ESP32
ESP-IDF 编程指南
Table of contents

Table of contents

1 快速入门 i

1.1 概述 .................................................. 3
1.2 准备工作 ................................................. 3
1.3 开发板简介 ............................................... 3
1.4 详细安装步骤 ............................................ 5
   1.4.1 设置开发环境 .................................. 5
   1.4.2 创建您的第一个工程 ................................. 5
1.5 第一步：安装准备 ......................................... 5
   1.5.1 Windows 平台工具链的标准设置 ......................... 5
   1.5.2 Linux 平台工具链的标准设置 ......................... 7
   1.5.3 MacOS 平台工具链的标准设置 ....................... 7
1.6 第二步：获取 ESP-IDF .................................... 8
   1.6.1 Linux 和 MacOS 操作系统 .................................. 9
   1.6.2 Windows 操作系统 .................................. 9
1.7 第三步：设置工具 ........................................ 9
   1.7.1 Windows 操作系统 .................................. 9
   1.7.2 Linux 和 MacOS 操作系统 ............................. 9
   1.7.3 自定义工具安装路径 ................................ 9
1.8 第四步：设置环境变量 .................................... 10
   1.8.1 Windows 操作系统 .................................. 10
   1.8.2 Linux 和 MacOS 操作系统 ............................. 10
1.9 第五步：开始创建工程 .................................. 10
   1.9.1 Linux 和 MacOS 操作系统 ............................. 10
   1.9.2 Windows 操作系统 .................................. 10
1.10 第六步：连接设备 ....................................... 11
1.11 第七步：配置 ........................................... 11
   1.11.1 Linux 和 MacOS 操作系统 ............................. 11
   1.11.2 Windows 操作系统 .................................. 11
1.12 第八步：编译工程 ....................................... 11
1.13 第九步：烧录到设备 .................................... 12
1.14 第十步：监视器 ......................................... 13
1.15 更新 ESP-IDF ........................................... 14
1.16 相关文档 ............................................... 14
   1.16.1 与 ESP32 创建串口连接 ............................... 14
   1.16.2 Eclipse IDE 创建和烧录指南 .......................... 20
   1.16.3 Getting Started with VS Code IDE ...................... 20
   1.16.4 IDF 监视器 ......................................... 21
   1.16.5 工具链的自定义设置 ................................ 24
   1.16.6 快速入门（传统 GNU Make） ......................... 29

2 API 参考 ................................................. 53

2.1 蓝牙 API ............................................... 53
   2.1.1 Controller && VHCI ..................................... 53
   2.1.2 BT COMMON ........................................ 61
   2.1.3 BT LE ............................................... 65
| 2.1.4  | CLASSIC BT                                      | 140 |
| 2.1.5  | NimBLE-based host APIs                         | 213 |
| 2.1.6  | ESP-BLE-MESH                                    | 909 |
| 2.2    | 连网 API                                        | 215 |
| 2.2.1  | Wi-Fi                                          | 422 |
| 2.2.2  | 以太网                                         | 422 |
| 2.2.3  | IP 网络层协议                                   | 495 |
| 2.2.4  | 应用层协议                                     | 510 |
| 2.3    | 外设 API                                        | 525 |
| 2.3.1  | Analog to Digital Converter                    | 525 |
| 2.3.2  | Digital To Analog Converter                    | 543 |
| 2.3.3  | GPIO & RTC GPIO                                 | 546 |
| 2.3.4  | I2C 驱动程序                                    | 559 |
| 2.3.5  | I2S                                             | 571 |
| 2.3.6  | LED PWM 控制器                                  | 583 |
| 2.3.7  | MCPWM                                           | 595 |
| 2.3.8  | Pulse Counter                                   | 613 |
| 2.3.9  | RMT                                             | 622 |
| 2.3.10 | SDMMC Host Driver                               | 639 |
| 2.3.11 | SD SPI Host Driver                              | 643 |
| 2.3.12 | SDIO Card Slave Driver                         | 647 |
| 2.3.13 | Sigma-delta Modulation                          | 658 |
| 2.3.14 | SPI Master Driver                               | 660 |
| 2.3.15 | SPI Slave Driver                                | 680 |
| 2.3.16 | ESP32-WROOM-32SE (Secure Element)               | 687 |
| 2.3.17 | 定时器                                          | 687 |
| 2.3.18 | 触摸传感器                                     | 697 |
| 2.3.19 | TWAI                                            | 710 |
| 2.3.20 | UART                                            | 725 |
| 2.4    | 应用层协议                                      | 748 |
| 2.4.1  | mDNS 服务                                       | 748 |
| 2.4.2  | ESP-TLS                                         | 756 |
| 2.4.3  | ESP HTTP Client                                 | 767 |
| 2.4.4  | ESP WebSocket Client                            | 779 |
| 2.4.5  | HTTP 服务器                                    | 786 |
| 2.4.6  | HTTPS server                                    | 807 |
| 2.4.7  | ICMP Echo                                       | 809 |
| 2.4.8  | ASIO port                                       | 813 |
| 2.4.9  | ESP-MQTT                                        | 814 |
| 2.4.10 | ESP-Modbus                                      | 824 |
| 2.4.11 | ESP Local Control                               | 829 |
| 2.4.12 | ESP Serial Slave Link                          | 836 |
| 2.4.13 | ESP x509 Certificate Bundle                    | 849 |
| 2.4.14 | IP 网络层协议                                   | 851 |
| 2.5    | 配网 API                                        | 851 |
| 2.5.1  | Unified Provisioning                            | 851 |
| 2.5.2  | Protocol Communication                           | 856 |
| 2.5.3  | Wi-Fi Provisioning                              | 865 |
| 2.6    | 存储 API                                        | 881 |
| 2.6.1  | SPI Flash API                                   | 881 |
| 2.6.2  | SD/SDIO/MMC 驱动程序                            | 900 |
| 2.6.3  | NVS 分区生成程序                               | 909 |
| 2.6.4  | NVS 分区生成程序                               | 926 |
| 2.6.5  | 虚拟文件系统组件                               | 931 |
| 2.6.6  | FAT 文件系统                                    | 942 |
| 2.6.7  | 模拟均衡 API                                   | 946 |
| 2.6.8  | SPIFFS 文件系统                                | 949 |
| 2.6.9  | 量产程序                                       | 953 |
# API

2.7 System API .......................................................... 957
  2.7.1 App Image Format ............................................... 957
  2.7.2 Application Level Tracing .................................... 962
  2.7.3 控制台终端 ..................................................... 966
  2.7.4 eFuse Manager .................................................. 974
  2.7.5 Error Codes and Helper Functions ....................... 984
  2.7.6 ESP HTTPS OTA ................................................. 985
  2.7.7 ESP-pthread .................................................... 989
  2.7.8 Event Loop Library ............................................. 991
  2.7.9 FreeRTOS ........................................................ 1006
  2.7.10 FreeRTOS Additions .......................................... 1099
  2.7.11 Heap Memory Allocation .................................... 1116
  2.7.12 Heap Memory Debugging .................................... 1127
  2.7.13 High Resolution Timer ..................................... 1137
  2.7.14 The himem allocation API .................................. 1141
  2.7.15 Inter-Processor Call ....................................... 1144
  2.7.16 Call function with external stack ...................... 1145
  2.7.17 Interrupt allocation ....................................... 1146
  2.7.18 Logging library .............................................. 1152
  2.7.19 Miscellaneous System APIs ................................. 1157
  2.7.20 空中升级 (OTA) ............................................... 1164
  2.7.21 Performance Monitor ....................................... 1173
  2.7.22 电源管理 ................................................... 1175
  2.7.23 Sleep Modes ................................................... 1180
  2.7.24 Watchdogs ................................................... 1188
  2.7.25 System Time .................................................. 1191
  2.7.26 Internal and Unstable APIs ............................... 1196

2.8 Project Configuration ................................. 1196
  2.8.1 Introduction .................................................. 1196
  2.8.2 Project Configuration Menu ............................... 1196
  2.8.3 Using sdkconfig.defaults .................................. 1197
  2.8.4 Kconfig Formatting Rules .................................. 1197
  2.8.5 Backward Compatibility of Kconfig Options .......... 1197
  2.8.6 Configuration Options Reference ...................... 1198
  2.8.7 Customisations .............................................. 1376

2.9 Error Codes Reference ................................. 1376

3 ESP32 H/W 硬件参考 ................................. 1383
  3.1 ESP32 系列模块和开发板 ................................. 1383
    3.1.1 相关文档 .................................................. 1383
  3.2 ESP32 模块与开发板（历史版本） ...................... 1383
    3.2.1 相关文档 .................................................. 1383

4 API 指南 ................................. 1385
  4.1 ESP-IDF 编程注意事项 ................................. 1385
    4.1.1 应用程序的启动流程 .................................. 1385
    4.1.2 应用程序的内存布局 .................................. 1386
    4.1.3 DMA 能力要求 ............................................. 1388
  4.2 构建系统 (CMake 版) ........................................ 1389
    4.2.1 概述 ....................................................... 1389
    4.2.2 使用构建系统 ............................................. 1389
    4.2.3 示例项目 .................................................. 1392
    4.2.4 项目 CMakeLists 文件 .................................. 1393
    4.2.5 组件 CMakeLists 文件 .................................. 1394
    4.2.6 组件配置 .................................................. 1396
    4.2.7 预处理器定义 ............................................. 1396
    4.2.8 组件依赖 .................................................. 1396
    4.2.9 构建的内部过程 ........................................... 1397
| 4.2.10  | 组件 CMakeLists 示例 | 1399 |
| 4.2.11  | 自定义 sdkconfig 的默认值 | 1402 |
| 4.2.12  | Flash 参数 | 1403 |
| 4.2.13  | 构建 Bootloader | 1403 |
| 4.2.14  | 选择“目标”芯片 | 1403 |
| 4.2.15  | 编写纯 CMake 组件 | 1404 |
| 4.2.16  | 组件中使用第三方 CMake 项目 | 1404 |
| 4.2.17  | 在自定义 CMake 项目中使用 ESP- IDF | 1405 |
| 4.2.18  | 文件通用符号 & 增量构建 | 1405 |
| 4.2.19  | 构建系统的元数据 | 1405 |
| 4.2.20  | 从 ESP-IDF GNU Make 构建系统迁移到 CMake 构建系统 | 1406 |
| 4.3    | 构建系统 (传统 GNU Make) | 1407 |
| 4.3.1  | 使用构建系统 | 1407 |
| 4.3.2  | 概述 | 1408 |
| 4.3.3  | 构建 Bootloader | 1417 |
| 4.4    | 错误处理 | 1417 |
| 4.4.1  | 概述 | 1417 |
| 4.4.2  | 错误码 | 1417 |
| 4.4.3  | 错误码到错误消息 | 1417 |
| 4.4.4  | ESP_ERROR_CHECK 宏 | 1418 |
| 4.4.5  | 错误处理模式 | 1418 |
| 4.4.6  | C++ 异常 | 1419 |
| 4.5    | 严重错误 | 1419 |
| 4.5.1  | 概述 | 1419 |
| 4.5.2  | 紧急处理程序 | 1419 |
| 4.5.3  | 寄存器转储与回溯 | 1420 |
| 4.5.4  | GDB Stub | 1422 |
| 4.5.5  | Guru Meditation 错误 | 1423 |
| 4.5.6  | 其它严重错误 | 1424 |
| 4.6    | Event Handling | 1425 |
| 4.6.1  | Wi-Fi, Ethernet, and IP Events | 1425 |
| 4.6.2  | Mesh Events | 1426 |
| 4.6.3  | Bluetooth Events | 1427 |
| 4.7    | Deep Sleep Wake Stubs | 1427 |
| 4.7.1  | Rules for Wake Stubs | 1427 |
| 4.7.2  | Implementing A Stub | 1427 |
| 4.7.3  | Loading Code Into RTC Memory | 1428 |
| 4.7.4  | Loading Data Into RTC Memory | 1428 |
| 4.8    | Core Dump | 1429 |
| 4.8.1  | Overview | 1429 |
| 4.8.2  | Configuration | 1429 |
| 4.8.3  | Save core dump to flash | 1430 |
| 4.8.4  | Print core dump to UART | 1430 |
| 4.8.5  | ROM Functions in Backtraces | 1430 |
| 4.8.6  | Dumping variables on demand | 1430 |
| 4.8.7  | Running ‘espcoredump.py’ | 1431 |
| 4.9    | Flash 加密 | 1431 |
| 4.9.1  | 概述 | 1431 |
| 4.9.2  | Flash 加密过程中使用的 eFuse | 1432 |
| 4.9.3  | Flash 的加密过程 | 1433 |
| 4.9.4  | 设置 Flash 加密的步骤 | 1433 |
| 4.9.5  | Flash 加密的要点 | 1439 |
| 4.9.6  | 使用加密的 Flash | 1439 |
| 4.9.7  | 更新加密的 Flash | 1440 |
| 4.9.8  | 关闭 Flash 加密 | 1440 |
| 4.9.9  | Flash 加密的局限性 | 1441 |
| 4.9.10 | Flash 加密与安全启动 | 1441 |
| 4.9.11 | 使用无安全启动的 Flash 加密 | 1441 |
4.9.12 Flash 加密的高级功能 ........................................... 1441
4.9.13 技术细节 ....................................................... 1442
4.10 ESP-IDF FreeRTOS SMP Changes .................................. 1443
  4.10.1 Overview .................................................... 1443
  4.10.2 Tasks and Task Creation .................................... 1443
  4.10.3 Scheduling .................................................. 1444
  4.10.4 Critical Sections & Disabling Interrupts .................... 1446
  4.10.5 Floating Point Arithmetic .................................... 1447
  4.10.6 Task Deletion ................................................ 1447
  4.10.7 Thread Local Storage Pointers & Deletion Callbacks ........ 1447
  4.10.8 Configuring ESP-IDF FreeRTOS ................................ 1447
4.11 Thread Local Storage ................................................ 1448
  4.11.1 Overview .................................................... 1448
  4.11.2 FreeRTOS Native API ....................................... 1448
  4.11.3 Pthread API ................................................. 1448
  4.11.4 C11 Standard ................................................ 1448
4.12 Hardware Abstraction ............................................... 1449
  4.12.1 Architecture ................................................. 1449
  4.12.2 LL (Low Level) Layer ....................................... 1450
  4.12.3 HAL (Hardware Abstraction Layer) .......................... 1451
4.13 High-Level Interrupts .............................................. 1452
  4.13.1 Interrupt Levels ............................................ 1452
  4.13.2 Notes ....................................................... 1452
4.14 JTAG 调试 ......................................................... 1453
  4.14.1 引言 ....................................................... 1453
  4.14.2 工作原理 .................................................. 1453
  4.14.3 选择 JTAG 适配器 ....................................... 1454
  4.14.4 安装 OpenOCD ............................................. 1454
  4.14.5 配置 ESP32 目标板 ....................................... 1455
  4.14.6 启动调试器 ................................................. 1460
  4.14.7 调试范例 .................................................. 1460
  4.14.8 从源码构建 OpenOCD ..................................... 1460
  4.14.9 注意事项和补充内容 ..................................... 1464
  4.14.10 相关文档 ................................................ 1468
4.15 引导加载程序（Bootloader） .................................... 1500
  4.15.1 恢复出厂设置 ............................................. 1500
  4.15.2 从测试固件启动 ........................................... 1501
  4.15.3 自定义引导程序 .......................................... 1501
4.16 分区表 ......................................................... 1501
  4.16.1 概述 ....................................................... 1501
  4.16.2 内置分区表 ................................................ 1501
  4.16.3 创建自定义分区表 ....................................... 1502
  4.16.4 生成二进制分区表 ....................................... 1503
  4.16.5 烧写分区表 ................................................ 1504
  4.16.6 分区工具 (parttool.py) .................................. 1504
4.17 Secure Boot ........................................................ 1505
  4.17.1 Background .................................................. 1506
  4.17.2 Secure Boot Process Overview ................................ 1506
  4.17.3 Keys ........................................................ 1506
  4.17.4 Bootloader Size ............................................ 1507
  4.17.5 How To Enable Secure Boot .................................. 1507
  4.17.6 Re-Flashable Software Bootloader .......................... 1508
  4.17.7 Generating Secure Boot Signing Key ......................... 1509
  4.17.8 Remote Signing of Images ................................... 1509
  4.17.9 Secure Boot Best Practices .................................. 1509
  4.17.10 Technical Details ........................................... 1509
  4.17.11 Secure Boot & Flash Encryption ............................ 1511
  4.17.12 Signed App Verification Without Hardware Secure Boot .... 1511


<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.17.13 Advanced Features</td>
<td>1511</td>
</tr>
<tr>
<td>4.18 Secure Boot V2</td>
<td>1512</td>
</tr>
<tr>
<td>4.18.1 Background</td>
<td>1512</td>
</tr>
<tr>
<td>4.18.2 Advantages</td>
<td>1512</td>
</tr>
<tr>
<td>4.18.3 Secure Boot V2 Process</td>
<td>1512</td>
</tr>
<tr>
<td>4.18.4 Signature Block Format</td>
<td>1513</td>
</tr>
<tr>
<td>4.18.5 Verifying the signature Block</td>
<td>1513</td>
</tr>
<tr>
<td>4.18.6 Bootloader Size</td>
<td>1513</td>
</tr>
<tr>
<td>4.18.7 eFuse usage</td>
<td>1514</td>
</tr>
<tr>
<td>4.18.8 How To Enable Secure Boot V2</td>
<td>1514</td>
</tr>
<tr>
<td>4.18.9 Restrictions after Secure Boot is enabled</td>
<td>1515</td>
</tr>
<tr>
<td>4.18.10 Generating Secure Boot Signing Key</td>
<td>1515</td>
</tr>
<tr>
<td>4.18.11 Remote Signing of Images</td>
<td>1515</td>
</tr>
<tr>
<td>4.18.12 Secure Boot Best Practices</td>
<td>1515</td>
</tr>
<tr>
<td>4.18.13 Technical Details</td>
<td>1515</td>
</tr>
<tr>
<td>4.18.14 Secure Boot &amp; Flash Encryption</td>
<td>1516</td>
</tr>
<tr>
<td>4.18.15 Advanced Features</td>
<td>1516</td>
</tr>
<tr>
<td>4.19 ULP 协处理器编程</td>
<td>1516</td>
</tr>
<tr>
<td>4.19.1 ESP32 ULP coprocessor instruction set</td>
<td>1516</td>
</tr>
<tr>
<td>4.19.2 Programming ULP coprocessor using C macros (legacy)</td>
<td>1529</td>
</tr>
<tr>
<td>4.19.3 安装工具链</td>
<td>1534</td>
</tr>
<tr>
<td>4.19.4 编译 ULP 代码</td>
<td>1534</td>
</tr>
<tr>
<td>4.19.5 访问 ULP 程序变量</td>
<td>1535</td>
</tr>
<tr>
<td>4.19.6 启动 ULP 程序</td>
<td>1535</td>
</tr>
<tr>
<td>4.19.7 ULP 程序流</td>
<td>1537</td>
</tr>
<tr>
<td>4.20 ULP 协处理器 (传统的 GNU Make)</td>
<td>1537</td>
</tr>
<tr>
<td>4.20.1 安装工具链</td>
<td>1538</td>
</tr>
<tr>
<td>4.20.2 编译 ULP 代码</td>
<td>1538</td>
</tr>
<tr>
<td>4.20.3 访问 ULP 程序变量</td>
<td>1538</td>
</tr>
<tr>
<td>4.20.4 启动 ULP 程序</td>
<td>1539</td>
</tr>
<tr>
<td>4.20.5 ULP 程序流</td>
<td>1540</td>
</tr>
<tr>
<td>4.21 ESP32 中的单元测试</td>
<td>1541</td>
</tr>
<tr>
<td>4.21.1 添加常规测试用例</td>
<td>1541</td>
</tr>
<tr>
<td>4.21.2 添加多设备测试用例</td>
<td>1542</td>
</tr>
<tr>
<td>4.21.3 添加多阶段测试用例</td>
<td>1543</td>
</tr>
<tr>
<td>4.21.4 应用于不同芯片的单元测试</td>
<td>1543</td>
</tr>
<tr>
<td>4.21.5 编译单元测试程序</td>
<td>1544</td>
</tr>
<tr>
<td>4.21.6 运行单元测试</td>
<td>1544</td>
</tr>
<tr>
<td>4.22 单元测试 (传统的 GNU Make)</td>
<td>1545</td>
</tr>
<tr>
<td>4.22.1 添加常规测试用例</td>
<td>1546</td>
</tr>
<tr>
<td>4.22.2 添加多设备测试用例</td>
<td>1546</td>
</tr>
<tr>
<td>4.22.3 添加多阶段测试用例</td>
<td>1547</td>
</tr>
<tr>
<td>4.22.4 编译单元测试程序</td>
<td>1548</td>
</tr>
<tr>
<td>4.22.5 运行单元测试</td>
<td>1548</td>
</tr>
<tr>
<td>4.23 ESP32 ROM console</td>
<td>1549</td>
</tr>
<tr>
<td>4.23.1 Full list of supported statements and functions</td>
<td>1549</td>
</tr>
<tr>
<td>4.23.2 Example programs</td>
<td>1550</td>
</tr>
<tr>
<td>4.23.3 Credits</td>
<td>1551</td>
</tr>
<tr>
<td>4.24 RF calibration</td>
<td>1551</td>
</tr>
<tr>
<td>4.24.1 Partial calibration</td>
<td>1551</td>
</tr>
<tr>
<td>4.24.2 Full calibration</td>
<td>1551</td>
</tr>
<tr>
<td>4.24.3 No calibration</td>
<td>1551</td>
</tr>
<tr>
<td>4.24.4 PHY initialization data</td>
<td>1552</td>
</tr>
<tr>
<td>4.25 Wi-Fi Driver</td>
<td>1552</td>
</tr>
<tr>
<td>4.25.1 ESP32 Wi-Fi Feature List</td>
<td>1552</td>
</tr>
<tr>
<td>4.25.2 How To Write a Wi-Fi Application</td>
<td>1552</td>
</tr>
<tr>
<td>4.25.3 ESP32 Wi-Fi API Error Code</td>
<td>1553</td>
</tr>
<tr>
<td>4.25.4 ESP32 Wi-Fi API Parameter Initialization</td>
<td>1553</td>
</tr>
</tbody>
</table>

vi
4.25.5 ESP32 Wi-Fi Programming Model .............................................. 1553
4.25.6 ESP32 Wi-Fi Event Description ........................................... 1554
4.25.7 ESP32 Wi-Fi Station General Scenario ............................... 1557
4.25.8 ESP32 Wi-Fi AP General Scenario ....................................... 1559
4.25.9 ESP32 Wi-Fi Scan ............................................................... 1561
4.25.10 ESP32 Wi-Fi Station Connecting Scenario ......................... 1567
4.25.11 ESP32 Wi-Fi Station Connecting When Multiple APs Are Found 1571
4.25.12 Wi-Fi Reconnect .............................................................. 1571
4.25.13 Wi-Fi Beacon Timeout ..................................................... 1571
4.25.14 ESP32 Wi-Fi Configuration ........................................... 1571
4.25.15 Wi-Fi Security ................................................................. 1577
4.25.16 ESP32 Wi-Fi Power-saving Mode ..................................... 1578
4.25.17 ESP32 Wi-Fi Throughput .................................................. 1578
4.25.18 Wi-Fi 80211 Packet Send ............................................... 1578
4.25.19 Wi-Fi Sniffer Mode ......................................................... 1581
4.25.20 Wi-Fi Multiple Antennas .................................................. 1581
4.25.21 Wi-Fi Channel State Information ....................................... 1582
4.25.22 Wi-Fi Channel State Information Configure ........................ 1583
4.25.23 Wi-Fi HT20/40 ................................................................ 1584
4.25.24 Wi-Fi QoS ........................................................................ 1584
4.25.25 Wi-Fi AMSDU ................................................................. 1585
4.25.26 Wi-Fi Fragment ................................................................. 1585
4.25.27 WPS Enrolle .................................................................. 1585
4.25.28 Wi-Fi Buffer Usage ........................................................... 1585
4.25.29 How to improve Wi-Fi performance .................................... 1586
4.25.30 Wi-Fi Menuconfig ............................................................ 1588
4.25.31 Troubleshooting ............................................................... 1591
4.26 ESP-BLE-MESH ................................................................. 1596
4.26.1 概述 .............................................................................. 1596
4.26.2 ESP-BLE-MESH 快速入门 .............................................. 1597
4.26.3 ESP-BLE-MESH 示例 ....................................................... 1601
4.26.4 ESP-BLE-MESH 演示视频 .............................................. 1604
4.26.5 ESP-BLE-MESH 常见问题手册 ........................................ 1604
4.26.6 相关文档 ...................................................................... 1604
4.27 ESP-MESH ................................................................. 1630
4.27.1 概述 .............................................................................. 1630
4.27.2 简介 .............................................................................. 1631
4.27.3 ESP-MESH 概念 ............................................................. 1632
4.27.4 建立网络 ...................................................................... 1636
4.27.5 管理网络 ..................................................................... 1641
4.27.6 数据传输 ...................................................................... 1643
4.27.7 信道切换 ...................................................................... 1646
4.27.8 性能 ............................................................................. 1648
4.27.9 更多注意事项 ............................................................... 1649
4.28 BluFi ................................................................. 1649
4.28.1 概览 ............................................................................. 1649
4.28.2 BluFi 流程 ................................................................... 1649
4.28.3 ESP32 配网流程 ............................................................ 1649
4.28.4 配网流程图 ................................................................. 1649
4.28.5 BluFi 传输格式 .............................................................. 1651
4.28.6 ESP32 端的安全实现 ..................................................... 1654
4.28.7 GATT 相关说明 ............................................................ 1655
4.29 片外 RAM ................................................................. 1655
4.29.1 简介 ............................................................................. 1655
4.29.2 硬件 ............................................................................. 1655
4.29.3 配置片外 RAM ............................................................ 1656
4.29.4 片外 RAM 使用限制 ..................................................... 1657
4.29.5 Chip revisions ............................................................... 1657
4.30 链接脚本生成机制.................................................. 1658
  4.30.1 概述 ......................................................... 1658
  4.30.2 快速上手 ..................................................... 1658
  4.30.3 链接脚本生成机制内核 ....................................... 1661
4.31 lwIP ............................................................. 1666
  4.31.1 Supported APIs .............................................. 1666
  4.31.2 BSD Sockets API ............................................ 1666
  4.31.3 Netconn API .................................................. 1670
  4.31.4 lwIP FreeRTOS Task .......................................... 1670
  4.31.5 esp-lwip custom modifications ............................... 1671
  4.31.6 Performance Optimization .................................... 1671
4.32 工具 ............................................................. 1673
  4.32.1 Downloadable Tools ........................................... 1673
  4.32.2 IDF Docker Image ............................................. 1680

5 Libraries and Frameworks ........................................... 1683
  5.1 Cloud Frameworks ................................................. 1683
    5.1.1 AWS IoT ...................................................... 1683
    5.1.2 Azure IoT .................................................... 1683
    5.1.3 Google IoT Core ............................................. 1683
    5.1.4 Aliyun IoT .................................................... 1683
    5.1.5 Joylink IoT ................................................... 1683
    5.1.6 Tencent IoT .................................................. 1683
    5.1.7 Tencentyun IoT ............................................... 1684
    5.1.8 Baidu IoT .................................................... 1684

6 Contributions Guide ............................................... 1685
  6.1 How to Contribute ................................................. 1685
  6.2 Before Contributing .............................................. 1685
  6.3 Pull Request Process ............................................. 1685
  6.4 Legal Part ........................................................ 1685
  6.5 Related Documents ............................................... 1686
    6.5.1 Espressif IoT Development Framework Style Guide ............ 1686
    6.5.2 编写代码文档 ................................................. 1692
    6.5.3 文件的附加工具和扩展功能指南 ........................... 1701
    6.5.4 创建示例项目 ............................................... 1704
    6.5.5 API Documentation Template ................................ 1705
    6.5.6 Contributor Agreement ...................................... 1707

7 ESP-IDF 版本简介 .................................................. 1711
  7.1 发布版本 ....................................................... 1711
  7.2 我该选择哪个版本？ ............................................. 1712
  7.3 版本管理 ....................................................... 1712
  7.4 支持期限 ....................................................... 1713
  7.5 查看当前版本 ................................................... 1713
  7.6 Git 工作流 ...................................................... 1714
  7.7 更新 ESP-IDF ................................................... 1714
    7.7.1 更新至一个稳定发布版本 .................................... 1715
    7.7.2 更新至一个预发布版本 ...................................... 1715
    7.7.3 更新至 master 分支 .......................................... 1715
    7.7.4 更新至一个发布分支 ........................................ 1715

8 资源 .............................................................. 1717
  8.1 PlatformIO ....................................................... 1717
    8.1.1 What is PlatformIO? ......................................... 1717
    8.1.2 Installation ................................................. 1717
    8.1.3 Configuration ................................................. 1718
    8.1.4 Tutorials ..................................................... 1718
    8.1.5 Project Examples .............................................. 1718
8.1.6 Next Steps ............................................................... 1718
8.2 有用的链接 ........................................................... 1718

9 Copyrights and Licenses .............................................. 1719
  9.1 Software Copyrights ................................................ 1719
    9.1.1 Firmware Components ....................................... 1719
    9.1.2 Build Tools ..................................................... 1720
    9.1.3 Documentation ................................................ 1720
  9.2 ROM Source Code Copyrights .................................... 1720
  9.3 Xtensa libhal MIT License ....................................... 1720
  9.4 TinyBasic Plus MIT License .................................... 1721
  9.5 TJpgDec License .................................................... 1721

10 关于本指南 ......................................................... 1723

11 Switch Between Languages/切换语言 ............................. 1725

索引 ............................................................................. 1727

索引 ............................................................................. 1727
这里是乐鑫 IoT 开发框架 (esp-idf) 的文档中心。ESP-IDF 是 ESP32 和 ESP32-S2 系列芯片的官方开发框架。

ESP-IDF 是 ESP32 芯片的官方开发框架。
Chapter 1

快速入门

本文档旨在指导用户搭建 ESP32 硬件开发的软件环境。通过一个简单的示例展示如何使用 ESP-IDF (Espressif IoT Development Framework) 配置菜单，编译、下载固件至 ESP32 开发板等步骤。

注解：这是 ESP-IDF master 分支（最新版本）的文档，该版本在持续开发中。还有 Stable version 的文档，以及其他版本的文档 ESP-IDF 版本简介 供参考。

1.1 概述

ESP32 采用 40 nm 工艺制成，具有最佳的功耗性能、射频性能、稳定性、通用性和可靠性，适用于各种应用场景和不同功耗需求。

乐鑫为用户提供完整的软、硬件资源，进行 ESP32 硬件设备的开发。其中，乐鑫的软件开发环境 ESP-IDF 旨在协助用户快速开发物联网 (IoT) 应用，可满足用户对 Wi-Fi、蓝牙、低功耗等方面的要求。

1.2 准备工作

硬件：
- 一款 ESP32 开发板
- USB 数据线 (A 转 Micro-B)
- PC（Windows、Linux 或 Mac OS）

软件：
- 设置工具链，用于编译 ESP32 代码；
- 编译工具——CMake 和 Ninja 编译工具，用于编译 ESP32 应用程序；
- 获取 ESP-IDF 软件开发框架。该框架已经基本包含 ESP32 使用的 API（软件库和源代码）和运行工具链的脚本；
- 安装 C 语言编程（工程）的文本编辑器，例如 Eclipse。

1.3 开发板简介

请点击下方连接，了解有关具体开发板的详细信息。
图 1: ESP32 应用程序开发
1.4 详细安装步骤

请根据下方详细步骤，完成安装过程。

1.4.1 设置开发环境

- 第一步：安装准备（Windows、Linux 和 MacOS）
- 第二步：获取 ESP-IDF
- 第三步：设置工具
- 第四步：设置环境变量

1.4.2 创建您的第一个工程

- 第五步：开始创建工程
- 第六步：连接设备
- 第七步：配置
- 第八步：编译工程
- 第九步：烧录到设备
- 第十步：监视器

1.5 第一步：安装准备

在正式开始创建工程前，请先完成工具的安装，具体步骤见下：

1.5.1 Windows 平台工具链的标准设置

概述

ESP-IDF 需要安装一些必备工具，才能围绕 ESP32 构建固件，包括 Python、Git、交叉编译器、menuconfig 工具、CMake 和 Ninja 编译工具等。在本入门指南中，我们通过命令提示符进行有关操作。不过，您在安装 ESP-IDF 后还可以使用 Eclipse 或其他支持 CMake 的图形化工具 IDE。

ESP-IDF 工具安装器

要安装 ESP-IDF 必备工具，最简易的方式是下载 ESP-IDF 工具安装器，地址如下：

https://dl.espressif.com/dl/esp-idf-tools-setup-2.3.exe

本安装器可为您安装所需的交叉编译器、OpenOCD、cmake 和 Ninja 编译工具，以及一款 mconf-idf 配置工具。此外，本安装器还可在有需要时下载、运行 Python 3.7 和 Git For Windows 的安装器。

本安装器还可用于下载任意 ESP-IDF 发布版本。推荐将 ESP-IDF 下载到 %userprofile%\esp 目录下，其中 %userprofile% 代表家目录。可运行以下命令，创建 %userprofile%\esp。

```bash
mkdir %userprofile%\esp
```
使用命令提示符

在后续步骤中，我们将使用 Windows 的命令提示符进行操作。

ESP-IDF 工具安装器可在“开始”菜单中，创建一个打开 ESP-IDF 命令提示符窗口的快捷方式。本快捷方式可以打开 Windows 命令提示符（即 cmd.exe），并运行 export.bat 脚本以设置回到环境变量（比如 PATH, IDF_PATH 等）。此外，您可还以通过 Windows 命令提示符使用各种已经安装的工具。

注意，本快捷方式仅适用于 ESP-IDF 工具安装器中指定的 ESP-IDF 路径。如果您的电脑上存在多个 ESP-IDF（比如您需要不同的 ESP-IDF 版本）需要使用快捷方式，您可以：

1. 为 ESP-IDF 工具安装器创建的快捷方式创建一个副本，并将新快捷方式的“当前路径”指定为您希望使用的 ESP-IDF 路径。
2. 运行 cmd.exe，并更改至您希望使用的 ESP-IDF 目录，然后运行 export.bat。注意，这种方法要求 PATH 中存在 Python 和 Git。如果您在使用时遇到有关“找不到 Python 或 Git”的错误信息，请使用第一种方法。

后续步骤

当 ESP-IDF 工具安装器安装完成后，则开发环境设置也到此结束。后续开发步骤，请前往第五步：开始创建工程查看。

相关文档

想要自定义安装流程的高阶用户可参照：

在 Windows 环境下更新 ESP-IDF 工具

使用脚本安装 ESP-IDF 工具 请从 Windows “命令提示符”窗口，切换至 ESP-IDF 的安装目录。然后运行：

```
install.bat
```

对于 Powershell，请切换至 ESP-IDF 的安装目录。然后运行：

```
install.ps1
```

该命令可下载安装 ESP-IDF 所需的工具。如您已经安装了某个版本的工具，则该命令将无效。该工具的下载安装位置由 ESP-IDF 工具安装器的设置决定，默认情况下为：C:\Users\username\.espressif。

使用“导出脚本”将 ESP-IDF 工具添加至 PATH  ESP-IDF 工具安装器将在“开始菜单”为“ESP-IDF 命令提示符”创建快捷方式。点击该快捷方式可打开 Windows 命令提示符窗口，您可在该窗口使用所有已安装的工具。

有些情况下，您正在使用的 ESP-IDF 版本可能并未创建命令提示符快捷方式，此时您可以根据下方步骤将 ESP-IDF 工具添加至 PATH。

首先，请打开需要使用 ESP-IDF 的命令提示符窗口，切换至 ESP-IDF 的安装路径，然后执行 export.bat：

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

对于 Powershell 用户，请同样切换至 ESP-IDF 的安装路径，然后执行 export.ps1：

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

运行完成后，您就可以通过命令提示符使用 ESP-IDF 工具了。
1.5.2 Linux 平台工具链的标准设置

安装准备

编译 ESP-IDF 需要以下软件包:

- CentOS 7:

  ```
  sudo yum install git wget flex bison gperf python cmake ninja-build ccache dfu-util
  ```

- Ubuntu 和 Debian:

  ```
  sudo apt-get install git wget flex bison gperf python python-pip python-setuptools cmake ninja-build ccache libffi-dev libssl-dev dfu-util
  ```

- Arch:

  ```
  sudo pacman -S --needed gcc git make flex bison gperf python-pip python-pyserial cmake ninja ccache dfu-util
  ```

注释：使用 ESP-IDF 需要 CMake 3.5 或以上版本。较早版本的 Linux 可能需要升级才能向后移植仓库，或安装“cmake3”软件包，而不是安装“cmake”。

其他提示

权限问题 /dev/ttyUSB0 使用某些 Linux 版本向 ESP32 烧写固件时，可能会出现 Failed to open port /dev/ttyUSB0 错误消息。此时，可以将当前用户增加至 ref: Linux Dialout 组 <linux-dialout-group>。

