses RSA 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.

Secure Boot V2 and RSA scheme (App Signing Scheme) options are available for ESP32 from ECO3 onwards. To use these options in menuconfig, set `CONFIG_ESP32_REV_MIN` greater than or equal to Rev 3.

### 4.27.1 Background

Secure Boot protects a device from running any unauthorized (i.e., unsigned) code by checking that each piece of software that is being booted is signed. On an ESP32, these pieces of software include the second stage bootloader and each application binary. Note that the first stage bootloader does not require signing as it is ROM code thus cannot be changed.

A 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 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.

### 4.27.2 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.
- Only one public key can be generated and stored in the chip during manufacturing.
- Same image format and signature verification method is applied for applications and software bootloader.
- No secrets are stored on the device. Therefore, it is immune to passive side-channel attacks (timing or power analysis, etc.)

### 4.27.3 Secure Boot V2 Process

This is an overview of the Secure Boot V2 Process. Instructions how to enable Secure Boot are supplied in section *How To Enable Secure Boot V2*.

Secure Boot V2 verifies the bootloader image and application binary images using a dedicated signature block. Each image has a separately generated signature block which is appended to the end of the image.

Only one signature block can be appended to the bootloader or application image in ESP32 ECO3.

Each signature block contains a signature of the preceding image as well as the corresponding RSA-3072 public key. For more details about the format, refer to *Signature Block Format*. A digest of the RSA-3072 public key is stored in the eFuse.

The application image is not only verified on every boot but also on each over the air (OTA) update. If the currently selected OTA app image cannot be verified, the bootloader will fall back and look for another correctly signed application image.

The Secure Boot V2 process follows these steps:

1. On startup, the ROM code checks the Secure Boot V2 bit in the eFuse. If Secure Boot is disabled, a normal boot will be executed. If Secure Boot is enabled, the boot will proceed according to the following steps.
2. The ROM code verifies the bootloader’s signature block (*Verifying a Signature Block*). If this fails, the boot process will be aborted.
3. The ROM code verifies the bootloader image using the raw image data, its corresponding signature block(s), and the eFuse (Verifying an Image). If this fails, the boot process will be aborted.

4. The ROM code executes the bootloader.

5. The bootloader verifies the application image’s signature block (Verifying a Signature Block). If this fails, the boot process will be aborted.

6. The bootloader verifies the application image using the raw image data, its corresponding signature blocks and the eFuse (Verifying an Image). If this fails, the boot process will be aborted. If the verification fails but another application image is found, the bootloader will then try to verify that other image using steps 5 to 7. This repeats until a valid image is found or no other images are found.

7. The bootloader executes the verified application image.

4.27.4 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.

4.27.5 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.

4.27.6 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.

### 4.27.7 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.

### 4.27.8 eFuse usage

ESP32-ECO3:

- ABS_DONE_1 - Enables Secure Boot protection on boot.
- BLK2 - Stores the SHA-256 digest of the public key. SHA-256 hash of public key modulus, exponent, pre-calculated R & M values (represented as 776 bytes – offsets 36 to 812 - as per the Signature Block Format) is written to an eFuse key block. The write-protection bit must be set, but the read-protection bit must not.

The key(s) must be readable in order to give software access to it. If the key(s) is read-protected then the software reads the key(s) as all zeros and the signature verification process will fail, and the boot process will be aborted.

### 4.27.9 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. For ESP32, Secure Boot V2 is available only ESP32 ECO3 onwards. To view the “Secure Boot V2” option the chip revision should be changed to revision 3 (ESP32- ECO3). To change the chip revision, set “Minimum Supported ESP32 Revision” to Rev 3 in “Component Config” -> “ESP32- Specific”.

3. Specify the path to Secure Boot signing key, relative to the project directory.

4. Select the desired UART ROM download mode in “UART ROM download mode”. By default the UART ROM download mode has been kept enabled in order to prevent permanently disabling it in the development phase, this option is a potentially insecure option. It is recommended to disable the UART download mode for better security.

5. Set other menuconfig options (as desired). 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.
10. Reset the ESP32 and it will boot the software bootloader you flashed. The software bootloader will enable Secure Boot on the chip, and then it verifies the app image signature and boots the app. You should watch the serial console output from the ESP32 to verify that Secure Boot is enabled and no errors have occurred due to the build configuration.

Note: Secure boot won’t be enabled until after a valid partition table and app image have been flashed. This is to prevent accidents before the system is fully configured.

Note: If the ESP32 is reset or powered down during the first boot, it will start the process again on the next boot.

11. On subsequent boots, the Secure Boot hardware will verify the software bootloader has not changed and the software bootloader will verify the signed app image (using the validated public key portion of its appended signature block).

### 4.27.10 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.

### 4.27.11 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.

### 4.27.12 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:
4.27.13 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.

4.27.14 Technical Details

The following sections contain low-level reference descriptions of various Secure Boot elements:

Manual Commands

Secure boot is integrated into the esp-idf build system, so idf.py build will sign an app image and idf.py bootloader will produce a signed bootloader if secure signed binaries on build is enabled.

However, it is possible to use the espsecure.py tool to make standalone signatures and digests.

To sign a binary image:

```
espsecure.py sign_data --version 2 --keyfile PRIVATE_SIGNING_KEY --output SIGNED_BINARY_FILE BINARY_FILE
```

Keyfile is the PEM file containing an RSA-3072 private signing key.

4.27.15 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.

4.27.16 Signed App Verification Without Hardware Secure Boot

The Secure Boot V2 signature of apps can be checked on OTA update, without enabling the hardware Secure Boot option. This option uses the same app signature scheme as Secure Boot V2, but unlike hardware Secure Boot it does not prevent an attacker who can write to flash from bypassing the signature protection.

This may be desirable in cases where the delay of Secure Boot verification on startup is unacceptable, and/or where the threat model does not include physical access or attackers writing to bootloader or app partitions in flash.

In this mode, the public key which is present in the signature block of the currently running app will be used to verify the signature of a newly updated app. (The signature on the running app isn’t verified during the update process, it’s assumed to be valid.) In this way the system creates a chain of trust from the running app to the newly updated app.

For this reason, it’s essential that the initial app flashed to the device is also signed. A check is run on app startup and the app will abort if no signatures are found. This is to try and prevent a situation where no update is possible. The app should have only one valid signature block in the first position. Note again that, unlike hardware Secure Boot V2, the signature of the running app isn’t verified on boot. The system only verifies a signature block in the first position and ignores any other appended signatures.
Note: In general, it’s recommended to use full hardware Secure Boot unless certain that this option is sufficient for application security needs.

How To Enable Signed App Verification

1. Open Project Configuration Menu -> Security features
2. Ensure App Signing Scheme is RSA. For ESP32 ECO3 chip, select CONFIG_ESP32_REV_MIN to Rev 3 to get RSA option available
3. Enable CONFIG_SECURE_SIGNEDE_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.

4.27.17 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.

4.28 Thread Local Storage

4.28.1 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.

4.28.2 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 than 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.

4.28.3 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.

4.28.4 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.

4.29 Tools

4.29.1 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

`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:

- `dist` — where the archives of the tools are downloaded.
- `tools` — where the tools are extracted. The tools are extracted into subdirectories: `tools/TOOL_NAME/VERSION/`. This arrangement allows different versions of tools to be installed side by side.

GitHub Assets Mirror

Most of the tools downloaded by the tools installer are GitHub Release Assets, which are files attached to a software release on GitHub.

If GitHub downloads are inaccessible or slow to access, it’s possible to configure a GitHub assets mirror.

To use Espressif’s download server, set the environment variable `IDF_GITHUB_ASSETS` to `dl.espressif.com/github_assets`. When the install process is downloading a tool from `github.com`, the URL will be rewritten to use this server instead.

Any mirror server can be used provided the URL matches the `github.com` download URL format: the install process will replace `https://github.com` with `https://${IDF_GITHUB_ASSETS}` for any GitHub asset URL that it downloads.

**Note:** The Espressif download server doesn’t currently mirror everything from GitHub, it only mirrors files attached as Assets to some releases as well as source archives for some releases.

`idf_tools.py` script

`tools/idf_tools.py` script bundled with ESP-IDF performs several functions:

- **install**: Download the tool into `${IDF_TOOLS_PATH}/dist` directory, extract it into `${IDF_TOOLS_PATH}/tools/TOOL_NAME/VERSION`. Install command accepts the list of tools to install, in `TOOL_NAME` or `TOOL_NAME@VERSION` format. If all is given, all the tools (required and optional ones) are installed. If no argument or `required` is given, only the required tools are installed.
- **download**: Similar to `install` but doesn’t extract the tools. An optional `--platform` argument may be used to download the tools for the specific platform.
- **export**: Lists the environment variables which need to be set to use the installed tools. For most of the tools, setting `PATH` environment variable is sufficient, but some tools require extra environment variables. The environment variables can be listed in either of shell or key-value formats, set by `--format` parameter:
  - `shell` produces output suitable for evaluation in the shell. For example,
    ```
    export PATH="/home/user/.espressif/tools/tool/v1.0.0/bin:$PATH"
    ```
    on Linux and macOS, and
Chapter 4. API Guides

```bash
set "PATH=C:\Users\user\.espressif\tools\v1.0.0\bin;%PATH%"
```
on Windows.

**Note:** Exporting environment variables in Powershell format is not supported at the moment. key-value format may be used instead.

The output of this command may be used to update the environment variables, if the shell supports this. For example:

```bash
eval $(IDF_PATH/tools/idf_tools.py export)
```

- key-value produces output in `VARIABLE=VALUE` format, suitable for parsing by other scripts:

```bash
PATH=/home/user/.espressif/tools/tool/v1.0.0:$PATH
```

Note that the script consuming this output has to perform expansion of `$VAR` or `%VAR%` patterns found in the output.

- **list:** Lists the known versions of the tools, and indicates which ones are installed.
- **check:** For each tool, checks whether the tool is available in the system path and in `IDF_TOOLS_PATH`.

### 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

Aside from downloading and installing the tools into `IDF_TOOLS_PATH`, these scripts prepare a Python virtual environment, and install the required packages into that environment.

### 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

**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`.
Chapter 4. API Guides

- **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

<table>
<thead>
<tr>
<th>Platform</th>
<th>Required</th>
<th>Download</th>
</tr>
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<tbody>
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</tr>
</tbody>
</table>

**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
### 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)
## Chapter 4. API Guides

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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

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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 | Required | Download |
|-----------|----------|----------|
| linux-amd64 | required | https://github.com/espressif/binutils-esp32ulp/releases/download/v2.28.51-esp-20191205/binutils-esp32ulp-linux-amd64-2.28.51-esp-20191205.tar.gz  
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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

### Platform | Required | Download |
|-----------|----------|----------|
| linux-amd64 | required | https://github.com/espressif/binutils-esp32ulp/releases/download/v2.28.51-esp-20191205/binutils-esp32s2ulp-linux-amd64-2.28.51-esp-20191205.tar.gz  
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| macos | required | https://github.com/espressif/binutils-esp32ulp/releases/download/v2.28.51-esp-20191205/binutils-esp32s2ulp-macos-2.28.51-esp-20191205.tar.gz  
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**cmake** CMake build system  
On Linux and macOS, it is recommended to install CMake using the OS-specific package manager (like apt, yum, brew, etc.). However, for convenience it is possible to install CMake using idf_tools.py along with the other tools.  
License: BSD-3-Clause  
More info: https://github.com/Kitware/CMake
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openocd-esp32  OpenOCD for ESP32  
License: GPL-2.0-only  
More info: https://github.com/espressif/openocd-esp32

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ninja  Ninja build system  
On Linux and macOS, it is recommended to install ninja using the OS-specific package manager (like apt, yum, brew, etc.). However, for convenience it is possible to install ninja using idf_tools.py along with the other tools.  
License: Apache-2.0  
More info: https://github.com/ninja-build/ninja
### 4.29.2 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 3.6 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.

---

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**idf-exe**  IDF wrapper tool for Windows

License: Apache-2.0

More info: [https://github.com/espressif/idf_py_exe_tool](https://github.com/espressif/idf_py_exe_tool)

**ccache**  Ccache (compiler cache)

License: GPL-3.0-or-later

More info: [https://github.com/ccache/ccache](https://github.com/ccache/ccache)

**dfu-util**  dfu-util (Device Firmware Upgrade Utilities)

License: GPL-2.0-only

Chapter 4. API Guides

The image entrypoint sets up PATH environment variable to point to the correct version of tools, and activates the Python virtual environment. As a result, the environment is ready to use the ESP-IDF build system.

The image can also be used as a base for custom images, if additional utilities are required.

**Tags**

Multiple tags of this image are maintained:

- **latest**: tracks master branch of ESP-IDF
- **vX.Y**: corresponds to ESP-IDF release vX.Y
- **release-vX.Y**: tracks release/vX.Y branch of ESP-IDF

**Note:** Versions of ESP-IDF released before this feature was introduced do not have corresponding Docker image versions. You can check the up-to-date list of available tags at https://hub.docker.com/r/espressif/idf/tags.

**Usage**

**Setting up Docker** Before using the espressif/idf Docker image locally, make sure you have Docker installed. Follow the instructions at https://docs.docker.com/install/, if it is not installed yet.

If using the image in CI environment, consult the documentation of your CI service on how to specify the image used for the build process.

**Building a project with CMake** In the project directory, run:

```
docker run --rm -v $PWD:/project -w /project espressif/idf idf.py build
```

The above command explained:

- `docker run`: runs a Docker image. It is a shorter form of the command `docker container run`.
- `--rm`: removes the container when the build is finished
- `-v $PWD:/project`: mounts the current directory on the host ($PWD) as /project directory in the container
- `espressif/idf`: uses Docker image espressif/idf with tag latest (implicitly added by Docker when no tag is specified)
- `idf.py build`: runs this command inside the container

To build with a specific docker image tag, specify it as `espressif/idf:TAG`, for example:

```
docker run --rm -v $PWD:/project -w /project espressif/idf:release-v4.0 idf.py -b
```

You can check the up-to-date list of available tags at https://hub.docker.com/r/espressif/idf/tags.

**Using the image interactively** It is also possible to do builds interactively, to debug build issues or test the automated build scripts. Start the container with `-i -t` flags:

```
docker run --rm -v $PWD:/project -w /project -it espressif/idf
```

Then inside the container, use `idf.py` as usual:

```
idf.py menuconfig
idf.py build
```
**Note:** Commands which communicate with the development board, such as `idf.py flash` and `idf.py monitor` will not work in the container unless the serial port is passed through into the container. However currently this is not possible with Docker for Windows ([https://github.com/docker/for-win/issues/1018](https://github.com/docker/for-win/issues/1018)) and Docker for Mac ([https://github.com/docker/for-mac/issues/900](https://github.com/docker/for-mac/issues/900)).

### 4.29.3 IDF Windows Installer

#### Command-line parameters

Windows Installer `esp-idf-tools-setup` provides the following command-line parameters:

- `/CONFIG=[PATH]` - Path to ini configuration file to override default configuration of the installer. Default: `config.ini`.
- `/HELP` - Display command line options provided by Inno Setup installer.
- `/IDFDIR=[PATH]` - Path to directory where it will be installed. Default: `{userdesktop}\esp-idf`.
- `/OFFLINE=[yes|no]` - Execute installation of Python packages by PIP in offline mode. The same result can be achieved by setting the environment variable PIP_NO_INDEX. Default: no.
- `/PYTHONNOUSERSITE=[yes|no]` - Set PYTHONNOUSERSITE variable before launching any Python command to avoid loading Python packages from AppDataRoaming. Default: yes.
- `/PYTHONWHEELSURL=[URL]` - Specify URLs to PyPi repositories for resolving binary Python Wheel dependencies. The same result can be achieved by setting the environment variable PIP_EXTRA_INDEX_URL. Default: [https://dl.espressif.com/pypi](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.
Chapter 4. API Guides

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/
```

### 4.29.4 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:
  example/cmp: ">=1.0.0"

  # # Other ways to define dependencies
```

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4.29.5 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 py clang` 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](https://github.com/llvm/llvm-project) 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`.

### 4.30 ULP Coprocessor programming

#### 4.30.1 ESP32 ULP coprocessor instruction set

This document provides details about the instructions used by ESP32 ULP coprocessor assembler.

ULP coprocessor has 4 16-bit general purpose registers, labeled R0, R1, R2, R3. It also has an 8-bit counter register (stage_cnt) which can be used to implement loops. Stage count register is accessed using special instructions.

ULP coprocessor can access 8k bytes of RTC_SLOW_MEM memory region. Memory is addressed in 32-bit word units. It can also access peripheral registers in RTC_CNTL, RTC_IO, and SENS peripherals.

All instructions are 32-bit. Jump instructions, ALU instructions, peripheral register and memory access instructions are executed in 1 cycle. Instructions which work with peripherals (TSENS, ADC, I2C) take variable number of cycles, depending on peripheral operation.

The instruction syntax is case insensitive. Upper and lower case letters can be used and intermixed arbitrarily. This is true both for register names and instruction names.

**Note about addressing**

ESP32 ULP coprocessor’s JUMP, ST, LD instructions which take register as an argument (jump address, store/load base address) expect the argument to be expressed in 32-bit words.

Consider the following example program:

```
entry:
   NOP
   NOP
   NOP
loop:
   MOVE R1, loop
   JUMP R1
```

When this program is assembled and linked, address of label `loop` will be equal to 16 (expressed in bytes). However `JUMP` instruction expects the address stored in register to be expressed in 32-bit words. To account for this common use case, assembler will convert the address of label `loop` from bytes to words, when generating `MOVE` instruction, so the code generated code will be equivalent to:
The other case is when the argument of MOVE instruction is not a label but a constant. In this case assembler will use the value as is, without any conversion:

```assembly
.set val, 0x10
MOVE R1, val
```

In this case, value loaded into R1 will be 0x10.

Similar considerations apply to LD and ST instructions. Consider the following code:

```assembly
.global array
array: .long 0
.long 0
.long 0
.long 0
MOVE R1, array
MOVE R2, 0x1234
ST R2, R1, 0 // write value of R2 into the first array element,
              // i.e. array[0]
ST R2, R1, 4 // write value of R2 into the second array element
              // {4 byte offset}, i.e. array[1]
ADD R1, R1, 2 // this increments address by 2 words (8 bytes)
ST R2, R1, 0 // write value of R2 into the third array element,
              // i.e. array[2]
```

**Note about instruction execution time**

ULP coprocessor is clocked from RTC_FAST_CLK, which is normally derived from the internal 8MHz oscillator. Applications which need to know exact ULP clock frequency can calibrate it against the main XTAL clock:

```c
#include "soc/rtc.h"

// calibrate 8M/256 clock against XTAL, get 8M/256 clock period
uint32_t rtc_8md256_period = rtc_clk_cal(RTC_CAL_8MD256, 100);
uint32_t rtc_fast_freq_hz = 1000000ULL * (1 << RTC_CLK_CAL_FRACT) * 256 / rtc_
                          _8md256_period;
```

ULP coprocessor needs certain number of clock cycles to fetch each instruction, plus certain number of cycles to execute it, depending on the instruction. See description of each instruction below for details on the execution time.

Instruction fetch time is:

- 2 clock cycles — for instructions following ALU and branch instructions.
- 4 clock cycles — in other cases.

Note that when accessing RTC memories and RTC registers, ULP coprocessor has lower priority than the main CPUs. This means that ULP coprocessor execution may be suspended while the main CPUs access same memory region as the ULP.
NOP - no operation

Syntax  NOP
Operands  None
Cycles  2 cycle to execute, 4 cycles to fetch next instruction
Description  No operation is performed. Only the PC is incremented.

Example:

1:  NOP

ADD - Add to register

Syntax  ADD Rdst, Rsrl, Rsr2
        ADD Rdst, Rsrl, imm

Operands
  •  Rdst - Register R[0..3]
  •  Rsrl - Register R[0..3]
  •  Rsr2 - Register R[0..3]
  •  Imm - 16-bit signed value

Cycles  2 cycles to execute, 4 cycles to fetch next instruction
Description  The instruction adds source register to another source register or to a 16-bit signed value and stores result to the destination register.

Examples:

1:  ADD R1, R2, R3     //R1 = R2 + R3
2:  Add R1, R2, 0x1234 //R1 = R2 + 0x1234
3:  .set value1, 0x03   //constant value1=0x03
    Add R1, R2, value1  //R1 = R2 + value1
4:  .global label      //declaration of variable label
    Add R1, R2, label   //R1 = R2 + label
    ...                 
    label: nop          //definition of variable label

SUB - Subtract from register

Syntax  SUB Rdst, Rsrl, Rsr2
        SUB Rdst, Rsrl, imm

Operands
  •  Rdst - Register R[0..3]
  •  Rsrl - Register R[0..3]
  •  Rsr2 - Register R[0..3]
  •  Imm - 16-bit signed value

Cycles  2 cycles to execute, 4 cycles to fetch next instruction
Description  The instruction subtracts the source register from another source register or subtracts 16-bit signed value from a source register, and stores result to the destination register.

Examples:

1:  SUB R1, R2, R3     //R1 = R2 - R3
2:  sub R1, R2, 0x1234 //R1 = R2 - 0x1234

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Chapter 4. API Guides

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3: .set value1, 0x03 //constant value1=0x03
   SUB R1, R2, value1 //R1 - R2 - value1
4: .global label //declaration of variable label
   SUB R1, R2, label //R1 - R2 - label

label:  nop //definition of variable label

AND - Logical AND of two operands

Syntax AND Rdst, Rsrc1, Rsrc2
   AND Rdst, Rsrc1, imm

Operands
• Rdst - Register R[0..3]
• Rsrc1 - Register R[0..3]
• Rsrc2 - Register R[0..3]
• Imm - 16-bit signed value

Cycles 2 cycles to execute, 4 cycles to fetch next instruction

Description The instruction does logical AND of a source register and another source register or 16-bit signed value and stores result to the destination register.

Examples:

1: AND R1, R2, R3 //R1 - R2 \& R3
2: AND R1, R2, 0x1234 //R1 - R2 \& 0x1234
3: .set value1, 0x03 //constant value1=0x03
   AND R1, R2, value1 //R1 - R2 \& value1
4: .global label //declaration of variable label
   AND R1, R2, label //R1 - R2 \& label

label:  nop //definition of variable label

OR - Logical OR of two operands

Syntax OR Rdst, Rsrc1, Rsrc2
   OR Rdst, Rsrc1, imm

Operands
• Rdst - Register R[0..3]
• Rsrc1 - Register R[0..3]
• Rsrc2 - Register R[0..3]
• Imm - 16-bit signed value

Cycles 2 cycles to execute, 4 cycles to fetch next instruction

Description The instruction does logical OR of a source register and another source register or 16-bit signed value and stores result to the destination register.

Examples:

1: OR R1, R2, R3 //R1 = R2 \| R3
2: OR R1, R2, 0x1234 //R1 = R2 \| 0x1234
3: .set value1, 0x03 //constant value1=0x03
   OR R1, R2, value1 //R1 = R2 \| value1
4: .global label //declaration of variable label

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LSH - Logical Shift Left

**Syntax**  
LSH $Rdst$, $Rsrc1$, $Rsrc2$  
LSH $Rdst$, $Rsrc1$, imm

**Operands**
- $Rdst$ - Register $R[0..3]$  
- $Rsrc1$ - Register $R[0..3]$  
- $Rsrc2$ - Register $R[0..3]$  
- $Imm$ - 16-bit signed value

**Cycles**  
2 cycles to execute, 4 cycles to fetch next instruction

**Description**  
The instruction does logical shift to left of source register to number of bits from another source register or 16-bit signed value and store result to the destination register.

**Examples:**

1:  
LSH R1, R2, R3  // R1 = R2 << R3

2:  
LSH R1, R2, 0x03 // R1 = R2 << 0x03

3:  
.set value1, 0x03 // constant value1=0x03  
LSH R1, R2, value1 // R1 = R2 << value1

4:  
.global label // declaration of variable label  
LSH R1, R2, label // R1 = R2 << label

label: nop // definition of variable label

RSH - Logical Shift Right

**Syntax**  
RSH $Rdst$, $Rsrc1$, $Rsrc2$  
RSH $Rdst$, $Rsrc1$, imm

**Operands**
- $Rdst$ - Register $R[0..3]$  
- $Rsrc1$ - Register $R[0..3]$  
- $Rsrc2$ - Register $R[0..3]$  
- $Imm$ - 16-bit signed value

**Cycles**  
2 cycles to execute, 4 cycles to fetch next instruction

**Description**  
The instruction does logical shift to right of source register to number of bits from another source register or 16-bit signed value and store result to the destination register.

**Examples:**

1:  
RSH R1, R2, R3 // R1 = R2 >> R3

2:  
RSH R1, R2, 0x03 // R1 = R2 >> 0x03

3:  
.set value1, 0x03 // constant value1=0x03  
RSH R1, R2, value1 // R1 = R2 >> value1

4:  
.global label // declaration of variable label  
RSH R1, R2, label // R1 = R2 >> label

label: nop // definition of variable label

MOVE – Move to register

**Syntax**  
MOVE $Rdst$, $Rsrc$  
MOVE $Rdst$, imm
Chapter 4. API Guides

Operands

• \textit{Rdst} – Register R[0..3]
• \textit{Rsrc} – Register R[0..3]
• \textit{Imm} – 16-bit signed value

Cycles 2 cycles to execute, 4 cycles to fetch next instruction

Description The instruction move to destination register value from source register or 16-bit signed value.

Note that when a label is used as an immediate, the address of the label will be converted from bytes to words. This is because LD, ST, and JUMP instructions expect the address register value to be expressed in words rather than bytes. To avoid using an extra instruction

Examples:

1: \texttt{MOVE R1, R2} //R1 = R2
2: \texttt{MOVE R1, 0x03} //R1 = 0x03
3: \texttt{.set value1, 0x03} //constant value1=0x03
   \texttt{MOVE R1, value1} //R1 = value1
4: \texttt{.global label} //declaration of label
   \texttt{MOVE R1, label} //R1 = address_of(label) / 4
   ...
   \texttt{label: nop} //definition of label

ST –Store data to the memory

Syntax \texttt{ST Rsrc, Rdst, offset}

Operands

• \textit{Rsrc} – Register R[0..3], holds the 16-bit value to store
• \textit{Rdst} – Register R[0..3], address of the destination, in 32-bit words
• \textit{Offset} – 13-bit signed value, offset in bytes

Cycles 4 cycles to execute, 4 cycles to fetch next instruction

Description The instruction stores the 16-bit value of \textit{Rsrc} to the lower half-word of memory with address \textit{Rdst}+offset. The upper half-word is written with the current program counter (PC) (expressed in words, shifted left by 5 bits) OR’ed with \textit{Rdst} (0..3):

\[
\text{Mem[\textit{Rdst} + \textit{offset} / 4]31:0} = \text{\(\{\text{PC}[10:0], 3'b0, \textit{Rdst}, \textit{Rsrc}[15:0]\}\)}
\]

The application can use higher 16 bits to determine which instruction in the ULP program has written any particular word into memory.

Examples:

1: \texttt{ST R1, R2, 0x12} //MEM[R2+0x12] = R1
2: \texttt{.data} //Data section definition
   \texttt{Addr1: .word 123} // Define label Addr1 16 bit
   \texttt{.set offs, 0x00} // Define constant offs
   \texttt{.text} //Text section definition
   \texttt{MOVE R1, 1} // R1 = 1
   \texttt{MOVE R2, Addr1} // R2 = Addr1
   \texttt{ST R1, R2, offs} // MEM[R2 + 0] = R1
   // MEM[Addr1 + 0] will be 32'h600001

LD –Load data from the memory

Syntax \texttt{LD Rdst, Rsrc, offset}

Operands \textit{Rdst} – Register R[0..3], destination

\textit{Rsrc} – Register R[0..3], holds address of destination, in 32-bit words

\textit{Offset} – 13-bit signed value, offset in bytes
Chapter 4. API Guides

Cycles 4 cycles to execute, 4 cycles to fetch next instruction

Description The instruction loads lower 16-bit half-word from memory with address Rsrrc+offset into the destination register Rdst:

$$Rdst[15:0] = \text{Mem}[Rsrc + \text{offset} / 4][15:0]$$

Examples:

1: \text{LD } R1, R2, 0x12 \quad // R1 = \text{MEM}[R2+0x12]

2: \text{.data} \quad // \text{Data section definition}
\text{Addr1: \ .word} 123 \quad // \text{Define label Addr1 16 bit}
\text{.set} \quad \text{offs, 0x00} \quad // \text{Define constant offs}
\text{.text} \quad // \text{Text section definition}
\text{MOVE} \quad R1, 1 \quad // \text{R1 = 1}
\text{MOVE} \quad R2, \text{Addr1} \quad // \text{R2 = Addr1 / 4} \quad \text{(address of label is... converted into words)}
\text{LD} \quad R1, R2, \text{offs} \quad // \text{R1 = MEM[R2 + 0]}
\quad // \text{R1 will be 123}

JUMP – Jump to an absolute address

Syntax \text{JUMP } Rdst
\quad \text{JUMP } \text{ImmAddr}
\quad \text{JUMP } Rdst, \text{Condition}
\quad \text{JUMP } \text{ImmAddr, Condition}

Operands

- \textit{Rdst} – Register R[0..3] containing address to jump to (expressed in 32-bit words)
- \textit{ImmAddr} – 13 bits address (expressed in bytes), aligned to 4 bytes
- \textit{Condition}:
  - \textit{EQ} – jump if last ALU operation result was zero
  - \textit{OV} – jump if last ALU has set overflow flag

Cycles 2 cycles to execute, 2 cycles to fetch next instruction

Description The instruction makes jump to the specified address. Jump can be either unconditional or based on an ALU flag.

Examples:

1: \text{JUMP } R1 \quad // \text{Jump to address in R1 (address in R1 is in... 32-bit words) }

2: \text{JUMP } 0x120, \text{EQ} \quad // \text{Jump to address 0x120 (in bytes) if ALU result is zero}

3: \text{JUMP } \text{label} \quad // \text{Jump to label}
\quad ... \quad \text{label: nop} \quad // \text{Definition of label}

4: \text{.global} \quad \text{label} \quad // \text{Declaration of global label}
\quad \text{MOVE} \quad R1, \text{label} \quad // \text{R1 = label (value loaded into R1 is in words)}
\quad \text{JUMP} \quad R1 \quad // \text{Jump to label}
\quad ... \quad \text{label: nop} \quad // \text{Definition of label}

JUMPR – Jump to a relative offset (condition based on R0)

Syntax \text{JUMPR } \text{Step, Threshold, Condition}

Operands

Espressif Systems 2015

Release v5.0-dev-1077-g397639d

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• **Step** – relative shift from current position, in bytes
• **Threshold** – threshold value for branch condition
• **Condition:**
  - **EQ** (equal) – jump if value in R0 == threshold
  - **LT** (less than) – jump if value in R0 < threshold
  - **LE** (less or equal) – jump if value in R0 <= threshold
  - **GT** (greater than) – jump if value in R0 > threshold
  - **GE** (greater or equal) – jump if value in R0 >= threshold

**Cycles** Conditions **LT**, **GE**, **LE** and **GT**: 2 cycles to execute, 2 cycles to fetch next instruction

**Conditions** **LE** and **GT** are implemented in the assembler using one **JUMPR** instructions:

```c
// JUMPR target, threshold, GT is implemented as:
JUMPR target, threshold+1, GE
```

**Conditions** **EQ** is implemented in the assembler using two **JUMPR** instructions:

```c
// JUMPR target, threshold, EQ is implemented as:
JUMPR next, threshold + 1, GE
JUMPR target, threshold, GE
```

Therefore the execution time will depend on the branches taken: either 2 cycles to execute + 2 cycles to fetch, or 4 cycles to execute + 4 cycles to fetch.

**Description** The instruction makes a jump to a relative address if condition is true. Condition is the result of comparison of R0 register value and the threshold value.

**Examples:**

```
1: pos: JUMPR 16, 20, GE // Jump to address (position + 16 bytes) if value in R0 >= 20
```

2: // Down counting loop using R0 register

```c
MOVE R0, 16 // load 16 into R0
label: SUB R0, R0, 1 // R0--
NOP // do something
JUMPR label, 1, GE // jump to label if R0 >= 1
```

**JUMPS** – Jump to a relative address (condition based on stage count)

**Syntax** **JUMPS** **Step**, **Threshold**, **Condition**

**Operands**

- **Step** – relative shift from current position, in bytes
- **Threshold** – threshold value for branch condition

- **Condition:**
  - **EQ** (equal) – jump if value in stage_cnt == threshold
  - **LT** (less than) – jump if value in stage_cnt < threshold
  - **LE** (less or equal) – jump if value in stage_cnt <= threshold
  - **GT** (greater than) – jump if value in stage_cnt > threshold
  - **GE** (greater or equal) – jump if value in stage_cnt >= threshold

**Cycles** Conditions **LE**, **LT**, **GE**: 2 cycles to execute, 2 cycles to fetch next instruction

**Conditions** **EQ**, **GT** are implemented in the assembler using two **JUMPS** instructions:

```c
// JUMPS target, threshold, EQ is implemented as:
```

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**JUMPS** next, threshold, LT
JUMPS target, threshold, LE

*next:*

// JUMPS target, threshold, GT is implemented as:

JUMPS next, threshold, LE
JUMPS target, threshold, GE

*next:*

Therefore the execution time will depend on the branches taken: either 2 cycles to execute + 2 cycles to fetch, or 4 cycles to execute + 4 cycles to fetch.

**Description** The instruction makes a jump to a relative address if condition is true. Condition is the result of comparison of count register value and threshold value.

**Examples:**

1:pos:  JUMPS  16, 20, EQ  // Jump to (position + 16 bytes) if stage_cnt_<-- 20

2: // Up counting loop using stage count register
STAGE_RST  // set stage_cnt to 0
label: STAGE_INC 1  // stage_cnt++
NOP  // do something
JUMPS label, 16, LT  // jump to label if stage_cnt < 16

**STAGE_RST** – Reset stage count register

**Syntax** STAGE_RST

**Operands** No operands

**Description** The instruction sets the stage count register to 0

**Cycles** 2 cycles to execute, 4 cycles to fetch next instruction

**Examples:**

1:  STAGE_RST  // Reset stage count register

**STAGE_INC** – Increment stage count register

**Syntax** STAGE_INC Value

**Operands**

- Value – 8 bits value

**Cycles** 2 cycles to execute, 4 cycles to fetch next instruction

**Description** The instruction increments stage count register by given value.

**Examples:**

1:  STAGE_INC 10  // stage_cnt ++ 10

2: // Up counting loop example:
STAGE_RST  // set stage_cnt to 0
label: STAGE_INC 1  // stage_cnt++
NOP  // do something
JUMPS label, 16, LT  // jump to label if stage_cnt < 16

**STAGE_DEC** – Decrement stage count register

**Syntax** STAGE_DEC Value
### Operands
- **Value** - 8 bits value

### Cycles
2 cycles to execute, 4 cycles to fetch next instruction

### Description
The instruction decrements stage count register by given value.

#### Examples:

```plaintext
1:   STAGE_DEC 10   // stage_cnt -= 10;
2:   // Down counting loop example
     STAGE_RST   // set stage_cnt to 0
     STAGE_INC 16   // increment stage_cnt to 16
     label: STAGE_DEC 1   // stage_cnt--;
     NOP   // do something
     JUMPS label, 0, GT // jump to label if stage_cnt > 0
```

### HALT – End the program

#### Syntax
**HALT**

#### Operands
No operands

#### Cycles
2 cycles to execute

#### Description
The instruction halts the ULP coprocessor and restarts ULP wakeup timer, if it is enabled.

#### Examples:

```plaintext
1:   HALT   // Halt the coprocessor
```

### WAKE – Wake up the chip

#### Syntax
**WAKE**

#### Operands
No operands

#### Cycles
2 cycles to execute, 4 cycles to fetch next instruction

#### Description
The instruction sends an interrupt from ULP to RTC controller.

- If the SoC is in deep sleep mode, and ULP wakeup is enabled, this causes the SoC to wake up.
- If the SoC is not in deep sleep mode, and ULP interrupt bit (RTC_CNTL_UPL_CP_INT_ENA) is set in RTC_CNTL_INT_ENA_REG register, RTC interrupt will be triggered.

Note that before using **WAKE** instruction, ULP program may needs to wait until RTC controller is ready to wake up the main CPU. This is indicated using RTC_CNTL_RDY_FOR_WAKEUP bit of RTC_CNTL_LOW_POWER_ST_REG register. If **WAKE** instruction is executed while RTC_CNTL_RDY_FOR_WAKEUP is zero, it has no effect (wake up does not occur).

#### Examples:

```plaintext
1: is_rdy_for_wakeup:   // Read RTC_CNTL_RDY_FOR_WAKEUP bit
     READ_RTC_FIELD(RTC_CNTL_LOW_POWER_ST_REG, RTC_CNTL_RDY_FOR_WAKEUP)
     AND r0, r0, 1
     JUMP is_rdy_for_wakeup, eq // Retry until the bit is set
     WAKE   // Trigger wake up
     REG_WR 0x006, 24, 24, 0 // Stop ULP timer (clear RTC_CNTL_UPL_CP_SLP_TIMER_EN)
     HALT   // Stop the ULP program
     // After these instructions, SoC will wake up,
     // and ULP will not run again until started by the main program.
```

### SLEEP – Set ULP wakeup timer period

#### Syntax
**SLEEP** *sleep_reg*

#### Operands
• sleep_reg ≈ 0..4, selects one of SENS_ULP_CP_SLEEP_CYCx_REG registers.

**Cycles** 2 cycles to execute, 4 cycles to fetch next instruction

**Description** The instruction selects which of the SENS_ULP_CP_SLEEP_CYCx_REG (x = 0..4) register values is to be used by the ULP wakeup timer as wakeup period. By default, the value from SENS_ULP_CP_SLEEP_CYC0_REG is used.

**Examples:**

```
1: SLEEP 1  // Use period set in SENS_ULP_CP_SLEEP_CYC1_REG
2: .set sleep_reg, 4  // Set constant
    SLEEP sleep_reg  // Use period set in SENS_ULP_CP_SLEEP_CYC4_REG
```

**WAIT** – wait some number of cycles

**Syntax** WAIT Cycles

**Operands**

- **Cycles** – number of cycles for wait

**Cycles** 2 + Cycles cycles to execute, 4 cycles to fetch next instruction

**Description** The instruction delays for given number of cycles.

**Examples:**

```
1: WAIT 10  // Do nothing for 10 cycles
2: .set wait_cnt, 10  // Set a constant
    WAIT wait_cnt  // wait for 10 cycles
```

**TSENS** – do measurement with temperature sensor

**Syntax**

```
• TSENS Rdst, Wait_Delay
```

**Operands**

- **Rdst** – Destination Register R[0..3], result will be stored to this register
- **Wait_Delay** – number of cycles used to perform the measurement

**Cycles** 2 + Wait_Delay + 3 * TSENS_CLK to execute, 4 cycles to fetch next instruction

**Description** The instruction performs measurement using TSENS and stores the result into a general purpose register.

**Examples:**

```
1: TSENS R1, 1000  // Measure temperature sensor for 1000 cycles,
    // and store result to R1
```

**ADC** – do measurement with ADC

**Syntax**

```
• ADC Rdst, Sar_sel, Mux
• ADC Rdst, Sar_sel, Mux, 0 — deprecated form
```

**Operands**

- **Rdst** – Destination Register R[0..3], result will be stored to this register
- **Sar_sel** – Select ADC: 0 = SARADC1, 1 = SARADC2
- **Mux** – Enable ADC channel. Channel number is [Mux-1]. If the user passes Mux value 1, then ADC channel 0 gets used.

**Cycles** 23 + max(1, SAR_AMP_WAIT1) + max(1, SAR_AMP_WAIT2) + max(1, SAR_AMP_WAIT3) + SARx_SAMPLE_CYCLE + SARx_SAMPLE_BIT cycles to execute, 4 cycles to fetch next instruction
Chapter 4. API Guides

Description The instruction makes measurements from ADC.

Examples:

```
1: ADC     R1, 0, 1  // Measure value using ADC1 channel 0 and store...
    ←result into R1
```

I2C_RD - read single byte from I2C slave

**Syntax**

- **I2C_RD** *Sub_addr, High, Low, Slave_sel*

**Operands**

- *Sub_addr* – Address within the I2C slave to read.
- *High, Low* — Define range of bits to read. Bits outside of [High, Low] range are masked.
- *Slave_sel* - Index of I2C slave address to use.

**Cycles** Execution time mostly depends on I2C communication time. 4 cycles to fetch next instruction.

**Description** I2C_RD instruction reads one byte from I2C slave with index Slave_sel. Slave address (in 7-bit format) has to be set in advance into SENS_I2C_SLAVE_ADDRx register field, where x == Slave_sel. 8 bits of read result is stored into R0 register.

Examples:

```
1: I2C_RD 0x10, 7, 0, 0  // Read byte from sub-address 0x10 of...
    ←slave with address set in SENS_I2C_SLAVE_ADDR0
```

I2C_WR - write single byte to I2C slave

**Syntax**

- **I2C_WR** *Sub_addr, Value, High, Low, Slave_sel*

**Operands**

- *Sub_addr* – Address within the I2C slave to write.
- *Value* — 8-bit value to be written.
- *High, Low* — Define range of bits to write. Bits outside of [High, Low] range are masked.
- *Slave_sel* - Index of I2C slave address to use.

**Cycles** Execution time mostly depends on I2C communication time. 4 cycles to fetch next instruction.

**Description** I2C_WR instruction writes one byte to I2C slave with index Slave_sel. Slave address (in 7-bit format) has to be set in advance into SENS_I2C_SLAVE_ADDRx register field, where x == Slave_sel.

Examples:

```
1: I2C_WR 0x20, 0x33, 7, 0, 1  // Write byte 0x33 to sub-address...
    ←0x20 of slave with address set in SENS_I2C_SLAVE_ADDR1.
```

REG_RD – read from peripheral register

**Syntax** **REG_RD** *Addr, High, Low*

**Operands**

- *Addr* – Register address, in 32-bit words
- *High* – Register end bit number
- *Low* – Register start bit number

**Cycles** 4 cycles to execute, 4 cycles to fetch next instruction

**Description** The instruction reads up to 16 bits from a peripheral register into a general purpose register: R0 = REG[Addr][High:Low].

This instruction can access registers in RTC_CNTL, RTC_IO, SENS, and RTC_I2C peripherals. Address of the the register, as seen from the ULP, can be calculated from the address of the same register on the DPORT bus as follows:
addr_ulp = (addr_dport - DR_REG_RTCCNTL_BASE) / 4

Examples:

```
1:   REG_RD   0x120, 7, 4   // load 4 bits: R0 = \{12'b0, REG[0x120][7:4]\}
```

**REG_WR – write to peripheral register**

**Syntax**  
REG_WR Addr, High, Low, Data

**Operands**

- **Addr** – Register address, in 32-bit words.
- **High** – Register end bit number
- **Low** – Register start bit number
- **Data** – Value to write, 8 bits

**Cycles**  
8 cycles to execute, 4 cycles to fetch next instruction

**Description**  
The instruction writes up to 8 bits from an immediate data value into a peripheral register: 
REG[Addr][High:Low] = data.

This instruction can access registers in RTC_CNTL, RTC_IO, SENS, and RTC_I2C peripherals. Address of the register, as seen from the ULP, can be calculated from the address of the same register on the DPORT bus as follows:

```
addr_ulp = (addr_dport - DR_REG_RTCCNTL_BASE) / 4
```

Examples:

```
1:   REG_WR   0x120, 7, 0, 0x10   // set 8 bits: REG[0x120][7:0] = 0x10
```

**Convenience macros for peripheral registers access**

ULP source files are passed through C preprocessor before the assembler. This allows certain macros to be used to facilitate access to peripheral registers.

Some existing macros are defined in `soc/soc_ulp.h` header file. These macros allow access to the fields of peripheral registers by their names. Peripheral registers names which can be used with these macros are the ones defined in `soc/rtc_cntl_reg.h`, `soc/rtc_io_reg.h`, `soc/sens_reg.h`, and `soc/rtc_i2c_reg.h`.

**READ_RTC_REG(rtc_reg, low_bit, bit_width)**  
Read up to 16 bits from rtc_reg[low_bit + bit_width - 1 : low_bit] into R0. For example:

```
#include "soc/soc_ulp.h"
#include "soc/rtc_cntl_reg.h"

/* Read 16 lower bits of RTC_CNTL_TIME0_REG into R0 */
READ_RTC_REG(RTC_CNTL_TIME0_REG, 0, 16)
```

**READ_RTC_FIELD(rtc_reg, field)**  
Read from a field in rtc_reg into R0, up to 16 bits. For example:

```
#include "soc/soc_ulp.h"
#include "soc/sens_reg.h"

/* Read 8-bit SENS_TSENS_OUT field of SENS_SAR_SLAVE_ADDR3_REG into R0 */
READ_RTC_FIELD(SENS_SAR_SLAVE_ADDR3_REG, SENS_TSENS_OUT)
```

**WRITE_RTC_REG(rtc_reg, low_bit, bit_width, value)**  
Write immediate value into rtc_reg[low_bit + bit_width - 1 : low_bit], bit_width <= 8. For example:
#include "soc/soc_ulp.h"
#include "soc/rtc_io_reg.h"

/* Set BIT(2) of RTC_GPIO_OUT_DATA_W1TS field in RTC_GPIO_OUT_W1TS_REG */
WRITE_RTC_REG(RTC_GPIO_OUT_W1TS_REG, RTC_GPIO_OUT_DATA_W1TS_S + 2, 1, 1)

WRITE_RTC_FIELD(rtc_reg, field, value)  
Write immediate value into a field in rtc_reg, up to 8 bits. For example:

#include "soc/soc_ulp.h"
#include "soc/rtc_cntl_reg.h"

/* Set RTC_CNTL_ULP_CP_SLP_TIMER_EN field of RTC_CNTL_STATE0_REG to 0 */
WRITE_RTC_FIELD(RTC_CNTL_STATE0_REG, RTC_CNTL_ULP_CP_SLP_TIMER_EN, 0)

4.30.2 Programming ULP 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:

const ulp_insn_t program[] = {
  I_MOVI(R3, 16),     // R3 <- 16
  I_LD(R0, R3, 0),    // R0 <- RTC_SLOW_MEM[R3 + 0]
  I_LD(R1, R3, 1),    // R1 <- RTC_SLOW_MEM[R3 + 1]
  I_ADDR(R2, R0, R1), // R2 <- R0 + R1
  I_ST(R2, R3, 2),    // R2 -> RTC_SLOW_MEM[R2 + 2]
  I_HALT()
};
size_t load_addr = 0;
size_t size = sizeof(program)/sizeof(ulp_insn_t);
ulp_process_macros_and_load(load_addr, program, &size);
ulp_run(load_addr);

The program array is an array of ulp_insn_t, i.e. ULP coprocessor instructions. Each I_XXX preprocessor define translates into a single 32-bit instruction. Arguments of these preprocessor defines can be register numbers (R0 - R3) and literal constants. See 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 numer.

Here is an example of using labels and branches:

const ulp_insn_t program[] = {
  I_MOVI(R0, 34),    // R0 <- 34
  M_LABEL(1),        // label_1
};

(continues on next page)
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/include/esp32/ulp.h

Functions

```c
esp_err_t ulp_process_macros_and_load(uint32_t load_addr, const ulp_insn_t *program, size_t *psize)
```

Resolve all macro references in a program and load it into RTC memory.

**Return**

- ESP_OK on success
- ESP_ERR_NO_MEM if auxiliary temporary structure cannot be allocated
- one of ESP_ERR_ULP_xxx if program is not valid or cannot 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

```c
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
Chapter 4. API Guides

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) instruc-
tion.

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 [20:18] = 3’b0
- bits [17:16] reg_addr (0..3)
- bits [15:0] are assigned the contents of reg_val

RTC_SLOW_MEM[addr + offset_] = { insn_PC[10:0], 3’b0, reg_addr, reg_val[15:0] }

I_LD (reg_dest, reg_addr, offset_)
Load value from RTC memory into reg_dest register.

Loads 16 LSBs from RTC memory word given by the sum of value in reg_addr and value of offset_.
I_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
Chapter 4. API Guides

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 l 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.

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.

### 4.30.3 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.

### 4.30.4 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.

4.30.5 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:

```plaintext
    .global measurement_count

    measurement_count: .long 0
    /* later, use measurement_count */
    move r3, measurement_count
    ld r3, r3, 0
```

The main program needs to initialize this variable before the ULP program is started. The build system makes this possible by generating the ${ULP_APP_NAME}.h and ${ULP_APP_NAME}.ld files which define the global symbols present in the ULP program. Each global symbol defined in the ULP program is included in these files and are prefixed with `ulp_`.

The header file contains the declaration of the symbol:

```plaintext
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:

```plaintext
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:

```plaintext
#include "ulp_app_name.h"

// later
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.:

```plaintext
printf("Last measurement value: %d\n", ulp_last_measurement & UINT16_MAX);
```

4.30.6 Starting the ULP Program

To run a ULP program, the main application needs to load the ULP program into RTC memory using the `ulp_load_binary` function, and then start it using the `ulp_run` function.

Note that “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
Chapter 4. API Guides

code and data. If the application components contain multiple ULP programs, then the size of the RTC memory must be sufficient to hold the largest one.

Each ULP program is embedded into the ESP-IDF application as a binary blob. The application can reference this blob and load it in the following way (suppose ULP_APP_NAME was defined to ulp_app_name):

```c
extern const uint8_t bin_start[] asm("_binary_ulp_app_name_bin_start");
extern const uint8_t bin_end[] asm("_binary_ulp_app_name_bin_end");

void start_ulp_program() {
    ESP_ERROR_CHECK( ulp_load_binary(
        0 /* load address, set to 0 when using default linker scripts */,
        bin_start,
        (bin_end - bin_start) / sizeof(uint32_t))
    );
}
```

`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

Once the program is loaded into RTC memory, the application can start it, passing the address of the entry point to the ulp_run function:

```c
ESP_ERROR_CHECK( ulp_run(&ulp_entry - RTC_SLOW_MEM) );
```

`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

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:

```
.global entry
entry:
    /* code starts here */
```
4.30.7 ESP32 ULP program flow

ESP32 ULP coprocessor is started by a timer. The timer is started once `ulp_run` is called. The timer counts a number of RTC_SLOW_CLK ticks (by default, produced by an internal 150 kHz RC oscillator). The number of ticks is set using `SENS_ULP_CP_SLEEP_CYCx_REG` registers (x = 0..4). When starting the ULP for the first time, `SENS_ULP_CP_SLEEP_CYC0_REG` will be used to set the number of timer ticks. Later the ULP program can select another `SENS_ULP_CP_SLEEP_CYCx_REG` register using `sleep` instruction.

The application can set ULP timer period values (`SENS_ULP_CP_SLEEP_CYCx_REG`, x = 0..4) using `ulp_set_wakeup_period` function.

```c
esp_err_t ulp_set_wakeup_period(size_t period_index, uint32_t period_us)
```

Set one of ULP wakeup period values.

ULP coprocessor starts running the program when the wakeup timer counts up to a given value (called period). There are 5 period values which can be programmed into `SENS_ULP_CP_SLEEP_CYCx_REG` registers, x = 0..4 for ESP32, and one period value which can be programmed into `RTC_CNTL_ULP_CP_TIMER_1_REG` register for ESP32-S2. By default, for ESP32, wakeup timer will use the period set into `SENS_ULP_CP_SLEEP_CYC0_REG`, i.e. period number 0. ULP program code can use `SLEEP` instruction to select which of the `SENS_ULP_CP_SLEEP_CYCx_REG` should be used for subsequent wakeups.

However, please note that `SLEEP` instruction issued (from ULP program) while the system is in deep sleep mode does not have effect, and sleep cycle count 0 is used.

For ESP32-s2 the `SLEEP` instruction not exist. Instead a WAKE instruction will be used.

**Note** The ULP FSM requires two clock cycles to wakeup before being able to run the program. Then additional 16 cycles are reserved after wakeup waiting until the 8M clock is stable. The FSM also requires two more clock cycles to go to sleep after the program execution is halted. The minimum wakeup period that may be set up for the ULP is equal to the total number of cycles spent on the above internal tasks. For a default configuration of the ULP running at 150kHz it makes about 133us.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if `period_index` is out of range

**Parameters**
- `period_index`: wakeup period setting number (0 - 4)
- `period_us`: wakeup period, us

Once the timer counts the number of ticks set in the selected `SENS_ULP_CP_SLEEP_CYCx_REG` register, ULP coprocessor powers up and starts running the program from the entry point set in the call to `ulp_run`.

The program runs until it encounters a `halt` instruction or an illegal instruction. Once the program halts, ULP coprocessor powers down, and the timer is started again.

To disable the timer (effectively preventing the ULP program from running again), clear the `RTC_CNTL_ULP_CP_SLP_TIMER_EN` bit in the `RTC_CNTL_STATE0_REG` register. This can be done both from ULP code and from the main program.

4.31 Unit Testing in ESP32

ESP-IDF provides the following methods to test software.

- Target based tests using a central unit test application which runs on the esp32. These tests use the Unity (<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.
4.31.1 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", 
{  
  // 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](http://www.throwtheswitch.org/unity) for more information about writing tests in Unity.

4.31.2 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:

```c
void gpio_master_test()
{
  gpio_config_t slave_config = {
    .pin_bit_mask = 1 << MASTER_GPIO_PIN,
    .mode = GPIO_MODE_INPUT,
  };
  gpio_config(&slave_config);
  unity_wait_for_signal("output high level");
  TEST_ASSERT(gpio_get_level(MASTER_GPIO_PIN) == 1);
}
```

```c
void gpio_slave_test()
{
  gpio_config_t master_config = {
    .pin_bit_mask = 1 << SLAVE_GPIO_PIN,
    .mode = GPIO_MODE_OUTPUT,
  };
  gpio_config(&master_config);
  unity_wait_for_signal("output low level");
  TEST_ASSERT(gpio_get_level(SLAVE_GPIO_PIN) == 0);
}
```

(continues on next page)
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.

### 4.31.3 Multi-stage Test Cases

The normal test cases are expected to finish without reset (or only need to check if reset happens). Sometimes we expect to run some specific tests after certain kinds of reset. For example, we want to test if the reset reason is correct after a wake up from deep sleep. We need to create a deep-sleep reset first and then check the reset reason. To support this, we can define multi-stage test cases, to group a set of test functions:

```c
static void trigger_deepsleep(void)
{
    esp_sleep_enable_timer_wakeup(2000);
    esp_deep_sleep_start();
}

void check_deepsleep_reset_reason()
{
    soc_reset_reason_t reason = esp_rom_get_reset_reason(0);
    TEST_ASSERT(reason == RESET_REASON_CORE_DEEP_SLEEP);
}

TEST_CASE_MULTIPLE_STAGES("reset reason check for deepsleep", "[esp32]", trigger_deepsleep, check_deepsleep_reset_reason);
```

Multi-stage test cases present a group of test functions to users. It needs user interactions (select cases and select different stages) to run the case.
4.31.4 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 SD SPI. For ESP32-S2, which doesn’t have SD host, among the tests only SD SPI 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_xxx_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.

4.31.5 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:
Chapter 4. API Guides

- 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.

### 4.31.6 Running Unit Tests

After flashing reset the ESP32 and it will boot the unit test app.

When unit test app is idle, press “Enter” will make it print test menu with all available tests:

```plaintext
Here's the test menu, pick your combo:
(1) "esp_ota_begin() verifies arguments" [ota]
(2) "esp_ota_get_next_update_partition logic" [ota]
(3) "Verify bootloader image in flash" [bootloader_support]
(4) "Verify unit test app image" [bootloader_support]
(5) "can use new and delete" [cxx]
(6) "can call virtual functions" [cxx]
(7) "can use static initializers for non-POD types" [cxx]
(8) "can use std::vector" [cxx]
(9) "static initialization guards work as expected" [cxx]
(10) "global initializers run in the correct order" [cxx]
(11) "before scheduler has started, static initializers work correctly" [cxx]
(12) "adc2 work with wifi" [adc]
(13) "gpio master/slave test example" [ignore][misc][test_env=UT_T2_1][multi_→device]
    (1) "gpio_master_test"
    (2) "gpio_slave_test"
(14) "SPI Master clockdiv calculation routines" [spi]
(15) "SPI Master test" [spi][ignore]
(16) "SPI Master test, interaction of multiple devs" [spi][ignore]
(17) "SPI Master no response when switch from host1 (SPI2) to host2 (SPI3)" [spi]
(18) "SPI Master DMA test, TX and RX in different regions" [spi]
(19) "SPI Master DMA test: length, start, not aligned" [spi]
(20) "reset reason check for deepsleep" [esp32][test_env=UT_T2_1][multi_stage]
    (1) "trigger_deepsleep"
    (2) "check_deepsleep_reset_reason"
```

The normal case will print the case name and description. Master-slave cases will also print the sub-menu (the registered test function names).

Test cases can be run by inputting one of the following:
• Test case name in quotation marks to run a single test case
• Test case index to run a single test case
• Module name in square brackets to run all test cases for a specific module
• An asterisk to run all test cases

[multi_device] and [multi_stage] tags tell the test runner whether a test case is a 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.

### 4.31.7 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 technique for eliminating 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.

```
// 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.

### 4.31.8 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.

One of the biggest problems regarding unit testing of embedded systems are the strong hardware dependencies. Running unit tests directly on the ESP32 can be especially difficult for higher layer components for the following reasons:

- Decreased test reliability due to lower layer components and/or hardware setup.
- Increased difficulty in testing edge cases due to limitations of lower layer components and/or hardware setup
- Increased difficulty in identifying the root cause due to the large number of dependencies influencing the behavior

When testing a particular component, (i.e., the component under test), 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” 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.

**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:
Chapter 4. API Guides

- 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`:

```cpp
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`:

```cpp
list(APPEND EXTRA_COMPONENT_DIRS "<mock_component_dir>")
```

Both methods will override existing components in ESP-IDF with the component mock. The latter is particularly convenient if you use component mocks that are already supplied by IDF.

Users 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.

4.32 Unit Testing on Linux

Note: Host testing with IDF is experimental for now. We try our best to keep interfaces stable but cannot 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.