设置 Python 3 为 Ubuntu 和 Debian 默认 Python 版本 Ubuntu v20.04 和 Debian v7 之前的版本默认解释器为 Python 2.7，但这里推荐使用 Python 3，您可以运行下方命令安装 Python 3。或者查看当前所用系统的相关文档，按照文档推荐的其它方法安装 Python 3:

```
sudo apt-get install python3 python3-pip python3-setuptools
```

设置 Python 3 为默认 Python 版本

```
sudo update-alternatives --install /usr/bin/python python /usr/bin/python3 10
```

注释：上述设置为全局设置，同时会影响到其它应用。

后续步骤

继续设置开发环境，请前往第二步：获取 ESP-IDF 章节。

1.5.3 MacOS 平台工具链的标准设置

安装准备

ESP-IDF 将使用 Mac OS 上默认安装的 Python 版本。

- 安装 pip:
Chapter 1. 快速入门

```bash
sudo easy_install pip
```

- 安装 CMake 和 Ninja 编译工具:
  - 若有 HomeBrew，您可以运行:
    ```bash
    brew install cmake ninja dfu-util
    ```
  - 若有 MacPorts，您可以运行:
    ```bash
    sudo port install cmake ninja dfu-util
    ```
  - 若以上均不适用，请访问 CMake 和 Ninja 主页，查询有关 MacOS 平台的下载安装问题。
- 强烈建议同时安装 ccache 以获得更快的编译速度。如有 HomeBrew，可通过 MacPorts 上的 brew install ccache 或 sudo port install ccache 完成安装。

**注解：** 如您在上述任何步骤中遇到以下错误:

```
xccrun: error: invalid active developer path (/Library/Developer/
→CommandLineTools), missing xccrun at:/Library/Developer/CommandLineTools/usr/bin/
→xccrun```

则必须安装 XCode 命令行工具，具体可运行 xcode-select --install。

后续步骤

继续设置开发环境，请前往第二步：获取 ESP-IDF 章节。

<table>
<thead>
<tr>
<th>Windows</th>
<th>Linux</th>
<th>Mac OS</th>
</tr>
</thead>
</table>

**注解：** 在本文档中，Linux 和 MacOS 操作系统中 ESP-IDF 的默认安装路径为～/esp；Windows 操作系统的默认路径为 %userprofile%\esp。您也可以将 ESP-IDF 安装在任何其他路径下，但请注意在使用命令行时进行相应替换。注意，ESP-IDF 不支持带有空格的路径。

1.6 第二步：获取 ESP-IDF

在围绕 ESP32 构建应用程序之前，请先获取乐鑫提供的软件库文件 ESP-IDF 仓库。
获取 ESP-IDF 的本地副本：打开终端，切换到您要保存 ESP-IDF 的工作目录，使用 git clone 命令克隆远程仓库。针对不同操作系统的详细步骤，请见下文。
1.6.1 Linux 和 MacOS 操作系统

打开终端，后运行以下命令:

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

ESP-IDF 将下载至 ~/esp/esp-idf。
请前往 ESP-IDF 版本简介，查看 ESP-IDF 不同版本的具体适用场景。

1.6.2 Windows 操作系统

除了安装必要工具外，第一步中介绍的 ESP-IDF 工具安装器 也能同时下载 ESP-IDF 本地副本。
请前往 ESP-IDF 版本简介，查看 ESP-IDF 不同版本的具体适用场景。
除了使用 ESP-IDF 工具安装器，您也可以参考 指南 手动下载 ESP-IDF。

1.7 第三步：设置工具

除了 ESP-IDF 本身，您还需要安装 ESP-IDF 使用的各种工具，比如编译器、调试器、Python 包等。

1.7.1 Windows 操作系统

请根据第一步中对 Windows (ESP-IDF 工具安装器) 的介绍，安装所有必需工具。
除了使用 ESP-IDF 工具安装器，您也可以通过 命令提示符 窗口手动安装这些工具。具体步骤见下:

```bash
cd %USERPROFILE%\esp\esp-idf
install.bat
```
或使用 Windows PowerShell

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

1.7.2 Linux 和 MacOS 操作系统

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

1.7.3 自定义工具安装路径

本步骤中介绍的脚本将 ESP-IDF 所需的编译工具默认安装在用户根文件夹中，即 Linux 和 MacOS 系统中的 $HOME/.espressif 和 Windows 系统的 %USERPROFILE%\espressif。此外，您可以可以将工具安装到其他目录中，但请在运行安装脚本前，重新设置环境变量 IDF_TOOLS_PATH。注意，请确保您的用户已具备了使用权该路径的权限。

如果修改了 IDF_TOOLS_PATH 变量，请确保该变量在每次执行 “安装脚本” (install.bat, install.ps1 或 install.sh) 和导出脚本 (export.bat, export.ps1 或 export.sh) 均保持一致。
1.8 第四步：设置环境变量

此时，您刚刚安装的工具尚未添加至 PATH 环境变量，无法通过“命令窗口”使用这些工具。因此，必须设置一些环境变量，这可以通过 ESP-IDF 提供的另一个脚本完成。

1.8.1 Windows 操作系统

Windows 安装器（ESP-IDF 安装器）可在“开始”菜单创建一个“ESP-IDF Command Prompt”快捷方式。该快捷方式可以打开命令提示符窗口，并设置所有环境变量。您可以点击该快捷方式，然后继续下一步。

此外，如果您希望在当下命令提示符窗口使用 ESP-IDF，请使用下方代码：

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

或使用 Windows PowerShell

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

1.8.2 Linux 和 MacOS 操作系统

请在您需要运行 ESP-IDF 的“命令提示符”窗口运行以下命令：

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

注意，命令开始的“.”与路径之间应有一个空格！

此外，您也可以将这行代码增加至您的 .profile 或 .bash_profile 脚本中，这样您就可以在任何命令窗口使用 ESP-IDF 工具了。

1.9 第五步：开始创建工程

现在，您可以开始准备开发 ESP32 应用程序了。您可以从 ESP-IDF 中 examples 目录下的 get-started/hello_world 工程开始。

将 get-started/hello_world 复制至您本地的 ~/esp 目录下：

1.9.1 Linux 和 MacOS 操作系统

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

1.9.2 Windows 操作系统

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

ESP-IDF 的 examples 目录下有一系列示例工程，都可以按照上面的方法进行创建。您可以按照上述方法复制并运行其中的任何示例，也可以直接编译示例，无需进行复制。

**重要：ESP-IDF 编译系统不支持带有空格的路径。**

Submit Document Feedback
1.10 第六步：连接设备

现在，请将您的 ESP32 开发板连接到 PC，并查看开发板使用的串口。

通常，串口在不同操作系统下显示的名称有所不同:

- **Windows 操作系统**: COM1 等
- **Linux 操作系统**: 以 `/dev/tty` 开始
- **MacOS 操作系统**: 以 `/dev/cu.` 开始

有关如何查看串口名称的详细信息，请见与 ESP32 创建串口连接。

**注解**: 请记住串口名，您会在后面的步骤中用到。

1.11 第七步：配置

请进入第五步：开始创建工程 中提到的 hello_world 目录，并运行工程配置工具 menuconfig。

1.11.1 Linux 和 MacOS 操作系统

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

1.11.2 Windows 操作系统

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

打开一个新项目后，应首先设置“目标”芯片 idf.py set-target esp32。注意，此操作将清除并初始化项目之前的编译和配置（如有）。您也可以直接将“目标”配置为环境变量（此时可跳过该步骤）。

更多信息，请见选择“目标”芯片。

如果之前的步骤都正确，则会显示下面的菜单：

工程配置—主窗口

menuconfig 工具的常见操作见下。

- 上下键头：移动
- 回车：进入子菜单
- ESC 键：返回上级菜单或退出
- 英文问号：调出帮助菜单（退出帮助菜单，请按回车键）。
- 空格、`或 `键：选择 [*] 配置选项
- N 键：禁用 [*] 配置选项
- 英文问号(查询配置选项)：调出有关该选项的帮助菜单
- `键：寻找配置工程

1.12 第八步：编译工程

请使用以下命令，编译烧录工程：

```
idf.py build
```
运行以上命令可以编译应用程序和所有 ESP-IDF 组件，接着生成 bootloader、分区表和应用程序二进制文件。

```
$ 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'
```

如果一切正常，编译完成后将生成.bin 文件。

### 1.13 第九步：烧录到设备

请使用以下命令，将刚刚生成的二进制文件烧录 (bootloader.bin, partition-table.bin 和 hello-world.bin) 至您的 ESP32 开发板:

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

请将 PORT 替换为 ESP32 开发板的串口名称，具体可见第六步: 连接设备。

您还可以将 BAUD 替换为您希望的烧录波特率，默认波特率为 460800。

更多有关 idf.py 参数的详情，请见idf.py。
### 注解：
勾选 `flash` 选项将自动编译并烧录程序，因此无需再运行 `idf.py build`。

<table>
<thead>
<tr>
<th>Running esptool.py in directory [...]/esp/hello_world</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executing &quot;python [...]/esp-idf/components/esptool_py/esptool/esptool.py -b 460800...</td>
</tr>
<tr>
<td>esptool.py -b 460800 write_flash --flash_mode dio --flash_size detect --flash_freq...</td>
</tr>
<tr>
<td>40m 0x1000 bootloader/bootloader.bin 0x8000 partition_table/partition-table.bin...</td>
</tr>
<tr>
<td>0x10000 hello-world.bin</td>
</tr>
<tr>
<td>esptool.py v2.3.1</td>
</tr>
<tr>
<td>Connecting...</td>
</tr>
<tr>
<td>Detecting chip type... ESP32</td>
</tr>
<tr>
<td>Chip is ESP32D0WDQ6 (revision 1)</td>
</tr>
<tr>
<td>Features: WiFi, BT, Dual Core</td>
</tr>
<tr>
<td>Uploading stub...</td>
</tr>
<tr>
<td>Running stub...</td>
</tr>
<tr>
<td>Stub running...</td>
</tr>
<tr>
<td>Changing baud rate to 460800</td>
</tr>
<tr>
<td>Changed.</td>
</tr>
<tr>
<td>Configuring flash size...</td>
</tr>
<tr>
<td>Auto-detected Flash size: 4MB</td>
</tr>
<tr>
<td>Flash params set to 0x0220</td>
</tr>
<tr>
<td>Compressed 22992 bytes to 13019...</td>
</tr>
<tr>
<td>Wrote 22992 bytes (13019 compressed) at 0x00001000 in 0.3 seconds (effective 558.9...</td>
</tr>
<tr>
<td>→ kbit/s)...</td>
</tr>
<tr>
<td>Hash of data verified.</td>
</tr>
<tr>
<td>Compressed 3072 bytes to 82...</td>
</tr>
<tr>
<td>Wrote 3072 bytes (82 compressed) at 0x00008000 in 0.0 seconds (effective 5789.3...</td>
</tr>
<tr>
<td>→ kbit/s)...</td>
</tr>
<tr>
<td>Hash of data verified.</td>
</tr>
<tr>
<td>Compressed 136672 bytes to 67544...</td>
</tr>
<tr>
<td>Wrote 136672 bytes (67544 compressed) at 0x00010000 in 1.9 seconds (effective 567.</td>
</tr>
<tr>
<td>→ 5 kbit/s)...</td>
</tr>
<tr>
<td>Hash of data verified.</td>
</tr>
<tr>
<td>Leaving...</td>
</tr>
<tr>
<td>Hard resetting via RTS pin...</td>
</tr>
</tbody>
</table>

如果一切顺利，烧录完成后，开发板将会复位，应用程序“hello_world”开始运行。

### 注解：
（目前不支持）如果您希望使用 Eclipse IDE，而非 `idf.py`，请参考 `Eclipse 指南`。

### 1.14 第十步：监视器

您可以使用 `idf.py -p PORT monitor` 命令，监视“hello_world”的运行情况。注意，不要忘记将 `PORT` 替换为您的串口名称。

运行该命令后，`IDF 监视器` 应用程序将启动：

```bash
$ 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 ---
ets Jun 8 2016 00:22:57
rst:0x1 (POWERON_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
```

(下页继续)
此时，您就可以在启动日志和诊断日志之后，看到打印的“Hello world!”了。

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

您可使用快捷键 Ctrl+]，退出 IDF 监视器。

**注解：** 您也可以运行以下命令，一次性执行构建、烧录和监视过程：

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

此外，

- 请前往 [IDF 监视器](https://esp-idf.readthedocs.io/en/latest/build_system.html#executing-flash-monitor) 了解更多信息。
- 请前往 `idf.py`，查看更多 idf.py 命令和选项。

恭喜您已完成 ESP32 的入门学习！

现在，您可以尝试一些其他 examples，或者直接开发自己的应用程序。

### 1.15 更新 ESP-IDF

乐鑫会不时推出更新版本的 ESP-IDF，修复 bug 或提出新的特性，因此，您在使用时，也应注意更新您本地的版本。最简单的方法是：直接删除您本地的 `esp-idf` 文件夹，然后按照第二步：获取 ESP-IDF 中的指示，重新完成克隆。

此外，您可以仅更新变更部分。具体方式，请前往更改章节查看。

注意，更新完成后，请执行 `install.sh`（Windows 系统中为 `install.bat`）脚本，避免新版 ESP-IDF 所需的工具也有所更新。具体请参考第三步：设置工具。

一旦重新安装好工具，请使用“导出脚本”更新环境，具体请参考第四步：设置环境变量。

### 1.16 相关文档

#### 1.16.1 与 ESP32 创建串口连接

本章节主要介绍如何创建 ESP32 和 PC 之间的串口连接。

**连接 ESP32 和 PC**

用 USB 线将 ESP32 开发板连接到 PC。如果设备驱动程序没有自动安装，请先确认 ESP32 开发板上的 USB 转串口芯片（或外部转串口适配器）型号，然后在网上搜索驱动程序，并进行手动安装。

以下是乐鑫 ESP32 开发板驱动程序的链接：

- CP210x: CP210x USB 至 UART 桥 VCP 驱动程序
Chapter 1. 快速入门

- FTDI: FTDI 虚拟 COM 端口驱动程序

以上驱动仅用于参考。一般情况下，当上述任一 ESP32 开发板与 PC 连接时，对应驱动程序应该已经被打包在操作系统中，并已经自动安装。

在 Windows 上查看端 口

检查 Windows 设备管理器中的 COM 端口列表。断开 ESP32 与 PC 的连接，然后重新连接，查看哪个端口从列表中消失，然后再次出现。

以下为 ESP32 DevKitC 和 ESP32 WROVER KIT 串口:

![Device Manager](image)

图 2: 设备管理器中 ESP32-DevKitC 的 USB 至 UART 桥

在 Linux 和 MacOS 上查看端 口

查看 ESP32 开发板（或外部转串口适配器）的串口设备名称，请运行两次以下命令。首先，断开开发板或适配器，第一次运行命令；然后，连接开发板或适配器，第二次运行命令。其中，第二次运行命令后出现的端口即是 ESP32 对应的串口：

Linux

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

MacOS

```bash
ls /dev/cu.*
```
图 3: Windows 设备管理器中 ESP-WROVER-KIT 的两个 USB 串行端口
**Chapter 1. 快速入门**

**注解：** 对于 MacOS 用户：若你没有看到串口，请检查你是否已按照《入门指南》安装了适用于你特定开发板的 USB/串口驱动程序。对于 MacOS High Sierra (10.13) 的用户，你可能还需要手动允许驱动程序的加载，具体可打开系统偏好设置 -> 安全和隐私 -> 通用，检查是否有信息显示：“来自开发人员的系统软件…”，其中开发人员的名称为 Silicon Labs 或 FTDI。

在 Linux 中添加用户到 dialout

当前登录用户应当可以通过 USB 对串口进行读写操作。在多数 Linux 版本中，你都可以通过以下命令，将用户添加到 dialout 组，获得读写权限:

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

在 Arch Linux 中，需要通过以下命令将用户添加到 uucp 组中:

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

请重新登录，确保串口读写权限可以生效。

确认串口连接

现在，请使用串口终端程序，验证串口连接是否可用。在本示例中，我们将使用 PuTTY SSH Client，PuTTY SSH Client 既可用于 Windows 也可用于 Linux，你也可以使用其他串口程序并设置如下的通信参数。

运行终端，配置串口：波特率 = 115200，数据位 = 8，停止位 = 1，奇偶校验 = N。以下截图分别展示了在 Windows 和 Linux 中配置串口和上述通信参数（如 115200-8-1-N）。注意，这里一定要选择在上述步骤中确认的串口进行配置。

然后，请检查 ESP32 是否有打印日志。如有，请在终端打开串口进行查看。这里，日志内容取决于加载到 ESP32 的应用程序，下图即为一个示例。

```bash
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)
configsp: 0, SPIWP:0x00
clock_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:2
load:0x3fff0000,len:8
load:0x3fff0010,len:3464
load:0x40078000,len:7828
load:0x40080000,len:252
entry 0x4008034
I (44) boot: ESP-IDF v2.0-rc1-401-gf9fba35 2nd stage bootloader
I (45) boot: compile time 18:48:10
...
```

如果打印出的日志是可读的（而不是乱码），则表示串口连接正常。此时，你可以继续进行安装，并最终将应用程序上载到 ESP32。

**注解：** 在某些串口接线方式下，在 ESP32 启动并开始打印串口日志前，需要在终端程序中禁用串口 RTS & DTR 引脚。该问题仅存在于将 RTS & DTR 引脚直接连接到 EN & GPIO0 引脚上的情况，绝大多数开发板（包括乐鑫所有的开发板）都没有这个问题。更多详细信息，请参见 esptool 文档。
图 4: 在 Windows 操作系统中使用 PuTTY 设置串口通信参数
图 5: 在 Linux 操作系统中使用 PuTTY 设置串口通信参数
1.16.2 Eclipse IDE 创建和烧录指南

ESP-IDF V4.0 默认采用基于 CMake 的构建系统。
针对 CMake 构建系统，ESP-IDF 有一款新的 Eclipse 插件。具体操作指南，请见 ESP-IDF Eclipse 插件。

1.16.3 Getting Started with VS Code IDE

我们有官方支持 VS Code 以及我们希望提供所有与 ESP-IDF 相关的动作的完全支持，比如构建、烧录、监控、调试、trace、core-dump、System Trace Viewer 等。

Quick Install Guide

我们推荐的安装 ESP-IDF Visual Studio Code 扩展的方式是通过下载它从 VS Code Marketplace 或者按照快速安装指南。

Supported Features

- **Onboarding**，将帮助您快速安装 ESP-IDF 及其相关的工具链，只要几步简单的点击。
- **Build**，通过一次点击构建和多目标构建，您可以轻松构建并部署您的应用程序。
- **Flash**，通过 UART 和 JTAG 模式烧录。
- **Monitoring**，带有一个内置终端，您可以在 VS Code 中触发 IDF Monitor 命令，就像您习惯于传统的终端一样。
- **Debugging**，提供硬件调试以及后端调试支持，比如 core-dump，您可以方便地分析错误。
- **GUI Menu Config**，提供简化用户界面来配置您的芯片。
- **App & Heap Tracing**，提供支持从您的应用程序收集的追踪以及简化 UI 来分析它们。
- **System View Tracing Viewer**，旨在读取和显示 .svdat 文件到跟踪 UI，我们还支持多个核心跟踪视图。
- **IDF Size Analysis Overview**，提供一个 UI 用于二进制大小分析。
- ‘Rainmaker Cloud <https://rainmaker.espressif.com/>‘，我们有内置的 Rainmaker Cloud 支持，您可以编辑/读取您连接的 IoT 设备的状态。
- **Code Coverage**，我们有内置的代码覆盖率支持，这些值将用颜色突出显示，已经覆盖的行。

Bugs & Feature Requests

如果您遇到某个 VS Code 特性的问题，或者 VS Code 本身的问题，我们建议您在论坛提问，或者在我们的 GitLab 问题中发起问题，以供我们的开发团队来审查。

我们也很欢迎新的功能请求，大多数今天的功能是由于人们询问而实现的，或者是为了改进现有功能，提高扩展性的某些方面，发起您的功能请求在 GitHub。
1.16.4 IDF 监视器

IDF 监视器是一个串行终端程序，用于收发目标设备串口的串行数据，IDF 监视器同时还具备 IDF 的其他特性。

在 IDF 中调用以下目标函数可以启用此监视器:

- 若使用 CMake 编译系统，则请调用: `idf.py monitor`
- 若使用传统 GNU Make 编译系统，请调用: `make monitor`

操作快捷键

为了方便与 IDF 监视器进行交互，请使用表中给出的快捷键。

<table>
<thead>
<tr>
<th>快捷键</th>
<th>操作</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl+]</td>
<td>退出监视器程序</td>
<td>无描述</td>
</tr>
</tbody>
</table>
| Ctrl+T | 菜单退出键 | 按下如下给出的任意键，开按指示操作。
| Ctrl+T | 将菜单字符发送至远程 | 无描述 |
| Ctrl+J | 将 exit 字符发送至远程 | 无描述 |
| Ctrl+P | 重置目标设备，进入 Bootloader，通过 RTS 线暂停应用程序 | 重置目标设备，通过 RTS 线（如已连接）进入 Bootloader，此时开发板不运行任何程序。等待其他设备启动时可以使用此操作。 |
| Ctrl+R | 通过 RTS 线重置目标设备 | 无描述 |
| Ctrl+F | 编译并烧录此项目 | 暂停 idf_monitor，运行 idf.py flash 目标，然后恢复 idf_monitor。任何改动的源文件都会被重新编译，然后重新烧录。 |
| Ctrl+A (A) | 仅编译及烧录应用程序 | 暂停 idf_monitor，运行 app-flash 目标，然后恢复 idf_monitor。这与 flash 类似，但只有主应用程序被编译并被重新烧录。 |
| Ctrl+Y | 停止/恢复日志输出在屏幕上打印 | 激活时，会丢弃所有传入的日志数据，允许在不退出监视器的情况下快速暂停和检查日志输出。 |
| Ctrl+L | 停止/恢复向文件写入日志输出 | 在工程目录下创建一个文件，用于写入日志输出。可使用快捷键停止/恢复该功能（退出 IDF 监视器也会终止该功能） |
| Ctrl+H (H) | 显示所有快捷键 | 无描述 |

除了 Ctrl-] 和 Ctrl-T，其他快捷键信号会通过串口发送到目标设备。

兼具 IDF 特性

自动解码地址 ESP-IDF 输出形式为 0x4________的十六进制代码地址后，IDF 监视器将使用 addr2line 查找该地址在源代码中的位置和对应的函数名。
ESP-IDF 应用程序发生的 crash 和 panic 事件时，将产生如下的寄存器转储和回溯:

Guru Meditation Error of type StoreProhibited occurred on core 0. Exception was unhandled.
Register dump:
PC : 0x400f360d PS : 0x00060330 A0 : 0x800dbf56 A1 : ...
A2 : 0x3ffb136c A3 : 0x00000005 A4 : 0x00000000  A5 : ...
A6 : 0x00000000 A7 : 0x00000000  A8 : 0x00000000 A9 : ...
A10 : 0x00000030 A11 : 0x00060f23 A12 : 0x00060f20 A13 : ...
A14 : 0x00000047 A15 : 0x0000000f SAR : 0x000000019 EXCCAUSE:
EXCVADDR: 0x00000000 LBEG : 0x4000c46c LEND : 0x4000c477 LCOUNT :

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

IDF 监视器为寄存器转储补充如下信息:

Guru Meditation Error of type StoreProhibited occurred on core 0. Exception was unhandled.
Register dump:
PC : 0x400f360d PS : 0x00060330 A0 : 0x800dbf56 A1 : ...
A2 : 0x3ffb136c A3 : 0x00000005 A4 : 0x00000000  A5 : ...
A6 : 0x00000000 A7 : 0x00000000  A8 : 0x00000000 A9 : ...
A10 : 0x00000030 A11 : 0x00060f23 A12 : 0x00060f20 A13 : ...
A14 : 0x00000047 A15 : 0x0000000f SAR : 0x000000019 EXCCAUSE:
EXCVADDR: 0x00000000 LBEG : 0x4000c46c LEND : 0x4000c477 LCOUNT :

Backtrace:
0x400f360d:0x3ffb7e00 0x400dbf56:0x3ffb7e20 0x400dbf5e:0x3ffb7e40...
0x400dbf82:0x3ffb7e60 0x400d071d:0x3ffb7e90
0x400f360d: do_something_to_crash at /home/gus/esp/32/idf/examples/get-started/hello_world/main./hello_world_main.c:57
(inlined by) inner_dont_crash at /home/gus/esp/32/idf/examples/get-started/hello_world/main./hello_world_main.c:52
A2 : 0x3ffb136c A3 : 0x00000005 A4 : 0x00000000  A5 : ...
A6 : 0x00000000 A7 : 0x00000000  A8 : 0x00000000 A9 : ...
A10 : 0x00000030 A11 : 0x00060f23 A12 : 0x00060f20 A13 : ...
A14 : 0x00000047 A15 : 0x0000000f SAR : 0x000000019 EXCCAUSE:
EXCVADDR: 0x00000000 LBEG : 0x4000c46c LEND : 0x4000c477 LCOUNT :

Backtrace:
0x400f360d:0x3ffb7e00 0x400dbf56:0x3ffb7e20 0x400dbf5e:0x3ffb7e40...
0x400dbf82:0x3ffb7e60 0x400d071d:0x3ffb7e90
0x400f360d: do_something_to_crash at /home/gus/esp/32/idf/examples/get-started/hello_world/main./hello_world_main.c:57
(inlined by) inner_dont_crash at /home/gus/esp/32/idf/examples/get-started/hello_world/main./hello_world_main.c:52
0x400dbf56: still_dont_crash at /home/gus/esp/32/idf/examples/get-started/hello_world/main./hello_world_main.c:52
0x400dbf5e: dont_crash at /home/gus/esp/32/idf/examples/get-started/hello_world/main./hello_world_main.c:47
0x400dbf82: app_main at /home/gus/esp/32/idf/examples/get-started/hello_world/main./hello_world_main.c:33
0x400d071d: main_task at /home/gus/esp/32/idf/components/esp32/.cpu_start.c:254

IDF 监视器在后台运行以下命令，解码各地址:
配置 GDBStub 以启用 GDB

在某些情况下，如果 ESP- IDF 应用程序发生 crash 事件，panic 处理器将在串口上打印相关寄存器和堆栈转储 (类似上述情况)，然后重置开发板。

或者选择配置 panic 处理器以运行 GDBStub。GDBStub 工具可以与 GDB 项目调试器进行通信，并允许读取内存、检查调试用堆栈帧和变量等。GDBStub 虽然没有 JTAG 通用，但不需要使用特殊硬件。

如需启用 GDBStub，请运行 idf.py menuconfig (适用于 CMake 编译系统) 并将 CONFIG_ESP_SYSTEM_PANIC 选项设置为 Invoke GDBStub。

在这种情况下，如果 panic 处理器被触发，只要 IDF 监视器控制 GDBStub 已经加载，panic 处理器就会自动暂停串行监控并使用必要的参数运行 GDB。GDB 退出后，通过 RTS 串口线复位开发板。如果未连接 RTS 串口线，请按复位键，手动复位开发板。

IDF 监视器在后台运行如下命令：

```
xtena-esp32-elf-gdb -ex "set serial baud BAUD" -ex "target remote PORT" -ex --interrupt build/PROJECT.elf
```

输出筛选 IDF 监视器有两种启用方式：运行 `idf.py monitor PRINT_FILTER=""` (适用于 CMake) 或者 `make monitor PRINT_FILTER=""` (适用于传统 GNU Make)，其中，--print-filter 是输出筛选的参数，参数默认值为空字符串，可打印任何内容。

若需对打印内容设置限制，可指定 `<tag>:<log_level>` 等选项，其中 `tag` 是标签字符串，`<log_level>` 是 `{N, E, W, I, D, V, *)}` 集合中的一个字母，指的是日志级别。

例如，PRINT_FILTER="tag1:N" 只匹配并打印 ESP_LOGW("tag1", ...) 所写的输出，或者写在较低冗余级别的输出，即 ESP_LOGE("tag1", ...)。请勿指定 `<log_level>` 或使用冗余级别默认值 *。

注解：编译时，可以使用主日志在日志库中禁用不需要的输出。也可以使用 IDF 监视器筛选输出来调整筛选设置，且无需重新编译应用程序。

应用程序标签不能包含空格、星号 *、冒号 :，以便兼容输出筛选功能。

如果应用程序输出的最后一行后面没有回车，可能会影响输出筛选功能。即，监视器开始打印该行，但后来发现该行不应该被写入。这是一个已知问题，可以通过添加回车来避免此问题（特别是在没有输出紧跟其后的情况下）。

筛选规则示例

* 可用于匹配任何类型标签。但 PRINT_FILTER="*:I tag1:E" 打印关于 tag1 的输出时会报错，这是因为 tag1 规则比 * 规则的优先级高。
* 默认规则（空）等价于 *:V，因为在冗余级别或更低级别匹配任意标签即意味匹配有何内容。
* "*:N" 不仅抑制了日志相关的输出，也抑制了 printf 的打印输出。为了避免这一问题，请使用 *:E 或更高的冗余级别。
* 规则 "tag1:V", "tag1:v", "tag1":, "tag1:*" 和 "tag1" 等同。
* 规则 "tag1:W tag1:E" 等同于 "tag1:E"，这是因为后续出现的具有相同名称的标签会覆盖掉前一个标签。
* 规则 "tag1:W tag1:W" 仅在 Info 冗余级别或更低级别打印 tag1，在 Warning 冗余级别或更低级别打印 tag2。
* 规则 "tag1:I tag2:W tag3:N" 在本质上等同于上一规则，这是因为 tag3:N 指定 tag3 不打印。
* tag3:N 在规则 "tag1:I tag2:W tag3:N *:V" 中更有意义，这是因为如果没有 tag3:N，tag3 信息就可能打印出来了；tag1 和 tag2 错误信息会打印在指定的冗余级别（或更低级别），并默认打印所有内容。
高级筛选规则示例 如下日志是在没有设置任何筛选选项的情况下获得的:

```
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
PRINT_FILTER="wifi esp_image:E light_driver:I"
```

筛选选项捕获的输出如下所示:

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

IDF 监视器已知问题

Windows 环境下已知问题

- 若在 Windows 环境下, 出现 “winpty: command not found” 错误, 请运行 pacman -S winpty 进行修复。
- 由于 Windows 控制台限制, 有些箭头键及其他一些特殊键无法在 GDB 中使用。
- 偶然情况下, idf.py 或 make 退出时, 可能会在 IDF 监视器恢复之前暂停 30 秒。
- GDB 运行时, 可能会暂停一段时间, 然后才开始与 GDBStub 进行通信。

1.16.5 工具链的自定义设置

除了从乐鑫官网（请见第三步：设置工具）下载二进制工具链外，您还可以自行编译工具链。

如无特殊需求，建议直接使用我们提供的预编译二进制工具链。不过，您可以在以下情况考虑自行编译工具链:

- 需要定时工具链编译配置
- 需要使用其他 GCC 版本（如 4.8.5）
- 需要破解 gcc, newlib 或 libstdc++
- 有相关兴趣或时间充裕
- 不信任从网站下载的 bin 文件

如需自行编译工具链，请查看以下文档:

从零开始设置 Windows 环境下的工具链

除了使用 ESP-IDF 工具安装器，用户也可以手动设置 Windows 环境下的工具链，这也是本文的主要内容。手动安装工具可以更好地控制安装流程，同时也可以高阶用户进行自定义安装。

使用 ESP-IDF 工具安装器对工具链及其他工具进行快速标准设置，请参照 Windows 平台工具链的标准设置。
获取 ESP-IDF

注意：较早版本 ESP-IDF 使用了 MSYS2 bash 终端命令行。目前，基于 CMake 的编译系统可使用常见的 Windows 命令窗口，即本指南中使用的终端。

请注意，如果您使用基于 bash 的终端或 PowerShell 终端，一些命令语法将与下面描述有所不同。

打开命令提示符，运行以下命令：

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

ESP-IDF 将下载至 %userprofile%\esp\esp-idf。

请前往 ESP-IDF 版本简介，查看 ESP-IDF 不同版本的具体适用场景。

注意：此命令将克隆 master 分支。该分支保存着 ESP-IDF 的最新版本。它功能齐全，每周都会更新一些新功能并修正一些错误。

注释：GitHub 中“下载 zip 文件”的功能不适用于 ESP-IDF，所以需要使用 git clone 命令。作为备份，可以在没有安装 Git 的环境中下载 Stable version 的 zip 归档文件。

注意：在克隆远程仓库时，不要忘记加上 --recursive 选项。否则，请接着运行以下命令，获取所有子模块

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

工具

**cmake 工具** 下载最新发布的 Windows 平台稳定版 CMake，并运行安装器。
当安装器询问“安装选项”时，选择“Add CMake to the system PATH for all users”（为所有用户的系统路径添加 CMake）或“Add CMake to the system PATH for the current user”（为当前用户的系统路径添加 CMake）。

**Ninja 编译工具**
注意：目前，Ninja 仅提供支持 64 位 Windows 版本的 bin 文件。您也可以配合其他编译工具在 32 位 Windows 版本中使用 CMake 和 idf.py，比如 mingw-make。但是目前暂无关于此工具的说明文档。

从（下载页面）下载最新发布的 Windows 平台稳定版 ninja。

适用于 Windows 平台的 Ninja 下载文件是一个 zip 文件，包含一个 ninja.exe 文件。您需要将该文件解压到目录，并添加到您的路径（或者选择您路径中的已有目录）。
Python 下载并运行适用于 Windows 安装器的最新版 Python。
Python 安装器的“自定义”菜单可为您提供一系列选项，最后一项为“Add python.exe to Path”（添加 python.exe 到路径中）。请将该选项更改为“Will be installed”（将会安装）。
Python 安装完成后，从 Windows 开始菜单中打开“命令提示符”窗口，并运行以下命令:
```
pip install --user pyserial
```

适用于 IDF 的 MConf 从 kconfig-frontends releases page 下载配置工具 mconf-idf。此为 mconf 配置工具，可针对 ESP-IDF 进行少量自定义操作。
请将此工具解压到目录，并添加到您的路径。

工具链设置 下载预编译的 Windows 工具链:
解压压缩包文件到 C:\Program Files (或其他位置)。压缩包文件包含一个 xtensa-esp32-elf 目录。
然后，请将该目录下的 bin 子目录添加到您的路径，例如 C:\Program Files\xtensa-esp32-elf\bin。

注解：如果您已安装 MSYS2 环境（适用 “GNU Make” 编译系统），则可以跳过下载那一步，直接添加目录 C:\msys2\opt\xtensa-esp32-elf\bin 到路径，因为 MSYS2 环境已包含工具链。

添加目录到路径 在 Windows 环境下，向 Path 环境变量增加任何新目录，请:
打开系统“控制面板”，找到环境变量对话框 (Windows 10 用户请前往“高级系统设置”)。
双击 Path 变量（选择“用户”或“系统路径”，具体取决于您是否希望其他用户路径中也存在该目录），
在最后数位那里新添 ;<new value>。

后续步骤 继续设置开发环境，请前往 第三步：设置工具 章节。

从零开始设置 Linux 环境下的工具链
除了从乐鑫官网直接下载已编译好的二进制工具链外，您还可以按照本文介绍，从头开始设置自己的工具链。如需快速使用已编译好的二进制工具链，可回到 Linux 平台工具链的标准设置 章节。

安装准备 编译 ESP-IDF 需要以下软件包:

- CentOS 7:
```
sudo yum install git wget ncurses-devel flex bison gperf python pyserial...
```

- Ubuntu 和 Debian:
```
sudo apt-get install git wget libncurses-dev flex bison gperf python python-
--pip python-setuptools python-serial python-click python-cryptography python-
--future python-pypparsing python-pyelftools cmake ninja-build ccache libffi-
--dev libssl-dev dfu-util
```

- Arch:
```
sudo pacman -S --needed gcc git make ncurses flex bison gperf python-pyserial...
```

... (下页继续)
Chapter 1. 快速入门

从源代码编译工具链 安装依赖项:

- CentOS 7:
  ```bash
  sudo yum install gawk gperf grep gettext ncurses-devel python python-devel
  --automake 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 libtool-bin make
  ```

- Ubuntu 16.04 或以上:
  ```bash
  sudo apt-get install gawk gperf grep gettext 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-dev
  --automake bison flex texinfo help2man libtool libtool-bin make
  ```

- Arch:
  ```bash
  TODO
  ```

创建工作目录，并进入该目录:

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

下载并编译 crosstool-NG:

```bash
git clone https://github.com/espressif/crosstool-NG.git
cd crosstool-NG
git checkout esp-2020r3
git submodule update --init
./bootstrap & & ./configure --enable-local & & make
```

编译工具链:

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

后续步骤 继续设置开发环境，请前往第二步：获取 ESP-IDF 章节。

从零开始设置 MacOS 环境下的工具链

软件包管理器 从零开始设置工具链，您需要安装 MacPorts 或 homebrew 软件包管理器。或者，您也可以直接下载预编译的工具链。

MacPorts 需要完整的 XCode 软件，而 homebrew 只需要安装 XCode 命令行工具即可。

请参考工具链自定义设置 章节，查看可能需要从头开始设置工具链的情况。
安装准备

- 安装 pip:
  ```
  sudo easy_install pip
  ```

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

- 安装 CMake 和 Ninja 编译工具:
  - 若有 HomeBrew，您可以运行:
    ```
    brew install cmake ninja dfu-util
    ```
  - 若有 MacPorts，您可以运行:
    ```
    sudo port install cmake ninja dfu-util
    ```

从源代码编译工具链 安装依赖项:

- 对于 MacPorts:
  ```
  sudo port install gsed gawk binutils qperf grep gettext wget libtool autoconf
  → automake make
  ```

- 对于 homebrew:
  ```
  brew install gnu-sed gawk binutils qperf tools gettext wget help2man libtool
  → autoconf automake make
  ```

创建一个文件系统镜像（区分大小写）:
```
hdutil create ~/esp/crosstool.dmg -volname "ctng" -size 10g -fs "Case-sensitive..."
```

挂载:
```
hdutil mount ~/esp/crosstool.dmg
```

创建指向您工作目录的符号链接:
```
mkdir -p ~/esp
ln -s /Volumes/ctng ~/esp/ctng-volume
```

前往新创建的目录:
```
cd ~/esp/ctng-volume
```

下载并编译 crosstool-NG
```
git clone https://github.com/espressif/crosstool-NG.git
cd crosstool-NG
git checkout esp-2020r3
git submodule update --init
./bootstrap && ./configure --enable-local && make
```

编译工具链:
```
./ct-ng xtensa-esp32-elf
./ct-ng build
chmod -R u+w builds/xtensa-esp32-elf
```
Chapter 1. 快速入门

編 译 得 到 的 工 具 链 会 被 保 存 到 ~/esp/ctng-volume/crosstool-NG/builds/xtensa-esp32-elf。使 用 工 具 链 前，请 将 ~/esp/ctng-volume/crosstool-NG/builds/xtensa-esp32-elf/bin 添加至 PATH 环境变量。

后续步骤 继续设置开发环境，请前往第二步：获取 ESP-IDF 章节。

1.16.6 快速入门（传统 GNU Make）

注 解：ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能不会继续支持基于 GNU Make 的构建系统。

本文档旨在指导用户搭建 ESP32 硬件开发的软件环境。通过一个简单的示例展示如何使用 ESP-IDF (Espressif IoT Development Framework) 配置菜单，并编译、下载固件至 ESP32 开发板等步骤。

注解：这是 ESP-IDF master 分支（最新版本）的文档，该版本在持续开发中。还有 Stable version 的文档，以及其他版本的文档 ESP-IDF 版本简介 供参考。

概述

ESP32 SoC 芯片支持以下功能：

- 2.4 GHz Wi-Fi
- 蓝牙 4.2
- 高性能双核
- 超低功耗协处理器
- 多种外设

ESP32 采用 40 nm 工艺制成，具有最佳的功耗性能、射频性能、稳定性和通用性和可靠性，适用于各种应用场景和不同功耗需求。

乐鑫为用户提供完整的软、硬件资源，进行 ESP32 硬件设备的开发。其中，乐鑫的软件开发环境 ESP-IDF 旨在协助用户快速开发物联网 (IoT) 应用，可满足用户对 Wi-Fi、蓝牙、低功耗等方面的要求。

准备工作

硬件：

- 一款 ESP32 开发板
- USB 数据线 (A 转 Micro-B)
- PC（Windows、Linux 或 Mac OS）

软件：

- 设置 工具链，用于编译 ESP32 应用程序；
- 获取 ESP-IDF 软件开发框架。该框架已经基本包含 ESP32 使用的 API（软件库和源代码）和运行工具链的脚本；
- 安装 C 语言编程（工程）的 文本编辑器，例如 Eclipse。

开发板简介

请 点 击 下 方 连 接，了 解 有 关 具 体 开 发 板 的 详 细 信 息。
详细安装步骤

请根据下方详细步骤，完成安装过程。

设置开发环境

- Windows、Linux 和 macOS 的第一步：设置工具链
- 第二步：获取 ESP-IDF
- 第三步：设置环境变量
- 第四步：安装 Python 软件包

创建您的第一个工程

- 第五步：开始创建工程
- 第六步：连接设备
- 第七步：配置
- 第八步：编译和烧录
- 第九步：监视器

第一步：设置工具链

工具链指一套用于编译代码和应用程序的程序。

为了加快开发进度，您可以直接使用乐鑫提供的预制工具链。请根据您的操作系点击对应的链接，并按照链接中的指导进行安装。

Windows 平台工具链的标准设置（传统 GNU Make）

注解：ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能不会继续支持基于 GNU Make 的构建系统。

概述

Windows 系统没有内置的“make”环境，所以除了安装工具链之外，您还需要一个兼容 GNU 的环境。这里，我们使用 MSYS2 环境兼容 GNU。您无需一直使用这个环境，比如您可以使用 Eclipse 或其他前端，仅在后台运行 MSYS2 即可。

工具链设置


请将压缩包文件解压至 C:\` (或其他目录，但本文档中以 `C:\` 为例)，该文件将为您创建一个带有预配置环境的 msys32 目录。

开始尝试

请运行 C:\msys32\mingw32.exe 文件。打开一个 MSYS2 MINGW32 终端窗口。该窗口的环境为 bash shell，请创建一个名为 esp 的文件夹，作为 ESP32 应用程序开发的默认目录。您可以使用以下命令创建文件夹：

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

您还可以通过 cd ~/esp 命令，进入刚刚创建的文件夹。如无其他问题，本步骤到此结束。

请在后续步骤中，使用本窗口配置 ESP32 的开发环境。

后续步骤

继续设置开发环境，请前往 第二步：获取 ESP-IDF 章节。
更新环境 当 ESP-IDF 有更新时，有时需要安装新的工具链或为 Windows MSYS2 环境添加新的要求。您可以通过以下步骤进行更新:

1. 复制旧的 MSYS2 环境 (即 C:\msys32)，并将其移动/重命名到不同目录下 (即 C:\msys32_old)。
2. 使用上述步骤，下载新的预编译环境。
3. 将新的 MSYS2 环境解压缩至 C:\msys32（或您指定的其他位置）。
4. 找到旧的 C:\msys32_old\home 文件夹，并将其移动至 C:\msys32。
5. 此时，如无其他需要，您可以删除旧的 C:\msys32_old\home 文件夹。

注意，您可以在电脑中安装多个不同的 MSYS2 环境，只需将它们保存在不同的路径下即可。此外，您还可以直接更新现有环境（无需下载新的版本），但步骤更加复杂。

相关文档

从零开始设置 Windows 环境下的工具链 (传统 GNU Make)

注解：ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能不会继续支持基于 GNU Make 的构建系统。

手动安装所有工具能更好地控制整个安装流程，同时也方便高阶用户进行自定义安装。此外，经验不足的用户还可以参考预编译环境中的步骤进行准备。

使用预编译环境对工具链进行快速标准设置，请参照 Windows 平台工具链的标准设置 (传统 GNU Make)。

从零开始配置工具链和环境 本文档包括：首先，安装 MSYS2；其次，安装 ESP-IDF 所需的 Python 工具包；最后，下载并安装 Xtensa 工具链。

- 请前往 MSYS2 安装器页面，并下载 msys2-i686-xxxxxx.exe 安装器（我们仅支持 32-bit MSYS 环境，32 位和 64 位 Window 均可使用）。截止至本文最新更新之时，最新版安装器为 msys2-i686-20161025.exe。
- 完成所有安装步骤。最后一步时，请不要勾选 “Run MSYS2 32-bit now”。
- 安装完成后，请从 “开始”菜单中找到“MSYS2 MinGW 32-bit”，运行“命令提示符”窗口。
  - 为什么要特别打开这个终端窗口？MSYS2 会对不同环境进行区分。默认的“MSYS”环境与 Cygwin 相仿，会为 Windows 系统的 API 调用增加一个转换层。但为了使用支持 COM 端口的原生 Python，我们需要准备好“MinGW”环境。
- GitHub 上的 ESP-IDF 仓库的 tools 目录下可以找到名为 windows_install_prerequisites.sh 的脚本。如果您还没有本地 ESP-IDF 副本，也可以从以下地址进行下载（请下载 raw 格式）: tools/windows/windows_install_prerequisites.sh，并将其保存至您的电脑。
- 请在 MSYS2 终端窗口中指定该脚本的保存路径。注意，路径格式与 Windows 路径相同，但需使用正斜杠 (/) 而不是反斜杠 (\)。例 C:\Users/myuser/Downloads/windows_install_prerequisites.sh。当然，您也可以直接打开查看该脚本的内容。
- windows_install_prerequisites.sh 脚本将帮助下载并安装支持 ESP-IDF 的软件包和 ESP32 工具链。
### 疑难解答

- MSYS 可能在脚本运行过程中进行自动升级，导致无法使用。此时，您会看到以下错误信息:

```markdown
*** fatal error - cygheap base mismatch detected - 0x612E5408/0x612E4408
```

这个问题很大可能是由于 cygwin DLL 版本不兼容。

这种情况下，请完全关闭终端窗口（相当于终止所有进程），并重新打开一个窗口。
然后，请在新窗口中重新运行 `windows_install_prerequisites.sh`（小技巧：您可以使用“向上箭头”找到之前运行的命令），此时，更新流程将重启。

- 注意，MSYS2 是一个“滚动”发行版，因此安装脚本可能会为您安装比“预编译环境”中更新的软件包。因此，如果遇到与 MSYS2 安装包有关的错误，请前往 MSYS2-packages 问题列表 页面寻找答案。如果没有找到相关答案，请提交一个 IDF Issue。

### 中国地区的 MSYS2 镜像

中国地区有一些（非官方的）MSYS2 镜像，这可以大幅提高中国地区的下载速度。

如需添加这些镜像，请在运行安装脚本前修改以下两个 MSYS2 镜像列表文件。镜像文件的保存路径为 `/etc/pacman.d`，比如 `c:\msys2\etc\pacman.d`。

请在 `mirrorlist.mingw32` 最上方增加如下语句:

```markdown
Server = https://mirrors.ustc.edu.cn/msys2/mingw/i686/
Server = http://mirror.bit.edu.cn/msys2/REPOS/MINGW/i686
```

请在 `mirrorlist.msys` 最上方增加如下语句:

```markdown
Server = http://mirrors.ustc.edu.cn/msys2/msys/$arch
Server = http://mirror.bit.edu.cn/msys2/REPOS/MSYS2/$arch
```

### HTTP 代理

- 您可以在运行“设置脚本”之前，在终端中设置 `http_proxy` 变量，从而允许使用 HTTP 代理下载 MSYS 和 PIP:

```bash
export http_proxy='http://http.proxy.server:PORT'
```

或者修改证书:

```bash
export http_proxy='http://user:password@http.proxy.server:PORT'
```

如需始终用代理使用 MSYS，请在 MSYS 目录中增加 `/etc/profile`。

### 其他设置：下载工具链

- 如果您已经安装了 MSYS2，或者想要以不同的方式执行操作，您可以在此处下载工具链:

```bash
```

### 注解

如果您已完成了从零开始配置工具链和环境 中介绍的所有步骤，则已经拥有了工具链，这里无需重复下载。

### 重要

- 仅拥有工具链 尚无法让您在 Windows 中使用 ESP-IDF。除此之外，您还至少需要安装 GNU make、bash 和 sed。上述环境已经包括这些配置，此外还有一个主机编译器（这样才能使用 menuconfig）。

### 后续步骤

继续设置开发环境，请前往 第二步：获取 ESP-IDF 章节。
更新环境  当 IDF 有更新时，有时需要安装新的工具链或为 Windows MSYS2 环境添加新的系统要求。此时，您无需重新配置环境，仅需更新现有 Windows 环境和工具链即可。

- 将 IDF 更新至您希望的版本。
- 请运行 IDF 仓库中的 tools/windows/windows_install_prerequisites.sh 脚本。该脚本将帮您安装所有新的软件包，并下载更新工具链至最新版本。

注意，该脚本在更新 MSYS2 时也会遇到疑难解答 中介绍的问题。

如需要同时支持多个 IDF 版本，您可以在不同的目录下配置独立的 MSYS2 环境。或者，您还可以下载多个工具链，并将其解压缩到不同的目录下，然后使用 PATH 环境变量指定默认工具链。

Linux 平台工具链的标准设置（传统 GNU Make）

注解：ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能不会继续支持基于 GNU Make 的构建系统。

安装准备  编译 ESP-IDF 需要以下软件包：

- CentOS 7:

  ```bash
  sudo yum install gcc git wget make flex bison gperf python python2-cryptography
  ```

- Ubuntu and Debian:

  ```bash
  sudo apt-get install gcc git wget make flex bison gperf python python-pip
  --python-setuptools python-serial python-cryptography python-future python-
  --pyparsing python-elftools libffi-dev libssl-dev
  ```

- Arch:

  ```bash
  sudo pacman -S --needed gcc git make flex bison gperf python-pyserial python-
  --cryptography python-future python-pyparsing python-elftools
  ```

注解：一些旧的（2014 年之前）Linux 发行版中使用的 pyserial 版本可能是 2.x，ESP-IDF 并不支持。这种情况下，请按照第四步：安装 Python 软件包 章节的介绍，使用 pip 安装软件包。

工具链设置  Linux 版的 ESP32 工具链可以从 Espressif 的网站下载：

- 64 位 Linux：
  ```
  https://dl.espressif.com/dl/xtensa-esp32-elf-gcc8_4_0-esp-2020r3-linux-amd64.tar.gz
  ```

- 32 位 Linux：
  ```
  ```

1. 下载压缩文件之后，解压到 ~/esp 目录中：

   - 64 位 Linux：
     ```bash
     mkdir -p ~/esp
     cd ~/esp
     tar -xzf ~/Downloads/xtensa-esp32-elf-gcc8_4_0-esp-2020r3-linux-amd64.tar.gz
     ```

   - 32 位 Linux：
     ```bash
     mkdir -p ~/esp
     cd ~/esp
     tar -xzf ~/Downloads/xtensa-esp32-elf-gcc8_4_0-esp-2020r3-linux-i686.tar.gz
     ```
Chapter 1. 快速入门

2. 工具链将被压到 ~/.esp/xtensa-esp32-elf/ 路径下。为了正常使用工具链，您必须更新 ~/.profile 文件中的 PATH 环境变量。此外，您还可以在 ~/.profile 文件中增加以下代码，这样一来，所有终端窗口均可以使用 xtensa-esp32-elf:

```bash
export PATH="$HOME/esp/xtensa-esp32-elf/bin:$PATH"
```

或者，您可以为上述命令创建一个别名。这样，您只有在需要时才可以使用工具链。如需设置别名，请将以下代码添加至您的 ~/.profile 文件中:

```bash
alias get_esp32='export PATH="$HOME/esp/xtensa-esp32-elf/bin:$PATH"'
```

这样，您可以在终端输入 get_esp32 命令将工具链添加至您的 PATH，从而使用工具链。

注解：如果您已将 /bin/bash 设置为登录 shell，且同时存在 .bash_profile 和 .profile，则请更新 .bash_profile。在 CentOS 环境下，alias 需要添加到 .bashrc 文件中。

3. 退出并重新登录以使 .profile 更改生效。运行以下命令来检查 PATH 设置是否正确

```bash
printenv PATH
```

检查字符串的开头是否包含类似的工具链路径:

```bash
$ printenv PATH /home/user-name/esp/xtensa-esp32-elf/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
```

这里，您需要将 /home/user-name 替换为您的安装主目录。

权限问题 /dev/ttyUSB0 某些 Linux 版本可能会在烧写 ESP32 时出现 Failed to open port /dev/ttyUSB0 错误消息，这可以通过将当前用户添加到 dialout 组来解决。

后续步骤 继续设置开发环境，请前往第二步：获取 ESP-IDF 章节。

相关文档

从 零 开 始 设置 Linux 环境下的工具链（传统 GNU Make）

注解：ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能不会继续支持基于 GNU Make 的构建系统。

注解：安装工具链的标准方法请见 这里。请参考 工具链自定义设置 章节，查看可能需要从头开始设置工具链的情况。

安装准备 编译 ESP-IDF 需要以下软件包：

- Ubuntu and Debian:

  ```bash
  sudo apt-get install gcc git wget make libncurses-dev flex bison gperf python
  → python-pip python-setuptools python-serial python-cryptography python-future
  → python-pyparsing python-pyelftools libffi-dev libssl-dev
  ```

- Arch:

  ```bash
  sudo pacman -S --needed gcc git make ncurses flex bison gperf python-pyserial
  → python-cryptography python-future python-pyparsing python-pyelftools
  ```

Espressif Systems 34 Release v4.3-dev-1561-g357a277603

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从源代码编译工具链

• 安装依赖项:
  - CentOS 7:
    ```
    sudo yum install gawk gperf grep gettext ncurses-devel python python-devel
    ```
  - Ubuntu pre-16.04:
    ```
    sudo apt-get install gawk gperf grep gettext libncurses-dev python
    ```
  - Ubuntu 16.04 或以上:
    ```
    sudo apt-get install gawk gperf grep gettext python-dev automake bison flex texinfo help2man libtool
    ```
  - Debian 9:
    ```
    sudo apt-get install gawk gperf grep gettext libncurses-dev python-dev automake bison flex texinfo help2man libtool libtool-bin
    ```
  - Arch:
    ```
    TODO
    ```

• 创建工作目录，并进入该目录:
  ```
  mkdir -p ~/esp
cd ~/esp
  ```

• 下载并编译 crosstool-NG:
  ```
  git clone https://github.com/espressif/crosstool-NG.git
cd crosstool-NG
git checkout esp-2020r3
git submodule update --init
  .bootstrap && ./configure --enable-local && make
  ```

• 编译工具链:
  ```
  ./ct-ng xtensa-esp32-elf
  ./ct-ng build
  chmod -R u+w builds/xtensa-esp32-elf
  ```
  编译得到的工具链会被保存到 ~ / esp / crosstool-NG / builds / xtensa-esp32-elf。请按照标准设置指南的介绍，将工具链添加到 PATH。

后续步骤 继续设置开发环境，请前往 第二步：获取 ESP-IDF 章节。

Mac OS 平台工具链的标准设置(传统 GNU Make)

注解：ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能不会继续支持基于 GNU Make 的构建系统。

安装准备

• 安装 pip:
Chapter 1. 快速入门

```bash
sudo easy_install pip
```

**注解：** pip 稍后将用于安装所需 Python 包。

工具链设置  Mac OS 版本的 ESP32 工具链可以从以下地址下载：
下载压缩文件之后，解压到 ~/esp 目录中：

```bash
mkdir -p ~/esp
cd ~/esp
tar -xzf ~/Downloads/xtensa-esp32-elf-gcc8_4_0-esp-2020r3-macos.tar.gz
```

工具链被解压到 ~/esp/xtensa-esp32-elf/ 路径下。
为了正常使用工具链，您必须更新 ~/profile 文件中的 PATH 环境变量。此外，您还可以在 ~/.profile 文件中增加以下代码，这样一来，所有终端窗口均可以使用 xtensa-esp32-elf:

```bash
export PATH=$HOME/esp/xtensa-esp32-elf/bin:$PATH
```

或者，您可以为上述命令创建一个别名。这样，您只有在需要时才可以使用工具链。如需设置别名，请将以下代码增加至您的 ~/.profile 文件中:

```bash
alias get_esp32="export PATH=$HOME/esp/xtensa-esp32-elf/bin:$PATH"
```

这样，您可以在终端输入 get_esp32 命令将工具链添加至您的 PATH，从而使用工具链。

后续步骤  继续设置开发环境，请前往第二步：获取 ESP-IDF 章节。

相关文档

从零开始设置 Mac OS 环境下的工具链（传统 GNU Make）

**注解：** ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能不会继续支持基于 GNU Make 的构建系统。

**注解：** 安装工具链的标准方法请见这里。请参考工具链自定义设置 章节，查看可能需要从头开始设置工具链的情况。

安装准备

* 安装 pip:

```bash
sudo easy_install pip
```

**注解：** pip 稍后将用于安装必要的 Python 软件包。
从源代码编译工具链

- 安装依赖项:
  - 安装 MacPorts 或 homebrew 安装包管理器。MacPorts 需要完整的 XCode 软件，而 homebrew 只需要安装 XCode 命令行工具即可。
  - 对于 MacPorts:
    ```bash
    sudo port install gsed gawk binutils gperf grep gettext wget
    →libtool autoconf automake
    ```
  - 对于 homebrew:
    ```bash
    brew install gnu-sed gawk binutils gperftools gettext wget
    →help2man libtool autoconf automake
    ```

- 创建一个文件系统镜像（区分大小写）:
  ```bash
  hdiutil create ~/esp/crosstool.dmg -volname "ctng" -size 10g -fs "Case-sensitive HFS+"
  ```

- 挂载:
  ```bash
  hdiutil mount ~/esp/crosstool.dmg
  ```

- 创建指向您工作目录的符号链接:
  ```bash
  mkdir -p ~/esp
  ln -s /Volumes/ctng ~/esp/ctng-volume
  ```

- 前往新创建的目录
  ```bash
  cd ~/esp/ctng-volume
  ```

- 下载并编译 crosstool-NG:
  ```bash
  git clone https://github.com/espressif/crosstool-NG.git
  cd crosstool-NG
  git checkout esp-2020r3
  git submodule update --init
  ./bootstrap && ./configure --enable-local && make
  ```

- 编译工具链:
  ```bash
  ./ct-ng xtensa-esp32-elf
  ./ct-ng build
  chmod -R u+w builds/xtensa-esp32-elf
  ```

编译得到的工具链会被保存到 ~/esp/ctng-volume/crosstool-NG/builds/xtensa-esp32-elf。请按照标准设置指南的介绍，将工具链添加到 PATH。

后续步骤 继续设置开发环境，请前往第二步：获取 ESP-IDF 章节。

<table>
<thead>
<tr>
<th>Windows</th>
<th>Linux</th>
<th>macOS</th>
</tr>
</thead>
</table>

Espressif Systems 37 Release v4.3-dev-1561-g357a277603

Submit Document Feedback
注解：在本文档中，Linux 和 MacOS 操作系统中 ESP-IDF 的默认安装路径为 ~/esp; Windows 操作系统的默认路径为 %userprofile%\esp。您也可以将 ESP-IDF 安装在任何其他路径下，但请注意在使用命令行时进行相应替换。注意，ESP-IDF 不支持带有空格的路径。

此外，您也可以根据自身经验和实际需求，对环境进行个性化设置，而非使用预置工具链。此时，请前往工具链自定义设置（传统 GNU Make 系统）章节获取更多信息。

第二步：获取 ESP-IDF

除了工具链，您还需要用 ESP32 使用的 API（软件库和源代码），具体请见 ESP-IDF 仓库。

获取本地副本：打开终端，切换到你要存放 ESP-IDF 的工作目录，使用 git clone 命令克隆远程仓库。打开终端，后运行以下命令：

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

ESP-IDF 将下载至 ~/esp/esp-idf。

请前往 ESP-IDF 版本简介，查看 ESP-IDF 不同版本的具体适用场景。

注解：此命令将克隆 master 分支，该分支保存着 ESP-IDF 的最新版本，但它功能齐全，每周都会更新一些新功能并修正一些错误。

注解：GitHub 中“下载 zip 文档”的功能不适用于 ESP-IDF，所以需要使用 git clone 命令，作为备份，可以在没有安装 Git 的环境中下载 Stable version 的 zip 归档文件。

注解：在克隆远程仓库时，不要忘记加上 --recursive 选项。否则，请接着运行以下命令，获取所有子模块：

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

第三步：设置环境变量

工具链通过环境变量 IDF_PATH 获得 ESP-IDF 的目录。因此，您需要在 PC 中设置该环境变量，否则无法编译工程。

您可以在每次重启会话时手动设置，也可以在用户配置文件中进行永久设置，具体请前往在用户配置文件中添加 IDF_PATH（传统 GNU Make）章节，查看 Windows、Linux 及 MacOS 操作系统的具体设置方式。

第四步：安装 Python 软件包

ESP-IDF 所需的 Python 软件包位于 IDF_PATH/requirements.txt 中。您可以运行以下命令进行安装:

```bash
python -m pip install --user -r $IDF_PATH/requirements.txt
```

注解：请注意查询您所使用的 Python 解释器的版本（运行命令 python --version），并根据查询结果将上方命令中的 python 替换为 python3,python3.7，例如:
第五步：开始创建工程

现在，您可以开始准备开发 ESP32 应用程序了。您可以从 ESP-IDF 中 examples 目录下的 get-started/hello_world 工程开始。

将 get-started/hello_world 复制至您本地的 ~/esp 目录下：

Linux 和 MacOS 操作系统

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

Windows 操作系统

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

ESP-IDF 的 examples 目录下有一系列示例工程，都可以按照上面的方法进行创建。您可以按照上述方法复制并运行其中的任何示例，也可以直接编译示例，无需进行复制。

重要：ESP-IDF 编译系统不支持带有空格的路径。

第六步：连接设备

现在，请将您的 ESP32 开发板连接到 PC，并查看开发板使用的串口。

通常，串口在不同操作系统下显示的名称有所不同：

- Windows 操作系统：COM1 等
- Linux 操作系统：以 /dev/tty 开始
- MacOS 操作系统：以 /dev/cu. 开始

有关如何查看串口名称的详细信息，请见 与 ESP32 创建串口连接（传统 GNU Make 系统）。

注解：请记住串口名，您会在下面的步骤中用到。

第七步：配置

请进入第五步：开始创建工程 中提到的 hello_world 目录，并运行工程配置工具 menuconfig。

Linux 和 MacOS 操作系统

```
cd ~/esp/hello_world
make menuconfig
```
Windows 操作系统

```bash
cd %userprofile%\esp\hello_world
make menuconfig
```

如果之前的步骤都正确，则会显示下面的菜单:

进入菜单后，选择 `Serial flasher config` > `Default serial port` 配置串口（设备将通过该串口加载工程）。按回车键确认选择，点击 `< Save >` 保存配置，然后点击 `< Exit >` 退出 `menuconfig`。

`menuconfig` 工具的常见操作见下:

- 上下箭头: 移动
- 回车: 进入子菜单
- ESC 键: 返回上级菜单或退出
- 英文问号: 调出帮助菜单（退出帮助菜单，请按回车键）
- 空格 ` ` 或 ` ` 键: 选择 `*` 配置选项
- N 键: 禁用 `*` 配置选项
- 英文问号 (查询配置选项): 调出有关该选项的帮助菜单
- / 键: 寻找配置工程

**注意:** 如果您使用的是 ESP32-DevKitC（板载 ESP32-SOLO-1 模组），请在烧写示例程序前，前往 `menuconfig` 中使能单核模式 (`CONFIG_FREERTOS_UNICORE`)。

**第八步: 编译和烧录**

请使用以下命令，编译烧录工程:

```bash
make flash
```

运行以上命令可以编译应用程序和所有 ESP-IDF 组件，接着生成 bootloader、分区表和应用程序二进制文件。接着，这些二进制文件将被烧录至 ESP32 开发板。

如果一切顺利，您可在烧录完成后看到类似下方的打印信息（代表加载进程）。接着，开发板将会复位，应用程序“hello_world”开始启动。
如果您希望使用 Eclipse IDE，而非 make 编译系统，请参考 Eclipse guide。

第九步：监视器

您可以使用 make monitor 命令，监视“hello_world”的运行情况。

运行该命令后，IDF 监视器 应用程序将启动:

```
$ make monitor
MONITOR
--- idf_monitor on /dev/ttyUSB0 115200 ---
--- Quit: Ctrl+I | Menu: Ctrl+T | Help: Ctrl+I followed by Ctrl+H ---
ets Jun 8 2016 00:22:57
rst:0x1 (PWRON_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
ets Jun 8 2016 00:22:57
...
```

此时，您就可以在启动日志和诊断日志之后，看到打印的“Hello world!”了。

```
...  Hello world!
Restarting in 10 seconds...
I (211) cpu_start: Starting scheduler on APP CPU.
Restarting in 9 seconds...
Restarting in 8 seconds...
Restarting in 7 seconds...
```

您可使用快捷键 Ctrl+I，退出 IDF 监视器。

如果 IDF 监视器在烧录后很快发生错误，或打印信息全是乱码（见下），很有可能是因为您的开发板采用了 26 MHz 晶振，而 ESP-IDF 默认支持大多数开发板使用的 40 MHz 晶振。
此时，请您：

1. 退出监视器。
2. 打开 `menuconfig`。
3. 进入 `Component config` -> `ESP32-specific` -> `Main XTAL frequency` 进行配置，将 `CONFIG_ESP32_XTAL_FREQ_SEL` 设置为 26 MHz。
4. 然后，请重新编译和烧录应用程序。

### 注解：
您可以运行以下命令，一次性执行构建、烧录和监视过程：

```
make flash monitor
```

此外，请前往 [IDF 监视器](https://idf.espressif.com) 了解更多使用 IDF 监视器的快捷键和其他详情。

恭喜，您已完成 ESP32 的入门学习！

现在，您可以尝试一些其他 examples，或者直接开发自己的应用程序。

### 环境变量

用户可以在使用 `make` 命令时 **直接设置** 部分环境变量，而无需进入 `make menuconfig` 进行重新配置。这些变量包括：

<table>
<thead>
<tr>
<th>变量</th>
<th>描述与使用方式</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESPPORT</td>
<td>覆盖 <code>flash</code> 和 <code>monitor</code> 命令使用的串口。例：<code>make flash ESPPORT=/dev/ttyUSB1</code></td>
</tr>
<tr>
<td>ESPBAUD</td>
<td>覆盖烧录 ESP32 时使用的串口速率。例：<code>make flash ESPBAUD=9600</code></td>
</tr>
<tr>
<td>MONITORBAUD</td>
<td>覆盖监控时使用的串口速率。例：<code>make monitor MONITORBAUD=9600</code></td>
</tr>
</tbody>
</table>

### 注解：
可导出环境变量（例：`export ESPPORT=/dev/ttyUSB1`）。在同一会话窗口中，如果未被同步覆盖，所有 `make` 命令均会使用导出的环境变量值。

### 更新 ESP-IDF

乐鑫会不定时推出更新版本的 ESP-IDF，修复 bug 或推出新的特性。因此，您在使用时，也应注意更新您本地的版本。最简单的方法是：直接删除您本地的 `esp-idf` 文件夹，然后按照第二步：获取 ESP-IDF 中的指示，重新完成克隆。

如果您希望将 ESP-IDF 克隆到新的路径下，请务必重新设置 `IDF_PATH`。否则，工具链将无法找到 ESP-IDF。

此外，您可以仅更新变更部分。具体方式，请前往 **更新** 章节查看。

### 相关文档

- **在用户配置文件中添加 IDF_PATH（传统 GNU Make）**

  注解：ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能不会继续支持基于 GNU Make 的构建系统。

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Release v4.3-dev-1561-g357a277603

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为了在系统多次启动时，保留 IDF_PATH 环境变量的设置，请按照以下说明将该变量的设置增加至用户配置文件。

**Windows 操作系统** 用户配置文件脚本保存在 C:/msys32/etc/profile.d/ 路径下，每次打开 MSYS2 窗口时均会执行。

1. 在 C:/msys32/etc/profile.d/ 目录下创建一个新的脚本文件，并将其命名为 export_idf_path.sh。
2. 指定您的 ESP-IDF 保存路径，这通常与您的系统配置有关，比如 C:\msys32\home\user-name\esp\esp-idf。
3. 在脚本文件中加入下方 export 命令行，例:

```bash
export IDF_PATH="C:/msys32/home/user-name/esp/esp-idf"
```

注意请将反斜杠替换为 Windows 操作系统路径要求的正斜杠。

4. 保存脚本文件。

5. 关闭 MSYS2 窗口，并重新打开。运行以下命令，检查 IDF_PATH 是否成功设置：

```bash
printenv IDF_PATH
```

如果您是在安装 ESP32 软件的过程中从 第三步：设置环境变量 章节跳转至此，请返回 第五步：开始创建工程 章节。

**Linux 和 MacOS 操作系统** 在 ~/.profile 文件中增加以下命令，设置 IDF_PATH 变量:

```bash
export IDF_PATH=/home/user-name/esp/esp-idf
```

退出并重新登录，检查设置是否生效。

**注解**：如果您已将 /bin/bash 设置为登录 shell，且同时存在 .bash_profile 和 .profile，则请更新 .bash_profile。

运行以下命令，检查 IDF_PATH 是否成功设置：

```bash
printenv IDF_PATH
```

如果您是在安装 ESP32 软件的过程中从 第三步：设置环境变量 章节跳转至此，请返回 第五步：开始创建工程 章节。

**与 ESP32 创建串口连接（使用 GNU Make 系统）**

**注解**：ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能不会继续支持基于 GNU Make 的构建系统。

本章节主要介绍如何创建 ESP32 和 PC 之间的串口连接。
连接 ESP32 和 PC 用 USB 线将 ESP32 开发板连接到 PC。如果设备驱动程序没有自动安装，请先确认 ESP32 开发板上的 USB 转串口芯片（或外部转串口适配器）型号，然后在网上搜索驱动程序，并进行手动安装。

以下是乐鑫 ESP32 等开发板驱动程序的链接：

<table>
<thead>
<tr>
<th>开发板</th>
<th>USB 驱动</th>
<th>备注</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-DevKitC</td>
<td>CP210x</td>
<td></td>
</tr>
<tr>
<td>ESP32-LyraT</td>
<td>CP210x</td>
<td></td>
</tr>
<tr>
<td>ESP32-LyraTD-MSC</td>
<td>CP210x</td>
<td></td>
</tr>
<tr>
<td>ESP32-PICO-KIT</td>
<td>CP210x</td>
<td></td>
</tr>
<tr>
<td>ESP-WROVER-KIT</td>
<td>FTDI</td>
<td></td>
</tr>
<tr>
<td>ESP32 Demo 板</td>
<td>FTDI</td>
<td></td>
</tr>
<tr>
<td>ESP-Prog</td>
<td>FTDI</td>
<td>编程板（w/o ESP32）</td>
</tr>
<tr>
<td>ESP32-MeshKit-Sense</td>
<td>n/a</td>
<td>搭配 ESP-Prog 使用</td>
</tr>
<tr>
<td>ESP32-Sense Kit</td>
<td>n/a</td>
<td>搭配 ESP-Prog 使用</td>
</tr>
</tbody>
</table>

- CP210x: CP210x USB to UART Bridge VCP Drivers
- FTDI: FTDI Virtual COM Port Drivers

以上驱动仅用作参考。正常情况下，当上述任一 ESP32 开发板与 PC 连接时，打包在操作系统中的驱动程序将会开始自动安装。

查看端口（Windows 用户）检查 Windows 设备管理器中的 COM 端口列表，断开 ESP32 与 PC 的连接，然后重连，查看从列表中消失后再次出现的是哪个端口。

以下为 ESP32 DevKitC 和 ESP32 WROVER KIT 端口：

![Device Manager](image)

图 8: Windows 设备管理器中 ESP32-DevKitC 的 USB 至 UART 桥
图 9: Windows 设备管理器中 ESP-WROVER-KIT 的两个 USB 串行端口
Chapter 1. 快速入门

查看端口（Linux 和 MacOS 用户） 查看 ESP32 开发板（或外部转串口适配器）的串口设备名称，请运行两次下述命令。首先，断开开发板或适配器，第一次运行命令；然后，连接开发板或适配器，第二次运行命令。其中，第二次运行命令后出现的端口即是 ESP32 对应的串口:

**Linux**

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

**MacOS**

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

将用户增加到 Linux 的 dialout 组 当前登录用户应当拥有通过 USB 对串口进行读写的权限。在多数 Linux 版本中，您都可以通过以下命令，将用户添加到 dialout 组，来获取读写权限:

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

在 Arch Linux 中，需要通过以下命令将用户添加到 uucp 组中:

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

请重新登录，确保串口读写权限可以生效。

确认串口连接 现在，请使用串口终端程序，验证串口连接是否可用。在本示例中，我们将使用 PuTTY SSH Client 进行验证。该工具同时适用于 Windows 和 Linux 操作系统。您也可以使用其他串口程序，设置通信参数如下。

运行终端，配置串口：波特率 = 115200，数据位 = 8，停止位 = 1，奇偶校验 = N。在 Windows 和 Linux 中配置串口和通信参数（如 115200-8-1-N）的截图如下。注意，这里一定要选择在上述步骤中确认的串口进行配置。

然后，请在终端打开串口，查看 ESP32 是否有任何打印，具体打印内容取决于加载至 ESP32 的程序。ESP32 打印示例