### 4.32.1 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).

### 4.32.2 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:

```
- 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 ommitted.
  - <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.
Chapter 4. API Guides

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.

4.33 Wi-Fi Driver

4.33.1 ESP32 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

4.33.2 How To Write a Wi-Fi Application

Preparation

Generally, the most effective way to begin your own Wi-Fi application is to select an example which is similar to your own application, and port the useful part into your project. It is not a MUST but it is strongly recommended that you take some time to read this article first, especially if you want to program a robust Wi-Fi application.

This article is supplementary to the Wi-Fi APIs/Examples. It describes the principles of using the Wi-Fi APIs, the limitations of the current Wi-Fi API implementation, and the most common pitfalls in using Wi-Fi. This article also reveals some design details of the Wi-Fi driver. We recommend you to select an example.

Setting Wi-Fi Compile-time Options

Refer to Wi-Fi Menuconfig.

Init Wi-Fi

Refer to ESP32 Wi-Fi station General Scenario, ESP32 Wi-Fi AP General Scenario.

Start/Connect Wi-Fi

Refer to ESP32 Wi-Fi station General Scenario, ESP32 Wi-Fi AP General Scenario.
Event-Handling

Generally, it is easy to write code in “sunny-day” scenarios, such as `WIFI_EVENT_STA_START`, `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 Wi-Fi Event Description, ESP32 Wi-Fi station General Scenario, ESP32 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 Wi-Fi API Error Code.

4.33.3 ESP32 Wi-Fi API Error Code

All of the ESP32 Wi-Fi APIs have well-defined return values, namely, the error code. The error code can be categorized into:

- No errors, e.g. ESP_OK means that the API returns successfully.
- Recoverable errors, such as ESP_ERR_NO_MEM, 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.

4.33.4 ESP32 Wi-Fi API Parameter Initialization

When initializing struct parameters for the API, one of two approaches should be followed:

- explicitly set all fields of the parameter
- use get API to get current configuration first, then set application specific fields

Initializing or getting the entire structure is very important because most of the time the value 0 indicates 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.

4.33.5 ESP32 Wi-Fi Programming Model

The ESP32 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
Chapter 4. API Guides

![Wi-Fi Programming Model](image)

Fig. 55: Wi-Fi Programming Model

and handles Wi-Fi events when necessary. Wi-Fi driver receives API calls, handles them, and post 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).

### 4.33.6 ESP32 Wi-Fi Event Description

#### WIFI_EVENT_WIFI_READY

The Wi-Fi driver will never generate this event, which, as a result, can be ignored by the application event callback. This event may be removed in future releases.

#### WIFI_EVENT_SCAN_DONE

The scan-done event is triggered by `esp_wifi_scan_start()` and will arise in the following scenarios:

- The scan is completed, e.g., the target AP is found successfully, or all channels have been scanned.
- The scan is stopped by `esp_wifi_scan_stop()`.
- The `esp_wifi_scan_start()` is called before the scan is completed. A new scan will override the current scan and a scan-done event will be generated.

The scan-done event will not arise in the following scenarios:

- It is a blocked scan.
- The scan is caused by `esp_wifi_connect()`.

Upon receiving this event, the event task does nothing. The application event callback needs to call `esp_wifi_scan_get_ap_num()` and `esp_wifi_scan_get_ap_records()` to fetch the scanned AP list and trigger the Wi-Fi driver to free the internal memory which is allocated during the scan (*do not forget to do this!*). Refer to *ESP32 Wi-Fi Scan* for a more detailed description.

#### WIFI_EVENT_STA_START

If `esp_wifi_start()` returns ESP_OK and the current Wi-Fi mode is station or station/AP, then this event will arise. Upon receiving this event, the event task will initialize the LwIP network interface (netif). Generally, the application event callback needs to call `esp_wifi_connect()` to connect to the configured AP.
**WIFI_EVENT_STA_STOP**

If `esp_wifi_stop()` returns ESP_OK and the current Wi-Fi mode is station or station/AP, then this event will arise. Upon receiving this event, the event task will release the station’s IP address, stop the DHCP client, remove TCP/UDP-related connections and clear the LwIP station netif, etc. The application event callback generally does not need to do anything.

**WIFI_EVENT_STA_CONNECTED**

If `esp_wifi_connect()` returns ESP_OK and the station successfully connects to the target AP, the connection event will arise. Upon receiving this event, the event task starts the DHCP client and begins the DHCP process of getting the IP address. Then, the Wi-Fi driver is ready for sending and receiving data. This moment is good for beginning the application work, provided that the application does not depend on LwIP, namely the IP address. However, if the application is LwIP-based, then you need to wait until the got ip event comes in.

**WIFI_EVENT_STA_DISCONNECTED**

This event can be generated in the following scenarios:

- When `esp_wifi_disconnect()` or `esp_wifi_stop()` is called and the station is already connected to the AP.
- When `esp_wifi_connect()` is called, but the Wi-Fi driver fails to set up a connection with the AP due to certain reasons, e.g., the scan fails to find the target AP, 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 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, 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 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.

### 4.33.7 ESP32 Wi-Fi Station General Scenario

Below is a “big scenario” which describes some small scenarios in station mode:

#### 1. Wi-Fi/LwIP Init Phase

- **s1.1**: The main task calls `esp_netif_init()` to create an LwIP core task and initialize LwIP-related work.
- **s1.2**: The main task calls `esp_event_loop_create()` to create a system Event task and initialize an application event’s callback function. In the scenario above, the application event’s callback function does nothing but relaying the event to the application task.
- **s1.3**: The main task calls `esp_netif_create_default_wifi_ap()` or `esp_netif_create_default_wifi_sta()` to create default network interface instance binding station or AP with TCP/IP stack.
- **s1.4**: The main task calls `esp_wifi_init()` to create the Wi-Fi driver task and initialize the Wi-Fi driver.
- **s1.5**: The main task calls OS API to create the application task.

Step 1.1 ~ 1.5 is a recommended sequence that initializes a Wi-Fi-/LwIP-based application. However, it is **NOT** a must-follow sequence, which means that you can create the application task in step 1.1 and put all other 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 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.
Fig. 56: Sample Wi-Fi Event Scenarios in Station Mode
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.

4.3.3.8 ESP32 Wi-Fi AP General Scenario

Below is a “big scenario” which describes some small scenarios in AP mode:
Fig. 57: Sample Wi-Fi Event Scenarios in AP Mode
### 4.33.9 ESP32 Wi-Fi Scan

Currently, the `esp_wifi_scan_start()` API is supported only in station or station/AP mode.

#### Scan Type

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Scan</td>
<td>Scan by sending a probe request. The default scan is an active scan.</td>
</tr>
<tr>
<td>Passive Scan</td>
<td>No probe request is sent out. Just switch to the specific channel and wait for a beacon. Application can enable it via the scan_type field of <code>wifi_scan_config_t</code>.</td>
</tr>
<tr>
<td>Foreground Scan</td>
<td>This scan is applicable when there is no Wi-Fi connection in station mode. Foreground or background scanning is controlled by the Wi-Fi driver and cannot be configured by the application.</td>
</tr>
<tr>
<td>Background Scan</td>
<td>This scan is applicable when there is a Wi-Fi connection in station mode or in station/AP mode. Whether it is a foreground scan or background scan depends on the Wi-Fi driver and cannot be configured by the application.</td>
</tr>
<tr>
<td>All-Channel Scan</td>
<td>It scans all of the channels. If the channel field of <code>wifi_scan_config_t</code> is set to 0, it is an all-channel scan.</td>
</tr>
<tr>
<td>Specific Channel Scan</td>
<td>It scans specific channels only. If the channel field of <code>wifi_scan_config_t</code> set to 1-14, it is a specific-channel scan.</td>
</tr>
</tbody>
</table>

The scan modes in above table can be combined arbitrarily, so 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`. 
### Field Description

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ssid</td>
<td>If the SSID is not NULL, it is only the AP with the same SSID that can be scanned.</td>
</tr>
<tr>
<td>bssid</td>
<td>If the BSSID is not NULL, it is only the AP with the same BSSID that can be scanned.</td>
</tr>
<tr>
<td>channel</td>
<td>If “channel” is 0, there will be an all-channel scan; otherwise, there will be a specific-channel scan.</td>
</tr>
<tr>
<td>show_hidden</td>
<td>If “show_hidden” is 0, the scan ignores the AP with a hidden SSID; otherwise, the scan considers the hidden AP a normal one.</td>
</tr>
<tr>
<td>scan_type</td>
<td>If “scan_type” is WIFI_SCAN_TYPE_ACTIVE, the scan is “active”; otherwise, it is a “passive” one.</td>
</tr>
<tr>
<td>scan_time</td>
<td>This field is used to control how long the scan dwells on each channel.</td>
</tr>
<tr>
<td></td>
<td>For passive scans, scan_time.passive designates the dwell time for each channel.</td>
</tr>
<tr>
<td></td>
<td>For active scans, dwell times for each channel are listed in the table below.</td>
</tr>
<tr>
<td></td>
<td>Here, min is short for scan_time.active.min and max is short for scan_time.active.max.</td>
</tr>
<tr>
<td></td>
<td>• min=0, max=0: scan dwells on each channel for 120 ms.</td>
</tr>
<tr>
<td></td>
<td>• min&gt;0, max=0: scan dwells on each channel for 120 ms.</td>
</tr>
<tr>
<td></td>
<td>• min=0, max&gt;0: scan dwells on each channel for max ms.</td>
</tr>
<tr>
<td></td>
<td>• min&gt;0, max&gt;0: the minimum time the scan dwells on each channel is min ms.</td>
</tr>
<tr>
<td></td>
<td>If no AP is found during this time frame, the scan switches to the next channel.</td>
</tr>
<tr>
<td></td>
<td>Otherwise, the scan dwells on the channel for max ms.</td>
</tr>
<tr>
<td></td>
<td>If you want to improve the performance of the the scan, you can try to modify these two parameters.</td>
</tr>
</tbody>
</table>

There are also some global scan attributes which are configured by API `esp_wifi_set_config()`, refer to [Station Basic Configuration](#).

### Scan All APs on All Channels (Foreground)

**Scenario:**

The scenario above describes an all-channel, foreground scan. The foreground scan can only occur in station mode where the station does not connect to any AP. Whether it is a foreground or background scan is totally determined by the Wi-Fi driver, and cannot be configured by the application.

**Detailed scenario description:**

**Scan Configuration Phase**

- s1.1: Call `esp_wifi_set_country()` to set the country info if the default country info is not what you want, refer to [Wi-Fi Country Code](#).
- s1.2: Call `esp_wifi_scan_start()` to configure the scan. To do so, you can refer to [Scan Configuration](#).

Since this is an all-channel scan, just set the SSID/BSSID/channel to 0.

**Wi-Fi Driver’s Internal Scan Phase**

- s2.1: The Wi-Fi driver switches to channel 1, in 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.
Fig. 58: Foreground Scan of all Wi-Fi Channels
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 and the target AP scan is found, the scan-done event will occur. If the scan-done event 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 when the scan is completed. If the target AP is found, the Wi-Fi driver will start the Wi-Fi connection; otherwise, WIFI_EVENT_STA_DISCONNECTED will be generated. Refer to Scan for Specific AP On All Channels.

Scan In Blocked Mode

If the block parameter of 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.

Parallel Scan

Two application tasks may call esp_wifi_scan_start() at the same time, or the same application task calls esp_wifi_scan_start() before it gets a scan-done event. Both scenarios can happen. However, the Wi-Fi driver does not support multiple concurrent scans adequately. As a result, concurrent scans should be avoided. Support for concurrent scan will be enhanced in future releases, as the ESP32’s Wi-Fi functionality improves continuously.
Fig. 59: Background Scan of all Wi-Fi Channels
Fig. 60: Scan of specific Wi-Fi Channels
Scan When Wi-Fi is Connecting

The `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-existent AP or if the station connects the existed AP with a wrong password, it always raises the event `WIFI_EVENT_STA_DISCONNECTED`.
- The application call `esp_wifi_connect()` to do reconnection on receiving the disconnect event.
- Another application task, e.g. the console task, call `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 reconnect 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 `<Wi-Fi Reconnect>`.

### 4.33.10 ESP32 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 ESP32 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:**

**Scan Phase**

- s1.1, The Wi-Fi driver begins scanning in “Wi-Fi Connect”. Refer to Scan in Wi-Fi Connect for more details.
- s1.2, If the scan fails to find the target AP, `WIFI_EVENT_STA_DISCONNECTED` will arise and the reason-code will be `WIFI_REASON_NO_AP_FOUND`. Refer to Wi-Fi Reason Code.

**Auth Phase**

- s2.1, The authentication request packet is sent and the auth timer is enabled.
- s2.2, If the authentication response packet is not received before the authentication timer times out, `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.
Fig. 61: Wi-Fi Station Connecting Process
• 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. 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>Mapped To</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNSPECIFIED</td>
<td>1</td>
<td>200</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>202</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 <code>esp_wifi_stop()</code>. • the station is de-authed by calling <code>esp_wifi_deauth_sta()</code></td>
</tr>
<tr>
<td>AUTH_BEAKE</td>
<td>3</td>
<td>203</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>204</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 <code>esp_wifi_stop()</code> • the station is de-authed by calling <code>esp_wifi_deauth_sta()</code></td>
</tr>
<tr>
<td>ASSOC_STOOMANY</td>
<td>5</td>
<td>205</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>206</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>207</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>208</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 <code>esp_wifi_disconnect()</code> and other APIs.</td>
</tr>
</tbody>
</table>

For the ESP station, this reason is reported when: - it is received from the AP. - the station is de-authed by calling `esp_wifi_deauth_sta()`.
4.33.11 ESP32 Wi-Fi Station Connecting When Multiple APs Are Found

This scenario is similar as ESP32 Wi-Fi Station Connecting Scenario, the difference is the station will not raise the event WIFI_EVENT_STA_DISCONNECTED unless it fails to connect all of the found APs.

4.33.12 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.

4.33.13 Wi-Fi Beacon Timeout

The beacon timeout mechanism is used by ESP32 station to detect whether the AP is alive or not. If the station 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.

4.33.14 ESP32 Wi-Fi Configuration

All configurations will be stored into flash when the Wi-Fi NVS is enabled; otherwise, refer to Wi-Fi NVS Flash.

**Wi-Fi Mode**

Call 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 broadcast beacon, 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.</td>
</tr>
<tr>
<td></td>
<td>For WIFI_ALL_CHANNEL_SCAN, the scan finds all matched APs on all channels.</td>
</tr>
<tr>
<td></td>
<td>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</td>
</tr>
<tr>
<td></td>
<td>the field ssid, while the field “bssid” is ignored. In all other cases, the</td>
</tr>
<tr>
<td></td>
<td>station connects to the AP whose SSID is the same as the “ssid” field, while</td>
</tr>
<tr>
<td></td>
<td>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</td>
</tr>
<tr>
<td></td>
<td>target AP; otherwise, the station starts by scanning the channel whose value</td>
</tr>
<tr>
<td></td>
<td>is the same as that of the “channel” field, and then scans others to find</td>
</tr>
<tr>
<td></td>
<td>the target AP. If you do not know which channel the target AP is running on,</td>
</tr>
<tr>
<td></td>
<td>set it to 0.</td>
</tr>
<tr>
<td>sort_method</td>
<td>This field is only for WIFI_ALL_CHANNEL_SCAN.</td>
</tr>
<tr>
<td></td>
<td>If the sort_method is WIFI_CONNECT_AP_BY_SIGNAL, all matched APs are</td>
</tr>
<tr>
<td></td>
<td>sorted by signal, for AP with best signal will be connected firstly. E.g. if</td>
</tr>
<tr>
<td></td>
<td>the station want to connect AP whose ssid is “apxx”, the scan finds two AP</td>
</tr>
<tr>
<td></td>
<td>whose ssid equals to “apxx”, the first AP’s signal is -90 dBm, the second</td>
</tr>
<tr>
<td></td>
<td>AP’s signal is -30 dBm, the station connects the second AP firstly, it doesn’</td>
</tr>
<tr>
<td></td>
<td>t connect the first one unless it fails to connect the second one. If the</td>
</tr>
<tr>
<td></td>
<td>sort_method is WIFI_CONNECT_AP_BY_SECURITY, all matched APs are sorted by</td>
</tr>
<tr>
<td></td>
<td>security. E.g. if the station wants to connect AP whose ssid is “apxx”, the</td>
</tr>
<tr>
<td></td>
<td>scan finds two AP whose ssid is “apxx”, the security of the first found AP</td>
</tr>
<tr>
<td></td>
<td>is open while the second one is WPA2, the stations connects to the second AP</td>
</tr>
<tr>
<td></td>
<td>firstly, it doesn’ t connect the second one unless it fails to connect the</td>
</tr>
<tr>
<td></td>
<td>first one.</td>
</tr>
<tr>
<td>threshold</td>
<td>The threshold is used to filter the found AP, if the RSSI or security mode</td>
</tr>
<tr>
<td></td>
<td>is less than the configured threshold, the AP will be discard. If the RSSI</td>
</tr>
<tr>
<td></td>
<td>set to 0, it means default threshold, the default RSSI threshold is -127 dBm.</td>
</tr>
<tr>
<td></td>
<td>If the authmode threshold is set to 0, it means default threshold, the default</td>
</tr>
<tr>
<td></td>
<td>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.
**Field** | **Description**
---|---
**ssid** | 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.

**password** | Password of AP; if the auth mode is WIFI_AUTH_OPEN, this field will be ignored.

**ssid_len** | Length of SSID; if ssid_len is 0, check the SSID until there is a termination character. If ssid_len > 32, change it to 32; otherwise, set the SSID length according to ssid_len.

**channel** | 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**.

**authmode** | 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.

**ssid_hidden** | If ssid_hidden is 1, AP does not broadcast the SSID; otherwise, it does broadcast the SSID.

**max_connection** | Currently, ESP Wi-Fi supports up to 10 Wi-Fi connections. If max_connection > 10, AP defaults the value to 10.

**beacon_interval** | 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.

---

### 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. <strong>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.</strong></td>
</tr>
</tbody>
</table>

---

### 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 devices can transmit and receive the LR data. In other words, the ESP32 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 may transmit data in LR rate, otherwise, ESP32 will transmit all data in traditional Wi-Fi data rate.

Following table depicts the Wi-Fi mode negotiation:
In the above table, the row is the Wi-Fi mode of AP and the column is the Wi-Fi mode of station. The “-” indicates Wi-Fi modes of the AP and station are not compatible.

According to the table, we can conclude that:

- For LR enabled in ESP32 AP, it’s incompatible with traditional 802.11 mode because the beacon is sent in LR mode.
- For LR enabled in ESP32 station and the mode is NOT LR only mode, it’s compatible with traditional 802.11 mode.
- If both station and AP are ESP32 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 octet 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.
### Chapter 4. API Guides

#### Wi-FiMode

<table>
<thead>
<tr>
<th>Wi-Fi Mode</th>
<th>Policy</th>
<th>Description</th>
</tr>
</thead>
</table>
| 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 `schan+nchan-1 > 11`:  
    Use active scan from `schan` to 11 and use passive scan from 12 to `schan+nchan-1`.  
  * If `schan+nchan-1 <= 11`:  
    Use active scan from `schan` to `schan+nchan-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.                                                                 |
| 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.                                                                 |
| Station/AP-coexistence| WIFI_COUNTRY_POLICY_MANUAL   | Always use the configured country info.                                                                                                        |

**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 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, `esp_wifi_set_vendor_ie()` and `esp_wifi_set_vendor_ie_cb()` are responsible for this kind of tasks.

### 4.33.15 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 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_Enterprise is supported by ESP32 only in station mode.

For establishing a secure connection, AP and station negotiate and agree on the best possible cipher suite to be used. ESP32 supports 802.1X/EAP (WPA) method of AKM and Advanced encryption standard with Counter Mode Cipher Block Chaining Message Authentication protocol (AES-CCM) cipher suite. It also supports the cipher suites supported by mbedTLS if `USE_MBEDTLS_CRYPTO` flag is set.

**ESP32 currently supports the following EAP methods:**

- **EAP-TLS:** This is 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,
  - 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 can be found in `wifi/wifi_enterprise`.

### 4.33.16 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.

### 4.33.17 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.

### 4.33.18 ESP32 Wi-Fi Power-saving Mode

**Station Sleep**

Currently, ESP32 Wi-Fi supports the Modem-sleep mode which refers to the legacy power-saving mode in the IEEE 802.11 protocol. Modem-sleep mode works in station-only mode and the station must connect to the AP first. If the
Modem-sleep mode is enabled, station will switch between active and sleep state periodically. In sleep state, RF, PHY and BB are turned off in order to reduce power consumption. Station can keep connection with AP in modem-sleep mode.

Modem-sleep mode includes minimum and maximum power 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 `esp_wifi_set_config()` before connecting to AP.

Call `esp_wifi_set_ps(WIFI_PS_MIN_MODEM)` to enable Modem-sleep minimum power save mode or `esp_wifi_set_ps(WIFI_PS_MAX_MODEM)` to enable Modem-sleep maximum power save mode after calling `esp_wifi_init()`. When station connects to AP, Modem-sleep will start. When station disconnects from AP, Modem-sleep will stop.

Call `esp_wifi_set_ps(WIFI_PS_NONE)` to disable modem sleep 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 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 AP are power save enabled, they may experience multicast packet loss.

In the future, all power save features will be supported on ESP32 AP.

### 4.33.19 ESP32 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/Throughput</th>
<th>Air In Lab</th>
<th>Shield-box</th>
<th>Test Tool</th>
<th>IDF Version (commit ID)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw 802.11 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 Packet TX</td>
<td>N/A</td>
<td>130 MBit/s</td>
<td>Internal tool</td>
<td>NA</td>
</tr>
<tr>
<td>UDP RX</td>
<td>30 MBit/s</td>
<td>85 MBit/s</td>
<td>iperf example</td>
<td>15575346</td>
</tr>
<tr>
<td>UDP TX</td>
<td>30 MBit/s</td>
<td>75 MBit/s</td>
<td>iperf example</td>
<td>15575346</td>
</tr>
<tr>
<td>TCP RX</td>
<td>20 MBit/s</td>
<td>65 MBit/s</td>
<td>iperf example</td>
<td>15575346</td>
</tr>
<tr>
<td>TCP TX</td>
<td>20 MBit/s</td>
<td>75 MBit/s</td>
<td>iperf example</td>
<td>15575346</td>
</tr>
</tbody>
</table>

When the throughput is tested by iperf example, the sdkconfig is `examples/wifi/iperf/sdkconfig.defaults.esp32`.

### 4.33.20 Wi-Fi 80211 Packet Send

The `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, 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.
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
</table>
| 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 address1 is the MAC of AP to which the station is connected, the MAC address2 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 address1 is the MAC of the station who connects to this AP, the MAC address2 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

### 4.33.21 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`, `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.

### 4.33.22 Wi-Fi Multiple Antennas

The Wi-Fi multiple antennas selecting can be depicted as following picture:

```
| Enabled | Antenna 0 | \____ |
-|---------|---------|______|
-| --- antenna 0 |
RX/TX | --- antenna 1 |
-| ... ... |
|--- antenna 15 |
\ | | | |
```

ESP32 supports up to sixteen antennas through external antenna switch. The antenna switch can be controlled by up to four address pins - antenna_select[0:3]. Different input value of `antenna_select[0:3]` means selecting different antenna. 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 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
};
```

4.33.23 Wi-Fi Channel State Information

Channel state information (CSI) refers to the channel information of a Wi-Fi connection. In ESP32, this information consists of channel frequency responses of sub-carriers and is estimated when packets are received from the transmitter. Each channel frequency response of sub-carrier is recorded by two bytes of signed characters. The first one is imaginary part and the second one is real part. There are up to three fields of channel frequency responses according to the type of received packet. They are legacy long training field (LLTF), high throughput LTF (HT-LTF) and space time block code HT-LTF (STBC-HT-LTF). For different types of packets which are received on channels with different state, the sub-carrier index and total bytes of signed characters of CSI is shown in the following table.
Chapter 4. API Guides

<table>
<thead>
<tr>
<th>channel</th>
<th>secondary channel</th>
<th>below</th>
<th>above</th>
</tr>
</thead>
<tbody>
<tr>
<td>non HT</td>
<td>HT 20 MHz</td>
<td>0-31</td>
<td>0-63</td>
</tr>
<tr>
<td>STBC</td>
<td>non STBC</td>
<td>0-63</td>
<td>0-63</td>
</tr>
<tr>
<td>STBC</td>
<td>STBC</td>
<td>0-63</td>
<td>0-63</td>
</tr>
<tr>
<td>STBC</td>
<td>STBC</td>
<td>0-63</td>
<td>0-63</td>
</tr>
</tbody>
</table>

All of the information in the table can be found in the structure wifi_csi_info_t.

- Secondary channel refers to secondary_channel field of rx_ctrl field.
- Signal mode of packet refers to sig_mode field of rx_ctrl field.
- Channel bandwidth refers to cwb field of rx_ctrl field.
- STBC refers to stbc field of rx_ctrl field.
- Total bytes refers to len field.
- The CSI data corresponding to each Long Training Field (LTF) type is stored in a buffer starting from the buf field. Each item is stored as two bytes: imaginary part followed by real part. The order of each item is the same as the sub-carrier in the table. The order of LTF is: LLTF, HT-LTF, STBC-HT-LTF. However all 3 LTFs may not be present, depending on the channel and packet information (see above).
- If first_word_invalid field of wifi_csi_info_t is true, it means that the first four bytes of CSI data is invalid due to a hardware limitation in ESP32.
- More information like RSSI, noise floor of RF, receiving time and antenna is in the rx_ctrl field.

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).

4.33.24 Wi-Fi Channel State Information Configure

To use Wi-Fi CSI, the following steps need to be done.
Chapter 4. API Guides

- 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, post necessary data to a queue and handle it from a lower priority task. Because station does not receive any packet when it is disconnected and only receives packets from AP when it is connected, it is suggested to enable sniffer mode to receive more CSI data by calling esp_wifi_set_promiscuous().

4.33.25 Wi-Fi HT20/40

ESP32 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 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 seperately. If both station and AP are negotiated to HT40, the HT40 channel should be the channel of station because the station always has higher priority than AP in ESP32. 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 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.

4.33.26 Wi-Fi QoS

ESP32 supports all the mandatory features required in WFA Wi-Fi QoS Certification.

Four ACs (Access Category) are defined in Wi-Fi specification, each AC has a 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, 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 be 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.

4.33.27 Wi-Fi AMSDU

ESP32 supports receiving and transmitting AMSDU.

4.33.28 Wi-Fi Fragment

supports Wi-Fi receiving fragment, but doesn’t support Wi-Fi transmitting fragment.

4.33.29 WPS Enrollee

ESP32 supports WPS enrollee feature in Wi-Fi mode WIFI_MODE_STA or WIFI_MODE_APSTA. Currently ESP32 supports WPS enrollee type PBC and PIN.

4.33.30 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 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 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 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.

4.33.31 How to improve Wi-Fi performance

The performance of ESP32 Wi-Fi is affected by many parameters, and there are mutual constraints between each parameter. A proper configuration 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

![Fig. 62: ESP32 datapath](image-url)
The ESP32 protocol stack is divided into four layers: Application, LWIP, Wi-Fi, and Hardware.

- During receiving, hardware puts the received packet into DMA buffer, and then transfers it into the RX buffer of Wi-Fi, 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_TCP_WND_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_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:

- **CONFIG_ESP32_WIFI_IRAM_OPT** If this option is enabled, some Wi-Fi functions are moved to IRAM, improving throughput. This increases IRAM usage by 15 kB.
- **CONFIG_ESP32_WIFI_RX_IRAM_OPT** If this option is enabled, some Wi-Fi RX functions are moved to IRAM, improving throughput. This increases IRAM usage by 16 kB.
- **CONFIG_LWIP_IRAM_OPTIMIZATION** If this option is enabled, some LWIP functions are moved to IRAM, improving throughput. This increases IRAM usage by 13 kB.

### Note:

The buffer size mentioned above is fixed as 1.6 KB.
How to configure parameters

ESP32’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 prior</th>
<th>TX prior</th>
<th>High-performance</th>
<th>RX prior</th>
<th>Default</th>
<th>Memory saving</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available memory (KB)</td>
<td>37.1</td>
<td>113.8</td>
<td>123.3</td>
<td>145.5</td>
<td>144.5</td>
<td>170.2</td>
<td>185.2</td>
</tr>
<tr>
<td>WIFI_STATIC_RX_BUFFER_NUM</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>WIFI_DYNAMIC_RX_BUFFER_NUM</td>
<td>124</td>
<td>34</td>
<td>20</td>
<td>12</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_DYNAMIC_TX_BUFFER_NUM</td>
<td>24</td>
<td>18</td>
<td>20</td>
<td>12</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_RX_BA_WIN</td>
<td>8</td>
<td>12</td>
<td>12</td>
<td>10</td>
<td>6</td>
<td>Disable</td>
<td></td>
</tr>
<tr>
<td>TCP_SND_BUF_DEFAULT</td>
<td></td>
<td></td>
<td>18</td>
<td>20</td>
<td>12</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>TCP_WND_DEFAULT (KB)</td>
<td></td>
<td></td>
<td>16</td>
<td>24</td>
<td>34</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>WIFI_IRAM_OPT</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>WIFI_RX_IRAM_OPT</td>
<td></td>
<td></td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>LWIP_IRAM_OPTIMIZATION</td>
<td></td>
<td></td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>TCP TX throughput (Mbit/s)</td>
<td>74.6</td>
<td>50.8</td>
<td>46.5</td>
<td>39.9</td>
<td>44.2</td>
<td>33.8</td>
<td>25.6</td>
</tr>
<tr>
<td>TCP RX throughput (Mbit/s)</td>
<td>63.6</td>
<td>35.5</td>
<td>42.3</td>
<td>48.5</td>
<td>40.5</td>
<td>30.1</td>
<td>27.8</td>
</tr>
<tr>
<td>UDP throughput (Mbit/s) TX</td>
<td>76.2</td>
<td>75.1</td>
<td>74.1</td>
<td>72.4</td>
<td>69.6</td>
<td>64.1</td>
<td>36.5</td>
</tr>
<tr>
<td>UDP throughput RX</td>
<td>83.1</td>
<td>66.3</td>
<td>75.1</td>
<td>75.6</td>
<td>73.1</td>
<td>65.3</td>
<td>54.7</td>
</tr>
</tbody>
</table>

Note: The test was performed with a single stream in a shielded box using an ASUS RT-N66U router. ESP32’s CPU is dual core with 240 MHz, ESP32’s flash is in QIO mode with 80 MHz.

Ranks:

- **Iperf rank** ESP32 extreme performance rank used to test extreme performance.
- **High-performance rank** The ESP32’s high-performance configuration rank, suitable for scenarios that the application occupies less memory and has high-performance requirements. In this rank, users can choose to use the RX prior rank or the TX prior rank according to the usage scenario.
- **Default rank** ESP32’s default configuration rank, the available memory, and performance are in balance.
- **Memory saving rank** This rank is suitable for scenarios where the application requires a large amount of memory, and the transceiver performance will be reduced in this rank.
- **Minimum rank** This is the minimum configuration rank of ESP32. The protocol stack only uses the necessary memory for running. It is suitable for scenarios 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` indi-
icates the number of DMA buffers at the hardware layer, increase this parameter can improve performance. The following are the recommended ranks for using PSRAM:

<table>
<thead>
<tr>
<th>Rank</th>
<th>Iperf</th>
<th>Default</th>
<th>Memory saving</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available memory (KB)</td>
<td>113.8</td>
<td>152.4</td>
<td>181.2</td>
<td>202.6</td>
</tr>
<tr>
<td>WIFI_STATIC_RX_BUFERR_NUM</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>WIFI_DYNAMIC_RX_BUFERR_NUM</td>
<td>128</td>
<td>128</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>WIFI_STATIC_TX_BUFERR_NUM</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>WIFI_RX_BA_WIN</td>
<td>16</td>
<td>16</td>
<td>8</td>
<td>Disable</td>
</tr>
<tr>
<td>TCP SND_BUF_DEFAULT (KB)</td>
<td>65</td>
<td>65</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>TCP WND_DEFAULT (KB)</td>
<td>65</td>
<td>65</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>WIFI_IRAM_OPT</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>WIFI_RX_IRAM_OPT</td>
<td>16</td>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LWIP IRAM OPTIMIZATION</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TCP TX throughput (Mbit/s)</td>
<td>37.5</td>
<td>31.7</td>
<td>21.7</td>
<td>14.6</td>
</tr>
<tr>
<td>TCP RX throughput (Mbit/s)</td>
<td>31.5</td>
<td>29.8</td>
<td>26.5</td>
<td>21.1</td>
</tr>
<tr>
<td>UDP TX throughput (Mbit/s)</td>
<td>69.1</td>
<td>31.5</td>
<td>27.1</td>
<td>24.1</td>
</tr>
<tr>
<td>UDP RX throughput (Mbit/s)</td>
<td>40.1</td>
<td>38.5</td>
<td>37.5</td>
<td>36.9</td>
</tr>
</tbody>
</table>

### 4.33.32 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)

**Fig. 63: TX Buffer Allocation**

**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:

**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 want to reduce the 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 menu-config, is used to limit the total un-freed Dynamic Rx Buffer number.</td>
</tr>
<tr>
<td>Dynamic TX Buffer</td>
<td>Dynamic</td>
<td>32</td>
<td>Yes</td>
<td>This is a kind of DMA memory. It is allocated to the heap. When the upper-layer (LwIP) sends packets to the Wi-Fi driver, it firstly allocates a ‘Dynamic TX Buffer’ and makes a copy of the upper-layer buffer. The Dynamic and Static TX Buffers are mutually exclusive.</td>
</tr>
<tr>
<td>Static TX Buffer</td>
<td>Static</td>
<td>16 * 1600Bytes</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 Buffer 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 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.

### 4.33.33 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.

```bash
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. 65: 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.

![Setting up Filters in Wireshark](image)

Click **Filter**, the top left blue button in the picture below. The *display filter* dialogue box will appear.

![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.
Fig. 68: Filter Expression Dialogue Box

Fig. 69: Filter Toolbar

Fig. 70: 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.

![Fig. 71: 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.

![Fig. 72: 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.

4.34 Wi-Fi Security
Fig. 73: Starting or Resuming the Packets Capture

Fig. 74: Saving Captured Packets
4.34.1 ESP32 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 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.

4.34.2 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.

API & Usage

`esp_wifi_set_config()` can be used to configure PMF mode by setting appropriate flags in `pmf_cfg` parameter. Currently, PMF is supported only in Station mode. While setting up a Station, configure PMF using two flags `capable` and `required` like below.

```c
wifi_config_t wifi_config = {
    .sta = {
        .ssid = EXAMPLE_WIFI_SSID,
        .password = EXAMPLE_WIFI_PASSWORD,
        .pmf_cfg = {
            .capable = true,
            .required = false
        }
    }
};
```

ESP32 supports three modes of PMF by combination of these two flags -

- PMF Optional: `.capable = true, .required = false`
- PMF Required: `.capable = true, .required = true`
- PMF Disabled: `.capable = false, .required = false`

Depending on what AP side PMF Mode is, the resulting connection will behave differently. The table below summarises all possible outcomes -
PMF Optional Mode, which is shown in the example of `wifi_confit_t`, is suggested to be used in all Station configurations. This is to take the additional security benefit of PMF whenever possible without breaking connections with legacy AP’s.

### 4.3.4.3 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**

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 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 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.

5.2 Migrate Peripherals to ESP-IDF 5.0

5.2.1 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.

5.2.2 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.

5.2.3 ADC

Previous driver/adc2_wifi_private.h has been moved to esp_private/adc2_wifi.h.
5.2.4 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.

5.2.5 Timer Group Driver

Timer Group driver has been redesigned into GPTimer, which aims to unify and simplify the usage of general purpose timer. Although it’s recommended to use the 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_DEPRECATED_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.

5.3 Migrate Build System to ESP-IDF 5.0

Please follow the **build system** guide for migrating make-based projects no longer supported in ESP-IDF v5.0.

5.4 Migrate System to ESP-IDF 5.0

5.4.1 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.

### 5.4.2 ESP Clock

The old headers `ESP32/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.

### 5.4.3 Cache Error Interrupt

The old headers `ESP32/cache_err_int.h` have been removed. Please include `esp_private/cache_err_int.h` instead.

### 5.4.4 Brownout

The header `brownout.h` has been made private. ESP-IDF developers should include `esp_private/brownout.h` instead.

### 5.4.5 Trax

The header `trax.h` has been made private. ESP-IDF developers should include `esp_private/trax.h` instead.

### 5.4.6 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/` (new include path: `ESP32/rom/*.h`).

### 5.4.7 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.

### 5.4.8 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.
Chapter 5. ESP-IDF 5.0 Migration Guides

5.4.9 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.

5.5 Migrate FreeRTOS to ESP-IDF 5.0

5.5.1 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.

5.5.2 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 COM- PILER_OPTIMIZATION_ASSERTION_LEVEL.

5.6 Migrate Ethernet Drivers to ESP-IDF 5.0

5.6.1 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:

```c
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:

```c
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:

```c
eth_duplex_t duplex_mode;
esp_eth_ioctl(eth_handle, ETH_CMD_G_DUPLEX_MODE, &duplex_mode);
```

5.6.2 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
### 5.6.3 ESP NETIF Glue Event Handlers

The `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.

### 5.7 Removed or deprecated components

Following components are removed from ESP-IDF and moved to IDF Component Registry:

- libsodium
- cbor
- jsmn
- esp_modem

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 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](https://components.espressif.com), search for the component by its name and check the versions listed on the component page.
Chapter 6

Libraries and Frameworks

6.1 Cloud Frameworks

ESP32 supports multiple cloud frameworks using agents built on top of ESP-IDF. Here are the pointers to various supported cloud frameworks’ agents and examples:

6.1.1 ESP RainMaker

ESP RainMaker is a complete solution for accelerated AIoT development. ESP RainMaker on GitHub.

6.1.2 AWS IoT

https://github.com/espressif/esp-aws-iot is an open source repository for ESP32 based on Amazon Web Services’ aws-iot-device-sdk-embedded-C.

6.1.3 Azure IoT

https://github.com/espressif/esp-azure is an open source repository for ESP32 based on Microsoft Azure’s azure-iot-sdk-c SDK.

6.1.4 Google IoT Core

https://github.com/espressif/esp-google-iot is an open source repository for ESP32 based on Google’s iot-device-sdk-embedded-c SDK.

6.1.5 Aliyun IoT

https://github.com/espressif/esp-aliyun is an open source repository for ESP32 based on Aliyun’s iotkit-embedded SDK.

6.1.6 Joylink IoT

https://github.com/espressif/esp-joylink is an open source repository for ESP32 based on Joylink’s joylink_dev_sdk SDK.
6.1.7 Tencent IoT

https://github.com/espressif/esp-welink is an open source repository for ESP32 based on Tencent’s welink SDK.

6.1.8 Tencentyun IoT

https://github.com/espressif/esp-qcloud is an open source repository for ESP32 based on Tencentyun’s qcloud-iot-sdk-embedded-c SDK.

6.1.9 Baidu IoT

https://github.com/espressif/esp-baidu-iot is an open source repository for ESP32 based on Baidu’s iot-sdk-c SDK.

6.2 Espressif’s Frameworks

Here you will find a collection of the official Espressif libraries and frameworks.

6.2.1 Espressif Audio Development Framework

The ESP-ADF is a comprehensive framework for audio applications including:

- CODEC’s HAL
- Music Players and Recorders
- Audio Processing
- Bluetooth Speakers
- Internet Radios
- Hands-free devices
- Speech Recognition

This framework is available at GitHub: ESP-ADF.

6.2.2 ESP-CSI

ESP-CSI is an experimental implementation that uses the Wi-Fi Channel State Information to detect the presence of a human body.

See ESP-CSI project for more information about it.

6.2.3 Espressif DSP Library

The library provides algorithms optimized specifically for digital signal processing applications. This library supports:

- Matrix multiplication
- Dot product
- FFT (Fast Fourier Transform)
- IIR (Infinite Impulse Response)
- FIR (Finite Impulse Response)
- Vector math operations

This library is available here: ESP-DSP library.
6.2.4 **ESP-WIFI-MESH Development Framework**

This framework is based on the ESP-WIFI-MESH protocol with the following features:

- Fast network configuration
- Stable upgrade
- Efficient debugging
- LAN control
- Various application demos

ESP-MDF.

6.2.5 **ESP-WHO**

The ESP-WHO is a face detection and recognition framework using the ESP32 and camera. To know more about the project, see [ESP-WHO on GitHub](#).

6.2.6 **ESP RainMaker**

ESP RainMaker is a complete solution for accelerated AIoT development. Using ESP RainMaker, you can create AIoT devices from the firmware to the integration with voice-assistant, phone apps and cloud backend.

ESP RainMaker on GitHub.

6.2.7 **ESP-IoT-Solution**

ESP-IoT-Solution contains commonly used device drivers and code frameworks when developing IoT systems. The device drivers and code frameworks within the ESP-IoT-Solution are organized as separate components, allowing them to be easily integrated into an ESP-IDF project.

ESP-IoT-Solution includes:

- Device drivers for sensors, display, audio, GUI, input, actuators, etc.
- Framework and documentation for low power, security, storage, etc.
- Guide for Espressif open source solutions from practical application point.

ESP-IoT-Solution on GitHub.

6.2.8 **ESP-Protocols**

ESP-Protocols repository contains collection of protocol components for ESP-IDF. The code within the ESP-Protocols is organized into separate components, allowing them to be easily integrated into an ESP-IDF project. In addition to that, each component is available in [IDF Component Registry](#).

ESP-Protocols components:

- `esp_modem` enables connectivity with GSM/LTE modems using AT commands or PPP protocol, see the [esp_modem documentation](#).
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.

```c
void function1()
{
    do_one_thing();
    do_another_thing();
        // INCORRECT, don't place empty line here
}

void function2()
{
    // place empty line here
    int var = 0;
    while (var < SOME_CONSTANT) {
        do_stuff(&var);
            // INCORRECT, don't use an empty line here
    }
}
```

(continues on next page)
The maximum line length is 120 characters as long as it doesn’t seriously affect the readability.

**Horizontal Space** Always add single space after conditional and loop keywords:

```c
if (condition) {    // correct
  // ...
}
switch (n) {        // correct
  case 0:
    // ...
}
for (int i = 0; i < CONST; ++i) {    // INCORRECT
  // ...
}
```

Add single space around binary operators. No space is necessary for unary operators. It is okay to drop space around multiply and divide operators:

```c
const int y = y0 + (x - x0) * (y1 - y0) / (x1 - x0);    // correct
const int y = y0 + (x - x0)*(y1 - y0)/(x1 - x0);       // also okay
int y_cur = -y;
  ++y_cur;
const int y = y0 + (x-x0)* (y1-y0)/(x1-x0);         // INCORRECT
```

No space is necessary around . and -> operators.

Sometimes adding horizontal space within a line can help make code more readable. For example, you can add space to align function arguments:

```c
esp_rom_gpio_connect_in_signal(PIN_CAM_D6, I2S0I_DATA_IN14_IDX, false);
esp_rom_gpio_connect_in_signal(PIN_CAM_D7, I2S0I_DATA_IN15_IDX, false);
esp_rom_gpio_connect_in_signal(PIN_CAM_HREF, I2S0I_H_ENABLE_IDX, false);
esp_rom_gpio_connect_in_signal(PIN_CAM_PCLK, I2S0I_DATA_IN15_IDX, false);
```

Note however that if someone goes to add new line with a longer identifier as first argument (e.g. PIN_CAM_VSYNC), it will not fit. So other lines would have to be realigned, adding meaningless changes to the commit.

Therefore, use horizontal alignment sparingly, especially if you expect new lines to be added to the list later.

Never use TAB characters for horizontal alignment.

Never add trailing whitespace at the end of the line.

**Braces**

- Function definition should have a brace on a separate line:

```c
// This is correct:
void function(int arg)
{
}
```
Chapter 7. Contributions Guide

(continued from previous page)

// NOT like this:
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...
    // load_resources(); // WHY is this thing commented, asks...
    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...
    // 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):

```bash
git rebase --exec 'git diff-tree --no-commit-id --name-only -r HEAD | xargs dos2unix & & git commit --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 the `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>
#endif __cplusplus
extern "C" { 
#endif /* declarations go here */
#endif __cplusplus
```

**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.`)
Chapter 7. Contributions Guide

- 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:

```cpp
class ForExample {
public:
    // first constructors, then default constructor, then destructor
    ForExample(double example_factor_arg);
    ForExample();
    ~ForExample();

    // then remaining public methods
    set_example_factor(double example_factor_arg);

    // then public member variables
    uint32_t public_data_member;

private:
    // first private methods
    void internal_method();

    // then private member variables
    double example_factor;
};
```

**Spacing**

- Don’t indent inside namespaces.
- Put public, protected and private labels at the same indentation level as the corresponding class label.
Simple Example

```cpp
// file spaceship.h
#ifndef SPACESHIP_H_
#define SPACESHIP_H_

#include <cstdlib>
namespace spaceships {

class SpaceShip {
public:
    SpaceShip(size_t crew);
    size_t get_crew_size() const;

private:
    const size_t crew;
};

class SpaceShuttle : public SpaceShip {
public:
    SpaceShuttle();
};

class Sojuz : public SpaceShip {
public:
    Sojuz();
};
template<typename T>
class CargoShip {
public:
    CargoShip(const T &cargo);

private:
    T cargo;
};
} // namespace spaceships
#endif // SPACESHIP_H_

// file spaceship.cpp
#include "spaceship.h"
namespace spaceships {

// Putting the curly braces in the same line for constructors is OK if it only...
// initializes
// values in the initializer list
SpaceShip::SpaceShip(size_t crew) : crew(crew) { }

size_t SpaceShip::get_crew_size() const
{
    return crew;
}

SpaceShuttle::SpaceShuttle() : SpaceShip(7)
{
    // doing further initialization
}

Sojuz::Sojuz() : SpaceShip(3)
{

(continues on next page)
```
// doing further initialization
}

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 3.6.1 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`.

```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.

**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 levels will be shown.

5. When documenting a `define` as well as members of a `struct` or `enum`, place specific comment like below after each member:

```c
typedef enum {
  NVS_READONLY,  /* Read only */
  NVS_READWRITE /* Read and write */
} nvs_open_mode;
```

6. To provide well formatted lists, break the line after command (like `@return` in example below).

```c
* @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`.

```c
/*
@attention
1. This API only impact WIFI_MODE_STA or WIFI_MODE_APSTA mode
2. If the ESP32 is connected to an AP, call esp_wifi_disconnect to disconnect.
*/
```

Above example also shows how to use a numbered list.

3. To provide common description to a group of similar functions, enclose them using `/** @}*/` and `/** @}*/` markup commands:

```c
/** @}*/
/**
 * @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.
Note: Code snippets, notes, links, etc. will not make it to the documentation, if not enclosed in a comment block associated with one of documented objects.

6. Prepare one or more complete code examples together with description. Place description to a separate file README.md in specific folder of examples directory.

Standardize Document Format

When it comes to text, please follow guidelines below to provide well formatted Markdown (.md) or reST (.rst) documents.

1. Please ensure that one paragraph is written in one line. Don’t break lines like below. Breaking lines to enhance readability is only suitable for writing codes. To make the text easier to read, it is recommended to place an empty line to separate the paragraph.

```
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 is 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).
```

Fig. 1: One line for one paragraph (click to enlarge)

```
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 is 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).
```

Fig. 2: No line breaks within the same paragraph (click to enlarge)

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:

build-docs build

or for specific target and language with:

build-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.
Chapter 7. Contributions Guide

• 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 Pull Request which includes an example, it’s OK not to include this file initially. The details can be discussed as part of the Pull Request.

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:

```bash
## 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:

```bash
.. include-build-file:: inc/esp_wifi.inc
```

For example see `docs/en/api-reference/network/esp_wifi.rst`
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 .. doxygendefine:: 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:

```latex
* :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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   “Documentation” means any non-software portion of a Contribution.

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IF THE DISCLAIMER AND DAMAGE WAIVER MENTIONED IN SECTION 4 AND SECTION 5 CANNOT BE GIVEN LEGAL EFFECT UNDER APPLICABLE LOCAL LAW, REVIEWING COURTS SHALL APPLY LOCAL LAW THAT MOST CLOSELY APPROXIMATES AN ABSOLUTE WAIVER OF ALL CIVIL LIABILITY IN CONNECTION WITH THE CONTRIBUTION.

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.
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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

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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: 2015-2021 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: 2015-2021 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: 2019-2021 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:
**Version String** | **Meaning**
--- | ---
```
v3.2-dev-306-gbeb3611ca
```
Master branch pre-release.
- `v3.2-dev` - in development for version 3.2.
- `306` - number of commits after v3.2 development started.
- `beb3611ca` - commit identifier.

```
v3.0.2
```
Stable release, tagged v3.0.2.

```
v3.1-beta1-75-g346d6b0ea
```
Beta version in development (on a release branch).
- `v3.1-beta1` - pre-release tag.
- `75` - number of commits after the pre-release beta tag was assigned.
- `346d6b0ea` - commit identifier.

```
v3.0.1-dirty
```
Stable release, tagged v3.0.1.
- `dirty` means that there are modifications in the local ESP-IDF directory.

### 8.6 Git Workflow

The development (Git) workflow of the Espressif ESP-IDF team is as follows:

- New work is always added on the master branch (latest version) first. The ESP-IDF version on master is always tagged with `-dev` (for “in development”), for example v3.1-dev.
- Changes are first added to an internal Git repository for code review and testing but are pushed to GitHub after automated testing passes.
- When a new version (developed on master) becomes feature complete and “beta” quality, a new branch is made for the release, for example release/v3.1. A pre-release tag is also created, for example v3.1-beta1. You can see a full list of branches and a list of tags on GitHub. Beta pre-releases have release notes which may include a significant number of Known Issues.
- As testing of the beta version progresses, bug fixes will be added to both the master branch and the release branch. New features for the next release may start being added to master at the same time.
- Once testing is nearly complete a new release candidate is tagged on the release branch, for example v3.1-rc1. This is still a pre-release version.
- If no more significant bugs are found or reported, then the final Major or Minor Version is tagged, for example v3.1. This version appears on the Releases page.
- As bugs are reported in released versions, the fixes will continue to be committed to the same release branch.
- Regular bugfix releases are made from the same release branch. After manual testing is complete, a bugfix release is tagged (i.e. v3.1.1) and appears on the Releases page.

### 8.7 Updating ESP-IDF

Updating ESP-IDF depends on which version(s) you wish to follow:

- *Updating to Stable Release* is recommended for production use.
• **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:

```bash
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?

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
Chapter 9. Resources

9.1.3 Configuration

Please go through the official PlatformIO configuration guide for ESP-IDF.

9.1.4 Tutorials

• ESP-IDF and ESP32-DevKitC: debugging, unit testing, project analysis

9.1.5 Project Examples

Please check ESP-IDF page in the official PlatformIO documentation

9.1.6 Next Steps

Here are some useful links for exploring the PlatformIO ecosystem:

• Learn more about integrations with other IDEs/Text Editors
• Get help from PlatformIO community

9.2 Useful Links

• The esp32.com forum is a place to ask questions and find community resources.
• Check the Issues section on GitHub if you find a bug or have a feature request. Please check existing Issues before opening a new one.
• A comprehensive collection of solutions, practical applications, components and drivers based on ESP-IDF is available in ESP IoT Solution repository. In most of cases descriptions are provided both in English and in 中文.
• To develop applications using Arduino platform, refer to Arduino core for the ESP32, ESP32-S2 and ESP32-C3.
• Several books have been written about ESP32 and they are listed on Espressif web site.
• If you’re interested in contributing to ESP-IDF, please check the Contributions Guide.
• For additional ESP32 product related information, please refer to documentation section of Espressif site.
• Download latest and previous versions of this documentation in PDF and HTML format.
Chapter 10

Copyrights and Licenses

10.1 Software Copyrights

All original source code in this repository is Copyright (C) 2015-2021 Espressif Systems. This source code is licensed under the Apache License 2.0 as described in the file LICENSE.

Additional third party copyrighted code is included under the following licenses.

Where source code headers specify Copyright & License information, this information takes precedence over the summaries made here.

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.

- **Newlib** is licensed under the BSD License and is Copyright of various parties, as described in COPYING.NEWLIB.
- **Xtensa header files** are Copyright (C) 2013 Tensilica Inc and are licensed under the MIT License as reproduced in the individual header files.
- Original parts of **FreeRTOS** (components/freertos) are Copyright (C) 2017 Amazon.com, Inc. or its affiliates are licensed under the MIT License, as described in license.txt.
- Original parts of **LWIP** (components/lwip) are Copyright (C) 2001, 2002 Swedish Institute of Computer Science and are licensed under the BSD License as described in COPYING file.
- **wpa_supplicant** Copyright (c) 2003-2005 Jouni Malinen and licensed under the BSD license.
- **FreeBSD net80211** Copyright (c) 2004-2008 Sam Leffler, Ernno Consulting and licensed under the BSD license.
- **argtable3** argument parsing library Copyright (C) 1998-2001,2003-2011,2013 Stewart Heitmann and licensed under 3-clause BSD license.
- **linenoise** line editing library Copyright (c) 2010-2014 Salvatore Sanfilippo, Copyright (c) 2010-2013 Pieter Noordhuis, licensed under 2-clause BSD license.
- **libcoap** COAP library Copyright (c) 2010-2017 Olaf Bergmann and others, is licensed under 2-clause BSD license as described in LICENSE file and COPYING file.
- **libexpat** XML parsing library Copyright (c) 1998-2000 Thai Open Source Software Center Ltd and Clark Cooper, Copyright (c) 2001-2017 Expat maintainers, is licensed under MIT license as described in COPYING file.
- **FatFS** library, Copyright (C) 2017 ChaN, is licensed under a BSD-style license.
- **cJSON** library, Copyright (c) 2009-2017 Dave Gamble and cJSON contributors, is licensed under MIT license as described in LICENSE file.
- **micro-ecc** library, Copyright (c) 2014 Kenneth MacKay, is licensed under 2-clause BSD license.
• nghttp2 library, Copyright (c) 2012, 2014, 2015, 2016 Tatsuhiro Tsujikawa, Copyright (c) 2012, 2014, 2015, 2016 nghttp2 contributors, is licensed under MIT license as described in COPYING file.
• Mbed TLS library, Copyright (C) 2006-2018 ARM Limited, is licensed under Apache License 2.0 as described in LICENSE file.
• SPIFFS library, Copyright (c) 2013-2017 Peter Andersson, is licensed under MIT license as described in LICENSE file.
• SD/MMC driver is derived from OpenBSD SD/MMC driver, Copyright (c) 2006 Uwe Stuehler, and is licensed under BSD license.
• Asio, Copyright (c) 2003-2018 Christopher M. Kohlhoff is licensed under the Boost Software License as described in COPYING file.
• ESP-MQTTPackage (contiki-mqtt) - Copyright (c) 2014, Stephen Robinson, MQTT-ESP - Tuan PM <tuanpm at live dot com> is licensed under Apache License 2.0 as described in LICENSE file.
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• openthread, Copyright (c) The OpenThread Authors, is licensed under BSD License as described in LICENSE file.
• UBSAN runtime —Copyright (c) 2016, Linaro Limited and Jiří Zárevúcky, licensed under the BSD 2-clause license.
• freemodbus Copyright (c) 2006-2013 Christian Walter, Armink and licensed under the BSD license.

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.

• esptool.py is Copyright (C) 2014-2016 Fredrik Ahlberg, Angus Gratton and is licensed under the GNU General Public License v2, as described in LICENSE file.

10.1.3 Documentation

• HTML version of the ESP-IDF Programming Guide uses the Sphinx theme sphinx_idf_theme, which is Copyright (c) 2013-2020 Dave Snider, Read the Docs, Inc. & contributors, and Espressif Systems (Shanghai) CO., LTD. It is based on sphinx_rtd_theme. Both are licensed under MIT license.

10.2 ROM Source Code Copyrights

ESP32, ESP8684, ESP32-S and ESP32-C Series SoCs mask ROM hardware includes binaries compiled from portions of the following third party software:

• Newlib, licensed under the BSD License and is Copyright of various parties, as described in COPYING.NEWLIB.
• Xtensa libhal, Copyright (c) Tensilica Inc and licensed under the MIT license (see below).
• TinyBasic Plus, Copyright Mike Field & Scott Lawrence and licensed under the MIT license (see below).
• miniz, by Rich Geldreich - placed into the public domain.
• wpa_supplicant Copyright (c) 2003-2005 Jouni Malinen and licensed under the BSD license.
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10.4  TinyBasic Plus MIT License

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10.5  TJpgDec License

TJpgDec - Tiny JPEG Decompressor R0.01 (C)ChaN, 2011 The TJpgDec is a generic JPEG decompressor module for tiny embedded systems. This is a free software that opened for education, research and commercial developments under license policy of following terms.

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- No restriction on use. You can use, modify and redistribute it for personal, non-profit or commercial products UNDER YOUR RESPONSIBILITY.
- Redistributions of source code must retain the above copyright notice.
Chapter 11

About

This is documentation of **ESP-IDF**, the framework to develop applications for **ESP32** chip by **Espressif**.

The ESP32 is 2.4 GHz Wi-Fi and Bluetooth combo, which integrates one or two Xtensa® 32-bit LX6 CPU, with up to 600 DMIPS processing power.

![Diagram](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 using Windows, Linux and Mac OS 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

Overview

In certain situations, execution of the program cannot be continued in a well defined way. In ESP-IDF, these situations include:

- genindex
eSetValueWithoutOverwrite (C++ enumerator), 1284
eSleepModeStatus (C++ enum), 1284
ESP_A2D_AUDIO_CFG_EVT (C++ enumerator), 251
ESP_A2D_AUDIO_STATE_EVT (C++ enumerator), 251
ESP_A2D_AUDIO_STATE_REMOTE_SUSPEND (C++ enumerator), 250
ESP_A2D_AUDIO_STATE_STARTED (C++ enumerator), 250
ESP_A2D_AUDIO_STATE_STOPPED (C++ enumerator), 250
esp_a2d_audio_state_t (C++ enum), 250
esp_a2d_cb_event_t (C++ enum), 251
esp_a2d_cb_param_t (C++ union), 247
esp_a2d_cb_param_t::a2d_audio_cfg_param (C++ class), 247
esp_a2d_cb_param_t::a2d_audio_cfg_param::mcc (C++ member), 248
esp_a2d_cb_param_t::a2d_audio_cfg_param::remote_bda (C++ member), 248
esp_a2d_cb_param_t::a2d_audio_stat_param (C++ class), 248
esp_a2d_cb_param_t::a2d_audio_stat_param::remote_bda (C++ member), 248
esp_a2d_cb_param_t::a2d_conn_stat_param (C++ class), 248
esp_a2d_cb_param_t::a2d_conn_stat_param::disc_rsp (C++ member), 248
esp_a2d_cb_param_t::a2d_conn_stat_param::remote_bda (C++ member), 248
esp_a2d_cb_param_t::a2d_conn_stat_param::state (C++ member), 248
esp_a2d_cb_param_t::a2d_prof_stat_param (C++ class), 248
esp_a2d_cb_param_t::a2d_prof_stat_param (C++ member), 248
esp_a2d_cb_param_t::a2d_prof_stat_param (C++ class), 248
esp_a2d_cb_param_t::a2d_prof_stat_param::init_stat (C++ member), 248
eSetValueWithOverwrite (C++ enumerator), 1284
DPP_BOOTSTRAP_NFC_URI (C++ enumerator), 601
DPP_BOOTSTRAP_PKEK (C++ enumerator), 601
DPP_BOOTSTRAP_QR_CODE (C++ enumerator), 601
dpp_bootstrap_type (C++ enum), 601
ESP_A2D_CIE_LEN_ATRAC (C macro), 249
ESP_A2D_CIE_LEN_M12 (C macro), 249
ESP_A2D_CIE_LEN_M12 (C macro), 249
DAC_CW_PHASE_180 (C++ enumerator), 675
dac_cw_phase_t (C++ enum), 675
DAC_CW_SCALE_1 (C++ enumerator), 674
DAC_CW_SCALE_2 (C++ enumerator), 674
DAC_CW_SCALE_4 (C++ enumerator), 674
DAC_CW_SCALE_8 (C++ enumerator), 674
dac_cw_scale_t (C++ enum), 674
DAC_GPIO25_CHANNEL (C macro), 674
DAC_GPIO26_CHANNEL (C macro), 674
dac_i2s_enable (C++ function), 672
dac_output_disable (C++ function), 673
dac_output_enable (C++ function), 673
dac_pad_get_io_num (C++ function), 673
DEFAULT_HTTP_BUF_SIZE (C macro), 972
DEL_DEV_ADDR_FLAG (C macro), 342
DEL_DEV_UUID_FLAG (C macro), 342
DAC_GPIO26_CHANNEL (C macro), 674
dac_i2s_enable (C++ function), 672
ESP_A2D_CIE_LEN_M24 (C macro), 249
ESP_A2D_CIE_LEN_SBC (C macro), 249
ESP_A2D_CONNECTION_STATE_CONNECTED (C++ enumerator), 250
ESP_A2D_CONNECTION_STATE_CONNECTING (C++ enumerator), 250
ESP_A2D_CONNECTION_STATE_DISCONNECTED (C++ enumerator), 250
ESP_A2D_MEDIA_CTRL_SUSPEND (C++ function), 251
ESP_A2D_MEDIA_CTRL_STOP (C++ function), 246
ESP_A2D_MEDIA_CTRL_START (C++ function), 246
ESP_A2D_MEDIA_CTRL_CHECK_SRC_RDY (C++ function), 246
ESP_A2D_MEDIA_CTRL_ACK (C++ function), 246
ESP_A2D_MEDIA_CTRL_ACK_EVT (C++ function), 246
ESP_A2D_MEDIA_CTRL_ACK_BUSY (C++ function), 246
esp_a2d_media_ctrl_ack_t (C++ type), 249
esp_a2d_media_ctrl (C++ member), 250
esp_a2d_register_callback (C++ function), 245
esp_a2d_sink_connect (C++ function), 246
esp_a2d_sink_data_cb_t (C++ type), 249
esp_a2d_sink_deinit (C++ function), 246
esp_a2d_sink_disconnect (C++ function), 246
esp_a2d_sink_init (C++ function), 245
esp_a2d_sink_register_data_callback (C++ function), 245
esp_a2d_source_connect (C++ function), 247
esp_a2d_source_data_cb_t (C++ type), 249
esp_a2d_source_deinit (C++ function), 246
esp_a2d_source_disconnect (C++ function), 247
esp_a2d_source_init (C++ function), 246
esp_a2d_source_register_data_callback (C++ function), 247
esp_adc_cal_characteristics_t (C++ class), 670
esp_adc_cal_characteristics_t::adc_num (C++ member), 670
esp_adc_cal_characteristics_t::atten (C++ member), 670
esp_adc_cal_characteristics_t::bit_width (C++ member), 670
esp_adc_cal_characteristics_t::coeff_a (C++ member), 670
esp_adc_cal_characteristics_t::coeff_b (C++ member), 670
esp_adc_cal_characteristics_t::high_curve (C++ member), 670
esp_adc_cal_characteristics_t::low_curve (C++ member), 670
esp_adc_cal_characteristics_t::version (C++ member), 670
esp_adc_cal_characteristics_t::vref (C++ member), 670
esp_adc_cal_characterize (C++ function), 669
esp_adc_cal_check_efuse (C++ function), 669
esp_adc_cal_get_voltage (C++ function), 669
esp_adc_cal_raw_to_voltage (C++ function), 669
ESP_ADC_CAL_DEFAULT_VREF (C++ member), 670
ESP_ADC_CAL_efuse_tp (C++ member), 670
ESP_ADC_CAL_efuse_vref (C++ member), 670
ESP_ADC_CAL_efuse_vref (C++ member), 670
ESP_ADC_CAL_MAX (C++ member), 670
ESP_ADC_CAL_NOT_SUPPORTED (C++ member), 670
esp_adc_cal_value_t (C++ type), 1380
ESP_APP_DESC_MAGIC_WORD (C macro), 1197

Index
Index

(C++ class), 257
ESP_AVRC_CT_REMOTE_FEATURES_EVT (C++
esp_avrc_ct_cb_param_t::avrc_ct_meta_rsp_param::attr_id
enumerator), 264
(C++ member), 257
esp_avrc_ct_send_get_rn_capabilities_cmd
esp_avrc_ct_cb_param_t::avrc_ct_meta_rsp_param::attr_length
(C++ function), 252
(C++ member), 257
esp_avrc_ct_send_metadata_cmd (C++ funcesp_avrc_ct_cb_param_t::avrc_ct_meta_rsp_param::attr_text
tion), 253
(C++ member), 257
esp_avrc_ct_send_passthrough_cmd (C++
esp_avrc_ct_cb_param_t::avrc_ct_psth_rsp_paramfunction), 253
(C++ class), 257
esp_avrc_ct_send_register_notification_cmd
esp_avrc_ct_cb_param_t::avrc_ct_psth_rsp_param::key_code
(C++ function), 252
(C++ member), 257
esp_avrc_ct_send_set_absolute_volume_cmd
esp_avrc_ct_cb_param_t::avrc_ct_psth_rsp_param::key_state
(C++ function), 253
(C++ member), 257
esp_avrc_ct_send_set_player_value_cmd
esp_avrc_ct_cb_param_t::avrc_ct_psth_rsp_param::tl
(C++ function), 252
ESP_AVRC_CT_SET_ABSOLUTE_VOLUME_RSP_EVT
(C++ member), 257
esp_avrc_ct_cb_param_t::avrc_ct_rmt_feats_param
(C++ enumerator), 264
(C++ class), 257
ESP_AVRC_FEAT_ADV_CTRL (C++ enumerator),
esp_avrc_ct_cb_param_t::avrc_ct_rmt_feats_param::feat_mask
260
(C++ member), 257
ESP_AVRC_FEAT_BROWSE (C++ enumerator), 260
esp_avrc_ct_cb_param_t::avrc_ct_rmt_feats_param::remote_bda
ESP_AVRC_FEAT_FLAG_BROWSING (C++ enumer(C++ member), 257
ator), 261
esp_avrc_ct_cb_param_t::avrc_ct_rmt_feats_param::tg_feat_flag
ESP_AVRC_FEAT_FLAG_CAT1 (C++ enumerator),
(C++ member), 257
260
esp_avrc_ct_cb_param_t::avrc_ct_set_volume_rsp_param
ESP_AVRC_FEAT_FLAG_CAT2 (C++ enumerator),
(C++ class), 257
260
esp_avrc_ct_cb_param_t::avrc_ct_set_volume_rsp_param::volume
ESP_AVRC_FEAT_FLAG_CAT3 (C++ enumerator),
(C++ member), 258
260
esp_avrc_ct_cb_param_t::change_ntf
ESP_AVRC_FEAT_FLAG_CAT4 (C++ enumerator),
(C++ member), 256
261
esp_avrc_ct_cb_param_t::conn_stat
ESP_AVRC_FEAT_FLAG_COVER_ART_GET_IMAGE
(C++ member), 256
(C++ enumerator), 261
esp_avrc_ct_cb_param_t::get_rn_caps_rspESP_AVRC_FEAT_FLAG_COVER_ART_GET_IMAGE_PROP
(C++ member), 256
(C++ enumerator), 261
esp_avrc_ct_cb_param_t::meta_rsp (C++ ESP_AVRC_FEAT_FLAG_COVER_ART_GET_LINKED_THUMBNAIL
member), 256
(C++ enumerator), 261
esp_avrc_ct_cb_param_t::psth_rsp (C++ ESP_AVRC_FEAT_META_DATA (C++ enumerator),
member), 256
260
esp_avrc_ct_cb_param_t::rmt_feats
ESP_AVRC_FEAT_RCCT (C++ enumerator), 260
(C++ member), 256
ESP_AVRC_FEAT_RCTG (C++ enumerator), 260
esp_avrc_ct_cb_param_t::set_volume_rsp ESP_AVRC_FEAT_VENDOR (C++ enumerator), 260
(C++ member), 256
esp_avrc_feature_flag_t (C++ enum), 260
esp_avrc_ct_cb_t (C++ type), 260
esp_avrc_features_t (C++ enum), 260
ESP_AVRC_CT_CHANGE_NOTIFY_EVT (C++ enu- ESP_AVRC_MD_ATTR_ALBUM (C++ enumerator),
265
merator), 264
ESP_AVRC_CT_CONNECTION_STATE_EVT (C++ ESP_AVRC_MD_ATTR_ARTIST (C++ enumerator),
265
enumerator), 264
esp_avrc_ct_deinit (C++ function), 252
ESP_AVRC_MD_ATTR_GENRE (C++ enumerator),
ESP_AVRC_CT_GET_RN_CAPABILITIES_RSP_EVT
265
(C++ enumerator), 264
esp_avrc_md_attr_mask_t (C++ enum), 265
esp_avrc_ct_init (C++ function), 252
ESP_AVRC_MD_ATTR_NUM_TRACKS (C++ enumerESP_AVRC_CT_METADATA_RSP_EVT (C++ enuator), 265
merator), 264
ESP_AVRC_MD_ATTR_PLAYING_TIME (C++ enuESP_AVRC_CT_PASSTHROUGH_RSP_EVT (C++
merator), 265
enumerator), 264
ESP_AVRC_MD_ATTR_TITLE (C++ enumerator),
ESP_AVRC_CT_PLAY_STATUS_RSP_EVT (C++
265
enumerator), 264
ESP_AVRC_MD_ATTR_TRACK_NUM (C++ enumeraesp_avrc_ct_register_callback (C++ functor), 265
tion), 251
ESP_AVRC_PLAYBACK_ERROR (C++ enumerator),

Espressif Systems

2141
Submit Document Feedback

Release v5.0-dev-1077-g397639d


ESP_AVRC_PLAYBACK_FWDSEEK (C++ enumerator, 268)
ESP_AVRC_PLAYBACK_PAUSED (C++ enumerator, 268)
ESP_AVRC_PLAYBACK_PLAYING (C++ enumerator, 268)
ESP_AVRC_PLAYBACK_REVSEEK (C++ enumerator, 268)
esp_avrc_playback_stat_t (C++ enum, 268)
esp_avrc_psth_bit_mask_t (C++ enumerator, 263)
esp_avrc_psth_bit_mask_t::bits (C++ member, 259)
esp_avrc_psth_bit_mask_t::class (C++ class, 259)
esp_avrc_psth_bit_mask_t::function (C++ function, 254)
ESP_AVRC_PS_SHUFFLE_ALL (C++ enumerator, 267)
ESP_AVRC_PS_SHUFFLE_GROUP (C++ enumerator, 267)
ESP_AVRC_PS_SHUFFLE_MODE (C++ enumerator, 266)
ESP_AVRC_PS_SHUFFLE_OFF (C++ enumerator, 267)
ESP_AVRC_PT_CMD_F1 (C++ enumerator, 263)
ESP_AVRC_PT_CMD_F2 (C++ enumerator, 263)
ESP_AVRC_PT_CMD_F3 (C++ enumerator, 263)
ESP_AVRC_PT_CMD_F4 (C++ enumerator, 263)
ESP_AVRC_PT_CMD_F5 (C++ enumerator, 263)
ESP_AVRC_PT_CMD_FAST_FORWARD (C++ enumerator, 263)
ESP_AVRC_PT_CMD_FAV_MENU (C++ enumerator, 263)
ESP_AVRC_PT_CMD_FORWARD (C++ enumerator, 263)
ESP_AVRC_PT_CMD_HELP (C++ enumerator, 263)
ESP_AVRC_PT_CMD_INPUT_GEL (C++ enumerator, 263)
ESP_AVRC_PT_CMD_LEFT (C++ enumerator, 261)
ESP_AVRC_PT_CMD_LEFT_DOWN (C++ enumerator, 263)
ESP_AVRC_PT_CMD_LEFT_UP (C++ enumerator, 263)
ESP_AVRC_PT_CMD_LEFT (C++ enumerator, 263)
ESP_AVRC_PT_CMD_MUTE (C++ enumerator, 262)
ESP_AVRC_PT_CMD_PAGE_DOWN (C++ enumerator, 262)
ESP_AVRC_PT_CMD_PAGE_UP (C++ enumerator, 262)
ESP_AVRC_PT_CMD_POWER (C++ enumerator, 262)
ESP_AVRC_PT_CMD_PAUSE (C++ enumerator, 262)
ESP_AVRC_PT_CMD_PLAY (C++ enumerator, 263)
ESP_AVRC_PT_CMD_POWER (C++ enumerator, 262)
ESP_AVRC_PT_CMD_PREV_CHAN (C++ enumerator, 262)
ESP_AVRC_PT_CMD_STOP (C++ enumerator, 262)
ESP_AVRC_PT_CMD_STOP (C++ enumerator, 262)
ESP_AVRC_PT_CMD_STOP (C++ enumerator, 262)
ESP_AVRC_PT_CMD_STOP (C++ enumerator, 262)
ESP_AVRC_PT_CMD_ALL (C++ enumerator, 262)
ESP_AVRC_PT_CMD_ALL (C++ enumerator, 262)
ESP_AVRC_PT_CMD_ALL (C++ enumerator, 262)
ESP_AVRC_PT_CMD_ALL (C++ enumerator, 262)
ESP_AVRC_PT_CMD_ALL (C++ enumerator, 262)
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ESP_AVRC_PT_CMD_ALL (C++ enumerator, 262)
ESP_AVRC_PT_CMD_ALL (C++ enumerator, 262)
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ESP_AVRC_PT_CMD_ALL (C++ enumerator, 262)
ESP_AVRC_PT_CMD_ALL (C++ enumerator, 262)
ESP_AVRC_PT_CMD_ALL (C++ enumerator, 262)
ESP_AVRC_PT_CMD_ALL (C++ enumerator, 262)
ESP_AVRC_PT_CMD_ALL (C++ enumerator, 262)
ESP_AVRC_PT_CMD_RECORD (C++ enumerator), 263
ESP_AVRC_PT_CMD_REWIND (C++ enumerator), 263
ESP_AVRC_PT_CMD_RIGHT (C++ enumerator), 261
ESP_AVRC_PT_CMD_RIGHT_DOWN (C++ enumerator), 261
ESP_AVRC_PT_CMD_RIGHT_UP (C++ enumerator), 261
ESP_AVRC_PT_CMD_ROOT_MENU (C++ enumerator), 261
ESP_AVRC_PT_CMD_SELECT (C++ enumerator), 261
ESP_AVRC_PT_CMD_SETUPLICATE (C++ enumerator), 262
ESP_AVRC_PT_CMD_SOUND_SEL (C++ enumerator), 262
ESP_AVRC_PT_CMD_STATE_PRESSED (C++ enumera
tor), 264
ESP_AVRC_PT_CMD_STATE_RELEASED (C++ enumera
tor), 264
ESP_AVRC_PT_CMD_VOL_DOWN (C++ enumerator), 262
ESP_AVRC_PT_CMD_VOL_UP (C++ enumerator), 261
ESP_AVRC_PT_CMD_VENDOR (C++ enumerator), 261
ESP_AVRC_PT_CMD_VOLUME (C++ enumerator), 264

esp_avrc_pt_cmd_t (C++ enum), 264
ESP_AVRC_PT_CMD_STOP (C++ enumerator), 263
ESP_AVRC_PT_CMD_SUBPICT (C++ enumerator), 263
esp_avrc_pt_cmd_t (C++ enum), 261
ESP_AVRC_PT_CMD_UP (C++ enumerator), 261
ESP_AVRC_PT_CMD_VENDOR (C++ enumerator), 261

esp_avrc_rn_param_t::batt (C++ member), 256
esp_avrc_rn_param_t::elm_id (C++ member), 256
esp_avrc_rn_param_t::play_pos (C++ member), 256
esp_avrc_rn_param_t::playback (C++ member), 256
esp_avrc_rn_param_t::volume (C++ member), 256
ESP_AVRC_RN_PLAY_POS_CHANGED (C++ enumera
tor), 265
ESP_AVRC_RN_PLAY_STATUS_CHANGE (C++ enumera
tor), 265
ESP_AVRC_RN_RSP_CHANGED (C++ enumerator), 266
ESP_AVRC_RN_RSP_INTERIM (C++ enumerator), 266
esp_avrc_rn_rsp_t (C++ enum), 266
ESP_AVRC_RN_SYSTEM_STATUS_CHANGE (C++ enumera
tor), 265
ESP_AVRC_RN_VOLUME_CHANGE (C++ enumerator), 265
ESP_AVRC_RSP_ACCEPT (C++ enumerator), 267
ESP_AVRC_RSP_CHANGED (C++ enumerator), 267
ESP_AVRC_RSP_IMPL_STBL (C++ enumerator), 267
ESP_AVRC_RSP_IN_TRANS (C++ enumerator), 267
ESP_AVRC_RSP_INTERIM (C++ enumerator), 267
ESP_AVRC_RSP_NOT_IMPL (C++ enumerator), 267
ESP_AVRC_RSP_REJECT (C++ enumerator), 267
esp_avrc_rsp_t (C++ enum), 267
esp_avrc_set_app_value_param_t (C++ class), 259
esp_avrc_set_app_value_param_t::attr_id (C++
member), 260
esp_avrc_set_app_value_param_t::attr_val (C++
member), 260
esp_avrc_tcp_event_ids_t (C++ enum), 265
esp_avrc_tcp_event_bit_mask_operation (C++ func
tion), 255
esp_avrc_tcp_event_cap_mask_t (C++ class), 259
esp_avrc_tcp_event_cap_mask_t::bits (C++ mem
er), 259
esp_avrc_tcp_event_cap_t (C++ enum), 266
ESP_AVRC_TCP_MAX_EVT (C++ enumerator), 266
ESP_AVRC_TG_CHANGE (C++ enumerator), 265
esp_avrc_tg_tcb_callback_param_t (C++ union), 255
Index
ESP_BLE_ADV_FLAG_BREDR_NOT_SPT (C
macro), 170
ESP_BLE_ADV_FLAG_DMT_HOST_SPT (C macro),
170
ESP_BLE_ADV_FLAG_DMT_CONTROLLER_SPT (C
macro), 170
ESP_BLE_ADV_FLAG_DMT_HOST_SPT (C macro),
170
ESP_BLE_ADV_FLAG_GEN_DISC (C macro), 170
ESP_BLE_ADV_FLAG_LIMIT_DISC (C macro),
170
ESP_BLE_ADV_FLAG_NON_LIMIT_DISC (C
macro), 170
esp_ble_adv_params_t (C++ class), 161
esp_ble_adv_params_t::adv_filter_policy
(C++ member), 161
esp_ble_adv_params_t::adv_int_max
(C++ member), 161
esp_ble_adv_params_t::adv_int_min
(C++ member), 161
esp_ble_adv_params_t::adv_type (C++
member), 161
esp_ble_adv_params_t::channel_map
(C++ member), 161
esp_ble_adv_params_t::own_addr_type
(C++ member), 161
esp_ble_adv_params_t::peer_addr
(C++
member), 161
esp_ble_adv_params_t::peer_addr_type
(C++ member), 161
ESP_BLE_ADV_REPORT_EXT_ADV_IND (C
macro), 174
ESP_BLE_ADV_REPORT_EXT_DIRECT_ADV
(C macro), 174
ESP_BLE_ADV_REPORT_EXT_SCAN_IND
(C macro), 174
ESP_BLE_ADV_REPORT_EXT_SCAN_RSP
(C macro), 174
esp_ble_adv_type_t (C++ enum), 178
ESP_BLE_APP_ENC_KEY_SIZE (C++
enumerator), 179
ESP_BLE_APPEARANCE_BLOOD_PRESSURE_ARM
(C macro), 172
ESP_BLE_APPEARANCE_BLOOD_PRESSURE_WRIST
(C macro), 172
ESP_BLE_APPEARANCE_CYCLING_CADENCE
(C macro), 172
ESP_BLE_APPEARANCE_CYCLING_COMPUTER
(C macro), 172
ESP_BLE_APPEARANCE_CYCLING_POWER (C
macro), 172
ESP_BLE_APPEARANCE_CYCLING_SPEED (C
macro), 172
ESP_BLE_APPEARANCE_CYCLING_SPEED_CADENCE
(C macro), 172
ESP_BLE_APPEARANCE_GENERIC_BARCODE_SCANNER
(C macro), 171
ESP_BLE_APPEARANCE_GENERIC_BLOOD_PRESSURE
(C macro), 172
ESP_BLE_APPEARANCE_GENERIC_CLOCK (C
macro), 171
ESP_BLE_APPEARANCE_GENERIC_COMPUTER (C
Index

ESP_BLE_APPEARANCE_GENERIC_CONTINUOUS_GLUCOSE (C macro), 172
ESP_BLE_APPEARANCE_GENERIC_HID (C macro), 172
ESP_BLE_APPEARANCE_GENERIC_Cycling (C) ESP_BLE_APPEARANCE_INSULIN_PEN (C macro), 172
ESP_BLE_APPEARANCE_GENERIC_DISPLAY (C) ESP_BLE_APPEARANCE_INSULIN_PUMP_DURABLE_PUMP (C macro), 172
ESP_BLE_APPEARANCE_GENERIC_EYEGGLASSES (C) ESP_BLE_APPEARANCE_INSULIN_PUMP_PATCH_PUMP (C macro), 172
ESP_BLE_APPEARANCE_GENERIC_GLUCOSE (C) ESP_BLE_APPEARANCE_MOBILITY_SCOOTER (C macro), 172
ESP_BLE_APPEARANCE_GENERIC_HEART_RATE (C) ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION (C macro), 173
ESP_BLE_APPEARANCE_GENERIC_HID (C) ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_AND_NA (C macro), 173
ESP_BLE_APPEARANCE_GENERIC_INSULIN_PUMP (C) ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_POD (C macro), 172
ESP_BLE_APPEARANCE_GENERIC_KEYRING (C) ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_POD_AND_NA (C macro), 173
ESP_BLE_APPEARANCE_GENERIC_MEDIA_PLAYER ESP_BLE_APPEARANCE_POWDERED_WHEELCHAIR (C macro), 171
ESP_BLE_APPEARANCE_GENERIC_MEDICATION (ESP BLE_APPEARANCE_PULSE_OXIMETER_FINGERTIP (C macro), 173
ESP_BLE_APPEARANCE_GENERIC_OUTDOOR_SPORTS (ESP BLE_APPEARANCE_PULSE_OXIMETER_WRIST (C macro), 172
ESP_BLE_APPEARANCE_GENERIC_PERSONAL_MOBILITY_DEV ESP_BLE_APPEARANCE_SPORTS_WATCH (C macro), 172
ESP_BLE_APPEARANCE_GENERIC_PHONE (C) ESP_BLE_APPEARANCE_THERMOMETER_EAR (C macro), 171
ESP_BLE_APPEARANCE_GENERIC_PULSE_OXIMETER (ESP BLE_APPEARANCE_UNKNOWN (C macro), 171
ESP_BLE_APPEARANCE_GENERIC_REMOTE (C) ESP_BLE_APPEARANCE_WALKING_IN_SHOE (C macro), 172
ESP_BLE_APPEARANCE_GENERIC_TAG (C) ESP_BLE_APPEARANCE_WALKING_ON_HIP (C macro), 172
ESP_BLE_APPEARANCE_GENERIC_THERMOMETER (C) ESP_BLE_APPEARANCE_WALKING_ON_SHOE (C macro), 172
ESP_BLE_APPEARANCE_GENERIC_WALKING (ESP BLE_AUTH_CMPL T:: failure_reason (C++ member), 166
ESP_BLE_APPEARANCE_GENERIC_WATCH (ESP BLE_AUTH_CMPL T:: addr_type (C++ member), 166
ESP_BLE_APPEARANCE_GENERIC_WEIGHT (ESP BLE_AUTH_CMPL T:: auth_mode (C++ member), 166
ESP_BLE_APPEARANCE_GENERIC_WEIGHT (ESP BLE_AUTH_CMPL T:: bd addr (C++ member), 166
ESP_BLE_APPEARANCE_HEART_RATE_BELT (ESP BLE_AUTH_CMPL T:: dev_type (C++ member), 166
ESP_BLE_APPEARANCE_HEART_RATE_BELL ESP BLE_AUTH_CMPL T:: fail_reason (C++ member), 166
ESP_BLE_APPEARANCE_HID_BARCODE_SCANNER ESP BLE_AUTH_CMPL T:: key (C++ member), 166
ESP_BLE_APPEARANCE_HID_CARD_READER ESP BLE_AUTH_CMPL T:: key_present (C++ member), 166
ESP_BLE_APPEARANCE_HID_DIGITAL_PEN ESP BLE_AUTH_CMPL T:: key_type (C++ member), 166
ESP_BLE_APPEARANCE_HID_DIGITIZER_TABLE ESP BLE_AUTH_CMPL T:: success (C++ member), 166
ESP_BLE_APPEARANCE_HID_GAMEPAD (C ESP_BLE_AUTH_CMPL T:: type (C++ type), 174
ESP_BLE_APPEARANCE_HID_JOYSTICK ESP BLE_BOND_DEV T:: bd addr (C++ member), 165
ESP_BLE_APPEARANCE_HID_KEYBOARD ESP BLE_BOND_DEV T:: class (C++ class), 165
Index

esp_ble_gap_cb_param_t::ble_scan_result" esp_ble_gap_cb_param_t::ble_update_duplicate_exceptional_list_cmpl_evt_param::status
(C++ member), 158
esp_ble_gap_cb_param_t::ble_scan_rsp_data_raw_cmpl_evt_param::status
(C++ class), 160
esp_ble_gap_cb_param_t::ble_scan_rsp_data_cmpl_evt_param::status
(C++ class), 160
esp_ble_gap_cb_param_t::ble_set_rand_cmpl_evt_param::status
(C++ class), 160
esp_ble_gap_cb_param_t::ble_set_rand_cmpl_evt_param::status
(C++ class), 160
esp_ble_gap_cb_param_t::ble_set_perf_phy_cmpl_evt_param::status
(C++ class), 160
esp_ble_gap_cb_param_t::ble_set_perf_def_phy_cmpl_evt_param::status
(C++ class), 160
esp_ble_gap_cb_param_t::ble_set_ext_scan_params_cmpl_param::status
(C++ class), 160
esp_ble_gap_cb_param_t::ble_set_channels_evt_param::stat
(C++ class), 160
esp_ble_gap_cb_param_t::ble_set_channels
(C++ class), 160
esp_ble_gap_cb_param_t::ble_security
(C++ class), 160
esp_ble_gap_cb_param_t::ble_scan_stop_cmpl_evt_param::status
(C++ class), 160
esp_ble_gap_cb_param_t::ble_scan_start_cmpl_evt_param::status
(C++ class), 160
esp_ble_gap_cb_param_t::ble_scan_rsp_data_raw_cmpl_evt_param::status
(C++ class), 160
esp_ble_gap_cb_param_t::ble_scan_rsp_data_cmpl_evt_param::status
(C++ class), 160

Index

esp_ble_gap_cb_param_t::period_adv_stop esp_ble_gap_clear_whitelist  (C++ function), 139
esp_ble_gap_cb_param_t::period_adv_start esp_ble_gap_config_adv_data  (C++ function), 137
esp_ble_gap_cb_param_t::period_adv_start esp_ble_gap_config_adv_data_raw  (C++ function), 140
esp_ble_gap_cb_param_t::periodic_adv_start esp_ble_gap_config_ext_adv_data_raw  (C++ function), 144
esp_ble_gap_cb_param_t::periodic_adv_start esp_ble_gap_config_ext_scan_rsp_data_raw  (C++ function), 145
esp_ble_gap_cb_param_t::periodic_adv_start esp_ble_gap_config_local_icon  (C++ function), 139
esp_ble_gap_cb_param_t::periodic_adv_set esp_ble_gap_config_local_privacy  (C++ function), 139
esp_ble_gap_cb_param_t::phy_update esp_ble_gap_config_periodic_adv_data_raw  (C++ function), 145
esp_ble_gap_cb_param_t::pkt_data_lenth esp_ble_gap_config_scan_rsp_data_raw  (C++ function), 140
esp_ble_gap_cb_param_t::read_phy  (C++ function), 149
esp_ble_gap_cb_param_t::read_rssi_cmpl esp_ble_gap_conn_params_t::interval_max  (C++ member), 168
esp_ble_gap_cb_param_t::remove_bond_dev_cmpl esp_ble_gap_conn_params_t::interval_min  (C++ member), 168
esp_ble_gap_cb_param_t::scan_param_cmpl esp_ble_gap_conn_params_t::latency  (C++ member), 168
esp_ble_gap_cb_param_t::scan_request_received esp_ble_gap_conn_params_t::max_ce_len  (C++ member), 168
esp_ble_gap_cb_param_t::scan_rsp_data_cmpl esp_ble_gap_conn_params_t::min_ce_len  (C++ member), 168
esp_ble_gap_cb_param_t::scan_rsp_data_raw_cmpl esp_ble_gap_conn_params_t::scan_interval (C++ member), 168
esp_ble_gap_cb_param_t::scan_rsp_data_raw_cmpl esp_ble_gap_conn_params_t::scan_window  (C++ member), 168
esp_ble_gap_cb_param_t::scan_rsp_set esp_ble_gap_conn_params_t::supervision_timeout (C++ member), 168
esp_ble_gap_cb_param_t::scan_rsp_set esp_ble_gap_disconnect  (C++ function), 143
esp_ble_gap_cb_param_t::scan_start_cmpl ESP_BLE_GAP_EXT_ADV_DATA_COMPLETE  (C macro), 174
esp_ble_gap_cb_param_t::scan_stop_cmpl ESP_BLE_GAP_EXT_ADV_DATA_INCOMPLETE  (C macro), 174
esp_ble_gap_cb_param_t::set_ext_scan_params esp_ble_gap_ext_adv_data_status_t  (C++ type), 174
esp_ble_gap_cb_param_t::set_perf_def_params ESP_BLE_GAP_EXT_ADV_DATA_TRUNCATED  (C macro), 174
esp_ble_gap_cb_param_t::set_perf_phy esp_ble_gap_ext_adv_params_t  (C++ class), 166
esp_ble_gap_cb_param_t::set_rand_addr_cmpl esp_ble_gap_ext_adv_params_t::channel_map  (C++ member), 166
esp_ble_gap_cb_param_t::set_rand_addr_cmpl esp_ble_gap_ext_adv_params_t::filter_policy  (C++ member), 167
esp_ble_gap_cb_param_t::set_rand_addr_cmpl esp_ble_gap_ext_adv_params_t::interval_max (C++ member), 166
esp_ble_gap_cb_param_t::set_rand_addr_cmpl esp_ble_gap_ext_adv_params_t::interval_min (C++ member), 166
esp_ble_gap_clean_duplicate_scan_exceptional_list esp_ble_gap_ext_adv_params_t::max_skip (C++ member), 167
esp_ble_gap_clear_rand_addr  (C++ function), 141
esp_ble_gap_ext_adv_params_t::own_addr_type (C++ member), 166

Espresif Systems 2151 Release v5.0-dev-1077-g397639d
Submit Document Feedback
Index

esp_ble_gap_ext_adv_params_t::peer_add (C++ member), 167
esp_ble_gap_ext_adv_params_t::peer_addr_type (C++ member), 167
esp_ble_gap_ext_adv_params_t::primary_phy (C++ member), 167
esp_ble_gap_ext_adv_params_t::scan_req_notif (C++ member), 168
esp_ble_gap_ext_adv_set_clear (C++ member), 167
esp_ble_gap_ext_adv_set_rand_addr (C++ member), 167
esp_ble_gap_ext_adv_set_remove (C++ member), 167
esp_ble_gap_ext_adv_start (C++ function), 145
esp_ble_gap_ext_adv_stop (C++ function), 145
esp_ble_gap_periodic_adv_add_dev_to_list (C++ function), 147
esp_ble_gap_periodic_adv_clear_dev (C++ function), 147
esp_ble_gap_periodic_adv_create_sync (C++ function), 146
esp_ble_gap_periodic_adv_clear_dev (C++ member), 168
esp_ble_gap_periodic_adv_params_t::interval_max (C++ member), 168
esp_ble_gap_periodic_adv_params_t::interval_min (C++ member), 168
esp_ble_gap_periodic_adv_remove_dev_from_list (C++ function), 147
esp_ble_gap_periodic_adv_report_t (C++ class), 169
esp_ble_gap_periodic_adv_report_t::addr (C++ member), 169
esp_ble_gap_periodic_adv_report_t::addr_type (C++ member), 169
esp_ble_gap_periodic_adv_report_t::adv_data (C++ member), 169
esp_ble_gap_periodic_adv_report_t::data_status (C++ member), 169
esp_ble_gap_periodic_adv_report_t::dir_addr (C++ member), 169
esp_ble_gap_periodic_adv_report_t::event_type (C++ member), 169
esp_ble_gap_periodic_adv_report_t::per_adv_interval (C++ function), 147
esp_ble_gap_periodic_adv_report_t::primary_phy (C++ member), 169
esp_ble_gap_periodic_adv_report_t::rssi (C++ member), 169
esp_ble_gap_periodic_adv_report_t::secondly_phy (C++ member), 169
esp_ble_gap_periodic_adv_report_t::sid (C++ member), 169
esp_ble_gap_periodic_adv_report_t::tx_power (C++ member), 169
esp_ble_gap_set_clear (C++ function), 145
esp_ble_gap_set_params (C++ function), 144
esp_ble_gap_set_rand_addr (C++ function), 144
esp_ble_gap_set_remove (C++ function), 145
esp_ble_gap_start (C++ function), 145
esp_ble_gap_stop (C++ function), 145
esp_ble_gap_ext_adv_report_t::tx_power (C++ member), 167
esp_ble_gap_ext_adv_report_t::sid (C++ member), 167
esp_ble_gap_ext_adv_report_t::secondly_phy (C++ member), 167
esp_ble_gap_ext_adv_report_t::primary_phy (C++ member), 167
esp_ble_gap_ext_adv_report_t::duration (C++ member), 167
esp_ble_gap_ext_adv_report_t::instance (C++ member), 167
esp_ble_gap_ext_adv_report_t::max_events (C++ member), 168
ESP_BLE_GAP_EXT_SCAN_CFG_CODE_MASK (C macro), 174
ESP_BLE_GAP_EXT_SCAN_CFG_CODEC (C macro), 174
esp_ble_gap_get_local_used_addr (C++ function), 140
esp_ble_gap_get_whitelist_size (C++ function), 139
ESP_BLE_GAP_NO_PREFER_RECEIVE_PHY (C macro), 173
ESP_BLE_GAP_NO_PREFER_TRANSMIT_PHY (C macro), 173
ESP_BLE_GAP_PERIODIC_ADV_ADD (C function), 147
ESP_BLE_GAP_PERIODIC_ADV_ADD (C function), 147
ESP_BLE_GAP_PERIODIC_ADV_CREATE_SYNC (C function), 146
ESP_BLE_GAP_PERIODIC_ADV_PARAMS (C function), 147
ESP_BLE_GAP_EXT_ADV_REPROT_T::tx_power (C function), 168
ESP_BLE_GAP_EXT_ADV_REPROT_T::sid (C function), 168
ESP_BLE_GAP_EXT_ADV_REPROT_T::secondly_phy (C function), 168
ESP_BLE_GAP_EXT_ADV_REPROT_T::rssi (C function), 168
ESP_BLE_GAP_EXT_ADV_REPROT_T::data_status (C function), 168
ESP_BLE_GAP_EXT_ADV_REPROT_T::data_length (C function), 168
ESP_BLE_GAP_EXT_ADV_REPROT_T::data (C function), 168
ESP_BLE_GAP_EXT_ADV_REPROT_T::dir_addr (C function), 168
ESP_BLE_GAP_EXT_ADV_REPROT_T::event_type (C function), 168
ESP_BLE_GAP_EXT_ADV_REPROT_T::per_adv_interval (C function), 147
ESP_BLE_GAP_EXT_ADV_REPROT_T::primary_phy (C function), 169
ESP_BLE_GAP_EXT_ADV_REPROT_T::rssi (C function), 169
ESP_BLE_GAP_EXT_ADV_REPROT_T::data (C function), 170
ESP_BLE_GAP_EXT_ADV_REPROT_T::data_length (C function), 170
ESP_BLE_GAP_EXT_ADV_REPROT_T::data_status (C function), 170
ESP_BLE_GAP_EXT_ADV_REPROT_T::rssi (C function), 170
ESP_BLE_GAP_EXT_ADV_REPROT_T::sync_handle (C function), 170
ESP_BLE_GAP_EXT_ADV_REPROT_T::tx_power (C function), 170
ESP_BLE_GAP_EXT_ADV_PARAMS (C function), 145
ESP_BLE_GAP_EXT_ADV_PARAMS (C function), 146
ESP_BLE_GAP_EXT_ADV_SYNC_CANCEL (C function), 146
ESP_BLE_GAP_EXT_ADV_SYNC_ESTAB (C function), 146
<table>
<thead>
<tr>
<th>Function/Member</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_ble_gatts_close</td>
<td>(C++ function), 205</td>
</tr>
<tr>
<td>esp_ble_gatts_execute_write</td>
<td>(C++ function), 210</td>
</tr>
<tr>
<td>esp_ble_gatts_get_all_char</td>
<td>(C++ function), 206</td>
</tr>
<tr>
<td>esp_ble_gatts_get_all_descr</td>
<td>(C++ function), 206</td>
</tr>
<tr>
<td>esp_ble_gatts_get_attr_count</td>
<td>(C++ function), 208</td>
</tr>
<tr>
<td>esp_ble_gatts_get_char_by_uuid</td>
<td>(C++ function), 206</td>
</tr>
<tr>
<td>esp_ble_gatts_get_db</td>
<td>(C++ function), 208</td>
</tr>
<tr>
<td>esp_ble_gatts_get_descr_by_char_handle</td>
<td>(C++ function), 207</td>
</tr>
<tr>
<td>esp_ble_gatts_get_include_service</td>
<td>(C++ function), 207</td>
</tr>
<tr>
<td>esp_ble_gatts_get_service</td>
<td>(C++ function), 205</td>
</tr>
<tr>
<td>esp_ble_gatts_open</td>
<td>(C++ function), 205</td>
</tr>
<tr>
<td>esp_ble_gatts_prepare_write</td>
<td>(C++ function), 210</td>
</tr>
<tr>
<td>esp_ble_gatts_prepare_write_char_descr</td>
<td>(C++ function), 210</td>
</tr>
<tr>
<td>esp_ble_gatts_read_by_type</td>
<td>(C++ function), 209</td>
</tr>
<tr>
<td>esp_ble_gatts_read_char</td>
<td>(C++ function), 209</td>
</tr>
<tr>
<td>esp_ble_gatts_read_char_descr</td>
<td>(C++ function), 209</td>
</tr>
<tr>
<td>esp_ble_gatts_read_multiple</td>
<td>(C++ function), 209</td>
</tr>
<tr>
<td>esp_ble_gatts_register_callback</td>
<td>(C++ function), 204</td>
</tr>
<tr>
<td>esp_ble_gatts_register_for_notify</td>
<td>(C++ function), 211</td>
</tr>
<tr>
<td>esp_ble_gatts_search_service</td>
<td>(C++ function), 205</td>
</tr>
<tr>
<td>esp_ble_gatts_send_mtu_req</td>
<td>(C++ function), 205</td>
</tr>
<tr>
<td>esp_ble_gatts_unregister_for_notify</td>
<td>(C++ function), 211</td>
</tr>
<tr>
<td>esp_ble_gatts_write_char</td>
<td>(C++ function), 209</td>
</tr>
<tr>
<td>esp_ble_gatts_write_char_descr</td>
<td>(C++ function), 209</td>
</tr>
<tr>
<td>esp_ble_gatts_add_char</td>
<td>(C++ function), 193</td>
</tr>
<tr>
<td>esp_ble_gatts_add_char_descr</td>
<td>(C++ function), 193</td>
</tr>
<tr>
<td>esp_ble_gatts_add_included_service</td>
<td>(C++ function), 193</td>
</tr>
<tr>
<td>esp_ble_gatts_app_register</td>
<td>(C++ function), 192</td>
</tr>
<tr>
<td>esp_ble_gatts_app_unregister</td>
<td>(C++ function), 192</td>
</tr>
<tr>
<td>esp_ble_gatts_add_attr_tab</td>
<td>(C++ union), 195</td>
</tr>
</tbody>
</table>
Index

esp_ble_gatts_cb_param_t::gatts_add_service_param::service::app_id (C++ class), 199
esp_ble_gatts_cb_param_t::gatts_add_service_param::service::attr_handle (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_add_service_param::service::conn_id (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_add_service_param::service::service_id (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_add_service_param::service::service_handle (C++ member), 198
esp_ble_gatts_cb_param_t::gatts_delete_service_param::service::app_id (C++ class), 200
esp_ble_gatts_cb_param_t::gatts_delete_service_param::service::service_id (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_delete_service_param::service::service_handle (C++ member), 198
esp_ble_gatts_cb_param_t::gatts_add_characteristic_param::chara::attr_handle (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_add_characteristic_param::chara::conn_id (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_add_characteristic_param::chara::desc_list (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_add_characteristic_param::chara::desc_list_len (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_add_characteristic_param::chara::desc_list_type (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_add_characteristic_param::chara::descs (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_add_characteristic_param::chara::description (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_add_characteristic_param::chara::flags (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_add_characteristic_param::chara::is長期 (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_add_characteristic_param::chara::properties (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_delete_characteristic_param::chara::attr_handle (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_delete_characteristic_param::chara::conn_id (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_delete_characteristic_param::chara::description (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_delete_characteristic_param::chara::flags (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_delete_characteristic_param::chara::properties (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_execute_write_param::trans_id (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_execute_write_param::conn_id (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_execute_write_param::bda (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_disconnect_param::remote_bda (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_disconnect_param::reason (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_disconnect_param::conn_id (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_rsp_param::status (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_rsp_param::handle (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_reg_param::app_id (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_reg_param::app_id_ext (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_reg_param::conn_id (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_reg_param (C++ class), 200
esp_ble_gatts_cb_param_t::gatts_conf_param::value (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_conf_param::status (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_conf_param::len (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_conf_param::handle (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_conf_param::conn_id (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_close_param::status (C++ member), 200
esp_ble_gatts_cb_param_t (C++ class), 198
esp_ble_gatts_cb_param_t::gatts_cancel_open_param (C++ class), 198
esp_ble_gatts_cb_param_t::gatts_add_included_service_param::service_handle (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_add_included_service_param::attr_handle (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_add_included_service_param (C++ class), 199
esp_ble_gatts_cb_param_t::gatts_conf_open_param (C++ class), 200
esp_ble_gatts_cb_param_t::gatts_conf_open_param::value (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_conf_open_param::status (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_conf_open_param::len (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_conf_open_param::handle (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_conf_open_param::conn_id (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_send_service_change_param (C++ class), 200
esp_ble_gatts_cb_param_t::gatts_rsp_param (C++ class), 200
esp_ble_gatts_cb_param_t::gatts_reg_param (C++ class), 200
esp_ble_gatts_cb_param_t::gatts_read_param::offset (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_read_param::need_rsp (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_read_param::is_long (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_read_param::bda (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_open_param (C++ class), 199
esp_ble_gatts_cb_param_t::gatts_open_param::status (C++ member), 199
esp_ble_gatts_cb_param_t::gatts_open_param::conn_id (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_open_param::bda (C++ member), 200
esp_ble_gatts_cb_param_t::gatts_exec_write_param::trans_id (C++ member), 200
esp BLE GATT_EVT_ENUMS_DISCONNECT_EVT (C++ member), 199
esp BLE GATT_EVT_ENUMS_CANCEL_OPEN_EVT (C++ member), 199
esp BLE GATT_EVT_ENUMS_OPEN_EVT (C++ member), 198
esp BLE GATT_EVT_ENUMS_CLOSE_EVT (C++ member), 198
esp BLE GATT_EVT_ENUMS_DISCONNECT_EVT (C++ member), 198
esp BLE GATT_EVT_ENUMS_delete_EVT (C++ member), 198
esp BLE GATT_EVT_ENUMS_ADD_SRVC_EVT (C++ member), 198
esp BLE GATT_EVT_ENUMS_ADD_CHARACTERISTIC_EVT (C++ member), 199
esp BLE GATT_EVT_ENUMS_ADD_SERVICE_EVT (C++ member), 199
esp BLE GATT_EVT_ENUMS祿_COLOR_CONCAT (C++ member), 199
esp BLE GATT_EVT_ENUMS_EXECUTE_WRITE_EVT (C++ member), 200
esp BLE GATT_EVT_ENUMS_RSP_EVT (C++ member), 200
esp BLE GATT_EVT_ENUMS_REG_EVT (C++ member), 200
esp BLE GATT_EVT_ENUMS_CONF_EVT (C++ member), 200
esp BLE GATT_EVT_ENUMS_CLOSE_EVT (C++ member), 200
esp BLE GATT_EVT_ENUMS_RSP_EVT (C++ member), 200
esp BLE GATT_EVT_ENUMS_REG_EVT (C++ member), 200
esp BLE GATT_EVT_ENUMS_READ_EVT (C++ member), 200
esp BLE GATT_EVT_ENUMS_CONNECTION_GATT_EVT (C++ member), 200
esp BLE GATT_EVT_ENUMS_Connect_EVT (C++ member), 200
esp BLE GATT_EVT_ENUMS_CONGESTION_EVT (C++ member), 200
esp BLE GATT_EVT_ENUMS_DISCONNECT_EVT (C++ member), 200
esp BLE GATT_EVT_ENUMS_CONN_EVT (C++ member), 200
Index

esp_ble_lcsrk_keys::csrk (C++ member), 164
esp_ble_lcsrk_keys::div (C++ member), 164
esp_ble_lcsrk_keys::sec_level (C++ member), 164
ESP_BLE_MESH_ADDR_TYPE_DIRECT_IND (C macro), 174
ESP_BLE_MESH_ADDR_TYPE_IND (C macro), 174
ESP_BLE_MESH_ADDR_TYPE_NONCON_IND (C macro), 174
ESP_BLE_MESH_ADDR_TYPE_SCAN_IND (C macro), 174
ESP_BLE_MESH_ADDR_TYPE_SCAN_RSP_TO_ADV_IND (C macro), 174
ESP_BLE_MESH_ADDR_TYPE_SCAN_RSP_TO_ADV_DIRECT_IND (C macro), 174
esp_ble_lenc_keys_t (C++ class), 164
esp_ble_lenc_keys_t::div (C++ member), 164
esp_ble_lenc_keys_t::key_size (C++ member), 164
esp_ble_lenc_keys_t::ltk (C++ member), 164
esp_ble_lenc_keys_t::sec_level (C++ member), 164
ESP_BLE_LINK_KEY_MASK (C macro), 134
esp_local_id_keys_t (C++ class), 165
esp_local_id_keys_t::dhk (C++ member), 166
esp_local_id_keys_t::irk (C++ member), 166
ESP_BLE_MESH_ACTUATOR_BLOCKED_WARNING (C macro), 408
ESP_BLE_MESH_ACTUATOR_BLOCKED_ERROR (C macro), 408
ESP_BLE_MESH_ADDR_ALL_NODES (C macro), 339
ESP_BLE_MESH_ADDR_FRIENDS (C macro), 339
ESP_BLE_MESH_ADDR_IS_GROUP (C macro), 340
ESP_BLE_MESH_ADDR_IS_RFU (C macro), 340
ESP_BLE_MESH_ADDR_IS_UNICAST (C macro), 340
ESP_BLE_MESH_ADDR_IS_VIRTUAL (C macro), 340
ESP_BLE_MESH_ADDR_PROXIES (C macro), 339
ESP_BLE_MESH_ADDR_RELAYS (C macro), 339
ESP_BLE_MESH_ADDR_TYPE_PUBLIC (C macro), 341
ESP_BLE_MESH_ADDR_TYPE_RANDOM (C macro), 342
ESP_BLE_MESH_ADDR_TYPE_RFA_PUBLIC (C macro), 342
ESP_BLE_MESH_ADDR_TYPE_RPA_RANDOM (C macro), 342
esp_ble_mesh_addr_type_t (C++ type), 353
ESP_BLE_MESH_ADDR_UNASSIGNED (C macro), 339
ESP_BLE_MESH_BATTERY_LOW_ERROR (C macro), 408
ESP_BLE_MESH_BATTERY_LOW_WARNING (C macro), 408
esp_ble_mesh_bd_addr_t (C++ type), 353
ESP_BLE_MESH_BEACON_DISABLED (C macro), 340
ESP_BLE_MESH_BEACON_ENABLED (C macro), 340
ESP_BLE_MESH_BEEP (C++ enumerator), 355
ESP_BLE_MESH_BLINK (C++ enumerator), 355
esp_ble_mesh_cb_t (C++ type), 353
esp_ble_mesh_cb_type_t (C++ enum), 355
esp_ble_mesh_cfg_app_key_add_t (C++ class), 386
esp_ble_mesh_cfg_app_key_add_t::app_idx (C++ member), 386
esp_ble_mesh_cfg_app_key_add_t::app_key (C++ member), 386
esp_ble_mesh_cfg_app_key_add_t::net_idx (C++ member), 386
esp_ble_mesh_cfg_app_key_delete_t (C++ class), 390
esp_ble_mesh_cfg_app_key_delete_t::app_idx (C++ member), 390
esp_ble_mesh_cfg_app_key_delete_t::net_idx (C++ member), 390
esp_ble_mesh_cfg_app_key_get_t (C++ class), 384
esp_ble_mesh_cfg_app_key_get_t::app_idx (C++ member), 384
esp_ble_mesh_cfg_app_key_get_t::net_idx (C++ member), 384
esp_ble_mesh_cfg_app_key_list_cb_t (C++ class), 396
esp_ble_mesh_cfg_app_key_list_cb_t::app_idx (C++ member), 396
esp_ble_mesh_cfg_app_key_list_cb_t::net_idx (C++ member), 396
esp_ble_mesh_cfg_app_key_status_cb_t::status (C++ member), 396
esp_ble_mesh_cfg_app_key_status_cb_t (C++ class), 394
esp_ble_mesh_cfg_app_key_status_cb_t::app_idx (C++ member), 394
esp_ble_mesh_cfg_app_key_status_cb_t::net_idx (C++ member), 394
esp_ble_mesh_cfg_app_key_status_cb_t::status (C++ member), 394
esp_ble_mesh_cfg_app_key_update_t (C++ class), 390
esp_ble_mesh_cfg_app_key_update_t::app_idx (C++ member), 390
esp_ble_mesh_cfg_app_key_update_t::app_key (C++ member), 390
esp_ble_mesh_cfg_app_key_update_t::net_idx (C++ member), 390
esp_ble_mesh_cfg Beacon_set_t (C++
Index

- esp_ble_mesh_cfg_model_app_list_cb_t::app_idx (C++ member), 392
- esp_ble_mesh_cfg_model_app_list_cb_t::company_id (C++ member), 396
- esp_ble_mesh_cfg_model_app_list_cb_t::element_addr (C++ member), 396
- esp_ble_mesh_cfg_model_app_list_cb_t::net_idx (C++ member), 396
- esp_ble_mesh_cfg_model_app_bind_t::model_id (C++ member), 396
- esp_ble_mesh_cfg_model_app_bind_t::model_app_idx (C++ member), 396
- esp_ble_mesh_cfg_model_app_bind_t::element_addr (C++ member), 396
- esp_ble_mesh_cfg_model_app_bind_t::company_id (C++ member), 396
- esp_ble_mesh_cfg_model_app_bind_t::app_idx (C++ member), 396
- esp_ble_mesh_cfg_model_pub_status_cb_t::element_addr (C++ member), 396
- esp_ble_mesh_cfg_model_pub_status_cb_t::cred_flag (C++ member), 396
- esp_ble_mesh_cfg_model_pub_status_cb_t::company_id (C++ member), 396
- esp_ble_mesh_cfg_model_pub_status_cb_t::app_idx (C++ member), 396
- esp_ble_mesh_cfg_model_pub_set_t::publish_ttl (C++ member), 396
- esp_ble_mesh_cfg_model_pub_set_t::publish_retransmit (C++ member), 396
- esp_ble_mesh_cfg_model_pub_set_t::publish_period (C++ member), 396
- esp_ble_mesh_cfg_model_pub_set_t::publish_app_idx (C++ member), 396
- esp_ble_mesh_cfg_model_pub_set_t::publish_addr (C++ member), 396
- esp_ble_mesh_cfg_model_pub_set_t::model_id (C++ member), 396
- esp_ble_mesh_cfg_model_pub_get_t::element_addr (C++ member), 396
- esp_ble_mesh_cfg_model_pub_get_t::company_id (C++ member), 396
- esp_ble_mesh_cfg_model_pub_get_t::app_idx (C++ member), 396
- esp_ble_mesh_cfg_model_app_unbind_t::model_id (C++ member), 396
- esp_ble_mesh_cfg_model_app_unbind_t::model_app_idx (C++ member), 396
- esp_ble_mesh_cfg_model_app_unbind_t::element_addr (C++ member), 396
- esp_ble_mesh_cfg_model_app_unbind_t::company_id (C++ member), 396
- esp_ble_mesh_cfg_model_app_list_cb_t::status (C++ member), 396
- esp_ble_mesh_cfg_model_app_list_cb_t::model_id (C++ member), 396
- esp_ble_mesh_cfg_model_app_list_cb_t::element_addr (C++ member), 396
- esp_ble_mesh_cfg_model_app_list_cb_t::app_idx (C++ member), 396
- esp_ble_mesh_cfg_mod_app_status_cb_t::status (C++ member), 397
- esp_ble_mesh_cfg_mod_app_status_cb_t::model_id (C++ member), 397
- esp_ble_mesh_cfg_mod_app_status_cb_t::company_id (C++ member), 397
- esp_ble_mesh_cfg_mod_app_status_cb_t::app_idx (C++ member), 397
- esp_ble_mesh_cfg_lpn_pollto_status_cb_t::poll_timeout (C++ member), 397
- esp_ble_mesh_cfg_lpn_pollto_status_cb_t::lpn_addr (C++ member), 397
- esp_ble_mesh_cfg_lpn_polltimeout_get_t::lpn_addr (C++ member), 397
- esp_ble_mesh_cfg_kr_phase_status_cb_t::phase (C++ member), 397
- esp_ble_mesh_cfg_kr_phase_status_cb_t::net_idx (C++ member), 397
- esp_ble_mesh_cfg_kr_phase_set_t::transition (C++ member), 397
- esp_ble_mesh_cfg_kr_phase_set_t::net_idx (C++ member), 397
- esp_ble_mesh_cfg_kr_phase_get_t::net_idx (C++ member), 397
- esp_ble_mesh_cfg_heartbeat_sub_set_t::src (C++ member), 397
- esp_ble_mesh_cfg_heartbeat_sub_set_t::dst (C++ member), 397
- esp_ble_mesh_cfg_model_pub_status_cb_t::model_id (C++ member), 397
- esp_ble_mesh_cfg_model_pub_status_cb_t::company_id (C++ member), 397
- esp_ble_mesh_cfg_model_pub_status_cb_t::app_idx (C++ member), 397
- esp_ble_mesh_cfg_model_pub_set_t::publish_ttl (C++ member), 397
- esp_ble_mesh_cfg_model_pub_set_t::publish_retransmit (C++ member), 397
- esp_ble_mesh_cfg_model_pub_set_t::publish_period (C++ member), 397
- esp_ble_mesh_cfg_model_pub_set_t::publish_app_idx (C++ member), 397
- esp_ble_mesh_cfg_model_pub_set_t::publish_addr (C++ member), 397
- esp_ble_mesh_cfg_model_pub_set_t::model_id (C++ member), 397
- espble_mesh_cfg_model_pub_get_t::element_addr (C++ member), 397
- espble_mesh_cfg_model_pub_get_t::company_id (C++ member), 397
- espble_mesh_cfg_model_pub_get_t::app_idx (C++ member), 397
- espble_mesh_cfg_model_pub_set_t::publish_ttl (C++ member), 397
- espble_mesh_cfg_model_pub_set_t::publish_retransmit (C++ member), 397
- espble_mesh_cfg_model_pub_set_t::publish_period (C++ member), 397
- espble_mesh_cfg_model_pub_set_t::publish_app_idx (C++ member), 397
- espble_mesh_cfg_model_pub_set_t::publish_addr (C++ member), 397
- espble_mesh_cfg_model_pub_set_t::model_id (C++ member), 397
- espble_mesh_cfg_model_pub_get_t::element_addr (C++ member), 397
- espble_mesh_cfg_model_pub_get_t::company_id (C++ member), 397
- espble_mesh_cfg_model_pub_get_t::app_idx (C++ member), 397
- espble_mesh_cfg_model_app_unbind_t::model_id (C++ member), 397
- espble_mesh_cfg_model_app_unbind_t::model_app_idx (C++ member), 397
- espble_mesh_cfg_model_app_unbind_t::element_addr (C++ member), 397
- espble_mesh_cfg_model_app_unbind_t::company_id (C++ member), 397
- espble_mesh_cfg_model_app_list_cb_t::status (C++ member), 397
- espble_mesh_cfg_model_app_list_cb_t::model_id (C++ member), 397
- espble_mesh_cfg_model_app_list_cb_t::element_addr (C++ member), 397
- espble_mesh_cfg_model_app_list_cb_t::app_idx (C++ member), 397

Espressif Systems 2162
Release v5.0-dev-1077-g397639d
Submit Document Feedback
Index

(C++ member), 382
esp_ble_mesh_cfg_srv::timer (C++ member), 383
esp_ble_mesh_cfg_srv::server_state_change (C++ member), 382
esp_ble_mesh_cfg_srv::server_state_change (C++ member), 382
esp_ble_mesh_cfg_srv::source (C++ member), 383
esp_ble_mesh_cfg_srv::relay_retransmit (C++ member), 383
esp_ble_mesh_cfg_srv::relay (C++ member), 383
esp_ble_mesh_cfg_srv::net_transmit (C++ member), 383
esp_ble_mesh_cfg_srv::net_idx (C++ member), 383
esp_ble_mesh_cfg_srv::netkey_update (C++ member), 383
esp_ble_mesh_cfg_srv::period (C++ member), 383
esp_ble_mesh_cfg_srv::model (C++ member), 383
esp_ble_mesh_cfg_srv::min_hops (C++ member), 383
esp_ble_mesh_cfg_srv::max_hops (C++ member), 383
esp_ble_mesh_cfg_srv::heartbeat_sub (C++ member), 383
esp_ble_mesh_cfg_srv::heartbeat_recv_cb (C++ member), 383
esp_ble_mesh_cfg_srv::heartbeat_pub (C++ member), 383
esp_ble_mesh_cfg_srv::heartbeat_sub (C++ member), 383
esp_ble_mesh_cfg_srv::max_hops (C++ member), 383
esp_ble_mesh_cfg_srv::min_hops (C++ member), 383
esp_ble_mesh_cfg_srv::model (C++ member), 383
esp_ble_mesh_cfg_srv::net_idx (C++ member), 383
esp_ble_mesh_cfg_srv::netkey_update (C++ member), 383
esp_ble_mesh_cfg_srv::period (C++ member), 383
esp_ble_mesh_cfg_srv::relay (C++ member), 383
esp_ble_mesh_cfg_srv::relay_retransmit (C++ member), 383
esp_ble_mesh_cfg_srv::source (C++ member), 383

Espresif Systems 2165 Release v5.0-dev-1077-g397639d

Submit Document Feedback
Index

ESP_BLE_MESH_CID_NVAL (C macro), 339
esp_ble_mesh_client_common_param_t (C++ class), 337
esp_ble_mesh_client_common_param_t::ct (C++ member), 337
esp_ble_mesh_client_common_param_t::mod (C++ member), 337
esp_ble_mesh_client_common_param_t::msg_type (C++ member), 337
esp_ble_mesh_client_common_param_t::msgid (C++ member), 337
esp_ble_mesh_client_common_param_t::opcode (C++ member), 337
esp_ble_mesh_client_model_deinit (C++ function), 365
esp_ble_mesh_client_model_deinit (C++ function), 365
ESP_BLE_MESH_CLIENT_MODEL_RECV_PUBLISH_EVT (C++ enumerator), 361
esp_ble_mesh_client_model_recv_publish (C++ function), 365
esp_ble_mesh_client_model_send_msg (C++ function), 365
esp_ble_mesh_client_op_pair (C++ class), 337
esp_ble_mesh_client_op_pair::status_op (C++ member), 337
esp_ble_mesh_client_op_pair::cli_op (C++ member), 337
esp_ble_mesh_client::model (C++ member), 337
esp_ble_mesh_client::msg_role (C++ member), 337
esp_ble_mesh_client::op_pair (C++ member), 337
esp_ble_mesh_client::op_pair_size (C++ member), 337
esp_ble_mesh_client::publish_status (C++ member), 337
esp_ble_mesh_comp_t (C++ class), 334
esp_ble_mesh_comp_t::cid (C++ member), 334
esp_ble_mesh_comp_t::element_count (C++ member), 334
esp_ble_mesh_comp_t::elements (C++ member), 334
esp_ble_mesh_comp_t::pid (C++ member), 334
esp_ble_mesh_comp_t::vid (C++ member), 334
ESP_BLE_MESH_CONDENSATION_ERROR (C macro), 408
ESP_BLE_MESH_CONDENSATION_WARNING (C macro), 408
esp_ble_mesh_config_client_get_state (C++ function), 378
esp_ble_mesh_config_client_set_state (C++ function), 378
ESP_BLE_MESH_CONFIGURATION_ERROR (C macro), 408
ESP_BLE_MESH_CONFIGURATION_WARNING (C macro), 408
esp_ble_mesh_deinit (C++ function), 361
ESP_BLE_MESH_DEINIT_MESH_COMP_EVT (C++ enumerator), 360
esp_ble_mesh_deinit_param_t (C++ class), 331
esp_ble_mesh_deinit_param_t::erase_flash (C++ member), 331
esp_ble_mesh_dev_add_flag_t::erase_flash (C++ member), 331
esp_ble_mesh_dev_role_t (C++ class), 354
esp_ble_mesh_dev_role_t (C++ type), 354
esp_ble_mesh_device_delete_t (C++ enum), 356
esp_ble_mesh_device_delete_t (C++ class), 335
esp_ble_mesh_device_delete_t::addr (C++ member), 335
esp_ble_mesh_device_delete_t::addr_type (C++ member), 335
esp_ble_mesh_device_delete_t::flag (C++ member), 335
esp_ble_mesh_device_delete_t::uuid (C++ member), 335
ESP_BLE_MESH_DEVICE_DROPPED_ERROR (C macro), 409
ESP_BLE_MESH_DEVICE_DROPPED_WARNING (C macro), 409
ESP_BLE_MESH_DEVICE_MOVED_ERROR (C macro), 409
ESP_BLE_MESH_DEVICE_MOVED_WARNING (C macro), 409
ESP_BLE_MESH_DEVICE_NAME_MAX_LEN (C macro), 339
ESP_BLE_MESH_DISPLAY_NUMBER (C++ enumerator), 355
ESP_BLE_MESH_DISPLAY_STRING (C++ enumerator), 355
esp_ble_meshElem_t (C++ class), 331
esp_ble_meshElem_t::element_addr (C++ member), 331
esp_ble_meshElem_t::location (C++ member), 331
esp_ble_meshElem_t::sig_model_count (C++ member), 331
esp_ble_meshElem_t::sig_models (C++ member), 331
esp_ble_meshElem_t::vnd_model_count (C++ member), 331
esp_ble_meshElem_t::vnd_models (C++ member), 331
ESP_BLE_MESH_ELEMENT (C macro), 341
ESP_BLE_MESH_ELEMENT_NOT_CALIBRATED_ERROR (C macro), 408
ESP_BLE_MESH_ELEMENT_NOT_CALIBRATED_WARNING (C macro), 408
Index

423 esp_ble_mesh_gen_levelsrv_t::*last esp_ble_mesh_gen_loc_local_set_t::*local_east
  (C++ member), 417
esp_ble_mesh_gen_levelsrv_t::*model esp_ble_mesh_gen_loc_local_set_t::*local_north
  (C++ member), 417
esp_ble_mesh_gen_levelsrv_t::*rsp_ctrl esp_ble_mesh_gen_loc_local_set_t::*uncertainty
  (C++ member), 417
esp_ble_mesh_gen_levelsrv_t::*state esp_ble_mesh_gen_loc_local_statuscb_t
  (C++ class), 421
esp_ble_mesh_gen_levelsrv_t::*transition esp_ble_mesh_gen_loc_local_statuscb_t::*floor_num
  (C++ member), 421
esp_ble_mesh_gen_levelstate_t  (C++ class), 423
esp_ble_mesh_gen_levelstate_t::*lastdelta esp BLE_MESH_GEN_LOC_LOCAL_STATUS_CB_T::*local_alt
  (C++ member), 421
esp_ble_mesh_gen_levelstate_t::*lastdelta esp BLE_MESH_GEN_LOC_LOCAL_STATUS_CB_T::*local_east
  (C++ member), 421
esp_ble_mesh_gen_levelstate_t::*level esp BLE_MESH_GEN_LOCATION_SETUP_SRVT
  (C++ class), 427
esp_ble_mesh_gen_levelstate_t::*move status esp BLE_MESH_GEN_LOCATION_SETUP_SRVT::*model
  (C++ member), 423
esp_ble_mesh_gen_levelstate_t::*positive esp BLE_MESH_GEN_LOCATION_SETUP_SRVT::*rsp_ctrl
  (C++ member), 423
esp_ble_mesh_gen_levelstate_t::*transition esp BLE_MESH_GEN_LOCATION_SETUP_SRVT::*state
  (C++ class), 427
esp_ble_mesh_gen_levelstatecb_t esp BLE_MESH_GEN_LOCATION_SRVT  (C++
  class), 427
esp_ble_mesh_gen_levelstatecb_t::*op esp BLE_MESH_GEN_LOCATION_SRVT::*model
  (C++ member), 427
esp_ble_mesh_gen_levelstatecb_t::*present esp BLE_MESH_GEN_LOCATION_SRVT::*rsp_ctrl
  (C++ member), 427
esp_ble_mesh_gen_levelstatecb_t::*remain esp BLE_MESH_GEN_LOCATION_SRVT::*state
  (C++ member), 427
esp_ble_mesh_gen_levelstatecb_t::*target esp BLE_MESH_GEN_LOCATION_STATE_T
  (C++ member), 427
esp_ble_mesh_gen_loc_globalset_t esp BLE_MESH_GEN_LOCATION_STATE_T::*floor_number
  (C++ member), 427
esp_ble_mesh_gen_locglobalset_t::*global_altitude esp BLE_MESH_GEN_LOCATION_STATE_T::*global_altitude
  (C++ member), 426
esp_ble_mesh_gen_locglobalset_t::*global_latitude esp BLE_MESH_GEN_LOCATION_STATE_T::*global_latitude
  (C++ member), 426
esp_ble_mesh_gen_locglobalset_t::*global_longitude esp BLE_MESH_GEN_LOCATION_STATE_T::*global_longitude
  (C++ member), 426
esp_ble_mesh_gen_locglobalset_t::*local_altitude esp BLE_MESH_GEN_LOCATION_STATE_T::*local_altitude
  (C++ member), 427
esp_ble_mesh_gen_locglobalset_t::*local_east esp BLE_MESH_GEN_LOCATION_STATE_T::*local_east
  (C++ member), 427
esp_ble_mesh_gen_locglobalset_t::*local_from esp BLE_MESH_GEN_LOCATION_STATE_T::*local_from
  (C++ member), 427
esp_ble_mesh_gen_locglobalset_t::*local_north esp BLE_MESH_GEN_LOCATION_STATE_T::*local_north
  (C++ member), 427
esp_ble_mesh_gen_locglobalset_t::*local_status esp BLE_MESH_GEN_LOCATION_STATE_T::*local_status
  (C++ member), 427
esp_ble_mesh_gen_loclocalset_t  (C++ ESP_BLE_MESH_GEN_MANU_ACCESS_READ
  class), 417
esp_ble_mesh_gen_loclocalset_t::*floor esp BLE_MESH_GEN_MANU_NOT_USER_PROP
  (C++ enumerator), 440
esp_ble_mesh_gen_loclocalset_t::*local_accuracy esp BLE_MESH_GEN_MANU_PROP_ACCESS_T
[...]

ESP_BLE_MESH_INVALID_SCENE_NUMBER (C macro), 475
ESP_BLE_MESH_INVALID_SENSOR_PROPERTY_ID (C macro), 452
ESP_BLE_MESH_INVALID_SETTINGSIDX (C macro), 339
esp_ble_mesh_light_client_get_state_t::lc_property_get (C++ member), 478
esp_ble_mesh_light_client_set_state_t::xyl_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::xyl_range_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::xyl_default_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::lightness_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::lightness_range_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::lightness_linear_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::lightness_default_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::ctl_temperature_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::ctl_temperature_range_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::ctl_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::ctl_default_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::lc_property_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::lc_om_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::lc_light_onoff_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::hsl_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::hsl_saturation_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::hsl_hue_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::hsl_range_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::hsl_default_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::ctl_temperature_range_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::ctl_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::ctl_default_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::lightness_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::lightness_range_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::lightness_linear_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::lightness_default_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::ctl_temperature_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::ctl_temperature_range_set (C++ member), 478
esp_ble_mesh_light_client_set_state_t::ctl_set (C++ member), 478
espble mesh_light_client_set_state_t::ctl_default_set (C++ member), 478
espble mesh_light_client_set_state_t::ctl_status (C++ member), 478
espble mesh_light_client_set_state_t::ctl_temperature (C++ member), 478

Index