```plaintext
tst:0x5 (DEEPSLEEP_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
tst: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
...
```

如果打印出的日志是可读的（而不是乱码），则表示串口连接正常。此时，您可以继续进行安装，并最终将应用程序下载到 ESP32。

注解：在某些串口接线方式下，在 ESP32 启动并开始打印串口日志前，需要在终端程序中禁用串口 RTS & DTR 引脚。该问题仅存在于将 RTS & DTR 引脚直接连接到 EN & GPIOO 引脚上的情况，绝大多数开发板（包括乐鑫所有的开发板）都没有这个问题。更多信息参见 esptool 文档。
图 10: 在 Windows 操作系统中使用 PuTTY 设置串口通信参数
图 11: 在 Linux 操作系统中使用 PuTTY 设置串口通信参数
Chapter 1. 快速入门

[注解:] 验证完成后，请关闭串口终端。我们将在后续步骤中向 ESP32 下载新的应用程序，如果未关闭终端，则该应用程序将无法访问串口。

如果您是在安装 ESP32 软件的过程中从第六步：连接设备 章节跳转至此，请返回第七步：配置 章节。

通过 make 指令创建和烧录项目（传统 GNU Make）

[注解:] ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能不会继续支持基于 GNU Make 的构建系统。

找到项目 除了 esp-idf-template 项目模板外，ESP-IDF 还在 GitHub 仓库中的 examples 目录下提供多个示例项目。

请找到并进入您想要的项目，开始配置、构建该项目。

配置项目

make menuconfig

编译项目

make all

该命令将配置 app 和 bootloader，并根据配置生成分区表。

烧录项目  make all 完成后将打印一行命令，提示您如何使用 esptool.py 烧录芯片。不过，您可以使用以下命令进行烧录:

make flash

该命令可以将整个项目（包括 app, bootloader 和分区表）烧录至新芯片。此外，如果分区表中存在 ota_data，则该命令还会将原始 ota_data 烧录至芯片。该命令允许您直接从 factory 分区中运行新加载的 app（如果 factory 分区不存在，则从第一个 OTA 分区开始运行）。您可以通过 make menuconfig 配置串口的烧录。

在运行 make flash 之前无需单独运行 make all。make flash 命令本身就可以自动构建所需的文件。

仅编辑和烧录应用程序 在首次烧录完成后，您可以只编辑并编译应用程序，而不再包括 bootloader 和分区表。这种情况可以使用以下命令:

    • make app —仅编译应用程序
    • make app-flash —仅烧录应用程序

make app-flash 在有需要时自动重新编译应用程序。

如果没有变化，每次都重新烧录，编译 bootloader 和分区表也没有坏处。

分区表 项目编译完成后，“build” 目录下将出现一个名为“my_app.bin”（例）的二进制文件。这是一个可由 bootloader 加载的 ESP32 映像文件。

ESP32 的一块 flash 可以包含多个应用程序，以及多种数据（校准数据、文件系统、参数存储等）。因此，在向 flash 烧录分区表时，通常保留 0x8000 的偏移量。

分区表中的每个条目都有名称（标签）、类型（app、数据或其他）、子类型及在 flash 中的偏移量。

使用分区表最简便的方法是：运行 make menuconfig，选择一个预定义分区表：

Espressif Systems Release v4.3-dev-1561-g357a277603
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Chapter 1. 快速入门

- “Single factory app, no OTA”
- “Factory app, two OTA definitions”

上述两种情况中，factory app 在 flash 中的烧录偏移地址均为 0x10000。运行 make partition_table 命令可以打印分区表摘要。

更多有关分区表及自定义分区表的内容，请见相关文档。

Eclipse IDE 的创建和烧录指南 (传统 GNU Make)

注解: ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能会继续支持基于 GNU Make 的构建系统。

安装 Eclipse IDE  Eclipse IDE 是一个可视化的集成开发环境，可用于编写、编译和调试 ESP-IDF 项目。

- 首先，请在您的平台上安装相应的 ESP-IDF，具体步骤请按照您的操作系统（Windows、OS X 和 Linux）对应的指示进行安装。
- 我们建议，您可以首先使用命令行创建一个项目，大致熟悉项目的创建流程。此外，您还需要使用命令行 (make menuconfig) 对您的 ESP-IDF 项目进行配置。目前，Eclipse 还无法配置 ESP-IDF 项目。
- 从 eclipse.org 下载对应操作系统的 Eclipse 安装器。
- 运行 Eclipse Installer，选择 “Eclipse for C/C++ Development”（有的版本也可能显示为 CDT）。

配置 Eclipse  打开安装好的 Eclipse IDE，并按照以下步骤进行操作:

导入新项目

- Eclipse 需使用 ESP-IDF 的 Makefile 功能。因此，在使用 Eclipse 前，您需要先创建一个 ESP-IDF 项目。在创建 ESP-IDF 项目时，您可以使用 GitHub 中的 idf-template 项目模板，或从 ESP-IDF 子目录中复制一个 example。
- 运行 Eclipse，选择 “File” -> “Import…”。
- 在弹出的对话框中选择 “C/C++” -> “Existing Code as Makefile Project”，点击 “Next”。
- 进入下一界面，在 “Existing Code Location” 处输入您的 IDF 项目路径。注意，这里应输入 ESP-IDF 项目的路径，而非 ESP-IDF 本身的路径（这个稍后再填）。此外，您指定的目标路径中应包含名为 Makefile (项目 Makefile) 的文件。
- 本界面中，找到 “Toolchain for Indexer Settings”，选择 “Cross GCC”，最后点击 “Finish”。

项目属性

- 新项目将出现在 “Project Explorer” 下。右键选择该项目，并在菜单中选择 “Properties”。
- 点击 “C/C++ Build” 下的 “Environment” 属性页，选择 “Add...”，并在对应位置输入 BATCH_BUILD 和 1。
- 再次点击 “Add...”，并在 IDF_PATH 处输入 ESP-IDF 所在的完整安装路径。Windows 用户可以从 Windows 浏览器复制 IDF_PATH。
- 编辑 PATH 环境变量。保留当前值，并将该路径增加至 Xtensa 工具链安装路径后，作为 IDF 设置的一部分（如已增加至 PATH，则可忽略）。工具链的常见路径为/home/user-name/esp/xtensa-esp32-elf/bin/（例）。注意，您需要在补充的路径前增加一个冒号(:)。Windows 用户需要注意将 PATH 环境变量前增加：C:\msys32\mingw32\bin;C:\msys32\opt\xtensa-esp32-elf\bin;C:\msys32\usr\bin。注意，请根据 msys32 的具体安装路径，修改 PATH 环境变量。
- MacOS 用户需要增加一个 PYTHONPATH 环境变量，并将其设置为/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/site-packages。保证系统中预先安装的 Python（需安装 pyserial 模块）可以覆盖 Eclipse 内置的任何 Python。

特别说明: 如果您的 IDF_PATH 或项目不在 c:\msys32\home 之下，则应使用自定义编译命令: python $(IDF_PATH)/tools/windows/eclipse_make.py（请注意，这种方法可能导致编译时间显著增加。）

- 前往 “C/C++ General” -> “Preprocessor Include Paths” 属性页面。点击 “Providers” 选项卡。
Chapter 1. 快速入门

- 从 “Providers” 列表中选择 “CDT Cross GCC Built-in Compiler Settings”，将 “Command to get compiler specs” 修改为 xtensa-esp32-elf-gcc $(\{FLAGS\}) -std=c++11 -E -P -v -dD \"$(\{INPUTS\})\"。
- 从 “Providers” 列表中选择 “CDT GCC Build Output Parser”，将 “Compiler command pattern” 修改为 xtensa-esp32-elf-\{gcc\|g++\|c++\|cc\|cpp\|clang\}。
  - 前往 “C/C++ General” -> “Indexer” 属性页面。
  - 勾选 “Enable project specific settings”，启用本页面上的其他设置。
  - 取消勾选 “Allow heuristic resolution of includes”。勾选该选项有时会导至 Eclipse 无法找到正确的头文件目录。
  - 前往 “C/C++ Build” -> “Behavior” 属性页面。
  - 勾选 “Enable parallel build”，启用 “并行编译” 配置。

在 Eclipse 中构建项目 在首次构建项目前，Eclipse IDE 可能会显示大量有关未定义值的错误和警告，这是因为 ESP-IDF 在编译过程中会自动生成一些源文件。因此，这些错误和警告均会在项目编译完成后消失。

  - 点击 “OK”，关闭 Eclipse IDE 中的 “Properties” 对话框。
  - 在 Eclipse IDE 界面外，打开命令提示符窗口。进入项目目录，运行 make menuconfig 设置项目的 ESP-IDF 配置。现阶段，您还无法在 Eclipse 中完成该操作。
  - 回到 Eclipse IDE 界面，选择 “Project” -> “Build” 开始编译项目。

小提示：如果您的项目不是通过 Eclipse 创建的，则在选择 “Project” -> “Build” 前还需进行 “Project” -> “Clean” 操作。此操作后，Eclipse 才能查看所有源文件的编译器参数，并借此确定头文件包含路径。

在 Eclipse 中烧录项目 您可以将 make flash 目标集成在 Eclipse 项目中，这样就可以通过 Eclipse UI 调用 esptool.py 进行烧录：

  - 打开 “Project Explorer”，并右击您的项目（请注意右击项目本身，而非项目下的子文件，否则 Eclipse 可能会找到错误的 Makefile）。
  - 从菜单中选择 “Build Targets” -> “Create…”。
  - 目标名称输入 “flash”，其他选项使用默认值。
  - 这时，您可以选择 “Project” -> “Build Target” -> “Build”（快捷键：Shift + F9），创建自定义烧录目标，用于编译、烧录项目。

注意，您仍需通过 make menuconfig 设置串行端口和其他烧录选项。make menuconfig 仍需通过命令行操作（具体请见对应操作系统的指南）。如有需要，请按照相同步骤添加 bootloader 和 partition_table 目标。

工具链自定义设置（传统 GNU Make 系统） 除了从乐鑫官网（请见第一步：设置工具链）下载二进制工具链外，您还可以自行编译工具链。

注解：ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能会继续支持基于 GNU Make 的构建系统。

如无特殊需求，建议直接使用我们提供的预编译二进制工具链。不过，您可以在以下情况考虑自行编译工具链：

  - 需要定制工具链编译配置
  - 需要使用其他 GCC 版本（如 4.8.5）
  - 需要破解 gcc、newlib 或 libc++
  - 有相关兴趣或时间充裕
  - 不信任从网站下载的 bin 文件

如需自行编译工具链，请查看以下文档：

Espressif Systems  Release v4.3-dev-1561-g357a277603
Submit Document Feedback
Chapter 1. 快速入门
Chapter 2

API 参考

2.1 蓝牙 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

- bt/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/BDTRM) 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_BT_controller_status_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
def 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_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
def 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
bool esp_bt_controller_is_sleeping( void )
```

to check whether Bluetooth controller is sleeping at the instant, if modem sleep is enabled

Note that this function shall not be invoked before esp_bt_controller_enable() This function is supposed to be used ORIG mode of modem sleep

**Return** true if in modem sleep state, false otherwise

```c
void esp_bt_controller_wakeup_request( void )
```

request controller to wakeup from sleeping state during sleep mode

Note that this function shall not be invoked before esp_bt_controller_enable() Note that this function is supposed to be used ORIG mode of modem sleep Note that after this request, Bluetooth controller may again enter sleep as long as the modem sleep is enabled

Profiling shows that it takes several milliseconds to wakeup from modem sleep after this request. Generally it takes longer if 32kHz XTAL is used than the main XTAL, due to the lower frequency of the former as the Bluetooth low power clock source.
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.

Return
- ESP_OK: success
- other: failed

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

tuint16_t controller_task_stack_size
Blueooth controller task stack size

tuint8_t controller_task_prio
Blueooth controller task priority

tuint8_t hci_uart_no
If use UART1/2 as HCI IO interface, indicate UART number

tuint32_t hci_uart_baudrate
If use UART1/2 as HCI IO interface, indicate UART baudrate

tuint8_t scan_duplicate_mode
Scan duplicate mode

tuint8_t scan_duplicate_type
Scan duplicate type

tuint16_t normal_adv_size
Normal adv size for scan duplicate

tuint16_t mesh_adv_size
Mesh adv size for scan duplicate

tuint16_t send_adv_reserved_size
Controller minimum memory value

tuint32_t controller_debug_flag
Controller debug log flag

tuint8_t mode
Controller mode: BR/EDR, BLE or Dual Mode

tuint8_t ble_max_conn
BLE maximum connection numbers

tuint8_t bt_max_acl_conn
BR/EDR maximum ACL connection numbers

tuint8_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)

uint32_t magic
    Magic number

struct esp_vhci_host_callback
    esp_vhci_host_callback used for vhci call host function to notify what host need to do

Public Members

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

int (*notify_host_recv)(uint8_t *data, uint16_t len)
    callback used to notify that the controller has a packet to send to the host

Macros

ESP_BT_CONTROLLER_CONFIG_MAGIC_VAL
BT_CONTROLLER_INIT_CONFIG_DEFAULT

Type Definitions

typedef struct esp_vhci_host_callback esp_vhci_host_callback_t
    esp_vhci_host_callback used for vhci call host function to notify what host need to do

Enumerations

design espp 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

design [anonymous]
    BLE sleep clock accuracy(SCA), values for ble_sca field in esp_bt_controller_config_t, currently only
ESP_BLE_SCA_500PPM and ESP_BLE_SCA_250PPM are supported.

    Values:

ESP_BLE_SCA_500PPM = 0
    BLE SCA at 500ppm

ESP_BLE_SCA_250PPM
    BLE SCA at 250ppm
Chapter 2. API 参考

```
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
```

```c
enum esp_bt_controller_status_t
{
    Bluetooth controller enable/disable/initialised/de-initialised status.

    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

```c
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
```

```c
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
   • bt/host/bluedroid/api/include/api/esp_bt_defs.h

Structures

   struct esp_bt_uuid_t
      UUID type.

      Public Members

         uint16_t len
            UUID length, 16bit, 32bit or 128bit

         uint16_t uuid16
            16bit UUID

         uint32_t uuid32
            32bit UUID

         uint8_t uuid128[ESP_UUID_LEN_128]
            128bit UUID

         union esp_bt_uuid_t::[anonymous] uuid
            UUID

Macros

ESP_BLUEDROID_STATUS_CHECK(status)
ESP_BT_OCTET16_LEN
ESP_BT_OCTET8_LEN
ESP_DEFAULT_GATT_IF
   Default GATT interface id.
ESP_BLE_CONN_INT_MIN
   relate to BTM_BLE_CONN_INT_MIN in stack/btm_ble_api.h
ESP_BLE_CONN_INT_MAX
   relate to BTM_BLE_CONN_INT_MAX in stack/btm_ble_api.h
ESP_BLE_CONN_LATENCY_MAX
   relate to ESP_BLE_CONN_LATENCY_MAX in stack/btm_ble_api.h
ESP_BLE_CONN_SUP_TOUT_MIN
   relate to BTM_BLE_CONN_SUP_TOUT_MIN in stack/btm_ble_api.h
Chapter 2. API

ESP_BLE_CONN_SUP_TOUT_MAX
relate to ESP_BLE_CONN_SUP_TOUT_MAX in stack/btm_ble_api.h

ESP_BLE_CONN_PARAM_UNDEF
ESP_BLE_SCAN_PARAM_UNDEF

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

ESP_UUID_LEN_16
ESP_UUID_LEN_32
ESP_UUID_LEN_128

ESP_BD_ADDR_LEN
Bluetooth address length.

ESP_BLE_ENC_KEY_MASK
Used to exchange the encryption key in the init key & response key.

ESP_BLE_ID_KEY_MASK
Used to exchange the IRK key in the init key & response key.

ESP_BLE_CSR_KEY_MASK
Used to exchange the CSRK key in the init key & response key.

ESP_BLE_LINK_KEY_MASK
Used to exchange the link key(this key just used in the BLE & BR/EDR coexist mode) in the init key & response key.

ESP_APP_ID_MIN
Minimum of the application id.

ESP_APP_ID_MAX
Maximum of the application id.

ESP_BD_ADDR_STR
ESP_BD_ADDR_HEX \((\text{addr})\)

Type Definitions
typedef uint8_t esp_bt_octet16_t[ESP_BT_OCTET16_LEN]
typedef uint8_t esp_bt_octet8_t[ESP_BT_OCTET8_LEN]

typedef uint8_t esp_link_key[ESP_BT_OCTET16_LEN]
typedef uint8_t esp_bd_addr_t[ESP_BD_ADDR_LEN]
Bluetooth device address.

typedef uint8_t esp_ble_key_mask_t

Enumerations
enum esp_bt_status_t
Status Return Value.

Values:

ESP_BT_STATUS_SUCCESS = 0
ESP_BT_STATUS_FAIL
ESP_BT_STATUS_NOT_READY
ESP_BT_STATUS_NOMEM
ESP_BT_STATUS_BUSY

Submit Document Feedback
ESP_BT_STATUS_DONE = 5
ESP_BT_STATUS_UNSUPPORTED
ESP_BT_STATUS_PARM_INVALID
ESP_BT_STATUS_UNHANDLED
ESP_BT_STATUS_AUTH_FAILURE
ESP_BT_STATUS_RMT_DEV_DOWN = 10
ESP_BT_STATUS_AUTH_REJECTED
ESP_BT_STATUS_INVALID_STATIC_RAND_ADDR
ESP_BT_STATUS_PENDING
ESP_BT_STATUS_UNACCEPT_CONN_INTERVAL
ESP_BT_STATUS_PARAM_OUT_OF_RANGE
ESP_BT_STATUS_TIMEOUT
ESP_BT_STATUS_PEER_LE_DATA_LEN_UNSUPPORTED
ESP_BT_STATUS_CONTROL_LE_DATA_LEN_UNSUPPORTED
ESP_BT_STATUS_ERR_ILLEGAL_PARAMETER_FMT
ESP_BT_STATUS_MEMORY_FULL = 20
ESP_BT_STATUS_EIR_TOO_LARGE

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

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

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

BT MAIN API

Overview  Instructions

Application Example  Instructions
API Reference

Header File
- 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

• bt/host/bluedroid/api/include/api/esp_bt_device.h

Functions

class 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: Success
• 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

• bt/host/bluedroid/api/include/api/esp_gap_ble_api.h

Functions

class 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
Chapter 2. API

- [in] callback: callback function

```c
esp_err_t esp_ble_gap_config_adv_data(esp_ble_adv_data_t *adv_data)
```
This function is called to override the BTA default ADV parameters.

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

**Parameters**
- [in] adv_data: Pointer to User defined ADV data structure. This memory space can not be freed until callback of config_adv_data is received.

```c
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

```c
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.

```c
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

```c
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.

```c
esp_err_t esp_ble_gap_stop_advertising(void)
```
This function is called to stop advertising.

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

```c
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

```c
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

```c
esp_err_t esp_ble_gap_set_rand_addr(esp_bd_addr_t rand_addr)
```
This function sets the random address for the application.

Return
• ESP_OK: success
• other: failed

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

```c
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

```c
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.

```c
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

```c
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

```c
esp_err_t esp_ble_gap_clear_whitelist(void)
```
Clear all white list.

Return
• ESP_OK: success
• other: failed

```c
esp_err_t esp_ble_gap_get_whitelist_size(uint16_t* length)
```
Get the whitelist size in the controller.

Return
• ESP_OK: success
## Chapter 2. API 参考

- 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]: minimum preferred connection interval
- [in]: maximum preferred connection interval
- [in]: preferred slave latency
- [in]: 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
Chapter 2. API

- ESP_OK: success
- other : failed

Parameters
- [in] raw_data: raw scan response data
- [in] raw_data_len: raw scan response 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.

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

- `[in] dev_num`: the number of the bonding devices
- `[in] dev_list`: bonding device list

```
• [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.

\[\text{esp_err_t} \ esp\_ble\_oob\_req\_reply(\esp\_bd\_addr\_t \ bd\_addr, uint8\_t \*TK, uint8\_t \ len)\]

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

\[\text{esp_err_t} \ esp\_ble\_gap\_disconnect(\esp\_bd\_addr\_t \ remote\_device)\]

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

\[\text{esp_err_t} \ esp\_ble\_get\_current\_conn\_params(\esp\_bd\_addr\_t \ bd\_addr, esp\_gap\_conn\_params\_t \*conn\_params)\]

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

\[\text{esp_err_t} \ esp\_gap\_ble\_set\_channels(esp\_gap\_ble\_channels \ channels)\]

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.

Unions
union esp_ble_key_value_t

#include <esp_gap_ble_api.h> union type of the security key value

Public Members

\[\text{esp\_ble\_penc\_keys\_t} \ penc\_key\]
received peer encryption key

\[\text{esp\_ble\_pcsrk\_keys\_t} \ pcsrk\_key\]
received peer device SRK
### Chapter 2. API

#### esp_ble_pid_keys_t
- **pid_key**
  - Peer device ID key

#### esp_ble_lenc_keys_t
- **lenc_key**
  - Local encryption reproduction keys \( \text{LTK} = d1(\text{ER}, \text{DIV}, 0) \)

#### esp_ble_lcsrk_keys
- **lcsrk_key**
  - Local device CSRK \( d1(\text{ER}, \text{DIV}, 1) \)

#### 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 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_set_rand_cmpl_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_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 esp_ble_adv_data_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 esp_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 esp_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_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_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_pkt_data_length_cmpl_evt_param`
'#include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_PKT_LENGTH_COMPLETE_EVT.

Public Members

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

`esp_ble_pkt_data_length_params_t params`
pkt data length value

`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.
Chapter 2. API

\[\text{esp_bd_addr_t}\] remote_addr
The remote device address

\textbf{struct ble_remove_bond_dev_cmplEvtParam}

#include <esp_gap_ble_api.h> ESP_GAP_BLE_REMOVE_BOND_DEV_COMPLETE_EVT.

\textbf{Public Members}

\[\text{esp_bt_status_t}\] status
Indicate the remove bond device operation success status

\[\text{esp_bd_addr_t}\] bd_addr
The device address which has been remove from the bond list

\textbf{struct ble_scan_param_cmplEvtParam}

#include <esp_gap_ble_api.h> ESP_GAP_BLE_SCAN_PARAM_SET_COMPLETE_EVT.

\textbf{Public Members}

\[\text{esp_bt_status_t}\] status
Indicate the set scan param operation success status

\textbf{struct ble_scan_resultEvtParam}

#include <esp_gap_ble_api.h> ESP_GAP_BLE_SCAN_RESULT_EVT.

\textbf{Public Members}

\[\text{esp_gap_search_evt_t}\] searchEvt
Search event type

\[\text{esp_bd_addr_t}\] bda
Bluetooth device address which has been searched

\[\text{esp_bt_dev_type_t}\] dev_type
Device type

\[\text{esp_bd_addr_type_t}\] ble_addr_type
Ble device address type

\[\text{esp_ble_evt_type_t}\] ble_evt_type
Ble scan result event type

\textbf{int} rssi
Searched device’s RSSI

\textbf{uint8_t} [ESP_BLE_ADV_DATA_LEN_MAX + ESP_BLE_SCAN_RSP_DATA_LEN_MAX]
Received EIR

\textbf{int} flag
Advertising data flag bit

\textbf{int} num_resps
Scan result number

\textbf{uint8_t} adv_data_len
Adv data length

\textbf{uint8_t} scan_rsp_len
Scan response length

\textbf{uint32_t} num_dis
The number of discard packets
struct ble_scan_rsp_data_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SCAN_RSP_DATA_SET_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate the set scan response data operation success status

struct ble_scan_rsp_data_raw_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SCAN_RSP_DATA_RAW_SET_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate the set raw advertising data operation success status

struct ble_scan_start_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SCAN_START_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate scan start operation success status

struct ble_scan_stop_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SCAN_STOP_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate scan stop operation success status

struct ble_set_channels_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_CHANNELS_EVT.

Public Members

esp_bt_status_t status
BLE set channel status

struct ble_set_rand_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_STATIC_RAND_ADDR_EVT.

Public Members

esp_bt_status_t status
Indicate set static rand address operation success status

struct ble_update_conn_params_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_UPDATE_CONN_PARAMS_EVT.
Public Members

*esp_bt_status_t* status
- Indicate update connection parameters success status

*esp_bd_addr_t* bda
- 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 conn_int
- Current connection interval

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

**struct ble_update_duplicate_exceptional_list_cmpl_evt_param**

```c
#include <esp_gap_ble_api.h>
ESP_GAP_BLE_UPDATE_DUPLICATE_EXCEPTIONAL_LIST_COMPLETE_EVT.
```

Public Members

*esp_bt_status_t* status
- Indicate update duplicate scan exceptional list operation success status

uint8_t subcode
- Define in esp_bt_duplicate_exceptional_subcode_type_t

uint16_t length
- The length of device_info

*esp_duplicate_info_t* device_info
- device information, when subcode is ESP_BLE_DUPLICATE_EXCEPTIONAL_LIST_CLEAN, the value is invalid

**struct ble_update_whitelist_cmpl_evt_param**

```c
#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_opration_t* wl_opration
- The value is ESP_BLE_WHITELIST_ADD if add address to whitelist operation success, ESP_BLE_WHITELIST_REMOVE if remove address from the whitelist operation success

**Structures**

**struct esp_ble_adv_params_t**
- Advertising parameters.
Public Members

```c
uint16_t adv_int_min
    Minimum advertising interval for undirected and low duty cycle directed advertising. Range: 0x0020 to 0x4000 Default: N = 0x0800 (1.28 second) Time = N * 0.625 msec Time Range: 20 ms to 10.24 sec
```

```c
uint16_t adv_int_max
    Maximum advertising interval for undirected and low duty cycle directed advertising. Range: 0x0020 to 0x4000 Default: N = 0x0800 (1.28 second) Time = N * 0.625 msec Time Range: 20 ms to 10.24 sec
```

```c
exp_ble_adv_type_t adv_type
    Advertising type
```

```c
exp_ble_addr_type_t own_addr_type
    Owner Bluetooth device address type
```

```c
exp_bd_addr_t peer_addr
    Peer device Bluetooth device address
```

```c
exp_ble_addr_type_t peer_addr_type
    Peer device Bluetooth device address type, only support public address type and random address type
```

```c
exp_ble_adv_channel_t channel_map
    Advertising channel map
```

```c
exp_ble_adv_filter_t adv_filter_policy
    Advertising filter policy
```

```c
struct esp_ble_adv_data_t
    Advertising data content, according to “Supplement to the Bluetooth Core Specification”.
```

Public Members

```c
bool set_scan_rsp
    Set this advertising data as scan response or not
```

```c
bool include_name
    Advertising data include device name or not
```

```c
bool include_txpower
    Advertising data include TX power
```

```c
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.
```

```c
int max_interval
    Advertising data show slave preferred connection max interval. The connection interval in the following manner: connIntervalmax = Conn_Interval_Max * 1.25 ms Conn_Interval_Max range: 0x0006 to 0x0C80 Conn_Interval_Max shall be equal to or greater than the Conn_Interval_Min. Value of 0xFFFF indicates no specific maximum. Values not defined above are reserved for future use.
```

```c
int appearance
    External appearance of device
```

```c
uint16_t manufacturer_len
    Manufacturer data length
```

```c
uint8_t* p_manufacturer_data
    Manufacturer data point
```

```c
uint16_t service_data_len
    Service data length
```
Chapter 2. API 参考

```c
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
```

```c
struct esp_ble_scan_params_t
    Ble scan parameters.
```

**Public Members**

```c
esp_ble_scan_type_t scan_type
    Scan type

esp_ble_addr_type_t own_addr_type
    Owner address type

esp_ble_scan_filter_t scan_filter_policy
    Scan filter policy
```

```c
uint16_t scan_interval
    Scan interval. This is defined as the time interval from when the Controller started its last LE scan until it begins the subsequent LE scan. Range: 0x0004 to 0x4000 Default: 0x0010 (10 ms) Time = N * 0.625 msec Time Range: 2.5 msec to 10.24 seconds

uint16_t scan_window
    Scan window. The duration of the LE scan. LE_Scan_Window shall be less than or equal to LE_Scan_Interval Range: 0x0004 to 0x4000 Default: 0x0010 (10 ms) Time = N * 0.625 msec Time Range: 2.5 msec to 10240 msec

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

```c
struct esp_gap_conn_params_t
    connection parameters information
```

**Public Members**

```c
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: 0x0000A to 0x0C80. Mandatory Range: 0x0000A 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
esp_bd_addr_t bda
    Bluetooth device address
```

```c
uint16_t min_int
    Min connection interval
```

```c
uint16_t max_int
    Max connection interval
```

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

```c
uint16_t 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 data length keys.
```

Public Members

```c
uint16_t rx_len
    pkt rx data length value
```

```c
uint16_t tx_len
    pkt tx data length value
```

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

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

```c
esp_bt_octet8_t rand
    The random number
```

```c
uint16_t ediv
    The ediv value
```

```c
uint8_t sec_level
    The security level of the security link
```

```c
uint8_t key_size
    The key size(7~16) of the security link
```

```c
struct esp_ble_pcsrk_keys_t
    BLE CSRK keys.
```

Public Members

```c
uint32_t counter
    The counter
```

```c
esp_bt_octet16_t csrk
    The csrk key
```

```c
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
```

```
struct 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

Macros

    ESP_BLE_ADV_FLAG_LIMIT_DISC
        BLE_ADV_DATA_FLAG data flag bit definition used for advertising data flag
    ESP_BLE_ADV_FLAG_BREDR_NOT_SPT
    ESP_BLE_ADV_FLAG_DMT_CONTROLLER_SPT
    ESP_BLE_ADV_FLAG_DMT_HOST_SPT
    ESP_BLE_ADV_FLAG_NON_LIMIT_DISC
    ESP_LE_KEY_NONE
    ESP_LE_KEY_PENC
    ESP_LE_KEY_PID
    ESP_LE_KEY_PCSRK
    ESP_LE_KEY_PLK
    ESP_LE_KEY_LLK
    ESP_LE_KEY_LENC
    ESP_LE_KEY_LID
    ESP_LE_KEY_LCSRK
    ESP_LE_AUTH_NO_BOND
    ESP_LE_AUTH_BOND
    ESP_LE_AUTH_REQ_MITM
ESP_LE_AUTH_REQ_BOND_MITM
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_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_GENERIC_THERMOMETER_EAR
ESP_BLE_APPEARANCE_GENERIC_HEART_RATE
ESP_BLE_APPEARANCE_HEART_RATE_BELT
ESP_BLE_APPEARANCE_GENERIC_BLOOD_PRESSURE
ESP_BLE_APPEARANCE_BLOOD_PRESSURE_ARM
ESP_BLE_APPEARANCE_BLOOD_PRESSURE_WRIST
ESP_BLE_APPEARANCE_GENERIC_HID
ESP_BLE_APPEARANCE_HID_KEYBOARD
ESP_BLE_APPEARANCE_HID_MOUSE
ESP_BLE_APPEARANCE_HID_JOYSTICK
ESP_BLE_APPEARANCE_HID_GAMEPAD
ESP_BLE_APPEARANCE_HID_DIGITIZER_TABLET
ESP_BLE_APPEARANCE_HID_CARD_READER
ESP_BLE_APPEARANCE_HID_DIGITAL_PEN
ESP_BLE_APPEARANCE_HID_BARCODE_SCANNER
ESP_BLE_APPEARANCE_GENERIC_GLUCOSE
ESP_BLE_APPEARANCE_GENERIC_WALKING
ESP_BLE_APPEARANCE_WALKING_IN_SHOE
ESP_BLE_APPEARANCE_WALKING_ON_SHOE
ESP_BLE_APPEARANCE_WALKING_ON_HIP
ESP_BLE_APPEARANCE_GENERIC_CYCLING
ESP_BLE_APPEARANCE_CYCLING_COMPUTER
ESP_BLE_APPEARANCE_CYCLING_SPEED
ESP_BLE_APPEARANCE_CYCLING_CADENCE
ESP_BLE_APPEARANCE_CYCLING_POWER
ESP_BLE_APPEARANCE_CYCLING_SPEED_CADENCE
ESP_BLE_APPEARANCE_GENERIC_PULSE_OXIMETER
ESP_BLE_APPEARANCE_PULSE_OXIMETER_FINGERTIP
ESP_BLE_APPEARANCE_PULSE_OXIMETER_WRIST
ESP_BLE_APPEARANCE_GENERIC_WEIGHT
ESP_BLE_APPEARANCE_GENERIC_PERSONAL_MOBILITY_DEVICE
ESP_BLE_APPEARANCE_POWERED_WHEELCHAIR
ESP_BLE_APPEARANCE_MOBILITY_SCOOTER
ESP_BLE_APPEARANCE_GENERIC_CONTINUOUS_GLUCOSE_MONITOR
ESP_BLE_APPEARANCE_GENERIC_INSULIN_PUMP
ESP_BLE_APPEARANCE_INSULIN_PUMP_DURABLE_PUMP
ESP_BLE_APPEARANCE_INSULIN_PUMP_PATCH_PUMP
ESP_BLE_APPEARANCE_INSULIN_PEN
ESP_BLE_APPEARANCE_GENERIC_MEDICATION_DELIVERY
ESP_BLE_APPEARANCE_GENERIC_OUTDOOR_SPORTS
ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION
ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_AND_NAV
ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_POD
ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_POD_AND_NAV
ESP_GAP_BLE_CHANNELS_LEN
ESP_GAP_BLE_ADD_WHITELIST_COMPLETE_EVT
    This is the old name, just for backwards compatibility.
ESP_BLE_ADV_DATA_LEN_MAX
    Advertising data maximum length.
ESP_BLE_SCAN_RSP_DATA_LEN_MAX
Scan response data maximum length.

BLE_BIT (n)

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

GAP callback function type.

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

Enumerations
enum esp_gap_ble_cb_event_t
GAP BLE callback event type.

Values:
ESP_GAP_BLE_ADV_DATA_SET_COMPLETE_EVT = 0
When advertising data set complete, the event comes
ESP_GAP_BLE_SCAN_RSP_DATA_SET_COMPLETE_EVT
When scan response data set complete, the event comes
ESP_GAP_BLE_SCAN_PARAM_SET_COMPLETE_EVT
When scan parameters set complete, the event comes
ESP_GAP_BLE_SCAN_RESULT_EVT
When one scan result ready, the event comes each time
ESP_GAP_BLE_ADV_DATA_RAW_SET_COMPLETE_EVT
When raw advertising data set complete, the event comes
ESP_GAP_BLE_SCAN_RSP_DATA_RAW_SET_COMPLETE_EVT
When raw advertising data set complete, the event comes
ESP_GAP_BLE_ADV_START_COMPLETE_EVT
When starting advertising complete, the event comes
ESP_GAP_BLE_SCAN_START_COMPLETE_EVT
When starting scan complete, the event comes
ESP_GAP_BLE_AUTH_CMPL_EVT
Authentication complete indication.
ESP_GAP_BLE_KEY_EVT
BLE key event for peer device keys
ESP_GAP_BLE_SEC_REQ_EVT
BLE security request
ESP_GAP_BLE_PASSKEY_NOTIF_EVT
passkey notification event
ESP_GAP_BLE_PASSKEY_REQ_EVT
  passkey request event

ESP_GAP_BLE_OOB_REQ_EVT
  OOB request event

ESP_GAP_BLE_LOCAL_IR_EVT
  BLE local IR event

ESP_GAP_BLE_LOCAL_ER_EVT
  BLE local ER event

ESP_GAP_BLE_NC_REQ_EVT
  Numeric Comparison request event

ESP_GAP_BLE_ADV_STOP_COMPLETE_EVT
  When stopping adv complete, the event comes

ESP_GAP_BLE_SCAN_STOP_COMPLETE_EVT
  When stopping scan complete, the event comes

ESP_GAP_BLE_SET_STATIC_RAND_ADDR_EVT
  When setting the static rand address complete, the event comes

ESP_GAP_BLE_UPDATE_CONN_PARAMS_EVT
  When updating connection parameters complete, the event comes

ESP_GAP_BLE_SET_PKT_LENGTH_COMPLETE_EVT
  When setting pkt length complete, the event comes

ESP_GAP_BLE_SET_LOCAL_PRIVACY_COMPLETE_EVT
  When enabling/disabling privacy on the local device complete, the event comes

ESP_GAP_BLE_REMOVE_BOND_DEV_COMPLETE_EVT
  When removing the bond device complete, the event comes

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

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

ESP_GAP_BLE_READ_RSSI_COMPLETE_EVT
  When reading the rssi complete, the event comes

ESP_GAP_BLE_UPDATE_WHITELIST_COMPLETE_EVT
  When adding or removing whitelist complete, the event comes

ESP_GAP_BLE_UPDATE_DUPLICATE_EXCEPTIONAL_LIST_COMPLETE_EVT
  When updating duplicate exceptional list complete, the event comes

ESP_GAP_BLE_SET_CHANNELS_EVT
  When setting BLE channels complete, the event comes

ESP_GAP_BLE_EVT_MAX

enum esp_ble_adv_data_type
  The type of advertising data(not adv_type)

Values:

ESP_BLE_AD_TYPE_FLAG = 0x01
ESP_BLE_AD_TYPE_16SRV_PART = 0x02
ESP_BLE_AD_TYPE_16SRV_CMPL = 0x03
ESP_BLE_AD_TYPE_32SRV_PART = 0x04
ESP_BLE_AD_TYPE_32SRV_CMPL = 0x05
ESP_BLE_AD_TYPE_128SRV_PART = 0x06
<table>
<thead>
<tr>
<th>Constant Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_BLE_AD_TYPE_128SRV_CMPL</td>
<td>0x07</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_NAME_SHORT</td>
<td>0x08</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_NAME_CMPL</td>
<td>0x09</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_TX_PWR</td>
<td>0xA</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_DEV_CLASS</td>
<td>0xD</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_SM_TK</td>
<td>0x10</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_SM_OOB_FLAG</td>
<td>0x11</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_INT_RANGE</td>
<td>0x12</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_SOL_SRV_UUID</td>
<td>0x14</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_128SOL_SRV_UUID</td>
<td>0x15</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_SERVICE_DATA</td>
<td>0x16</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_PUBLIC_TARGET</td>
<td>0x17</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_RANDOM_TARGET</td>
<td>0x18</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_APPEARANCE</td>
<td>0x19</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_ADV_INT</td>
<td>0x1A</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_LE_DEV_ADDR</td>
<td>0x1b</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_LE_ROLE</td>
<td>0x1c</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_SPAIR_C256</td>
<td>0x1d</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_SPAIR_R256</td>
<td>0x1e</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_32SOL_SRV_UUID</td>
<td>0x1f</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_32SERVICE_DATA</td>
<td>0x20</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_128SERVICE_DATA</td>
<td>0x21</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_LE_SECURE_CONFIRM</td>
<td>0x22</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_LE_SECURE_RANDOM</td>
<td>0x23</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_URI</td>
<td>0x24</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_INDOOR_POSITION</td>
<td>0x25</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_TRANS_DISC_DATA</td>
<td>0x26</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_LE_SUPPORT_FEATURE</td>
<td>0x27</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_CHAN_MAP_UPDATE</td>
<td>0x28</td>
</tr>
<tr>
<td>ESP_BLE_AD_TYPE_MANUFACTURER_SPECIFIC_TYPE</td>
<td>0xFF</td>
</tr>
</tbody>
</table>

```c
enum esp_ble_adv_type_t
{
    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
   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_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_PRA_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_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_ADDR
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 | Len | 0x20 | 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 | Len | 0x20 | 0x01 | flags | 0x03 | 0x03 | 0x1828 | ...

enum esp_duplicate_scan_exceptional_list_type_t
Values:

ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_ADDR_LIST = BLE_BIT(0)
duplicate scan exceptional addr list
ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_MESH_LINK_ID_LIST = BLE_BIT(1)
duplicate scan exceptional mesh link ID list

ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_MESH_BEACON_TYPE_LIST = BLE_BIT(2)
duplicate scan exceptional mesh beacon type list

ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_MESH_PROV_SRV_ADV_LIST = BLE_BIT(3)
duplicate scan exceptional mesh adv with provisioning service uuid

ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_MESH_PROXY_SRV_ADV_LIST = BLE_BIT(4)
duplicate scan exceptional mesh adv with provisioning service uuid

ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_ALL_LIST = 0xFFFF
duplicate scan exceptional all list

GATT DEFINES

Overview   Instructions

Application Example   Instructions

API Reference

Header File

• bt/host/bluedroid/api/include/api/esp_gatt_defs.h

Unions

union esp_gatt_rsp_t
#include <esp_gatt_defs.h> GATT remote read request response type.

Public Members

esp_gatt_value_t attr_value
Gatt attribute structure

uint16_t handle
Gatt attribute handle

Structures

struct esp_gatt_id_t
Gatt id, include uuid and instance id.

Public Members

esp_bt_uuid_t uuid
UUID

uint8_t inst_id
Instance id

struct esp_gatt_srvc_id_t
Gatt service id, include id (uuid and instance id) and primary flag.
Chapter 2. API

Public Members


\texttt{esp\_gatt\_id\_t id}

GATT id, include uuid and instance

\texttt{bool is\_primary}

This service is primary or not

\textbf{struct esp\_attr\_desc\_t}

Attribute description (used to create database)

Public Members

\begin{verbatim}
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
\end{verbatim}

\textbf{struct esp\_attr\_control\_t}

attribute auto response flag

Public Members

\begin{verbatim}
uint8_t auto\_rsp
  if auto\_rsp set to ESP\_GATT\_RSP\_BY\_APP, means the response of Write/Read operation will by replied by application. if auto\_rsp set to ESP\_GATT\_AUTO\_RSP, means the response of Write/Read operation will be replied by GATT stack automatically.
\end{verbatim}

\textbf{struct esp\_gatts\_attr\_db\_t}

attribute type added to the gatt server database

Public Members

\begin{verbatim}
\end{verbatim}

\textbf{struct esp\_attr\_value\_t}

set the attribute value type

Public Members

\begin{verbatim}
uint16_t attr\_max\_len
  attribute max value length
\end{verbatim}
Chapter 2. API

```c
uint16_t attr_len
    attribute current value length
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
uint16_t end_hdl
    Gatt end handle value of included service
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
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
uint16_t handle
    Gatt attribute handle
uint16_t offset
    Gatt attribute value offset
uint16_t len
    Gatt attribute value length
uint8_t auth_req
    Gatt authentication request
```

```c
struct esp_gatt_conn_params_t
    Connection parameters information.
```

**Public Members**

```c
uint16_t interval
    connection interval
uint16_t latency
    Slave latency for the connection in number of connection events. Range: 0x0000 to 0x01F3
```
uint16_t timeout
Supervision timeout for the LE Link. Range: 0x000A to 0x0C80. Mandatory Range: 0x000A to 0x0C80
Time = N * 10 msec Time Range: 100 msec to 32 seconds

struct esp_gattc_multi_t
read multiple attribute

Public Members

uint8_t num_attr
The number of the attribute

uint16_t handles[ESP_GATT_MAX_READ_MULTI_HANDLES]
The handles list

struct esp_gattc_db_elem_t
data base attribute element

Public Members

esp_gatt_db_attr_type_t type
The attribute type

uint16_t attribute_handle
The attribute handle, it’s valid for all of the type

uint16_t start_handle
The service start handle, it’s valid only when the type = ESP_GATT_DB_PRIMARY_SERVICE or ESP_GATT_DB_SECONDARY_SERVICE

uint16_t end_handle
The service end handle, it’s valid only when the type = ESP_GATT_DB_PRIMARY_SERVICE or ESP_GATT_DB_SECONDARY_SERVICE

esp_gatt_char_prop_t properties
The characteristic properties, it’s valid only when the type = ESP_GATT_DB_CHARACTERISTIC

esp_bt(uuid_t) uid
The attribute uuid, it’s valid for all of the type

struct esp_gattc_service_elem_t
service element

Public Members

bool is_primary
The service flag, true if the service is primary service, else is secondary service

uint16_t start_handle
The start handle of the service

uint16_t end_handle
The end handle of the service

esp_bt(uuid_t) uuid
The uuid of the service

struct esp_gattc_char_elem_t
characteristic element
Public Members

uint16_t char_handle
The characteristic handle

esp_gatt_char_prop_t properties
The characteristic properties

esp_bt_uuid_t uuid
The characteristic uuid

struct esp_gattc_descr_elem_t
descriptor element

Public Members

uint16_t handle
The characteristic descriptor handle

esp_bt_uuid_t uuid
The characteristic descriptor uuid

struct esp_gattc_incl_svc_elem_t
include service element

Public Members

uint16_t handle
The include service current attribute handle

uint16_t incl_srvc_s_handle
The start handle of the service which has been included

uint16_t incl_srvc_e_handle
The end handle of the service which has been included

esp_bt_uuid_t uuid
The include service uuid

Macros

ESP_GATT_UUID_IMMEDIATE_ALERT_SVC
All “ESP_GATT_UUID_XXX” is attribute types
ESP_GATT_UUID_LINK_LOSS_SVC
ESP_GATT_UUID_TX_POWER_SVC
ESP_GATT_UUID_CURRENT_TIME_SVC
ESP_GATT_UUID_REF_TIME_UPDATE_SVC
ESP_GATT_UUID_NEXT_DST_CHANGE_SVC
ESP_GATT_UUID_GLUCOSE_SVC
ESP_GATT_UUID_HEALTH_THERMOM_SVC
ESP_GATT_UUID_DEVICE_INFO_SVC
ESP_GATT_UUID_HEART_RATE_SVC
ESP_GATT_UUID_PHONE_ALERT_STATUS_SVC
ESP_GATT_UUID_BATTERY_SERVICE_SVC
ESP_GATT_UUID_BLOOD_PRESSURE_SVC
ESP_GATT_UUID_ALERT_NTF_SVC
ESP_GATT_UUID_HID_SVC
ESP_GATT_UUID_SCAN_PARAMETERS_SVC
ESP_GATT_UUID_RUNNING_SPEED_CADENCE_SVC
ESP_GATT_UUID_Automation_IO_SVC
ESP_GATT_UUID_CYCLING_SPEED_CADENCE_SVC
ESP_GATT_UUID_CYCLING_POWER_SVC
ESP_GATT_UUID_LOCATION_AND_NAVIGATION_SVC
ESP_GATT_UUID_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_GLUOSE_MONITOR_SVC
ESP_GATT_UUID_PRI_SERVICE
ESP_GATT_UUID_SEC_SERVICE
ESP_GATT_UUID_INCLUDE_SERVICE
ESP_GATT_UUID_CHAR_DECLARE
ESP_GATT_UUID_CHAR_EXT_PROP
ESP_GATT_UUID_CHAR_DESCRIPTION
ESP_GATT_UUID_CHAR_CLIENT_CONFIG
ESP_GATT_UUID_CHAR_SRVR_CONFIG
ESP_GATT_UUID_CHAR_PRESENT_FORMAT
ESP_GATT_UUID_CHAR_AGG_FORMAT
ESP_GATT_UUID_CHAR_VALID_RANGE
ESP_GATT_UUID_RPT_REF_DESCR
ESP_GATT_UUID_CHAR_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_UUID_BATTERY_LEVEL
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
Chapter 2. API 参考

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_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 gattc_if/gatts_if as this macro, means this event is not correspond to any app

Type Definitions
typedef uint16_t esp_gatt_perm_t
typedef uint8_t esp_gatt_char_prop_t
typedef uint8_t esp_gatt_if_t
  Gatt interface type, different application on GATT client use different gatt_if
Enumerations

**enum esp_gatt_prep_write_type**
Attribute write data type from the client.

*Values:*

- `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`
- `ESP_GATT_NOT_LONG = 0x0b`
- `ESP_GATT_INSUF_KEY_SIZE = 0x0c`
- `ESP_GATT_INVALID_ATTR_LEN = 0x0d`
- `ESP_GATT_ERR_UNLIKELY = 0x0e`
- `ESP_GATT_INSUF_ENCRYPTION = 0x0f`
- `ESP_GATT_UNSUPPORT_GRP_TYPE = 0x10`
- `ESP_GATT_INSUF_RESOURCE = 0x11`
- `ESP_GATT_NO_RESOURCES = 0x80`
- `ESP_GATT_INTERNAL_ERROR = 0x81`
- `ESP_GATT_WRONG_STATE = 0x82`
- `ESP_GATT_DB_FULL = 0x83`
- `ESP_GATT_BUSY = 0x84`
- `ESP_GATT_ERROR = 0x85`
- `ESP_GATT_CMD_STARTED = 0x86`
- `ESP_GATT_ILLEGAL_PARAMETER = 0x87`
- `ESP_GATT_PENDING = 0x88`
- `ESP_GATT_AUTH_FAIL = 0x89`
- `ESP_GATT_MORE = 0x8a`
- `ESP_GATT_INVALID_CFG = 0x8b`
ESP_GATT_SERVICE_STARTED = 0x8c
ESP_GATT_ENCRYPED_MITM = ESP_GATT_OK
ESP_GATT_ENCRYPED_NO_MITM = 0x8d
ESP_GATT_NOT_ENCRYPTED = 0x8e
ESP_GATT_CONGESTED = 0x8f
ESP_GATT_DUP_REG = 0x90
ESP_GATT_ALREADY_OPEN = 0x91
ESP_GATT_CANCEL = 0x92
ESP_GATT_STACK_RSP = 0xe0
ESP_GATT_APP_RSP = 0xe1
ESP_GATT_UNKNOWN_ERROR = 0xef
ESP_GATT_CCC_CFG_ERR = 0xfd
ESP_GATT_PRC_IN_PROGRESS = 0xfe
ESP_GATT_OUT_OF_RANGE = 0xff

enum esp_gatt_conn_reason_t
Gatt Connection reason enum.
Values:

ESP_GATT_CONN_UNKNOWN = 0
Gatt connection unknown
ESP_GATT_CONN_L2C_FAILURE = 1
General L2cap failure
ESP_GATT_CONN_TIMEOUT = 0x08
Connection timeout
ESP_GATT_CONN_TERMINATE_PEER_USER = 0x13
Connection terminate by peer user
ESP_GATT_CONN_TERMINATE_LOCAL_HOST = 0x16
Connection terminated by local host
ESP_GATT_CONN_FAIL_ESTABLISH = 0x3e
Connection fail to establish
ESP_GATT_CONN_LMP_TIMEOUT = 0x22
Connection fail for LMP response tout
ESP_GATT_CONN_CONN_CANCEL = 0x0100
L2CAP connection cancelled
ESP_GATT_CONN_NONE = 0x0101
No connection to cancel

enum esp_gatt_auth_req_t
Gatt authentication request type.
Values:

ESP_GATT_AUTH_REQ_NONE = 0
ESP_GATT_AUTH_REQ_NO_MITM = 1
ESP_GATT_AUTH_REQ_MITM = 2
ESP_GATT_AUTH_REQ_SIGNED_NO_MITM = 3
ESP_GATT_AUTH_REQ_SIGNED_MITM = 4
enum esp_service_source_t
Values:

ESP_GATT_SERVICE_FROM_REMOTE_DEVICE = 0
ESP_GATT_SERVICE_FROM_NVS_FLASH = 1
ESP_GATT_SERVICE_FROM_UNKNOWN = 2

enum esp_gatt_write_type_t
Gatt write type.
Values:

ESP_GATT_WRITE_TYPE_NO_RSP = 1
Gatt write attribute need no response
ESP_GATT_WRITE_TYPE_RSP
Gatt write attribute need remote response

enum esp_gatt_db_attr_type_t
the type of attribute element
Values:

ESP_GATT_DB_PRIMARY_SERVICE
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
Gatt include service attribute type in the cache
ESP_GATT_DB_ALL
Gatt 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

- bt/host/bluedroid/api/include/api/esp_gatts_api.h

Functions

```c
esp_err_t esp_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_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_gatts_app_unregister(esp_gatt_if_t gatts_if)
```

unregister with GATT Server.

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

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

```c
esp_err_t esp_gatts_create_service(esp_gatt_if_t gatts_if, esp_gatt_srvc_id_t *service_id, uint16_t num_handle)
```

Create a service. When service creation is done, a callback event ESP_GATTS_CREATE_EVT is called to report status and service ID to the profile. The service ID obtained in the callback function needs to be used when adding included service and characteristics.descriptors into the service.

**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.

```c
esp_err_t esp_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

```c
esp_err_t esp_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_gatts_create_service’ and ‘esp_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

- `service_handle`: service handle to which this included service is to be added.
- `included_service_handle`: the service ID to be included.

```c
esp_err_t esp_ble_gatts_add_char (uint16_t service_handle, esp_bt_uuid_t *char_uuid, esp_gatt_perm_t perm, esp_gatt_char_prop_t property, esp_attr_value_t *char_val, esp_attr_control_t *control)
```

This function is called to add a characteristic into a service.

**Return**

- `ESP_OK`: success
- `other`: failed

Parameters

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

```c
esp_err_t esp_ble_gatts_add_char_descr (uint16_t service_handle, esp_bt_uuid_t *descr_uuid, esp_gatt_perm_t perm, esp_attr_value_t *char_descr_val, esp_attr_control_t *control)
```

This function is called to add characteristic descriptor. When it’s done, a callback event ESP_GATTS_ADD_DESCR_EVT is called to report the status and an ID number for this descriptor.

**Return**

- `ESP_OK`: success
- `other`: failed

Parameters

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

```c
esp_err_t esp_ble_gatts_delete_service (uint16_t service_handle)
```

This function is called to delete a service. When this is done, a callback event ESP_GATTS_DELETE_EVT is called to report the status.

**Return**

- `ESP_OK`: success
- `other`: failed

Parameters

- `service_handle`: service handle to be deleted.

```c
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

- `service_handle`: the service handle to be started.

```c
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

- `service_handle`: service to be stopped.
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
Chapter 2. API

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

```c
esp_err_t esp_ble_gatts_close(esp_gatt_if_t gatts_if, uint16_t conn_id)
```
Close a connection to 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.

```c
esp_err_t esp_ble_gatts_send_service_change_indication(esp_gatt_if_t gatts_if, esp_bd_addr_t remote_bda)
```
Send service change indication.

Return

- ESP_OK : success
- other : failed

Parameters

- [in] gatts_if: GATT server access interface
- [in] remote_bda: remote device Bluetooth device address. If remote_bda is NULL then it will send service change indication to all the connected devices and if not then to a specific device

Unions

```c
union esp_ble_gatts_cb_param_t
```

Unions

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

Public Members

```c
struct esp_ble_gatts_cb_param_t::gatts_reg_evt_param reg
```
Gatt server callback param of ESP_GATTS_REG_EVT

```c
struct esp_ble_gatts_cb_param_t::gatts_read_evt_param read
```
Gatt server callback param of ESP_GATTS_READ_EVT

```c
struct esp_ble_gatts_cb_param_t::gatts_write_evt_param write
```
Gatt server callback param of ESP_GATTS_WRITE_EVT

```c
struct esp_ble_gatts_cb_param_t::gatts_exec_write_evt_param exec_write
```
Gatt server callback param of ESP_GATTS_EXEC_WRITE_EVT

```c
struct esp_ble_gatts_cb_param_t::gatts_mtu_evt_param mtu
```
Gatt server callback param of ESP_GATTS_MTU_EVT

```c
struct esp_ble_gatts_cb_param_t::gatts_conf_evt_param conf
```
Gatt server callback param of ESP_GATTS_CONF_EVT (confirm)

```c
struct esp_ble_gatts_cb_param_t::gatts_create_evt_param create
```
Gatt server callback param of ESP_GATTS_CREATE_EVT

```c
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

```c
struct esp_ble_gatts_cb_param_t::gatts_add_char_evt_param add_char
```
Gatt server callback param of ESP_GATTS_ADD_CHAR_EVT

```c
struct esp_ble_gatts_cb_param_t::gatts_add_char_descr_evt_param add_char_descr
```
Gatt server callback param of ESP_GATTS_ADD_CHAR_DESCR_EVT

```c
struct esp_ble_gatts_cb_param_t::gatts_delete_evt_param del
```
Gatt server callback param of ESP_GATTS_DELETE_EVT

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### Public Members

```c
struct esp_ble_gatts_cb_param_t::gatts_start_evt_param start
  Gatt server callback param of ESP_GATTS_START_EVT
```

```c
struct esp_ble_gatts_cb_param_t::gatts_stop_evt_param stop
  Gatt server callback param of ESP_GATTS_STOP_EVT
```

```c
struct esp_ble_gatts_cb_param_t::gatts_connect_evt_param connect
  Gatt server callback param of ESP_GATTS_CONNECT_EVT
```

```c
struct esp_ble_gatts_cb_param_t::gatts_disconnect_evt_param disconnect
  Gatt server callback param of ESP_GATTS_DISCONNECT_EVT
```

```c
struct esp_ble_gatts_cb_param_t::gatts_open_evt_param open
  Gatt server callback param of ESP_GATTS_OPEN_EVT
```

```c
struct esp_ble_gatts_cb_param_t::gatts_cancel_open_evt_param cancel_open
  Gatt server callback param of ESP_GATTSCANCEL_OPEN_EVT
```

```c
struct esp_ble_gatts_cb_param_t::gatts_close_evt_param close
  Gatt server callback param of ESP_GATTS_CLOSE_EVT
```

```c
struct esp_ble_gatts_cb_param_t::gatts_congest_evt_param congest
  Gatt server callback param of ESP_GATTS_CONGEST_EVT
```

```c
struct esp_ble_gatts_cb_param_t::gatts_rsp_evt_param rsp
  Gatt server callback param of ESP_GATTS_RESPONSE_EVT
```

```c
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
```

```c
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
```

```c
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
```

```c
struct gatts_add_attr_tab_evt_param
  #include <esp_gatts_api.h> ESP_GATTS_CREAT_ATTR_TAB_EVT.
```

#### Public Members

```c
esp_gatt_status_t status
  Operation status
```

```c
esp_bt_uuid_t svc_uuid
  Service uuid type
```

```c
uint8_t svc_inst_id
  Service id
```

```c
uint16_t num_handle
  The number of the attribute handle to be added to the gatts database
```

```c
uint16_t *handles
  The number to the handles
```

```c
struct gatts_add_char_descr_evt_param
  #include <esp_gatts_api.h> ESP_GATTS_ADD_CHAR_DESCR_EVT.
```

#### Public Members

```c
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_GATT_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_GATT_ADD_INCL_SRVC_EVT.

Public Members

esp_gatt_status_t status
Operation status

uint16_t attr_handle
Included service attribute handle

uint16_t service_handle
Service attribute handle

struct gatts_cancel_open_evt_param
#include <esp_gatts_api.h> ESP_GATT_CANCEL_OPEN_EVT.

Public Members

esp_gatt_status_t status
Operation status

struct gatts_close_evt_param
#include <esp_gatts_api.h> ESP_GATT_CLOSE_EVT.

Public Members

esp_gatt_status_t status
Operation status

uint16_t conn_id
Connection id

struct gatts_conf_evt_param
#include <esp_gatts_api.h> ESP_GATT_CONF_EVT.
Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
uint16_t conn_id
Connection id
```

```c
uint16_t handle
attribute handle
```

```c
uint16_t len
The indication or notification value length, len is valid when send notification or indication failed
```

```c
uint8_t* value
The indication or notification value, value is valid when send notification or indication failed
```

```c
struct gatts_congest_evt_param
#include <esp_gatts_api.h> ESP_GATTS_LISTEN_EVT.
ESP_GATTS_CONGEST_EVT
```

Public Members

```c
uint16_t conn_id
Connection id
```

```c
bool congested
Congested or not
```

```c
struct gatts_connect_evt_param
#include <esp_gatts_api.h> ESP_GATTS_CONNECT_EVT.
```

Public Members

```c
uint16_t conn_id
Connection id
```

```c
uint8_t link_role
Link role: master role = 0; slave role = 1
```

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

```c
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.
ESP_GATTS_CREATE_EVT
```

Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
uint16_t service_handle
Service attribute handle
```

```c
esp_gatt_srvc_id_t service_id
Service id, include service uuid and other information
```
struct gatts_delete_evt_param
#include <esp_gatts_api.h> ESP_GATTS_DELETE_EVT.

Public Members

esp_gatt_status_t status
Operation status

uint16_t service_handle
Service attribute handle

struct gatts_disconnect_evt_param
#include <esp_gatts_api.h> ESP_GATTS_DISCONNECT_EVT.

Public Members

uint16_t conn_id
Connection id

esp_bd_addr_t remote_bda
Remote bluetooth device address

esp_gatt_conn_reason_t reason
Indicate the reason of disconnection

struct gatts_exec_write_evt_param
#include <esp_gatts_api.h> ESP_GATTS_EXEC_WRITE_EVT.

Public Members

uint16_t conn_id
Connection id

uint32_t trans_id
Transfer id

esp_bd_addr_t bda
The bluetooth device address which been written

uint8_t exec_write_flag
Execute write flag

struct gatts_mtu_evt_param
#include <esp_gatts_api.h> ESP_GATTS_MTU_EVT.

Public Members

uint16_t conn_id
Connection id

uint16_t mtu
MTU size

struct gatts_open_evt_param
#include <esp_gatts_api.h> ESP_GATTS_OPEN_EVT.
Public Members

`esp_gatt_status_t status`
Operation status

`struct gatts_read_evt_param`
#include <esp_gatts_api.h> ESP_GATTS_READ_EVT.

Public Members

uint16_t conn_id
Connection id

uint32_t trans_id
Transfer id

`esp_bd_addr_t bda`
The bluetooth device address which been read

uint16_t handle
The attribute handle

uint16_t offset
Offset of the value, if the value is too long

bool is_long
The value is too long or not

bool need_rsp
The read operation need to do response

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

Public Members

`esp_gatt_status_t status`
Operation status

uint16_t app_id
Application id which input in register API

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

Public Members

`esp_gatt_status_t status`
Operation status

uint16_t handle
Attribute handle which send response

`struct gatts_send_service_change_evt_param`
#include <esp_gatts_api.h> ESP_GATTS_SEND_SERVICE_CHANGE_EVT.
Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
struct gatts_set_attr_val_evt_param
#include <esp_gatts_api.h> ESP_GATTS_SET_ATTR_VAL_EVT.
```

Public Members

```c
uint16_t srvc_handle
The service handle
```

```c
uint16_t attr_handle
The attribute handle
```

```c
esp_gatt_status_t status
Operation status
```

```c
struct gatts_start_evt_param
#include <esp_gatts_api.h> ESP_GATTS_START_EVT.
```

Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
uint16_t service_handle
Service attribute handle
```

```c
struct gatts_stop_evt_param
#include <esp_gatts_api.h> ESP_GATTS_STOP_EVT.
```

Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
uint16_t service_handle
Service attribute handle
```

```c
struct gatts_write_evt_param
#include <esp_gatts_api.h> ESP_GATTS_WRITE_EVT.
```

Public Members

```c
uint16_t conn_id
Connection id
```

```c
uint32_t trans_id
Transfer id
```

```c
esp_bd_addr_t bda
The bluetooth device address which been written
```

```c
uint16_t handle
The attribute handle
```

```c
uint16_t offset
Offset of the value, if the value is too long
```
bool need_rsp
   The write operation need to do response

bool is_prep
   This write operation is prepare write

uint16_t len
   The write attribute value length

uint8_t* value
   The write attribute value

Macros
ESP_GATT_PREP_WRITE_CANCEL
   Prepare write flag to indicate cancel prepare write
ESP_GATT_PREP_WRITE_EXEC
   Prepare write flag to indicate execute prepare write

Type Definitions
typedef void (*esp_gatts_cb_t)(esp_gatts_cb_event_t event,
                               esp_gatt_if_t gatts_if,
                               esp_ble_gatts_cb_param_t *param)
   GATT Server callback function type.

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

Enumerations
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_GATT_ADD_CHAR_DESCR_EVT = 10
When add descriptor complete, the event comes

ESP_GATT_DELETE_EVT = 11
When delete service complete, the event comes

ESP_GATT_START_EVT = 12
When start service complete, the event comes

ESP_GATT_STOP_EVT = 13
When stop service complete, the event comes

ESP_GATT_CONNECT_EVT = 14
When gatt client connect, the event comes

ESP_GATT_DISCONNET_EVT = 15
When gatt client disconnect, the event comes

ESP_GATT_OPEN_EVT = 16
When connect to peer, the event comes

ESP_GATT_CANCEL_OPEN_EVT = 17
When disconnect from peer, the event comes

ESP_GATT_CLOSE_EVT = 18
When gatt server close, the event comes

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

ESP_GATT_CONGEST_EVT = 20
When congest happen, the event comes

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

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

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

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

GATT CLIENT API

Overview

Application Example  Check bluetooth/bluedroid/ble folder in ESP-IDF examples, which contains the following demos and their tutorials:

- This is a GATT 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
- bt/host/bluedroid/api/include/api/esp_gattc_api.h

Functions

**esp_err_t esp_ble_gattc_register_callback (esp_gattc_cb_t callback)**
This function is called to register application callbacks with GATTC module.

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

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

**esp_err_t esp_ble_gattc_app_register (uint16_t app_id)**
This function is called to register application callbacks with GATTC module.

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

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

**esp_err_t esp_ble_gattc_app_unregister (esp_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

**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.

`esp_gatt_status_t esp_ble_gattc_get_service (esp_gatt_if_t gattc_if, uint16_t conn_id, esp_bt_uuid_t svc_uuid, esp_gattc_service_elem_t *result, uint16_t *count, uint16_t offset)`

Find all the service with the given service uuid in the gattc cache, if the svc_uuid is NULL, find all the service. Note: It just get service from local cache, won’t get from remote devices. If want to get it from remote device, need to used the esp_ble_gattc_search_service.

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.

`esp_gatt_status_t esp_ble_gattc_get_all_char (esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t start_handle, uint16_t end_handle, esp_gattc_char_elem_t *result, uint16_t *count, uint16_t offset)`

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

Return
• ESP_OK: success
• other: failed

Parameters
• [in] gattc_if: Gatt client access interface.
• [in] conn_id: connection ID which identify the server.
• [in] start_handle: the attribute start handle.
• [in] end_handle: the attribute end handle
• [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.
esp_gatt_status_t esp_ble_gattc_get_all_descr(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t char_handle, esp_gattc_descr_elem_t *result, uint16_t *count, uint16_t offset)

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

Return
- ESP_OK: success
- other: failed

Parameters
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID which identify the server.
- [in] char_handle: the given characteristic handle
- [out] result: The pointer to the descriptor in the characteristic.
- [inout] count: input the number of descriptor want to find, it will output the number of descriptor has been found in the gattc cache with the given characteristic.
- [in] offset: Offset of the descriptor position to get.

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

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

Return
- ESP_OK: success
- other: failed

Parameters
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID which identify the server.
- [in] start_handle: the attribute start handle
- [in] end_handle: the attribute end handle
- [in] char_uuid: the characteristic uuid
- [out] result: The pointer to the characteristic in the service.
- [inout] count: input the number of characteristic want to find, it will output the number of characteristic has been found in the gattc cache with the given service.

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.
**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.

**esp_gatt_status_t esp_ble_gattc_get_include_service**

`esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t start_handle, uint16_t end_handle, esp_bt_uuid_t *incl_uuid, esp_gattc_incl_svc_elem_t *result, uint16_t *count)`

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

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

**Parameters**
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID which identify the server.
- [in] start_handle: the attribute start handle.
- [in] end_handle: the attribute end handle.
- [in] incl_uuid: the include service uuid.
- [out] result: The pointer to the include service in the given service.
- [inout] count: input the number of include service want to find, it will output the number of include service has been found in the gattc cache with the given service.

**esp_gatt_status_t esp_ble_gattc_get_attr_count**

`esp_gatt_if_t gattc_if, uint16_t conn_id, esp_gatt_db_attr_type_t type, uint16_t start_handle, uint16_t end_handle, uint16_t char_handle, uint16_t *count)`

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

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

**Parameters**
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID which identify the server.
- [in] type: the attribute type.
- [in] start_handle: the attribute start handle, if the type is ESP_GATT_DB_DESCRIPTOR, this parameter should be ignore.
- [in] end_handle: the attribute end handle, if the type is ESP_GATT_DB_DESCRIPTOR, this parameter should be ignore.
- [in] char_handle: the characteristic handle, this parameter valid when the type is ESP_GATT_DB_DESCRIPTOR. If the type isn’t ESP_GATT_DB_DESCRIPTOR, this parameter should be ignore.
Chapter 2. API

- **[out] count**: output the number of attribute has been found in the gattc cache with the given attribute type.

```c
esp_gatt_status_t esp_ble_gattc_get_db(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t start_handle, uint16_t end_handle, esp_gatt_db_elem_t *db, uint16_t *count)
```

This function is called to get the GATT database. Note: It just get attribute database from local cache, won’t get from remote devices.

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

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

```c
esp_err_t esp_ble_gattc_read_char(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t handle, esp_gatt_auth_req_t auth_req)
```

This function is called to read a service’s characteristics of the given characteristic handle.

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

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

```c
esp_err_t esp_ble_gattc_read_multiple(esp_gatt_if_t gattc_if, uint16_t conn_id, esp_gattc_multi_t *read_multi, esp_gatt_auth_req_t auth_req)
```

This function is called to read multiple characteristic or characteristic descriptors.

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

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

```c
esp_err_t esp_ble_gattc_read_char_descr(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t handle, esp_gatt_auth_req_t auth_req)
```

This function is called to read a characteristics descriptor.

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

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

```c
esp_err_t esp_ble_gattc_write_char(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t handle, uint16_t value_len, uint8_t *value, esp_gatt_write_type_t write_type, esp_gatt_auth_req_t auth_req)
```
This function is called to write characteristic value.

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

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

```c
def esp_err_t esp_ble_gattc_write_char_descr(esp_gatt_if_t gatt_if, uint16_t conn_id, uint16_t handle, uint16_t value_len, uint8_t *value, esp_gatt_write_type_t write_type, esp_gatt_auth_req_t auth_req)
```

This function is called to write characteristic descriptor value.

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

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

```c
def esp_err_t esp_ble_gattc_prepare_write_char_descr(esp_gatt_if_t gatt_if, uint16_t conn_id, uint16_t handle, uint16_t offset, uint16_t value_len, uint8_t *value, esp_gatt_auth_req_t auth_req)
```

This function is called to prepare write a characteristic value.

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

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

```c
def esp_err_t esp_ble_gattc_prepare_write_char_descr(esp_gatt_if_t gatt_if, uint16_t conn_id, uint16_t handle, uint16_t offset, uint16_t value_len, uint8_t *value, esp_gatt_auth_req_t auth_req)
```
• [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.

\texttt{esp_err_t esp_ble_gattc_execute_write(esp_gatt_if_t gattc_if, uint16_t conn_id, bool is_execute)}

This function is called to execute write a prepare write sequence.

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

\textbf{Parameters}
• [in] gattc_if: Gatt client access interface.
• [in] conn_id:: connection ID.
• [in] is_execute:: execute or cancel.

\texttt{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.

\textbf{Return}
• ESP_OK: registration succeeds
• other: failed

\textbf{Parameters}
• [in] gattc_if: Gatt client access interface.
• [in] server_bda:: target GATT server.
• [in] handle:: GATT characteristic handle.

\texttt{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.

\textbf{Return}
• ESP_OK: unregister succeeds
• other: failed

\textbf{Parameters}
• [in] gattc_if: Gatt client access interface.
• [in] server_bda:: target GATT server.
• [in] handle:: GATT characteristic handle.

\texttt{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.

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

\textbf{Parameters}
• [in] remote_bda: remote device BD address.

\texttt{esp_err_t esp_ble_gattc_cache_assoc(esp_gatt_if_t gattc_if, esp_bd_addr_t src_addr, esp_bd_addr_t assoc_addr, bool is_assoc)}

Add or delete the associated address with the source address. Note: The role of this API is mainly when the client side has stored a server-side database, when it needs to connect another device, but the device's attribute database is the same as the server database stored on the client-side, calling this API can use the database that the device has stored used as the peer server database to reduce the attribute database search and discovery process and speed up the connection time. The associated address main is that device want to used the database has stored in the local cache. The source address main is that device want to share the database to the associated address device.

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

\textbf{Parameters}
Chapter 2. API

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

```c
esp_err_t esp_ble_gattc_cache_clean(esp_bd_addr_t remote_bda)
```

Clean the service cache of this device in the gattc stack.