```
C++ class, 485
C++ member, 486

esp_ble_mesh_light_ctl_state_t::lightness
(C++ member), 496
esp_ble_mesh_light_ctl_temperature_range_status_cb_t::range_min
(C++ member), 490
esp_ble_mesh_light_ctl_temperature_range_status_cb_t::range_max
(C++ member), 490
esp_ble_mesh_light_ctl_temperature_status_cb_t::target_ctl_temperature
(C++ member), 485
esp_ble_mesh_light_ctl_temperature_status_cb_t::target_ctl_lightness
(C++ member), 485
```

Submit Document Feedback
Index

(C++ member), 486
esp_ble_mesh_light_hsl_hue_set_t::op_en
(C++ member), 486

(C++ member), 499
esp_ble_mesh_light_hsl_hue_set_t::tid
esp_ble_mesh_light_hsl_sat_srv_t::model
(C++ member), 499

(C++ member), 499
estble mesh light hsl_range_status_cb_t::status_code
esp_ble_mesh_light_hsl_range_status_cb_t::saturation_range_max
esp_ble_mesh_light_hsl_range_status_cb_t::hue_range_min

esp_ble_mesh_light_hsl_range_set_t::saturation_range_min
esp_ble_mesh_light_hsl_range_set_t::saturation_range_max
esp_ble_mesh_light_hsl_range_set_t::hue_range_min

ESP_BLE_MESH_LIGHT_HSL_LIGHTNESS_STATE
esp_ble_mesh_light_hsl_hue_srv_t::tt_delta_hue
esp_ble_mesh_light_hsl_hue_srv_t::state
esp_ble_mesh_light_hsl_hue_srv_t::rsp_ctrl

esp_ble_mesh_light_hsl_hue_set_t::saturation
esp_ble_mesh_light_hsl_hue_set_t::hue
esp_ble_mesh_light_hsl_hue_set_t::delay

(C++ member), 486
 ESP_BLE_MESH_LIGHT_HSL_HUE_STATE
(C++ member), 486
estble mesh light hsl_saturation_status_cb_t::target_saturation
esp_ble_mesh_light_hsl_saturation_status_cb_t::remain_time
esp_ble_mesh_light_hsl_saturation_status_cb_t::present_saturation
esp_ble_mesh_light_hsl_saturation_status_cb_t::op_en

ESP_BLE_MESH_LIGHT_HSL_LIGHTNESS_STATE
espble mesh light hsl_sat_srv_t::model
espble mesh light hsl_sat_srv_t::tt_delta_satur

C++ member, 486
espble mesh light hsl_sat_srv_t::rsp_ctrl

C++ member, 499
espble mesh light hsl_sat_srv_t::transit

C++ member, 499
espble mesh light hsl_sat_srv_t::state
espble mesh light hsl_sat_srv_t::last
C++ member, 499
espble mesh light hsl_sat_srv_t::model

C++ member, 499
espble mesh light hsl_sat_srv_t::model

C++ member, 499
estble mesh light hsl_saturation_set_t::trans_time
espble mesh light hsl_saturation_set_t::tid
espble mesh light hsl_saturation_set_t::saturation
espble mesh light hsl_saturation_set_t::op_en

C++ member, 499
espble mesh light hsl_saturation_set_t::model

C++ member, 499
espble mesh light hsl_saturation_set_t::model

C++ class, 499
espble mesh light hsl_sat_srv_t::rsp_ctrl

C++ class, 499
<table>
<thead>
<tr>
<th>C++ member</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>esp_ble_mesh_light_lc_property_set_t::property_value</code></td>
<td>488</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_set_t::property_id</code></td>
<td>501</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_state_machine_t::trans_time</code></td>
<td>502</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_state_machine_t::timer</code></td>
<td>503</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_state_machine_t::fade</code></td>
<td>504</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_state_machine_t::fade_on</code></td>
<td>504</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_state_machine_t::fade_standby</code></td>
<td>504</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_state_machine_t::state</code></td>
<td>504</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_state_machine_t::timer</code></td>
<td>504</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_state_machine_t::trans_time</code></td>
<td>504</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lightness_default_set_t::lightness</code></td>
<td>494</td>
</tr>
<tr>
<td><code>ESP_BLE_MESH_LIGHT_LIGHTNESS_ACTUAL_STATE</code></td>
<td>488</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_id</code></td>
<td>501</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>501</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>502</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>503</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>504</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>505</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>506</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>507</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>508</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>509</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>510</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>511</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>512</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>513</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>514</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>515</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>516</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>517</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>518</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>519</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>520</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>521</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>522</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>523</td>
</tr>
<tr>
<td><code>esp_ble_mesh_light_lc_property_get_t::property_value</code></td>
<td>524</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc state t::ambient luxlevel</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_state t::light_onoff</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_state t::linear output</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_state t::mode</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_state t::occupancy</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_state t::occupancy mode</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_state t::target light onoff</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_property state_t::ESP_BLE_MESH_LIGHT_LIGHTNESS_ACTUAL_STATE</code></td>
<td>360</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_property status_t</code></td>
<td>484</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_property status_t::light</code></td>
<td>484</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_property status_t::light</code></td>
<td>484</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_setup srv_t</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_setup srv_t::light</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_setup srv_t::light</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_setup srv_t::lc</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_setup srv_t::model</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_setup srv_t::last</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_setup srv_t::lc</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_setup srv_t::rsp_ctrl</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_setup srv_t::lc</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_setup srv_t::rsp_ctrl</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_setup srv_t::lc</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light lc_setup srv_t::last</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::target_light_onoff</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::time_run_on</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::time_prolong</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::time_occupancy_delay</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::time_fade_standby_manual</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::time_fade_standby_auto</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::time_fade_on</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::time_fade</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::regulator_kpu</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::regulator_kpd</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::regulator_accuracy</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::lightness_standby</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::lightness_prolong</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::lightness_on</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::ambient_luxlevel_standby</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::ambient_luxlevel_prolong</code></td>
<td>494</td>
</tr>
<tr>
<td><code>esp bleed mesh light_lc_state_machine_t::ambient_luxlevel_on</code></td>
<td>494</td>
</tr>
</tbody>
</table>
Index

(C++ class), 487
 esp_ble_mesh_light_xyl_default_set_t::lightness
 esp_ble_mesh_light_xyl_setup_srv_t::rsp_ctrl
(C++ member), 501
 esp_ble_mesh_light_xyl_default_set_t::x_range_max
 esp_ble_mesh_light_xyl_setup_srv_t::state
(C++ member), 501
 esp_ble_mesh_light_xyl_default_set_t::x_range_min
 esp_ble_mesh_light_xyl_srv_t (C++ class),
(C++ member), 500
 esp_ble_mesh_light_xyl_default_status_1::state
 esp_ble_mesh_light_xyl_srv_t::last
(C++ member), 501
 esp_ble_mesh_light_xyl_default_status_1::model
 esp_ble_mesh_light_xyl_srv_t::model
(C++ member), 500
 esp_ble_mesh_light_xyl_default_status_1::rsp_ctrl
 esp_ble_mesh_light_xyl_srv_t::rsp_ctrl
(C++ member), 500
 esp_ble_mesh_light_xyl_default_status_1::state
 esp_ble_mesh_light_xyl_srv_t::state
(C++ member), 500
 ESP_BLE_MESH_LIGHT_XYL_LIGHTNESS_STATE esp_ble_mesh_light_xyl_srv_t::transition
(C++ member), 501
 esp_ble_mesh_light_xyl_range_set_t esp_ble_mesh_light_xyl_srv_t::tt_delta_lightness
(C++ class), 487
 esp_ble_mesh_light_xyl_range_set_t::x_range_min
 esp_ble_mesh_light_xyl_srv_t::tt_delta_x
(C++ member), 501
 esp_ble_mesh_light_xyl_range_set_t::x_range_max
 esp_ble_mesh_light_xyl_srv_t::tt_delta_y
(C++ member), 487
 esp_ble_mesh_light_xyl_range_set_t::x_default
 esp_ble_mesh_light_xyl_state_t (C++ class),
(C++ member), 500
 esp_ble_mesh_light_xyl_range_status_cb_t esp_ble_mesh_light_xyl_state_t::lightness_default
(C++ class), 487
 esp_ble_mesh_light_xyl_range_status_cb_t::x_range_min
 esp_ble_mesh_light_xyl_state_t::state
(C++ member), 500
 esp_ble_mesh_light_xyl_range_status_cb_t::x_range_max
 esp_ble_mesh_light_xyl_state_t::target_lightness
(C++ member), 500
 esp_ble_mesh_light_xyl_range_status_cb_t::x_range_min
 esp_ble_mesh_light_xyl_state_t::target_x
(C++ member), 500
 esp_ble_mesh_light_xyl_range_status_cb_t::x_range_max
 esp_ble_mesh_light_xyl_state_t::target_y
(C++ member), 500
 esp_ble_mesh_light_xyl_range_status_cb_t::x_range_min
 esp_ble_mesh_light_xyl_state_t::x
(C++ member), 500
 esp_ble_mesh_light_xyl_range_status_cb_t::x_range_max
 esp_ble_mesh_light_xyl_state_t::x_default
(C++ member), 500
 esp_ble_mesh_light_xyl_range_status_cb_t::x_range_min
 esp_ble_mesh_light_xyl_state_t::x_range_max
(C++ member), 500
 esp_ble_mesh_light_xyl_range_status_cb_t::x_range_min
 esp_ble_mesh_light_xyl_state_t::y
(C++ member), 500
 esp_ble_mesh_light_xyl_range_status_cb_t::x_range_max
 esp_ble_mesh_light_xyl_state_t::y_range_min
(C++ member), 500
 esp_ble_mesh_light_xyl_range_status_cb_t::x_range_min
 esp_ble_mesh_light_xyl_state_t::y_range_max
(C++ member), 500
 esp_ble_mesh_light_xyl_range_status_cb_t::x_range_max
 esp_ble_mesh_light_xyl_state_t::x
(C++ member), 487
 esp_ble_mesh_light_xyl_range_status_cb_t::x_range_min
 esp_ble_mesh_light_xyl_state_t::y
(C++ member), 487
 esp_ble_mesh_light_xyl_default_set_t esp_ble_mesh_light_xyl_status_cb_t::op_en
(C++ class), 501
 esp_ble_mesh_light_xyl_setup_srv_t esp_ble_mesh_light_xyl_status_cb_t::remain_time
(C++ class), 501
 esp_ble_mesh_light_xyl_setup_srv_t::tt_delta_lightness
 esp_ble_mesh_light_xyl_srv_t::tt_delta_lightness
(C++ member), 487
 esp_ble_mesh_light_xyl_setup_srv_t::tt_delta_x
 esp_ble_mesh_light_xyl_srv_t::tt_delta_x
(C++ member), 487
 esp_ble_mesh_light_xyl_setup_srv_t::tt_delta_y
 esp_ble_mesh_light_xyl_srv_t::tt_delta_y
(C++ member), 487
 esp_ble_mesh_light_xyl_srv_t::tt_delta_lightness
 esp_ble_mesh_light_xyl_srv_t::tt_delta_lightness
(C++ member), 500
 esp_ble_mesh_light_xyl_srv_t::tt_delta_x
 esp_ble_mesh_light_xyl_srv_t::tt_delta_x
(C++ member), 500
 esp_ble_mesh_light_xyl_srv_t::tt_delta_y
 esp_ble_mesh_light_xyl_srv_t::tt_delta_y
(C++ member), 500
 esp_ble_mesh_light_xyl_srv_t::transition
 esp_ble_mesh_light_xyl_srv_t::transition
(C++ member), 500
 esp_ble_mesh_light_xyl_srv_t::state
 esp_ble_mesh_light_xyl_state_t::state
(C++ member), 500
 esp_ble_mesh_light_xyl_srv_t::last
 esp_ble_mesh_light_xyl_state_t::last
(C++ member), 500
 esp_ble_mesh_light_xyl_srv_t::state
 esp_ble_mesh_light_xyl_state_t::state
(C++ member), 500
 esp_ble_mesh_light_xyl_srv_t::last
 esp_ble_mesh_light_xyl_state_t::last
(C++ member), 500
 esp_ble_mesh_light_xyl_srv_t::model
 esp_ble_mesh_light_xyl_state_t::model
(C++ member), 500
 esp_ble_mesh_light_xyl_srv_t::model
 esp_ble_mesh_light_xyl_state_t::model
(C++ member), 500
<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_ble_mesh_model::element_idx</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::flags</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::groups</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::keys</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::mode_set</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::model_id</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::company_id</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::cb</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::operation_evt_param::model</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::operation_evt_param::length</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::operation_evt_param::ctx</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::operation_evt_param</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::recv_publish_msg_param::opcode</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::recv_publish_msg_param::msg</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::recv_publish_msg_param::length</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::recv_publish_msg_param::model</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::client_model_send_timeout_param::opcode</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::client_model_send_timeout_param::model</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::client_model_send_timeout_param::ctx</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::client_model_send_timeout_param</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::key_set</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::model_set</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_model::set</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_lighting_server_state_change_t::publish</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_lighting_server_state_change_t::client_model_send_timeout</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_lighting_server_state_change_t::ack</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_lighting_server_state_change_t::lightness_set</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_lighting_server_state_change_t::lightness_range_set</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_lighting_server_state_change_t::lightness_linear_set</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_lighting_server_state_change_t::lightness_default_set</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_lighting_server_state_change_t::lc_property_set</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_lighting_server_state_change_t::lc_mode_set</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_lighting_server_state_change_t::hsl_set</td>
<td>(C++ member), 481</td>
</tr>
<tr>
<td>esp_ble_mesh_lighting_server_state_change_t::hsl_saturation_set</td>
<td>(C++ member), 481</td>
</tr>
</tbody>
</table>

Espressif Systems 2185  Release v5.0-dev-1077-g397639d
Submit Document Feedback
ESP_BLE_MESH_MODEL_ID_LIGHT_LIGHTNESS_SRV
(C macro), 343
ESP_BLE_MESH_MODEL_ID_LIGHT_LIGHTNESS_CLI
(C macro), 343
ESP_BLE_MESH_MODEL_ID_LIGHT_LC_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_LC_SETUP_SRV
(C macro), 343
ESP_BLE_MESH_MODEL_ID_LIGHT_LC_CLI
ESP_BLE_MESH_MODEL_ID_LIGHT_HSL_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_HSL_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_HSL_SAT_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_HSL_HUE_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_HSL_CLI
ESP_BLE_MESH_MODEL_ID_LIGHT_CTL_TEMP_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_CTL_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_CTL_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_CTL_CLI
ESP_BLE_MESH_MODEL_ID_HEALTH_SRV
ESP_BLE_MESH_MODEL_ID_HEALTH_CLI
ESP_BLE_MESH_MODEL_ID_GEN_USER_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_PROP_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_ONOFF_SRV
ESP_BLE_MESH_MODEL_ID_GEN_ONOFF_CLI
ESP_BLE_MESH_MODEL_ID_GEN_MANUFACTURER_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_LOCATION_SRV
ESP_BLE_MESH_MODEL_ID_GEN_LOCATION_SETUP_SRV

Index
ESP_BLE_MESH_MODEL_OP_GEN_LOC_LOCAL_SET
ESP_BLE_MESH_MODEL_OP_GEN_LOC_LOCAL_SET_UNACK
ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_SET_UNACK
ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_SET
ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_GET
ESP_BLE_MESH_MODEL_OP_GEN_POWER_LAST_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_POWER_LAST_GET
ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_SET
ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_GET
ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_SET_UNACK
ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_SET
ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_GET
ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_SET
ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_GET
ESP_BLE_MESH_MODEL_OP_GEN_MOVE_SET
ESP_BLE_MESH_MODEL_OP_GEN_MOVE_SET_UNACK
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET_UNACK
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_GET
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_SET_UNACK
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_SET
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_GET
ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_SET_UNACK
ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_SET
ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_GET
ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_SET
ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_GET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_STATUS
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_SET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_GET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_STATUS
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_SET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_GET
ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_STATUS
ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET_UNACK
ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET
ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_GET
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST_UNACK
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_STATUS
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_GET
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR_UNACK
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR
ESP_BLE_MESH_MODEL_OP_HEALTH_CURRENT_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTIES_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTIES_GET
ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL
ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_STATUS
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_GET
ESP_BLE_MESH_MODEL_OP_GEN_POWER_LAST_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_POWER_LAST_GET
ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_SET
ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_GET
ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_SET_UNACK
ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_SET
ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_GET
ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_SET
ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_GET
ESP_BLE_MESH_MODEL_OP_GEN_MOVE_SET
ESP_BLE_MESH_MODEL_OP_GEN_MOVE_SET_UNACK
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET_UNACK
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_GET
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_SET_UNACK
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_SET
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_GET
ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_SET_UNACK
ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_SET
ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_GET
ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_SET
ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_GET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_STATUS
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_SET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_GET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_STATUS
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_SET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_GET
ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_STATUS
ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET_UNACK
ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET
ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_GET
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST_UNACK
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_STATUS
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_GET
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR_UNACK
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR
ESP_BLE_MESH_MODEL_OP_HEALTH_CURRENT_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTIES_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTIES_GET
<table>
<thead>
<tr>
<th>Function and Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_ble_mesh_opcode_client_set</td>
<td>Function to set BLE Mesh opcode parameters.</td>
</tr>
<tr>
<td>esp_ble_mesh_opcode_client_get</td>
<td>Function to get BLE Mesh opcode parameters.</td>
</tr>
<tr>
<td>esp_ble_mesh_model_unsub_group_addr_comp_param</td>
<td>BLE Mesh model unsubscribe group address completion parameter.</td>
</tr>
<tr>
<td>esp_ble_mesh_model_sub_group_addr_comp_param</td>
<td>BLE Mesh model subscribe group address completion parameter.</td>
</tr>
<tr>
<td>esp_ble_mesh_model_sub_group_addr_comp_param::company_id</td>
<td>Company ID parameter in the BLE Mesh model subscribe group address completion.</td>
</tr>
<tr>
<td>esp_ble_mesh_model_sub_group_addr_comp_param::element_addr</td>
<td>Element Address parameter in the BLE Mesh model subscribe group address completion.</td>
</tr>
<tr>
<td>esp_ble_mesh_model_sub_group_addr_comp_param::group_addr</td>
<td>Group Address parameter in the BLE Mesh model subscribe group address completion.</td>
</tr>
<tr>
<td>esp_ble_mesh_model_sub_group_addr_comp_param::model_id</td>
<td>Model ID parameter in the BLE Mesh model subscribe group address completion.</td>
</tr>
<tr>
<td>esp_ble_mesh_model_sub_group_addr_comp_param::err_code</td>
<td>Error code parameter in the BLE Mesh model subscribe group address completion.</td>
</tr>
<tr>
<td>esp_ble_mesh_model_sub_group_addr_comp_param::ble_mesh_model_sub_group_addr_comp_param::model_id</td>
<td>Model ID parameter in the BLE Mesh model subscribe group address completion.</td>
</tr>
<tr>
<td>esp_ble_mesh_model_sub_group_addr_comp_param::ble_mesh_model_sub_group_addr_comp_param::element_addr</td>
<td>Element Address parameter in the BLE Mesh model subscribe group address completion.</td>
</tr>
<tr>
<td>esp_ble_mesh_model_sub_group_addr_comp_param::ble_mesh_model_sub_group_addr_comp_param::group_addr</td>
<td>Group Address parameter in the BLE Mesh model subscribe group address completion.</td>
</tr>
<tr>
<td>esp_ble_mesh_model_sub_group_addr_comp_param::ble_mesh_model_sub_group_addr_comp_param::err_code</td>
<td>Error code parameter in the BLE Mesh model subscribe group address completion.</td>
</tr>
<tr>
<td>esp_ble_mesh_model_sub_group_addr_comp_param::ble_mesh_model_sub_group_addr_comp_param::company_id</td>
<td>Company ID parameter in the BLE Mesh model subscribe group address completion.</td>
</tr>
<tr>
<td>Function/Parameter</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provision_complete_evt_param::net_key</td>
<td>net_key parameter for the provisioning complete event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provision_complete_evt_param::iv_index</td>
<td>iv_index parameter for the provisioning complete event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provision_complete_evt_param::flags</td>
<td>flags parameter for the provisioning complete event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_local_net_key_comp_param::net_idx</td>
<td>net_idx parameter for the provisioning local network key event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_local_net_key_comp_param::err_code</td>
<td>error code parameter for the provisioning local network key event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_local_app_key_comp_param::err_code</td>
<td>error code parameter for the provisioning local application key event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_local_app_key_comp_param::app_idx</td>
<td>application index parameter for the provisioning local application key event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_local_app_key_comp_param::company_id</td>
<td>company ID parameter for the provisioning local application key event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_local_app_key_comp_param::element_addr</td>
<td>element address parameter for the provisioning local application key event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_unprov_dev_comp_param::err_code</td>
<td>error code parameter for the provisioning unprovisioned device event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_bind_local_mod_app_comp_param::model_id</td>
<td>model ID parameter for the provisioning local module application event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_bind_local_mod_app_comp_param::err_code</td>
<td>error code parameter for the provisioning local module application event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_bind_local_mod_app_comp_param::element_addr</td>
<td>element address parameter for the provisioning local module application event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_bind_local_mod_app_comp_param::company_id</td>
<td>company ID parameter for the provisioning local module application event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_bind_local_mod_app_comp_param::app_idx</td>
<td>application index parameter for the provisioning local module application event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_dev_comp_param::err_code</td>
<td>error code parameter for the provisioning delete device event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_addr_comp_param::unicast_addr</td>
<td>unicast address parameter for the provisioning delete node with address event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_uuid_comp_param::err_code</td>
<td>error code parameter for the provisioning delete node with UUID event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_uuid_comp_param::uuid</td>
<td>UUID parameter for the provisioning delete node with UUID event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_uuid_comp_param::element_addr</td>
<td>element address parameter for the provisioning delete node with UUID event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_uuid_comp_param::company_id</td>
<td>company ID parameter for the provisioning delete node with UUID event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_uuid_comp_param::app_idx</td>
<td>application index parameter for the provisioning delete node with UUID event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisionerakedirs_group_comp_param::err_code</td>
<td>error code parameter for the provisioning create group event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisionerakedirs_group_comp_param::group_idx</td>
<td>group index parameter for the provisioning create group event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisionerakedirs_group_comp_param::group_addr</td>
<td>group address parameter for the provisioning create group event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisionerakedirs_group_comp_param::element_addr</td>
<td>element address parameter for the provisioning create group event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisionerakedirs_group_comp_param::company_id</td>
<td>company ID parameter for the provisioning create group event</td>
</tr>
<tr>
<td>esp_ble_mesh_prov_cb_param_t::ble_mesh_provisionerakedirs_group_comp_param::app_idx</td>
<td>application index parameter for the provisioning create group event</td>
</tr>
</tbody>
</table>
Index

esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_disconnect_comp_param::conn_handle (C++ member), 325
esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_connected_param::net_idx (C++ member), 325
esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_connected_param::conn_handle (C++ member), 325
esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_connected_param::addr_type (C++ member), 325
esp BLE Mesh Layer 6.0 API Reference
(C++ member), 335
ESP_BLE_MESH_provEvt (C++ enumerator), 360
ESP_BLE_MESH_PROV_GATT (C++ enumerator), 355
ESP_BLE_MESH_PROV_INPUT_OOB_MAX_LEN (C macro), 341
ESP_BLE_MESH_PROV_OOB_2D_CODE (C++ enumerator), 355
ESP_BLE_MESH_PROV_OOB_BAR_CODE (C++ enumerator), 355
ESP_BLE_MESH_PROV_OOB_IN_BOX (C++ enumerator), 356
ESP_BLE_MESH_PROV_OOB_IN_MANUAL (C++ enumerator), 356
esp_ble_mesh_prov_oob_info_t (C++ enum), 355
ESP_BLE_MESH_PROV_OOB_NFC (C++ enumerator), 356
ESP_BLE_MESH_PROV_OOB_NUMBER (C++ enumerator), 356
ESP_BLE_MESH_PROV_OOB_ON_BOX (C++ enumerator), 356
ESP_BLE_MESH_PROV_OOB_ON_DEV (C++ enumerator), 356
ESP_BLE_MESH_PROV_OOB_ON_PAPER (C++ enumerator), 356
ESP_BLE_MESH_PROV_OOB_OTHER (C++ enumerator), 355
ESP_BLE_MESH_PROV_OOB_STRING (C++ enumerator), 356
ESP_BLE_MESH_PROV_OOB_URI (C++ enumerator), 355
ESP_BLE_MESH_PROV_OUTPUT_OOB_MAX_LEN (C macro), 341
ESP_BLE_MESH_PROV_REGISTER_COMP_EVT (C++ enumerator), 356
ESP_BLE_MESH_PROV_STATIC_OOB_MAX_LEN (C macro), 341
esp_ble_mesh_prov_t (C++ class), 334
esp_ble_mesh_provisioner_add_local_app_key (C++ function), 368
ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_APP_KEY (C++ enumerator), 358
esp_ble_mesh_provisioner_add_local_net_key (C++ function), 369
ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_NET_KEY (C++ enumerator), 358
esp_ble_mesh_provisioner_add_unprov_dev (C++ function), 373
ESP_BLE_MESH_PROVISIONER_ADD_UNPROV_DEV (C++ enumerator), 357
esp_ble_mesh_provisioner_bind_app_key_to_model_comp_evt (C++ function), 371
ESP_BLE_MESH_PROVISIONER_BIND_APP_KEY_TO_MODEL_COMP_EVT (C++ function), 371
esp_ble_mesh_provisioner_close_settings (C++ function), 370
ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGS_WITH_INDEX (C++ function), 370
esp_ble_mesh_provisioner_close_settings_with_uid (C++ function), 370
ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGS_WITH_UID (C++ enumerator), 359
esp_ble_mesh_provisioner_delete_dev (C++ function), 375
ESP_BLE_MESH_PROVISIONER_DELETE_DEV_COMP_EVT (C++ enumerator), 358
esp_ble_mesh_provisioner_delete_node_with_addr (C++ function), 368
ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_ADDR_COMP_EVT (C++ enumerator), 358
esp_ble_mesh_provisioner_delete_node_with_uid (C++ function), 368
ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_UID_COMP_EVT (C++ enumerator), 358
esp_ble_mesh_provisioner_delete_settings (C++ function), 371
ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_COMP_EVT (C++ function), 371
esp_ble_mesh_provisioner_delete_settings_with_index (C++ function), 371
ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_INDEX_COMP_EVT (C++ function), 371
esp_ble_mesh_provisioner_delete_settings_with_uid (C++ function), 371
ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_UID_COMP_EVT (C++ function), 371
esp_ble_mesh_provisioner_direct_erase_settings (C++ function), 370
ESP_BLE_MESH_PROVISIONER_DIRECT_ERASE_SETTINGS_COMP_EVT (C++ function), 370
esp_ble_mesh_provisioner_get_free_settings_count (C++ function), 368
esp_ble_mesh_provisioner_get_local_app_key (C++ function), 369
esp_ble_mesh_provisioner_get_local_net_key (C++ function), 369
esp_ble_mesh_provisioner_get_node_index (C++ function), 367
esp_ble_mesh_provisioner_get_node_name (C++ function), 367
esp_ble_mesh_provisioner_get_node_table_entry (C++ function), 367
esp_ble_mesh_provisioner_get_node_with_addr (C++ function), 367
esp_ble_mesh_provisioner_get_node_with_uuid (C++ function), 367
esp_ble_mesh_provisioner_get_prov_node_count (C++ function), 367
esp_ble_mesh_provisioner_get_prov_node_count (C++ function), 367
esp_ble_mesh_provisioner_get_prov_node_count (C++ function), 367
esp_ble_mesh_provisioner_get_prov_node_count (C++ function), 367
esp_ble_mesh_provisioner_get_prov_node_count (C++ function), 367
esp_ble_mesh_provisioner_get_settings_count (C++ function), 367
esp_ble_mesh_provisioner_get_settings_index (C++ function), 371
esp_ble_mesh_provisioner_get_settings_uid (C++ function), 371
esp_ble_mesh_provisioner_input_number (C++ function), 370
esp_ble_mesh_provisioner_input_number (C++ function), 370
// Other ESP BLE Mesh Provisioner methods are listed here...

ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGS_WITH_INDEX (C++ function), 370
esp_ble_mesh_provisioner_close_settings_with_uid (C++ function), 370
ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGS_WITH_UID (C++ enumerator), 359
esp_ble_mesh_provisioner_delete_dev (C++ function), 375
ESP_BLE_MESH_PROVISIONER_DELETE_DEV_COMP_EVT (C++ enumerator), 358
esp_ble_mesh_provisioner_delete_node_with_addr (C++ function), 368
ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_ADDR_COMP_EVT (C++ enumerator), 358
esp_ble_mesh_provisioner_delete_node_with_uid (C++ function), 368
ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_UID_COMP_EVT (C++ enumerator), 358
esp_ble_mesh_provisioner_delete_settings (C++ function), 371
ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_COMP_EVT (C++ function), 371
esp_ble_mesh_provisioner_delete_settings_with_index (C++ function), 371
ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_INDEX_COMP_EVT (C++ function), 371
esp_ble_mesh_provisioner_delete_settings_with_uid (C++ function), 371
ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_UID_COMP_EVT (C++ function), 371
esp_ble_mesh_provisioner_direct_erase_settings (C++ function), 370
ESP_BLE_MESH_PROVISIONER_DIRECT_ERASE_SETTINGS_COMP_EVT (C++ function), 370
esp_ble_mesh_provisioner_get_free_settings_count (C++ function), 368
esp_ble_mesh_provisioner_get_local_app_key (C++ function), 369
esp_ble_mesh_provisioner_get_local_net_key (C++ function), 369
esp_ble_mesh_provisioner_get_node_index (C++ function), 367
esp_ble_mesh_provisioner_get_node_name (C++ function), 367
esp_ble_mesh_provisioner_get_node_table_entry (C++ function), 367
esp_ble_mesh_provisioner_get_node_with_addr (C++ function), 367
esp_ble_mesh_provisioner_get_node_with_uuid (C++ function), 367
esp_ble_mesh_provisioner_get_prov_node_count (C++ function), 367
esp_ble_mesh_provisioner_get_prov_node_count (C++ function), 367
esp_ble_mesh_provisioner_get_prov_node_count (C++ function), 367
esp_ble_mesh_provisioner_get_prov_node_count (C++ function), 367
esp_ble_mesh_provisioner_get_prov_node_count (C++ function), 367
esp_ble_mesh_provisioner_get_settings_count (C++ function), 367
esp_ble_mesh_provisioner_get_settings_index (C++ function), 371
esp_ble_mesh_provisioner_get_settings_uid (C++ function), 371
esp_ble_mesh_provisioner_input_number (C++ function), 370

// More ESP BLE Mesh Provisioner methods are listed here...

// End of ESP BLE Mesh Provisioner methods list.

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// Additional notes or comments about ESP BLE Mesh Provisioner methods...

// Additional notes or comments about ESP BLE Mesh Provisioner methods...

// End of ESP BLE Mesh Provisioner methods list.
Index

esp_ble_mesh_provisioner_input_string  ESP_BLE_MESH_PROVISIONER_SET_HEARTBEAT_FILTER_TYPE
(C++ function), 373

esp_ble_mesh_provisioner_open_settings  ESP_BLE_MESH_PROVISIONER_SET_NODE_NAME_COMP_EVT
(C++ function), 370

ESP_BLE_MESH_PROVISIONER_OPEN_SETTINGS  ESP_BLE_MESH_PROVISIONER_SET_NODE_NAME_COMP_EVT
(C++ function), 370

esp_ble_mesh_provisioner_open_settings  ESP_BLE_MESH_PROVISIONER_SET_PRIMARY_ELEM_ADDR
(C++ function), 370

ESP_BLE_MESH_PROVISIONER_OPEN_SETTINGS  ESP_BLE_MESH_PROVISIONER_SET_PRIMARY_ELEM_ADDR
(C++ function), 370

esp_ble_mesh_provisioner_prov_disable  ESP_BLE_MESH_PROVISIONER_PROV_DISABLE_COMP_EVT
(C++ function), 375

esp_ble_mesh_provisioner_prov_disable  ESP_BLE_MESH_PROVISIONER_PROV_DISABLE_COMP_EVT
(C++ function), 375

esp_ble_mesh_provisioner_prov_enable  ESP_BLE_MESH_PROVISIONER_PROV_ENABLE_COMP_EVT
(C++ function), 373

ESP_BLE_MESH_PROVISIONER_PROV_ENABLE_COMP_EVT  ESP_BLE_MESH_PROVISIONER_PROV_ENABLE_COMP_EVT
(C++ function), 373

esp_ble_mesh_provisioner_update_local_app_key  ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_APP_KEY_COMP_EVT
(C++ function), 377

esp_ble_mesh_provisioner_set_component_local_net_key  ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_NET_KEY_COMP_EVT
(C++ function), 377

ESP_BLE_MESH_PROVISIONER_PROV_LINK_CLOSED  ESP_BLE_MESH_PROXY_CLIENT_ADD_FILTER_ADDR
(C++ function), 377

ESP_BLE_MESH_PROVISIONER_PROV_LINK_CLOSED  ESP_BLE_MESH_PROXY_CLIENT_ADD_FILTER_ADDR
(C++ function), 377

ESP_BLE_MESH_PROVISIONER_PROV_OUTPUT_EVT  ESP_BLE_MESH_PROXY_CLIENT_CONNECT_COMP_EVT
(C++ function), 377

ESP_BLE_MESH_PROVISIONER_PROV_OUTPUT_EVT  ESP_BLE_MESH_PROXY_CLIENT_CONNECT_COMP_EVT
(C++ function), 377

esp_ble_mesh_provisioner_read_oob_pub_key  ESP_BLE_MESH_PROXY_CLIENT_DISCONNECT_COMP_EVT
(C++ function), 377

esp_ble_mesh_provisioner_recv_heartbeat  ESP_BLE_MESH_PROXY_CLIENT_DISCONNECT_COMP_EVT
(C++ function), 369

ESP_BLE_MESH_PROVISIONER_RECV_HEARTBEAT  ESP_BLE_MESH_PROXY_CLIENT_DISCONNECTED_EVT
(C++ function), 369

ESP_BLE_MESH_PROVISIONER_RECV_HEARTBEAT  ESP_BLE_MESH_PROXY_CLIENT_DISCONNECTED_EVT
(C++ function), 369

esp_ble_mesh_provisioner_set_device_with_addr  ESP_BLE_MESH_PROXY_CLIENT_REMOVE_FILTER_ADDR_COMP_EVT
(C++ function), 377

esp_ble_mesh_provisioner_set_device_with_addr  ESP_BLE_MESH_PROXY_CLIENT_REMOVE_FILTER_ADDR_COMP_EVT
(C++ function), 377

ESP_BLE_MESH_PROVISIONER_PROV_SET_FILTER_TYPE  ESP_BLE_MESH_PROXY_CLIENT_SET_FILTER_TYPE_COMP_EVT
(C++ function), 377

ESP_BLE_MESH_PROVISIONER_PROV_SET_FILTER_TYPE  ESP_BLE_MESH_PROXY_CLIENT_SET_FILTER_TYPE_COMP_EVT
(C++ function), 377

ESP_BLE_MESH_PROVISIONER_PROV_SET_FILTER_INFO_COMP_EVT  ESP_BLE_MESH_PROXY_CLIENT_SET_FILTER_TYPE_COMP_EVT
(C++ function), 377

ESP_BLE_MESH_PROVISIONER_PROV_SET_FILTER_INFO_COMP_EVT  ESP_BLE_MESH_PROXY_CLIENT_SET_FILTER_TYPE_COMP_EVT
(C++ function), 377
Index

esp_ble_mesh_proxy_filter_type_t (C++ enum), 356
esp_ble_mesh_proxy_gatt_disable (C++ function), 377
esp_ble_mesh_proxy_gatt_enable (C++ function), 376
esp_ble_mesh_proxy_identity_enable (C++ function), 376
ESP_BLE_MESH_PUBLISH_TRANSMIT (C macro), 341
ESP_BLE_MESH_PUSH (C++ enumerator), 355
esp_ble_mesh_register_config_client_callback (C++ function), 378
esp_ble_mesh_register_config_server_callback (C++ member), 460
esp_ble_mesh_register_custom_model_callback (C++ function), 364
esp_ble_mesh_register_sensor_server_callback (C++ function), 410
esp_ble_mesh_register_sensor_client_callback (C++ function), 410
esp_ble_mesh_register_time_scene_server_callback (C++ function), 372
esp_ble_mesh_register_library (C++ class), 401
esp_ble_mesh_register_sensor_server_callback (C++ function), 441
esp_ble_mesh_register_time_scene_server_callback (C++ function), 456
ESP_BLE_MESH_RELAY_DISABLED (C macro), 339
ESP_BLE_MESH_RELAY_ENABLED (C macro), 340
ESP_BLE_MESH_RELAY_NOT_SUPPORTED (C macro), 340
ESP_BLE_MESH_SAMPLE_FUNC_ACCUMULATED (C++ enumerator), 455
ESP_BLE_MESH_SAMPLE_FUNC_ARITHMETIC_MEAN (C++ enumerator), 455
ESP_BLE_MESH_SAMPLE_FUNC_COUNT (C++ enumerator), 455
ESP_BLE_MESH_SAMPLE_FUNC_INSTANTANEOUS (C++ enumerator), 455
ESP_BLE_MESH_SAMPLE_FUNC_MAXIMUM (C++ enumerator), 455
ESP_BLE_MESH_SAMPLE_FUNC_MINIMUM (C++ enumerator), 455
ESP_BLE_MESH_SAMPLE_FUNC_RMS (C++ enumerator), 455

ESP_BLE_MESH_SCENE_NOT_FOUND (C macro), 476
ESP_BLE_MESH_SCENE_NUMBER_LEN (C macro), 475
esp_ble_mesh_render_frame (C++ function), 460
esp_ble_mesh_scene_delete_t (C++ class), 460
esp_ble_mesh_scene_delete_t::scene_number (C++ member), 460
esp_ble_mesh_scene_recall_t (C++ class), 460
esp_ble_mesh_scene_recall_t::delay (C++ member), 460
esp_ble_mesh_scene_recall_t::op_en (C++ member), 460
esp_ble_mesh_scene_recall_t::scene_number (C++ member), 460
esp_ble_mesh_scene_recall_t::tid (C++ member), 460
esp_ble_mesh_scene_recall_t::trans_time (C++ member), 460
ESP_BLE_MESH_SCENE_REG_FULL (C macro), 476
esp_ble_mesh_scene_register_status_cb_t (C++ function), 463
esp_ble_mesh_scene_register_status_cb_t::current_ (C++ function), 463
esp_ble_mesh_scene_register_status_cb_t::current_ (C++ function), 463
esp_ble_mesh_scene_register_status_cb_t::status_c (C++ function), 463
esp_ble_mesh_scene_register_status_cb_t::status_c (C++ function), 463
esp_ble_mesh_scene_register_status_cb_t::status_c (C++ function), 463
esp_ble_mesh_scene_recall_t::trans_time (C++ member), 463
esp_ble_mesh_scene_recall_t::trans_time (C++ member), 463
esp_ble_mesh_scene_recall_t::trans_time (C++ member), 463
esp_ble_mesh_scene_recall_t::trans_time (C++ member), 463

ESP_BLE_MESH_SCENE_REG_FULL (C macro), 476

espressif Systems 2203 Release v5.0-dev-1077-g397639d
Submit Document Feedback
(C++ member), 466

esp_ble_mesh_scheduler_act_set_t::second (C++ class), 462
esp_ble_mesh_scheduler_act_set_t::scene_number (C++ member), 462
esp_ble_mesh_scheduler_act_get_t::index (C++ member), 467

esp_ble_mesh_scenes_state_t::target_scene (C++ member), 462
esp_ble_mesh_scenes_state_t::status_code (C++ member), 462
esp_ble_mesh_scenes_state_t::remain_time (C++ member), 462
esp_ble_mesh_scenes_state_t::op_en (C++ member), 462

esp_ble_mesh_scenes_state_t::current_scene (C++ member), 462
esp_ble_mesh_scenes_state_t::status_code (C++ member), 462
esp_ble_mesh_scenes_state_t::target_scene (C++ member), 462
esp_ble_mesh_scenes_state_t::current_scene (C++ member), 462

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466
esp_ble_mesh_scenes_state_t::current_scenes (C++ member), 466

Index
Index

esp_ble_mesh_scheduler_act_set_t::trans_time  macro, 408
(C++ member), 461

esp_ble_mesh_scheduler_act_set_t::year  C++ class, 443
(C++ member), 461

esp_ble_mesh_scheduler_act_status_cb_t::act()  C++ class, 443
(C++ member), 463

esp_ble_mesh_scheduler_act_status_cb_t::day  (C++ member), 463
(C++ member), 463

esp_ble_mesh_scheduler_act_status_cb_t::day_of()  C++ member, 444
(C++ member), 463

esp_ble_mesh_scheduler_act_status_cb_t::hour  (C++ member), 463
(C++ member), 463

esp_ble_mesh_scheduler_act_status_cb_t::index  (C++ member), 444
(C++ member), 463

esp_ble_mesh_scheduler_act_status_cb_t::minut()  (C++ member), 444
(C++ member), 463

esp_ble_mesh_scheduler_act_status_cb_t::month  (C++ member), 444
(C++ member), 463

espble_mesh_scheduler_act_status_cb_t::scene  C++ member, 444
(C++ member), 463

espble_mesh_scheduler_act_status_cb_t::second  C++ member, 444
(C++ member), 463

espble_mesh_scheduler_act_status_cb_t::trans()  C++ class, 445
(C++ member), 463

espble_mesh_scheduler_act_status_cb_t::year  (C++ member), 445
(C++ member), 463

espble_mesh_scheduler_setup_srv_t::trans_time  macro, 408
(C++ class), 447

espble_mesh_scheduler_setup_srv_t::model  (C++ member), 468
(C++ class), 447

espble_mesh_scheduler_setup_srv_t::rsp_ctrl  (C++ member), 468
(C++ class), 447

espble_mesh_scheduler_setup_srv_t::state  (C++ member), 468
(C++ class), 447

ESP_BLE_MESH_SDU_MAX_LEN  C macro, 339