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

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

**Unions**

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

**Public Members**

```c
struct esp_ble_gattc_cb_param_t::gattc_reg_evt_param reg
```
Gatt client callback param of ESP_GATTC_REG_EVT

```c
struct esp_ble_gattc_cb_param_t::gattc_open_evt_param open
```
Gatt client callback param of ESP_GATTC_OPEN_EVT

```c
struct esp_ble_gattc_cb_param_t::gattc_close_evt_param close
```
Gatt client callback param of ESP_GATTC_CLOSE_EVT

```c
struct esp_ble_gattc_cb_param_t::gattc_cfg_mtu_evt_param cfg_mtu
```
Gatt client callback param of ESP_GATTC_CFG_MTU_EVT

```c
struct esp_ble_gattc_cb_param_t::gattc_search_cmpl_evt_param search_cmpl
```
Gatt client callback param of ESP_GATTC_SEARCH_CMPL_EVT

```c
struct esp_ble_gattc_cb_param_t::gattc_search_res_evt_param search_res
```
Gatt client callback param of ESP_GATTC_SEARCH_RES_EVT

```c
struct esp_ble_gattc_cb_param_t::gattc_read_char_evt_param read
```
Gatt client callback param of ESP_GATTC_READ_CHAR_EVT

```c
struct esp_ble_gattc_cb_param_t::gattc_write_evt_param write
```
Gatt client callback param of ESP_GATTC_WRITE_DESCR_EVT

```c
struct esp_ble_gattc_cb_param_t::gattc_exec_cmpl_evt_param exec_cmpl
```
Gatt client callback param of ESP_GATTC_EXEC_EVT

```c
struct esp_ble_gattc_cb_param_t::gattc_notify_evt_param notify
```
Gatt client callback param of ESP_GATTC_NOTIFY_EVT

```c
struct esp_ble_gattc_cb_param_t::gattc_srvc_chg_evt_param srvc_chg
```
Gatt client callback param of ESP_GATTC_SRVC_CHG_EVT


```c
struct esp_ble_gattc_cb_param_t::gattc_congest_evt_param congest
    Gatt client callback param of ESP_GATTC_CONGEST_EVT

struct esp_ble_gattc_cb_param_t::gatt_reg_for_notify_evt_param reg_for_notify
    Gatt client callback param of ESP_GATTC_REG_FOR_NOTIFY_EVT

struct esp_ble_gattc_cb_param_t::gatt_unreg_for_notify_evt_param unreg_for_notify
    Gatt client callback param of ESP_GATTC_UNREG_FOR_NOTIFY_EVT

struct esp_ble_gattc_cb_param_t::gatt_connect_evt_param connect
    Gatt client callback param of ESP_GATTC_CONNECT_EVT

struct esp_ble_gattc_cb_param_t::gatt_disconnect_evt_param disconnect
    Gatt client callback param of ESP_GATTC_DISCONNECT_EVT

struct esp_ble_gattc_cb_param_t::gatt_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::gatt_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::gatt_queue_full_evt_param queue_full
    Gatt client callback param of ESP_GATTC_QUEUE_FULL_EVT

struct esp_ble_gattc_cb_param_t::gatt_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.
```

Espressif Systems

Release v4.3-dev-1561-g357a277603

Submit Document Feedback
Public Members

```c
uint16_t conn_id
Connection id
```

```c
bool congested
Congested or not
```

```c
struct gattc_connect_evt_param
#include <esp_gattc_api.h> ESP_GATTC_CONNECT_EVT.
```

Public Members

```c
uint16_t conn_id
Connection id
```

```c
uint8_t link_role
Link role: master role = 0; slave role = 1
```

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

```c
esp_gatt_conn_params_t conn_params
current connection parameters
```

```c
struct gattc_dis_svc_cmpl_evt_param
#include <esp_gattc_api.h> ESP_GATTC_DIS_SRVC_CMPL_EVT.
```

Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
uint16_t conn_id
Connection id
```

```c
struct gattc_disconnect_evt_param
#include <esp_gattc_api.h> ESP_GATTC_DISCONNECT_EVT.
```

Public Members

```c
esp_gatt_conn_reason_t reason
disconnection reason
```

```c
uint16_t conn_id
Connection id
```

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

```c
struct gattc_exec_cmpl_evt_param
#include <esp_gattc_api.h> ESP_GATTC_EXEC_EVT.
```

Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
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

esp_bd_addr_t *addr_list
The pointer to the address list which has been get from the gattc cache

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

struct gattc_open_evt_param
#include <esp_gattc_api.h> ESP_GATTC_OPEN_EVT.

Public Members

esp_gatt_status_t status
Operation status

uint16_t conn_id
Connection id

esp_bd_addr_t remote_bda
Remote bluetooth device address

uint16_t mtu
MTU size

struct gattc_queue_full_evt_param
#include <esp_gattc_api.h> ESP_GATTC_QUEUE_FULL_EVT.
Public Members

*esp_gatt_status_t* status
Operation status

*uint16_t* conn_id
Connection id

*bool* is_full
The gattc command queue is full or not

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

Public Members

*esp_gatt_status_t* status
Operation status

*uint16_t* conn_id
Connection id

*uint16_t* handle
Characteristic handle

*uint8_t* value
Characteristic value

*uint16_t* value_len
Characteristic value length

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

Public Members

*esp_gatt_status_t* status
Operation status

*uint16_t* app_id
Application id which input in register API

```
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

```
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
#include <esp_gattc_api.h>
ESP_GATTC_SEARCH_RES_EVT.
```

Public Members

```c
#include <esp_gattc_api.h>
ESP_GATTC_SEARCH_RES_EVT.
```

`uint16_t conn_id`
Connection id

`uint16_t start_handle`
Service start handle

`uint16_t end_handle`
Service end handle

`esp_gatt_id_t srvc_id`
Service id, includes service uuid and other information

`bool is_primary`
True if this is the primary service

```c
#include <esp_gattc_api.h>
ESP_GATTC_SET_ASSOC_EVT.
```

Public Members

```c
#include <esp_gattc_api.h>
ESP_GATTC_SRVC_CHG_EVT.
```

`esp_gatt_status_t status`
Operation status

```c
#include <esp_gattc_api.h>
ESP_GATTC_SRVC_CHG_EVT.
```

Public Members

```c
#include <esp_gattc_api.h>
ESP_GATTC_SRVC_CHG_EVT.
```

`esp_status_t status`
Operation status

`uint16_t handle`
The characteristic or descriptor handle

```c
#include <esp_gattc_api.h>
ESP_GATTC_UNREG_FOR_NOTIFY_EVT.
```

Public Members

```c
#include <esp_gattc_api.h>
ESP_GATTC_SRVC_CHG_EVT.
```

`esp_status_t status`
Operation status

`uint16_t handle`
The characteristic or descriptor handle
struct gattc_write_evt_param
#include <esp_gattc_api.h> ESP_GATTC_WRITE_CHAR_EVT, ESP_GATTC_PREP_WRITE_EVT, ESP_GATTC_WRITE_DESCR_EVT.

Public Members

esp_gatt_status_t status
Operation status

uint16_t conn_id
Connection id

uint16_t handle
The Characteristic or descriptor handle

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
• gatts_if: GATT client access interface, normally different gattc_if correspond to different profile
• param: Point to callback parameter, currently is union type

Enumerations
type 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
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/bluedroid/ble 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/bluedroid/ble/blufi

API Reference

Header File

- bt/host/bluedroid/api/include/api/esp_blufi_api.h

Functions

\[
\text{esp_err_t esp_blufi_register_callbacks (esp_blufi_callbacks_t *callbacks)}
\]
This function is called to receive blufi callback event.

- Return  ESP_OK - success, other - failed
- Parameters  
  \[
  \text{[in] callbacks: callback functions}
  \]

\[
\text{esp_err_t esp_blufi_profile_init (void)}
\]
This function is called to initialize blufi_profile.
Chapter 2. API

Return ESP_OK - success, other - failed

\[
\text{\textbf{esp_err_t}} \ \text{\textbf{esp_blufi_profile_deinit}} \ (\text{void})
\]

This function is called to de-initialize blufi_profile.

Return ESP_OK - success, other - failed

\[
\text{\textbf{esp_err_t}} \ \text{\textbf{esp_blufi_send_wifi_conn_report}} \ (\text{wifi_mode_t } \text{opmode}, \ \text{esp_blufi_sta_conn_state_t } \text{sta_conn_state}, \ \text{uint8_t } \text{softap_conn_num}, \ \text{esp_blufi_extra_info_t } *\text{extra_info})
\]

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
- softap_conn_num: softap connection number
- extra_info: extra information, such as sta_ssid, softap_ssid and etc.

\[
\text{\textbf{esp_err_t}} \ \text{\textbf{esp_blufi_send_wifi_list}} \ (\text{uint16_t } \text{apCount, esp_blufi_ap_record_t } *\text{list})
\]

This function is called to send wifi list.

Return ESP_OK - success, other - failed

Parameters
- apCount: wifi list count
- list: wifi list

\[
\text{\textbf{uint16_t}} \ \text{\textbf{esp_blufi_get_version}} \ (\text{void})
\]

Get BLUFI profile version.

Return Most 8bit significant is Great version, Least 8bit is Sub version

\[
\text{\textbf{esp_err_t}} \ \text{\textbf{esp_blufi_close}} \ (\text{esp_gatt_if_t } \text{gatts_if, uint16_t } \text{conn_id})
\]

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.

\[
\text{\textbf{esp_err_t}} \ \text{\textbf{esp_blufi_send_error_info}} \ (\text{esp_blufi_error_state_t } \text{state})
\]

This function is called to send blufi error information.

Return ESP_OK - success, other - failed

Parameters
- state: error state

\[
\text{\textbf{esp_err_t}} \ \text{\textbf{esp_blufi_send_custom_data}} \ (\text{uint8_t } *\text{data, uint32_t } \text{data_len})
\]

This function is called to custom data.

Return ESP_OK - success, other - failed

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

Unions

\[
\text{union esp_blufi_cb_param_t}
\]

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

```c
struct esp_blufi_cb_param_t::blufi_init_finish_evt_param init_finish
    Blufi callback param of ESP_BLUFI_EVENT_INIT_FINISH

struct esp_blufi_cb_param_t::blufi_deinit_finish_evt_param deinit_finish
    Blufi callback param of ESP_BLUFI_EVENT_DEINIT_FINISH

struct esp_blufi_cb_param_t::blufi_set_wifi_mode_evt_param wifi_mode
    Blufi callback param of ESP_BLUFI_EVENT_INIT_FINISH

struct esp_blufi_cb_param_t::blufi_connect_evt_param connect
    Blufi callback param of ESP_BLUFI_EVENT_CONNECT

struct esp_blufi_cb_param_t::blufi_disconnect_evt_param disconnect
    Blufi callback param of ESP_BLUFI_EVENT_DISCONNECT

struct esp_blufi_cb_param_t::blufi_recv_sta_bssid_evt_param sta_bssid
    Blufi callback param of ESP_BLUFI_EVENT_RECV_STA_BSSID

struct esp_blufi_cb_param_t::blufi_recv_sta_ssid_evt_param sta_ssid
    Blufi callback param of ESP_BLUFI_EVENT_RECV_STA_SSID

struct esp_blufi_cb_param_t::blufi_recv_softap_ssid_evt_param softap_ssid
    Blufi callback param of ESP_BLUFI_EVENT_RECV_SOFTAP_SSID

struct esp_blufi_cb_param_t::blufi_recv_softap_passwd_evt_param softap_passwd
    Blufi callback param of ESP_BLUFI_EVENT_RECV_SOFTAP_PASSWD

struct esp_blufi_cb_param_t::blufi_recv_softap_max_conn_num_evt_param softap_max_conn_num
    Blufi callback param of ESP_BLUFI_EVENT_RECV_SOFTAP_MAX_CONN_NUM

struct esp_blufi_cb_param_t::blufi_recv_softap_auth_mode_evt_param softap_auth_mode
    Blufi callback param of ESP_BLUFI_EVENT_RECV_SOFTAP_AUTHMODE

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

\textit{esp_bd_addr_t remote_bda}
Blufi Remote bluetooth device address

\textit{uint8_t server_if}
server interface

\textit{uint16_t conn_id}
Connection id

\textbf{struct blufi_deinit_finish_evt_param}
\#include <esp_blufi_api.h> ESP_BLUFI_EVENT_DEINIT_FINISH.

Public Members

\textit{esp_blufi_deinit_state_t state}
De-initial status

\textbf{struct blufi_disconnect_evt_param}
\#include <esp_blufi_api.h> ESP_BLUFI_EVENT_DISCONNECT.

Public Members

\textit{esp_bd_addr_t remote_bda}
Blufi Remote bluetooth device address

\textbf{struct blufi_get_error_evt_param}
\#include <esp_blufi_api.h> ESP_BLUFI_EVENT_REPORT_ERROR.

Public Members

\textit{esp_blufi_error_state_t state}
Blufi error state

\textbf{struct blufi_init_finish_evt_param}
\#include <esp_blufi_api.h> ESP_BLUFI_EVENT_INIT_FINISH.

Public Members

\textit{esp_blufi_init_state_t state}
Initial status

\textbf{struct blufi_recv_ca_evt_param}
\#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_CA_CERT.

Public Members

\textit{uint8_t* cert}
CA certificate point

\textit{int cert_len}
CA certificate length

\textbf{struct blufi_recv_client_cert_evt_param}
\#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_CLIENT_CERT.
Chapter 2. API 参考

Public Members

uint8_t *cert
   Client certificate point

int cert_len
   Client certificate length

struct blufi_recv_client_pkey_evt_param
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_CLIENT_PRIV_KEY

Public Members

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

int pkey_len
   Client Private key length

struct blufi_recv_custom_data_evt_param
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_CUSTOM_DATA.

Public Members

uint8_t *data
   Custom data

uint32_t data_len
   Custom data Length

struct blufi_recv_server_cert_evt_param
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_SERVER_CERT

Public Members

uint8_t *cert
   Client certificate point

int cert_len
   Client certificate length

struct blufi_recv_server_pkey_evt_param
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_SERVER_PRIV_KEY

Public Members

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

int pkey_len
   Client Private key length

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

\texttt{wifi\_auth\_mode\_t auth\_mode}

Authentication mode

\texttt{struct blufi\_recv\_softap\_channel\_evt\_param}

\#include <esp\_blufi\_api\_h> ESP\_BLUFI\_EVENT\_RECV\_SOFTAP\_CHANNEL.

Public Members

\texttt{uint8\_t channel}

Authentication mode

\texttt{struct blufi\_recv\_softap\_max\_conn\_num\_evt\_param}

\#include <esp\_blufi\_api\_h> ESP\_BLUFI\_EVENT\_RECV\_SOFTAP\_MAX\_CONN\_NUM.

Public Members

\texttt{int max\_conn\_num}

SSID

\texttt{struct blufi\_recv\_softap\_passwd\_evt\_param}

\#include <esp\_blufi\_api\_h> ESP\_BLUFI\_EVENT\_RECV\_SOFTAP\_PASSWD.

Public Members

\texttt{uint8\_t \*passwd}

Password

\texttt{int passwd\_len}

Password Length

\texttt{struct blufi\_recv\_softap\_ssid\_evt\_param}

\#include <esp\_blufi\_api\_h> ESP\_BLUFI\_EVENT\_RECV\_SOFTAP\_SSID.

Public Members

\texttt{uint8\_t \*ssid}

SSID

\texttt{int ssid\_len}

SSID length

\texttt{struct blufi\_recv\_sta\_bssid\_evt\_param}

\#include <esp\_blufi\_api\_h> ESP\_BLUFI\_EVENT\_RECV\_STA\_BSSID.

Public Members

\texttt{uint8\_t bssid[6]}

BSSID

\texttt{struct blufi\_recv\_sta\_passwd\_evt\_param}

\#include <esp\_blufi\_api\_h> ESP\_BLUFI\_EVENT\_RECV\_STA\_PASSWD.
### Public Members

- `uint8_t* passwd`  
  Password

- `int passwd_len`  
  Password Length

#### struct blufi_recv_sta_ssid_evt_param

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

### Public Members

- `uint8_t* ssid`  
  SSID

- `int ssid_len`  
  SSID length

#### struct blufi_recv_username_evt_param

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

### Public Members

- `uint8_t* name`  
  Username point

- `int name_len`  
  Username length

#### struct blufi_set_wifi_mode_evt_param

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

### Public Members

- `wifi_mode_t op_mode`  
  Wifi operation mode

### Structures

#### struct esp_blufi_extra_info_t

BLUFI extra information structure.

### 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
**Chapter 2. API**

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)
Type Definitions

typedef void (*esp_blufi_event_cb_t)(esp_blufi_cb_event_t event, esp_blufi_cb_param_t *param)

BLUFI event callback function type.

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

typedef void (*esp_blufi_negotiate_data_handler_t)(uint8_t *data, int len, uint8_t **output_data, int *output_len, bool *need_free)

BLUFI negotiate data handler.

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

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
Chapter 2. API

ESP_BLUFI_EVENT_DEAUTHENTICATE_STA
ESP_BLUFI_EVENT_RECV_STA_BSSID
ESP_BLUFI_EVENT_RECV_STA_SSID
ESP_BLUFI_EVENT_RECV_STA_PASSWD
ESP_BLUFI_EVENT_RECV_SOFTAP_SSID
ESP_BLUFI_EVENT_RECV_SOFTAP_PASSWD
ESP_BLUFI_EVENT_RECV_SOFTAP_MAX_CONN_NUM
ESP_BLUFI_EVENT_RECV_SOFTAP_AUTH_MODE
ESP_BLUFI_EVENT_RECV_SOFTAP_CHANNEL
ESP_BLUFI_EVENT_RECV_USERNAME
ESP_BLUFI_EVENT_RECV_CA_CERT
ESP_BLUFI_EVENT_RECV_CLIENT_CERT
ESP_BLUFI_EVENT_RECV_SERVER_CERT
ESP_BLUFI_EVENT_RECV_CLIENT_PRIV_KEY
ESP_BLUFI_EVENT_RECV_SERVER_PRIV_KEY
ESP_BLUFI_EVENT_RECV_SLAVE_DISCONNECT_BLE
ESP_BLUFI_EVENT_GET_WIFI_LIST
ESP_BLUFI_EVENT_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
Chapter 2. API 參考

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

• bt/host/bluedroid/api/include/api/esp_gap_bt_api.h

Functions

static uint32_t esp_bt_gap_get_cod_srvc(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)
declare the integrity of COD

Return
  • true if cod is valid
  • false otherwise

Parameters
  • [in] cod: Class of Device
**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. It 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_SRVRC_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_eir_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_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_ERR_INVALID_ARG: if param is invalid
- ESP_FAIL: others

Parameters
- [in] eir_data: - pointer of EIR data content

esp_err_t esp_bt_gap_set_cod(esp_bt_cod_t cod, esp_bt_cod_mode_t mode)

This function is called to set class of device. 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_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_ERR_INVALID_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_cod(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
Chapter 2. API

• 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.

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

\texttt{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.

\texttt{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.

\texttt{esp_err_t esp\_bt\_gap\_set\_afh\_channels (esp\_bt\_afh\_channels \_t 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.

\texttt{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

Unions
union esp\_bt\_gap\_cb\_param\_t

\#include <esp\_gap\_bt\_api\_h> A2DP state callback parameters.

Public Members

\texttt{struct esp\_bt\_gap\_cb\_param\_t::disc\_res\_param disc\_res}
discovery result parameter struct

\texttt{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

struct esp_bt_gap_cb_param_t::rmt_srvc_rec_param rmt_srvc_rec
    specific service record from remote device parameter struct

struct esp_bt_gap_cb_param_t::read_rssi_delta_param read_rssi_delta
    read rssi parameter struct

struct esp_bt_gap_cb_param_t::config_eir_data_param config_eir_data
    config EIR data

struct esp_bt_gap_cb_param_t::auth_cmpl_param auth_cmpl
    authentication complete parameter struct

struct esp_bt_gap_cb_param_t::pin_req_param pin_req
    pin request parameter struct

struct esp_bt_gap_cb_param_t::cfm_req_param cfm_req
    confirm request parameter struct

struct esp_bt_gap_cb_param_t::key_notif_param key_notif
    passkey notif parameter struct

struct esp_bt_gap_cb_param_t::key_req_param key_req
    passkey request parameter struct

struct esp_bt_gap_cb_param_t::set_afh_channels_param set_afh_channels
    set AFH channel parameter struct

struct esp_bt_gap_cb_param_t::read_rmt_name_param read_rmt_name
    read Remote Name parameter struct

struct esp_bt_gap_cb_param_t::mode_chg_param mode_chg
    mode change event parameter struct

struct esp_bt_gap_cb_param_t::bt_remove_bond_dev_cmpl_evt_param remove_bond_dev_cmpl
    Event parameter of ESP_BT_GAP_REMOVE_BOND_DEV_COMPLETE_EVT

struct auth_cmpl_param
    #include <esp_gap_bt_api.h> ESP_BT_GAP_AUTH_CMPL_EVT.

Public Members

esp_bt_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_bt_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
**Chapter 2. API 参考**

```c
uint32_t passkey
the numeric value for passkey entry.
```

**struct key_req_param**

```c
#include <esp_gap_bt_api.h> ESP_BT_GAP_KEY_REQ_EVT.
```

**Public Members**

```c
typedef struct key_req_param {
    esp_bd_addr_t bda
    remote bluetooth device address
} key_req_param;
```

**struct mode_chg_param**

```c
#include <esp_gap_bt_api.h> ESP_BT_GAP_MODE_CHG_EVT.
```

**Public Members**

```c
typedef struct mode_chg_param {
    esp_bd_addr_t bda
    remote bluetooth device address
    esp_bt_pm_mode_t mode
    PM mode
} mode_chg_param;
```

**struct pin_req_param**

```c
#include <esp_gap_bt_api.h> ESP_BT_GAP_PIN_REQ_EVT.
```

**Public Members**

```c
typedef struct pin_req_param {
    esp_bd_addr_t bda
    remote bluetooth device address
    bool min_16_digit
    TRUE if the pin returned must be at least 16 digits
} pin_req_param;
```

**struct read_rmt_name_param**

```c
#include <esp_gap_bt_api.h> ESP_BT_GAP_READ_REMOTE_NAME_EVT.
```

**Public Members**

```c
typedef struct read_rmt_name_param {
    esp_bt_status_t stat
    read Remote Name status
    uint8_t rmt_name[ESP_BT_GAP_MAX_BDNAME_LEN + 1]
    Remote device name
} read_rmt_name_param;
```

**struct read_rssi_delta_param**

```c
#include <esp_gap_bt_api.h> ESP_BT_GAP_READ_RSSI_DELTA_EVT.*.
```

**Public Members**

```c
typedef struct read_rssi_delta_param {
    esp_bd_addr_t bda
    remote bluetooth device address
    esp_bt_status_t stat
    read rssi status
} read_rssi_delta_param;
```
int8_t rssi_delta
    rssi delta value range -128 ~127. The value zero indicates that the RSSI is inside the Golden Receive
    Power Range, the Golden Receive Power Range is from ESP_BT_GAP_RSSI_LOW_THRLD to
    ESP_BT_GAP_RSSI_HIGH_THRLD

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

ESP_BT_GAP_MAX_BDNAME_LEN
Maximum bytes of Bluetooth device name.

ESP_BT_GAP_EIR_DATA_LEN
Maximum size of EIR Significant part.
Chapter 2. API 参考

ESP_BT_EIR_TYPE_FLAGS
Extended Inquiry Response data type.
Flag with information such as BR/EDR and LE support

ESP_BT_EIR_TYPE_INCMPL_16BITS_UUID
Incomplete list of 16-bit service UUIDs

ESP_BT_EIR_TYPE_CMPL_16BITS_UUID
Complete list of 16-bit service UUIDs

ESP_BT_EIR_TYPE_INCMPL_32BITS_UUID
Incomplete list of 32-bit service UUIDs

ESP_BT_EIR_TYPE_CMPL_32BITS_UUID
Complete list of 32-bit service UUIDs

ESP_BT_EIR_TYPE_INCMPL_128BITS_UUID
Incomplete list of 128-bit service UUIDs

ESP_BT_EIR_TYPE_CMPL_128BITS_UUID
Complete list of 128-bit service UUIDs

ESP_BT_EIR_TYPE_SHORT_LOCAL_NAME
Shortened Local Name

ESP_BT_EIR_TYPE_CMPL_LOCAL_NAME
Complete Local Name

ESP_BT_EIR_TYPE_TX_POWER_LEVEL
Tx power level, value is 1 octet ranging from -127 to 127, unit is dBm

ESP_BT_EIR_TYPE_URL
Uniform resource identifier

ESP_BT_EIR_TYPE_MANU_SPECIFIC
Manufacturer specific data

ESP_BT_EIR_TYPE_MAX_NUM
MAX number of EIR type

ESP_BT_EIR_FLAG_LIMIT_DISC
ESP_BT_EIR_FLAG_GEN_DISC
ESP_BT_EIR_FLAG_BREDR_NOT_SPT
ESP_BT_EIR_FLAG_DMT_CONTROLLER_SPT
ESP_BT_EIR_FLAG_DMT_HOST_SPT
ESP_BT_EIR_MAX_LEN
ESP_BT_PIN_CODE_LEN
Max pin code length

ESP_BT_IO_CAP_OUT
ESP_BT_IO_CAP_IO
ESP_BT_IO_CAP_IN
ESP_BT_IO_CAP_NONE

ESP_BT_PM_MD_ACTIVE
Active mode

ESP_BT_PM_MD_HOLD
Hold mode

ESP_BT_PM_MD_SNIFF
Sniff mode
Chapter 2. API

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
typedef uint8_t esp_bt_gap_afh_channels[ESP_BT_GAP_AFH_CHANNELS_LEN]
typedef uint8_t esp_bt_eir_type_t

typedef uint8_t esp_bt_pin_code_t[ESP_BT_PIN_CODE_LEN]
Pin Code (upto 128 bits) MSB is 0

typedef uint8_t esp_bt_io_cap_t
combination of the io capability

typedef uint8_t esp_bt_pm_mode_t

typedef void (*esp_bt_gap_cb_t)(esp_bt_gap_cb_event_t event, esp_bt_gap_cb_param_t *param)
bluetooth GAP callback function type

Parameters
- event:: Event type
- param:: Pointer to callback parameter

Enumerations
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
enum esp_bt_connection_mode_t
    Discoverability and Connectability mode.
    Values:
    ESP_BT_NON_CONNECTABLE
        Non-connectable
    ESP_BT_CONNECTABLE
        Connectable
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
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 []
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 = 0x1
        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_CAPTURING = 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
Chapter 2. API

```plaintext
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
    AUTH complete event
  ESP_BT_GAP_PIN_REQ_EVT
    Legacy Pairing Pin code request
  ESP_BT_GAP_CFM_REQ_EVT
    Simple Pairing User Confirmation request.
  ESP_BT_GAP_KEY_NOTIF_EVT
    Simple Pairing Passkey Notification
  ESP_BT_GAP_KEY_REQ_EVT
    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_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
  • bt/host/bluedroid/api/include/api/esp_a2dp_api.h

Functions

`esp_err_t esp_a2d_register_callback(esp_a2d_cb_t callback)`
  Register application callback function to A2DP module. This function should be called only after esp_bluedroid_enable() completes successfully, used by both A2DP source and sink.

  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 event callback function

`esp_err_t esp_a2d_sink_register_data_callback (esp_a2d_sink_data_cb_t callback)`
  Register A2DP sink data output function; For now the output is PCM data stream decoded from SBC format. This function should be called only after esp_bluedroid_enable() completes successfully, used only by A2DP sink. The callback is invoked in the context of A2DP sink task whose stack size is configurable through menuconfig.

  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 sink data callback function

`esp_err_t esp_a2d_sink_init(void)`
  Initialize the bluetooth A2DP sink module. This function should be called after esp_bluedroid_enable() completes successfully. 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 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.

**Return**
- ESP_OK: success
- 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, must after `esp_a2d_sink_init()`

**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_a2d_sink_disconnect (esp_bd_addr_t remote_bda)`

Disconnect from the remote A2DP source device.

**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_a2d_media_ctrl (esp_a2d_media_ctrl_t ctrl)`

Media control commands; this API can be used for both A2DP sink and source

**Return**
- ESP_OK: control command is sent to lower layer
- 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. This function should be called after `esp_bluedroid_enable()` completes successfully. 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 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.

**Return**
- 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 is 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.
Retum
• 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, must after esp_a2d_source_init()

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_a2d_source_disconnect (esp_bd_addr_t remote_bda)
Disconnect from the remote A2DP sink device.

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
#include <esp_a2dp_api.h> A2DP state callback parameters.

Public Members

struct esp_a2d_cb_param_t::a2d_conn_stat_param conn_stat
A2DP connection status

struct esp_a2d_cb_param_t::a2d_audio_stat_param audio_stat
audio stream playing state

struct esp_a2d_cb_param_t::a2d_audio_cfg_param audio_cfg
media codec configuration information

struct esp_a2d_cb_param_t::media_ctrl_stat_param media_ctrl_stat
status in acknowledgement to media control commands

struct 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

```c
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
```

```c
struct a2d_conn_stat_param
    #include <esp_a2dp_api.h> ESP_A2D_CONNECTION_STATE_EVT.
```

Public Members

```c
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”
```

```c
struct media_ctrl_stat_param
    #include <esp_a2dp_api.h> ESP_A2D_MEDIA_CTRL_ACK_EVT.
```

Public Members

```c
esp_a2d_media_ctrl_t cmd
    media control commands to acknowledge
esp_a2d_media_ctrl_ack_t status
    acknowledgement to media control commands
```

Structures

```c
struct esp_a2d_mcc_t
    A2DP media codec capabilities union
```

Public Members

```c
esp_a2d_mct_t type
    A2DP media codec type
uint8_t sbc[ESP_A2D_CIE_LEN_SBC]
    SBC codec capabilities
uint8_t m12[ESP_A2D_CIE_LEN_M12]
    MPEG-1,2 audio codec capabilities
uint8_t m24[ESP_A2D_CIE_LEN_M24]
    MPEG-2, 4 AAC audio codec capabilities
uint8_t atrac[ESP_A2D_CIE_LEN_ATRAC]
    ATRAC family codec capabilities
union esp_a2d_mcc_t::[anonymous] cie
    A2DP codec information element
```
Macros

**ESP_A2D_MCT_SBC**

Media codec types supported by A2DP.

SBC

**ESP_A2D_MCT_M12**

MPEG-1, 2 Audio

**ESP_A2D_MCT_M24**

MPEG-2, 4 AAC

**ESP_A2D_MCT_ATRAC**

ATRAC family

**ESP_A2D_MCT_NON_A2DP**

**ESP_A2D_CIE_LEN_SBC**

**ESP_A2D_CIE_LEN_M12**

**ESP_A2D_CIE_LEN_M24**

**ESP_A2D_CIE_LEN_ATRAC**

Type Definitions

```c
typedef uint8_t esp_a2d_mct_t
typedef void(* esp_a2d_cb_t)(esp_a2d_cb_event_t event, esp_a2d_cb_param_t *param)
```

A2DP profile callback function type.

**Parameters**

- `event::`: Event type
- `param::`: Pointer to callback parameter

```c
typedef void(* esp_a2d_sink_data_cb_t)(const uint8_t*buf,uint32_t len)
```

A2DP profile data callback function.

**Parameters**

- `[in] buf::`: data received from A2DP source device and is PCM format decoder from SBC decoder; buf references to a static memory block and can be overwritten by upcoming data
- `[in] len::`: size(in bytes) in buf

```c
typedef int32_t(* esp_a2d_source_data_cb_t)(uint8_t*buf,int32_t len)
```

A2DP source data read callback function.

**Return**

size of bytes read successfully, if the argument len is -1, this value is ignored.

**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

```c
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
Chapter 2. API

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_cb_event_t
A2DP callback events.

Values:

ESP_A2D_CONNECTION_STATE_EVT = 0
connection state changed event
Chapter 2. API

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_A2D_MEDIA_CTRL_ACK_EVT
acknowledge event in response to media control commands

BT AVRCP APIs

Overview  Bluetooth AVRCP reference APIs.

Instructions

Application Example   Instructions

API Reference

Header File

- 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

- 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

def 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.

def 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.

def 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%

def 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 AVRCP 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 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 AVRCP 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 AVRCP 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 yet enabled or AVRCP 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 “NOTIMPLEMENTED” (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(esp_avrc_rn_evt_cap_t cap, esp_avrc_rn_evt_cap_mask_t *evt_set)**

Get the requested event notification capabilities on local AVRC target. The capability is returned in a bit mask representation in evt_set. This function should be called after esp_avrc_tg_init(). For capability type “ESP_AVRC_RN_CAP_ALLOWED_EVT”, the retrieved event set is constant and it covers all of the notification events that can possibly be supported with current implementation. For capability type ESP_AVRC_RN_CAP_SUPPORTED_EVT, the event set covers the notification events selected to be supported under current configuration. The configuration can be changed using esp_avrc_tg_set_rn_evt_cap().

**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(const esp_avrc_rn_evt_cap_mask_t *evt_set)**

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(esp_avrc_bit_mask_op_t op, esp_avrc_rn_evt_cap_mask_t *events, esp_avrc_rn_event_ids_t event_id)**

Operate on the type esp_avrc_rn_evt_cap_mask_t with regard to a specific event.
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] events: pointer to event notification capability bit mask structure
- [in] event_id: notification event code

```c
esp_err_t esp_avrc_tg_send_rn_rsp(esp_avrc_rn_event_ids_t event_id, esp_avrc_rn_rsp_t rsp, esp_avrc_rn_param_t *param)
```

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
```c
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
```c
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
  - pass through 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

struct avrc_ct_change_notify_param
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_conn_stat_param
remote_bda
remote Bluetooth device address

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

struct avrc_ct_get_rn_caps_rsp_param
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_meta_rsp_param
#include <esp_avrc_api.h> ESP_AVRC_CT_PASSTHROUGH_RSP_EVT.
Public Members

uint8_t tl
   transaction label, 0 to 15

uint8_t keycode
   passthrough command code

uint8_t key_state
   0 for PRESSED, 1 for RELEASED

\texttt{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

\texttt{esp\_bd\_addr\_t remote\_bda}
   remote bluetooth device address

\texttt{struct avrc\_ct\_set\_volume\_rsp\_param}
#include <esp\_avrc\_api.h> ESP\_AVRC\_CT\_SET\_ABSOLUTE\_VOLUME\_RSP\__EVT.

Public Members

uint8_t volume
   the volume which has actually been set, range is 0 to 0x7f, means 0% to 100%

union esp\_avrc\_tg\_cb\_param\_t
   #include <esp\_avrc\_api.h> AVRC target callback parameters.

Public Members

\texttt{struct esp\_avrc\_tg\_cb\_param\_t::avrc\_tg\_conn\_stat\_param} conn_stat
   AVRC connection status

\texttt{struct esp\_avrc\_tg\_cb\_param\_t::avrc\_tg\_rmt\_feats\_param} rmt_feats
   AVRC features discovered through SDP

\texttt{struct esp\_avrc\_tg\_cb\_param\_t::avrc\_tg\_psth\_cmd\_param} psth_cmd
   passthrough command

\texttt{struct esp\_avrc\_tg\_cb\_param\_t::avrc\_tg\_set\_abs\_vol\_param} set_abs_vol
   set absolute volume command targeted on audio sink

\texttt{struct esp\_avrc\_tg\_cb\_param\_t::avrc\_tg\_reg\_ntf\_param} reg_ntf
   register notification

\texttt{struct avrc\_tg\_conn\_stat\_param}
#include <esp\_avrc\_api.h> ESP\_AVRC\_TG\_CONNECTION\_STATE\__EVT.
Chapter 2. API

Public Members

```c
bool connected
    whether AVRC connection is set up

esp_bd_addr_t remote_bda
    remote bluetooth device address
```

```c
#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
#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
```

```c
#include <esp_avrc_api.h> ESP_AVRC_TG_REMOTE_FEATURES_EVT.
```

Public Members

```c
uint32_t feat_mask
    AVRC feature mask of remote device
```

```c
uint16_t ct_feat_flag
    feature flag of remote device as CT
```

```c
esp_bd_addr_t remote_bda
    remote bluetooth device address
```

```c
#include <esp_avrc_api.h> ESP_AVRC_TG_SET_ABSOLUTE_VOLUME_CMD_EVT.
```

Public Members

```c
uint8_t volume
    volume ranges from 0 to 127
```

Structures

```c
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

Macros

```
ESP_AVRC_TRANS_LABEL_MAX
```

max transaction label

Type Definitions

```
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

```
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

```
enum esp_avrc_features_t
```

AVRC feature bit mask.

Values:

```
ESP_AVRC_FEAT_RCTG = 0x0001
remote control target
ESP_AVRC_FEAT_R CCT = 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
```

```
enum esp_avrc_feature_flag_t
```

AVRC supported features flag retrieved in SDP record.