ESP_BLE_MESH_SELF_TEST_ERROR  C macro, 408
ESP_BLE_MESH_SELF_TEST_WARNING  C ESP_BLE_MESH_SENSOR_CLIENT_EVT_MAX

Submit Document Feedback

Espressif Systems 2205  Release v5.0-dev-1077-g397639d
Index

esp_ble_mesh_sensor_setting_status_cb_t::op仡(C++ member), 449
esp_ble_mesh_sensor_state_t::setting_count (C++ member), 448
esp_ble_mesh_sensor_state_t::settings (C++ member), 448
esp_ble_mesh_sensor_status_cb_t::marshalled_sensor_data (C++ member), 446
esp_ble_mesh_sensor_status_cb_t::state_count (C++ member), 446
esp_ble_mesh_server_model_update_state (C++ function), 432
ESP_BLE_MESH_SENSOR_STATUS_MIN_INTERVAL_LEN (C macro), 453
ESP_BLE_MESH_SENSOR_STATUS_MIN_INTERVAL_MAX (C macro), 453
ESP_BLE_MESH_SENSOR_STATUS_TRIGGER_TYPE_CHAR (C macro), 453
ESP_BLE_MESH_SENSOR_STATUS_TRIGGER_TYPE_UINT16 (C macro), 453
ESP_BLE_MESH_SENSOR_UNSPECIFIED_NEG_TOLERANCE (C macro), 453
ESP_BLE_MESH_SENSOR_UNSPECIFIED_POS_TOLERANCE (C macro), 453
ESP_BLE_MESH_SERVER_ADMIN_PROPERTY_GET (C function), 365
ESP_BLE_MESH_SERVER_ADMIN_PROPERTY_SET (C function), 365
ESP_BLE_MESH_SERVER_AUTO_RSP (C macro), 353
ESP_BLE_MESH_SERVER_FLAG_MAX (C++ enumerantion), 360
esp_ble_mesh_server_model_send_msg (C++ function), 431
ESP_BLE_MESH_SERVER_MODEL_UPDATE_STATE_COMP_EVT (C++ enumeration), 361
ESP_BLE_MESH_SERVER_MODEL_UPDATE_STATE_MAX (C++ enumeration), 360
esp_ble_mesh_server_model_update_state (C++ function), 432
esp_ble_mesh_server_recv_gen_admin_property_set_t (C++ class), 449
esp_ble_mesh_server_recv_gen_admin_property_get_t (C++ class), 449
esp_ble_mesh_server_recv_gen_admin_property_set_t (C++ class), 448
esp_ble_mesh_server_recv_gen_admin_property_get_t (C++ class), 448
esp_ble_mesh_server_recv_gen_client_properties_get_t (C++ class), 448
esp_ble_mesh_server_recv_gen_client_properties_set_t (C++ class), 448
esp_ble_mesh_server_recv_gen_def_trans_time_set_t (C++ class), 448
esp_ble_mesh_sensor_get_t (C++ class), 447
esp_ble_mesh_sensor_get_t::property_id (C++ member), 447
esp_ble_mesh_sensor_get_t::raw (C++ member), 447
esp_ble_mesh_sensor_get_t::access (C++ member), 447
esp_ble_mesh_sensor_get_t::settings (C++ member), 447
esp_ble_mesh_sensor_settings_get_t::sensor_property_id (C++ member), 449
esp_ble_mesh_sensor_settings_get_t::sensor_data (C++ member), 449
esp_ble_mesh_sensor_settings_get_t::descriptor (C++ member), 449
esp_ble_mesh_sensor_settings_get_t::cadence (C++ member), 449
esp_ble_mesh_sensor_settings_get_t::settings (C++ member), 449
esp_ble_mesh_sensor_settings_get_t::property_id (C++ member), 449
esp_ble_mesh_sensor_settings_get_t::access (C++ member), 449
esp_ble_mesh_sensor_settings_get_t::raw (C++ member), 449
esp_ble_mesh_sensor_settings_get_t::settings (C++ member), 449
esp_ble_mesh_sensor_setup_srv_t::model (C++ member), 449
esp_ble_mesh_sensor_setup_srv_t::state_count (C++ member), 449
esp_ble_mesh_sensor_setup_srv_t::states (C++ member), 449
esp_ble_mesh_sensor_setup_srv_t::rsp_ctrl (C++ member), 449
esp_ble_mesh_sensor_setup_srv_t::model (C++ member), 449
esp_ble_mesh_sensor_setup_srv_t::rsp_ctrl (C++ member), 449
esp_ble_mesh_sensor_setup_srv_t::states (C++ member), 449
esp_ble_mesh_sensor_setup_srv_t::states (C++ member), 449
esp_ble_mesh_sensor_setup_srv_t::states (C++ member), 448
esp_ble_mesh_sensor_setup_srv_t::model (C++ member), 449
esp_ble_mesh_sensor_setup_srv_t::rsp_ctrl (C++ member), 449
esp_ble_mesh_sensor_setup_srv_t::states (C++ member), 449
esp_ble_mesh_sensor_setup_srv_t::states (C++ member), 448
esp_ble_mesh_sensor_setup_srv_t::rsp_ctrl (C++ member), 448
esp_ble_mesh_server_recv_gen_def_trans_time_set_t (C++ class), 433
esp_ble_mesh_server_recv_gen_client_properties_get_t (C++ class), 431
esp_ble_mesh_server_recv_gen_client_properties_set_t (C++ class), 432
esp_ble_mesh_server_recv_gen_delta_set_t (C++ class), 432
esp_ble_mesh_server_recv_gen_delta_set_t::delay (C++ member), 432
Index

esp_ble_mesh_state_change_light_lightness_set_t
esp_ble_mesh_state_change_scheduler_act_set_t::sc
(C++ class), 504
(C++ member), 470
esp_ble_mesh_state_change_light_lightness_set_t::lightness
esp_ble_mesh_state_change_scheduler_act_set_t::se
(C++ member), 504
(C++ member), 470
esp_ble_mesh_state_change_light_xyl_default_set_t
esp_ble_mesh_state_change_scheduler_act_set_t::tr
(C++ class), 507
(C++ member), 470
esp_ble_mesh_state_change_light_xyl_default_set_t::lightness
esp_ble_mesh_state_change_scheduler_act_set_t::ye
(C++ member), 507
(C++ member), 470
esp_ble_mesh_state_change_light_xyl_default_set_t::x
esp_ble_mesh_state_change_sensor_cadence_set_t
(C++ member), 507
(C++ class), 449
esp_ble_mesh_state_change_light_xyl_default_set_t::y
esp_ble_mesh_state_change_sensor_cadence_set_t::f
(C++ member), 507
(C++ member), 450
esp_ble_mesh_state_change_light_xyl_range_set_t
esp_ble_mesh_state_change_sensor_cadence_set_t::f
(C++ class), 507
(C++ member), 450
esp_ble_mesh_state_change_light_xyl_range_set_t::x_range_max
esp_ble_mesh_state_change_sensor_cadence_set_t::m
(C++ member), 507
(C++ member), 450
esp_ble_mesh_state_change_light_xyl_range_set_t::x_range_min
esp_ble_mesh_state_change_sensor_cadence_set_t::p
(C++ member), 507
(C++ member), 449
esp_ble_mesh_state_change_light_xyl_range_set_t::y_range_max
esp_ble_mesh_state_change_sensor_cadence_set_t::p
(C++ member), 507
(C++ member), 449
esp_ble_mesh_state_change_light_xyl_range_set_t::y_range_min
esp_ble_mesh_state_change_sensor_cadence_set_t::t
(C++ member), 507
(C++ member), 449
esp_ble_mesh_state_change_light_xyl_set_t
esp_ble_mesh_state_change_sensor_cadence_set_t::t
(C++ class), 507
(C++ member), 449
esp_ble_mesh_state_change_light_xyl_set_t::lightness
esp_ble_mesh_state_change_sensor_cadence_set_t::t
(C++ member), 507
(C++ member), 449
esp_ble_mesh_state_change_light_xyl_set_t::x
esp_ble_mesh_state_change_sensor_setting_set_t
(C++ member), 507
(C++ class), 450
esp_ble_mesh_state_change_light_xyl_set_t::y
esp_ble_mesh_state_change_sensor_setting_set_t::p
(C++ member), 507
(C++ member), 450
esp_ble_mesh_state_change_scene_delete_t
esp_ble_mesh_state_change_sensor_setting_set_t::s
(C++ class), 469
(C++ member), 450
esp_ble_mesh_state_change_scene_delete_t::scene_number
esp_ble_mesh_state_change_sensor_setting_set_t::s
(C++ member), 470
(C++ member), 450
esp_ble_mesh_state_change_scene_recall_t
esp_ble_mesh_state_change_sensor_status_t
(C++ class), 469
(C++ class), 508
esp_ble_mesh_state_change_scene_recall_t::scene_number
esp_ble_mesh_state_change_sensor_status_t::ambien
(C++ member), 469
(C++ member), 508
esp_ble_mesh_state_change_scene_store_tesp_ble_mesh_state_change_sensor_status_t::occupa
(C++ class), 469
(C++ member), 508
esp_ble_mesh_state_change_scene_store_t::scene_number
esp_ble_mesh_state_change_sensor_status_t::proper
(C++ member), 469
(C++ member), 508
esp_ble_mesh_state_change_scheduler_act_set_t
esp_ble_mesh_state_change_sensor_status_t::set_oc
(C++ class), 470
(C++ member), 508
esp_ble_mesh_state_change_scheduler_act_set_t::action
esp_ble_mesh_state_change_sensor_status_t::state
(C++ member), 470
(C++ member), 508
esp_ble_mesh_state_change_scheduler_act_set_t::day
esp_ble_mesh_state_change_tai_utc_delta_set_t
(C++ member), 470
(C++ class), 469
esp_ble_mesh_state_change_scheduler_act_set_t::day_of_week
esp_ble_mesh_state_change_tai_utc_delta_set_t::ta
(C++ member), 470
(C++ member), 469
esp_ble_mesh_state_change_scheduler_act_set_t::hour
esp_ble_mesh_state_change_tai_utc_delta_set_t::ta
(C++ member), 470
(C++ member), 469
esp_ble_mesh_state_change_scheduler_act_set_t::index
esp_ble_mesh_state_change_time_role_set_t
(C++ member), 470
(C++ class), 469
esp_ble_mesh_state_change_scheduler_act_set_t::minute
esp_ble_mesh_state_change_time_role_set_t::time_r
(C++ member), 470
(C++ member), 469
esp_ble_mesh_state_change_scheduler_act_set_t::month
esp_ble_mesh_state_change_time_set_t
(C++ member), 470
(C++ class), 468

Espressif Systems

2216
Submit Document Feedback

Release v5.0-dev-1077-g397639d


Index

esp_ble_mesh_state_change_time_set_t::ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_HIGH_WARNING (C++ class), 468
(upper), 459
esp_ble_mesh_state_change_time_set_t::ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_LOW_ERROR (C++ member), 468
esp_ble_mesh_state_change_time_set_t::ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_LOW_ERROR (C macro), 408
esp_ble_mesh_state_change_time_set_t::ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_HIGH_WARNING (C macro), 475
esp_ble_mesh_state_change_time_set_t::ESP_BLE_MESH_TAI_OF_DELTA_CHANGE_LEN (C macro), 469
esp_ble_mesh_state_change_time_set_t::ESP_BLE_MESH_TAI_OF_ZONE_CHANGE_LEN (C macro), 475
esp_ble_mesh_state_change_time_set_t::ESP_BLE_MESH_TAI_SECONDS_LEN (C macro), 475
esp_ble_mesh_state_change_time_status_t::ESP_BLE_MESH_TAI.UTC_DELTA_MAX_VALUE (C macro), 408
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_set_t (C++ class), 459
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_set_t::padding (C++ member), 468
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_set_t::padding (C++ member), 469
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_set_t::tai_delta_change (C++ member), 469
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_set_t::tai_delta_change (C++ member), 470
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_set_t::tai_utc_delta_new (C++ member), 470
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t (C++ class), 462
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::padding_1 (C++ member), 462
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::padding_2 (C++ member), 462
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 462
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 470
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 471
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 472
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 473
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 474
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 475
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 476
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 477
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 478
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 479
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 480
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 481
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 482
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 483
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 484
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 485
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 486
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 487
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 488
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 489
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 490
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 491
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 492
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 493
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 494
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 495
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 496
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 497
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 498
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_status_cb_t::tai_utc_delta_new (C++ member), 499
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_statusCb_t (C++ class), 337
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_statusCb_t::padding_1 (C++ member), 337
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_statusCb_t::padding_2 (C++ member), 337
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_statusCb_t::tai_utc_delta_new (C++ member), 337
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_statusCb_t::tai_utc_delta_new (C++ member), 337
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_statusCb_t::tai_utc_delta_new (C++ member), 337
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_statusCb_t::tai_utc_delta_new (C++ member), 337
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_statusCb_t::tai_utc_delta_new (C++ member), 337
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_statusCb_t::tai_utc_delta_new (C++ member), 337
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_statusCb_t::tai_utc_delta_new (C++ member), 337
esp_ble_mesh_state_change_time_status_t::esp_ble_mesh_tai_utc_delta_statusCb_t::tai_utc_delta_new (C++ member), 337
esp_ble_mesh_state_change_time_transition_t::BLE_MESH_SUPPLY_VOLTAGE_TOO_HIGH_ERROR (C macro), 409
esp_ble_mesh_state_change_time_transition_t::BLE_MESH_SUPPLY_VOLTAGE_TOO_LOW_ERROR (C macro), 408
esp_ble_mesh_state_change_time_transition_t::counters (C++ function), 408
esp_ble_mesh_state_change_time_transition_t::counters (C++ member), 408
esp_ble_mesh_state_change_time_transition_t::delay (C++ member), 476
esp_ble_mesh_state_change_time_transition_t::delay (C++ member), 476
esp_ble_mesh_state_change_time_transition_t::delay (C++ member), 476
esp_ble_mesh_state_change_time_transition_t::just (C++ member), 476
esp_ble_mesh_state_change_time_transition_t::last (C++ member), 476
esp_ble_mesh_state_change_time_transition_t::params (C++ member), 476
ESP_BLE_MESH_STATIC_OOB (C++ enumerator), 335
ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_HIGH_ERROR (C macro), 408
ESP_BLE_MESH_SUPPLY_VOLTAGE TOO HIGH_ERROR (C macro), 408
ESP_BT Codable Major Device Computer (C++ member), 226
ESP_BT Codable Major Device Bit Offset (C++ member), 226
ESP_BT Codable Major Device SSID (C++ member), 226
ESP_BT Codable Major Device SSID Len (C++ member), 226
ESP_BT Codable Major Device Get Version (C++ function), 221
ESP_BT Codable Major Device Init Failed (C++ enumerator), 229
ESP_BT Codable Major Device Init Ok (C++ enumerator), 229
ESP_BT Codable Major Device Security Error (C++ enumerator), 229
ESP_BT Codable Major Device Init State T (C++ enum), 229
ESP_BT Codable Major Device Make Public Error (C++ enumerator), 229
ESP_BT Codable Major Device Negotiate Data Handler T (C++ type), 227
ESP_BT Codable Major Device Profile Deinit (C++ function), 220
ESP_BT Codable Major Device Profile Init (C++ function), 220
ESP_BT Codable Major Device Read Param Error (C++ enumerator), 229
ESP_BT Codable Major Device Register Callbacks (C++ function), 220
ESP_BT Codable Major Device Send Custom Data (C++ function), 221
ESP_BT Codable Major Device Send Error Info (C++ function), 221
ESP_BT Codable Major Device Send WiFi Conn Report (C++ function), 220
ESP_BT Codable Major Device Send WiFi List (C++ function), 221
ESP_BT Codable Major Device Sequence Error (C++ enumerator), 229
ESP_BT Codable Major Device Sta Conn Fail (C++ enumerator), 229
ESP_BT Codable Major Device Sta Conn State T (C++ enum), 229
ESP_BT Codable Major Device Sta Conn Success (C++ enumerator), 229
ESP_BT Codable Major Dev Av (C++ enumerator), 243
ESP_BT Codable Major Dev Bit Mask (C macro), 241
ESP_BT Codable Major Dev Bit Offset (C macro), 241
ESP_BT Codable Major Dev Av (C++ enumerator), 243
ESP_BT Codable Major Dev Bit Mask (C macro), 241
ESP_BT Codable Major Dev Bit Offset (C macro), 241
ESP_BT Codable Major Dev Computer (C++ enumerator), 243
ESP_BT Codable Major Dev Health (C++ enumerator), 243
ESP_BT Codable Major Dev Imaging (C++ enumerator), 243
ESP_BT Codable Major Dev Lan Nap (C++ enumerator), 243
ESP_BT Codable Major Dev Misc (C++ enumerator), 243
ESP_BT Codable Major Dev Peripheral (C++ enumerator), 243
ESP_BT Codable Major Dev Phone (C++ enumerator), 243
ESP_BT Codable Major Dev T (C++ enum), 243
ESP_BT Codable Major Dev Toy (C++ enumerator), 243
ESP_BT Codable Major Dev Uncategorized (C++ enumerator), 244
ESP_BT Codable Minor Dev Bit Mask (C macro), 241
ESP_BT Codable Minor Dev Bit Offset (C macro), 241
ESP_BT Codable Mode T (C++ enum), 242
ESP_BT Codable Srvc Audio (C++ enumerator), 243
ESP_BT Codable Srvc Bit Mask (C macro), 241
ESP_BT Codable Srvc Bit Offset (C macro), 241
ESP_BT Codable Srvc Capturing (C++ enumerator), 243
ESP_BT Codable Srvc Information (C++ enumerator), 243
ESP_BT Codable Srvc Lmtd Discover (C++ enumerator), 243
ESP_BT Codable Srvc Networking (C++ enumerator), 243
ESP_BT Codable Srvc None (C++ enumerator), 242
ESP_BT Codable Srvc Obj Transfer (C++ enumerator), 243
ESP_BT Codable Srvc Positioning (C++ enumerator), 242
ESP_BT Codable Srvc Rendering (C++ enumerator), 243
ESP_BT Codable Srvc Rendering (C++ enumerator), 243
ESP_BT Codable Srvc Tel Phony (C++ enumerator), 243
ESP_BT Codable T (C++ class), 238
ESP_BT Codable T T::Major (C++ member), 239
ESP_BT Codable T T::Minor (C++ member), 238
ESP_BT Codable T T::Reserved 2 (C++ member), 238
ESP_BT Codable T T::Reserved 8 (C++ member), 239
ESP_BT Codable T T::Service (C++ member), 239
ESP_BT Connectable (C++ enumerator), 242
ESP_BT Connection Mode T (C++ enum), 242
ESP_BT Controller Config Magic Val (C macro), 130

Index
Espresif Systems

2225

Release v5.0-dev-1077-g397639d

Submit Document Feedback
The image contains a page from the documentation of the Espessif Systems esp_bt_gap_dev_prop_t structure. The page lists various member functions and variables related to the Bluetooth GAP (Generic Access Profile) protocol. The text is dense and technical, covering topics such as Bluetooth protocol events, configuration data, and various enumerated types and classes related to Bluetooth device properties and operations. The page also includes references to other parts of the documentation, indicated by index numbers (e.g., 232, 234, 235, 237, 238, 239, 240, 241, 242, 244). The page is part of the Espessif Systems documentation, as indicated by the header.
Index

ESP_BT_STATUS_AUTH_FAILURE (C++ enumerator), 134
ESP_BT_STATUS_AUTH_REJECTED (C++ enumerator), 134
ESP_BT_STATUS_BUSY (C++ enumerator), 134
ESP_BT_STATUS_CONTROL_LE_DATA_LEN_UNSUPPORTED (C++ enumerator), 135
ESP_BT_STATUS_DONE (C++ enumerator), 134
ESP_BT_STATUS_EIR_TOO_LARGE (C++ enumerator), 135
ESP_BT_STATUS_ERR_ILLEGAL_PARAMETER_FMT (C++ enumerator), 135
ESP_BT_STATUS_FAIL (C++ enumerator), 134
ESP_BT_STATUS_INVALID_STATIC_RAND_ADDR (C++ enumerator), 135
ESP_BT_STATUS_MEMORY_FULL (C++ enumerator), 135
ESP_BT_STATUS_NOMEM (C++ enumerator), 134
ESP_BT_STATUS_NOT_READY (C++ enumerator), 134
ESP_BT_STATUS_PARAM_OUT_OF_RANGE (C++ enumerator), 135
ESP_BT_STATUS_PARAM_INVALID (C++ enumerator), 135
ESP_BT_STATUS_PEER_LE_DATA_LEN_UNSUPPORTED (C++ enumerator), 135
ESP_BT_STATUS_FACING (C++ enumerator), 134
ESP_BT_STATUS_C特斯 (C++ class), 134
esp_console_t::cmd (C++ member), 1210
esp_console_t::argtable (C++ member), 1210
esp_console_t::command (C++ member), 1210
esp_console_t::hint (C++ member), 1209
ESP_CONSOLE_CONFIG_DEFAULT (C macro), 1210
esp_console_config_t (C++ class), 1208
esp_console_config_t::hint (C++ member), 1209
esp_console_config_t::hint (C++ member), 1208
esp_console_config_t::max_cmdline_args (C++ member), 1208
esp_console_config_t::max_cmdline_length (C++ member), 1208
esp_console_deinit (C++ function), 1206
ESP_CONSOLE_DEV_CDC_CONFIG_DEFAULT (C macro), 1210
ESP_CONSOLE_DEV_UART_CONFIG_DEFAULT (C macro), 1210
esp_console_dev_uart_config_t (C++ class), 1209
esp_console_dev_uart_config_t::baud_rate (C++ member), 1209
esp_console_dev_uart_config_t::channel (C++ member), 1209
esp_console_dev_uart_config_t::rx_gpio_num (C++ member), 1209
esp_console_dev_uart_config_t::tx_gpio_num (C++ member), 1209
esp_console_dev_usb_cdc_config_t (C++ class), 1209
esp_console_get_completion (C++ function), 1207
esp_console_get_hint (C++ function), 1207
esp_console_init (C++ function), 1206
esp_console_new_repl_uart (C++ function), 1207
esp_console_new_repl_usb_cdc (C++ function), 1208
esp_console_register_help_command (C++ function), 1207
ESP_CONSOLE REPL_CONFIG_DEFAULT (C macro), 1210
esp_console_repl_config_t (C++ class), 1209
esp_console_repl_config_t::history_save_path (C++ member), 1209
esp_console_repl_config_t::max_cmdline_length (C++ member), 1209
esp_console_repl_config_t::max_history_len (C++ member), 1209
esp_console_repl_config_t::task_priority (C++ member), 1209

Espressif Systems

Submit Document Feedback
esp_console_repl_config_t::task_stack_size
ESP_DEFAULT_GATT_IF (C++ member), 1209
esp_console_repl_s (C++ class), 1210
esp_console_repl_s::del (C++ member), 1210
esp_console_repl_t (C++ type), 1210
esp_console_run (C++ function), 1206
esp_console_split_argv (C++ function), 1207
esp_console_start_repl (C++ function), 1208
esp_crt_bundle_attach (C++ function), 1072
esp_crt_bundle_detach (C++ function), 1072
esp_crt_bundle_set (C++ function), 1072
esp_deep_sleep (C++ function), 1454
esp_deep_sleep_disable_rom_logging
(C++ function), 1455
esp_deep_sleep_start (C++ function), 1454
esp_deep_sleep_wake_stub_fn_t (C++ type), 1455
ESP_DEFAULT_GATT_IP (C macro), 133
esp_default_wake_deep_sleep (C++ function), 1455
esp_deregister_freertos_idle_hook
(C++ function), 1372
esp_deregister_freertos_idle_hook_for_active
(C++ function), 1372
esp_deregister_freertos_tick_hook
(C++ function), 1373
esp_deregister_freertos_tick_hook_for_TRAP
(C++ function), 1373
espderive_local_mac(C++ function), 1426
ESP_DRAM_LOGD (C macro), 1419
ESP_DRAM_LOGE (C macro), 1419
ESP_DRAM_LOGI (C macro), 1419
ESP_DRAM_LOGV (C macro), 1419
ESP_DRAM_LOGW (C macro), 1419
esp_duplicate_info_t (C++ type), 174
esp_duplicate_scan_exceptional_list_type_t
(C++ enum), 181
ESP_EARLY_LOGD (C macro), 1418
ESP_EARLY_LOGE (C macro), 1418
ESP_EARLY_LOGI (C macro), 1418
ESP_EARLY_LOGV (C macro), 1419
ESP_EARLY_LOGW (C macro), 1418
esp_efuse_batch_write_begin (C++ function), 1222
esp_efuse_batch_write_cancel (C++ function), 1223
esp_efuse_batch_write_commit (C++ function), 1223
esp_efuse_block_is_empty (C++ function), 1223
esp_efuse_check_secure_version (C++ function), 1222
esp_efuse_desc_t (C++ class), 1225
esp_efuse_desc_t::bit_count
(C++ member), 1225
esp_efuse_desc_t::bit_start
(C++ member), 1225
esp_efuse_disable_basic_rom_console
(C++ function), 1221
esp_efuse_disable_basic_rom_download_mode
(C++ function), 1221
esp_efuse_find Purpose (C++ function), 1224
esp_efuse_get_chip_ver (C++ function), 1221
esp_efuse_get_coding_scheme (C++ function), 1220
esp_efuse_get_field_size (C++ function), 1220
esp_efuse_get_key_dis_read (C++ function), 1223
esp_efuse_get_key_dis_write (C++ function), 1224
esp_efuse_get_key_purpose (C++ function), 1224
esp_efuse_get_keypurpose_dis_write
(C++ function), 1224
esp_efuse_get_pkg_ver (C++ function), 1224
esp_efuse_mac_get_custom (C++ function), 1425
esp_efuse_mac_get_default (C++ function), 1425
esp_efuse_mac_get_read_block (C++ function), 1221
esp_efuse_read_field_bit (C++ function), 1221
esp_efuse_read_field_blob (C++ function), 1218
esp_efuse_read_field_cnt (C++ function), 1219
esp_efuse_read_reg (C++ function), 1220
esp_efuse_read_secure_version (C++ function), 1222
esp_efuse_reset (C++ function), 1221
ESP_EFUSE_ROM_LOG_ALWAYS_OFF (C++ enumerator), 1226
ESP_EFUSE_ROM_LOG_ALWAYS_ON (C++ enumerator), 1226
ESP_EFUSE_ROM_LOG_ON_GPIO_HIGH (C++
enumerator), 1226
ESP_EFUSE_ROM_LOG_ON_GPIO_LOW (C++ enumerator), 1226
esp_efuse_rom_log_scheme_t (C++ enum), 1226
esp_efuse_set_key_dis_read (C++ function), 1223
esp_efuse_set_key_dis_write (C++ function), 1224
esp_efuse_set_read_protect (C++ function), 1220
esp_efuse_set_rom_log_scheme (C++ function), 1225
esp_efuse_set_read_protect (C++ function), 1225
esp_efuse_set_key_dis_read
(C++ function), 1224
esp_efuse_set_key_dis_write
(C++ function), 1224
esp_efuse_set_keypurpose_dis_write
(C++ function), 1224
esp_efuse_set_rom_log_scheme (C++ function), 1225
esp_efuse_set_read_protect (C++ function), 1225
esp_efuse_set_keydis_read
(C++ function), 1224
esp_efuse_set_keydis_write
(C++ function), 1224

ESP_ERR_INVALID_ARG (C macro), 1227
ESP_ERR_INVALID_MAC (C macro), 1227
ESP_ERR_INVALID_RESPONSE (C macro), 1227
ESP_ERR_INVALID_SIZE (C macro), 1227
ESP_ERR_INVALID_STATE (C macro), 1227
ESP_ERR_INVALID_VERSION (C macro), 1227
ESP_ERR_MEMPROT_BASE (C macro), 1228
ESP_ERR_MESH_ARGUMENT (C macro), 594
ESP_ERR_MESH_BASE (C macro), 1227
ESP_ERR_MESH_DISCARD (C macro), 595
ESP_ERR_MESH_DISCARD_DUPLICATE (C macro), 595
ESP_ERR_MESH_DISCONNECTED (C macro), 594
ESP_ERR_MESH_EXCEED_MTU (C macro), 594
ESP_ERR_MESH_INTERFACE (C macro), 594
ESP_ERR_MESH_NO_MEMORY (C macro), 594
ESP_ERR_MESH_NO_PARENT_FOUND (C macro), 594
ESP_ERR_MESH_NO_ROUTE_FOUND (C macro), 594
ESP_ERR_MESH_NOT_ALLOWED (C macro), 594
ESP_ERR_MESH_NOT_CONFIG (C macro), 594
ESP_ERR_MESH_NOT_INIT (C macro), 594
ESP_ERR_MESH_NOT_START (C macro), 594
ESP_ERR_MESH_NOT_SUPPORT (C macro), 594
ESP_ERR_MESH_OPTION_NULL (C macro), 594
ESP_ERR_MESH_OPTION_UNKNOWN (C macro), 594
ESP_ERR_MESH_PS (C macro), 595
ESP_ERR_MESH_QUEUE_FAIL (C macro), 594
ESP_ERR_MESH_QUEUE_FULL (C macro), 594
ESP_ERR_MESH_QUEUE_READ (C macro), 595
ESP_ERR_MESH_RECV_RELEASE (C macro), 595
ESP_ERR_MESH_TIMEOUT (C macro), 594
ESP_ERR_MESH_VOTING (C macro), 595
ESP_ERR_MESH_WIFI_NOT_START (C macro), 594
ESP_ERR_MESH_XMIT (C macro), 595
ESP_ERR_MESH_XON_NO_WINDOW (C macro), 594
ESP_ERR_NO_MEM (C macro), 1227
ESP_ERR_NOT_ENOUGH_UNUSED_KEY_BLOCKS (C macro), 1226
ESP_ERR_NOT_FINISHED (C macro), 1227
ESP_ERR_NOT_FOUND (C macro), 1227
ESP_ERR_NOT_SUPPORTED (C macro), 1227
ESP_ERR_NVSS_BASE (C macro), 1130
ESP_ERR_NVSS_CONTENT_DIFERS (C macro), 1130
ESP_ERR_NVSS_CORRUPT_KEY_PART (C macro), 1131
ESP_ERR_NVSS_ENCNOT_SUPPORTED (C macro), 1131
ESP_ERR_NVSS_INVALID_HANDLE (C macro), 1130
ESP_ERR_NVSS_INVALID_LENGTH (C macro), 1130
ESP_ERR_NVSS_INVALID_NAME (C macro), 1130
ESP_ERR_NVSS_INVALID_STATE (C macro), 1130
ESP_ERR_NVSS_KEY_TOO_LONG (C macro), 1130

Espressif Systems 2231 Release v5.0-dev-1077-g397639d
Submit Document Feedback
Index

ESP_ERR_NVS_KEYS_NOT_INITIALIZED (C macro), 1131
ESP_ERR_NVS_NEW_VERSION_FOUND (C macro), 1131
ESP_ERR_NVS_NO_FREE_PAGES (C macro), 1130
ESP_ERR_NVS_NOT_ENOUGH_SPACE (C macro), 1130
ESP_ERR_NVS_NOT_FOUND (C macro), 1130
ESP_ERR_NVS_NOT_INITIALIZED (C macro), 1130
ESP_ERR_NVS_PAGE_FULL (C macro), 1130
ESP_ERR_NVS_PART_NOT_FOUND (C macro), 1131
ESP_ERR_NVS_READ_ONLY (C macro), 1130
ESP_ERR_NVS_REMOVE_FAILED (C macro), 1130
ESP_ERR_NVS_TYPE_MISMATCH (C macro), 1130
ESP_ERR_NVS_VALUE_TOO_LONG (C macro), 1131
ESP_ERR_NVS_WRONG_ENCRYPTION (C macro), 1131
ESP_ERR_NVS_XTS_DECR_FAILED (C macro), 1131
ESP_ERR_NVS_XTS_CFG_NOT_FOUND (C macro), 1131
ESP_ERR_NVS_XTS_DECRL_FAILED (C macro), 1131
ESP_ERR_NVS_XTS_ENCR_FAILED (C macro), 1131
ESP_ERR_OTA_BASE (C macro), 1436
ESP_ERR_OTA_PARTITION_CONFLICT (C macro), 1436
ESP_ERR_OTA.Rollback_FAILED (C macro), 1436
ESP_ERR_OTA.Rollback_INVALID_STATE (C macro), 1436
ESP_ERR_OTA_SELECT_INFO_INVALID (C macro), 1436
ESP_ERR_OTA_SMALL_SEC_VER (C macro), 1436
ESP_ERR_OTA_VALIDATE_FAILED (C macro), 1436
ESP_ERR_OTA_VALIDATE_FAILED (C macro), 1436
ESP_ERR_OTA_VALIDATE_FAILED (C macro), 1436
esp_err_t (C++ type), 1228
ESP_ERR_TIMEOUT (C macro), 1227
esp_err_to_name (C++ function), 1226
esp_err_to_name_r (C++ function), 1227
ESP_ERR_UVP_BASE (C macro), 2023
ESP_ERR_UVP_BRANCH_OUT_OF_RANGE (C macro), 2024
ESP_ERR_UVP_DUPLICATE_LABEL (C macro), 2023
ESP_ERR_UVP_INVALID_LOAD_ADDR (C macro), 2023
ESP_ERR_UVP_SIZE_TOO_BIG (C macro), 2023
ESP_ERR_UVP_UNDEFINED_LABEL (C macro), 2024
ESP_ERR_WIFI_BASE (C macro), 1227
ESP_ERR_WIFI_CONN (C macro), 535
ESP_ERR_WIFI_IF (C macro), 535
ESP_ERR_WIFI_INIT_STATE (C macro), 535
ESP_ERR_WIFI_MAC (C macro), 535
ESP_ERR_WIFI_MODE (C macro), 535
ESP_ERR_WIFI_NOT_ASSOC (C macro), 535
Index

esp_eth_mac_s::set_duplex (C++ member), 620
esp_eth_mac_s::set_link (C++ member), 620
esp_eth_mac_s::set_mediator (C++ member), 618
esp_eth_mac_s::set_peer_pause_ability (C++ member), 621
esp_eth_mac_s::set_promiscuous (C++ member), 620
esp_eth_mac_s::set_speed (C++ member), 620
esp_eth_mac_s::start (C++ member), 618
esp_eth_mac_s::stop (C++ member), 618
esp_eth_mac_s::transmit (C++ member), 618
esp_eth_mac_s::write_phy_reg (C++ member), 619
esp_eth_mac_t (C++ type), 622
esp_eth_mediator_s (C++ class), 616
esp_eth_mediator_s::on_state_changed (C++ member), 616
esp_eth_mediator_s::phy_reg_read (C++ member), 616
esp_eth_mediator_s::phy_reg_write (C++ member), 616
esp_eth_mediator_s::stack_input (C++ member), 616
esp_eth_mediator_t (C++ type), 616
esp_netif_glue_handle_t (C++ type), 627
esp_new_netif_glue (C++ function), 627
ESP_ETH_PHY_ADDR_AUTO (C macro), 626
ESP_ETH_PHY_AUTONEGO_DIS (C++ enumerator), 626
ESP_ETH_PHY_AUTONEGO_EN (C++ enumerator), 626
ESP_ETH_PHY_AUTONEGO_G_STAT (C++ enumerator), 626
ESP_ETH_PHY_AUTONEGO_RESTART (C++ enumerator), 626
esp_ethphy_new_dp83848 (C++ function), 623
esp_ethphy_new_ip101 (C++ function), 622
esp_ethphy_new_ksz88ox (C++ function), 623
esp_ethphy_new_lan87xx (C++ function), 623
esp_ethphy_new_rtl8201 (C++ function), 623
esp_ethphy_s (C++ class), 623
esp_ethphy_s::advertise_pause_ability (C++ member), 625
esp_ethphy_s::autonego_ctrl (C++ member), 625
esp_ethphy_s::definit (C++ member), 624
esp_ethphy_s::del (C++ member), 626
esp_ethphy_s::get_addr (C++ member), 625
esp_ethphy_s::get_link (C++ member), 624
esp_ethphy_s::init (C++ member), 624
esp_ethphy_s::loopback (C++ member), 625
esp_ethphy_s::pwrctl (C++ member), 624
esp_ethphy_s::reset (C++ member), 624
esp_ethphy_s::reset_hw (C++ member), 624
esp_ethphy_s::set_addr (C++ member), 625
esp_ethphy_s::set_duplex (C++ member), 625
esp_ethphy_s::set_mediator (C++ member), 623
esp_ethphy_s::set_speed (C++ member), 625
esp_ethphy_t (C++ type), 626
esp_eth_receive (C++ function), 612
esp_eth_start (C++ function), 611
esp_eth_state_t (C++ enum), 616
esp_eth_stop (C++ function), 611
esp_eth_transmit (C++ function), 611
esp_eth_update_input_path (C++ function), 611
ESP_EVENT_BASE (C macro), 1247
ESP_EVENT_ID (C macro), 1247
esp_event_base_t (C++ type), 1247
ESP_EVENT_DECLARE_BASE (C macro), 1247
ESP_EVENT_DEFINE_BASE (C macro), 1247
esp_event_dump (C++ function), 1245
esp_event_handler_instance_register (C++ function), 1242
esp_event_handler_instance_register_with (C++ function), 1241
esp_event_handler_instance_unregister (C++ function), 1244
esp_event_handler_instance_unregister_with (C++ function), 1243
esp_event_handler_register (C++ function), 1240
esp_event_handler_register_with (C++ function), 1241
esp_event_handler_t (C++ type), 1247
esp_event_handler_unregister (C++ function), 1243
esp_event_handler_unregister_with (C++ function), 1243
esp_event_isr_post (C++ function), 1245
esp_event_isr_post_to (C++ function), 1245
esp_event_loop_delete (C++ function), 1240
esp_event_loop_delete_default (C++ function), 1245
esp_event_loop_args_t::task_stack_size (C++ member), 1240
esp_event_loop_args_t::task_priority (C++ member), 1240
esp_event_loop_args_t::task_name (C++ member), 1246
esp_event_loop_args_t::queue_size (C++ member), 1246
esp_event_loop_delete (C++ function), 1240
esp_event_loop_delete_default (C++ function), 1245
esp_event_loop_base_t::task_stack_size (C++ member), 1240
esp_event_loop_base_t::task_priority (C++ member), 1240
esp_event_loop_base_t::task_name (C++ member), 1246
esp_event_loop_base_t::queue_size (C++ member), 1246
esp_event_loop_base_t::event_loop_id (C++ member), 1246
esp_event_loop_base_t::event_handler_count (C++ member), 1246
esp_event_loop_base_t::event_handler_register (C++ function), 1240
esp_event_loop_delete (C++ function), 1240
esp_event_loop_delete_default (C++ function), 1245
...
Index

tion), 1240
esp_event_loop_handle_t (C++ type), 1247
esp_event_loop_init (C++ function), 1248
esp_event_loop_run (C++ function), 1240
esp_event_loop_set_cb (C++ function), 1248
esp_event_post (C++ function), 1244
esp_event_post_to (C++ function), 1244
esp_event_process_default (C++ function), 1248
esp_event_send (C++ function), 1247
esp_event_send_internal (C++ function), 1247
esp_event_set_default_eth_handlers (C++ function), 1248
esp_event_set_default_wifi_handlers (C++ function), 1248
ESP_EXECUTE_EXPRESSION_WITH_STACK (C
macro), 1408
esp_execute_shared_stack_function (C++ function), 1408
ESP_EXT1_WAKEUP_ALL_LOW (C++ enumerator), 1455
ESP_EXT1_WAKEUP_ANY_HIGH (C++ enumerator), 1455
ESP_FAIL (C macro), 1227
esp_fill_random (C++ function), 1447
ESP FLASH 10MHZ (C++ enumerator), 1164
ESP FLASH 120MHZ (C++ enumerator), 1164
ESP FLASH 20MHZ (C++ enumerator), 1164
ESP FLASH 26MHZ (C++ enumerator), 1164
ESP FLASH 40MHZ (C++ enumerator), 1164
ESP FLASH 5MHZ (C++ enumerator), 1164
ESP FLASH 80MHZ (C++ enumerator), 1164
esp_flash_chip_driver_initialized (C++ function), 1156
ESPFLASH ENC_MODE DEVELOPMENT (C++
enumerator), 1173
ESPFLASH ENC_MODE DISABLED (C++ enumera-
tor), 1173
ESPFLASH ENC_MODE RELEASE (C++ enumerator), 1173
esp_flash_enc_mode_t (C++ enum), 1173
esp_flash_encrypt_check_and_update (C++ function), 1172
esp_flash_encrypt_region (C++ function), 1172
esp_flash_encryption_enable_secure_features (C++ function), 1172
esp_flash_encryption_enabled (C++ function), 1172
esp_flash_encryption_init_checks (C++ function), 1172
esp_flash_encryption_set_release_mode (C++ function), 1173
esp_flash_erase_chip (C++ function), 1156
esp_flash_erase_region (C++ function), 1156
esp_flash_get_chip_write_protect (C++ function), 1157
esp_flash_get_protectable_regions (C++ function), 1157
esp_flash_get_protected_region (C++ function), 1157
espflash_get_size (C++ function), 1156
espflash_init (C++ function), 1155
espflash_io_mode_t (C++ enum), 1165
espflash_is_quad_mode (C++ function), 1159
espflash_os_functions_t (C++ class), 1159
espflash_os_functions_t::check_yield (C++ member), 1160
espflash_os_functions_t::delay_us (C++ member), 1159
espflash_os_functions_t::end (C++ member), 1159
espflash_os_functions_t::get_system_time (C++ member), 1160
espflash_os_functions_t::get_temp_buffer (C++ member), 1159
espflash_os_functions_t::region_protected (C++ member), 1159
espflash_os_functions_t::release_temp_buffer (C++ member), 1160
espflash_os_functions_t::start (C++ member), 1159
espflash_os_functions_t::yield (C++ member), 1160
espflash_read (C++ function), 1158
espflash_read_encrypted (C++ function), 1159
espflash_read_id (C++ function), 1156
espflash_read_unique_chip_id(C++ func-
tion), 1156
espflash_region_t (C++ class), 1159
espflash_region_t::offset (C++ member), 1159
espflash_region_t::size (C++ member), 1159
espflash_set_chip_write_protect (C++ function), 1157
espflash_set_protected_region (C++ function), 1157
ESPFLASH SPEED MAX (C++ enumerator), 1165
ESPFLASH SPEED MIN (C macro), 1164
espflash_speed_t (C++ enum), 1164
espflash_spi_device_config_t (C++ class), 1155
espflash_spi_device_config_t::cs_id (C++ member), 1155
espflash_spi_device_config_t::cs_io_num (C++ member), 1155
espflash_spi_device_config_t::host_id (C++ member), 1155
espflash_spi_device_config_t::input_delay_ns (C++ member), 1155
espflash_spi_device_config_t::io_mode (C++ member), 1155
espflash_spi_device_config_t::speed
## Index

| ESP_GAP_BLE_ENUMERATE_EVT (C++ enumerator), 175 | esp_gap_searchEvt_t (C++ enum), 180 |
| ESP_GAP_BLE.ScanParamSetCompleteEvt (C++ enumerator), 175 | ESP_GAP_SEARCH_INQ_CMPL_EVT (C++ enumerator), 180 |
| ESP_GAP_BLE.ScanReqReceivedEvt (C++ enumerator), 177 | ESP_GAP_SEARCH_INQ_DISCARD_NUM_EVT (C++ enumerator), 180 |
| ESP_GAP_BLE.ScanResultEvt (C++ enumerator), 175 | ESP_GAP_SEARCH_INQ_RES_EVT (C++ enumerator), 180 |
| ESP_GAP_BLE.ScanRspDataRawSetCompleteEvt (C++ enumerator), 175 | ESP_GAP_SEARCH_SEARCH_CANCEL_CMPL_EVT (C++ enumerator), 180 |
| ESP_GAP_BLE.ScanRspDataSetCompleteEvt (C++ enumerator), 175 | ESP_GATT_ALREADY_OPEN (C++ enumerator), 190 |
| ESP_GAP_BLE.ScanStartCompleteEvt (C++ enumerator), 175 | ESP_GATT_APP_RSP (C++ enumerator), 190 |
| ESP_GAP_BLE.ScanStopCompleteEvt (C++ enumerator), 175 | ESP_GATT_ATTR_HANDLE_MAX (C macro), 188 |
| ESP_GAP_BLE.ScanTimeoutEvt (C++ enumerator), 176 | ESP_GATT_AUTH_FAIL (C++ enumerator), 190 |
| ESP_GAP_BLE_SEC_REQ_EVT (C++ enumerator), 176 | ESP_GATT_AUTH_REQ_MITM (C++ enumerator), 191 |
| esp_gap_ble_set_authorization (C++ function), 143 | ESP_GATT_AUTH_REQ_NO_MITM (C++ enumerator), 191 |
| esp_gap_ble_set_channels (C++ function), 143 | ESP_GATT_AUTH_REQ_P2P (C macro), 189 |
| ESP_GAP_BLE_SET_CHANNELS_EVT (C++ enumerator), 176 | ESP_GATT_BODY_SENSOR_LOCATION (C macro), 188 |
| ESP_GAP_BLE_SET_EXT_SCAN_PARAMS_COMPLETE_EVT (C++ enumerator), 176 | ESP_GATT_BUSY (C++ enumerator), 190 |
| ESP_GAP_BLE_SET_LOCAL_PRIVACY_COMPLETE_EVT (C++ enumerator), 175 | ESP_GATT_CANCELS (C++ enumerator), 190 |
| ESP_GAP_BLE_SET_PKT_LENGTH_COMPLETE_EVT (C++ enumerator), 175 | ESP_GATT_CHARSET_PROP_BIT_AUTH (C macro), 188 |
| ESP_GAP_BLE_SET_PREFERED_DEFAULT_PHY_COMPLETE_EVT (C++ enumerator), 176 | ESP_GATT_CHARSET_PROP_BIT_BROADCAST (C macro), 188 |
| ESP_GAP_BLE_SET_PREFERED_PHY_COMPLETE_EVT (C++ enumerator), 176 | ESP_GATT_CHARSET_PROP_BIT_EXT_PROP (C macro), 189 |
| ESP_GAP_BLE_SET_STATIC_ADDR_ADDR_EVT (C++ enumerator), 175 | ESP_GATT_CHARSET_PROP_BIT_INDEICATE (C macro), 189 |
| ESP_GAP_BLE_UPDATE_CONN_PARAMS_EVT (C++ enumerator), 175 | ESP_GATT_CHARSET_PROP_BIT_NOTIFY (C macro), 189 |
| ESP_GAP_BLE_UPDATE_DUPLICATE_EXCEPTIONAL_LIST_EVT (C++ enumerator), 176 | ESP_GATT_CHARSET_PROP_BIT_READ (C macro), 189 |
| ESP_GAP_BLE_UPDATE_WHITELIST_COMPLETE_EVT (C++ enumerator), 176 | ESP_GATT_CHARSET_PROP_BIT_WRITE (C macro), 189 |
| esp_gap_conn_params_t (C++ class), 162 | ESP_GATT_CHARSET_PROP_BIT_WRITE_NR (C macro), 189 |
| esp_gap_conn_params_t::interval member, 163 | esp_gatt_char_prop_bit_t (C++ type), 189 |
| esp_gap_conn_params_t::latency member, 163 | ESP_GATT_CMD_STARTED (C++ enumerator), 190 |
| esp_gap_conn_params_t::timeout member, 163 | ESP_GATT_CONGESTED (C++ enumerator), 190 |
| ESP_GAP_SEARCH_DISC_CMPL_EVT (enumerator), 180 | ESP_GATT_CONN_CONN_CANCEL (C++ enumerator), 191 |
| ESP_GAP_SEARCH_DISC_BLE_RES_EVT (C++ enumerator), 180 | ESP_GATT_CONN_FAIL_ESTABLISH (C++ enumerator), 191 |
| ESP_GAP_SEARCH_DISC_CMPL_EVT (C++ enumerator), 180 | ESP_GATT_CONN_L2C_FAILURE (C++ enumerator), 191 |
| ESP_GAP_SEARCH_DISC_RES_EVT (C++ enumerator), 180 | ESP_GATT_CONN_LMP_TIMEOUT (C++ enumerator), 191 |
| ESP_GATT_SERVICE_FROM_NVS_FLASH | (C++ enumerator), 191 |
| ESP_GATT_SERVICE_FROM_REMOTE_DEVICE | (C++ enumerator), 191 |
| ESP_GATT_SERVICE_FROM_UNKNOWN | (C++ enumerator), 191 |
| ESP_GATT_SERVICE_STARTED | (C++ enumerator), 190 |
| esp_gatt_srvc_id_t | (C++ class), 182 |
| esp_gatt_srvc_id_t::id | (C++ member), 182 |
| esp_gatt_srvc_id_t::is_primary | (C++ member), 182 |
| ESP_GATT_STACK_RSP | (C++ enumerator), 190 |
| esp_gatt_status_t | (C++ enum), 189 |
| ESP_GATT_UNKNOWN_ERROR | (C++ enumerator), 190 |
| ESP_GATT_UNSUPPORT_GRP_TYPE | (C++ enumerator), 190 |
| ESP_GATT_UUID_ALERT_LEVEL | (C macro), 187 |
| ESP_GATT_UUID_ALERT_NTF_SVC | (C macro), 186 |
| ESP_GATT_UUID_ALERT_STATUS | (C macro), 187 |
| ESP_GATT_UUID_ALERT_NTF_SVC | (C macro), 186 |
| ESP_GATT_UUID_BATTERY_SERVICE_SVC | (C macro), 186 |
| ESP_GATT_UUID_BATTERY_SERVICE_SVC | (C macro), 186 |
| ESP_GATT_UUID_BLOOD_PRESSURE_SVC | (C macro), 186 |
| ESP_GATT_UUID_BODypressure_SVC | (C macro), 186 |
| ESP_GATT_UUID_BONE_COMPOSITION | (C macro), 186 |
| ESP_GATT_UUID_BOND_CONFIG_DESCR | (C macro), 187 |
| ESP_GATT_UUID_BOND_CONFIG_DESCR | (C macro), 187 |
| ESP_GATT_UUID_BOND_MANAGEMENT_SVC | (C macro), 186 |
| ESP_GATT_UUID_CHAR_AGG_FORMAT | (C macro), 187 |
| ESP_GATT_UUID_CHAR_CLIENT_CONFIG | (C macro), 186 |
| ESP_GATT_UUID_CHAR_CLIENT_CONFIG | (C macro), 186 |
| ESP_GATT_UUID_CHAR_DECLARE | (C macro), 186 |
| ESP_GATT_UUID_CHAR_DESCRIPTION | (C macro), 186 |
| ESP_GATT_UUID_CHAR_EXT_PROP | (C macro), 186 |
| ESP_GATT_UUID_CHAR_EXT_PROP | (C macro), 186 |
| ESP_GATT_UUID_CHAR_PRESENT_FORMAT | (C macro), 186 |
| ESP_GATT_UUID_CHAR_SRV_CONFIG | (C macro), 186 |
| ESP_GATT_UUID_CHAR_VALID_RANGE | (C macro), 187 |
| ESP_GATT_UUID_CONT_GLUCOSE_MONITOR_SVC | (C macro), 186 |
| ESP_GATT_UUID_CSC_FEATURE | (C macro), 188 |
| ESP_GATT_UUID_CSC_MEASUREMENT | (C macro), 188 |
| ESP_GATT_UUID_CURRENT_TIME | (C macro), 187 |
| ESP_GATT_UUID_CURRENT_TIME_SVC | (C macro), 186 |
| ESP_GATT_UUID_CYCLING_POWER_SVC | (C macro), 186 |
ESP_GATT_UUID_INCLUDE_SERVICE (C macro), 186
ESP_GATT_UUID_LINK_LOSS_SVC (C macro), 186
ESP_GATT_UUID_LOCAL_TIME_INFO (C macro), 187
ESP_GATT_UUID_LOCATION_AND_NAVIGATION_SVC (C macro), 186
ESP_GATT_UUID_MANU_NAME (C macro), 187
ESP_GATT_UUID_MODEL_NUMBER_STR (C macro), 187
ESP_GATT_UUID_NEXT_DST_CHANGE_SVC (C macro), 186
ESP_GATT_UUID_NUM_DIGITALS_DESCR (C macro), 187
ESP_GATT_UUID_NW_STATUS (C macro), 187
ESP_GATT_UUID_NW_TRIGGER (C macro), 187
ESP_GATT_UUID_PHONE_ALERT_STATUS_SVC (C macro), 187
ESP_GATT_UUID_RPT_REF_DESCR (C macro), 187
ESP_GATT_UUID_RINGER_CP (C macro), 187
ESP_GATT_UUID_RINGER_SETTING (C macro), 187
ESP_GATT_UUID_RSC_FEATURE (C macro), 188
ESP_GATT_UUID_RSC_MEASUREMENT (C macro), 188
ESP_GATT_UUID_RUNNING_SPEED_CADENCE_SVC (C macro), 186
ESP_GATT_UUID_SC_CONTROL_POINT (C macro), 188
ESP_GATT_UUID_SCAN_INT_WINDOW (C macro), 188
ESP_GATT_UUID_SCAN_PARAMETERS_SVC (C macro), 186
ESP_GATT_UUID_SCAN_REFRESH (C macro), 188
ESP_GATT_UUID_SEC_SERVICE (C macro), 186
ESP_GATT_UUID_SENSOR_LOCATION (C macro), 188
ESP_GATT_UUID_SERIAL_NUMBER_STR (C macro), 187
ESP_GATT_UUID_SW_VERSION_STR (C macro), 187
ESP_GATT_UUID_SYSTEM_ID (C macro), 187
ESP_GATT_UUID_TIME_TRIGGER_DESCR (C macro), 187
ESP_GATT_UUID_TX_POWER_LEVEL (C macro), 187
ESP_GATT_UUID_TX_POWER_SVC (C macro), 186
ESP_GATT_UUID_USER_DATA_SVC (C macro), 186
ESP_GATT_UUID_VALUE_TRIGGER_DESCR (C macro), 187
ESP_GATT_UUID_WEIGHT_SCALE_SVC (C macro), 186
esp_gatt_value_t (C++ class), 183
esp_gatt_value_t::auth_req (C++ member), 184
esp_gatt_value_t::handle (C++ member), 184
esp_gatt_value_t::len (C++ member), 184
esp_gatt_value_t::offset (C++ member), 184
esp_gatt_value_t::value (C++ member), 184
ESP_GATT_WRITE_NOT_PERMIT (C++ enumerator), 189
ESP_GATT_WRITE_TYPE_NO_RSP (C++ enumerator), 191
ESP_GATT_WRITE_TYPE_RSP (C++ enumerator), 191
esp_gatt_write_type_t (C++ enum), 191
ESP_GATT_Wrong_STATE (C++ enumerator), 190
ESP_GATTC_ACL_EVT (C++ enumerator), 218
ESP_GATTC_ADV_DATA_EVT (C++ enumerator), 219
ESP_GATTC_ADV_VSC_EVT (C++ enumerator), 219
ESP_GATTC_BTH_SCAN_CFG_EVT (C++ enumerator), 219
ESP_GATTC_BTH_SCAN_DIS_EVT (C++ enumerator), 219
ESP_GATTC_BTH_SCAN_ENB_EVT (C++ enumerator), 219
ESP_GATTC_BTH_SCAN_PARAM_EVT (C++ enumerator), 219
ESP_GATTC_BTH_SCAN_RD_EVT (C++ enumerator), 219
ESP_GATTC_BTH_SCAN_THR_EVT (C++ enumerator), 219
ESP_GATTC_CANCEL_OPEN_EVT (C++ enumerator), 218
esp_gattc_cb_event_t (C++ enum), 218
esp_gattc_cb_t (C++ type), 218
ESP_GATTC_CFG_MTU_EVT (C++ enumerator), 219
esp_gattc_char_elem_t (C++ class), 185
esp_gattc_char_elem_t::char_handle (C++ member), 185
esp_gattc_char_elem_t::properties (C++ member), 185
esp_gattc_char_elem_t::uuid (C++ member), 185
ESP_GATTC_CLOSE_EVT (C++ enumerator), 218
ESP_GATTC_CONGEST_EVT (C++ enumerator), 219
ESP_GATTC_CONNECT_EVT (C++ enumerator), 219
esp_gattc_db_elem_t (C++ class), 184
esp_gattc_db_elem_t::attribute_handle (C++ member), 184
esp_gattc_db_elem_t::end_handle (C++ member), 184
esp_gattc_db_elem_t::properties (C++ member), 184
Index

esp_gattc_db_elem_t::start_handle (C++ member), 184
esp_gattc_db_elem_t::type (C++ member), 184
esp_gattc_db_elem_t::uuid (C++ member), 185
esp_gattc_descr_elem_t (C++ class), 185
esp_gattc_descr_elem_t::handle (C++ member), 185
esp_gattc_descr_elem_t::uuid (C++ member), 185
ESP_GATTC_SCAN_FLT_CFG_EVT (C++ enumerator), 219
ESP_GATTC_SCAN_FLT_PARAM_EVT (C++ enumerator), 219
ESP_GATTC_SCAN_FLT_STATUS_EVT (C++ enumerator), 219
ESP_GATTC_SEARCH_CMPL_EVT (C++ enumerator), 218
ESP_GATTC_SEARCH_RES_EVT (C++ enumerator), 218
esp_gattc_service_elem_t (C++ class), 185
esp_gattc_service_elem_t::end_handle (C++ member), 185
esp_gattc_service_elem_t::is_primary (C++ member), 185
esp_gattc_service_elem_t::start_handle (C++ member), 185
esp_gattc_service_elem_t::uuid (C++ member), 185
ESP_GATTC_DISCONNECT_EVT (C++ enumerator), 219
ESP_GATTC_EXEC_CMPL_CB_EVT (C++ enumerator), 219
ESP_GATTC_EXEC_WRITE_EVT (C++ enumerator), 203
ESP_GATTS_ADD_CHAR_DESCR_EVT (C++ enumerator), 203
ESP_GATTS_ADD_CHAR_EVT (C++ enumerator), 203
esp_gatts_attr_db_t (C++ class), 183
esp_gatts_attr_db_t::att_desc (C++ member), 183
esp_gatts_attr_db_t::attr_control (C++ member), 183
ESP_GATTS_CANCEL_OPEN_EVT (C++ enumerator), 203