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

```c
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
ESP_AVRC_PT_CMD_1 = 0x21
ESP_AVRC_PT_CMD_2 = 0x22
ESP_AVRC_PT_CMD_3 = 0x23
ESP_AVRC_PT_CMD_4 = 0x24
ESP_AVRC_PT_CMD_5 = 0x25
ESP_AVRC_PT_CMD_6 = 0x26
ESP_AVRC_PT_CMD_7 = 0x27
ESP_AVRC_PT_CMD_8 = 0x28
ESP_AVRC_PT_CMD_9 = 0x29
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**

```c
enum esp_avrc_bit_mask_op_t
{
    ESP_AVRC_BIT_MASK_OP_TEST = 0,
    operation code to test a specific bit
    ESP_AVRC_BIT_MASK_OP_SET = 1,
    operation code to set a specific bit
    ESP_AVRC_BIT_MASK_OP_CLEAR = 2,
    operation code to clear a specific bit
}
```

**AVRC passthrough command state.**

```c
enum esp_avrc_pt_cmd_state_t
{
    ESP_AVRC_PT_CMD_STATE_PRESSED = 0,
    key pressed
    ESP_AVRC_PT_CMD_STATE_RELEASED = 1,
    key released
}
```

**AVRC Controller callback events.**

```c
enum esp_avrc_ct_cb_event_t
{
    ESP_AVRC_CT_CONNECTION_STATE_EVT = 0,
    connection state changed event
    ESP_AVRC_CT_PASSTHROUGH_RSP_EVT = 1,
    passthrough response event
    ESP_AVRC_CT_METADATA_RSP_EVT = 2,
    metadata response event
    ESP_AVRC_CT_PLAY_STATUS_RSP_EVT = 3,
    play status response event
    ESP_AVRC_CT_CHANGE_NOTIFY_EVT = 4,
    notification event
    ESP_AVRC_CT_REMOTE_FEATURES_EVT = 5,
    feature of remote device indication event
    ESP_AVRC_CT_GET_RN_CAPABILITIES_RSP_EVT = 6,
    supported notification events capability of peer device
    ESP_AVRC_CT_SET_ABSOLUTE_VOLUME_RSP_EVT = 7,
    set absolute volume response event
}
```

**AVRC Target callback events.**

```c
enum esp_avrc_tg_cb_event_t
{
    ESP_AVRC_TG_CONNECTION_STATE_EVT = 0,
    connection state changed event
    ESP_AVRC_TG_REMOTE_FEATURES_EVT = 1,
    feature of remote device indication event
    ESP_AVRC_TG_PASSTHROUGH_CMD_EVT = 2,
    passthrough command event
    ESP_AVRC_TG_SET_ABSOLUTE_VOLUME_CMD_EVT = 3,
    set absolute volume command from remote device
}```
Chapter 2. API

```c
ESP_AVRC_TG_REGISTER_NOTIFICATION_EVT = 4
register notification event

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 milliseconds

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
```
Chapter 2. API

**ESP_AVRC_RN_VOLUME_CHANGE** = 0x0d
volume changed locally on TG

**ESP_AVRC_RN_MAX_EVT**

```c
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_MAX**

```c
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
```

**ESP_AVRC_PS_ATTR_IDS**

```c
enum esp_avrc_ps_attr_ids_t
AVRC players 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
```

**ESP_AVRC_PS_EQ_VALUE_IDS**

```c
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
```

**ESP_AVRC_PS_RPT_VALUE_IDS**

```c
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
```
ESP_AVRC_PS_REPEAT_GROUP = 0x3
  group repeat

enum esp_avrc_ps_shfl_value_ids_t
AVRC shuffle modes.

Values:
  ESP_AVRC_PS_SHUFFLE_OFF = 0x1
  ESP_AVRC_PS_SHUFFLE_ALL = 0x2
  ESP_AVRC_PS_SHUFFLE_GROUP = 0x3

enum esp_avrc_ps_scn_value_ids_t
AVRC scan modes.

Values:
  ESP_AVRC_PS_SCAN_OFF = 0x1
    scan off
  ESP_AVRC_PS_SCAN_ALL = 0x2
    all tracks scan
  ESP_AVRC_PS_SCAN_GROUP = 0x3
    group scan

enum esp_avrc_rsp_t
AVCTP response codes.

Values:
  ESP_AVRC_RSP_NOT_IMPL = 8
    not implemented
  ESP_AVRC_RSP_ACCEPT = 9
    accept
  ESP_AVRC_RSP_REJECT = 10
    reject
  ESP_AVRC_RSP_IN_TRANS = 11
    in transition
  ESP_AVRC_RSP_IMPL_STBL = 12
    implemented/stable
  ESP_AVRC_RSP_CHANGED = 13
    changed
  ESP_AVRC_RSP_INTERIM = 15
    interim

enum esp_avrc_batt_stat_t
AVRCP battery status.

Values:
  ESP_AVRC_BATT_NORMAL = 0
    normal state
  ESP_AVRC_BATT_WARNING = 1
    unable to operate soon
  ESP_AVRC_BATT_CRITICAL = 2
    cannot operate any more
  ESP_AVRC_BATT_EXTERNAL = 3
    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 recive SPP data bluetooh/bluedroid/classic_bt.bt_spp_acceptor, bluetooth/bluedroid/classic_bt.bt_spp_initiator

**API Reference**

**Header File**

- 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.

**Return**

- ESP_OK: success
- other: failed

**Parameters**

- [in] mode: Choose the mode of SPP, ESP_SPP_MODE_CB or ESP_SPP_MODE_VFS.
### Chapter 2. API 参考

**esp_err_t esp_spp_deinit (void)**

This function is called to uninit SPP.

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

**esp_err_t esp_spp_start_discovery (esp_bd_addr_t bd_addr)**

This function is called to perform service discovery for the services provided by the given peer device. When the operation is complete the callback function will be called with a ESP_SPP_DISCOVERY_COMP_EVT.

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

**Parameters**
- [in] bd_addr: Remote device Bluetooth device address.

**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.

**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.

**esp_err_t esp_spp_disconnect (uint32_t handle)**

This function closes an SPP connection.

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

**Parameters**
- [in] handle: The connection handle.

**esp_err_t esp_spp_start_srv (esp_spp_sec_t sec_mask, esp_spp_role_t role, uint8_t local_scn, const char *name)**

This function create a SPP server and starts listening for an SPP connection request from a remote Bluetooth device. When the server is started successfully, the callback is called with ESP_SPP_START_EVT. When the connection is established, the callback is called with ESP_SPP_SRV_OPEN_EVT.

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

**Parameters**
- [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.

**esp_err_t esp_spp_stop_srv (void)**

This function stops a SPP server When the server is stopped successfully, the callback is called with ESP_SPP_SRV_STOP_EVT.

**Return**
- ESP_OK: success
**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.

### 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.

**esp_err_t esp_spp_vfs_register**(void)

This function is used to register VFS.

### Return

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

### Unions

union esp_spp_cb_param_t

```c
#include <esp_spp_api.h>
```

SPP callback parameters union.

### Public Members

- **struct esp_spp_cb_param_t::spp_init_evt_param** init
  - SPP callback param of SPP_INIT_EVT
- **struct esp_spp_cb_param_t::spp_uninit_evt_param** uninit
  - SPP callback param of SPP_UNINIT_EVT
- **struct esp_spp_cb_param_t::spp_discovery_comp_evt_param** disc_comp
  - SPP callback param of SPP_DISCOVERY_COMP_EVT
- **struct esp_spp_cb_param_t::spp_open_evt_param** open
  - SPP callback param of ESP_SPP_OPEN_EVT
- **struct esp_spp_cb_param_t::spp_srv_open_evt_param** srv_open
  - SPP callback param of ESP_SPP_SRV_OPEN_EVT
- **struct esp_spp_cb_param_t::spp_close_evt_param** close
  - SPP callback param of ESP_SPP_CLOSE_EVT
- **struct esp_spp_cb_param_t::spp_start_evt_param** start
  - SPP callback param of ESP_SPP_START_EVT
- **struct esp_spp_cb_param_t::spp_srv_stop_evt_param** srv_stop
  - SPP callback param of ESP_SPP_SRV_STOP_EVT
- **struct esp_spp_cb_param_t::spp_cl_init_evt_param** cl_init
  - SPP callback param of ESP_SPP_CL_INIT_EVT
- **struct esp_spp_cb_param_t::spp_write_evt_param** write
  - SPP callback param of ESP_SPP_WRITE_EVT
- **struct esp_spp_cb_param_t::spp_data_ind_evt_param** data_ind
  - SPP callback param of ESP_SPP_DATA_IND_EVT
- **struct esp_spp_cb_param_t::spp_cong_evt_param** cong
  - SPP callback param of ESP_SPP_CONG_EVT
- **struct spp_cl_init_evt_param**

```c
#include <esp_spp_api.h>
```

ESP_SPP_CL_INIT_EVT.
Public Members

```c
esp_spp_status_t status
```
status

```c
uint32_t handle
```
The connection handle

```c
uint8_t sec_id
```
security ID used by this server

bool use_co
TRUE to use co_rfc_data

```c
struct spp_close_evt_param
#include <esp_spp_api.h> ESP_SPP_CLOSE_EVT.
```

Public Members

```c
esp_spp_status_t status
```
status

```c
uint32_t port_status
```
PORT status

```c
uint32_t handle
```
The connection handle

bool async
FALSE, if local initiates disconnect

```c
struct spp_cong_evt_param
#include <esp_spp_api.h> ESP_SPP_CONG_EVT.
```

Public Members

```c
esp_spp_status_t status
```
status

```c
uint32_t handle
```
The connection handle

bool cong
TRUE, congested. FALSE, uncongested

```c
struct spp_data_ind_evt_param
#include <esp_spp_api.h> ESP_SPP_DATA_IND_EVT.
```

Public Members

```c
esp_spp_status_t status
```
status

```c
uint32_t handle
```
The connection handle

```c
uint16_t len
```
The length of data

```c
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
   status
   uint8_t scn_num
   The num of scn_num
   uint8_t[ESP_SPP_MAX_SCN] channel #

struct spp_init_evt_param
#include <esp_spp_api.h> SPP_INIT_EVT.

Public Members

   esp_spp_status_t status
   status

struct spp_open_evt_param
#include <esp_spp_api.h> ESP_SPP_OPEN_EVT.

Public Members

   esp_spp_status_t status
   status
   uint32_t handle
   The connection handle
   int fd
   The file descriptor only for ESP_SPP_MODE_VFS
   esp_bd_addr_t rem_bda
   The peer address

struct spp_srv_open_evt_param
#include <esp_spp_api.h> ESP_SPP_SRV_OPEN_EVT.

Public Members

   esp_spp_status_t status
   status
   uint32_t handle
   The connection handle
   uint32_t new_listen_handle
   The new listen handle
   int fd
   The file descriptor only for ESP_SPP_MODE_VFS
   esp_bd_addr_t rem_bda
   The peer address

struct spp_srv_stop_evt_param
#include <esp_spp_api.h> ESP_SPP_SRV_STOP_EVT.
Chapter 2. API Reference

Public Members

```
esp_spp_status_t status
```

```
struct spp_start_evt_param
#include <esp_spp_api.h> ESP_SPP_START_EVT.
```

Public Members

```
esp_spp_status_t 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_uninit_evt_param
#include <esp_spp_api.h> SPP_UNINIT_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
```
Chapter 2. API

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
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.

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 set pm control block

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:
**Chapter 2. API 参考**

```
ESP_SPP_INIT_EVT = 0
    When SPP is initied, 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**
- `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_INVALID_IDX`
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 BtHFRVRState

typedef void (*esp_hf_answer_call_cmd_callback)(exp_bd_addr_t *bd_addr)
Callback for answer incoming call (ATA)

typedef void (*esp_hf_hangup_call_cmd_callback)(exp_bd_addr_t *bd_addr)
Callback for disconnect call (AT+CHUP)

typedef void (*esp_hf_volume_cmd_callback)(exp_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+BCS 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 (COFS)

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

denum 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_CALL_ID = 0x91
  international address

denum 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

denum esp_hf_btrh_status_t
+BTRH response and hold result code

Values:

ESP_HF_BTRH_STATUS_HELD = 0
  incoming call is put on hold 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 resposne 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 Instructions

API Reference

Header File

- bt/host/bluedroid/api/include/api/esp_hf_client_api.h
Chapter 2. API

Functions

```c
.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, used by HFP client.

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

```c
.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

```c
.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

```c
.esp_err_t esp_hf_client_connect(esp_bd_addr_t remote_bda)
```

Connect to remote bluetooth HFP audio gateway(AG) device, must after esp_hf_client_init()

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

```c
.esp_err_t esp_hf_client_disconnect(esp_bd_addr_t remote_bda)
```

Disconnect from the remote HFP audio gateway.

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

```c
.esp_err_t esp_hf_client_connect_audio(esp_bd_addr_t remote_bda)
```

Create audio connection with remote HFP AG. As a precondition to use this API, Service Level Connection shall exist with AG.

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

```c
.esp_err_t esp_hf_client_disconnect_audio(esp_bd_addr_t remote_bda)
```

Release the established audio connection with remote HFP AG.

Return
Chapter 2. API Reference

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

**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.

**Parameters**
- `[in]` type: volume control target, speaker or microphone
- `[in]` volume: gain of the speaker or 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.

**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.

**Parameters**
- `[in]` location: location of the number in the memory

`esp_err_t esp_hf_client_send_chld_cmd(esp_hf_chld_type_t chld, int idx)`
Send call hold and multiparty commands, or enhanced call control commands (Use AT+CHLD). As a precondition to use this API, Service Level Connection shall exist with AG.

**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

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

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

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

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

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

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 Bluetooth 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 used in the case that Voice Over HCI is enabled. Precondition is that the HFP audio connection is connected. After this function is called, lower layer will invoke esp_hf_client_outgoing_data_cb_t to fetch data.

**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**
Chapter 2. API

- [in] src: pointer to the buffer where the original sampling PCM are stored
- [in] in_bytes: length of the input PCM sample buffer in byte
- [in] dst: pointer to the buffer which is to be used to store the converted PCM samples

Unions

union esp_hf_client_cb_param_t
#include <esp_hf_client_api.h> HFP client callback parameters.

Public Members

struct esp_hf_client_cb_param_t::hf_client_conn_stat_param conn_stat
HF callback param of ESP_HF_CLIENT_CONNECTION_STATE_EVT

struct esp_hf_client_cb_param_t::hf_client_audio_stat_param audio_stat
HF callback param of ESP_HF_CLIENT_AUDIO_STATE_EVT

struct esp_hf_client_cb_param_t::hf_client_bvra_param bvra
HF callback param of ESP_HF_CLIENT_BVRA_EVT

struct esp_hf_client_cb_param_t::hf_client_service_availability_param service_availability
HF callback param of ESP_HF_CLIENT_CIND_SERVICE_AVAILABILITY_EVT

struct esp_hf_client_cb_param_t::hf_client_network_roaming_param roaming
HF callback param of ESP_HF_CLIENT_CIND_ROAMING_STATUS_EVT

struct esp_hf_client_cb_param_t::hf_client_signal_strength_ind_param signal_strength
HF callback param of ESP_HF_CLIENT_CIND_SIGNAL_STRENGTH_EVT

struct esp_hf_client_cb_param_t::hf_client_battery_level_ind_param battery_level
HF callback param of ESP_HF_CLIENT_CIND_BATTERY_LEVEL_EVT

struct esp_hf_client_cb_param_t::hf_client_current_operator_param cops
HF callback param of ESP_HF_CLIENT_COPS_CURRENT_OPERATOR_EVT

struct esp_hf_client_cb_param_t::hf_client_call_ind_param call
HF callback param of ESP_HF_CLIENT_CIND_CALL_EVT

struct esp_hf_client_cb_param_t::hf_client_call_setup_ind_param call_setup
HF callback param of ESP_HF_CLIENT_BVRA_EVT

struct esp_hf_client_cb_param_t::hf_client_call_held_ind_param call_held
HF callback param of ESP_HF_CLIENT_BVRA_EVT

struct esp_hf_client_cb_param_t::hf_client_btrh_param btrh
HF callback param of ESP_HF_CLIENT_BRTH_EVT

struct esp_hf_client_cb_param_t::hf_client_clip_param clip
HF callback param of ESP_HF_CLIENT_CLIP_EVT

struct esp_hf_client_cb_param_t::hf_client_ccwa_param ccwa
HF callback param of ESP_HF_CLIENT_BVRA_EVT

struct esp_hf_client_cb_param_t::hf_client_clcc_param clcc
HF callback param of ESP_HF_CLIENT_CLCC_EVT

struct esp_hf_client_cb_param_t::hf_client_volume_control_param volume_control
HF callback param of ESP_HF_CLIENT_VOLUME_CONTROL_EVT

struct esp_hf_client_cb_param_t::hf_client_at_response_param at_response
HF callback param of ESP_HF_CLIENT_AT_RESPONSE_EVT

struct esp_hf_client_cb_param_t::hf_client_cnum_param cnum
HF callback param of ESP_HF_CLIENT_CNUM_EVT

struct esp_hf_client_cb_param_t::hf_client_bsirparam bsir
HF callback param of ESP_HF_CLIENT_BSIR_EVT
struct esp_hf_client_ch_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

```c
esp_hf_btrh_status_t status
```
call hold and response status result code

```c
struct hf_client_bvra_param
```
#include <esp_hf_client_api.h> ESP_HF_CLIENT_BVRA_EVT.

Public Members

```c
esp_hf_vr_state_t value
```
voice recognition state

```c
struct hf_client_call_held_ind_param
```
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_CALL_HELD_EVT.

Public Members

```c
esp_hf_call_held_status_t status
```
bluetooth proprietary call hold status indicator

```c
struct hf_client_call_ind_param
```
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_CALL_EVT.

Public Members

```c
esp_hf_call_status_t status
```
call status indicator

```c
struct hf_client_call_setup_ind_param
```
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_CALL_SETUP_EVT.

Public Members

```c
esp_hf_call_setup_status_t status
```
call setup status indicator

```c
struct hf_client_ccwa_param
```
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CCWA_EVT.

Public Members

```c
const char *number
```
phone number string of waiting call

```c
struct hf_client_clcc_param
```
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CLCC_EVT.

Public Members

```c
int idx
```
numbering(starting with 1) of the call

```c
esp_hf_current_call_direction_t dir
```
direction of the call
Chapter 2. API

```c

```esp_hf_current_call_status_t status
```
status of the call

```esp_hf_current_call_mpty_type_t mpty
```
multi-party flag

```char *number```
phone number(optional)

```struct hf_client_clip_param```
```
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CLIP_EVT.
```

Public Members

```const char *number```
phone number string of call

```struct hf_client_cnum_param```
```
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CNUM_EVT.
```

Public Members

```const char *number```
phone number string

```esp_hf_subscriber_service_type_t type```
service type that the phone number relates to

```struct hf_client_conn_stat_param```
```
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CONNECTION_STATE_EVT.
```

Public Members

```esp_hf_client_connection_state_t state```
HF connection state

```uint32_t peer_feat```
AG supported features

```uint32_t chld_feat```
AG supported features on call hold and multiparty services

```esp_bd_addr_t remote_bda```
remote bluetooth device address

```struct hf_client_current_operator_param```
```
#include <esp_hf_client_api.h> ESP_HF_CLIENT_COPS_CURRENT_OPERATOR_EVT.
```

Public Members

```const char *name```
name of the network operator

```struct hf_client_network_roaming_param```
```
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_ROAMING_STATUS_EVT.
```

Espressif Systems 199

Submit Document Feedback

Release v4.3-dev-1561-g357a277603
Public Members

```c
esp_hf_roaming_status_t status
```
roaming status

```c
struct hf_client_service_availability_param
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_SERVICE_AVAILABILITY_EVT.
```

Public Members

```c
esp_hf_network_state_t status
```
service availability status

```c
struct hf_client_signal_strength_ind_param
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_SIGNAL_STRENGTH_EVT.
```

Public Members

```c
int value
```
signal strength value, ranges from 0 to 5

```c
struct hf_client_volume_control_param
#include <esp_hf_client_api.h> ESP_HF_CLIENT_VOLUME_CONTROL_EVT.
```

Public Members

```c
esp_hf_volume_control_target_t type
```
volume control target, speaker or microphone

```c
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**

- **[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

```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.

**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
- **[out]** length: of data successfully read

```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
enum 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
enum 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

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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 changed 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
Chapter 2. API 参考

HFP AG API

API Reference

Header File

- bt/host/bluedroid/api/include/api/esp_hf_ag_api.h

Functions

```c
esp_err_t esp_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, used by HFP AG.

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 AG event callback function

```c
esp_err_t esp_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.

Return

- ESP_OK: if the initialization request is sent successfully
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters

- [in] remote_addr: remote Bluetooth device address

```c
esp_err_t esp_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.

Return

- ESP_OK: success
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

Parameters

- [in] remote_addr: remote Bluetooth device address

```c
esp_err_t esp_hf_connect(esp_bd_addr_t remote_bda)
```

Connect to remote Bluetooth HFP client device, must after esp_hf_init()

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 HFP client device address

**esp_err_t esp_bt_hf_disconnect (esp_bd_addr_t remote_bda)**

Disconnect from the remote 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_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 between HF client and 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_bt_hf_disconnect_audio (esp_bd_addr_t remote_bda)**

Release the established audio connection with remote 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_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**
- [in] remote_bda: the device address of voice recognition initiator
- [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**
- [in] remote_bda: remote bluetooth device address
- [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_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 between AG and HF 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.

`esp_err_t esp_bt_hf_cmee_response(esp_bd_addr_t remote_bda, esp_hf_at_response_code_t response_code, esp_hf_cmee_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 between AG and HF 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_bda: remote bluetooth device address
• [in] response_code: AT command response code
• [in] error_code: CME error code

`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)`

Unsolicited send device status notification to HFP Client. As a precondition to use this API, Service Level Connection shall exist between AG and HF 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

`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 between AG and HF 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
• [in] batt_lev: battery level from 0 to 5
• [in] call_held_status: call held status
esp_err_t esp_bt_hf_cops_response(esp_bd_addr_t remote_addr, char *name)

Response 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

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 current_call_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 between AG and HF 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 unknown

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 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_addr: remote bluetooth device address
- [in] number: registration number
- [in] type: service type (unknown/voice/fax)

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 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_addr: remote bluetooth device address
- [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 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_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 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_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)
```

Reject incoming call from 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_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
Chapter 2. API

```
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 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_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. Precondition is that the HFP audio connection is connected. 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 param of ESP_HF_CONNECTION_STATE_EVT

struct esp_hf_cb_param_t::hf_audio_stat_param audio_stat
    AG callback param of ESP_HF_AUDIO_STATE_EVT

struct esp_hf_cb_param_t::hf_vra_rep_param vra_rep
    AG callback param of ESP_HF_BVRA_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_volume_control_param volume_control
    AG callback param of ESP_HF_VOLUME_CONTROL_EVT

struct esp_hf_cb_param_t::hf_unat_rep_param unat_rep
    AG callback param of ESP_HF_UNAT_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_cind_param cind
    AG callback param of ESP_HF_CIND_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_outcall_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

esp_hf_roaming_status_t roam
bluetooth proprietary call hold status indicator

int battery_level
battery charge value, ranges from 0 to 5

esp_hf_call_held_status_t call_held_status
bluetooth proprietary call hold status indicator

struct hf_conn_stat_param
#include <esp_hf_ag_api.h> ESP_HS_CONNECTION_STATE_EVT.
Public Members

`esp_bd_addr_t remote_bda`
remote bluetooth device address

`esp_hf_connection_state_t state`
Connection state

`uint32_t peer_feat`
HF supported features

`uint32_t child_feat`
AG supported features on call hold and multiparty services

```
struct hf_nrec_param
#include <esp_hf_ag_api.h> ESP_HF_NREC_RESPONSE_EVT.
```

Public Members

`esp_hf_nrec_t state`
NREC enabled or disabled

```
struct hf_out_call_param
#include <esp_hf_ag_api.h> ESP_HF_DIAL_EVT.
```

Public Members

`esp_bd_addr_t remote_addr`
remote bluetooth device address

`char *num_or_loc`
location in phone memory

```
struct hf_unat_rep_param
#include <esp_hf_ag_api.h> ESP_HF_UNAT_RESPONSE_EVT.
```

Public Members

`char *unat`
unknown AT command string

```
struct hf_volume_control_param
#include <esp_hf_ag_api.h> ESP_HF_VOLUME_CONTROL_EVT.
```

Public Members

`esp_hf_volume_type_t type`
volume control target, speaker or microphone

`int volume`
gain, ranges from 0 to 15

```
struct hf_vra_rep_param
#include <esp_hf_ag_api.h> ESP_HF_BVRA_RESPONSE_EVT.
```
Public Members

\texttt{esp_bd_addr_t remote_addr}
remote bluetooth device address

\texttt{esp_hf_vr_state_t value}
voice recognition state

\texttt{struct hf_vts_rep_param}
#include <esp_hf_ag_api.h> ESP_HF_VTS_RESPONSE_EVT.

Public Members

\texttt{char *code}
MTF code from HF Client

\texttt{struct hf_wbs_rep_param}
#include <esp_hf_ag_api.h> ESP_HF_WBS_RESPONSE_EVT.

Public Members

\texttt{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_EXTErr
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 (*\texttt{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

• [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 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.

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
• [out] length: of data successfully read

typedef void(*esp_hf_cb_t)(esp_hf_cb_event_t event, esp_hf_cb_param_t *param)

HF AG callback function type.

Parameters
• event:: Event type
• param:: Pointer to callback parameter

Enumerations

enum esp_hf_cb_event_t

HF callback events.

Values:

ESP_HF_CONNECTION_STATE_EVT = 0
Connection state changed event

ESP_HF_AUDIO_STATE_EVT
Audio connection state change event

ESP_HF_BVRA_RESPONSE_EVT
Voice recognition state change event

ESP_HF_VOLUME_CONTROL_EVT
Audio volume control command from HF Client, provided by +VGM or +VGS message

ESP_HF_UNAT_RESPONSE_EVT
Unknown AT cmd Response

ESP_HF_IND_UPDATE_EVT
Indicator Update Event

ESP_HF_CIND_RESPONSE_EVT
Call And Device Indicator Response

ESP_HF_COPS_RESPONSE_EVT
Current operator information

ESP_HF_CLCC_RESPONSE_EVT
List of current calls notification

ESP_HF_CNUM_RESPONSE_EVT
Subscriber information response from HF Client

ESP_HF_VTS_RESPONSE_EVT
Enable or not DTMF

ESP_HF_NREC_RESPONSE_EVT
Enable or not NREC

ESP_HF_ATA_RESPONSE_EVT
Answer an Incoming Call
**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.

![ESP NimBLE Stack](#)

**Threading Model**

The NimBLE host can run inside the application thread or can have its own independent thread. This flexibility is inherently provided by NimBLE design. By default, a thread is spawned by the porting function `nimble_port_freertos_init`. This behavior can be changed by overriding the same function. For BLE Mesh, additional thread (advertising thread) is used which keeps on feeding advertisement events to the main thread.

**Programming Sequence**

To begin with, make sure that the NimBLE stack is enabled from menuconfig choose *NimBLE for the Bluetooth host*. Typical programming sequence with NimBLE stack consists of the following steps:

- **ESP_HF_CHUP_RESPONSE_EVT**
  - Reject an Incoming Call
- **ESP_HF_DIAL_EVT**
  - Origin an outgoing call with specific number or the dial the last number
- **ESP_HF_WBS_RESPONSE_EVT**
  - Codec Status
- **ESP_HF_BCS_RESPONSE_EVT**
  - Final Codec Choice
Chapter 2. API 参考

- 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

- bt/host/nimble/esp-hci/include/esp_nimble_hci.h

Functions

`esp_err_t esp_nimble_hci_init(void)`

Initialize VHCI transport layer between NimBLE Host and ESP Bluetooth controller.

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

Return

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

`esp_err_t esp_nimble_hci_and_controller_init(void)`

Initialize ESP Bluetooth controller(link layer) and VHCI transport layer between NimBLE Host and ESP Bluetooth controller.

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

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

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

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

nimble_port_init();

//Initialize the NimBLE Host configuration
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.
Chapter 2. API

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 deinitialization is successful
• Appropriate error codes from esp_err_t in case of an error

Macros
BLE_HCI_UART_H4_NONE
BLE_HCI_UART_H4_CMD
BLE_HCI_UART_H4_ACL
BLE_HCI_UART_H4_SCO
BLE_HCI_UART_H4_EVT

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 unprovisioned device, will join the ESP-BLE-MESH network and become a ESP-BLE-MESH node, communicating with other nodes within or beyond the radio range.

Apart from ESP-BLE-MESH nodes, inside ESP-BLE-MESH network, there is also ESP32 that works as ESP-BLE-MESH Provisioner, which could provision unprovisioned devices into ESP-BLE-MESH nodes and configure the nodes with various features.
Chapter 2. API 参考

For information how to start using ESP32 and ESP-BLE-MESH, please see the Section ESP-BLE-MESH 快速入门. If you are interested in information on ESP-BLE-MESH architecture, including some details of software implementation, please see Section ESP-BLE-MESH 架构.

Application Examples and Demos

Please refer to Sections ESP-BLE-MESH 示例 and ESP-BLE-MESH 演示视频.

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

• bt/esp_ble_mesh/api/esp_ble_mesh_defs.h

Unions

union esp_ble_mesh_prov_cb_param_t
#include <esp_ble_mesh_defs.h> BLE Mesh Node/Provisioner callback parameters union.

Public Members

 struct esp_ble_mesh_prov_cb_param_t::ble_mesh_prov_register_comp_param prov_register_comp
  Event parameter of ESP_BLE_MESH_PROV_REGISTER_COMP_EVT

 struct esp_ble_mesh_prov_cb_param_t::ble_mesh_set_unprov_dev_name_comp_param node_set_unprov_dev_name_comp
  Event parameter of ESP_BLE_MESH_NODE_SET_UNPROV_DEV_NAME_COMP_EVT

 struct esp_ble_mesh_prov_cb_param_t::ble_mesh_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
### Chapter 2. API Reference

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_input_evt_param node_prov_input
   Event parameter of ESP_BLE_MESH_NODE_PROV_INPUT_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provision_complete_evt_param node_prov_complete
   Event parameter of ESP_BLE_MESH_NODE_PROV_COMPLETE_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provision_reset_param node_prov_reset
   Event parameter of ESP_BLE_MESH_NODE_PROV_RESET_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_set_oob_pub_key_comp_param node_prov_set_oob_pub_key_comp
   Event parameter of ESP_BLE_MESH_NODE_PROV_SET_OOB_PUB_KEY_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_input_number_comp_param node_prov_input_num_comp
   Event parameter of ESP_BLE_MESH_NODE_PROV_INPUT_NUM_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_input_string_comp_param node_prov_input_str_comp
   Event parameter of ESP_BLE_MESH_NODE_PROV_INPUT_STR_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_identity_enable_comp_param node_proxy_identity_enable_comp
   Event parameter of ESP_BLE_MESH_NODE_PROXY_IDENTITY_ENABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_gatt_enable_comp_param node_proxy_gatt_enable_comp
   Event parameter of ESP_BLE_MESH_NODE_PROXY_GATT_ENABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_gatt_disable_comp_param node_proxy_gatt_disable_comp
   Event parameter of ESP_BLE_MESH_NODE_PROXY_GATT_DISABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_recv_unprov_adv_pkt_param node_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 node_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 node_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 node_provisioner_link_open_evt
   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 node_provisioner_prov_read_oob_pub_key_evt
   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 node_provisioner_prov_input_evt
   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 node_provisioner_prov_output_evt
   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 node_provisioner_link_close_evt
   Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_LINK_CLOSE_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_complete_param node_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 node_provisioner_add_unprov_dev_comp
   Event parameter of ESP_BLE_MESH_PROVISIONER_ADD_UNPROV_DEV_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_dev_with_addr_comp_param node_provisioner_prov_dev_with_addr_comp
   Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_DEV_WITH_ADDR_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_dev_comp_param node_provisioner_delete_dev_comp
   Event parameter of ESP_BLE_MESH_PROVISIONER_DELETE_DEV_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_set_dev_uuid_match_comp_param node_provisioner_set_dev_uuid_match_comp
   Event parameter of ESP_BLE_MESH_PROVISIONER_SET_DEV_UUID_MATCH_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_set_prov_data_info_comp_param node_provisioner_set_prov_data_info_comp
   Event parameter of ESP_BLE_MESH_PROVISIONER_SET_PROV_DATA_INFO_COMP_EVT
```
**Chapter 2. API**

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_set_static_oob_val_comp_param
provisioner_set_static_oob_val_comp

Event parameter of ESP_BLE_MESH_PROVISIONER_SET_STATIC_OOB_VALUE_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_set_primary_elem_addr_comp_param
provisioner_set_primary_elem_addr_comp

Event parameter of ESP_BLE_MESH_PROVISIONER_SET_PRIMARY_ELEM_ADDR_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_read_oob_pub_key_comp_param
provisioner_prov_read_oob_pub_key_comp

Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_READ_OOB_PUB_KEY_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_input_num_comp_param
provisioner_prov_input_num_comp

Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_INPUT_NUMBER_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_input_str_comp_param
provisioner_prov_input_str_comp

Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_INPUT_STRING_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_set_node_name_comp_param
provisioner_set_node_name_comp

Event parameter of ESP_BLE_MESH_PROVISIONER_SET_NODE_NAME_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_local_app_key_comp_param
provisioner_add_local_app_key_comp

Event parameter of ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_APP_KEY_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_update_local_app_key_comp_param
provisioner_update_local_app_key_comp

Event parameter of ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_APP_KEY_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_bind_local_mod_app_comp_param
provisioner_bind_local_mod_app_comp

Event parameter of ESP_BLE_MESH_PROVISIONER_BIND_APP_KEY_TO_MODEL_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_read_local_net_key_comp_param
provisioner_prov_read_local_net_key_comp

Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_READ_LOCAL_NET_KEY_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_set_node_comp_data_comp_param
provisioner_set_node_comp_data_comp

Event parameter of ESP_BLE_MESH_PROVISIONER_STORE_NODE_COMP_DATA_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_node_id_comp_param
provisioner_delete_node_with_node_id_comp

Event parameter of ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_NODE_ID_COMP_EVT
```

```c
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
```

```c
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
```

```c
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
```

```c
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
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_lpn_poll_comp_param
lpn_poll_comp

Event parameter of ESP_BLE_MESH_LPN_POLL_COMP_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_lpn_friendship_establish_comp_param
lpn_friendship_establish

Event parameter of ESP_BLE_MESH_LPN_FRIENDSHIP_ESTABLISH_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_lpn_friendship_terminate_comp_param
lpn_friendship_terminate

Event parameter of ESP_BLE_MESH_LPN_FRIENDSHIP_TERMINATE_EVT
```

```c
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_friend_friendship_establish_comp_param
frnd_friendship_establish

Event parameter of ESP_BLE_MESH_FRIEND_FRIENDSHIP_ESTABLISH_EVT
```
`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_friend_friendship_terminate_param` frnd_friendship_terminate
Event parameter of ESP_BLE_MESH_FRIEND_FRIENDSHIP_TERMINATE_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_recv_adv_pkt_param` proxy_client_recv_adv_pkt
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_RECV_ADV_PKT_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_connected_param` proxy_client_connected
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_CONNECTED_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_disconnected_param` proxy_client_disconnected
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_DISCONNECTED_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_recv_filter_status_param` proxy_client_recv_filter_status
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_RECV_FILTER_STATUS_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_connect_comp_param` proxy_client_connect_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_CONNECT_COMP_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_disconnect_comp_param` proxy_client_disconnect_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_DISCONNECT_COMP_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_set_filter_type_comp_param` proxy_client_set_filter_type_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_SET_FILTER_TYPE_COMP_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_add_filter_addr_comp_param` proxy_client_add_filter_addr_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_ADD_FILTER_ADDR_COMP_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_remove_filter_addr_comp_param` proxy_client_remove_filter_addr_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_REMOVE_FILTER_ADDR_COMP_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_start_ble_advertising_comp_param` start_ble_advertising_comp
Event parameter of ESP_BLE_MESH_START_BLE_ADVERTISING_COMP_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_stop_ble_advertising_comp_param` stop_ble_advertising_comp
Event parameter of ESP_BLE_MESH_STOP_BLE_ADVERTISING_COMP_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_model_sub_group_addr_comp_param` model_sub_group_addr_comp
Event parameters of ESP_BLE_MESH_MODEL_SUBSCRIBE_GROUP_ADDR_COMP_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_model_unsub_group_addr_comp_param` model_unsub_group_addr_comp
Event parameters of ESP_BLE_MESH_MODEL_UNSUBSCRIBE_GROUP_ADDR_COMP_EVT

`struct esp_ble_mesh_prov_cb_param_t::ble_mesh_deinit_mesh_comp_param` deinit_mesh_comp
Event parameter of ESP_BLE_MESH_DEINIT_MESH_COMP_EVT

`struct ble_mesh_deinit_mesh_comp_param`

`#include <esp_ble_mesh_defs.h>` ESP_BLE_MESH_DEINIT_MESH_COMP_EVT.

**Public Members**

`int err_code`
Indicate the result of BLE Mesh deinitialization

`struct ble_mesh_friend_friendship_establish_param`

`#include <esp_ble_mesh_defs.h>` ESP_BLE_MESH_FRIEND_FRIENDSHIP_ESTABLISH_EVT.

**Public Members**

`uint16_t lpn_addr`
Low Power Node unicast address

`struct ble_mesh_friend_friendship_terminate_param`

`#include <esp_ble_mesh_defs.h>` ESP_BLE_MESH_FRIEND_FRIENDSHIP_TERMINATE_EVT.
Public Types

```cpp
enum [anonymous]
This enum value is the reason of friendship termination on the friend node side
Values:

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

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

ESP_BLE_MESH_FRND_FRIENDSHIP_TERMINATE_RECV_FRND_REQ
Receive Friend Request from existing Low Power Node

ESP_BLE_MESH_FRND_FRIENDSHIP_TERMINATE_RECV_FRND_CLEAR
Receive Friend Clear from other friend node

ESP_BLE_MESH_FRND_FRIENDSHIP_TERMINATE_DISABLE
Friend feature disabled or corresponding NetKey is deleted
```

Public Members

```cpp
uint16_t lpn_addr
Low Power Node unicast address

esp_ble_mesh_prov_ch_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

```cpp
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

```cpp
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.
```
Chapter 2. API

Public Members

```c
int err_code
```
Indicate the result of inputting number

```c
struct ble_mesh_input_string_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_INPUT_STR_COMP_EVT.
```

Public Members

```c
int err_code
```
Indicate the result of inputting string

```c
struct ble_mesh_link_close_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_LINK_CLOSE_EVT.
```

Public Members

```c
esp_ble_mesh_prov_bearer_t * bearer
```
Type of the bearer used when device link is closed

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

Public Members

```c
esp_ble_mesh_prov_bearer_t * bearer
```
Type of the bearer used when device link is open

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

Public Members

```c
int err_code
```
Indicate the result of disabling LPN functionality

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

Public Members

```c
int err_code
```
Indicate the result of enabling LPN functionality

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

Public Members

```c
uint16_t friend_addr
```
Friend Node unicast address

```c
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_LPNU_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_output_num_evt_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_OUTPUT_NUMBER_EVT.
```
Public Members

`esp_ble_mesh_output_action_t action`
Action of Output OOB Authentication

`uint32_t number`
Number of Output OOB Authentication

```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

```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

```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

```c
#include <esp_ble_mesh_defs.h>
ESP_BLE_MESH_PROV_REGISTER_COMP_EVT.
```

Public Members

```c
int err_code
```
Indicate the result of BLE Mesh initialization

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

Public Members

```c
uint16_t net_idx
```
NetKey Index

```c
uint8_t net_key[16]
```
NetKey

```c
uint16_t addr
```
Primary address

```c
uint8_t flags
```
Flags
Chapter 2. API 参考

```c
uint32_t iv_index
IV Index

struct ble_mesh_provision_reset_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_RESET_EVT.

struct ble_mesh_provisioner_add_local_app_key_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_APP_KEY_COMP_EVT.

Public Members

int err_code
Indicate the result of adding local AppKey by the Provisioner

uint16_t net_idx
NetKey Index

uint16_t app_idx
AppKey Index

struct ble_mesh_provisioner_add_local_net_key_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_NET_KEY_COMP_EVT.

Public Members

int err_code
Indicate the result of adding local NetKey by the Provisioner

uint16_t net_idx
NetKey Index

struct ble_mesh_provisioner_add_unprov_dev_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_ADD_UNPROV_DEV_COMP_EVT.

Public Members

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

struct ble_mesh_provisioner_bind_local_mod_app_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_BIND_APP_KEY_TO_MODEL_COMP_EVT.

Public Members

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

uint16_t element_addr
Element address

uint16_t app_idx
AppKey Index

uint16_t company_id
Company ID

uint16_t model_id
Model ID

struct ble_mesh_provisioner_delete_dev_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_DELETE_DEV_COMP_EVT.
```
Public Members

int `err_code`

Indicate the result of deleting device by the Provisioner

```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

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

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
esp_ble_mesh_prov_bearer_t `bearer`

Type of the bearer used when Provisioner link is closed
```

```c
uint8_t `reason`

Reason of the closed provisioning link
```