esp_gatts_cb_event_t (C++ enum), 202
esp_gatts_cb_t (C++ type), 202
ESP_GATTS_CLOSE_EVT (C++ enumerator), 203
ESP_GATTS_CONF_EVT (C++ enumerator), 203
ESP_GATTS_CONGEST_EVT (C++ enumerator), 203
esp_gatts_connect_evt (C++ member), 203
esp_gatts_create_attr_tab_evt (C++ enumerator), 204
ESP_GATTS_CREATE_EVT (C++ enumerator), 203
esp_gatts_delete_evt (C++ enumerator), 203
ESP_GATTS_DISCONNECT_EVT (C++ enumerator), 203
esp_gatts_exec_write_evt (C++ enumerator), 203
esp_gatts_incl128_svc_desc_t (C++ class), 183
Index
## Index

<table>
<thead>
<tr>
<th>C++ enumerator</th>
<th>293</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_HF_CLIENT_CONNECTION_STATE_EVT</td>
<td>(C++ enumerator)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_CONNECTION_STATE_SLC_CONNECTED</td>
<td>(C++ enumerator)</td>
</tr>
<tr>
<td>esp_hf_client_connection_state_t</td>
<td>(C++ enum)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_COPS_CURRENT_OPERATOR_EVT</td>
<td>(C++ enumerator)</td>
</tr>
<tr>
<td>esp_hf_client_deinit</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_disconnect</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_disconnect_audio</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_in_band_ring_state_t</td>
<td>(C++ enum)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_IN_BAND_RINGTONE_NOT_PROVIDED</td>
<td>(C++ enumerator)</td>
</tr>
<tr>
<td>esp_hf_client_incoming_data_cb_t</td>
<td>(C++ type)</td>
</tr>
<tr>
<td>esp_hf_client_init</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_outgoing_data_cb_t</td>
<td>(C++ type)</td>
</tr>
<tr>
<td>esp_hf_client_outgoing_data_ready</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_pcm_resample</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_pcm_resample_deinit</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_pcm_resample_init</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_PEER_FEAT_3WAY</td>
<td>(C macro)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_PEER_FEAT_CODEC</td>
<td>(C macro)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_PEER_FEAT_ECC</td>
<td>(C macro)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_PEER_FEAT_ECNR</td>
<td>(C macro)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_PEER_FEAT_ECS</td>
<td>(C macro)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_PEER_FEAT_EXTErr</td>
<td>(C macro)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_PEER_FEAT_INBAND</td>
<td>(C macro)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_PEER_FEAT_REJECT</td>
<td>(C macro)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_PEER_FEAT_VREC</td>
<td>(C macro)</td>
</tr>
<tr>
<td>esp_hf_client_query_current_calls</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_query_current_operator_name</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_register_callback</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_register_data_callback</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_register_callback</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_reject_call</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_request_last_voice_tag_number</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_retrieve_subscriber_info</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_RING_IND_EVT</td>
<td>(C++ enumerator)</td>
</tr>
<tr>
<td>esp_hf_client_send_btrh_cmd</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_send_chld_cmd</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_send_dtmf</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_send_nrec</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_start_voice_recognition</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>esp_hf_client_stop_voice_recognition</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>ESP_HF_CLIENT_VOLUME_CONTROL_EVT</td>
<td>(C++ enumerator)</td>
</tr>
<tr>
<td>esp_hf_client_volume_update</td>
<td>(C++ function)</td>
</tr>
<tr>
<td>ESP_HF_CME_AG_FAILURE</td>
<td>(C++ enumerator)</td>
</tr>
<tr>
<td>ESP_HF_CME_DIAL_STRING_TOO_LONG</td>
<td>(C++ enumerator)</td>
</tr>
<tr>
<td>esp_hf_cme_err_t</td>
<td>(C++ enum)</td>
</tr>
<tr>
<td>ESP_HF_CME_INCORRECT_PASSWORD</td>
<td>(C++ enumerator)</td>
</tr>
<tr>
<td>ESP_HF_CME_INVALID_CHARACTERS_IN_DIAL_STRING</td>
<td>(C++ enumerator)</td>
</tr>
<tr>
<td>ESP_HF_CME_INVALID_CHARACTERS_IN_TEXT_STRING</td>
<td>(C++ enumerator)</td>
</tr>
<tr>
<td>ESP_HF_CME_MEMORY_FAILURE</td>
<td>(C++ enum)</td>
</tr>
<tr>
<td>ESP_HF_CME_MEMORY_FULL</td>
<td>(C++ enum)</td>
</tr>
<tr>
<td>ESP_HF_CME_NETWORK_NOT_ALLOWED</td>
<td>(C++ enum)</td>
</tr>
<tr>
<td>ESP_HF_CME_NETWORK_TIMEOUT</td>
<td>(C++ enum)</td>
</tr>
<tr>
<td>ESP_HF_CME_NO_CONNECTION_TO_PHONE</td>
<td>(C++ enum)</td>
</tr>
<tr>
<td>ESP_HF_CME_NO_NETWORK_SERVICE</td>
<td>(C++ enum)</td>
</tr>
<tr>
<td>ESP_HF_CME_OPERATION_NOT_ALLOWED</td>
<td>(C++ enum)</td>
</tr>
<tr>
<td>ESP_HF_CME_OPERATION_NOT_SUPPORTED</td>
<td>(C++ enum)</td>
</tr>
<tr>
<td>ESP_HF_CME_PH_SIM_PIN_REQUIRED</td>
<td>(C++ enum)</td>
</tr>
</tbody>
</table>
ESP_HF_CME_SIM_BUSY (C++ enumerator), 283
ESP_HF_CME_SIM_FAILURE (C++ enumerator), 283
ESP_HF_CME_SIM_NOT_INSERTED (C++ enumerator), 282
ESP_HF_CME_SIM_PIN2_REQUIRED (C++ enumerator), 283
ESP_HF_CME_SIM_PIN_REQUIRED (C++ enumerator), 282
ESP_HF_CME_SIM_PUK2_REQUIRED (C++ enumerator), 283
ESP_HF_CME_TEXT_STRING_TOO_LONG (C++ enumerator), 283
esp_hf_cnum_cmd_callback (C++ type), 277
ESP_HF_CNUM_RESPONSE_EVT (C++ enumerator), 304
esp_hf_connection_state_callback (C++ type), 277
ESP_HF_CONNECTION_STATE_CONNECTED (C++ enumerator), 281
ESP_HF_CONNECTION_STATE_CONNECTING (C++ enumerator), 281
ESP_HF_CONNECTION_STATE_DISCONNECTED (C++ enumerator), 281
ESP_HF_CONNECTION_STATE_DISCONNECTING (C++ enumerator), 281
ESP_HF_CONNECTION_STATE_EVT (C++ enumerator), 304
ESP_HF_CONNECTION_STATE_SLC_CONNECTED (C++ enumerator), 281
esp_hf_connection_state_t (C++ enum), 281
esp_hf_cops_cmd_callback (C++ type), 277
ESP_HF_COPS_RESPONSE_EVT (C++ enumerator), 304
esp_hf_dial_call_cmd_callback (C++ type), 277
ESP_HF_DIAL_EVT (C++ enumerator), 305
esp_hf_dtmf_cmd_callback (C++ type), 277
esp_hf_hangup_call_cmd_callback (C++ type), 277
esp_hf_in_band_ring_state_t (C++ enum), 277
ESP_HF_IN_BAND_RINGTONE_NOT_PROVIDED (C++ enumerator), 277
esp_hf_incoming_data_cb_t (C++ type), 303
ESP_HF_IND_UPDATE_EVT (C++ enumerator), 304
esp_hf_key_pressed_cmd_callback (C++ type), 277
ESP_HF_NETWORK_STATE_AVAILABLE (C++ enumerator), 278
ESP_HF_NETWORK_STATE_NOT_AVAILABLE (C++ enumerator), 278
esp_hf_network_state_t (C++ enum), 278
esp_hf_nrec_cmd_callback (C++ type), 277
ESP_HF_NREC_RESPONSE_EVT (C++ enumerator), 304
ESP_HF_CURRENT_CALL_DIRECTION_INCOMING (C++ enumerator), 280
ESP_HF_CURRENT_CALL_DIRECTION_OUTGOING (C++ enumerator), 280
esp_hf_current_call_direction_t (C++ enum), 279
ESP_HF_CURRENT_CALL_MODE_DATA (C++ enumerator), 280
ESP_HF_CURRENT_CALL_MODE_FAX (C++ enumerator), 280
esp_hf_current_call_mode_t (C++ enum), 280
ESP_HF_CURRENT_CALL_MODE_VOICE (C++ enumerator), 280
ESP_HF_CURRENT_CALL_MPTY_TYPE_MULTI (C++ enumerator), 280
esp_hf_current_call_mpty_type_t (C++ enum), 280
ESP_HF_CURRENT_CALL_MPTY_TYPE_SINGLE (C++ enumerator), 280
ESP_HF_CURRENT_CALL_STATUS_ACTIVE (C++ enumerator), 279
ESP_HF_CURRENT_CALL_STATUS_ALERTING (C++ enumerator), 279
ESP_HF_CURRENT_CALL_STATUS_DIALED (C++ enumerator), 279
ESP_HF_CURRENT_CALL_STATUS_Held (C++ enumerator), 279
ESP_HF_CURRENT_CALL_STATUS_Held_by_RESP_HOLD (C++ enumerator), 279
ESP_HF_CURRENT_CALL_STATUS_INCOMING (C++ enumerator), 279
esp_hf_current_call_status_t (C++ enum), 279
ESP_HF_CURRENT_CALL_STATUS_WAITING (C++ enumerator), 279
esp_hf_dial_call_cmd_callback (C++ type), 277
ESP_HF_DIAL_EVT (C++ enumerator), 305
esp_hf_dtmf_cmd_callback (C++ type), 277
esp_hf_hangup_call_cmd_callback (C++ type), 277
esp_hf_in_band_ring_state_t (C++ enum), 277
ESP_HF_IN_BAND_RINGTONE_NOT_PROVIDED (C++ enumerator), 277
esp_hf_incoming_data_cb_t (C++ type), 303
ESP_HF_IND_UPDATE_EVT (C++ enumerator), 304
esp_hf_key_pressed_cmd_callback (C++ type), 277
ESP_HF_NETWORK_STATE_AVAILABLE (C++ enumerator), 278
ESP_HF_NETWORK_STATE_NOT_AVAILABLE (C++ enumerator), 278
esp_hf_network_state_t (C++ enum), 278
esp_hf_nrec_cmd_callback (C++ type), 277
ESP_HF_NREC_RESPONSE_EVT (C++ enumerator), 304
ESP_HF_PEER_FEAT_3WAY (C macro), 303
ESP_HF_PEER_FEAT_CODEC (C macro), 303
ESP_HF_PEER_FEAT_ECC (C macro), 303
ESP_HF_PEER_FEAT_ECNR (C macro), 303
ESP_HF_PEER_FEAT_ECS (C macro), 303
ESP_HF_PEER_FEAT_EXTERN (C macro), 303
ESP_HF_PEER_FEAT_INBAND (C macro), 303
ESP_HF_PEER_FEAT_REJECT (C macro), 303
ESP_HF_PEER_FEAT_VREC (C macro), 303
ESP_HF_PEER_FEAT_VTAG (C macro), 303
ESP_HF_ROAMING_STATUS_ACTIVE (C++ enumerator), 279
ESP_HF_ROAMING_STATUS_INACTIVE (C++ enumerator), 279
Index

esp_hf_roaming_status_t (C++ enum), 279
ESP_HF_SERVICE_TYPE_HOME (C++ enumerator), 278
ESP_HF_SERVICE_TYPE_ROAMING (C++ enumerator), 278
esp_hf_service_type_t (C++ enum), 278
ESP_HF_SUBSCRIBER_SERVICE_TYPE_FAX (C++ enumerator), 280
esp_hf_subscriber_service_type_t (C++ enum), 280
ESP_HF_SUBSCRIBER_SERVICE_TYPE_UNKNOWN (C++ enumerator), 280
ESP_HF_SUBSCRIBER_SERVICE_TYPE_VOICE (C++ enumerator), 280
esp_hf_unat_response (C++ function), 296
ESP_HF_UNAT_RESPONSE_EVT (C++ enumerator), 304
esp_hf_unknown_at_cmd_callback (C++ type), 277
esp_hf_volume_cmd_callback (C++ type), 277
ESP_HF_VOLUME_CONTROL_EVT (C++ enumerator), 304
ESP_HF_VOLUME_CONTROL_TARGET_MIC (C++ enumerator), 278
ESP_HF_VOLUME_CONTROL_TARGET_SPK (C++ enumerator), 278
esp_hf_volume_control_target_t (C++ enum), 278
ESP_HF_VOLUME_TYPE_MIC (C++ enumerator), 278
ESP_HF_VOLUME_TYPE_SPK (C++ enumerator), 278
esp_hf_volume_type_t (C++ enum), 278
esp_hf_vk_cmd_callback (C++ type), 277
ESP_HF_VIRTUAL_REG_EVT (C++ enumerator), 304
ESP_HF_VIRTUAL_REGARGET_MIC (C++ enumerator), 278
ESP_HF_VIRTUAL_REGARGET_SPK (C++ enumerator), 278
esp_hf_virtual_regarget_t (C++ enum), 278
ESP_HF_VIRTUAL_REGARGET_ENABLED (C++ enumerator), 278
esp_hf_vr_state_t (C++ enum), 278
ESP_HF_VTS_RESPONSE_EVT (C++ enumerator), 304
esp_hf_wbs_callback (C++ type), 277
esp_hf_wbs_config_t (C++ enum), 281
ESP_HF_WBS_No (C++ enumerator), 281
ESP_HF_WBS_NONE (C++ enumerator), 281
ESP_HF_WBS_RESPONSE_EVT (C++ enumerator), 305
ESP_HF_WBS_YES (C++ enumerator), 281
esp_himem_alloc (C++ function), 1401
esp_himem_alloc_map_range (C++ function), 1401
ESP_HIMEM_BLKSZ (C macro), 1403
esp_himem_free (C++ function), 1402
esp_himem_free_map_range (C++ function), 1402
esp_himem_get_free_size (C++ function), 1402
esp_himem_get_phys_size (C++ function), 1402
esp_himem_get_phys_size (C++ function), 2247
Index

esp_https_ota_config_t::max_http_request_size
(C++ member), 1197
esp_https_ota_config_t::partial_http_download
(C++ member), 1197
esp_https_ota_finish (C++ function), 1230
esp_https_ota_get_image_len_read (C++ function), 1231
esp_https_ota_get_image_size (C++ function), 1231
esp_https_ota_get_img_desc (C++ function), 1230
esp_https_ota_handle_t (C++ type), 1232
esp_https_ota_is_complete_data_received
(C++ function), 1230
esp_https_ota_perform (C++ function), 1230
esp_https_server_user_cb (C++ type), 999
esp_https_server_user_cb_arg (C++ class), 998
esp_https_server_user_cb_arg_t (C++ type), 999
ESP_IDF_VERSION (C macro), 1425
ESP_IDF_VERSION_MAJOR (C macro), 1424
ESP_IDF_VERSION_MINOR (C macro), 1424
ESP_IDF_VERSION_PATCH (C macro), 1424
ESP_IDF_VERSION_VAL (C macro), 1425
ESP_IMAGE_FLASH_SIZE_16MB (C++ enumerator), 1198
ESP_IMAGE_FLASH_SIZE_1MB (C++ enumerator), 1198
ESP_IMAGE_FLASH_SIZE_2MB (C++ enumerator), 1198
ESP_IMAGE_FLASH_SIZE_4MB (C++ enumerator), 1198
ESP_IMAGE_FLASH_SIZE_8MB (C++ enumerator), 1198
ESP_IMAGE_FLASH_SIZE_MAX (C++ enumerator), 1198
esp_image_flash_size_t (C++ enum), 1198
ESP_IMAGE_HEADER_MAGIC (C macro), 1197
esp_image_header_t (C++ class), 1195
esp_image_header_t::chip_id (C++ member), 1195
esp_image_header_t::entry_addr (C++ member), 1195
esp_image_header_t::hash_appended (C++ member), 1196
esp_image_header_t::magic (C++ member), 1195
esp_image_header_t::min_chip_rev (C++ member), 1196
esp_image_header_t::reserved (C++ member), 1195
esp_image_header_t::segment_count
(C++ member), 1195
esp_image_header_t::spi_mode (C++ member), 1195
esp_image_header_t::spi_pin_drv (C++ member), 1195
esp_image_header_t::spi_size (C++ member), 1195
esp_image_header_t::spi_speed (C++ member), 1195
esp_image_header_t::wp_pin (C++ member), 1195
ESP_IMAGE_MAX_SEGMENTS (C macro), 1197
esp_image_segment_header_t (C++ class), 1196
esp_image_segment_header_t::data_len
(C++ member), 1196
esp_image_segment_header_t::load_addr
(C++ member), 1196
ESP_IMAGE_SPI_FREQ_T (C++ enumerator), 1197
ESP_IMAGE_SPI_MODE_DIO (C++ enumerator), 1197
ESP_IMAGE_SPI_MODE_DOUT (C++ enumerator), 1197
ESP_IMAGE_SPI_MODE_FORMAT (C++ enumerator), 1197
ESP_IMAGE_SPI_MODE_FAST_READ (C++ enumerator), 1197
ESP_IMAGE_SPI_MODE_QIO (C++ enumerator), 1197
ESP_IMAGE_SPI_MODE_QOUT (C++ enumerator), 1197
ESP_IMAGE_SPI_MODE_SLOW_READ (C++ enumerator), 1197
esp_image_spi_mode_t (C++ enum), 1197
ESP_IMAGE_SPI_SPEED_20M (C++ enumerator), 1197
ESP_IMAGE_SPI_SPEED_26M (C++ enumerator), 1197
ESP_IMAGE_SPI_SPEED_40M (C++ enumerator), 1197
ESP_IMAGE_SPI_SPEED_80M (C++ enumerator), 1197
esp_int_wdt_init (C++ function), 1458
esp_intr_alloc (C++ function), 1411
esp_intr_alloc_intrstatus (C++ function), 1411
ESP_INTR_DISABLE (C macro), 1414
esp_intr_disable (C++ function), 1412
esp_intr_disable_source (C++ function), 1413
ESP_INTR_ENABLE (C macro), 1414
esp_intr_enable (C++ function), 1412
esp_intr_enable_source (C++ function), 1413
ESP_INTR_FLAG_EDGE (C macro), 1413
ESP_INTR_FLAG_HIGH (C macro), 1413
ESP_INTR_FLAG_LEVEL1 (C macro), 1413
ESP_INTR_FLAG_LEVEL2 (C macro), 1413
ESP_INTR_FLAG_LEVEL3 (C macro), 1413
ESP_INTR_FLAG_LEVEL4 (C macro), 1413
ESP_INTR_FLAG_LEVEL5 (C macro), 1413
ESP_INTR_FLAG_LEVEL6 (C macro), 1413
ESP_INTR_FLAG_LEVELMASK (C macro), 1414
ESP_INTR_FLAG_LOWMED (C macro), 1414

Espressif Systems Release v5.0-dev-1077-g397639d
Submit Document Feedback
Index

ESP_INTR_FLAG_NMI (C macro), 1413
ESP_INTR_FLAG_SHARED (C macro), 1413
esp_intr_flags_to_level (C++ function), 1413
esp_intr_free (C++ function), 1412
esp_intr_get_cpu (C++ function), 1412
esp_intr_get_intrno (C++ function), 1412
esp_intr_mark_shared (C++ function), 1410
esp_intr_noniram_disable (C++ function), 1413
esp_intr_noniram_enable (C++ function), 1413
esp_intr_reserve (C++ function), 1411
ESP_IO_CAP_IN (C macro), 171
ESP_IO_CAP_IO (C macro), 171
ESP_IO_CAP_KBDISP (C macro), 171
ESP_IO_CAP_NONE (C macro), 171
ESP_IO_CAP_OUT (C macro), 171
esp_ip4addr_aton (C++ function), 646
esp_ip4addr_ntoa (C++ function), 646
esp_ipc_call (C++ function), 1405
esp_ipc_call_blocking (C++ function), 1405
esp_ipc_func_t (C++ type), 1406
esp_ipc_isr_asm_call (C++ function), 1406
esp_ipc_isr_asm_call_blocking (C++ function), 1406
esp_ipc_isr_func_t (C++ type), 1407
esp_ipc_isr_init (C++ function), 1406
esp_ipc_isr_release_other_cpu (C++ function), 1407
esp_ipc_isr_stall_abort (C++ function), 1407
esp_ipc_isr_stall_other_cpu (C++ function), 1407
esp_ipc_isr_stall_pause (C++ function), 1407
esp_ipc_isr_stall_resume (C++ function), 1407
ESP_LCD_COLOR_SPACE_BGR (C++ enumerator), 733
ESP_LCD_COLOR_SPACE_MONOCHROME (C++ enumerator), 733
ESP_LCD_COLOR_SPACE_RGB (C++ enumerator), 733
esp_lcd_color_space_t (C++ enum), 733
esp_lcd_del_i80_bus (C++ function), 735
esp_lcd_i80_bus_handle_t (C++ type), 735
esp_lcd_i80_bus_config_t (C++ class), 737
esp_lcd_i80_bus_config_t::bus_width (C++ member), 737
esp_lcd_i80_bus_config_t::clk_src (C++ member), 737
esp_lcd_i80_bus_config_t::data_gpio_num (C++ member), 737
esp_lcd_i80_bus_config_t::dc_gpio_num (C++ member), 737
esp_lcd_i80_bus_config_t::max_transfer_i80 (C++ member), 737
esp_lcd_i80_bus_config_t::max_transfer_i2c (C++ member), 737
esp_lcd_i80_bus_config_t::max_transfer_i2c_config (C++ member), 737
esp_lcd_i80_color_trans_done (C++ function), 735
esp_lcd_i80_color_trans_done_cb_t (C++ function), 735
esp_lcd_i80_color_trans_done_ignore_cb (C++ function), 735
esp_lcd_i80_rgb_config_t (C++ function), 735
esp_lcd_new_i80_bus (C++ function), 735
esp_lcd_new_panel_io_i2c (C++ function), 735
esp_lcd_new_panel_io_i80 (C++ function), 735
esp_lcd_new_panel_io_spi (C++ function), 734
esp_lcd_new_panel_nt35510 (C++ function), 740
esp_lcd_new_panel_ssd1306 (C++ function), 740
esp_lcd_new_panel_st7789 (C++ function), 740
esp_lcd_panel_dev_config_t (C++ class), 741
esp_lcd_panel_dev_config_t::bits_per_pixel (C++ member), 741
esp_lcd_panel_dev_config_t::color_space (C++ member), 741
esp_lcd_panel_dev_config_t::reset_active_high (C++ member), 741
esp_lcd_panel_dev_config_t::reset_gpio_num (C++ member), 741
esp_lcd_panel_dev_config_t::reset_gpio_num (C++ member), 741
esp_lcd_panel_disp_off (C++ function), 740
esp_lcd_panel_draw_bitmap (C++ function), 739
esp_lcd_panel_handle_t (C++ function), 733
esp_lcd_panel init (C++ function), 738
esp_lcd_panel_invert_color (C++ function), 739
esp_lcd_panel_invert_color (C++ function), 739
esp_lcd_panel_io_color_trans_done_cb_t (C++ type), 738
esp_lcd_panel_io_color_trans_done_cb_t (C++ type), 738
esp_lcd_panel_io_color_trans_done_cb_t (C++ type), 738
esp_lcd_panel_io_color_trans_done_cb_t (C++ type), 738
esp_lcd_panel_io_color_trans_done_cb_t (C++ type), 738
esp_lcd_panel_io_color_trans_done_cb_t (C++ type), 738
esp_lcd_panel_io_config_t (C++ type), 738
esp_lcd_panel_io_config_t (C++ type), 738
esp_lcd_panel_io_config_t (C++ type), 738
esp_lcd_panel_io_config_t (C++ type), 738
esp_lcd_panel_io_config_t (C++ type), 738
esp_lcd_panel_io_config_t (C++ type), 738
esp_lcd_panel_io_config_t (C++ type), 738
esp_lcd_panel_io_config_t (C++ type), 738
esp_lcd_panel_io_config_t (C++ type), 738
esp_lcd_panel_io_color_trans_done (C++ function), 738
esp_lcd_panel_io_color_trans_done (C++ function), 738
esp_lcd_panel_io_config_t::control_phase_bytes (C++ member), 737
esp_lcd_panel_io_config_t::data_gpio_num (C++ member), 737
esp_lcd_panel_io_config_t::dc_gpio_num (C++ member), 737
esp_lcd_panel_io_config_t::max_transfer (C++ member), 737

Espressif Systems 2250 Release v5.0-dev-1077-g397639d
Submit Document Feedback
(C++ member), 1010
esp_local_ctrl_handlers::usr_ctx (C++ member), 1010
esp_local_ctrl_handlers::usr_ctx_free_fn (C++ member), 1011
esp_local_ctrl_handlers_t (C++ type), 1011
esp_local_ctrl_transport_config_t (C++ type), 1011
esp_local_ctrl_transport_config_httpd_t (C++ type), 1011
esp_local_ctrl_transport_config_ble_t (C++ type), 1011
ESP_LOCAL_CTRL_TRANSPORT_BLE (C macro), 1011
esp_local_ctrl_stop (C++ function), 1011
esp_local_ctrl_start (C++ function), 1011
ESP_LOG_BUFFER_CHAR (C macro), 1418
ESP_LOG_BUFFER_CHAR_LEVEL (C macro), 1417
ESP_LOG_BUFFER_HEX (C macro), 1418
ESP_LOG_BUFFER_HEX_LEVEL (C macro), 1417
ESP_LOG_BUFFER_HEXDUMP (C macro), 1418
ESP_LOG_DEBUG (C++ enumerator), 1420
ESP_LOG_EARLY_IMPL (C macro), 1419
esp_log_early_timestamp (C++ function), 1417
ESP_LOG_ERROR (C++ enumerator), 1420
ESP_LOG_INFO (C++ enumerator), 1420
ESP_LOG_LEVEL (C macro), 1419
esp_log_level_get (C++ function), 1416
ESP_LOGLEVELLOCAL (C macro), 1419
esp_log_level_set (C++ function), 1416
esp_log_level_t (C++ enum), 1420
ESP_LOG_NONE (C++ enumerator), 1420
esp_log_set_vprintf (C++ function), 1416
esp_log_system_timestamp (C++ function), 1417
ESP_LOGE (C macro), 1419
ESP_LOGI (C macro), 1419
ESP_LOGV (C macro), 1419
ESP_LOGW (C macro), 1419
ESP_MAC_BT (C++ enumerator), 1426
ESP_MAC_ETH (C++ function), 1426
ESP_MAC_MAC (C++ function), 1426
ESP_MAC_PAGE_802154 (C++ function), 1426
ESP_MAC_PTH (C++ enumerator), 1426
ESP_MAC_TYPE (C++ enum), 1426
ESP_MAC_WIFI_SOFTAP (C++ enumerator), 1426
ESP_MAC_WIFI_STA (C++ enumerator), 1426
esp_mesh_allow_root_conflicts (C++ function), 581
esp_mesh_available_txupQ_num (C++ function), 581
esp_mesh_connect (C++ function), 584
esp_mesh_deinit (C++ function), 573
esp_mesh_delete_group_id (C++ function), 581
esp_mesh_disable_ps (C++ function), 585
esp_mesh_disconnect (C++ function), 584
esp_mesh_enable_ps (C++ function), 585
esp_mesh_fix_root (C++ function), 583
esp_mesh_flush_scan_result (C++ function), 584
esp_mesh_flush_upstream_packets (C++ function), 584
ESP_Local_CTRL_TRANSPORT_HTTPD (C macro), 1011
Index
<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_mesh_get_active_duty_cycle</td>
<td>(C++ function), 586</td>
</tr>
<tr>
<td>esp_mesh_get_ap_assoc_expire</td>
<td>(C++ function), 580</td>
</tr>
<tr>
<td>esp_mesh_get_ap_authmode</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_get_ap_connections</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_get_capacity_num</td>
<td>(C++ function), 582</td>
</tr>
<tr>
<td>esp_mesh_get_config</td>
<td>(C++ function), 576</td>
</tr>
<tr>
<td>esp_mesh_get_group_list</td>
<td>(C++ function), 582</td>
</tr>
<tr>
<td>esp_mesh_get_group_num</td>
<td>(C++ function), 581</td>
</tr>
<tr>
<td>esp_mesh_get_id</td>
<td>(C++ function), 577</td>
</tr>
<tr>
<td>esp_mesh_get_ie_crypto_key</td>
<td>(C++ function), 582</td>
</tr>
<tr>
<td>esp_mesh_get_layer</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_get_max_layer</td>
<td>(C++ function), 577</td>
</tr>
<tr>
<td>esp_mesh_get_network_duty_cycle</td>
<td>(C++ function), 587</td>
</tr>
<tr>
<td>esp_mesh_get_non_mesh_connections</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_get_parent_bssid</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_get_root_healing_delay</td>
<td>(C++ function), 583</td>
</tr>
<tr>
<td>esp_mesh_get_router</td>
<td>(C++ function), 576</td>
</tr>
<tr>
<td>esp_mesh_get_router_bssid</td>
<td>(C++ function), 576</td>
</tr>
<tr>
<td>esp_mesh_get_routing_table</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_get_routing_table_size</td>
<td>(C++ function), 579</td>
</tr>
<tr>
<td>esp_mesh_get_running_active_duty_cycle</td>
<td>(C++ function), 587</td>
</tr>
<tr>
<td>esp_mesh_get_rx_pending</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_get_self_organized</td>
<td>(C++ function), 580</td>
</tr>
<tr>
<td>esp_mesh_get_subnet_nodes_list</td>
<td>(C++ function), 584</td>
</tr>
<tr>
<td>esp_mesh_get_subnet_nodes_num</td>
<td>(C++ function), 584</td>
</tr>
<tr>
<td>esp_mesh_get_topology</td>
<td>(C++ function), 585</td>
</tr>
<tr>
<td>esp_mesh_get_total_node_num</td>
<td>(C++ function), 580</td>
</tr>
<tr>
<td>esp_mesh_get_tsf_time</td>
<td>(C++ function), 585</td>
</tr>
<tr>
<td>esp_mesh_get_tx_pending</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_get_type</td>
<td>(C++ function), 577</td>
</tr>
<tr>
<td>esp_mesh_get_votecnt_percentage</td>
<td>(C++ function), 579</td>
</tr>
<tr>
<td>esp mesh_get_xon_qsize</td>
<td>(C++ function), 581</td>
</tr>
<tr>
<td>esp_mesh_init</td>
<td>(C++ function), 586</td>
</tr>
<tr>
<td>esp_mesh_is_device_active</td>
<td>(C++ function), 586</td>
</tr>
<tr>
<td>esp_mesh_is_my_group</td>
<td>(C++ function), 582</td>
</tr>
<tr>
<td>esp_mesh_is_ps_enabled</td>
<td>(C++ function), 582</td>
</tr>
<tr>
<td>esp_mesh_is_root</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_is_root_conflicts_allowed</td>
<td>(C++ function), 581</td>
</tr>
<tr>
<td>esp_mesh_is_root_fixed</td>
<td>(C++ function), 583</td>
</tr>
<tr>
<td>esp_mesh_is_root_conflicts_allowed</td>
<td>(C++ function), 581</td>
</tr>
<tr>
<td>esp_mesh_post_toDS_state</td>
<td>(C++ function), 580</td>
</tr>
<tr>
<td>esp_mesh_ps_duty_signaling</td>
<td>(C++ function), 587</td>
</tr>
<tr>
<td>esp_mesh_recv</td>
<td>(C++ function), 574</td>
</tr>
<tr>
<td>esp_mesh_recv_toDS</td>
<td>(C++ function), 575</td>
</tr>
<tr>
<td>esp_mesh_scan_get_ap_ie_len</td>
<td>(C++ function), 583</td>
</tr>
<tr>
<td>esp_mesh_scan_get_ap_record</td>
<td>(C++ function), 584</td>
</tr>
<tr>
<td>esp_mesh_send</td>
<td>(C++ function), 573</td>
</tr>
<tr>
<td>esp_mesh_send_block_time</td>
<td>(C++ function), 574</td>
</tr>
<tr>
<td>esp_mesh_set_active_duty_cycle</td>
<td>(C++ function), 586</td>
</tr>
<tr>
<td>esp_mesh_set_ap_assoc_expire</td>
<td>(C++ function), 580</td>
</tr>
<tr>
<td>esp_mesh_set_ap_authmode</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_set_ap_connections</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_set_ap_password</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_set_capacity_num</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_set_config</td>
<td>(C++ function), 576</td>
</tr>
<tr>
<td>esp_mesh_set_group_id</td>
<td>(C++ function), 581</td>
</tr>
<tr>
<td>esp_mesh_set_id</td>
<td>(C++ function), 576</td>
</tr>
<tr>
<td>esp_mesh_set_ie_crypto_funcs</td>
<td>(C++ function), 582</td>
</tr>
<tr>
<td>esp_mesh_set_ie_crypto_key</td>
<td>(C++ function), 582</td>
</tr>
<tr>
<td>esp_mesh_set_max_layer</td>
<td>(C++ function), 577</td>
</tr>
<tr>
<td>esp_mesh_set_network_duty_cycle</td>
<td>(C++ function), 586</td>
</tr>
<tr>
<td>esp_mesh_set_parent</td>
<td>(C++ function), 583</td>
</tr>
<tr>
<td>esp_mesh_set_root_healing_delay</td>
<td>(C++ function), 582</td>
</tr>
<tr>
<td>esp_mesh_set_root</td>
<td>(C++ function), 576</td>
</tr>
<tr>
<td>esp_mesh_set_self_organized</td>
<td>(C++ function), 579</td>
</tr>
<tr>
<td>esp_mesh_set_topology</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp_mesh_set_total_node_num</td>
<td>(C++ function), 578</td>
</tr>
<tr>
<td>esp mesh_set_votecnt_percentage</td>
<td>(C++ function), 579</td>
</tr>
<tr>
<td>esp mesh_set_xon_qsize</td>
<td>(C++ function), 581</td>
</tr>
<tr>
<td>esp mesh_start</td>
<td>(C++ function), 573</td>
</tr>
<tr>
<td>esp mesh_stop</td>
<td>(C++ function), 573</td>
</tr>
<tr>
<td>esp mesh_switch_channel</td>
<td>(C++ function), 584</td>
</tr>
<tr>
<td>esp mesh_topology_t</td>
<td>(C++ enum), 599</td>
</tr>
<tr>
<td>esp mesh waive root</td>
<td>(C++ function), 579</td>
</tr>
<tr>
<td>esp mqt_client_config_t</td>
<td>(C++ class), 920</td>
</tr>
<tr>
<td>esp mqt_client_config_t::alpn_protos</td>
<td>(C++ member), 921</td>
</tr>
<tr>
<td>esp mqt_client_config_t::buffer_size</td>
<td>(C++ member), 921</td>
</tr>
</tbody>
</table>

Submit Document Feedback
Index

ESP_RST_UNKNOWN (C++ enumerator), 1424
ESP_RST_WDT (C++ enumerator), 1424
ESP_SCO_DATA_PATH_HCI (C++ enumerator), 132
ESP_SCO_DATA_PATH_PCM (C++ enumerator), 132
esp_sco_data_path_t (C++ enum), 132
esp_service_source_t (C++ enum), 191
esp_set_deep_sleep_wake_stub (C++ function), 1455
esp_sleep_config_gpio_isolate (C++ function), 1455
esp_sleep_disable_wakeup_source (C++ function), 1451
esp_sleep_disable_wifi_wakeup (C++ function), 1453
esp_sleep_enable_ext0_wakeup (C++ function), 1452
esp_sleep_enable_ext1_wakeup (C++ function), 1452
esp_sleep_enable_gpio_switch (C++ function), 1455
esp_sleep_enable_gpio_wakeup (C++ function), 1453
esp_sleep_enable_timer_wakeup (C++ function), 1452
esp_sleep_enable_touchpad_wakeup (C++ function), 1453
esp_sleep_enable_uart_wakeup (C++ function), 1453
esp_sleep_enable_ulp_wakeup (C++ function), 1451
esp_sleep_enable_wifi_wakeup (C++ function), 1453
esp_sleep_ext1_wakeup_mode_t (C++ enum), 1455
esp_sleep_get_ext1_wakeup_status (C++ function), 1454
esp_sleep_get_touchpad_wakeup_status (C++ function), 1452
esp_sleep_get_wakeup_cause (C++ function), 1454
esp_sleep_is_valid_wakeup_gpio (C++ function), 1452
esp_sleep_is_valid_sleep_mode (C++ function), 1454
esp_sleep_path_t (C++ enum), 1455
ESP_SLEEP_WAKEUP_ALL (C++ enumerator), 1456
ESP_SLEEP_WAKEUP_BT (C++ enumerator), 1456
esp_sleep_wakeup_cause_t (C++ type), 1455
ESP_SLEEP_WAKEUP_COCPU (C++ enumerator), 1456
ESP_SLEEP_WAKEUP_COCPU_TRAP_TRIG (C++ enumerator), 1456
ESP_SLEEP_WAKEUP_EXT0 (C++ enumerator), 1456
ESP_SLEEP_WAKEUP_EXT1 (C++ enumerator), 1456
ESP_SLEEP_WAKEUP_GPIO (C++ enumerator), 1456
ESP_SLEEP_WAKEUP_TIMER (C++ enumerator), 1456
ESP_SLEEP_WAKEUP_TOUCHPAD (C++ enumerator), 1456
ESP_SLEEP_WAKEUP_UART (C++ enumerator), 1456
ESP_SLEEP_WAKEUP_WIFI (C++ enumerator), 1456
ESP_SLEEP_WAKEUP_UPL (C++ enumerator), 1456
ESP_SLEEP_WAKEUP_UNDEFINED (C++ enumerator), 1456
esp_smartconfig_fast_mode (C++ function), 559
esp_smartconfig_get_rvd_data (C++ function), 559
esp_smartconfig_get_version (C++ function), 558
esp_smartconfig_set_type (C++ function), 559
esp_smartconfig_start (C++ function), 558
esp_smartconfig_stop (C++ function), 558
esp_spiffs_format (C++ function), 1176
esp_spiffs_info (C++ function), 1176
esp_spiffs_mounted (C++ function), 1175
ESP_SPP_BUSY (C++ enumerator), 275
esp_spp_cb_event_t (C++ enum), 275
esp_spp_cb_param_t (C++ union), 270
esp_spp_cb_param_t::cl_init (C++ member), 271
esp_spp_cb_param_t::close (C++ member), 271
esp_spp_cb_param_t::cong (C++ member), 271
esp_spp_cb_param_t::data_ind (C++ member), 271
esp_spp_cb_param_t::disc_comp (C++ member), 271
esp_spp_cb_param_t::init (C++ member), 270
esp_spp_cb_param_t::open (C++ member), 271
esp_spp_cb_param_t::spp_cl_init_evt_param (C++ class), 271
esp_spp_cb_param_t::spp_cl_init_evt_param::handle (C++ member), 271
esp_spp_cb_param_t::spp_cl_init_evt_param::sec_id (C++ member), 271
esp_spp_cb_param_t::spp_cl_init_evt_param::status (C++ member), 271
esp_spp_cb_param_t::spp_cl_init_evt_param::use_co (C++ member), 271
esp_spp_cb_param_t::spp_close_evt_param (C++ class), 271
esp_spp_cb_param_t::spp_close_evt_param::async (C++ member), 271
esp_spp_cb_param_t::spp_close_evt_param::handle (C++ member), 271

Submit Document Feedback
Index

esp_spp_mode_t (C++ enum), 275
ESP_SPP_MODE_VFS (C++ enumerator), 275
ESP_SPP_NEED_DEINIT (C++ enumerator), 275
ESP_SPP_NEED_INIT (C++ enumerator), 275
ESP_SPP_NO_CONNECTION (C++ enumerator), 275
ESP_SPP_NO_DATA (C++ enumerator), 275
ESP_SPP_NO_RESOURCE (C++ enumerator), 275
ESP_SPP_NO_SERVER (C++ enumerator), 275
ESP_SPP_OPEN_EVT (C++ enumerator), 276
esp_spp_register_callback (C++ function), 268
ESP_SPP_ROLE_MASTER (C++ enumerator), 275
ESP_SPP_ROLE_SLAVE (C++ enumerator), 275
esp_spp_role_t (C++ enum), 275
ESP_SPP_SEC_AUTHENTICATE (C macro), 274
ESP_SPP_SEC_AUTHORIZE (C macro), 274
ESP_SPP_SEC_ENCRYPT (C macro), 274
ESP_SPP_SEC_IN_16_DIGITS (C macro), 274
ESP_SPP_SEC_MTM (C macro), 274
ESP_SPP_SEC_MODE4_LEVEL4 (C macro), 274
ESP_SPP_SEC_NONE (C macro), 274
esp_spp_sec_t (C++ type), 275
ESP_SPP_SRV_CONF (C++ enumerator), 276
ESP_SPP_SRV_OPEN_EVT (C++ enumerator), 276
ESP_SPP_SRV_STOP_EVT (C++ enumerator), 276
esp_spp_start_discovery (C++ function), 269
ESP_SPP_START_EVT (C++ enumerator), 276
esp_spp_start_srv (C++ function), 269
esp_spp_status_t (C++ enum), 275
esp_spp_stop_srv (C++ function), 270
esp_spp_stop_srv_scn (C++ function), 270
ESP_SPP_SUCCESS (C++ enum), 275
ESP_SPP_UNINIT_EVT (C++ enumerator), 275
esp_spp_vfs_register (C++ function), 270
esp_spp_write (C++ function), 270
ESP_SPP_WRITE_EVT (C++ enumerator), 276
esp_supp_dpp_bootstrap_gen (C++ function), 600
esp_supp_dpp_bootstrap_t (C++ type), 601
ESP_SUPP_DPP_CFG_RECVD (C++ enum), 601
esp_supp_dpp_deinit (C++ function), 600
esp_supp_dpp_eventCb_t (C++ type), 601
esp_supp_dpp_event_t (C++ enum), 601
ESP_SUPP_DPP_FAIL (C++ enum), 601
esp_supp_dpp_init (C++ function), 600
esp_supp_dpp_start_listen (C++ function), 600
esp_supp_dpp_stop_listen (C++ function), 601
ESP_SUPP_DPP_URI_READY (C++ enum), 601
esp_system_abort (C++ function), 1423
esp_sysview_flush (C++ function), 1202
esp_sysview_heap_trace_alloc (C++ function), 1202
esp_sysview_heap_trace_free (C++ function), 1202
esp_sysview_heap_trace_start (C++ function), 1202
esp_sysview_heap_trace_stop (C++ function), 1202
esp_sysview_vprintf (C++ function), 1202
estask_wdt_add (C++ function), 1459
estask_wdt_deinit (C++ function), 1459
estask_wdt_delete (C++ function), 1459
estask_wdt_init (C++ function), 1458
estask_wdt_reset (C++ function), 1459
estask_wdt_status (C++ function), 1460
estimer_cb_t (C++ type), 1400
timer_create (C++ function), 1397
timer_create_argst (C++ class), 1400
timer_create_ags_t::arg (C++ member), 1400
timer_create_ags_t::callback (C++ member), 1400
timer_create_ags_t::dispatch_method (C++ member), 1400
timer_create_ags_t::name (C++ member), 1400
timer_create_ags_t::skip_unhandled_events (C++ member), 1400
timer_deinit (C++ function), 1397
timer_delete (C++ function), 1398
timer_dispatch_t (C++ enum), 1400
timer_dump (C++ function), 1399
timer_early_init (C++ function), 1397
timer_get_expiry_time (C++ function), 1399
timer_get_next_alarm (C++ function), 1398
timer_get_next_alarm_for_wake_up (C++ function), 1399
timer_get_period (C++ function), 1399
timer_get_time (C++ function), 1398
timer_handle_t (C++ type), 1400
timer_init (C++ function), 1397
timer_is_active (C++ function), 1400
ESP_TIMER_MAX (C++ enumerator), 1400
timer_start_once (C++ function), 1398
timer_start_periodic (C++ function), 1398
timer_stop (C++ function), 1398
ESP_TIMER_TASK (C++ enumerator), 1400
tls (C++ class), 933
tls::cacert (C++ member), 933
tls::cacert_ptr (C++ member), 933
tls::clientcert (C++ member), 933
tls::clientkey (C++ member), 933
tls::conf (C++ member), 933
tls::conn_state (C++ member), 933
tls::entropy (C++ member), 933
tls::error_handle (C++ member), 934
tls::is_tls (C++ member), 934
tls::read (C++ member), 933
Index

esp_tls::role (C++ member), 934
esp_tls::rset (C++ member), 934
esp_tls::server_fd (C++ member), 933
esp_tls::sockfd (C++ member), 933
esp_tls::ssl (C++ member), 933
esp_tls::write (C++ member), 933
esp_tls::wset (C++ member), 934
esp_tls_cfg (C++ class), 931
esp_tls_cfg::alpn_protos (C++ member), 931
esp_tls_cfg::cacert_bytes (C++ member), 932
esp_tls_cfg::cacert_pem_buf (C++ member), 932
esp_tls_cfg::cacert_pem_bytes (C++ member), 932
esp_tls_cfg::clientcert_buf (C++ member), 932
esp_tls_cfg::clientcert_bytes (C++ member), 932
esp_tls_cfg::clientcert_pem_buf (C++ member), 932
esp_tls_cfg::clientcert_pem_bytes (C++ member), 932
esp_tls_cfg::clientkey_buf (C++ member), 932
esp_tls_cfg::clientkey_bytes (C++ member), 932
esp_tls_cfg::clientkey_password (C++ member), 932
esp_tls_cfg::clientkey_password_len (C++ member), 932
esp_tls_cfg::clientkey_pem_buf (C++ member), 932
esp_tls_cfg::clientkey_pem_bytes (C++ member), 932
esp_tls_cfg::common_name (C++ member), 932
esp_tls_cfg::crt_bundle_attach (C++ member), 933
esp_tls_cfg::ds_data (C++ member), 933
esp_tls_cfg::if_name (C++ member), 933
esp_tls_cfg::is_plain_tcp (C++ member), 933
esp_tls_cfg::keep_alive_cfg (C++ member), 933
esp_tls_cfg::non_block (C++ member), 932
esp_tls_cfg::psk_hint_key (C++ member), 933
esp_tls_cfg::skip_common_name (C++ member), 932
esp_tls_cfg::timeout_ms (C++ member), 932
esp_tls_cfg::use_global_ca_store (C++ member), 932
esp_tls_cfg::use_secure_element (C++ member), 932
esp_tls_cfg_t (C++ type), 934
ESP_TLS_CLIENT (C++ enumerator), 935
esp_tls_conn_delete (C++ function), 929
esp_tls_conn_destroy (C++ function), 929
esp_tls_conn_http_new (C++ function), 927
esp_tls_conn_http_new_async (C++ function), 928
esp_tls_conn_new (C++ function), 927
esp_tls_conn_new_async (C++ function), 928
esp_tls_conn_new_sync (C++ function), 927
esp_tls_conn_read (C++ function), 928
esp_tls_conn_state (C++ enum), 934
esp_tls_conn_state_t (C++ type), 934
esp_tls_conn_write (C++ function), 928
ESP_TLS.CONNECTING (C++ enumerator), 934
ESP_TLS_DONE (C++ enumerator), 934
ESP_TLS_FAIL (C++ enumerator), 934
esp_tls_free_global_ca_store (C++ function), 930
esp_tls_get_and_clear_error_type (C++ function), 930
esp_tls_get_and_clear_last_error (C++ function), 930
esp_tls_get_bytes_avail (C++ function), 929
esp_tls_get_conn_sockfd (C++ function), 929
esp_tls_get_global_ca_store (C++ function), 930
ESP_TLS.HANDSHAKE (C++ enumerator), 934
ESP_TLS.INIT (C++ enumerator), 934
esp_tls_init (C++ function), 927
esp_tls_init_global_ca_store (C++ function), 929
esp_tls_plain_tcp_connect (C++ function), 930
esp_tls_role (C++ enum), 935
esp_tls_role_t (C++ type), 934
ESP_TLS.SERVER (C++ enumerator), 935
esp_tls_set_global_ca_store (C++ function), 929
esp_tls_t (C++ type), 934
esp_unregister_shutdown_handler (C++ function), 1423
ESP_UUID_LEN_128 (C macro), 134
ESP_UUID_LEN_16 (C macro), 133
ESP_UUID_LEN_32 (C macro), 134
esp_vendor_ie_cb_t (C++ type), 536
esp_vfs_close (C++ function), 1181
esp_vfs_dev_uart_port_set_rx_line_endings (C++ function), 1188
esp_vfs_dev_uart_port_set_tx_line_endings (C++ function), 1188
esp_vfs_dev_uart_register (C++ function), 1187
esp_vfs_dev_uart_set_rx_line_endings (C++ function), 1187
esp_vfs_dev_uart_set_tx_line_endings (C++ function), 1188
esp_vfs_dev_uart_use_driver (C++ function), 1188

Espressif Systems  2263  Release v5.0-dev-1077-g397639d
Submit Document Feedback
<table>
<thead>
<tr>
<th>Function/Method</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_vfs_dev_uart_use_nonblocking (C++ function)</td>
<td>1188</td>
</tr>
<tr>
<td>ESP_VFS_EVENTD_CONFIG_DEFAULT (C macro)</td>
<td>1189</td>
</tr>
<tr>
<td>esp_vfs_eventfd_config_t (C++ class)</td>
<td>1189</td>
</tr>
<tr>
<td>esp_vfs_eventfd_config_t::max_fds (C++ function)</td>
<td>1189</td>
</tr>
<tr>
<td>esp_vfs_eventfd_register (C++ function)</td>
<td>1189</td>
</tr>
<tr>
<td>esp_vfs_eventfd_unregister (C++ function)</td>
<td>1189</td>
</tr>
<tr>
<td>esp_vfs_fat_mount_config_t (C++ class)</td>
<td>1106, 1191</td>
</tr>
<tr>
<td>esp_vfs_fat_mount_config_t::allocation (C++ member)</td>
<td>1106, 1191</td>
</tr>
<tr>
<td>esp_vfs_fat_mount_config_t::format_if_mount_failed (C++ member)</td>
<td>1176</td>
</tr>
<tr>
<td>esp_vfs_fat_register (C++ function)</td>
<td>1106</td>
</tr>
<tr>
<td>esp_vfs_fat_rawflash_mount (C++ function)</td>
<td>1106</td>
</tr>
<tr>
<td>esp_vfs_fat_rawflash_unmount (C++ function)</td>
<td>1107</td>
</tr>
<tr>
<td>esp_vfs_fat_register (C++ function)</td>
<td>1104</td>
</tr>
<tr>
<td>esp_vfs_fat_sdcard_unmount (C++ function)</td>
<td>1106</td>
</tr>
<tr>
<td>esp_vfs_fat_sdmmc_mount (C++ function)</td>
<td>1104</td>
</tr>
<tr>
<td>esp_vfs_fat_sdsdi_mount (C++ function)</td>
<td>1105</td>
</tr>
<tr>
<td>esp_vfs_fat_spiflash_mount (C++ function)</td>
<td>1190</td>
</tr>
<tr>
<td>esp_vfs_fat_spiflash_unmount (C++ function)</td>
<td>1191</td>
</tr>
<tr>
<td>esp_vfs_fat_unregister_path (C++ function)</td>
<td>1104</td>
</tr>
<tr>
<td>ESP_VFS_FLAG_CONTEXT_PTR (C macro)</td>
<td>1187</td>
</tr>
<tr>
<td>ESP_VFS_FLAG_DEFAULT (C macro)</td>
<td>1187</td>
</tr>
<tr>
<td>esp_vfs_fstat (C++ function)</td>
<td>1181</td>
</tr>
<tr>
<td>esp_vfs_id_t (C++ type)</td>
<td>1187</td>
</tr>
<tr>
<td>esp_vfs_link (C++ function)</td>
<td>1181</td>
</tr>
<tr>
<td>esp_vfs_lseek (C++ function)</td>
<td>1180</td>
</tr>
<tr>
<td>esp_vfs_open (C++ function)</td>
<td>1181</td>
</tr>
<tr>
<td>ESP_VFS_PATH_MAX (C macro)</td>
<td>1187</td>
</tr>
<tr>
<td>esp_vfs_pread (C++ function)</td>
<td>1183</td>
</tr>
<tr>
<td>esp_vfs_pwrite (C++ function)</td>
<td>1183</td>
</tr>
<tr>
<td>esp_vfs_read (C++ function)</td>
<td>1180</td>
</tr>
<tr>
<td>esp_vfs_register (C++ function)</td>
<td>1181</td>
</tr>
<tr>
<td>esp_vfs_register_fd (C++ function)</td>
<td>1182</td>
</tr>
<tr>
<td>esp_vfs_register_fd_range (C++ function)</td>
<td>1181</td>
</tr>
<tr>
<td>esp_vfs_register_fd_with_local_fd (C++ function)</td>
<td>1182</td>
</tr>
<tr>
<td>esp_vfs_register_with_id (C++ function)</td>
<td>1181</td>
</tr>
<tr>
<td>esp_vfs_rename (C++ function)</td>
<td>1181</td>
</tr>
<tr>
<td>esp_vfs_select (C++ function)</td>
<td>1182</td>
</tr>
<tr>
<td>esp_vfs_select_sem_t (C++ class)</td>
<td>1183</td>
</tr>
<tr>
<td>esp_vfs_select_sem_t::is_sem_local (C++ member)</td>
<td>1183</td>
</tr>
<tr>
<td>esp_vfs_select_sem_t::sem (C++ member)</td>
<td>1183</td>
</tr>
<tr>
<td>esp_vfs_select_triggered (C++ function)</td>
<td>1182</td>
</tr>
<tr>
<td>esp_vfs_select_triggered_isr (C++ function)</td>
<td>1183</td>
</tr>
<tr>
<td>esp_vfs_spiffs_conf_t (C++ class)</td>
<td>1176</td>
</tr>
<tr>
<td>esp_vfs_spiffs_conf_t::base_path (C++ member)</td>
<td>1176</td>
</tr>
<tr>
<td>esp_vfs_spiffs_conf_t::format_if_mount_failed (C++ member)</td>
<td>1176</td>
</tr>
<tr>
<td>esp_vfs_spiffs_register (C++ function)</td>
<td>1175</td>
</tr>
<tr>
<td>esp_vfs_spiffs_unregister (C++ function)</td>
<td>1175</td>
</tr>
<tr>
<td>esp_vfs_stat (C++ function)</td>
<td>1181</td>
</tr>
<tr>
<td>esp_vfs_t (C++ class)</td>
<td>1183</td>
</tr>
<tr>
<td>esp_vfs_t::access (C++ member)</td>
<td>1186</td>
</tr>
<tr>
<td>esp_vfs_t::access_p (C++ member)</td>
<td>1186</td>
</tr>
<tr>
<td>esp_vfs_t::close (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::close_p (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::closedir (C++ member)</td>
<td>1185</td>
</tr>
<tr>
<td>esp_vfs_t::closedir_p (C++ member)</td>
<td>1185</td>
</tr>
<tr>
<td>esp_vfs_t::end_select (C++ member)</td>
<td>1187</td>
</tr>
<tr>
<td>esp_vfs_t::fcntl1 (C++ member)</td>
<td>1185</td>
</tr>
<tr>
<td>esp_vfs_t::fcntl1_p (C++ member)</td>
<td>1185</td>
</tr>
<tr>
<td>esp_vfs_t::flags (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::fstat (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::fstat_p (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::fsync (C++ member)</td>
<td>1186</td>
</tr>
<tr>
<td>esp_vfs_t::fsync_p (C++ member)</td>
<td>1186</td>
</tr>
<tr>
<td>esp_vfs_t::get_socket_select_semaphore (C++ member)</td>
<td>1187</td>
</tr>
<tr>
<td>esp_vfs_t::ioctl (C++ member)</td>
<td>1185</td>
</tr>
<tr>
<td>esp_vfs_t::ioctl_p (C++ member)</td>
<td>1185</td>
</tr>
<tr>
<td>esp_vfs_t::link (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::link_p (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::lseek (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::lseek_p (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::mkdir (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::mkdir_p (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::open (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::open_p (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::opendir (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::opendir_p (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::pread (C++ member)</td>
<td>1185</td>
</tr>
<tr>
<td>esp_vfs_t::pread_p (C++ member)</td>
<td>1185</td>
</tr>
<tr>
<td>esp_vfs_t::pwrite (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::pwrite_p (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::read (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::read_p (C++ member)</td>
<td>1184</td>
</tr>
<tr>
<td>esp_vfs_t::readdir (C++ member)</td>
<td>1185</td>
</tr>
<tr>
<td>Function/Member</td>
<td>Line Number</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>esp_vhci_host_callback::notify_host_recv</td>
<td>126</td>
</tr>
<tr>
<td>esp_vhci_host_callback</td>
<td>127</td>
</tr>
<tr>
<td>esp_vhci_host_check_send_available</td>
<td>130</td>
</tr>
<tr>
<td>esp_vhci_host_register_callback</td>
<td>130</td>
</tr>
<tr>
<td>esp_vhci_host_send_packet</td>
<td>130</td>
</tr>
<tr>
<td>esp_vhci_connect_device</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_close</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_close_with_code</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::buffer_size</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::cert_len</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::cert_pem</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::client_cert</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::client_cert_len</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::client_key</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::client_key_len</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::disable_auto_reconnect</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::disable_pingpong_dial</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::headers</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::host</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::if_name</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::keep_alive_count</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::keep_alive_enable</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::keep_alive_idle</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::keep_alive_interval</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::password</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::path</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::ping_interval</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::pingpong_timeout</td>
<td>130</td>
</tr>
<tr>
<td>esp_websocket_client_config_t::port</td>
<td>130</td>
</tr>
</tbody>
</table>
Index

```
esp_websocket_client_config_t::skip_cert_common_name_check
(C++ member), 1054  
esp_websocket_transport_t
(C++ member), 1054  
esp_websocket_client_config_t::subprotocol
(C++ member), 1053  
esp_websocket_event_id_t
(C++ member), 1053  
esp_websocket_client_config_t::task_prio
(C++ member), 1053  
esp_websocket_client_config_t::task_stack
(C++ member), 1053  
esp_websocket_client_config_t::transport
(C++ member), 1053  
esp_websocket_client_config_t::uri
(C++ member), 1052  
esp_websocket_client_config_t::use_global_ca_store
(C++ member), 1053  
esp_websocket_client_config_t::user_agent
(C++ member), 1053  
esp_websocket_client_config_t::user_context
(C++ member), 1053  
esp_websocket_client_config_t::username
(C++ member), 1053  
esp_websocket_client_delete (C++ function), 1050  
esp_websocket_client_handle_t (C++ member), 1054  
esp_websocket_client_init (C++ function), 1050  
esp_websocket_client_is_connected (C++ function), 1052  
esp_websocket_client_send_bin (C++ function), 1051  
esp_websocket_client_send_text (C++ function), 1051  
esp_websocket_client_set_uri (C++ function), 1050  
esp_websocket_client_start (C++ function), 1050  
esp_websocket_client_stop (C++ function), 1050  
esp_websocket_event_data_t (C++ class), 1052  
esp_websocket_event_data_t::client
(C++ member), 1052  
esp_websocket_event_data_t::data_len
(C++ member), 1052  
esp_websocket_event_data_t::data_ptr
(C++ member), 1052  
esp_websocket_event_data_t::op_code
(C++ member), 1052  
esp_websocket_event_data_t::payload_len
(C++ member), 1052  
esp_websocket_event_data_t::payload_offset
(C++ member), 1052  
esp_websocket_event_data_t::user_context
(C++ member), 1052  
esp_websocket_event_id_t (C++ enum), 1054  
esp_websocket_register_events (C++ function), 1052  
esp_websocket_transport_t (C++ enum),
```
Index

esp_wifi_scan_get_ap_records (C++ function), 522
esp_wifi_scan_start (C++ function), 522
esp_wifi_scan_stop (C++ function), 522
es Wilpi_set_ant (C++ function), 530
es Wilpi_set_ant_gpio (C++ function), 530
es Wilpi_set_bandwidth (C++ function), 524
es Wilpi_set_channel (C++ function), 524
es Wilpi_set_config (C++ function), 527
es Wilpi_set_connectionless_wake_intr (C++ function), 533
es Wilpi_set_country (C++ function), 524
es Wilpi_set_country_code (C++ function), 533
es Wilpi_set_csi (C++ function), 530
es Wilpi_set_csi_config (C++ function), 530
es Wilpi_set_csi_rx_cb (C++ function), 530
es Wilpi_set_default_wifi_ap_handlers (C++ function), 648
es Wilpi_set_default_wifi_sta_handlers (C++ function), 648
es Wilpi_set_event_mask (C++ function), 529
es Wilpi_set_inactive_time (C++ function), 531
es Wilpi_set_mac (C++ function), 525
es Wilpi_set_max_tx_power (C++ function), 528
es Wilpi_set_mode (C++ function), 520
es Wilpi_set_promiscuous (C++ function), 526
es Wilpi_set_promiscuous_ctrl_filter (C++ function), 526
es Wilpi_set_promiscuous_filter (C++ function), 526
es Wilpi_set_promiscuous_rx_cb (C++ function), 526
es Wilpi_set_protocol (C++ function), 523
es Wilpi_set_ps (C++ function), 523
es Wilpi_set_rssi_threshold (C++ function), 531
es Wilpi_set_storage (C++ function), 528
es Wilpi_set_vendor_ie (C++ function), 528
es Wilpi_set_vendor_ie_cb (C++ function), 528
es Wilpi_sta_get_ap_info (C++ function), 533
es Wilpi_start (C++ function), 520
es Wilpi_stats_dump (C++ function), 531
essl_clear_intr (C++ function), 504
essl_get_intr (C++ function), 504
essl_get_intr_ena (C++ function), 504
essl_get_packet (C++ function), 503
essl_get_rx_data_size (C++ function), 502
essl_get_tx_buffer_num (C++ function), 502
essl_handle_t (C++ type), 505
essl_init (C++ function), 502
essl_read_reg (C++ function), 503
Index

eth_event_t (C++ enum), 617
eth_mac_clock_config_t (C++ union), 617
eth_mac_clock_config_t::clock_gpio
(C++ member), 618
eth_mac_clock_config_t::clock_mode
(C++ member), 617
eth_mac_clock_config_t::mii (C++ member), 617
eth_mac_clock_config_t::rmii (C++ member), 618
eth_mac_config_t (C++ class), 621
eth_mac_config_t::clock_config (C++
member), 621
eth_mac_config_t::flags (C++ member), 621
eth_mac_config_t::interface (C++ member),
621
eth_mac_config_t::rx_task_prio (C++
member), 621
eth_mac_config_t::rx_task_stack_size
(C++ member), 621
eth_mac_config_t::smi_mdc_gpio_num
(C++ member), 621
eth_mac_config_t::smi_mdio_gpio_num
(C++ member), 621
eth_mac_config_t::sw_reset_timeout_ms
(C++ member), 621
ETH_MAC_DEFAULT_CONFIG (C macro), 622
ETH_MAC_FLAG_PIN_TO_CORE (C macro), 621
ETH_MAC_FLAG_WORK_WITH_CACHE_DISABLE
(C macro), 621
eophy_autoneg_cmd_t (C++ enum), 626
eophy_config_t (C++ class), 626
eophy_config_t::autonego_timeout_ms
(C++ member), 626
eophy_config_t::phy_addr (C++ member),
626
eophy_config_t::reset_gpio_num (C++
member), 626
eophy_config_t::reset_timeout_ms
(C++ member), 626
ETH_PHY_DEFAULT_CONFIG (C macro), 626
ETH_STATE_DEFINIT (C++ enumerator), 617
ETH_STATE_DUPLEX (C++ enumerator), 617
ETH_STATE_LINK (C++ enumerator), 617
ETH_STATE_LLINIT (C++ enumerator), 617
ETH_STATE_PAUSE (C++ enumerator), 617
ETH_STATE_SPEED (C++ enumerator), 617
ETHERNET_EVENT_CONNECTED (C++ enumer-
ator), 617
ETHERNET_EVENT_DISCONNECTED (C++ enumer-
ator), 617
ETHERNET_EVENT_START (C++ enumer-
ator), 617
ETHERNET_EVENT_STOP (C++ enumer-
ator), 617
ETS_INTERNAL_INTR_SOURCE_OFF (C
macro), 1414
ETS_INTERNAL_PROFILING_INTR_SOURCE
(C macro), 1414
ETS_INTERNAL_SW0_INTR_SOURCE (C macro),
1414
ETS_INTERNAL_SW1_INTR_SOURCE (C macro),
1414
ETS_INTERNAL_TIMER0_INTR_SOURCE (C
macro), 1414
ETS_INTERNAL_TIMER1_INTR_SOURCE (C
macro), 1414
ETS_INTERNAL_TIMER2_INTR_SOURCE (C
macro), 1414
EventBits_t (C++ type), 1340
eventfd (C++ function), 1189
EventGroupHandle_t (C++ type), 1340

F

FAST_PROV_ACT_ENTER (C++ enumerator), 356
FAST_PROV_ACT_EXIT (C++ enumerator), 356
FAST_PROV_ACT_MAX (C++ enumerator), 356
FAST_PROV_ACT_NONE (C++ enumerator), 356
FAST_PROV_ACT_SUSPEND (C++ enumerator), 356
ff_diskio_impl_t (C++ class), 1107
ff_diskio_impl_t::init (C++ member), 1107
ff_diskio_impl_t::ioctl (C++ member),
1107
ff_diskio_impl_t::read (C++ member), 1107
ff_diskio_impl_t::status (C++ member),
1107
ff_diskio_impl_t::write (C++ member),
1107
ff_diskio_register (C++ function), 1107
ff_diskio_register_raw_partition (C++
function), 1108
ff_diskio_register_sdmmc (C++ function),
1107
ff_diskio_register_wl_partition (C++
function), 1108
filter_cb_t (C++ type), 868
FTM_STATUS_CONF_REJECTED (C++ enumer-
ator), 558
FTM_STATUS_FAIL (C++ enumerator), 558
FTM_STATUS_NO_RESPONSE (C++ enumer-
ator), 558
FTM_STATUS_SUCCESS (C++ enumerator), 558
FTM_STATUS_UNSUPPORTED (C++ enumer-
ator), 558

G
gpio_config (C++ function), 676
gpio_config_t (C++ class), 682
gpio_config_t::intr_type (C++ member),
682
gpio_config_t::mode (C++ member), 682
gpio_config_t::pin_bit_mask (C++ mem-
ber), 682
gpio_config_t::pull_down_en (C++ mem-
ber), 682
 gpio_config_t::pull_up_en (C++ member),
682
 Espressif Systems 2268 Release v5.0-dev-1077-g397639d
Submit Document Feedback
Espressif Systems

Submit Document Feedback
Index

GPIO_PIN_REG_32 (C macro), 685
GPIO_PIN_REG_33 (C macro), 685
GPIO_PIN_REG_34 (C macro), 685
GPIO_PIN_REG_35 (C macro), 685
GPIO_PIN_REG_36 (C macro), 685
GPIO_PIN_REG_37 (C macro), 685
GPIO_PIN_REG_38 (C macro), 685
GPIO_PIN_REG_39 (C macro), 685
GPIO_PIN_REG_4 (C macro), 684
GPIO_PIN_REG_40 (C macro), 685
GPIO_PIN_REG_41 (C macro), 685
GPIO_PIN_REG_42 (C macro), 685
GPIO_PIN_REG_43 (C macro), 685
GPIO_PIN_REG_44 (C macro), 685
GPIO_PIN_REG_45 (C macro), 685
GPIO_PIN_REG_46 (C macro), 685
GPIO_PIN_REG_5 (C macro), 684
GPIO_PIN_REG_6 (C macro), 684
GPIO_PIN_REG_7 (C macro), 684
GPIO_PIN_REG_8 (C macro), 684
GPIO_PIN_REG_9 (C macro), 684
gpio_port_0 (C++ enumerator), 686
gpio_port_max (C++ enumerator), 686
gpio_pull_mode_t (C++ enum), 686
gpio_pulldown_dis (C++ function), 688
gpio_pulldown_disable (C++ enumerator), 688
gpio_pulldown_en (C++ function), 689
gpio_pulldown_enable (C++ enumerator), 688
gpio_pulldown_only (C++ enumerator), 688
gpio_pulldown_t (C++ enum), 688
gpio_pullup_dis (C++ function), 679
gpio_pullup_disable (C++ enumerator), 688
gpio_pullup_en (C++ function), 678
gpio_pullup_enable (C++ enumerator), 688
gpio_pullup_pulldown (C++ enumerator), 688
gpio_pullup_t (C++ enum), 688
gpio_reset_pin (C++ function), 676
GPIO_SEL_0 (C macro), 682
GPIO_SEL_1 (C macro), 683
GPIO_SEL_10 (C macro), 683
GPIO_SEL_11 (C macro), 683
GPIO_SEL_12 (C macro), 683
GPIO_SEL_13 (C macro), 683
GPIO_SEL_14 (C macro), 683
GPIO_SEL_15 (C macro), 683
GPIO_SEL_16 (C macro), 683
GPIO_SEL_17 (C macro), 683
GPIO_SEL_18 (C macro), 683
GPIO_SEL_19 (C macro), 683
GPIO_SEL_2 (C macro), 683
GPIO_SEL_20 (C macro), 683
GPIO_SEL_21 (C macro), 683
GPIO_SEL_22 (C macro), 683
GPIO_SEL_23 (C macro), 683
GPIO_SEL_24 (C macro), 683
GPIO_SEL_25 (C macro), 683
GPIO_SEL_26 (C macro), 684
GPIO_SEL_27 (C macro), 684
GPIO_SEL_28 (C macro), 684
GPIO_SEL_29 (C macro), 684
GPIO_SEL_3 (C macro), 683
GPIO_SEL_30 (C macro), 684
GPIO_SEL_31 (C macro), 684
GPIO_SEL_32 (C macro), 684
GPIO_SEL_33 (C macro), 684
GPIO_SEL_34 (C macro), 684
GPIO_SEL_35 (C macro), 684
GPIO_SEL_36 (C macro), 684
GPIO_SEL_37 (C macro), 684
GPIO_SEL_38 (C macro), 684
GPIO_SEL_39 (C macro), 684
GPIO_SEL_4 (C macro), 683
GPIO_SEL_5 (C macro), 683
GPIO_SEL_6 (C macro), 683
GPIO_SEL_7 (C macro), 683
GPIO_SEL_8 (C macro), 683
GPIO_SEL_9 (C macro), 683
gpio_set_direction (C++ function), 677
gpio_set_drive_capability (C++ function), 680
gpio_set_intr_type (C++ function), 676
gpio_set_level (C++ function), 677
gpio_set_pull_mode (C++ function), 678
gpio_sleep_sel_dis (C++ function), 681
gpio_sleep_sel_en (C++ function), 681
gpio_sleep_set_direction (C++ function), 681
gpio_sleep_set_pull_mode (C++ function), 682
gpio_uninstall_isr_service (C++ function), 679
gpio_wakeup_disable (C++ function), 678
gpio_wakeup_enable (C++ function), 678
gptimer_alarm_cb_t (C++ type), 700
gptimer_alarm_config_t (C++ class), 700
gptimer_alarm_config_t::alarm_count (C++ member), 700
gptimer_alarm_config_t::auto_reload_on_alarm (C++ member), 700
gptimer_alarm_config_t::reload_count (C++ member), 700
gptimer_alarm_event_data_t (C++ class), 699
gptimer_alarm_event_data_t::alarm_value (C++ member), 700
gptimer_alarm_event_data_t::count_value (C++ member), 700
GPTIMER_CLK_SRC_APB (C++ enumerator), 701
gptimer_clock_source_t (C++ enum), 701
gptimer_config_t (C++ class), 700
gptimer_config_t::clk_src (C++ member), 700

Espressif Systems 2270 Release v5.0-dev-1077-g397639d
Submit Document Feedback
heap_caps_get_minimum_free_size (C++ function), 1376
heap_caps_init (C++ function), 1380
heap_caps_malloc (C++ function), 1375
heap_caps_malloc_extmem_enable (C++ function), 1378
heap_caps_malloc_prefer (C++ function), 1378
heap_caps_print_heap_info (C++ function), 1377
heap_caps_realloc (C++ function), 1375
heap_caps_realloc_prefer (C++ function), 1378
heap_caps_register_failed_alloc_callback (C++ function), 1375
HEAP_TRACE_ALL (C++ enumerator), 1395
heap_trace_dump (C++ function), 1394
heap_trace_get (C++ function), 1394
heap_trace_get_count (C++ function), 1394
heap_trace_init_standalone (C++ function), 1393
heap_trace_init_tohost (C++ function), 1393
HEAP_TRACE_LEAKS (C++ enumerator), 1395
heap_trace_mode_t (C++ enum), 1395
heap_trace_record_t (C++ class), 1394
heap_trace_record_t::address (C++ member), 1394
heap_trace_record_t::allocated_by (C++ member), 1394
heap_trace_record_t::ccount (C++ member), 1394
heap_trace_record_t::freed_by (C++ member), 1394
heap_trace_record_t::size (C++ member), 1394
heap_trace_resume (C++ function), 1394
heap_trace_start (C++ function), 1393
heap_trace_stop (C++ function), 1393
HOST_CONNECTION_MODE_CLI_UART (C++ enumerator), 630
HOST_CONNECTION_MODE_NONE (C++ enumerator), 630
HTTP_CONNECTION_MODE_RCP_UART (C++ enumerator), 630
HTTP_AUTH_TYPE_BASIC (C++ enumerator), 974
HTTP_AUTH_TYPE_DIGEST (C++ enumerator), 974
HTTP_AUTH_TYPE_NONE (C++ enumerator), 974
http_client_init_cb_t (C++ type), 1232
HTTP_EVENT_DISCONNECTED (C++ enumerator), 973
HTTP_EVENT_ERROR (C++ enumerator), 973
http_event_handle_cb (C++ type), 973
HTTP_EVENT_HEADER_SENT (C++ enumerator), 973
HTTP_EVENT_HEADERS_SENT (C++ enumerator), 973
HTTP_EVENT_ON_CONNECTED (C++ enumerator), 973

Hall_sensor_read (C++ function), 662
heap_caps_add_region (C++ function), 1380
heap_caps_add_region_with_caps (C++ function), 1381
heap_caps_aligned_alloc (C++ function), 1376
heap_caps_aligned_alloc (C++ function), 1376
heap_caps_aligned_free (C++ function), 1376
heap_caps_calloc (C++ function), 1376
heap_caps_calloc_prefer (C++ function), 1378
heap_caps_check_integrity (C++ function), 1377
heap_caps_check_integrity_address (C++ function), 1377
heap_caps_check_integrity_all (C++ function), 1377
heap_caps_dump (C++ function), 1378
heap_caps_dump_all (C++ function), 1379
heap_caps_enable_nonos_stack_heaps (C++ function), 1380
heap_caps_free (C++ function), 1375
heap_caps_get_allocated_size (C++ function), 1379
heap_caps_get_free_size (C++ function), 1376
heap_caps_get_info (C++ function), 1377
heap_caps_get_largest_free_block (C++ function), 1377
heap_caps_get_minimum_free_size (C++ function), 1377

http_event_handleCb_t::on_alarm (C++ function), 89
http_event_handleCb_t::on_error (C++ function), 89

G

gptimer_config_t::direction (C++ member), 700
gptimer_config_t::intr_shared (C++ member), 700
gptimer_config_t::resolution_hz (C++ member), 700
gptimer_count_direction_t (C++ enum), 701
GPTIMER_COUNT_DOWN (C++ enumerator), 701
GPTIMER_COUNT_UP (C++ enumerator), 701

gptimer_del_timer (C++ function), 698

gptimer_event_callbacks_t (C++ class), 700

gptimer_event_callbacks_t::on_alarm (C++ member), 700
gptimer_get_raw_count (C++ function), 698

gptimer_handle_t (C++ type), 700

gptimer_new_timer (C++ function), 698

GPTIMER_SET_RAW_COUNT (C++ function), 699

GPTIMER_SET_ALARM_ACTION (C++ function), 699

GPTIMER_SET_RAW_COUNT (C++ function), 699
gptimer_start (C++ function), 699
gptimer_stop (C++ function), 699

H

http_client_init (C++ function), 1380
heap_caps_free_size (C++ function), 1376
heap_caps_get_total_size (C++ function), 1376
heap_caps_init (C++ function), 1380
heap_caps_malloc (C++ function), 1375
heap_caps_malloc_extmem_enable (C++ function), 1378
heap_caps_malloc_prefer (C++ function), 1378
heap_caps_print_heap_info (C++ function), 1377
heap_caps_realloc (C++ function), 1375
heap_caps_realloc_prefer (C++ function), 1378
heap_caps_register_failed_alloc_callback (C++ function), 1375
HEAP_TRACE_ALL (C++ enumerator), 1395
heap_trace_dump (C++ function), 1394
heap_trace_get (C++ function), 1394
heap_trace_get_count (C++ function), 1394
heap_trace_init_standalone (C++ function), 1393
heap_trace_init_tohost (C++ function), 1393
HEAP_TRACE_LEAKS (C++ enumerator), 1395
heap_trace_mode_t (C++ enum), 1395
heap_trace_record_t (C++ class), 1394
heap_trace_record_t::address (C++ member), 1394
heap_trace_record_t::allocated_by (C++ member), 1394
heap_trace_record_t::ccount (C++ member), 1394
heap_trace_record_t::freed_by (C++ member), 1394
heap_trace_record_t::size (C++ member), 1394
heap_trace_resume (C++ function), 1394
heap_trace_start (C++ function), 1393
heap_trace_stop (C++ function), 1393
HOST_CONNECTION_MODE_CLI_UART (C++ enumerator), 630
HOST_CONNECTION_MODE_NONE (C++ enumerator), 630
HTTP_CONNECTION_MODE_RCP_UART (C++ enumerator), 630
HTTP_AUTH_TYPE_BASIC (C++ enumerator), 974
HTTP_AUTH_TYPE_DIGEST (C++ enumerator), 974
HTTP_AUTH_TYPE_NONE (C++ enumerator), 974
http_client_init_cb_t (C++ type), 1232
HTTP_EVENT_DISCONNECTED (C++ enumerator), 973
HTTP_EVENT_ERROR (C++ enumerator), 973
http_event_handle_cb (C++ type), 973
HTTP_EVENT_HEADER_SENT (C++ enumerator), 973
HTTP_EVENT_HEADERS_SENT (C++ enumerator), 973
HTTP_EVENT_ON_CONNECTED (C++ enumerator), 973
HTTP_EVENT_ON_DATA (C++ enumerator), 973
HTTP_EVENT_ON_FINISH (C++ enumerator), 973
HTTP_EVENT_ON_HEADER (C++ enumerator), 973
HTTP_METHOD_COPY (C++ enumerator), 974
HTTP_METHOD_DELETE (C++ enumerator), 974
HTTP_METHOD_GET (C++ enumerator), 974
HTTP_METHOD_HEAD (C++ enumerator), 974
HTTP_METHOD_LOCK (C++ enumerator), 974
HTTP_METHOD_MAX (C++ enumerator), 974
HTTP_METHOD_MKCOL (C++ enumerator), 974
HTTP_METHOD_MOVE (C++ enumerator), 974
HTTP_METHOD_NOTIFY (C++ enumerator), 974
HTTP_METHOD_OPTIONS (C++ enumerator), 974
HTTP_METHOD_PATCH (C++ enumerator), 974
HTTP_METHOD_POST (C++ enumerator), 974
HTTP_METHOD_PROPFIND (C++ enumerator), 974
HTTP_METHOD_PROPPATCH (C++ enumerator), 974
HTTP_METHOD_PUT (C++ enumerator), 974
HTTP_METHOD_SUBSCRIBE (C++ enumerator), 974
HTTP_METHOD_UNLOCK (C++ enumerator), 974
HTTP_METHOD_UNSUBSCRIBE (C++ enumerator), 974
HTTP_TRANSPORT_OVER_SSL (C++ enumerator), 973
HTTP_TRANSPORT_OVER_TCP (C++ enumerator), 973
HTTPD_200 (C macro), 993
HTTPD_204 (C macro), 993
HTTPD_207 (C macro), 993
HTTPD_400 (C macro), 993
HTTPD_400_BAD_REQUEST (C++ enumerator), 997
HTTPD_401_UNAUTHORIZED (C++ enumerator), 997
HTTPD_403_FORBIDDEN (C++ enumerator), 997
HTTPD_404 (C macro), 993
HTTPD_404_NOT_FOUND (C++ enumerator), 997
HTTPD_405_METHOD_NOT_ALLOWED (C++ enumerator), 997
HTTPD_408 (C macro), 994
HTTPD_408_REQ_TIMEOUT (C++ enumerator), 997
HTTPD_411_LENGTH_REQUIRED (C++ enumerator), 997
HTTPD_414_URI_TOO_LONG (C++ enumerator), 997
HTTPD_431_REQ_HDR_FIELDS_TOO_LARGE (C++ enumerator), 997
HTTPD_500 (C macro), 994
HTTPD_500_INTERNAL_SERVER_ERROR (C++ enumerator), 997
HTTPD_501_METHOD_NOT_IMPLEMENTED (C++ enumerator), 997
HTTPD_505_VERSION_NOT_SUPPORTED (C++ enumerator), 997
httpd_close_func_t (C++ type), 996
httpd_config (C++ class), 991
httpd_config::backlog_conn (C++ member), 991
httpd_config::close_fn (C++ member), 992
httpd_config::core_id (C++ member), 991
httpd_config::ctrl_port (C++ member), 991
httpd_config::global_transport_ctx (C++ member), 991
httpd_config::global_transport_ctx_free_fn (C++ member), 991
httpd_config::global_user_ctx (C++ member), 991
httpd_config::global_user_ctx_free_fn (C++ member), 991
httpd_config::lru_purge_enable (C++ member), 991
httpd_config::max_open_sockets (C++ member), 991
httpd_config::max_resp_headers (C++ member), 991
httpd_config::max_uri_handlers (C++ member), 991
httpd_config::open_fn (C++ member), 991
httpd_config::recv_wait_timeout (C++ member), 991
httpd_config::send_wait_timeout (C++ member), 991
httpd_config::server_port (C++ member), 991
httpd_config::stack_size (C++ member), 991
httpd_config::task_priority (C++ member), 991
httpd_config::uri_match_fn (C++ member), 992
httpd_config_t (C++ type), 996
HTTPD_DEFAULT_CONFIG (C macro), 994
HTTPD_ERR_CODE_MAX (C++ enumerator), 997
httpd_err_code_t (C++ enum), 996
httpd_err_handler_func_t (C++ type), 995
httpd_free_ctx_fn_t (C++ type), 996
httpd_get_client_list (C++ function), 990
httpd_get_global_transport_ctx (C++ function), 990
httpd_get_user_ctx_t (C++ function), 998
httpd_handle_t (C++ type), 996
HTTPD_MAX_REQ_HDR_LEN (C macro), 993
HTTPD_MAX_URI_LEN (C macro), 993
httpd_method_t (C++ type), 996
httpd_open_func_t (C++ type), 996
httpd_pending_func_t (C++ type), 995
httpd_query_key_value (C++ function), 982
httpd_query_value (C++ function), 988
httpd_recv_func_t (C++ type), 995
httpd_register_err_handler (C++ function), 987
httpd_register_uri_handler (C++ function), 978
LEDCC_TIMER_3 (C++ enumerator), 754
LEDCC_TIMER_3_BIT (C++ enumerator), 754
LEDCC_TIMER_4_BIT (C++ enumerator), 754
LEDCC_TIMER_5_BIT (C++ enumerator), 754
LEDCC_TIMER_6_BIT (C++ enumerator), 754
LEDCC_TIMER_7_BIT (C++ enumerator), 754
LEDCC_TIMER_8_BIT (C++ enumerator), 754
LEDCC_TIMER_9_BIT (C++ enumerator), 755
LEDCC_TIMER_BIT_MAX (C++ enumerator), 755
ledc_timer_bit_t (C++ enum), 754
ledc_timer_config (C++ function), 744
ledc_timer_config_t (C++ class), 751
ledc_timer_config_t::bit_num (C++ member), 751
ledc_timer_config_t::clk_cfg (C++ member), 751
ledc_timer_config_t::duty_resolution (C++ member), 751
ledc_timer_config_t::freq_hz (C++ member), 751
ledc_timer_config_t::speed_mode (C++ member), 751
ledc_timer_config_t::timer_num (C++ member), 751
LEDCC_TIMER_MAX (C++ enumerator), 754
ledc_timer_pause (C++ function), 747
ledc_timer_resume (C++ function), 748
ledc_timer_rst (C++ function), 747
ledc_timer_set (C++ function), 747
ledc_timer_t (C++ enum), 754
ledc_update_duty (C++ function), 744
LEDCC_USE_APB_CLK (C++ enumerator), 753
LEDCC_USE_REF_TICK (C++ enumerator), 753
LEDCC_USE_RTC32M_CLK (C++ enumerator), 753
linenoiseCompletions (C++ type), 1210
M
M_BGE (C macro), 2026
M.BL (C macro), 2026
M.BX (C macro), 2026
M.BXF (C macro), 2026
M.BXZ (C macro), 2026
M_LABEL (C macro), 2026
MALLOC_CAP_32BIT (C macro), 1379
MALLOC_CAP_8BIT (C macro), 1379
MALLOC_CAP_DEFAULT (C macro), 1379
MALLOC_CAP_DMA (C macro), 1379
MALLOC_CAP_EXEC (C macro), 1379
MALLOC_CAP_INTERNAL (C macro), 1379
MALLOC_CAP_INVALID (C macro), 1380
MALLOC_CAP_IRAM_8BIT (C macro), 1379
MALLOC_CAP_PTD2 (C macro), 1379
MALLOC_CAP_PTD3 (C macro), 1379
MALLOC_CAP_PTD4 (C macro), 1379
MALLOC_CAP_PTD5 (C macro), 1379
MALLOC_CAP_PTD6 (C macro), 1379
MALLOC_CAP_PTD7 (C macro), 1379
MALLOC_CAP_RETENTION (C macro), 1379
MALLOC_CAP_RTCRAM (C macro), 1380
MALLOC_CAP_SPIRAM (C macro), 1379
MAX_BLE_DEVNAMBLN (C macro), 1082
MAX_BLE_MANUFACTURER_DATA_LEN (C macro), 1082
MAX_FDS (C macro), 1187
MAX_PASSPHRASE_LEN (C macro), 550
MAX_SSID_LEN (C macro), 550
MAX_WPS_AP_CRED (C macro), 550
mb_communication_info_t (C++ union), 1038
mb_communication_info_t::baudrate (C++ member), 1039
mb_communication_info_t::dummy_port (C++ member), 1039
mb_communication_info_t::ip_addr (C++ member), 1039
mb_communication_info_t::ip_addr_type (C++ member), 1039
mb_communication_info_t::ip_mode (C++ member), 1039
mb_communication_info_t::ip_netif_ptr (C++ member), 1039
mb_communication_info_t::ip_port (C++ member), 1039
mb_communication_info_t::mode (C++ member), 1039
mb_communication_info_t::parity (C++ member), 1039
mb_communication_info_t::port (C++ member), 1039
mb_communication_info_t::slave_addr (C++ member), 1039
mb_communication_info_t::[anonymous] (C++ member), 1039
MB_CONTROLLER_PRIORITY (C macro), 1039
MB_CONTROLLER_STACK_SIZE (C macro), 1039
mb_descr_size_t (C++ enum), 1045
mb_descr_type_t (C++ enum), 1045
MB_DEVICE_ADDRESS (C macro), 1039
MB_DEVICE_SPEED (C macro), 1039
MB_EVENT_COILS_RD (C++ enumerator), 1040
MB_EVENT_COILS_WR (C++ enumerator), 1040
MB_EVENT_DISCRETE_RD (C++ enumerator), 1040
mb_event_group_t (C++ enum), 1040
MB_EVENT_HOLDING_REG_RD (C++ enumerator), 1040
MB_EVENT_HOLDING_REG_WR (C++ enumerator), 1040
MB_EVENT_INPUT_REG_RD (C++ enumerator), 1040
MB_EVENT_NO_EVENTS (C++ enumerator), 1040
MB_EVENT_STACK_STARTED (C++ enumerator), 1040
MB_IPV4 (C++ enumerator), 1041
MB_IPV6 (C++ enumerator), 1041
MB_MODE_ASCII (C++ enumerator), 1041
MB_MODE_RTU (C++ enumerator), 1041
MB_MODE_TCP (C++ enumerator), 1041
Index

mb_mode_type_t (C++ enum), 1041
MB_MODE_UDP (C++ enumerator), 1041
MB_FAN_INFO_TOUT (C macro), 1039
MB_PARAM_COIL (C++ enumerator), 1041
MB_PARAM_COUNT (C++ enumerator), 1041
MB_PARAM_DISCRETE (C++ enumerator), 1041
MB_PARAM_HOLDING (C++ enumerator), 1040
mb_parameter_info_t::param_units (C++ member), 1047
mb_parameter_info_t::param_type (C++ member), 1044
mb_parameter_info_t::param_size (C++ member), 1044
mb_parameter_info_t::param_opts (C++ member), 1044
mb_parameter_info_t::param_offset (C++ class), 1047
mb_parameter_info_t::address (C++ member), 1047
mb_parameter_info_t::mb_offset (C++ member), 1047
mb_parameter_info_t::size (C++ member), 1047
mb_parameter_info_t::time_stamp (C++ member), 1047
mb_parameter_info_t::type (C++ member), 1047
MB_PARAM_INPUT (C++ enumerator), 1041
mb_param_perms_t (C++ enumerator), 1045
mb_param_request_t (C++ class), 1045
mb_param_request_t::command (C++ member), 1045
mb_param_request_t::reg_size (C++ member), 1045
mb_param_request_t::reg_start (C++ member), 1045
mb_param_request_t::slave_addr (C++ member), 1045
mb_param_type_t (C++ enum), 1040
MB_PARAM_UNKNOWN (C++ enumerator), 1041
mb_parameter_descriptor_t (C++ class), 1044
mb_parameter_descriptor_t::access (C++ member), 1044
mb_parameter_descriptor_t::cid (C++ member), 1044
mb_parameter_descriptor_t::mb_param_type (C++ member), 1044
mb_parameter_descriptor_t::mb_reg_start (C++ member), 1044
mb_parameter_descriptor_t::mb_size (C++ member), 1044
mb_parameter_descriptor_t::mb_slave_addr (C++ member), 1044
mb_parameter_descriptor_t::param_key (C++ member), 1044
mb_parameter_descriptor_t::param_offset (C++ member), 1044
mb_parameter_descriptor_t::param_opts (C++ member), 1044
mb_parameter_descriptor_t::param_size (C++ member), 1044
mb_parameter_descriptor_t::param_type (C++ member), 1044
mb_parameter_descriptor_t::param_units (C++ member), 1044
mb_parameter_opt_t (C++ union), 1043
mb_parameter_opt_t::max (C++ member), 1044
mb_parameter_opt_t::min (C++ member), 1044
mb_parameter_opt_t::opt1 (C++ member), 1044
mb_parameter_opt_t::opt2 (C++ member), 1044
mb_parameter_opt_t::opt3 (C++ member), 1044
mb_parameter_opt_t::step (C++ member), 1044
mb_parameter_opt_t::{anonymous} (C++ member), 1044
MB_PARITY_NONE (C macro), 1039
MB_PORT_COUNT (C++ enumerator), 1040
MB_PORT_INACTIVE (C++ enumerator), 1040
MB_PORT_SERIAL_MASTER (C++ enumerator), 1040
MB_PORT_SERIAL_SLAVE (C++ enumerator), 1040
MB_PORT_TCP_MASTER (C++ enumerator), 1040
MB_PORT_TCP_SLAVE (C++ enumerator), 1040
mb_port_type_t (C++ enum), 1040
mb_register_area_descriptor_t (C++ class), 1047
mb_register_area_descriptor_t::address (C++ member), 1048
mb_register_area_descriptor_t::size (C++ member), 1048
mb_register_area_descriptor_t::start_offset (C++ member), 1048
mb_register_area_descriptor_t::type (C++ member), 1048
mb_tcp_addr_type_t (C++ enum), 1041
MB_UART_PORT (C macro), 1039
mbc_master_destroy (C++ function), 1042
mbc_master_get_cid_info (C++ function), 1042
mbc_master_get_parameter (C++ function), 1043
mbc_master_init (C++ function), 1041
mbc_master_init_iface (C++ function), 1042
mbc_master_init_tcp (C++ function), 1041
mbc_master_set_descriptor (C++ function), 1042
mbc_master_set_parameter (C++ function), 1043
mbc_master_setup (C++ function), 1042
mbc_master_start (C++ function), 1042
mbc_slave_check_event (C++ function), 1047
mbc_slave_destroy (C++ function), 1046
mbc_slave_get_param_info (C++ function), 1047
mbc_slave_init (C++ function), 1046
mbc_slave_init_iface (C++ function), 1046
mbc_slave_init_tcp (C++ function), 1046
mbc_slave_set_descriptor (C++ function), 1047
mbc_slave_setup (C++ function), 1047
mbc_slave_start (C++ function), 1046
MCPWMOA (C++ enumerator), 774
MCPWM0B (C++ enumerator), 774
MCPWM1A (C++ enumerator), 774
MCPWM1B (C++ enumerator), 774
MCPWM2A (C++ enumerator), 774
MCPWM2B (C++ enumerator), 774
MCPWM_ACTION_FORCE_HIGH (C++ enumerator), 779
MCPWM_ACTION_FORCE_LOW (C++ enumerator), 779
MCPWM_ACTION_NO_CHANGE (C++ enumerator), 778
mc pwm_action_on_pwmxa_t (C++ type), 774
mc pwm_action_on_pwmxb_t (C++ type), 774
MCPWM_ACTION_TOGGLE (C++ enumerator), 779
MCPWM_ACTIVE_HIGH_COMPLEMENT_MODE (C++ enumerator), 778
MCPWM_ACTIVE_HIGH_MODE (C++ enumerator), 778
MCPWM_ACTIVE_LOW_COMPLEMENT_MODE (C++ enumerator), 778
MCPWM_ACTIVE_LOW_MODE (C++ enumerator), 778
MCPWM_ACTIVE_RED_FED_FROM_PWMXA (C++ enumerator), 778
MCPWM_ACTIVE_RED_FED_FROM_PWMXB (C++ enumerator), 778
MCPWM_BOTH_EDGE (C++ enumerator), 777
MCPWM_BYPASS_FED (C++ enumerator), 778
MCPWM_BYPASS_RED (C++ enumerator), 778
MCPWM_CAP_0 (C++ enumerator), 775
MCPWM_CAP_1 (C++ enumerator), 775
MCPWM_CAP_2 (C++ enumerator), 775
mc pwm_capture_config_t (C++ class), 774
mc pwm_capture_config_t::cap_edge (C++ member), 773
mc pwm_capture_config_t::cap_prescale (C++ member), 773
mc pwm_capture_config_t::capture_cb (C++ member), 773
mc pwm_capture_config_t::user_data (C++ member), 773
mc pwm_capture_disable (C++ function), 769
mc pwm_capture_disable_channel (C++ function), 769
mc pwm_capture_enable (C++ function), 769
mc pwm_capture_enable_channel (C++ function), 769
mc pwm_capture_on_edge_t (C++ enum), 777
mc pwm_capture_signal_get_edge (C++ function), 770
mc pwm_capture_signal_get_value (C++ function), 769
mc pwm_capture_t (C++ enum), 779
mc pwm_carrier_config_t (C++ class), 772
mc pwm_carrier_config_t::carrier_duty (C++ member), 773
mc pwm_carrier_config_t::carrier_ivt_mode (C++ member), 773
mc pwm_carrier_config_t::carrier_os_mode (C++ member), 773
mc pwm_carrier_config_t::carrier_period (C++ member), 773
mc pwm_carrier_config_t::pulse_width_in_os (C++ member), 773
mc pwm_carrier_disable (C++ function), 766
mc pwm_carrier_enable (C++ function), 766
mc pwm_carrier_init (C++ function), 766
mc pwm_carrier_oneshot_mode_disable (C++ function), 767
mc pwm_carrier_oneshot_mode_enable (C++ function), 767
mc pwm_carrier_os_t (C++ enum), 776
MCPWM_CARRIER_OUT_IVT_DIS (C++ enumerator), 776
MCPWM_CARRIER_OUT_IVT_EN (C++ enumerator), 776
mc pwm_carrier_out_ivt_t (C++ enum), 776
mc pwm_carrier_output_invert (C++ function), 767
mc pwm_carrier_set_duty_cycle (C++ function), 767
mc pwm_carrier_set_period (C++ function), 766
mc pwm_config_t (C++ class), 772
mc pwm_config_t::cmpr_a (C++ member), 772
mc pwm_config_t::cmpr_b (C++ member), 772
mc pwm_config_t::counter_mode (C++ member), 772
mc pwm_config_t::duty_mode (C++ member), 772
mc pwm_config_t::frequency (C++ member), 772
MCPWM_COUN TER_MAX (C++ enumerator), 777
mc pwm_counter_type_t (C++ enum), 777
MCPWM_DEADTIME_BYPASS (C++ enumerator), 778
mc pwm_deadtime_disable (C++ function), 768
mc pwm_deadtime_enable (C++ function), 767
MCPWM_DEADTIME_TYPE_MAX (C++ enumerator), 778
mc pwm_deadtime_type_t (C++ enum), 778
MCPWM_DOWN_COUNTER (C++ enumerator), 777
MCPWM_DUTY_MODE_0 (C++ enumerator), 778
MCPWM_DUTY_MODE_1 (C++ enumerator), 778
MCPWM_DUTY_MODE_MAX (C++ enumerator), 778
mc pwm_duty_type_t (C++ enum), 777
MCPWM_FAULT_0 (C++ enumerator), 775
MCPWM_FAULT_1 (C++ enumerator), 775
MCPWM_FAULT_2 (C++ enumerator), 775
mc pwm_fault_deinit (C++ function), 768
mc pwm_fault_input_level_t (C++ enum), 777
mc pwm_fault_set_cyc_mode (C++ function), 768
mcpwm_fault_set_oneshot_mode (C++ function), 768
mcpwm_fault_signal_t (C++ enum), 776
MCPWM_FORCE_MCPWMXA_HIGH (C macro), 774
MCPWM_FORCE_MCPWMXA_LOW (C macro), 774
MCPWM_FORCE_MCPWMXB_HIGH (C macro), 774
MCPWM_FORCE_MCPWMXB_LOW (C macro), 774
MCPWM_FREEZE_COUNTER (C++ enumerator), 777
MCPWM_GEN_A (C++ enumerator), 775
MCPWM_GEN_ACTION_HIGH (C++ enumerator), 762
MCPWM_GEN_ACTION_KEEP (C++ enumerator), 762
MCPWM_GEN_ACTION_LOW (C++ enumerator), 762
MCPWM_GEN_ACTION_TOGGLE (C++ enumerator), 763
MCPWM_HAL_GENERATOR_MODE_FORCE_HIGH (C++ enumerator), 778
MCPWM_HAL_GENERATOR_MODE_FORCE_LOW (C++ enumerator), 778
MCPWM_HIGH_LEVEL_TGR (C++ enumerator), 777
mcpwm_init (C++ function), 763
mcpwm_intr_t (C++ enum), 777
mcpwm_io_signals_t (C++ enum), 774
mcpwm_isr_register (C++ function), 771
MCPWM_LL_INTR_CAP0 (C++ enumerator), 777
MCPWM_LL_INTR_CAP1 (C++ enumerator), 777
MCPWM_LL_INTR_CAP2 (C++ enumerator), 777
MCPWM_LOW_LEVEL_TGR (C++ enumerator), 777
MCPWM_NEG_EDGE (C++ enumerator), 777
MCPWM_NO_CHANGE_IN_MCPWMXA (C macro), 774
MCPWM_NO_CHANGE_IN_MCPWMXB (C macro), 774
MCPWM_ONESHOT_MODE_DIS (C++ enumerator), 776
MCPWM_ONESHOT_MODE_EN (C++ enumerator), 776
mcpwm_operator_t (C++ type), 774
MCPWM_OPR_A (C macro), 773
MCPWM_OPR_B (C macro), 773
MCPWM_OPR_MAX (C macro), 773
mcpwm_output_action_t (C++ enum), 778
mcpwm_pin_config_t (C++ class), 771
mcpwm_pin_config_t::mcpwm0a_out_num (C++ member), 771
mcpwm_pin_config_t::mcpwm0b_out_num (C++ member), 771
mcpwm_pin_config_t::mcpwm2a_out_num (C++ member), 772
mcpwm_pin_config_t::mcpwm2b_out_num (C++ member), 772
mcpwm_pin_config_t::mcpwm_cap0_in_num (C++ member), 772
mcpwm_pin_config_t::mcpwm_cap1_in_num (C++ member), 772
mcpwm_pin_config_t::mcpwm_cap2_in_num (C++ member), 772
mcpwm_pin_config_t::mcpwm_capfault0_in_num (C++ member), 772
mcpwm_pin_config_t::mcpwm_capfault1_in_num (C++ member), 772
mcpwm_pin_config_t::mcpwm_fault2_in_num (C++ member), 772
mcpwm_pin_config_t::mcpwm_fault2_in_num (C++ member), 772
mcpwm_pin_config_t::mcpwm_fault3_in_num (C++ member), 772
mcpwm_pin_config_t::mcpwm_sync0_in_num (C++ member), 772
mcpwm_pin_config_t::mcpwm_sync1_in_num (C++ member), 772
mcpwm_pin_config_t::mcpwm_sync2_in_num (C++ member), 772
MCPWM_POS_EDGE (C++ enumerator), 777
MCPWM_SELECT_F0 (C++ enumerator), 773
MCPWM_SELECT_F1 (C++ enumerator), 773
MCPWM_SELECT_F2 (C++ enumerator), 773
MCPWM_SELECT_GPIO_SYNC0 (C++ enumerator), 776
MCPWM_SELECT_GPIO_SYNC1 (C++ enumerator), 776
MCPWM_SELECT_GPIO_SYNC2 (C++ enumerator), 776
MCPWM_SELECT_GPIO_SYNC3 (C++ enumerator), 776
MCPWM_SELECT_TIMER0_SYNC (C++ enumerator), 776
MCPWM_SELECT_TIMER1_SYNC (C++ enumerator), 776
MCPWM_SELECT_TIMER2_SYNC (C++ enumerator), 776
mcpwm_set_duty (C++ function), 764
mcpwm_set_duty_in_us (C++ function), 764
mcpwm_set_frequency (C++ function), 764
mcpwm_set_input (C++ function), 763
mcpwm_set_signal_high (C++ function), 765
mcpwm_set_signal_low (C++ function), 765
mcpwm_set_timer_sync_output (C++ function), 770
mcpwm_start (C++ function), 766
mcpwm_stop (C++ function), 766
MCPWM_SWSYNC_SOURCE_DISABLED (C++ enumerator), 777
MCPWM_SWSYNC_SOURCE_SYNCIN (C++ enumerator), 776
MCPWM_SWSYNC_SOURCE_TEP (C++ enumerator), 777
MCPWM_SWSYNC_SOURCE_TEZ (C++ enumerator), 777
MCPWM_SYNC_0 (C++ enumerator), 775
MCPWM_SYNC_1 (C++ enumerator), 775
MCPWM_SYNC_2 (C++ enumerator), 775
mcpwm_sync_config_t (C++ class), 773
mcpwm_sync_config_t::count_direction (C++ member), 773
mcpwm_sync_config_t::timer_val (C++ member), 773
mcpwm_sync_config (C++ function), 770
mcpwm_sync_disable (C++ function), 770
mcpwm_sync_enable (C++ function), 770
mcpwm_sync_invert_gpio_synchronizer (C++ function), 771
mcpwm_sync_signal_t (C++ enum), 776
MCPWM_TIMER_0 (C++ enumerator), 775
MCPWM_TIMER_1 (C++ enumerator), 775
MCPWM_TIMER_2 (C++ enumerator), 775
MCPWM_TIMER_COUNT_MODE_DOWN (C++ enumerator), 762
MCPWM_TIMER_COUNT_MODE_PAUSE (C++ enumerator), 762
mcpwm_timer_count_mode_t (C++ enum), 762
MCPWM_TIMER_COUNT_MODE_UP_DOWN (C++ enumerator), 762
MCPWM_TIMER_COUNT_MODE_UP (C++ enumerator), 762
MCPWM_TIMER_EVENT_PEAK (C++ enumerator), 762
mcpwm_timer_event_t (C++ enum), 762
MCPWM_TIMER_EVENT_ZERO (C++ enumerator), 762
mcpwm_timer_execute_cmd_t (C++ enum), 762
MCPWM_TIMER_MAX (C++ enumerator), 775
mcpwm_timer_set_resolution (C++ function), 764
MCPWM_TIMER_START_NO_STOP (C++ enumerator), 762
MCPWM_TIMER_START_STOP_AT_PEAK (C++ enumerator), 762
MCPWM_TIMER_START_STOP_AT_ZERO (C++ enumerator), 762
MCPWM_TIMER_STOP_AT_PEAK (C++ enumerator), 762
mcpwm_timer_stop_at_zero (C++ function), 771
mcpwm_timer_stop_at_peak (C++ function), 771
mcpwm_timer_trigger_soft_sync (C++ function), 771
MCPWM_TIMER_RESET (C++ enumerator), 771
MCPWM_TIMER_RESET (C++ enum), 771
MCPWM_TIMER_SYNC_TRIGGER_T (C++ enum), 771
MCPWM_TIMER_SYNC_TRIGGER_T (C++ function), 771
MCPWM_TIMER_SYNC_TRIGGER_T (C++ macro), 771
MCPWM_TIMER_SYNC_TRIGGER_T (C macro), 771
MCPWM_TIMER_SYNC_TRIGGER_T (C macro), 771
MCPWM_TIMER_STOP_AT_ZERO (C++ enum), 775
mcpwm_timer_stop_at_zero (C++ function), 771
mcpwm_timer_stop_at_peak (C++ function), 771
MCPWM_TIMER_START_NO_STOP (C++ enum), 775
mcpwm_timer_start_stop_at_zero (C++ function), 771
mcpwm_timer_start_stop_at_peak (C++ function), 771
MCPWM_TIMER_START_STOP_AT_ZERO (C++ enum), 775
MCPWM_UNIT_0 (C++ enum), 775
MCPWM_UNIT_1 (C++ enum), 775
MCPWM_UNIT_MAX (C++ enum), 775
mcpwm_unit_t (C++ enum), 775
MCPWM_UP_COUNTER (C++ enum), 775
MCPWM_UP_DOWN_COUNTER (C++ enum), 775
MCPWM_UP_DOWN_COUNTER (C++ function), 775
dns_delegate_hostname_add (C++ function), 1015
dns_delegate_hostname_remove (C++ function), 1016
dns_free (C++ function), 1015
dns_handle_system_event (C++ function), 1024
mdns_hostname_exists (C++ function), 1016
mdns_hostname_set (C++ function), 1015
MDNS_IF_AP (C++ enum), 1026
MDNS_IF_ETH (C++ enum), 1026
mdns_if_internal (C++ function), 1026
MDNS_IF_MAX (C++ enum), 1026
MDNS_IF_STA (C++ enum), 1026
dns_if_t (C++ type), 1025
mdns_init (C++ function), 1015
mdns_instance_name_set (C++ function), 1016
mdns_ip_addr_s (C++ class), 1024
mdns_ip_addr_s::addr (C++ member), 1024
mdns_ip_addr_s::next (C++ member), 1024
mdns_ip_addr_t (C++ type), 1025
MDNS_IP_PROTOCOL_MAX (C++ enum), 1026
mdns_ip_protocol_t (C++ enum), 1026
MDNS_IP_PROTOCOL_V4 (C++ enum), 1026
MDNS_IP_PROTOCOL_V6 (C++ enum), 1026
mdns_query (C++ function), 1022
mdns_query_a (C++ function), 1023
mdns_query_aaaa (C++ function), 1024
mdns_query_async_delete (C++ function), 1022
mdns_query_async_get_results (C++ function), 1022
mdns_query_async_new (C++ function), 1022
mdns_query_notify_t (C++ type), 1025
mdns_query_ptr (C++ function), 1023
mdns_query_results_free (C++ function), 1023
mdns_query_srv (C++ function), 1023
mdns_query_txt (C++ function), 1023
mdns_result_s (C++ class), 1024
mdns_result_s::addr (C++ member), 1025
mdns_result_s::hostname (C++ member), 1025
mdns_result_s::instance_name (C++ member), 1025
mdns_result_s::ip_protocol (C++ member), 1025
mdns_result_s::next (C++ member), 1024
mdns_result_s::port (C++ member), 1025
mdns_result_s::proto (C++ member), 1025
mdns_result_s::service_type (C++ member), 1025
mdns_result_s::tcpip_if (C++ member), 1024
mdns_result_s::ttl (C++ member), 1025
mdns_result_s::txt (C++ member), 1025
mdns_result_s::txt_count (C++ member), 1025
mdns_result_s::txt_value_len (C++ member), 1025
mdns_result_t (C++ type), 1025
mdns_search_once_t (C++ type), 1025
mdns_service_add (C++ function), 1016
mdns_service_add_for_host (C++ function), 1016
mdns_service_add_for_host (C++ function), 1017
mdns_service_exists (C++ function), 1017
mdns_service_exists_with_instance (C++ function), 1017
mdns_service_instance_name_set (C++ function), 1018
mdns_service_instance_name_set_for_host (C++ function), 1018
mdns_service_port_set (C++ function), 1018
mdns_service_port_set_for_host (C++ function), 1018
mdns_service_remove (C++ function), 1017
mdns_service_remove_all (C++ function), 1022
mdns_service_remove_for_host (C++ function), 1017
mdns_service_subtype_add_for_host (C++ function), 1021
mdns_service_txt_item_remove (C++ function), 1021
mdns_service_txt_item_remove_for_host (C++ function), 1021
mdns_service_txt_item_set (C++ function), 1019
mdns_service_txt_item_set_for_host (C++ function), 1020
mdns_service_txt_item_set_for_host_with_explicit_value_len (C++ function), 1020
mdns_service_txt_item_set_with_explicit_value_len (C++ function), 1019
mdns_service_set (C++ function), 1019
mdns_service_set_for_host (C++ function), 1019
mdns_txt_item_t (C++ class), 1024
mdns_txt_item_t::key (C++ member), 1024
mdns_txt_item_t::value (C++ member), 1024
MDNS_TYPE_A (C macro), 1024
MDNS_TYPE_AAAA (C macro), 1025
MDNS_TYPE_ANY (C macro), 1025
MDNS_TYPE_NSEC (C macro), 1025
MDNS_TYPE_OPT (C macro), 1025
MDNS_TYPE_PTR (C macro), 1025
MDNS_TYPE_SRV (C macro), 1025
MDNS_TYPE_TXT (C macro), 1025
mesh_addr_t (C++ union), 587
mesh_addr_t::addr (C++ member), 587
mesh_addr_t::mip (C++ member), 587
mesh_ap_cfg_t (C++ class), 592
mesh_ap_cfg_t::max_connection (C++ member), 592
mesh_ap_cfg_t::nonmesh_max_connection (C++ member), 592
mesh_ap_cfg_t::password (C++ member), 592
MESH_ASSOC_FLAG_NETWORK_FREE (C macro), 595
MESH_ASSOC_FLAG_ROOT FIXED (C macro), 595
MESH_ASSOC_FLAG_ROOTS FOUND (C macro), 595
MESH_ASSOC_FLAG_VOTE_IN_PROGRESS (C macro), 595
mesh_cfg_t (C++ class), 592
mesh_cfg_t::allow_channel_switch (C++ member), 592
mesh_cfg_t::channel (C++ member), 592
mesh_cfg_t::crypto_funcs (C++ member), 593
mesh_cfg_t::mesh_ap (C++ member), 593
mesh_cfg_t::mesh_id (C++ member), 593
mesh_cfg_t::router (C++ member), 593
MESH_DATA_DROP (C macro), 595
MESH_DATA_ENC (C macro), 595
MESH_DATA_FROMDS (C macro), 595
MESH_DATA_GROUP (C macro), 595
MESH_DATA_NONBLOCK (C macro), 595
MESH_DATA_P2P (C macro), 595
mesh_data_t (C++ class), 591
mesh_data_t::data (C++ member), 592
mesh_data_t::proto (C++ member), 592
mesh_data_t::size (C++ member), 592
mesh_data_t::tos (C++ member), 592
MESH_DATA_TODS (C macro), 595
mesh_disconnect_reason_t (C++ enum), 598
MESH_EVENT_CHANNEL_SWITCH (C++ enumerator), 596
mesh_event_child_connected_t (C++ class), 589
mesh_event_channel_switch_t::channel (C++ member), 589
MESH_EVENT_CHILD_CONNECTED (C++ enumerator), 596
mesh_event_child_connected_t (C++ type), 596
MESH_EVENT_CHILD_DISCONNECTED (C++ enumerator), 596
mesh_event_child_disconnected_t (C++ type), 596
mesh_event_connected_t (C++ class), 589
mesh_event_connected_t::connected (C++ member), 589
mesh_event_connected_t::duty (C++ member), 589
mesh_event_connected_t::self_layer (C++ member), 589
mesh_eventDisconnected_t (C++ type), 596
MESH_EVENT_FIND_NETWORK (C++ enumerator), 597
mesh_event_find_network_t (C++ class), 590
mesh_event_find_network_t::channel (C++ member), 590
mesh_event_find_network_t::router_bssid (C++ member), 590
mesh_event_id_t (C++ union), 596
mesh_event_info_t (C++ union), 588
mesh_event_info_t::channel_switch (C++ member), 588
mesh_event_info_t::child_connected (C++ member), 588
mesh_event_info_t::child_disconnected (C++ member), 588
mesh_event_info_t::connected (C++ member), 588
mesh_event_info_t::disconnected (C++ member), 588
mesh_event_info_t::find_network (C++ member), 588
mesh_event_info_t::layer_change (C++ member), 588
mesh_event_info_t::network_state (C++ member), 588
mesh_event_info_t::no_parent (C++ member), 588
mesh_event_info_t::ps_duty (C++ member), 588
mesh_event_info_t::root_addr (C++ member), 588
mesh_event_info_t::root_conflict (C++ member), 588
mesh_event_info_t::root_fixed (C++ member), 588
mesh_event_info_t::router_switch (C++ member), 588
mesh_event_info_t::routing_table (C++ member), 588
mesh_event_info_t::scan_done (C++ member), 588
mesh_event_info_t::switch_req (C++ member), 588
mesh_event_info_t::toDS_state (C++ member), 588
mesh_event_info_t::vote_started (C++ member), 588
MESH_EVENT_LAYER_CHANGE (C++ enumerator), 597
mesh_event_layer_change_t (C++ class), 589
mesh_event_layer_change_t::new_layer (C++ member), 590
MESH_EVENT_MAX (C++ enumerator), 597
MESH_EVENT_NETWORK_STATE (C++ enumerator), 597
mesh_event_network_state_t (C++ class), 591
mesh_event_network_state_t::is_rootless (C++ member), 591
MESH_EVENT_NO_PARENT_FOUND (C++ enumerator), 596
mesh_event_no_parent_found_t (C++ class), 589
mesh_event_no_parent_found_t::scan_times (C++ member), 589
MESH_EVENT_PARENT_CONNECTED (C++ enumerator), 596
MESH_EVENT_PARENT_DISCONNECTED (C++ enumerator), 596
MESH_EVENT_PS_CHILD_DUTY (C++ enumerator), 597
MESH_EVENT_PS_DEVICE_DUTY (C++ enumerator), 597
mesh_event_ps_duty_t (C++ class), 591
mesh_event_ps_duty_t::child_connected (C++ member), 591
mesh_event_ps_duty_t::duty (C++ member), 591
MESH_EVENT_PS_PARENT_DUTY (C++ enumerator), 597
MESH_EVENT_ROOT_ADDRESS (C++ enumerator), 597
mesh_event_root_address_t (C++ type), 596
MESH_EVENT_ROOT_ASIGNED_YIELD (C++ enumerator), 597
mesh_event_root_asigned_yield_t (C++ class), 590
mesh_event_root_conflict_t (C++ class), 590
mesh_event_root_conflict_t::addr (C++ member), 590
mesh_event_root_conflict_t::capacity (C++ member), 590
mesh_event_root_conflict_t::rc_addr (C++ member), 590
mesh_event_root_conflict_t::rssl (C++ member), 590
MESH_EVENT_ROOT_FIXED (C++ enumerator), 597
mesh_event_root_fixed_t::is_fixed (C++ member), 591
MESH_EVENT_ROOT_SWITCH_ACK (C++ enumerator), 597
MESH_EVENT_ROOT_SWITCH_REQ (C++ enumerator), 597
mesh_event_root_switch_req_t (C++ class), 590
mesh_event_root_switch_req_t::rc_addr (C++ member), 590
mesh_tx_pending_t::to_child (C++ member), 593
mesh_tx_pending_t::to_child_p2p (C++ member), 593
mesh_tx_pending_t::to_parent (C++ member), 593
mesh_tx_pending_t::to_parent_p2p (C++ member), 593
mesh_type_t (C++ enum), 597
MESH_VOTE_REASON.Child_INITIATED (C++ enumerator), 98
MESH_VOTE_REASON_ROOT_INITIATED (C++ enumerator), 98
multi_heap_free (C++ function), 1392
multi_heap_free_all (C++ function), 1392
multi_heap_free_blocks (C++ member), 1394
multi_heap_free_size (C++ function), 1392
multi_heap_get_allocated (C++ function), 1382
multi_heap_get_allocated_size (C++ function), 1382
multi_heap_get_info (C++ function), 1383
multi_heap_get_handle (C++ member), 1384
multi_heap_get_info (C++ function), 1383
multi_heap_get_info (C++ function), 1384
multi_heap_get_info (C++ member), 1384
multi_heap_get_info (C++ function), 1384
multi_heap_get_info (C++ member), 1384
multi_heap_get_info (C++ function), 1384
multi_heap_get_info (C++ function), 1384
multi_heap_get_info (C++ member), 1384
multi_heap_get_info (C++ member), 1384
multi_heap_get_info (C++ function), 1384
multi_heap_get_info (C++ member), 1384
Mqtt_ERROR_TYPE_CONNECTION_REFUSED (C++ enumerator), 924
MQTT_EVENT_CONNECTED (C++ function), 924
MQTT_PROTOCOL_V_3_1_1 (C++ enumerator), 924
MQTT_PROTOCOL_UNDEFINED (C++ enumerator), 924
MQTT_TRANSPORT_OVER_SSL (C++ enumerator), 924
MQTT_TRANSPORT_OVER_TCP (C++ enumerator), 924
MQTT_TRANSPORT_OVER_WS (C++ enumerator), 924
MQTT_TRANSPORT_OVER_WSS (C++ enumerator), 924
MQTT_TRANSPORT_UNKNOWN (C++ enumerator), 924
N
name_namespace (C++ class), 1082
name_namespace::name (C++ member), 1082
name_namespace::uuid (C++ member), 1082
nvs_close (C++ function), 1127
nvs_commit (C++ function), 1127
NVS_DEFAULT_PART_NAME (C macro), 1131
nvs_entry_find (C++ function), 1129
nvs_entry_find (C++ function), 1129
nvs_entry_find (C++ function), 1129
nvs_entry_find (C++ function), 1129
nvs_entry_find (C++ function), 1129
nvs_entry_find (C++ function), 1129
nvs_entry_find (C++ function), 1129
nvs_entry_find (C++ function), 1129
nvs_entry_find (C++ function), 1129
nvs_entry_find (C++ function), 1129
nvs_entry_find (C++ function), 1129
nvs_entry_find (C++ function), 1129
Index

dv_entry_info_t::type (C++ member), 1130
dv_entry_next (C++ function), 1129
dv_erase_all (C++ function), 1127
dv_erase_key (C++ function), 1127
dv_flash_deinit (C++ function), 1120
dv_flash_deinit_partition (C++ function), 1120
dv_flash_erase (C++ function), 1121
dv_flash_erase_partition (C++ function), 1121

dv_flash_erase_partition_ptr (C++ function), 1121

dv_flash_generate_keys (C++ function), 1122

dv_flash_init (C++ function), 1119

dv_flash_init_partition (C++ function), 1120

dv_flash_init_partition_ptr (C++ function), 1120

dv_flash_read_security_cfg (C++ function), 1122

dv_flash_secure_init (C++ function), 1121

dv_flash_secure_init_partition (C++ function), 1121

dv_get_blob (C++ function), 1125

dv_get_i16 (C++ function), 1124

dv_get_i32 (C++ function), 1124

dv_get_i64 (C++ function), 1125

dv_get_i8 (C++ function), 1124

dv_get_stats (C++ function), 1128

dv_get_str (C++ function), 1125

dv_get_u16 (C++ function), 1124

dv_get_u32 (C++ function), 1125

dv_get_u64 (C++ function), 1125

dv_get_u8 (C++ function), 1124


dv_get_used_entry_count (C++ function), 1128

dv_handler (C++ type), 1131

dv_iterator_t (C++ type), 1131

dv_iterator_t (C++ type), 1131

NVS_KEY_NAME_MAX_SIZE (C macro), 1131

NVS_KEY_SIZE (C macro), 1122

NVS_open (C++ function), 1126

dv_open_from_partition (C++ function), 1126

NVS_open_mode (C++ type), 1131

dv_open_mode_t (C++ enum), 1131

NVS_PART_NAME_MAX_SIZE (C macro), 1131

NVS_RDONLY (C++ enumerator), 1131

NVS_READWRITE (C++ enumerator), 1132

dv_release_iterator (C++ function), 1129

NVS_SEC_CFG_T::tky (C++ member), 1122

NVS_SEC_CFG_T::tky (C++ member), 1122

NVS_set_blob (C++ function), 1126

NVS_set_i16 (C++ function), 1123

NVS_set_i32 (C++ function), 1123

NVS_set_i64 (C++ function), 1123

NVS_set_i8 (C++ function), 1123

NVS_set_str (C++ function), 1123

NVS_set_u16 (C++ function), 1123

NVS_set_u32 (C++ function), 1123

NVS_set_u64 (C++ function), 1123

NVS_set_u8 (C++ function), 1123

NVS_stats_t::free_entries (C++ member), 1130

NVS_stats_t::namespace_count (C++ member), 1130

NVS_stats_t::total_entries (C++ member), 1130

NVS_stats_t::used_entries (C++ member), 1130

NVS_TYPE_ANY (C++ enumerator), 1132

NVS_TYPE_BLOB (C++ enumerator), 1132

NVS_TYPE_I16 (C++ enumerator), 1132

NVS_TYPE_I32 (C++ enumerator), 1132

NVS_TYPE_I64 (C++ enumerator), 1132

NVS_TYPE_I8 (C++ enumerator), 1132

NVS_TYPE_STR (C++ enumerator), 1132

NVS_TYPE_T (C++ enum), 1132

NVS_TYPE_U16 (C++ enum), 1132

NVS_TYPE_U32 (C++ enum), 1132

NVS_TYPE_U64 (C++ enum), 1132

NVS_TYPE_U8 (C++ enum), 1132


O

OPENTHREAD_EVENT_GOT_IP6 (C++ enumerator), 630

OPENTHREAD_EVENT_IF_DOWN (C++ enumerator), 629

OPENTHREAD_EVENT_IF_UP (C++ enumerator), 629

OPENTHREAD_EVENT_LOST_IP6 (C++ enumerator), 630

OPENTHREAD_EVENT_MULTICAST_GROUP_JOIN (C++ enumerator), 630

OPENTHREAD_EVENT_MULTICASTGROUP_LEAVE (C++ enumerator), 630

OPENTHREAD_EVENT_START (C++ enumerator), 629

OPENTHREAD_EVENT_STOP (C++ enumerator), 629

OPENTHREAD_EVENT_TREL_ADD_IP6 (C++ enumerator), 630

OPENTHREAD_EVENT_TREL_MULTICASTGROUP_JOIN (C++ enumerator), 630

OPENTHREAD_EVENT_TREL_REMOVE_IP6 (C++ enumerator), 630

OTA_SIZE_UNKNOWN (C macro), 1436

OTA_WITHSEQUENTIAL_WRITES (C macro), 1436

P

PAR_PERMS_READ (C++ enumerator), 1045

PAR_PERMS_READ_TRIGGER (C++ enumerator), 1046

PAR_PERMS_READ_WRITE (C++ enumerator), 1046
PCNT_UNIT_COUNT_SIGN_ZERO_NEG (C++ enumerator), 788
PCNT_UNIT_COUNT_SIGN_ZERO_POS (C++ enumerator), 788
PCNT_UNIT_MAX (C++ enumerator), 787
pcnt_unit_t (C++ enum), 787
pcQueueGetName (C++ function), 1291
pcTaskGetName (C++ function), 1268
pcTimerGetName (C++ function), 1322
PendedFunction_t (C++ type), 1332
portGET_ARGUMENT_COUNT_INNER (C macro), 1418
PROTOCOMM_SEC0 (C++ enumerator), 1012
PROTOCOMM_SEC1 (C++ enumerator), 1012
PROTOCOMM_SEC_CUSTOM (C++ enumerator), 1012
protocomm_add_endpoint (C++ function), 1076
protocomm_ble_config (C++ class), 1082
protocomm_ble_config::device_name (C++ member), 1082
protocomm_ble_config::manufacturer_data (C++ member), 1082
protocomm_ble_config::manufacturer_data_len (C++ member), 1082
protocomm_ble_config::nu_lookup (C++ member), 1082
protocomm_ble_config::nu_lookup_count (C++ member), 1082
protocomm_ble_config::service_uuid (C++ member), 1082
protocomm_ble_config_t (C++ type), 1082
protocomm_ble_name_uuid_t (C++ type), 1082
protocomm_ble_start (C++ function), 1081
protocomm_close_session (C++ function), 1076
protocomm_delete (C++ function), 1075
protocomm_http_server_config_t (C++ class), 1080
protocomm_httpd_config_data_t (C++ union), 1080
protocomm_httpd_httpd_config_data_t (C++ member), 1080
protocomm_httpd_httpd_config_data_t (C++ member), 1080
protocomm_httpd_httpd_config_data_t (C++ class), 1081
protocomm_httpd_httpd_config_t (C++ member), 1081
protocomm_httpd_httpd_config_t::ext_handle (C++ member), 1081
PROTOCOL_HTTPD_DEFAULT_CONFIG (C macro), 1081
protocomm_httpd_start (C++ function), 1080
protocomm_httpd_stop (C++ function), 1080
protocomm_new (C++ function), 1075
protocomm_open_session (C++ function), 1076
protocomm_remove_endpoint (C++ function), 1076
protocomm_req_handle (C++ function), 1077
protocomm_req_handler_t (C++ type), 1078
protocomm_security (C++ class), 1079
protocomm_security::cleanup (C++ member), 1079
protocomm_security::close_transport_session (C++ member), 1079
protocomm_security::decrypt (C++ member), 1079
protocomm_security::encrypt (C++ member), 1079
protocomm_security::init (C++ member), 1079
protocomm_security::new_transport_session (C++ member), 1079
protocomm_security::security_req_handler (C++ member), 1079
protocomm_security::security_req_handler (C++ member), 1079
protocomm_security::security_req_handler (C++ member), 1079
protocomm_security::ver (C++ member), 1079
protocomm_security_handle_t (C++ type), 1079
protocomm_security_pop (C++ class), 1078
protocomm_security_pop::data (C++ member), 1078
protocomm_security_pop::len (C++ member), 1078
protocomm_security_pop::type (C++ member), 1078
protocomm_set_security (C++ function), 1077
protocomm_set_version (C++ function), 1078
protocomm_set_version (C++ function), 1078
protocomm_unset_security (C++ function), 1077
protocomm_unset_version (C++ function), 1078
PSK_DATA_FLAGS_FLAG (C macro), 342
PSK_DATA_INDEX_FLAG (C macro), 342
PROV_DATA_NET_IDX_FLAG (C macro), 342
PROXY_FILTER_BLACKLIST (C++ enumerator), 356
PROXY_FILTER_WHITELIST (C++ enumerator), 356
psk_hint_key_t (C++ type), 934
psk_key_hint (C++ class), 931
psk_key_hint::hint (C++ member), 931
psk_key_hint::key (C++ member), 931
psk_key_hint::key_size (C++ member), 931
PTHREAD_STACK_MIN (C macro), 1236
pvTaskGetLocalStorageAddress (C++ function), 1269
pvTaskGetThreadLocalStorageAddress (C++ function), 1269
pxTimerGetTimerID (C++ function), 1319
pxTaskGetStackStart (C++ function), 1269
QueueHandle_t (C++ type), 1302
QueueSetHandle_t (C++ type), 1302
QueueSetMemberHandle_t (C++ type), 1302

R0 (C macro), 2024
R1 (C macro), 2024
R2 (C macro), 2024
R3 (C macro), 2024
RADIO_MODE_NATIVE (C++ enumerator), 630
RADIO_MODE_SPI_RCP (C++ enumerator), 630
RADIO_MODE_UART_RCP (C++ enumerator), 630
RINGBUF_TYPE ALLOWSPLIT (C++ enumerator), 1371
RINGBUF_TYPE_BYTEBUF (C++ enumerator), 1371
RINGBUF_TYPE_MAX (C++ enumerator), 1371
RINGBUFFER_TYPE NOSPLIT (C++ enumerator), 1371
RingbufferType_t (C++ enum), 1371
RingbufferHandle_t (C++ type), 1371
RMT_BASECLK_APB (C++ enumerator), 806
RMT_BASECLK_MAX (C++ enumerator), 806
RMT_BASECLK_REF (C++ enumerator), 806
RMT_CARRIER_LEVEL_HIGH (C++ enumerator), 806
RMT_CARRIER_LEVEL_LOW (C++ enumerator), 806
RMT_CARRIER_LEVEL_MAX (C++ enumerator), 806
rmt_carrier_level_t (C++ enum), 806
RMT_CHANNEL_0 (C++ enumerator), 805
RMT_CHANNEL_1 (C++ enumerator), 805
RMT_CHANNEL_2 (C++ enumerator), 805
RMT_CHANNEL_3 (C++ enumerator), 805
RMT_CHANNEL_4 (C++ enumerator), 805
RMT_CHANNEL_5 (C++ enumerator), 805
RMT_CHANNEL_6 (C++ enumerator), 805
RMT_CHANNEL_7 (C++ enumerator), 805
RMT_CHANNEL_BUSY (C++ enumerator), 807
RMT_CHANNEL_FLAGS_AWARE DFS (C macro), 804
RMT_CHANNEL_FLAGS_INVERT_SIG (C macro), 804
RMT_CHANNEL_IDLE (C++ enumerator), 807
RMT_CHANNEL_MAX (C++ enumerator), 805
rmt_channel_status_result_t (C++ class), 805
rmt_channel_status_result_t:::status (C++ member), 805
rmt_channel_status_t (C++ enum), 806
rmt_channel_t (C++ enum), 805
RMT_CHANNEL_UNINIT (C++ enumerator), 806
rmtclr_intr_enable_mask (C++ function), 802
rmt_config (C++ function), 799
rmt_config_t (C++ class), 803
rmt_config_t::channel (C++ member), 803
rmt_config_t::clk_div (C++ member), 803
rmt_config_t::flags (C++ member), 804
rmt_config_t::gpio_num (C++ member), 803
rmt_config_t::mem_block_num (C++ member), 803
rmt_config_t::rmt_mode (C++ member), 803
rmt_config_t::rx_config (C++ member), 804
rmt_config_t::tx_config (C++ member), 804
RMT_DATA_MODE_FIFO (C++ enumerator), 806
RMT_DATA_MODE_MAX (C++ enumerator), 806
RMT_DATA_MODE_MEM (C++ enumerator), 806
rmt_data_mode_t (C++ enum), 806
RMT_DEFAULT_CONFIG_RX (C macro), 804
RMT_DEFAULT_CONFIG_TX (C macro), 804
rmt_driver_install (C++ function), 799
rmt_driver_uninstall (C++ function), 800
rmt_fill_tx_items (C++ function), 799
rmt_get_channel_status (C++ function), 800
rmt_get_clk_div (C++ function), 793
rmt_get_counter_clock (C++ function), 800
rmt_get_idle_level (C++ function), 797
rmt_get_mem_block_num (C++ function), 794
rmt_get_mem_pd (C++ function), 795
rmt_get_memory_owner (C++ function), 796
rmt_get_ringbuf_handle (C++ function), 801
rmt_getRx_idle_thresh (C++ function), 794
rmt_get_source_clk (C++ function), 797
rmt_get_status (C++ function), 798
rmt_get_tx_loop_mode (C++ function), 796
RMT_IDLE_LEVEL_HIGH (C++ enumerator), 806
RMT_IDLE_LEVEL_LOW (C++ enumerator), 806
RMT_IDLE_LEVEL_MAX (C++ enumerator), 806
rmt_idle_level_t (C++ enum), 806
rmt_isr_deregister (C++ function), 799
rmt_isr_handle_t (C++ type), 804
rmt_isr_register (C++ function), 799
rmt_item32_t (C++ class), 802
rmt_item32_t::duration0 (C++ member), 802
rmt_item32_t::duration1 (C++ member), 802
rmt_item32_t::level0 (C++ member), 802
rmt_item32_t::level1 (C++ member), 802
rmt_item32_t::val (C++ member), 803
RMT_MEM_ITEM_NUM (C macro), 804
RMT_MEM_OWNER_MAX (C++ enumerator), 805
RMT_MEM_OWNER_RX (C++ enumerator), 805
rmt_mem_owner_t (C++ enum), 805
RMT_MEM_OWNER_TX (C++ enumerator), 805
rmt_memory_rw_rst (C++ function), 802
RMT_MEM_MAX (C++ enumerator), 806
RMT_MODE_MAX (C++ enumerator), 806
RMT_MODE_RX (C++ enumerator), 806
rmt_mode_t (C++ enum), 806
RMT_MODE_TX (C++ enumerator), 806
rmt_register_tx_end_callback (C++ function), 802
rmt_rx_config_t (C++ class), 803
rmt_rx_config_t::filter_en (C++ member), 803
rmt_rx_config_t::filter_ticks_thresh (C++ member), 803
rmt_rx_config_t::idle_threshold (C++ member), 803

Espressif Systems 2290 Release v5.0-dev-1077-g397639d
Submit Document Feedback
Index

sdio_slave_config_t (C++ class), 828
sdio_slave_config_t::event_cb (C++ member), 829
sdio_slave_config_t::flags (C++ member), 829
sdio_slave_config_t::recv_buffer_size (C++ member), 828
sdio_slave_config_t::send_queue_size (C++ member), 828
sdio_slave_config_t::sending_mode (C++ member), 828
sdio_slave_config_t::timing (C++ member), 828
sdio_slave_deinit (C++ function), 825
SDIO_SLAVE_FLAG_DAT2_DISABLED (C macro), 829
SDIO_SLAVE_FLAG_HOST_INTR_DISABLED (C macro), 829
SDIO_SLAVE_FLAG_INTERNAL_PULLUP (C macro), 829
sdio_slave_get_host_intena (C++ function), 828
SDIO_SLAVE_HOSTINT.Bit0 (C++ enumerator), 824
SDIO_SLAVE_HOSTINT.Bit1 (C++ enumerator), 824
SDIO_SLAVE_HOSTINT.Bit2 (C++ enumerator), 824
SDIO_SLAVE_HOSTINT.Bit3 (C++ enumerator), 824
SDIO_SLAVE_HOSTINT.Bit4 (C++ enumerator), 824
SDIO_SLAVE_HOSTINT.Bit5 (C++ enumerator), 824
SDIO_SLAVE_HOSTINT.Bit6 (C++ enumerator), 824
SDIO_SLAVE_HOSTINT.Bit7 (C++ enumerator), 824
SDIO_SLAVE_HOSTINT_SEND_NEW_PACKET (C++ enumerator), 824
sdio_slave_hostint_t (C++ enum), 824
sdio_slave_initialize (C++ function), 825
sdio_slave_read_reg (C++ function), 827
sdio_slave_recv (C++ function), 826
sdio_slave_recv_get_buf (C++ function), 827
sdio_slave_recv_load_buf (C++ function), 826
SDIO_SLAVE_RECV_MAX_BUFFER (C macro), 829
sdio_slave_recv_packet (C++ function), 826
sdio_slave_recv_register_buf (C++ function), 826
sdio_slave_recv_unregister_buf (C++ function), 826
sdio_slave_reset (C++ function), 825
sdio_slave_send_get_finished (C++ function), 827
sdio_slave_send_host_int (C++ function), 828
SDIO_SLAVE_SEND_PACKET (C++ enumerator), 825
sdio_slave_send_queue (C++ function), 827
SDIO_SLAVE_SEND_STREAM (C++ enumerator), 825
sdio_slave_sending_mode_t (C++ enum), 825
sdio_slave_set_host_intena (C++ function), 828
sdio_slave_start (C++ function), 825
sdio_slave_stop (C++ function), 825
SDIO_SLAVE_TIMING_NSEND_NSAMPLE (C++ enumerator), 825
SDIO_SLAVE_TIMING_PSEND_NSAMPLE (C++ enumerator), 825
SDIO_SLAVE_TIMING_PSEND_PSAMPLE (C++ enumerator), 825
dsio_slave Timing_t (C++ enum), 825
dsio_slave_transmit (C++ function), 827
sdio_slave_wait_int (C++ function), 828
sdio_slave_write_reg (C++ function), 827
sdmmc_card_init (C++ function), 1141
sdmmc_card_print_info (C++ function), 1141
sdmmc_card_t (C++ class), 1147
sdmmc_card_t::cld (C++ member), 1147
sdmmc_card_t::csl (C++ member), 1147
sdmmc_card_t::ext_csd (C++ member), 1147
sdmmc_card_t::host (C++ member), 1147
sdmmc_card_t::is_ddr (C++ member), 1147
sdmmc_card_t::is_mm (C++ member), 1147
sdmmc_card_t::is_mm (C++ member), 1147
sdmmc_card_t::is_sdio (C++ member), 1147
sdmmc_card_t::log bus_width (C++ member), 1147
sdmmc_card_t::max freq khz (C++ member), 1147
sdmmc_card_t::num io functions (C++ member), 1144
sdmmc_card_t::ocr (C++ member), 1147
sdmmc_card_t::raw_cid (C++ member), 1147
sdmmc_card_t::rca (C++ member), 1147
sdmmc_card_t::reserved (C++ member), 1147
sdmmc_card_t::scr (C++ member), 1147
sdmmc_card_t::ct (C++ class), 1145
sdmmc_card_t::date (C++ member), 1145
sdmmc_card_t::fmg_id (C++ member), 1145
sdmmc_card_t::name (C++ member), 1145
sdmmc_card_t::oem_id (C++ member), 1145
sdmmc_card_t::revision (C++ member), 1145
sdmmc_card_t::serial (C++ member), 1145
sdmmc_command_t (C++ class), 1145
sdmmc_command_t::arg (C++ member), 1146
sdmmc_command_t::bfc (C++ member), 1146
sdmmc_command_t::data (C++ member), 1146
sdmmc_command_t::datalen (C++ member), 1146
sdmmc_command_t::error (C++ member), 1146
sdmmc_command_t::flags (C++ member), 1146
sdmmc_command_t::opcode (C++ member),
1146
sdmmc_command_t::response (C++ member),
1146
sdmmc_command_t::timeout_ms (C++ mem-
ber), 1146
sdmmc_csd_t (C++ class), 1144
sdmmc_csd_t::capacity (C++ member), 1144
sdmmc_csd_t::card_command_class (C++ mem-
ber), 1145
sdmmc_csd_t::csd_ver (C++ member), 1144
sdmmc_csd_t::mmc_ver (C++ member), 1144
sdmmc_csd_t::read_block_len (C++ mem-
ber), 1145
sdmmc_csd_t::sector_size (C++ member),
1144
sdmmc_csd_t::tr_speed (C++ member), 1145
sdmmc_ext_csd_t (C++ class), 1145
sdmmc_ext_csd_t::power_class (C++ mem-
ber), 1145
SDMMC_FREQ_26M (C macro), 1148
SDMMC_FREQ_52M (C macro), 1148
SDMMC_FREQ_DEFAULT (C macro), 1148
SDMMC_FREQ_HIGHSPEED (C macro), 1148
SDMMC_FREQ_PROBING (C macro), 1148
dsmmc_get_status (C++ function), 1141
SDMMC_HOST_DEFAULT (C macro), 815
sdmmc_host_deinit (C++ function), 814
sdmmc_host_do_transaction (C++ function),
813
SDMMC_HOST_FLAG_1BIT (C macro), 1148
SDMMC_HOST_FLAG_4BIT (C macro), 1148
SDMMC_HOST_FLAG_8BIT (C macro), 1148
SDMMC_HOST_FLAG_DDR (C macro), 1148
SDMMC_HOST_FLAG_DEFINT_ARG (C macro), 1148
SDMMC_HOST_FLAG_SPI (C macro), 1148
sdmmc_host_get_slot_width (C++ function),
813
sdmmc_host_init (C++ function), 812
sdmmc_host_init_slot (C++ function), 812
sdmmc_host_io_int_enable (C++ function),
813
sdmmc_host_io_int_wait (C++ function), 813
sdmmc_host_pullup_en (C++ function), 814
sdmmc_host_set_bus_ddr_mode (C++ func-
tion), 813
sdmmc_host_set_bus_width (C++ function),
812
sdmmc_host_set_card_clk (C++ function), 813
SDMMC_HOST_SLOT_0 (C macro), 814
SDMMC_HOST_SLOT_1 (C macro), 815
sdmmc_host_t (C++ class), 1146
sdmmc_host_t::command_timeout_ms (C++ mem-
ber), 1147
sdmmc_host_t::deinit (C++ member), 1147
sdmmc_host_t::deinit_p (C++ member), 1147
sdmmc_host_t::do_transaction (C++ mem-
ber), 1147
sdmmc_host_t::flags (C++ member), 1146
sdmmc_host_t::get_bus_width (C++ mem-
ber), 1146
sdmmc_host_t::init (C++ member), 1146
sdmmc_host_t::io_int_enable (C++ member),
1146
sdmmc_host_t::io_int_wait (C++ member),
1147
sdmmc_host_t::io_voltage (C++ member),
1146
sdmmc_host_t::max_freq_khz (C++ member),
1146
sdmmc_host_t::set_bus_ddr_mode (C++ mem-
ber), 1146
sdmmc_host_t::set_bus_width (C++ mem-
ber), 1146
sdmmc_host_t::set_card_clk (C++ member),
1146
sdmmc_host_t::slot (C++ member), 1146
sdmmc_io_enable_int (C++ function), 1143
sdmmc_io_get_cis_data (C++ function), 1143
sdmmc_io_print_cis_info (C++ function),
1144
sdmmc_io_read_blocks (C++ function), 1143
sdmmc_io_read_byte (C++ function), 1142
sdmmc_io_read_bytes (C++ function), 1142
sdmmc_io_wait_int (C++ function), 1143
sdmmc_io_write_blocks (C++ function), 1143
sdmmc_io_write_byte (C++ function), 1142
sdmmc_io_write_bytes (C++ function), 1142
sdmmc_read_sectors (C++ function), 1141
sdmmc_response_t (C++ type), 1148
sdmmc_scr_t (C++ class), 1145
sdmmc_scr_t::bus_width (C++ member),
1145
sdmmc_scr_t::sd_spec (C++ member), 1145
SDMMC_SLOT_CONFIG_DEFAULT (C macro), 815
sdmmc_slot_config_t (C++ class), 814
sdmmc_slot_config_t::cd (C++ member), 814
sdmmc_slot_config_t::flags (C++ member),
814
sdmmc_slot_config_t::gpio_cd (C++ mem-
ber), 814
sdmmc_slot_config_t::gpio_wp (C++ mem-
ber), 814
sdmmc_slot_config_t::width (C++ member),
814
sdmmc_slot_config_t::wp (C++ member),
814
SDMMC_SLOT_FLAG_INTERNAL_PULLUP (C macro), 815
SDMMC_SLOT_NO_CD (C macro), 815
SDMMC_SLOT_NO_WP (C macro), 815
SDMMC_SLOT_WIDTH_DEFAULT (C macro), 815
sdmmc_switch_func_rsp_t (C++ class), 1145
sdmmc_switch_func_rsp_t::data (C++ mem-
ber), 1145
sdmmc_write_sectors (C++ function), 1141

Espressif Systems

Submit Document Feedback
SDSPI_DEFAULT_HOST (C macro), 820
sdspi_dev_handle_t (C++ type), 820
SDSPI_CONFIG_DEFAULT (C macro), 820
sdspi_device_config_t (C++ class), 819
sdspi_device_config_t::gpio_cd (C++ member), 819
sdspi_device_config_t::gpio_cs (C++ member), 819
sdspi_device_config_t::gpio_int (C++ member), 819
sdspi_device_config_t::gpio_wp (C++ member), 819
sdspi_device_config_t::host_id (C++ member), 819
SDSPI_HOST_DEFAULT (C macro), 820
sdspi_host_deinit (C++ function), 818
sdspi_host_do_transaction (C++ function), 818
sdspi_host_init (C++ function), 817
sdspi_host_init_device (C++ function), 817
sdspi_host_init_slot (C++ function), 819
sdspi_host_io_int_enable (C++ function), 818
sdspi_host_io_int_wait (C++ function), 818
sdspi_host_set_card_clk (C++ function), 818
SDSPI_SLOT_CONFIG_DEFAULT (C macro), 820
sdspi_slot_config_t (C++ class), 819
sdspi_slot_config_t::dma_channel (C++ member), 820
sdspi_slot_config_t::gpio_cd (C++ member), 819
sdspi_slot_config_t::gpio_cs (C++ member), 819
sdspi_slot_config_t::gpio_int (C++ member), 819
sdspi_slot_config_t::gpio_miso (C++ member), 819
sdspi_slot_config_t::gpio_mosi (C++ member), 819
sdspi_slot_config_t::gpio_sck (C++ member), 819
sdspi_slot_config_t::gpio_wp (C++ member), 819
SDSPI_SLOT_NO_CD (C macro), 820
SDSPI_SLOT_NO_INT (C macro), 820
SDSPI_SLOT_NO_WP (C macro), 820
SemaphoreHandle_t (C++ type), 1315
semBINARY_SEMAPHORE_QUEUE_LENGTH (C macro), 1302
semGIVE_BLOCK_TIME (C macro), 1302
semSEMAPHORE_QUEUE_ITEM_LENGTH (C macro), 1302
shared_stack_function (C++ type), 1409
shutdown_handler_t (C++ type), 1424
SIGMADELTA_CHANNEL_0 (C++ enumerator), 832
SIGMADELTA_CHANNEL_1 (C++ enumerator), 832
SIGMADELTA_CHANNEL_2 (C++ enumerator), 832
SIGMADELTA_CHANNEL_3 (C++ enumerator), 832
SIGMADELTA_CHANNEL_4 (C++ enumerator), 832
SIGMADELTA_CHANNEL_5 (C++ enumerator), 832
SIGMADELTA_CHANNEL_6 (C++ enumerator), 832
SIGMADELTA_CHANNEL_7 (C++ enumerator), 832
SIGMADELTA_CHANNEL_MAX (C++ enumerator), 832
sigmadelta_channel_t (C++ enum), 832
sigmadelta_config (C++ function), 830
sigmadelta_config_t (C++ class), 831
sigmadelta_config_t::channel (C++ member), 831
sigmadelta_config_t::sigmadelta_duty (C++ member), 831
sigmadelta_config_t::sigmadelta_gpio (C++ member), 831
sigmadelta_config_t::sigmadelta_prescale (C++ member), 831
SIGMADELTA_PORT_0 (C++ enumerator), 832
SIGMADELTA_PORT_MAX (C++ enumerator), 832
sigmadelta_port_t (C++ enum), 832
sigmadelta_set_duty (C++ function), 831
sigmadelta_set_pin (C++ function), 831
sigmadelta_set_prescale (C++ function), 831
slave_transaction_cb_t (C++ type), 860
smartconfig_event_got_ssid_pswd_t (C++ class), 559
smartconfig_event_got_ssid_pswd_t::bssid (C++ member), 559
smartconfig_event_got_ssid_pswd_t::bssid_set (C++ member), 559
smartconfig_event_got_ssid_pswd_t::cellphone_ip (C++ member), 560
smartconfig_event_got_ssid_pswd_t::password (C++ member), 559
smartconfig_event_got_ssid_pswd_t::ssid (C++ member), 559
smartconfig_event_got_ssid_pswd_t::token (C++ member), 560
smartconfig_event_got_ssid_pswd_t::type (C++ member), 560
smartconfig_event_t (C++ enum), 560
SMARTCONFIG_START_CONFIG_DEFAULT (C macro), 560
smartconfig_start_config_t (C++ class), 560
smartconfig_start_config_t::enable_log (C++ member), 560
smartconfig_start_config_t::esp_touch_v2_enable_crypt (C++ member), 560
smartconfig_start_config_t::esp_touch_v2_key (C++ member), 560
smartconfig_type_t (C++ enum), 560
sntp_get_sync_interval (C++ function), 1463
sntp_get_sync_mode (C++ function), 1462
sntp_get_sync_status (C++ function), 1463
Index

snpr_set_sync_interval (C++ function), 1463
snpr_set_sync_mode (C++ function), 1463
snpr_set_sync_status (C++ function), 1463
snpr_set_time_sync_notification_cb (C++ function), 1463
SNTP_SYNC_MODE_IMMED (C++ enumerator), 1463
SNTP_SYNC_MODE_SMOOTH (C++ enumerator), 1463
snpr_sync_mode_t (C++ enum), 1463
SNTP_SYNC_STATUS_COMPLETED (C++ enumerator), 1464
SNTP_SYNC_STATUS_IN_PROGRESS (C++ enumerator), 1464
SNTP_SYNC_STATUS_RESET (C++ enumerator), 1464
snpr_sync_status_t (C++ enum), 1463
snpr_sync_time (C++ function), 1462
SPI_HOST (C++ enumerator), 842
SPI2_HOST (C++ enumerator), 842
SPI3_HOST (C++ enumerator), 842
spi_bus_add_device (C++ function), 846
spi_bus_add_flash_device (C++ function), 846
spi_bus_config_t (C++ class), 844
spi_bus_config_t::data0_io_num (C++ member), 844
spi_bus_config_t::data1_io_num (C++ member), 844
spi_bus_config_t::data2_io_num (C++ member), 844
spi_bus_config_t::data3_io_num (C++ member), 844
spi_bus_config_t::data4_io_num (C++ member), 844
spi_bus_config_t::data5_io_num (C++ member), 844
spi_bus_config_t::data6_io_num (C++ member), 844
spi_bus_config_t::data7_io_num (C++ member), 844
spi_bus_config_t::flags (C++ member), 844
spi_bus_config_t::intr_flags (C++ member), 844
spi_bus_config_t::max_transfer_sz (C++ member), 844
spi_bus_config_t::miso_io_num (C++ member), 844
spi_bus_config_t::mosi_io_num (C++ member), 844
spi_bus_config_t::quadhd_io_num (C++ member), 844
spi_bus_config_t::quadwp_io_num (C++ member), 844
spi_bus_config_t::sclk_io_num (C++ member), 844
spi_bus_free (C++ function), 843
spi_bus_initialize (C++ function), 843
spi_bus_remove_device (C++ function), 846
spi_bus_remove_flash_device (C++ function), 1155
spi_cal_clock (C++ function), 849
spi_common_dma_t (C++ enum), 846
SPI_DEVICE_3WIRE (C macro), 852
spi_device_acquire_bus (C++ function), 848
SPI_DEVICE_BIT_LSBFIRST (C macro), 852
SPI_DEVICE_CLK_AS_CS (C macro), 852
SPI_DEVICE_DDRCLK (C macro), 852
spi_device_get_trans_result (C++ function), 847
SPI_DEVICE_HALFDUPLEX (C macro), 852
spi_device_handle_t (C++ type), 853
spi_device_interface_config_t (C++ class), 849
spi_device_interface_config_t::address_bits (C++ member), 849
spi_device_interface_config_t::clock_speed_hz (C++ member), 850
spi_device_interface_config_t::command_bits (C++ member), 849
spi_device_interface_config_t::cs_ena_posttrans (C++ member), 850
spi_device_interface_config_t::cs_ena_pretrans (C++ member), 850
spi_device_interface_config_t::dummy_bits (C++ member), 849
spi_device_interface_config_t::duty_cycle_pos (C++ member), 850
spi_device_interface_config_t::flags (C++ member), 850
spi_device_interface_config_t::input_delay_ns (C++ member), 850
spi_device_interface_config_t::mode (C++ member), 850
spi_device_interface_config_t::post_cb (C++ member), 850
spi_device_interface_config_t::pre_cb (C++ member), 850
spi_device_interface_config_t::queue_size (C++ member), 850
spi_device_interface_config_t::spics_io_num (C++ member), 850
SPI_DEVICE_NO_DUMMY (C macro), 852
spi_device_polling_end (C++ function), 848
spi_device_polling_start (C++ function), 847
spi_device_polling_transmit (C++ function), 848
SPI_DEVICE_POSITIVE_CS (C macro), 852
spi_device_queue_trans (C++ function), 847
SPI_DEVICE_RXBIT_LSBFIRST (C macro), 852
spi_device_transmit (C++ function), 847
SPI_DEVICE_TXBIT_LSBFIRST (C macro), 852
SPI_DMA_CH1 (C++ enumerator), 846
spi_slave_transmit

spi_slave_transaction_t::tx_buffer (C++ member), 859
spi_slave_transmit (C++ function), 858
SPI_SLAVE_RBIT_LSBFIRST (C macro), 860
spi_slave_transaction_t::trans_len (C++ member), 859
spi_slave_transaction_t::tx_buffer (C++ member), 859
spi_slave_transaction_t::user (C++ member), 860
spi_slave_transmit (C++ function), 858
SPI_SLAVE_TXBIT_LSBFIRST (C macro), 860
SPI_SWAP_DATA_RX (C macro), 845
SPI_SWAP_DATA_TX (C macro), 845
SPI_TRANS_CS_KEEP_ACTIVE (C macro), 853
SPI_TRANS_MODE_DIO (C macro), 852
SPI_TRANS_MODE_DIOQIO_ADDR (C macro), 852
SPI_TRANS_MODE_QIO (C macro), 852
SPI_TRANS_MULTIQIO_ADDR (C macro), 853
SPI_TRANS_MULTIQIO_CMD (C macro), 853
SPI_TRANS_USE_RXDATA (C macro), 852
SPI_TRANS_USE_TXDATA (C macro), 852
SPI_TRANS酎VARIABLE_ADDR (C macro), 853
SPI_TRANS.getWritableDatabase (C macro), 853
SPI_TRANS_VARIOABLE_QIO_ADDR (C macro), 853
spi_transaction_ext_t::address_bits (C++ member), 851
spi_transaction_ext_t::base (C++ member), 851
spi_transaction_ext_t::command_bits (C++ member), 851
spi_transaction_ext_t::dummy_bits (C++ member), 851
spi_transaction_t (C++ class), 850
spi_transaction_t::addr (C++ type), 853
spi_transaction_t::cmd (C++ member), 850
spi_transaction_t::flags (C++ member), 850
spi_transaction_t::length (C++ member), 850
spi_transaction_t::tx_buffer (C++ member), 851
spi_transaction_t::tx_data (C++ member), 851
<table>
<thead>
<tr>
<th>System Event IDs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYSTEM_EVENT_FTM_REPORT</td>
<td>System event to report FTM completion</td>
</tr>
<tr>
<td>SYSTEM_EVENT_ETH_STOP</td>
<td>System event to stop Ethernet</td>
</tr>
<tr>
<td>SYSTEM_EVENT_ETH_GOT_IP</td>
<td>System event to get Ethernet IP address</td>
</tr>
<tr>
<td>SYSTEM_EVENT_ETH_CONNECTED</td>
<td>System event to connect to Ethernet</td>
</tr>
<tr>
<td>system_event_ap_staipassigned</td>
<td>System event to assign IP address</td>
</tr>
<tr>
<td>SYSTEM_EVENT_AP_STA_DISCONNECTED</td>
<td>System event to disconnect from access point</td>
</tr>
<tr>
<td>SYSTEM_EVENT_AP_STA_CONNECTED</td>
<td>System event to connect to access point</td>
</tr>
<tr>
<td>SYSTEM_EVENT_AP_STA_GOT_IP6</td>
<td>System event to get IPv6 address</td>
</tr>
<tr>
<td>system_event_ap_probe_req_rx_t</td>
<td>System event to receive probe request</td>
</tr>
<tr>
<td>StaticRingbuffer_t</td>
<td>Structure for holding ringbuffer information</td>
</tr>
<tr>
<td>StreamBufferHandle_t</td>
<td>Structure for managing stream buffer handles</td>
</tr>
<tr>
<td>system_event_info_t::got_ip</td>
<td>Event to get IP address</td>
</tr>
<tr>
<td>system_event_info_t::got_ip6</td>
<td>Event to get IPv6 address</td>
</tr>
<tr>
<td>system_event_info_t::ftm_report</td>
<td>Event to report FTM status</td>
</tr>
<tr>
<td>system_event_info_t::sta_er_success</td>
<td>Event to indicate successful network event</td>
</tr>
<tr>
<td>system_event_info_t::sta_er_fail_reason</td>
<td>Event to indicate failure reason</td>
</tr>
<tr>
<td>system_event_info_t::sta_connected</td>
<td>Event to indicate network connection status</td>
</tr>
<tr>
<td>system_event_info_t::sta_disconnected</td>
<td>Event to indicate network disconnection status</td>
</tr>
<tr>
<td>system_event_info_t::auth_change</td>
<td>Event to indicate authentication change</td>
</tr>
</tbody>
</table>

C++ types and enumerators are used to represent these system events.
system_event_sta_scan_done_t (C++ type), 1249
SYSTEM_EVENT_STA_START (C++ enumerator), 1250
SYSTEM_EVENT_STA_STOP (C++ enumerator), 1250
SYSTEM_EVENT_STA_WPS_ER_FAILED (C++ enumerator), 1251
SYSTEM_EVENT_STA_WPS_ER_PBC_OVERLAP (C++ enumerator), 1251
system_event_sta_wps_er_pin_t (C++ type), 1250
SYSTEM_EVENT_STA_WPS_ER_SUCCESS (C++ enumerator), 1251
system_event_sta_wps_success_t (C++ type), 1250
SYSTEM_EVENT_STA_WPS_ER_TIMEOUT (C++ enumerator), 1251
system_event_sta_wps_fail_reason_t (C++ type), 1249
system_event_t (C++ class), 1249
system_event_t::event_id (C++ member), 1249
system_event_t::event_info (C++ member), 1249
SYSTEM_EVENT_WIFI_READY (C++ enumerator), 1250

taskDISABLE_INTERRUPTS (C macro), 1282
taskENABLE_INTERRUPTS (C macro), 1282
taskEXIT_CRITICAL_FROM_ISR (C macro), 1281
taskENTER_CRITICAL_FROM_ISR (C macro), 1281
taskEXIT_CRITICAL_ISR (C macro), 1281
taskEXIT_CRITICAL_FROM_ISR (C macro), 1281
taskEXIT_CRITICAL_ISR (C macro), 1282
TaskHandle_t (C++ type), 1283
TaskHookFunction_t (C++ type), 1283
taskSCHEDULER_NOT_STARTED (C macro), 1282
taskSCHEDULER_RUNNING (C macro), 1282
taskSCHEDULER_SUSPENDED (C macro), 1282
taskYIELD (C macro), 1281
TimerCallbackFunction_t (C++ type), 1332
TimerHandle_t (C++ type), 1332
tls_keep_alive_cfg_t (C++ class), 931
tls_keep_alive_cfg_.keep_alive_count (C++ member), 931
tls_keep_alive_cfg_.keep_alive_enable (C++ member), 931
tls_keep_alive_cfg_.keep_alive_idle (C++ member), 931
tls_keep_alive_cfg_.keep_alive_interval (C++ member), 931
tls_keep_alive_cfg_.keep_alive_count (C++ member), 931
tls_keep_alive_cfg_.keep_alive_enable (C++ member), 931
tls_keep_alive_cfg_.keep_alive_idle (C++ member), 931
tls_keep_alive_cfg_.keep_alive_interval (C++ member), 931

T

touch_pad_filter_start (C++ function), 867
touch_pad_filter_delete (C++ function), 867
touch_pad_deinit (C++ function), 867
touch_pad_config (C++ function), 863
touch_pad_deinit (C++ function), 868
touch_pad_clear_group_mask (C++ function), 866

touch_pad_clear_status (C++ function), 870
touch_pad_bit_mask_ALL (C macro), 871
touch_pad_bit_mask_MAX (C macro), 871
tmsDeleteCallbackFunction_t (C++ type), 1283
tmrCOMMAND_CHANGE_PERIOD (C macro), 1323
tmrCOMMAND.Change.PERIOD_FROM_ISR (C macro), 1323
tmrCOMMAND.DELETE (C macro), 1323
tmrCOMMAND_EXECUTE_CALLBACK (C macro), 1323
tmrCOMMAND_EXECUTE_CALLBACK_FROM_ISR (C macro), 1323
tmrCOMMAND_RESET (C macro), 1323
tmrCOMMAND_RESET_FROM_ISR (C macro), 1323
tmrCOMMAND.START (C macro), 1323
tmrCOMMAND.START.DONT_TRACE (C macro), 1323
tmrCOMMAND.START_FROM_ISR (C macro), 1323
tmrCOMMAND_STOP_FROM_ISR (C macro), 1323
tmrFIRST_FROM_ISR_COMMAND (C macro), 1323
touch_cnt_slope_t (C++ enum), 873
TOUCH_FSM_MODE_DEFAULT (C macro), 871
TOUCH_FSM_MODE_MAX (C++ enumerator), 874
TOUCH_FSM_MODE_SW (C++ enumerator), 874
TOUCH_FSM_MODE_TIMER (C++ enumerator), 873
touch_high_volt_t (C++ enum), 872
TOUCH_HVOLT_2V4 (C++ enumerator), 872
TOUCH_HVOLT_2V5 (C++ enumerator), 872
TOUCH_HVOLT_2V6 (C++ enumerator), 872
TOUCH_HVOLT_2V7 (C++ enumerator), 872
TOUCH_HVOLT_ATTEN_0V (C++ enumerator), 873
TOUCH_HVOLT_ATTEN_0V5 (C++ enumerator), 873
TOUCH_HVOLT_ATTEN_1V (C++ enumerator), 873
TOUCH_HVOLT_ATTEN_1V5 (C++ enumerator), 873
TOUCH_HVOLT_ATTEN_KEEP (C++ enumerator), 873
TOUCH_HVOLT_ATTEN_MAX (C++ enumerator), 873
TOUCH_HVOLT_KEEP (C++ enumerator), 872
TOUCH_HVOLT_MAX (C++ enumerator), 872
TOUCH_LOW_VOLT (C++ enum), 872
TOUCH_LOW_VOLT_0V5 (C++ enumerator), 872
TOUCH_LOW_VOLT_0V6 (C++ enumerator), 872
TOUCH_LOW_VOLT_0V7 (C++ enumerator), 872
TOUCH_LOW_VOLT_0V8 (C++ enumerator), 872
TOUCH_LOW_VOLT_KEEP (C++ enumerator), 872
TOUCH_LOW_VOLT_MAX (C++ enumerator), 872
TOUCH_PAD_ATTEN_VOLTAGE_THRESHOLD (C macro), 871
TOUCH_PAD_BIT_MASK_ALL (C macro), 871
TOUCH_PAD_BIT_MASK_MAX (C macro), 871

touch_pad_clean_group_mask (C++ function), 866

touch_pad_clear_status (C++ function), 870
touch_pad_config (C++ function), 863
touch_pad_deinit (C++ function), 868
touch_pad_filter_delete (C++ function), 867
touch_pad_filter_start (C++ function), 867

Index
Index

TOUCh_TRIGGER_SOURCE_SET1 (C++ enum), 874

touch_trigger_src_t (C++ enum), 874
touch_volt_atten_t (C++ enum), 872
transaction_cb_t (C++ type), 853
tskDEFAULT_INDEX_TO_NOTIFY (C macro), 1281
tskIDLE_PRIORITY (C macro), 1281
tskKERNEL_VERSION_BUILD (C macro), 1281
tskKERNEL_VERSION_MAJOR (C macro), 1281
tskKERNEL_VERSION_MINOR (C macro), 1281
tskKERNEL_VERSION_NUMBER (C macro), 1281
tskMPU_REGION_DEVICE_MEMORY (C macro), 1281
tskMPU_REGION_EXECUTE_NEVer (C macro), 1281
tskMPU_REGION_NORMAL_MEMORY (C macro), 1281
tskMPU_REGION_READ_ONLY (C macro), 1281
tskMPU_REGION_READ_WRITE (C macro), 1281
tskNO_AFFINITY (C macro), 1281
twai_clear_receive_queue (C++ function), 888
twai_clear_transmit_queue (C++ function), 888
twai_driver_install (C++ function), 885
twai_driver_uninstall (C++ function), 886
TWAI_ERR_PASS_THRESH (C macro), 885
TWAI_EXTD_ID_MASK (C macro), 885
twai_filter_config_t (C++ class), 884
twai_filter_config_t::acceptance_code (C++ member), 884
twai_filter_config_t::acceptance_mask (C++ member), 884
twai_filter_config_t::single_filter (C++ member), 884
TWAI_FRAME_EXTD_ID_LEN_BYTES (C macro), 885
TWAI_FRAME_MAX_DLC (C macro), 885
TWAI_FRAME_STD_ID_LEN_BYTES (C macro), 885
twai_general_config_t (C++ class), 888
twai_general_config_t::alerts_enabled (C++ member), 888
twai_general_config_t::bus_off_io (C++ member), 888
twai_general_config_t::clkout_divider (C++ member), 888
twai_general_config_t::clkout_io (C++ member), 888
twai_general_config_t::intr_flags (C++ member), 888
twai_general_config_t::mode (C++ member), 888
twai_general_config_t::rx_io (C++ member), 888
twai_general_config_t::rx_queue_len (C++ member), 888
twai_get_status_info (C++ function), 887
twai_initiate_recovery (C++ function), 887
TWAI_IO_UNUSED (C macro), 889
twai_message_t (C++ class), 883
twai_message_t::data (C++ member), 884
twai_message_t::data_length_code (C++ member), 884
twai_message_t::dlc_non_comp (C++ member), 884
twai_message_t::extd (C++ member), 883
twai_message_t::flags (C++ member), 884
twai_message_t::identifier (C++ member), 884
twai_message_t::reserved (C++ member), 884
twai_message_t::rtr (C++ member), 883
twai_message_t::self (C++ member), 884
twai_message_t::ss (C++ member), 883
TWAI_MODE_LISTEN_ONLY (C++ enumerator), 885
TWAI_MODE_NO_ACK (C++ enumerator), 885
TWAI_MODE_NORMAL (C++ enumerator), 885
twai_mode_t (C++ enum), 885
twai_read_alerts (C++ function), 887
twai_receive (C++ function), 886
twai_reconfigure_alerts (C++ function), 887
twai_start (C++ function), 886
TWAI_STATE_BUS_OFF (C++ enumerator), 889
TWAI_STATE_RECOVERING (C++ enumerator), 889
TWAI_STATE_RUNNING (C++ enumerator), 889
TWAI_STATE_STOPPED (C++ enumerator), 889
twai_state_t (C++ enum), 889
twai_status_info_t (C++ class), 888
twai_status_info_t::arb_lost_count (C++ member), 889
twai_status_info_t::bus_error_count (C++ member), 889
twai_status_info_t::msgs_to_rx (C++ member), 889
twai_status_info_t::msgs_to_tx (C++ member), 889
twai_status_info_t::rx_error_counter (C++ member), 889
twai_status_info_t::rx_missed_count (C++ member), 889
twai_status_info_t::rx_overrun_count (C++ member), 889
twai_status_info_t::state (C++ member), 889
twai_status_info_t::tx_error_counter (C++ member), 889
twai_status_info_t::tx_failed_count (C++ member), 889
TWAI_STD_ID_MASK (C macro), 885
twai_stop (C++ function), 886
twai_timing_config_t (C++ class), 884
twai_timing_config_t::tseg_2 (C++ member), 884
twai_timing_config_t::tseg_1 (C++ member), 884
twai_transmit (C++ function), 886
uart_disable_rx_intr (C++ function), 884
uart_disable_intr_mask (C++ member), 884
UART_DATA_BREAK (C++ macro), 899
UART_DATA_7_BITS (C++ enumerator), 895
UART_DATA_5_BITS (C++ enumerator), 895
UART_DATA_BITS_MAX (C++ function), 898
UART_DATA_4_BITS_MAX (C++ function), 898
UART_DATA_3_BITS_MAX (C++ function), 898
UART_DATA_2_BITS_MAX (C++ function), 898
UART_DATA_BITS_MIN (C++ function), 898
uart_disable_pattern_det_baud_intr (C++ function), 903
uart_disable_pattern_det_intr (C++ function), 903
uart_enable_rx_intr (C++ function), 899
uart_enable_tx_intr (C++ function), 899
UART_EVENT_MAX (C++ enumerator), 908
uart_event_t (C++ class), 906
uart_event_t::size (C++ member), 907
uart_event_t::timeout_flag (C++ member), 907
uart_event_t::type (C++ member), 907
uart_event_type_t (C++ member), 907
UART_FIFO_LEN (C macro), 907
UAR_CODEC (C++ function), 907
UART_BREAK (C++ enumerator), 907
UART_BUFFER_FULL (C++ enumerator), 907
uart_clear_intr_status (C++ function), 898
uart_config_t (C++ class), 908
uart_config_t::baud_rate (C++ member), 908
uart_config_t::data_bits (C++ member), 908
uart_config_t::flow_ctrl (C++ member), 909
uart_config_t::parity (C++ member), 909
uart_config_t::rx_flow_ctrl_thresh (C++ member), 909
uart_config_t::source_clk (C++ member), 909
uart_config_t::stop_bits (C++ member), 909
uart_config_t::use_ref_tick (C++ member), 909
UART_CTS_GPIO19_DIRECT_CHANNEL (C macro), 911
UART_CTS_GPIO6_DIRECT_CHANNEL (C macro), 912
UART_CTS_GPIO8_DIRECT_CHANNEL (C macro), 912
UART_DATA (C++ enumerator), 907
UART_DATA_5_BITS (C++ enumerator), 909
UART_DATA_6_BITS (C++ enumerator), 909
UART_DATA_7_BITS (C++ enumerator), 909
UART_DATA_8_BITS (C++ enumerator), 909
UART_DATA_BITS_MAX (C++ enumerator), 909
UART_DATA_BREAK (C++ enumerator), 907
uart_disable_intr_mask (C++ function), 898
uart_disable_pattern_det_intr (C++ function), 902
uart_disable_rx_intr (C++ function), 899
uart_disable_tx_intr (C++ function), 899
uart_driver_delete (C++ function), 896
uart_driver_install (C++ function), 896
uart_enable_intr_mask (C++ function), 898
uart_enable_pattern_det_baud_intr (C++ function), 903
uart_enable_pattern_det_intr (C++ function), 903
uart_event_config (C++ function), 901
uart_intr_config_t (C++ class), 906
uart_intr_config_t::intr_enable_mask (C++ member), 906
uart_intr_config_t::rx_timeout_threshold (C++ member), 906
uart_intr_config_t::tx_timeout_threshold (C++ member), 906
uart_get_word_length (C++ function), 896
UART_GPIO10_DIRECT_CHANNEL (C macro), 911
UART_GPIO11_DIRECT_CHANNEL (C macro), 912
UART_GPIO16_DIRECT_CHANNEL (C macro), 912
UART_GPIO17_DIRECT_CHANNEL (C macro), 912
UART_GPIO19_DIRECT_CHANNEL (C macro), 911
UART_GPIO1_DIRECT_CHANNEL (C macro), 911
UART_GPIO22_DIRECT_CHANNEL (C macro), 911
UART_GPIO3_DIRECT_CHANNEL (C macro), 911
UART_GPIO6_DIRECT_CHANNEL (C macro), 912
UART_GPIO7_DIRECT_CHANNEL (C macro), 912
UART_GPIO8_DIRECT_CHANNEL (C macro), 912
UART_GPIO9_DIRECT_CHANNEL (C macro), 912
UART_HW_FLOWCTRL_DISABLE (C++ function), 909
UART_HW_FLOWCTRL_CTS (C++ function), 910
UART_HW_FLOWCTRL_DISABLE (C++ function), 910
UART_HW_FLOWCTRL_FLAGS (C++ function), 910
UART_HW_FLOWCTRL_RTS (C++ function), 910
UART_HW_FLOWCTRL_RTS (C++ function), 910
uart_intr_config_t (C++ function), 901
uart_intr_config_t (C++ class), 906
uart_intr_config_t::intr_enable_mask (C++ member), 906
uart_intr_config_t::rx_timeout_threshold (C++ member), 906
UAR_CODEC (C++ function), 907
UART_DBG (C++ function), 907
UART_BREAK (C++ function), 907
UART_BUFFER_FULL (C++ function), 907
uart_clear_intr_status (C++ function), 897
uart_get_baudrate (C++ function), 897
uart_get_buffered_data_len (C++ function), 902
uart_getcollision_flag (C++ function), 905
uart_get_hw_flowctrl (C++ function), 898
uart_getparity (C++ function), 897
uart_get_stop_bits (C++ function), 897
uart_get_wakeup_threshold (C++ function), 905
uart_get_word_length (C++ function), 896
UART_GPIO10_DIRECT_CHANNEL (C macro), 911
UART_GPIO11_DIRECT_CHANNEL (C macro), 912
UART_GPIO16_DIRECT_CHANNEL (C macro), 912
UART_GPIO17_DIRECT_CHANNEL (C macro), 912
UART_GPIO19_DIRECT_CHANNEL (C macro), 911
UART_GPIO1_DIRECT_CHANNEL (C macro), 911
UART_GPIO22_DIRECT_CHANNEL (C macro), 911
UART_GPIO3_DIRECT_CHANNEL (C macro), 911
UART_GPIO6_DIRECT_CHANNEL (C macro), 912
UART_GPIO7_DIRECT_CHANNEL (C macro), 912
UART_GPIO8_DIRECT_CHANNEL (C macro), 912
uart_hw_flowcontrol_t (C++ function), 910
UART_HW_FLOWCTRL_CTS (C++ enumerator), 909
UART_HW_FLOWCTRL_CTS_RTS (C++ enumerator), 909
uart_intr_config_t::txfifo_full_thresh uart_port_t (C++ type), 909
uart_intr_config_t::txfifo_empty_intr_thresh uart_read_bytes (C++ function), 902
UART_PIN_NO_CHANGE UART_RS_GPIO11_DIRECT_CHANNEL (C macro), 912
UART_PIN_NO_CHANGE UART_RS_GPIO22_DIRECT_CHANNEL (C macro), 912
UART_PIN_NO_CHANGE UART_RS_GPIO107_DIRECT_CHANNEL (C macro), 912
UART_PIN_NO_CHANGE UART_RXD_GPIO16_DIRECT_CHANNEL (C macro), 912
UART_PIN_NO_CHANGE UART_RXD_GPIO3_DIRECT_CHANNEL (C macro), 912
UART_PIN_NO_CHANGE UART_RXD_GPIO1 директив (C++ ENUM), 907
UART_PIN_NO_CHANGE UART_RXD_GPIO3 директив (C++ ENUM), 907
UART_PIN_NO_CHANGE UART_RXD_GPIO1 директив (C++ ENUM), 907
uart_isr_register (C++ function), 899
uart_isr_free (C++ function), 899
uart_isr_handler_t (C++ type), 907
uart_mode IRA (C++ enumerator), 909
UART_MODE_RS485_APP_CTRL (C++ enumerator), 909
UART_MODE_RS485_APP_CTRL (C++ enumerator), 909
UART_MODE_RS485_COLLISION_DETECT (C++ enumerator), 909
UART_MODE_RS485_HALF_DUPLEX (C++ enumerator), 909
UART_MODE_UART (C++ enumerator), 909
UART_NUM_0 (C macro), 907
UART_NUM_0_CTS_DIRECT_GPIO_NUM (C macro), 911
UART_NUM_0_CTS_DIRECT_GPIO_NUM (C macro), 911
UART_NUM_0_CTS_DIRECT_GPIO_NUM (C macro), 911
UART_NUM_1 (C macro), 907
UART_NUM_1_CTS_DIRECT_GPIO_NUM (C macro), 912
UART_NUM_1_CTS_DIRECT_GPIO_NUM (C macro), 912
UART_NUM_1_CTS_DIRECT_GPIO_NUM (C macro), 912
UART_NUM_1_CTS_DIRECT_GPIO_NUM (C macro), 912
UART_NUM_2 (C macro), 907
UART_NUM_2_CTS_DIRECT_GPIO_NUM (C macro), 912
UART_NUM_2_CTS_DIRECT_GPIO_NUM (C macro), 912
UART_NUM_2_CTS_DIRECT_GPIO_NUM (C macro), 912
UART_NUM_2_CTS_DIRECT_GPIO_NUM (C macro), 912
UART_NUM_2_CTS_DIRECT_GPIO_NUM (C macro), 912
UART_NUM_MAX (C macro), 907
uart_param_config (C++ function), 900
UART_PARITY_DISABLE (C++ enumerator), 910
UART_PARITY_DISABLE (C++ enumerator), 910
UART_PARITY_DISABLE (C++ enumerator), 910
UART_PARITY_DISABLE (C++ enumerator), 910
UART_PARITY_DISABLE (C++ enumerator), 910
UART_PATTERN_DET (C++ enumerator), 907
UART_PATTERN_DET (C++ enumerator), 907
UART_PATTERN_DET (C++ enumerator), 907
UART_PATTERN_DET (C++ enumerator), 907
UART_PATTERN_DET (C++ enumerator), 907
uart_pattern_get_pos (C++ function), 903
uart_pattern_pop_pos (C++ function), 903
uart_pattern_queue_reset (C++ function), 904
UART_PIN_NO_CHANGE (C macro), 907
W

WEBSOCKET_EVENT_ANY (C++ enumerator), 1054
WEBSOCKET_EVENT_CLOSED (C++ enumerator), 1054
WEBSOCKET_EVENT_CONNECTED (C++ enumerator), 1054
WEBSOCKET_EVENT_DATA (C++ enumerator), 1054
WEBSOCKET_EVENT_DISCONNECTED (C++ enumerator), 1054
WEBSOCKET_EVENT_ERROR (C++ enumerator), 1054
WEBSOCKET_EVENT_MAX (C++ enumerator), 1054
WEBSOCKET_TRANSPORT_OVER_SSL (C++ enumerator), 1054
WEBSOCKET_TRANSPORT_OVER_TCP (C++ enumerator), 1054
WEBSOCKET_TRANSPORT_UNKNOWN (C++ enumerator), 1054
wifi_action_rx_cb_t (C++ type), 550
wifi_action_tx_req_t (C++ class), 545
wifi_action_tx_req_t::data (C++ member), 545
wifi_action_tx_req_t::data_len (C++ member), 545
wifi_action_tx_req_t::dest_mac (C++ member), 545
wifi_action_tx_req_t::ifx (C++ member), 545
wifi_action_tx_req_t::no_ack (C++ member), 545
wifi_action_tx_req_t::rx_cb (C++ member), 545
wifi_active_scan_time_t (C++ class), 537
wifi_active_scan_time_t::max (C++ member), 537
wifi_active_scan_time_t::min (C++ member), 537
WIFI_ALL_CHANNEL_SCAN (C++ enumerator), 553
WIFI_AMPDU_RX_ENABLED (C macro), 536
WIFI_AMPDU_TX_ENABLED (C macro), 536
WIFI_AMSDU_TX_ENABLED (C macro), 536
WIFI_ANT_ANT0 (C++ enumerator), 553
WIFI_ANT_ANT1 (C++ enumerator), 553
wifi_ant_config_t (C++ class), 544
wifi_ant_config_t::enabled_ant0 (C++ member), 544
wifi_ant_config_t::enabled_ant1 (C++ member), 544
wifi_ant_config_t::rx_ant_default (C++ member), 544
wifi_ant_config_t::rx_ant_mode (C++ member), 544
wifi_ant_config_t::tx_ant_mode (C++ member), 544
wifi_ant_gpio_config_t (C++ class), 544
wifi_ant_gpio_config_t::gpio_cfg (C++ member), 544
wifi_ant_gpio_t (C++ class), 544
wifi_ant_gpio_t::gpio_num (C++ member), 544
wifi_ant_gpio_t::gpio_select (C++ member), 544
WIFI_ANT_MAX (C++ enumerator), 553
WIFI_ANT_MODE_ANT0 (C++ enumerator), 555
WIFI_ANT_MODE_ANT1 (C++ enumerator), 555
WIFI_ANT_MODE_AUTO (C++ enumerator), 555
WIFI_ANT_MODE_MAX (C++ enumerator), 555
wifi_ant_mode_t (C++ enum), 554
wifi_ant_mode_t::ant1 (C++ enum), 553
wifi_ap_config_t (C++ class), 539
wifi_ap_config_t::authmode (C++ member), 539
wifi_ap_config_t::beacon_interval (C++ member), 540
wifi_ap_config_t::channel (C++ member), 539
wifi_ap_config_t::ftm_responder (C++ member), 540
wifi_ap_config_t::max_connection (C++ member), 539
wifi_ap_config_t::pairwise_cipher (C++ member), 540
wifi_ap_config_t::password (C++ member), 539
wifi_ap_config_t::ssid (C++ member), 539
wifi_ap_config_t::ssid_hidden (C++ member), 539
wifi_ap_config_t::ssid_len (C++ member), 539
wifi_ap_record_t (C++ class), 538
wifi_ap_record_t::ant (C++ member), 538
wifi_ap_record_t::authmode (C++ member), 538
wifi_ap_record_t::bssid (C++ member), 538
wifi_ap_record_t::country (C++ member), 539
wifi_ap_record_t::ftm_initiator (C++ member), 539
wifi_ap_record_t::ftm_responder (C++ member), 539
wifi_ap_record_t::group_cipher (C++ member), 538
wifi_ap_record_t::pairwise_cipher (C++ member), 538
wifi_ap_record_t::phy_11b (C++ member), 538
wifi_ap_record_t::phy_11g (C++ member), 538
wifi_ap_record_t::phy_11n (C++ member), 538
wifi_ap_record_t::phy_lr (C++ member), 538
wifi_ap_record_t::primary (C++ member), 538
wifi_ap_record_t::primary (C++ member), 539
wifi_ap_record_t::reserved (C++ member), 539
wifi_ap_record_t::rssi (C++ member), 538
wifi_ap_record_t::second (C++ member), 538
wifi_ap_record_t::ssid (C++ member), 538
wifi_ap_record_t::wps (C++ member), 539
WIFI_AUTH_MAX (C++ enumerator), 551
wifi_auth_mode_t (C++ enum), 551
WIFI_AUTH_OPEN (C++ enumerator), 551
WIFI_AUTH_WAPI_PSK (C++ enumerator), 551
WIFI_AUTH_WEP (C++ enumerator), 551
WIFI_AUTH_WPA2_ENTERPRISE (C++ enumerator), 551
WIFI_AUTH_WPA2_PSK (C++ enumerator), 551
WIFI_AUTH_WPA3_PSK (C++ enumerator), 551
WIFI_AUTH_WPA_PSK (C++ enumerator), 551
WIFI_AUTH_WPA2 enterprise (C++ enumerator), 551
WIFI_BW_HT20 (C++ enumerator), 554
WIFI_BW_HT40 (C++ enumerator), 554
WIFI_CACHE_TX_BUFFER_NUM (C macro), 535
WIFI_CIPHER_TYPE_AES_CMAC128 (C++ enumerator), 553
WIFI_CIPHER_TYPE_AES_GMAC128 (C++ enumerator), 553
WIFI_CIPHER_TYPE_AES_GMAC256 (C++ enumerator), 553
WIFI_CIPHER_TYPE_CCMP (C++ enumerator), 553
WIFI_CIPHER_TYPE_GCM (C++ enumerator), 553
WIFI_CIPHER_TYPE_GCM256 (C++ enumerator), 553
WIFI_CIPHER_TYPE_NONE (C++ enumerator), 552
WIFI_CIPHER_TYPE_SMS4 (C++ enumerator), 553
wifi_cipher_type_t (C++ enum), 552
WIFI_CIPHER_TYPE_Tkip (C++ enumerator), 553
WIFI_CIPHER_TYPE_Tkip_CCMP (C++ enumerator), 553
WIFI_CIPHER_TYPE_UNKNOWN (C++ enumerator), 553
WIFI_CIPHER_TYPE_WEP104 (C++ enumerator), 553
WIFI_CIPHER_TYPE_WEP40 (C++ enumerator), 552
wifi_config_t (C++ union), 537
wifi_config_t::ap (C++ member), 537
wifi_config_t::sta (C++ member), 537
WIFI_CONNECT_AP_BY_SECURITY (C++ enumerator), 553
WIFI_CONNECT_AP_BY_SIGNAL (C++ enumerator), 553
WIFI_COUNTRY_POLICY_AUTO (C++ enumerator), 551
WIFI_COUNTRY_POLICY_MANUAL (C++ enumerator), 551
wifi_country_policy_t (C++ enum), 551
wifi_country_policy_t (C++ class), 537
wifi_country_t::cc (C++ member), 537
wifi_country_t::max_tx_power (C++ member), 537
wifi_country_t::nchan (C++ member), 537
wifi_country_t::policy (C++ member), 537
wifi_country_t::schan (C++ member), 537
wifi_csi_cb_t (C++ type), 536
wifi_csi_config_t (C++ class), 543
wifi_csi_config_t::channel_filter_en (C++ member), 543
wifi_csi_config_t::hintlf_en (C++ member), 543
wifi_csi_config_t::ltlf_en (C++ member), 543
wifi_csi_config_t::manu_scale (C++ member), 543
wifi_csi_config_t::shift (C++ member), 544
wifi_csi_config_t::stbc_hintlf2_en (C++ member), 543
WIFI_ENABLED (C enum), 535
WIFI_CIPHER_TYPE_WEP (C++ enumerator), 544
wifi_cipher_info_t (C++ class), 544
wifi_cipher_info_t::buf (C++ member), 544
wifi_cipher_info_t::first_word_invalid (C++ member), 544
wifi_cipher_info_t::len (C++ member), 544
wifi_cipher_info_t::mac (C++ member), 544
wifi_cipher_info_t::rx_ctrl (C++ member), 544
WIFI_DEFAULT_RX_BA_WIN (C macro), 536
WIFI_DYNAMIC_TX_BUFFER_NUM (C macro), 535
wifi_err_reason_t (C++ enum), 551
WIFI_EVENT_ACTION_TX_STATUS (C++ enumerator), 557
wifi_event_action_tx_status_t (C++ class), 548
wifi_event_action_tx_status_t::context (C++ member), 548
wifi_event_action_tx_status_t::da (C++ member), 548
wifi_event_action_tx_status_t::ifx (C++ member), 548
wifi_event_action_tx_status_t::status (C++ member), 548
wifi_event_ap_probe_req_rx_t (C++ class), 547
wifi_event_ap_probe_req_rx_t::mac (C++ member), 547
wifi_event_ap_probe_req_rx_t::rssi (C++ member), 547
WIFI_EVENT_AP_PROBEREQRECVED (C++ enumerator), 557
WIFI_EVENT_AP_STACONNECTED (C++ enumerator), 557
wifi_event_ap_staconnected_t (C++ class), 547
wifi_event_ap_staconnected_t::aid (C++ member), 547
wifi_event_ap_staconnected_t::is_mesh_child (C++ member), 547
wifi_event_ap_staconnected_t::mac (C++ member), 547
WIFI_EVENT_AP_STADISCONNECTED (C++ enumerator), 557
wifi_event_ap_stadisconnected_t (C++ class), 547
wifi_event_ap_stadisconnected_t::aid (C++ member), 547
wifi_event_ap_stadisconnected_t::is_mesh_child (C++ member), 547
wifi_event_ap_stadisconnected_t::mac (C++ member), 547
WIFI_EVENT_AP_START (C++ enumerator), 557
WIFI_EVENT_AP_STOP (C++ enumerator), 557
wifi_event_bss_rssi_low_t::rssi (C++ member), 547
WIFI_EVENT_BSS_RSSI_LOW (C++ enumerator), 557
wifi_event_bss_rssi_low_t::rssi (C++ member), 547
WIFI_EVENT_BSS_RSSI_LOW (C++ enumerator), 557
wifi_event_bss_rssi_low_t::rssi (C++ member), 547
WIFI_EVENT_FTМ_REPORT (C++ enumerator), 557
wifi_event_ftm_report_t::status (C++ member), 548
wifi_event_ftm_report_t::peer_mac (C++ member), 548
wifi_event_ftm_report_t::rtt_est (C++ member), 548
wifi_event_ftm_report_t::rtt_raw (C++ member), 548
wifi_event_ftm_report_t::status (C++ member), 548
WIFI_EVENT_MASK_ALL (C macro), 550
WIFI_EVENT_MASK_AP_PROBEREQRECVED (C macro), 550
WIFI_EVENT_MASK_NONE (C macro), 550
WIFI_EVENT_MAX (C++ enumerator), 557
WIFI_EVENT_MASK_ALL (C++ enumerator), 557
WIFI_EVENT_ROC_DONE (C++ enumerator), 557
wifi_event_roc_done_t::context (C++ member), 549
WIFI_EVENT_SCAN_DONE (C++ enumerator), 556
WIFI_EVENT_STA_AUTHMODE_CHANGE (C++ enumerator), 557
wifi_event_sta_authmode_change_t (C++ class), 546
wifi_event_sta_authmode_change_t::context (C++ member), 549
wifi_event_sta_authmode_change_t::new_mode (C++ member), 546
wifi_event_sta_authmode_change_t::old_mode (C++ member), 546
WIFI_EVENT_STA_BEACON_TIMEOUT (C++ enumerator), 557
WIFI_EVENT_STA_BSS_RSSI_LOW (C++ enumerator), 557
WIFI_EVENT_STA_CONNECTED (C++ enumerator), 556
wifi_event_sta_connected_t (C++ class), 545
wifi_event_sta_connected_t::authmode (C++ member), 546
wifi_event_sta_connected_t::bssid (C++ member), 546
wifi_event_sta_connected_t::channel (C++ member), 546
wifi_event_sta_connected_t::ssid (C++ member), 546
wifi_event_sta_connected_t::ssid_len (C++ member), 546
WIFI_EVENT_STA_DISCONNECTED (C++ enumerator), 557
wifi_event_sta_disconnected_t (C++ class), 546
wifi_event_sta_disconnected_t::bssid (C++ member), 546
wifi_event_sta_disconnected_t::reason (C++ member), 546
wifi_event_sta_disconnected_t::ssid (C++ member), 546
wifi_event_sta_disconnected_t::ssid_len (C++ member), 546
WIFI_EVENT_STA_SCAN_DONE (C++ enumerator), 556
wifi_event_sta_scan_done_t (C++ class), 545
wifi_event_sta_scan_done_t::number (C++ member), 545
wifi_event_sta_scan_done_t::scan_id (C++ member), 545
wifi_event_sta_scan_done_t::status (C++ member), 545
WIFI_EVENT_STA_START (C++ enumerator), 556
WIFI_EVENT_STA_STOP (C++ enumerator), 556
WIFI_EVENT_STA_WPS_ER_FAILED (C++ enumerator), 557
WIFI_EVENT_STA_WPS_ER_PBC_OVERLAP (C++ enumerator), 557
WIFI_EVENT_STA_WPS_ER_PIN (C++ enumerator), 557
wifi_event_sta_wps_er_pin_t (C++ class), 546
wifi_event_sta_wps_er_pin_t::pin_code (C++ member), 546
WIFI_EVENT_STA_WPS_ER_SUCCESS (C++ enumerator), 557
wifi_event_sta_wps_er_success_t (C++ class), 546
wifi_event_sta_wps_er_success_t::ap_cred (C++ member), 547
wifi_event_sta_wps_er_success_t::ap_cred_cnt (C++ member), 546
wifi_event_sta_wps_er_success_t::passphrase (C++ member), 547
wifi_event_sta_wps_er_success_t::ssid (C++ member), 546
WIFI_EVENT_STA_WPS_ER_FAILED (C++ enumerator), 556
wifi_event_sta_wps_er_failed_t (C++ class), 548
wifi_event_sta_wps_er_failed_t::ap_cred (C++ member), 547
wifi_event_sta_wps_er_failed_t::ap_cred_cnt (C++ member), 546
wifi_event_sta_wps_er_failed_t::passphrase (C++ member), 547
wifi_event_sta_wps_er_failed_t::ssid (C++ member), 546
WIFI_EVENT_STA_WPS_ER_PIN (C++ enumerator), 557
wifi_event_sta_wps_er_pin_t (C++ class), 546
wifi_event_sta_wps_er_pin_t::pin_code (C++ member), 546
WIFI_EVENT_STA_STOP (C++ class), 545
WIFI_EVENT_STA_BSS_RSSI_LOW (C++ class), 547
WIFI_EVENT_STA_SCAN_DONE (C++ class), 545
Index

(C++ member), 546
WIFI_EVENT_STA_WPS_ER_TIMEOUT (C++ enumerator), 557
wifi_event_sta_wps_fail_reason_t (C++ enum), 557
wifi_event_t (C++ enum), 556
WIFI_EVENT_WIFI_READY (C++ enumerator), 556
WIFI_FAST_SCAN (C++ enumerator), 553
wifi_ftm_initiator_cfg_t (C++ class), 545
wifi_ftm_initiator_cfg_t::burst_period (C++ member), 545
wifi_ftm_initiator_cfg_t::channel (C++ member), 545
wifi_ftm_initiator_cfg_t::frm_count (C++ member), 545
wifi_ftm_initiator_cfg_t::resp_mac (C++ member), 545
wifi_ftm_report_entry_t (C++ class), 547
wifi_ftm_report_entry_t::dlog_token (C++ member), 548
wifi_ftm_report_entry_t::rssi (C++ member), 548
wifi_ftm_report_entry_t::rtt (C++ member), 548
wifi_ftm_report_entry_t::t1 (C++ member), 548
wifi_ftm_report_entry_t::t2 (C++ member), 548
wifi_ftm_report_entry_t::t3 (C++ member), 548
wifi_ftm_report_entry_t::t4 (C++ member), 548
wifi_ftm_status_t (C++ enum), 557
WIFI_IF_AP (C++ enumerator), 551
WIFI_IF_STA (C++ enumerator), 551
WIFI_INIT_CONFIG_DEFAULT (C macro), 536
WIFI_INIT_CONFIG_MAGIC (C macro), 536
wifi_init_config_t (C++ class), 533
wifi_init_config_t::ampdu_rx_enable (C++ member), 534
wifi_init_config_t::ampdu_tx_enable (C++ member), 534
wifi_init_config_t::amsdu_tx_enable (C++ member), 534
wifi_init_config_t::beacon_max_len (C++ member), 534
wifi_init_config_t::cache_tx_buf_num (C++ member), 534
wifi_init_config_t::csi_enable (C++ member), 534
wifi_init_config_t::dynamic_rx_buf_num (C++ member), 534
wifi_init_config_t::dynamic_tx_buf_num (C++ member), 534
wifi_init_config_t::event_handler (C++ member), 534
wifi_init_config_t::feature_caps (C++ member), 534
wifi_init_config_t::magic (C++ member), 534
wifi_init_config_t::mgmt_sbuf_num (C++ member), 534
wifi_init_config_t::nano_enable (C++ member), 534
wifi_init_config_t::nvs_enable (C++ member), 534
wifi_init_config_t::osi_funcs (C++ member), 534
wifi_init_config_t::rx_ba_win (C++ member), 534
wifi_init_config_t::sta_disconnected_pm (C++ member), 534
wifi_init_config_t::static_rx_buf_num (C++ member), 534
wifi_init_config_t::static_tx_buf_num (C++ member), 534
wifi_init_config_t::tx_buf_type (C++ member), 534
wifi_init_config_t::wifi_task_core_id (C++ member), 534
wifi_init_config_t::wpa_cryptofuncs (C++ member), 534
wifi_interface_t (C++ enum), 551
WIFI_MGMT_SBUF_NUM (C macro), 536
WIFI_MODE_AP (C++ enumerator), 550
WIFI_MODE_APSTA (C++ enumerator), 550
WIFI_MODE_MAX (C++ enumerator), 550
WIFI_MODE_NULL (C++ enumerator), 550
WIFI_MODE_STA (C++ enumerator), 550
wifi_mode_t (C++ enum), 550
WIFI_NANO_FORMAT_ENABLED (C macro), 536
WIFI_NV_S_ENABLE (C macro), 536
WIFI_OFFCHAN_TX_CANCEL (C macro), 549
WIFI_OFFCHAN_TX_REQ (C macro), 549
WIFI_PHY_RATE_11M_L (C++ enumerator), 555
WIFI_PHY_RATE_11M_S (C++ enumerator), 555
WIFI_PHY_RATE_12M (C++ enumerator), 555
WIFI_PHY_RATE_18M (C++ enumerator), 555
WIFI_PHY_RATE_1M_L (C++ enumerator), 555
WIFI_PHY_RATE_24M (C++ enumerator), 555
WIFI_PHY_RATE_2M_L (C++ enumerator), 555
WIFI_PHY_RATE_2M_S (C++ enumerator), 555
WIFI_PHY_RATE_36M (C++ enumerator), 555
WIFI_PHY_RATE_48M (C++ enumerator), 555
WIFI_PHY_RATE_54M (C++ enumerator), 555
WIFI_PHY_RATE_9M (C++ enumerator), 555
WIFI_PHY_RATE_LORA_250K (C++ enumerator), 556
WIFI_PHY_RATE_LORA_500K (C++ enumerator), 556
WIFI_PHY_RATE_MAX (C++ enumerator), 556
WIFI_PHY_RATE_MCS0_LGI (C++ enumerator), 555
WIFI_PHY_RATE_MCS0_SGI (C++ enumerator), wifi_pkt_rx_ctrl_t::cwb (C++ member), 542
WIFI_PHY_RATE_MCS1_LGI (C++ enumerator), wifi_pkt_rx_ctrl_t::fec_coding (C++ member), 542
WIFI_PHY_RATE_MCS1_SGI (C++ enumerator), wifi_pkt_rx_ctrl_t::mcs (C++ member), 542
WIFI_PHY_RATE_MCS2_LGI (C++ enumerator), wifi_pkt_rx_ctrl_t::noise_floor (C++ member), 542
WIFI_PHY_RATE_MCS2_SGI (C++ enumerator), wifi_pkt_rx_ctrl_t::not_sounding (C++ member), 542
WIFI_PHY_RATE_MCS3_LGI (C++ enumerator), wifi_pkt_rx_ctrl_t::rate (C++ member), 542
WIFI_PHY_RATE_MCS3_SGI (C++ enumerator), wifi_pkt_rx_ctrl_t::rssi (C++ member), 542
WIFI_PHY_RATE_MCS4_LGI (C++ enumerator), wifi_pkt_rx_ctrl_t::rx_state (C++ member), 543
WIFI_PHY_RATE_MCS4_SGI (C++ enumerator), wifi_pkt_rx_ctrl_t::secondary_channel (C++ member), 542
WIFI_PHY_RATE_MCS5_LGI (C++ enumerator), wifi_pkt_rx_ctrl_t::sgi (C++ member), 542
WIFI_PHY_RATE_MCS5_SGI (C++ enumerator), wifi_pkt_rx_ctrl_t::sig_len (C++ member), 543
WIFI_PHY_RATE_MCS6_LGI (C++ enumerator), wifi_pkt_rx_ctrl_t::sig_mode (C++ member), 542
WIFI_PHY_RATE_MCS6_SGI (C++ enumerator), wifi_pkt_rx_ctrl_t::smoothing (C++ member), 542
WIFI_PHY_RATE_MCS7_LGI (C++ enumerator), wifi_pkt_rx_ctrl_t::stbc (C++ member), 542
WIFI_PHY_RATE_MCS7_SGI (C++ enumerator), wifi_pkt_rx_ctrl_t::timestamp (C++ member), 542
wifi_pmf_config_t (C++ class), 539
wifi_pmf_config_t::capable (C++ member), 539
wifi_pmf_config_t::required (C++ member), 539
WIFI_PROMIS_CTRL_FILTER_MASK_ACK (C macro), 550
WIFI_PROMIS_CTRL_FILTER_MASK_ALL (C macro), 549
WIFI_PROMIS_CTRL_FILTER_MASK_BAR (C macro), 549
WIFI_PROMIS_CTRL_FILTER_MASK_CTS (C macro), 550
WIFI_PROMIS_CTRL_FILTER_MASK_CFEND (C macro), 550
WIFI_PROMIS_CTRL_FILTER_MASK_CFENDACK (C macro), 550
WIFI_PROMIS_CTRL_FILTER_MASK_CTS (C macro), 550
WIFI_PROMIS_CTRL_FILTER_MASK_PSPOLL (C macro), 549
WIFI_PROMIS_CTRL_FILTER_MASK_RTS (C macro), 549
WIFI_PROMIS_CTRL_FILTER_MASK_WRAPPER (C macro), 549
WIFI_PROMIS_FILTER_MASK_ALL (C macro), 549
WIFI_PROMIS_FILTER_MASK_CTRL (C macro), 549
WIFI_PROMIS_FILTER_MASK_DATA (C macro),
wifi_prov_config_set_data_t::password (C++ member), 1102
wifi_prov_config_set_data_t::channel (C++ member), 1102
wifi_prov_config_set_data_t::bssid (C++ member), 1102
wifi_prov_config_set_data_t::ssid (C++ member), 1102
WIFI.PROV.CRED.FAIL (C++ enumerator), 1099
WIFI.PROV.CRED.RECV (C++ enumerator), 1099
WIFI.PROV.CRED.SUCCESS (C++ enumerator), 1099
wifi_prov_ctx_t (C++ type), 1102
WIFI.PROV.DEINIT (C++ enumerator), 1099
WIFI.PROV.END (C++ enumerator), 1099
WIFI.PROV.EVENT_HANDLER_NONE (C macro), 1098
wifi_prov_event_handler_t (C++ class), 1097
wifi_prov_event_handler_t::event_cb (C++ member), 1097
wifi_prov_event_handler_t::user_data (C++ member), 1097
WIFI.PROV.INIT (C++ enumerator), 1099
wifi_prov_mgr_config_t (C++ class), 1098
wifi_prov_mgr_config_t::app_event_handler (C++ member), 1098
wifi_prov_mgr_config_t::scheme_event_handler (C++ member), 1098
wifi_prov_mgr_config_t::scheme (C++ member), 1098
wifi_prov_mgr_config_t::scheme_handler (C++ function), 1097
wifi_prov_mgr_deinit (C++ function), 1093
wifi_prov_mgr_disable_auto_stop (C++ function), 1095
wifi_prov_mgr_endpoint_create (C++ function), 1095
wifi_prov_mgr_endpoint_register (C++ function), 1096
wifi_prov_mgr_endpoint_unregister (C++ function), 1096
wifi_prov_mgr_get_wifi_disconnect_reason (C++ function), 1096
wifimprov_mgr_get_wifi_state (C++ function), 1096
wifi_prov_mgr_get_wifi_disconnect_reason (C++ function), 1096
wifi_prov_mgr_get_wifi_state (C++ function), 1096
wifi_prov_mgr_init (C++ function), 1093
wifi_prov_mgr_is_provisioned (C++ function), 1093
wifi_prov_mgr_reset_provisioning (C++ function), 1097
wifi_prov_mgr_reset_sm_state_on_failure (C++ function), 1097
wifi_prov_mgr_set_app_info (C++ function), 1095
wifi_prov_mgr_start_provisioning (C++ function), 1094
wifi_prov_mgr_stop_provisioning (C++ function), 1094
wifi_prov_mgr_wait (C++ function), 1094
wifi_prov_scheme (C++ class), 1097
wifi_prov_scheme::delete_config (C++ member), 1102
member), 1098
wifi_prov_scheme::new_config (C++ member), 1098
wifi_prov_scheme::prov_start (C++ member), 1098
wifi_prov_scheme::prov_stop (C++ member), 1098
wifi_prov_scheme::set_config_endpoint (C++ member), 1098
wifi_prov_scheme::set_config_service (C++ member), 1098
wifi_prov_scheme::wifi_mode (C++ member), 1098
wifi_prov_scheme_ble_event_cb_free_ble (C++ function), 1100
wifi_prov_scheme_ble_event_cb_free_bt (C++ function), 1100
wifi_prov_scheme_ble_event_cb_free_btdm (C++ function), 1100
WIFI_PROV.Scheme_BLE.Event_Handler_Free_BLE (C macro), 1100
WIFI_PROV.Scheme_BLE.Event_Handler_Free_BT (C macro), 1100
WIFI_PROV.Scheme_BLE.Event_Handler_Free_BTDM (C macro), 1100
wifi_prov_scheme_t (C++ type), 1099
wifi_prov_security (C++ enum), 1099
WIFI_PROV_SECURITY_0 (C++ enumerator), 1099
WIFI_PROV_SECURITY_1 (C++ enumerator), 1099
wifi_prov_security_t (C++ type), 1099
WIFI_PROV_STA_AP_NOT_FOUND (C++ enumerator), 1103
WIFI_PROV_STA_AUTH_ERROR (C++ enumerator), 1103
wifi_prov_sta_conn_info_t (C++ class), 1101
wifi_prov_sta_conn_info_t::auth_mode (C++ member), 1101
wifi_prov_sta_conn_info_t::bssid (C++ member), 1101
wifi_prov_sta_conn_info_t::channel (C++ member), 1101
wifi_prov_sta_conn_info_t::ip_addr (C++ member), 1101
wifi_prov_sta_conn_info_t::ssid (C++ member), 1101
WIFI_PROV_STA_CONNECTED (C++ enumerator), 1103
WIFI_PROV_STA_CONNECTING (C++ enumerator), 1102
WIFI_PROV_STA_DISCONNECTED (C++ enumerator), 1103
wifi_prov_sta_fail_reason_t (C++ enum), 1103
wifi_prov_sta_state_t (C++ enum), 1102
WIFI_PROV_START (C++ enumerator), 1099
WIFI_PS_MAX_MODEM (C++ enumerator), 1099
WIFI_PS_MIN_MODEM (C++ enumerator), 1099
WIFI_PS_NONE (C++ enumerator), 1099
wifi_ps_type_t (C++ enum), 1099
WIFI_REASON_4WAY_HANDSHAKE_TIMEOUT (C++ enumerator), 1099
WIFI_REASON_802_1X_HANDSHAKE_TIMEOUT (C++ enumerator), 1099
WIFI_REASON_AKMP_INVALID (C++ enumerator), 1099
WIFI_REASON_ASSOC_EXPIRE (C++ enumerator), 1099
WIFI_REASON_ASSOC_FAIL (C++ enumerator), 1099
WIFI_REASON_ASSOC_LEAVE (C++ enumerator), 1099
WIFI_REASON_ASSOC_NOT_AUTHED (C++ enumerator), 1099
WIFI_REASON_ASSOC_TOOMANY (C++ enumerator), 1099
WIFI_REASON_AUTH_EXPIRE (C++ enumerator), 1099
WIFI_REASON_AUTH_FAIL (C++ enumerator), 1099
WIFI_REASON_AUTH_LEAVE (C++ enumerator), 1099
WIFI_REASON_BEACON_TIMEOUT (C++ enumerator), 1099
WIFI_REASON_BSS_TRANSITION_DISASSOC (C++ enumerator), 1099
WIFI_REASON_CIPHER_SUITE_REJECTED (C++ enumerator), 1099
WIFI_REASON_CONNECTION_FAIL (C++ enumerator), 1099
WIFI_REASON_DISASSOC_PNRCAP_BAD (C++ enumerator), 1099
WIFI_REASON_DISASSOC_SUPCHAN_BAD (C++ enumerator), 1099
WIFI_REASON_GROUP_CIPHER_INVALID (C++ enumerator), 1099
WIFI_REASON_GROUP_KEY_UPDATE_TIMEOUT (C++ enumerator), 1099
WIFI_REASON_HANDSHAKE_TIMEOUT (C++ enumerator), 1099
WIFI_REASON_IE_4WAY_DIFFERS (C++ enumerator), 1099
WIFI_REASON_IE_INVALID (C++ enumerator), 1099
WIFI_REASON_MIC_FAILURE (C++ enumerator), 1099
WIFI_REASON_4WAY_HANDSHAKE_TIMEOUT (C++ enumerator), 1099
WIFI_REASON_ASSOC_EXPIRE (C++ enumerator), 1099
WIFI_REASON_ASSOC_FAIL (C++ enumerator), 1099
WIFI_REASON_ASSOC_LEAVE (C++ enumerator), 1099
WIFI_REASON_ASSOC_NOT_AUTHED (C++ enumerator), 1099
WIFI_REASON_ASSOC_TOOMANY (C++ enumerator), 1099
WIFI_REASON_AUTH_EXPIRE (C++ enumerator), 1099
WIFI_REASON_AUTH_FAIL (C++ enumerator), 1099
WIFI_REASON_AUTH_LEAVE (C++ enumerator), 1099
WIFI_REASON_BEACON_TIMEOUT (C++ enumerator), 1099
WIFI_REASON_BSS_TRANSITION_DISASSOC (C++ enumerator), 1099
WIFI_REASON_CIPHER_SUITE_REJECTED (C++ enumerator), 1099
WIFI_REASON_CONNECTION_FAIL (C++ enumerator), 1099
WIFI_REASON_DISASSOC_PNRCAP_BAD (C++ enumerator), 1099
WIFI_REASON_DISASSOC_SUPCHAN_BAD (C++ enumerator), 1099
WIFI_REASON_GROUP_CIPHER_INVALID (C++ enumerator), 1099
WIFI_REASON_GROUP_KEY_UPDATE_TIMEOUT (C++ enumerator), 1099
WIFI_REASON_HANDSHAKE_TIMEOUT (C++ enumerator), 1099
WIFI_REASON_IE_4WAY_DIFFERS (C++ enumerator), 1099
WIFI_REASON_IE_INVALID (C++ enumerator), 1099
WIFI_REASON_MIC_FAILURE (C++ enumerator), 1099
WIFI_VND_IE_TYPE_ASSOC_REQ (C++ enumerator), 554
WIFI_VND_IE_TYPE_ASSOC_RESP (C++ enumerator), 554
WIFI_VND_IE_TYPE_BEACON (C++ enumerator), 554
WIFI_VND_IE_TYPE_PROBE_REQ (C++ enumerator), 554
WIFI_VND_IE_TYPE_PROBE_RESP (C++ enumerator), 554
xMessageBufferSpacesAvailable (C macro), 1355
xQueueAddToSet (C++ function), 1292
xQueueCreate (C macro), 1293
xQueueCreateSet (C++ function), 1291
xQueueCreateStatic (C macro), 1294
xQueueGenericCreate (C++ function), 1291
xQueueGenericCreateStatic (C++ function), 1291
xQueueGenericSend (C++ function), 1284
xQueueGenericSendFromISR (C++ function), 1288
xQueueGiveFromISR (C++ function), 1289
xQueueIsQueueEmptyFromISR (C++ function), 1290
xQueueIsQueueFullFromISR (C++ function), 1290
xQueueOverwrite (C macro), 1298
xQueueOverwriteFromISR (C macro), 1300
xQueuePeek (C++ function), 1285
xQueuePeekFromISR (C++ function), 1286
xQueueReceive (C++ function), 1287
xQueueReceiveFromISR (C++ function), 1289
xQueueRemoveFromSet (C++ function), 1292
xQueueReset (C macro), 1302
xQueueSelectFromSet (C++ function), 1292
xQueueSelectFromSetFromISR (C++ function), 1293
xQueueSend (C macro), 1296
xQueueSendFromISR (C macro), 1301
xQueueSendToFront (C macro), 1295
xQueueSendToFrontFromISR (C macro), 1299
xQueueSendToFront (C macro), 1295
xQueueSendToFromISR (C macro), 1299
xRingbufferAddToQueueSetRead (C++ function), 1370
xRingbufferCanRead (C++ function), 1370
xRingbufferCreate (C++ function), 1366
xRingbufferCreateNoSplit (C++ function), 1366
xRingbufferCreateStatic (C++ function), 1366
xRingbufferGetCurFreeSize (C++ function), 1370
xRingbufferGetMaxItemSize (C++ function), 1369
xRingbufferPrintInfo (C++ function), 1371
xRingbufferReceive (C++ function), 1367
xRingbufferReceiveFromISR (C++ function), 1367
xRingbufferReceiveSplit (C++ function), 1368
xRingbufferReceiveSplitFromISR (C++ function), 1368
xRingbufferReceiveUpTo (C++ function), 1368
xRingbufferReceiveUpToFromISR (C++ function), 1369
xRingbufferRemoveFromQueueSetRead
xtensa_perfmon_exec (C++ function), 1439
xtensa_perfmon_init (C++ function), 1438
xtensa_perfmon_overflow (C++ function), 1438
xtensa_perfmon_reset (C++ function), 1438
xtensa_perfmon_start (C++ function), 1438
xtensa_perfmon_stop (C++ function), 1438
xtensa_perfmon_value (C++ function), 1438
xtensa_perfmon_view_cb (C++ function), 1439
xTimerChangePeriod (C macro), 1324
xTimerChangePeriodFromISR (C macro), 1330
xTimerCreate (C++ function), 1315
xTimerCreateStatic (C++ function), 1317
xTimerDelete (C macro), 1325
xTimerGetExpiryTime (C++ function), 1322
xTimerGetPeriod (C++ function), 1322
xTimerGetTimerDaemonTaskHandle (C++ function), 1320
xTimerIsTimerActive (C++ function), 1320
xTimerPendFunctionCall (C++ function), 1321
xTimerPendFunctionCallFromISR (C++ function), 1320
xTimerReset (C macro), 1326
xTimerResetFromISR (C macro), 1331
xTimerStart (C macro), 1323
xTimerStartFromISR (C macro), 1328
xTimerStop (C macro), 1324
xTimerStopFromISR (C macro), 1329