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

Public Members

```c
esp_ble_mesh_prov_bearer_t `bearer`

Type of the bearer used when Provisioner link is opened
```

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

Public Members

```c
uint16_t `node_idx`

Index of the provisioned device
```

```c
esp_ble_mesh_octet16_t `device_uuid`[16]

Device UUID of the provisioned device
```
Chapter 2. API

```
uint16_t unicast_addr
    Primary address of the provisioned device

uint8_t element_num
    Element count of the provisioned device

uint16_t netkey_idx
    NetKey Index of the provisioned device

struct ble_mesh_provisioner_prov_dev_with_addr_comp_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_DEV_WITH_ADDR_COMP_EVT.

    Public Members

    int err_code
        Indicate the result of Provisioner starting to provision a device

struct ble_mesh_provisioner_prov_disable_comp_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_DISABLE_COMP_EVT.

    Public Members

    int err_code
        Indicate the result of disabling BLE Mesh Provisioner

struct ble_mesh_provisioner_prov_enable_comp_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_ENABLE_COMP_EVT.

    Public Members

    int err_code
        Indicate the result of enabling BLE Mesh Provisioner

struct ble_mesh_provisioner_prov_input_evt_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_INPUT_EVT.

    Public Members

    esp_ble_mesh_oob_method_t method
        Method of device Output OOB Authentication

    esp_ble_mesh_output_action_t action
        Action of device Output OOB Authentication

    uint8_t size
        Size of device Output OOB Authentication

    uint8_t link_idx
        Index of the provisioning link

struct ble_mesh_provisioner_prov_input_num_comp_param
    #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
**Chapter 2. API**

### esp_ble_mesh_addr_type_t

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 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
\texttt{esp\_ble\_mesh\_bd\_addr\_t \textit{addr}}

Device address of the Proxy Server

\texttt{esp\_ble\_mesh\_addr\_type\_t \textit{addr\_type}}

Device address type

\texttt{uint16\_t \textit{net\_idx}}

Corresponding NetKey Index

\textbf{struct ble\_mesh\_proxy\_client\_connected\_param}

#include <esp\_ble\_mesh\_defs\_h> ESP\_BLE\_MESH\_PROXY\_CLIENT\_CONNECTED\_EVT.

\textbf{Public Members}

\texttt{esp\_ble\_mesh\_bd\_addr\_t \textit{addr}}

Device address of the Proxy Server

\texttt{esp\_ble\_mesh\_addr\_type\_t \textit{addr\_type}}

Device address type

\texttt{uint8\_t \textit{conn\_handle}}

Proxy connection handle

\texttt{uint16\_t \textit{net\_idx}}

Corresponding NetKey Index

\textbf{struct ble\_mesh\_proxy\_client\_disconnect\_comp\_param}

#include <esp\_ble\_mesh\_defs\_h> ESP\_BLE\_MESH\_PROXY\_CLIENT\_DISCONNECT\_COMP\_EVT.

\textbf{Public Members}

\texttt{int \textit{err\_code}}

Indicate the result of Proxy Client disconnect

\texttt{uint8\_t \textit{conn\_handle}}

Proxy connection handle

\textbf{struct ble\_mesh\_proxy\_client\_disconnected\_param}

#include <esp\_ble\_mesh\_defs\_h> ESP\_BLE\_MESH\_PROXY\_CLIENT\_DISCONNECTED\_EVT.

\textbf{Public Members}

\texttt{esp\_ble\_mesh\_bd\_addr\_t \textit{addr}}

Device address of the Proxy Server

\texttt{esp\_ble\_mesh\_addr\_type\_t \textit{addr\_type}}

Device address type

\texttt{uint8\_t \textit{conn\_handle}}

Proxy connection handle

\texttt{uint16\_t \textit{net\_idx}}

Corresponding NetKey Index

\texttt{uint8\_t \textit{reason}}

Proxy disconnect reason

\textbf{struct ble\_mesh\_proxy\_client\_recv\_adv\_pkt\_param}

#include <esp\_ble\_mesh\_defs\_h> ESP\_BLE\_MESH\_PROXY\_CLIENT\_RECV\_ADV\_PKT\_EVT.

\textbf{ESP BLE Mesh Proxy API Reference}
**Public Members**

```c
esp_ble_mesh_bd_addr_t addr
Device address
```

```c
esp_ble_mesh_addr_type_t addr_type
Device address type
```

```c
uint16_t net_idx
Network ID related NetKey Index
```

```c
uint8_t net_id[8]
Network ID contained in the advertising packet
```

```c
int8_t rssi
RSSI of the received advertising packet
```

```c
struct ble_mesh_proxy_client_recv_filter_status_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_CLIENT_RECV_FILTER_STATUS_EVT.
```

**Public Members**

```c
uint8_t conn_handle
Proxy connection handle
```

```c
uint16_t server_addr
Proxy Server primary element address
```

```c
uint16_t net_idx
Corresponding NetKey Index
```

```c
uint8_t filter_type
Proxy Server filter type (whitelist or blacklist)
```

```c
uint16_t list_size
Number of addresses in the Proxy Server filter list
```

```c
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**

```c
int err_code
Indicate the result of Proxy Client remove filter address
```

```c
uint8_t conn_handle
Proxy connection handle
```

```c
uint16_t net_idx
Corresponding NetKey Index
```

```c
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**

```c
int err_code
Indicate the result of Proxy Client set filter type
```

```c
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

```c
int err_code
```

Indicate the result of setting OOB Public Key

```c
struct ble_mesh_set_unprov_dev_name_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_SET_UNPROV_DEV_NAME_COMP_EVT.
```

### Public Members

```c
int err_code
```

Indicate the result of setting BLE Mesh device name

```c
struct ble_mesh_start_ble_advertising_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_START_BLE_ADVERTISING_COMP_EVT.
```

### Public Members

```c
int err_code
```

Indicate the result of starting BLE advertising

```c
uint8_t index
```

Index of the BLE advertising

```c
struct ble_mesh_stop_ble_advertising_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_STOP_BLE_ADVERTISING_COMP_EVT.
```

### Public Members

```c
int err_code
```

Indicate the result of stopping BLE advertising

```c
uint8_t index
```

Index of the BLE advertising

```c
union esp_ble_mesh_server_state_value_t
#include <esp_ble_mesh_defs.h> Server model state value union.
```

### Public Members

```c
uint8_t onoff
```

The value of the Generic OnOff state

The value of the Light LC Light OnOff state

```c
struct esp_ble_mesh_server_state_value_t::[anonymous] gen_onoff
```

The Generic OnOff state

```c
int16_t level
```

The value of the Generic Level state

```c
struct esp_ble_mesh_server_state_value_t::[anonymous] gen_level
```

The Generic Level state

```c
uint8_t onpowerup
```

The value of the Generic OnPowerUp state

```c
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

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

uint16_t hue
The value of the Light HSL Hue state

struct esp_ble_mesh_server_state_value_t::[anonymous] light_hsl_hue
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_saturation
The Light HSL Saturation state

struct esp_ble_mesh_server_state_value_t::[anonymous] light_xyl_lightness
The Light xYL Lightness state

struct esp_ble_mesh_server_state_value_t::[anonymous] light_lc_light_onoff
The Light LC Light OnOff state

union esp_ble_mesh_model_cb_param_t
#include <esp_ble_mesh_defs.h> BLE Mesh model callback parameters union.

Public Members

struct esp_ble_mesh_model_cb_param_t::ble_mesh_model_operation_evt_param model_operation
Event parameter of ESP_BLE_MESH_MODEL_OPERATION_EVT

struct esp_ble_mesh_model_cb_param_t::ble_mesh_model_send_comp_param model_send_comp
Event parameter of ESP_BLE_MESH_MODEL_SEND_COMP_EVT
struct esp_ble_mesh_model_cb_param_t::ble_mesh_model_publish_comp_param model_publish_comp
    Event parameter of ESP_BLE_MESH_MODEL_PUBLISH_COMP_EVT

struct esp_ble_mesh_model_cb_param_t::ble_mesh_mod_recv_publish_msg_param client_recv_publish_msg
    Event parameter of ESP_BLE_MESH_CLIENT_MODEL_RECV_PUBLISH_MSG_EVT

struct esp_ble_mesh_model_cb_param_t::ble_mesh_client_model_send_timeout_param client_send_timeout
    Event parameter of ESP_BLE_MESH_CLIENT_MODEL_SEND_TIMEOUT_EVT

struct esp_ble_mesh_model_cb_param_t::ble_mesh_model_publish_update_evt_param model_publish_update
    Event parameter of ESP_BLE_MESH_MODEL_PUBLISH_UPDATE_EVT

struct esp_ble_mesh_model_cb_param_t::ble_mesh_server_model_update_state_comp_param server_model_update_state
    Event parameter of ESP_BLE_MESH_SERVER_MODEL_UPDATE_STATE_COMP_EVT

struct ble_mesh_client_model_send_timeout_param
    #include <esp_ble_meshDefs.h> ESP_BLE_MESH_CLIENT_MODEL_SEND_TIMEOUT_EVT.

Public Members

uint32_t opcode
    Opcode of the previously sent message

esp_ble_mesh_model_t *model
    Pointer to the model which sends the previous message

esp_ble_mesh_msg_ctx_t *ctx
    Pointer to the context of the previous message

struct ble_mesh_mod_recv_publish_msg_param
    #include <esp_ble_meshDefs.h> ESP_BLE_MESH_CLIENT_MODEL_RECV_PUBLISH_MSG_EVT.

Public Members

uint32_t opcode
    Opcode of the unsolicited received message

esp_ble_mesh_model_t *model
    Pointer to the model which receives the message

esp_ble_mesh_msg_ctx_t *ctx
    Pointer to the context of the received message

uint16_t length
    Length of the received message

uint8_t *msg
    Value of the received message

struct ble_mesh_model_operation_evt_param
    #include <esp_ble_meshDefs.h> ESP_BLE_MESH_MODEL_OPERATION_EVT.

Public Members

uint32_t opcode
    Opcode of the received message

esp_ble_mesh_model_t *model
    Pointer to the model which receives the message

esp_ble_mesh_msg_ctx_t *ctx
    Pointer to the context of the received message
Chapter 2. API

uint16_t length
   Length of the received message

uint8_t *msg
   Value of the received message

struct ble_mesh_model_publish_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_MODEL_PUBLISH_COMP_EVT.

    Public Members

    int err_code
       Indicate the result of publishing a message

    esp_ble_mesh_model_t *model
       Pointer to the model which publishes the message

struct ble_mesh_model_publish_update_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_MODEL_PUBLISH_UPDATE_EVT.

    Public Members

    esp_ble_mesh_model_t *model
       Pointer to the model which is going to update its publish message

struct ble_mesh_model_send_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_MODELSEND_COMP_EVT.

    Public Members

    int err_code
       Indicate the result of sending a message

    uint32_t opcode
       Opcode of the message

    esp_ble_mesh_model_t *model
       Pointer to the model which sends the message

    esp_ble_mesh_msg_ctx_t *ctx
       Context of the message

struct ble_mesh_server_model_update_state_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_SERVER_MODEL_UPDATE_STATE_COMP_EVT.

    Public Members

    int err_code
       Indicate the result of updating server model state

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

    esp_ble_mesh_server_state_type_t type
       Type of the updated server state

Structures

struct esp_ble_mesh_deinit_param_t
   BLE Mesh deinit parameters
## Public Members

**bool erase_flash**
Indicate if erasing flash when deinit mesh stack

**struct esp_ble_mesh_elem_t**
Abstraction that describes a BLE Mesh Element. This structure is associated with struct bt_mesh_elem in mesh_access.h

### Public Members

**uint16_t element_addr**
Element Address, assigned during provisioning.

**const uint16_t location**
Location Descriptor (GATT Bluetooth Namespace Descriptors)

**const uint8_t sig_model_count**
SIG Model count

**const uint8_t vnd_model_count**
Vendor Model count

**esp_ble_mesh_model_t *sig_models**
SIG Models

**esp_ble_mesh_model_t *vnd_models**
Vendor Models

**struct esp_ble_mesh_model_pub_t**
Abstraction that describes a model publication context. This structure is associated with struct bt_mesh_model_pub in mesh_access.h

### Public Members

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

**uint16_t publish_addr**
Publish Address.

**uint16_t app_idx : 12**
Publish AppIdx Index.

**uint16_t cred : 1**
Friendship Credentials Flag.

**uint16_t send_rel : 1**
Force reliable sending (segment acks)

**uint8_t ttl**
Publish Time to Live.

**uint8_t retransmit**
Retransmit Count & Interval Steps.

**uint8_t period**
Publish Period.

**uint8_t period_div : 4**
Divisor for the Period.

**uint8_t fast_period : 1**
Use FastPeriodDivisor
uint8_t count : 3
    Retransmissions left.

uint32_t period_start
    Start of the current period.

struct net_buf_simple *msg
    Publication buffer, containing the publication message.
    This will get correctly created when the publication context has been defined using the
    ESP_BLE_MESH_MODEL_PUB_DEFINE macro.
    ESP_BLE_MESH_MODEL_PUB_DEFINE(name, size);

esp_ble_mesh_cb_t update
    Callback used to update publish message. Initialized by the stack.

struct k_delayed_work timer
    Publish Period Timer. Initialized by the stack.

uint8_t dev_role
    Role of the device that is going to publish messages

struct esp_ble_mesh_model_op_t
    Abstraction that describes a model operation context. This structure is associated with struct
    bt_mesh_model_op in mesh_access.h

Public Members

const uint32_t opcode
    Message opcode

const size_t min_len
    Message minimum length

desp_ble_mesh_cb_f 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_f init_cb
    Callback used during model initialization. Initialized by the stack.

desp_ble_mesh_cb_f deinit_cb
    Callback used during model deinitialization. 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
### Chapter 2. API 📖

**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_cbx_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.

*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

*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

addr
  Device address

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

bearer
  Provisioning Bearer

struct esp_ble_mesh_device_delete_t
  Information of the device which is going to be deleted.

Public Members

addr
  Device address

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

cchar 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_ble_adv_param_t
Context of BLE advertising parameters.

Public Members

uint16_t interval
BLE advertising interval

uint8_t adv_type
BLE advertising type

uint8_t own_addr_type
Own address type

uint8_t peer_addr_type
Peer address type

uint8_t peer_addr[BD_ADDR_LEN]
Peer address

uint16_t duration
Duration is milliseconds

uint16_t period
Period in milliseconds

uint16_t count
Number of advertising duration

uint8_t priority: 2
Priority of BLE advertising packet

struct esp_ble_mesh_ble_adv_data_t
Context of BLE advertising data.
Public Members

uint8_t **adv_data_len**
Advertising data length

uint8_t **adv_data[31]**
Advertising data

uint8_t **scan_rsp_data_len**
Scan response data length

uint8_t **scan_rsp_data[31]**
Scan response data

**struct esp_ble_mesh_client_op_pair_t**
BLE Mesh client models related definitions.
Client model Get/Set message opcode and corresponding Status message opcode

Public Members

uint32_t *cli_op
The client message opcode

uint32_t *status_op
The server status opcode corresponding to the client message opcode

**struct esp_ble_mesh_client_t**
Client Model user data context.

Public Members

esp_ble_mesh_opcode_t *opcode
Message opcode

esp_ble_mesh_model_t *model
Pointer to the client model structure

esp_ble_mesh_msg_ctx_t *ctx
The context used to send message

const esp_ble_mesh_client_op_pair_t **op_pair
Table containing get/set message opcode and corresponding status message opcode

uint32_t *publish_status
Callback used to handle the received unsolicited message. Initialized by the stack.

void **internal_data
Pointer to the internal data of client model

uint8_t *msg_role
Role of the device (Node/Provisioner) that is going to send messages

**struct esp_ble_mesh_client_common_param_t**
Common parameters of the messages sent by Client Model.

Public Members

esp_ble_mesh_opcode_t opcode
Message opcode

esp_ble_mesh_model_t *model
Pointer to the client model structure

esp_ble_mesh_msg_ctx_t *ctx
The context used to send message
int32_t msg_timeout
    Timeout value (ms) to get response to the sent message
    Note: if using default timeout value in menuconfig, make sure to set this value to 0

uint8_t msg_role
    Role of the device - Node/Provisioner

struct esp_ble_mesh_state_transition_t
    Parameters of the server model state transition

Public Functions

BLE_MESH_ATOMIC_DEFINE (flag, ESP_BLE_MESH_SERVER_FLAG_MAX)
    Flag used to indicate if the transition timer has been started internally.

    If the model which contains esp_ble_mesh_state_transition_t sets “set_auto_rsp” to
    ESP_BLE_MESH_SERVER_RSP_BY_APP, the handler of the timer shall be initialized by the
    users.

    And users can use this flag to indicate whether the timer is started or not.

Public Members

bool just_started
    Indicate if the state transition has just started

uint8_t trans_time
    State transition time

uint8_t remain_time
    Remaining time of state transition

uint8_t delay
    Delay before starting state transition

uint32_t quo_tt
    Duration of each divided transition step

uint32_t counter
    Number of steps which the transition duration is divided

uint32_t total_duration
    State transition total duration

int64_t start_timestamp
    Time when the state transition is started

struct k_delayed_work timer
    Timer used for state transition

struct esp_ble_mesh_last_msg_info_t
    Parameters of the server model received last same set message.

Public Members

uint8_t tid
    Transaction number of the last message

uint16_t src
    Source address of the last message

uint16_t dst
    Destination address of the last message
int64_t timestamp
Time when the last message is received

struct esp_ble_mesh_server_rsp_ctrl_t
Parameters of the Server Model response control

Public Members

uint8_t get_auto_rsp: 1
BLE Mesh Server Response Option.
  1. If get_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, then the response of Client
     Get messages need to be replied by the application;
  2. If get_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, then the response of Client Get
     messages will be replied by the server models;
  3. If set_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, then the response of Client
     Set messages need to be replied by the application;
  4. If set_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, then the response of Client Set
     messages will be replied by the server models;
  5. If status_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, then the response of Server
     Status messages need to be replied by the application;
  6. If status_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, then the response of Server
     Status messages will be replied by the server models; Response control for Client Get messages

uint8_t set_auto_rsp: 1
Response control for Client Set messages

uint8_t status_auto_rsp: 1
Response control for Server Status messages

Macros

ESP_BLE_HOST_STATUS_ENABLED
ESP_BLE_HOST_STATUS_CHECK(status)
The maximum length of a BLE Mesh message, including Opcode, Payload and TransMIC

ESP_BLE_MESH_SDU_MAX_LEN
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
Define the BLE Mesh octet 16 bytes size

ESP_BLE_MESH_OCTET16_LEN

ESP_BLE_MESH_OCTET8_LEN

ESP_BLE_MESH_CID_NVAL
Special TTL value to request using configured default TTL

ESP_BLE_MESH_TTL_DEFAULT
Maximum allowed TTL value

ESP_BLE_MESH_TTL_MAX

ESP_BLE_MESH_ADDR_UNASSIGNED

ESP_BLE_MESH_ADDR_ALL_NODES
ESP BLE_MESH_ADDR_PROXIES
ESP BLE_MESH_ADDR_FRIENDS
ESP BLE_MESH_ADDR_RELAYS
ESP BLE_MESH_KEY_UNUSED
ESP BLE_MESH_KEY_DEV
ESP BLE_MESH_KEY_PRIMARY
ESP BLE_MESH_KEY_ANY
    Primary Network Key index
ESP BLE_MESH_NET_PRIMARY
    Relay state value
ESP BLE_MESH_RELAY_DISABLED
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.
Chapter 2. API

**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.

**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_BLE_ADV_INFINITE
Count for sending BLE advertising packet infinitely This enum value is the priority of BLE advertising packet
Chapter 2. API Reference

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_GEN_ONOFF_CLI
ESP_BLE_MESH_MODEL_ID_GEN_LEVEL_SRV
ESP_BLE_MESH_MODEL_ID_GEN_LEVEL_CLI
ESP_BLE_MESH_MODEL_ID_GEN_DEF_TRANS_TIME_SRV
ESP_BLE_MESH_MODEL_ID_GEN_DEF_TRANS_TIME_CLI
ESP_BLE_MESH_MODEL_ID_GEN_POWER_ONOFF_SRV
ESP_BLE_MESH_MODEL_ID_GEN_POWER_ONOFF_CLI
ESP_BLE_MESH_MODEL_ID_GEN_POWER_LEVEL_SRV
ESP_BLE_MESH_MODEL_ID_GEN_POWER_LEVEL_CLI
ESP_BLE_MESH_MODEL_ID_GEN_BATTERY_SRV
ESP_BLE_MESH_MODEL_ID_GEN_BATTERY_CLI
ESP_BLE_MESH_MODEL_ID_GEN_LOCATION_SRV
ESP_BLE_MESH_MODEL_ID_GEN_LOCATION_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_LOCATION_CLI
ESP_BLE_MESH_MODEL_ID_GEN_ADMIN_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_MANUFACTURER_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_USER_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_CLIENT_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_PROP_CLI
ESP_BLE_MESH_MODEL_ID_SENSOR_SRV
ESP_BLE_MESH_MODEL_ID_SENSOR_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_SENSOR_CLI
ESP_BLE_MESH_MODEL_ID_TIME_SRV
ESP_BLE_MESH_MODEL_ID_TIME_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_TIME_CLI
ESP_BLE_MESH_MODEL_ID_SCENE_SRV
ESP_BLE_MESH_MODEL_ID_SCENE_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_SCENE_CLI
ESP_BLE_MESH_MODEL_ID_SCHEDULER_SRV
ESP_BLE_MESH_MODEL_ID_SCHEDULER_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_SCHEDULER_CLI
Chapter 2. API

ESP_BLE_MESH_MODEL_ID_SCHEDULER_CLI
ESP_BLE_MESH_MODEL_ID_LIGHT_LIGHTNESS_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_LIGHTNESS_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_LIGHTNESS_CLI
ESP_BLE_MESH_MODEL_ID_LIGHT_CTL_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_CTL_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_CTL_CLI
ESP_BLE_MESH_MODEL_ID_LIGHT_CTL_TEMP_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_HSL_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_HSL_SETUP_SRV
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_LPOLL_TIMEOUT_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
Chapter 2. API 参考

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
Chapter 2. API

| ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_STATUS |
| ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_STATUS |
| ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_STATUS |
| ESP_BLE_MESH_MODEL_OP_LP_POLLTIMEOUT_STATUS |
| ESP_BLE_MESH_MODEL_OP_NETWORK_TRANSMIT_STATUS |
| ESP_BLE_MESH_CFG_STATUS_SUCCESS |
| ESP_BLE_MESH_CFG_STATUS_INVALID_ADDRESS |
| ESP_BLE_MESH_CFG_STATUS_INVALID_MODEL |
| ESP_BLE_MESH_CFG_STATUS_INVALID_APPKEY |
| ESP_BLE_MESH_CFG_STATUS_INVALID_NETKEY |
| ESP_BLE_MESH_CFG_STATUS_INSUFFICIENT_RESOURCES |
| ESP_BLE_MESH_CFG_STATUS_KEY_INDEX_ALREADY_STORED |
| ESP_BLE_MESH_CFG_STATUS_INVALID_PUBLISH_PARAMETERS |
| ESP_BLE_MESH_CFG_STATUS_NOT_A_SUBSCRIBE_MODEL |
| ESP_BLE_MESH_CFG_STATUS_STORAGE_FAILURE |
| ESP_BLE_MESH_CFG_STATUS_FEATURE_NOT_SUPPORTED |
| ESP_BLE_MESH_CFG_STATUS_CANNOT_UPDATE |
| ESP_BLE_MESH_CFG_STATUS_CANNOT_REMOVE |
| ESP_BLE_MESH_CFG_STATUS_CANNOT_BIND |
| ESP_BLE_MESH_CFG_STATUS_TEMP_UNABLE_TO_CHANGE_STATE |
| ESP_BLE.Mesh_CFG_STATUS_CANNOT_SET |
| ESP_BLE_MESH_CFG_STATUS_UNSPECIFIED_ERROR |
| ESP_BLE_MESH_CFG_STATUS_INVALID_BINDING |

Health Fault Get

Health Period Get

Health Attention Get

Health Fault Clear

Health Fault Clear Unacknowledged

Health Fault Test

Health Fault Test Unacknowledged

Health Period Set

Health Period Set Unacknowledged
ESP_BLE_MESH_MODEL_OP_ATTENTION_SET
Health Attention Set

ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_UNACK
Health Attention Set Unacknowledged

ESP_BLE_MESH_MODEL_OP_HEALTH_CURRENT_STATUS

ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_STATUS

ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_STATUS

ESP_BLE_MESH_MODEL_OP_ATTENTION_STATUS

ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_GET

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
Chapter 2. API Reference

- 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
  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
  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
  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
ESP_BLE_MESH_MODEL_OP_SCHEDULER_GET
ESP_BLE_MESH_MODEL_OP_SCHEDULER_STATUS
   Scheduler Setup Message Opcode

ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_SET
ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LAST_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LAST_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_STATUS
   Light Lightness Setup Message Opcode

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_SET_UNACK
   Light CTL Message Opcode

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_STATUS
Chapter 2. API

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_STATUS
  Light CTL Setup Message Opcode
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_SET_UNACK
  Light HSL Message Opcode
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_TARGET_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_TARGET_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_STATUS
  Light HSL Setup Message Opcode
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_SET_UNACK
  Light xyL Message Opcode
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_TARGET_GET
Chapter 2. API

ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_TARGET_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_STATUS
  Light xyL Setup Message Opcode
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_SET_UNACK
  Light Control Message Opcode
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_STATUS
ESP_BLE_MESH_MODEL_STATUS_SUCCESS
ESP_BLE_MESH_MODEL_STATUS_CANNOT_SET_RANGE_MIN
ESP_BLE_MESH_MODEL_STATUS_CANNOT_SET_RANGE_MAX
ESP_BLE_MESH_SERVER_RSP_BY_APP
  Response need to be sent in the application
ESP_BLE_MESH_SERVER_AUTO_RSP
  Response will be sent internally

Type Definitions

typedef uint8_t esp_ble_mesh_octet16_t[ESP_BLE_MESH_OCTET16_LEN]
  Define the BLE Mesh octet 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 esp_ble_mesh_config_client_get_state function.

typedef uint32_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 Config 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 esp_ble_mesh_gen generic_client_get_state & esp_ble_mesh_gen 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 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 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

define 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)

define 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_ble_adv_priority_t
   Values:
   ESP_BLE_MESH_BLE_ADV_PRIO_LOW
   ESP_BLE_MESH_BLE_ADV_PRIO_HIGH

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
Chapter 2. API

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_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_PROV_COMPLETE_EVT**
Provisioner provisioning done event

**ESP_BLE_MESH_PROVISIONER_PROV_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_PROV_DEV_WITH_ADDR_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_SET_FAST_PROV_INFO_COMP_EVT**
Set fast provisioning information (e.g. unicast address range, net_idx, etc.) completion event
Chapter 2. API

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_BLE_MESH_SET_FAST_PROV_ACTION_COMP_EVT</td>
<td>Set fast provisioning action completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_HEARTBEAT_MESSAGE_RECV_EVT</td>
<td>Receive Heartbeat message event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_LPN_ENABLE_COMP_EVT</td>
<td>Enable Low Power Node completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_LPN_DISABLE_COMP_EVT</td>
<td>Disable Low Power Node completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_LPN_POLL_COMP_EVT</td>
<td>Low Power Node send Friend Poll completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_LPN_FRIENDSHIP_ESTABLISH_EVT</td>
<td>Low Power Node establishes friendship event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_LPN_FRIENDSHIP_TERMINATE_EVT</td>
<td>Low Power Node terminates friendship event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_FRIEND_FRIENDSHIP_ESTABLISH_EVT</td>
<td>Friend Node establishes friendship event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_FRIEND_FRIENDSHIP_TERMINATE_EVT</td>
<td>Friend Node terminates friendship event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_PROXY_CLIENT_RECV_ADV_PKT_EVT</td>
<td>Proxy Client receives Network ID advertising packet event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_PROXY_CLIENT_CONNECTED_EVT</td>
<td>Proxy Client establishes connection successfully event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_PROXY_CLIENT_DISCONNECTED_EVT</td>
<td>Proxy Client terminates connection successfully event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_PROXY_CLIENT_RECV_FILTER_STATUS_EVT</td>
<td>Proxy Client receives Proxy Filter Status event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_PROXY_CLIENT_CONNECT_COMP_EVT</td>
<td>Proxy Client connect completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_PROXY_CLIENT_DISCONNECT_COMP_EVT</td>
<td>Proxy Client disconnect completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_PROXY_CLIENT_SET_FILTER_TYPE_COMP_EVT</td>
<td>Proxy Client set filter type completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_PROXY_CLIENT_ADD_FILTER_ADDR_COMP_EVT</td>
<td>Proxy Client add filter address completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_PROXY_CLIENT_REMOVE_FILTER_ADDR_COMP_EVT</td>
<td>Proxy Client remove filter address completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_START_BLE_ADVERTISING_COMP_EVT</td>
<td>Start BLE advertising completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_STOP_BLE_ADVERTISING_COMP_EVT</td>
<td>Stop BLE advertising completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_MODEL_SUBSCRIBE_GROUP_ADDR_COMP_EVT</td>
<td>Local model subscribes group address completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_MODEL_UNSUBSCRIBE_GROUP_ADDR_COMP_EVT</td>
<td>Local model unsubscribes group address completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_DEINIT_MESH_COMP_EVT</td>
<td>De-initialize BLE Mesh stack completion event</td>
</tr>
<tr>
<td>ESP_BLE_MESH_PROV_EVT_MAX</td>
<td></td>
</tr>
</tbody>
</table>
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_LIGHTNESS_STATE
ESP_BLE_MESH_LIGHT_HSL_HUE_STATE
ESP_BLE_MESH_LIGHT_HSL_SATURATION_STATE
ESP_BLE_MESH_LIGHT_XYL_LIGHTNESS_STATE
ESP_BLE_MESH_LIGHT_LC_LIGHT_ONOFF_STATE
ESP_BLE_MESH_SERVER_MODEL_STATE_MAX

enum esp_ble_mesh_model_cb_event_t
Values:
ESP_BLE_MESH_MODEL_OPERATION_EVT
User-defined models receive messages from peer devices (e.g. get, set, status, etc) event
ESP_BLE_MESH_MODEL_SEND_COMP_EVT
User-defined models send messages completion event
ESP_BLE_MESH_MODEL_PUBLISH_COMP_EVT
User-defined models publish messages completion event
ESP_BLE_MESH_CLIENT_MODEL_RECV_PUBLISH_MSG_EVT
User-defined client models receive publish messages event
ESP_BLE_MESH_CLIENT_MODEL_SEND_TIMEOUT_EVT
Timeout event for the user-defined client models that failed to receive response from peer server models
ESP_BLE_MESH_MODEL_PUBLISH_UPDATE_EVT
When a model is configured to publish messages periodically, this event will occur during every publish period
ESP_BLE_MESH_SERVER_MODEL_UPDATE_STATE_COMP_EVT
Server models update state value completion event
ESP_BLE_MESH_MODEL_EVT_MAX
**ESP-BLE-MESH Core API Reference**

This section contains ESP-BLE-MESH Core related APIs, which can be used to initialize ESP-BLE-MESH stack, provision, send/publish messages, etc.

This API reference covers six components:

- **ESP-BLE-MESH Stack Initialization**
- **Reading of Local Data Information**
- **Low Power Operation (Updating)**
- **Send/Publish Messages, add Local AppKey, etc.**
- **ESP-BLE-MESH Node/Provisioner Provisioning**
- **ESP-BLE-MESH GATT Proxy Server**

**ESP-BLE-MESH Stack Initialization**

**Header File**

- `bt/esp_ble_mesh/api/core/include/esp_ble_mesh_common_api.h`

**Functions**

```c
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.

```c
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**

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

**Functions**

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

Get the model publish period, the unit is ms.

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

**Parameters**


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

Get the address of the primary element.

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

esp_ble_mesh_elem_t *esp_ble_mesh_find_element (uint16_t element_addr)

Find the BLE Mesh element pointer via the element address.

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

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

uint8_t esp_ble_mesh_get_element_count (void)

Get the number of elements that have been registered.

**Return** Number of elements.

esp_ble_mesh_model_t *esp_ble_mesh_find_vendor_model (const esp_ble_mesh_elem_t *element, uint16_t company_id, uint16_t model_id)

Find the Vendor specific model with the given element, the company ID and the Vendor Model ID.

**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.

esp_ble_mesh_model_t *esp_ble_mesh_find_sig_model (const esp_ble_mesh_elem_t *element, uint16_t model_id)

Find the SIG model with the given element and Model id.

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

**Parameters**
- [in] element: Element to which the model belongs.

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] 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.

### Low Power Operation (Updating)

**Header File**

- bt/esp_ble_mesh/api/core/include/esp_ble_mesh_low_power_api.h

**Functions**

**esp_err_t esp_ble_mesh_lpn_enable** (void)

Enable BLE Mesh device LPN functionality.

**Note** This API enables LPN functionality. Once called, the proper Friend Request will be sent.

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

**esp_err_t esp_ble_mesh_lpn_disable** (bool *force)

Disable BLE Mesh device LPN functionality.

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

**Parameters**
- **[in]** force: when disabling LPN functionality, use this flag to indicate whether directly clear corresponding information or just send friend clear to disable it if friendship has already been established.

**esp_err_t esp_ble_mesh_lpn_poll** (void)

LPN tries to poll messages from the Friend Node.

**Note** The Friend Poll message is sent by a Low Power node to ask the Friend node to send a message that it has stored for the Low Power node. Users can call this API to send Friend Poll message manually. If this API is not invoked, the bottom layer of the Low Power node will send Friend Poll before the PollTimeout timer expires. If the corresponding Friend Update is received and MD is set to 0, which means there are no messages for the Low Power node, then the Low Power node will stop scanning.

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

### Send/Publish Messages, add Local AppKey, etc.

**Header File**

- bt/esp_ble_mesh/api/core/include/esp_ble_mesh_networking_api.h

**Functions**

**esp_err_t esp_ble_mesh_register_custom_model_callback** (esp_ble_mesh_model_cb_t *callback)

Register BLE Mesh callback for user-defined models’ operations. This callback can report the following events generated for the user-defined models:

- Call back the messages received by user-defined client and server models to the application layer;
• If users call esp_ble_mesh_server/client_model_send, this callback notifies the application layer of the send_complete event;
• If user-defined client model sends a message that requires response, and the response message is received after the timer expires, the response message will be reported to the application layer as published by a peer device;
• If the user-defined client model fails to receive the response message during a specified period of time, a timeout event will be reported to the application layer.

**Note** The client models (i.e. Config Client model, Health Client model, Generic Client models, Sensor Client model, Scene Client model and Lighting Client models) that have been realized internally have their specific register functions. For example, esp_ble_mesh_register_config_client_callback is the register function for Config Client Model.

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

**Parameters**
- **[in]** callback: Pointer to the callback function.

```c
esp_err_t esp_ble_mesh_model_msg_opcode_init(uint8_t* data, uint32_t opcode)
```

Add the message opcode to the beginning of the model message before sending or publishing the model message.

**Note** This API is only used to set the opcode of the message.

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

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

```c
esp_err_t esp_ble_mesh_client_model_init(esp_ble_mesh_model_t* model)
```

Initialize the user-defined client model. All user-defined client models shall call this function to initialize the client model internal data. Node: Before calling this API, the op_pair_size and op_pair variabled within the user_data(defined using esp_ble_mesh_client_t_) of the client model need to be initialized.

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

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

```c
esp_err_t esp_ble_mesh_client_model_deinit(esp_ble_mesh_model_t* model)
```

De-initialize the user-defined client model.

**Note** This function shall be invoked before esp_ble_mesh_deinit() is called.

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

**Parameters**
- **[in]** model: Pointer of the Client model.

```c
esp_err_t esp_ble_mesh_server_model_send_msg(esp_ble_mesh_model_t* model,
                                           esp_ble_mesh_msg_ctx_t* ctx,
                                           uint32_t opcode, uint16_t length, uint8_t* data)
```

Send server model messages (such as server model status messages).

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

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

```c
esp_err_t esp_ble_mesh_client_model_send_msg(esp_ble_mesh_model_t* model,
                                           esp_ble_mesh_msg_ctx_t* ctx,
                                           uint32_t opcode, uint16_t length, uint8_t* data,
                                           int32_t msg_timeout, bool need_rsp,
                                           esp_ble_mesh_dev_role_t device_role)
```

Send client model message (such as model get, set, etc).

**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]** `opcode`: Message opcode.
- **[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.

```c
esp_err_t esp_ble_mesh_model_publish(esp_ble_mesh_model_t *model, uint32_t opcode, uint16_t length, uint8_t *data, esp_ble_mesh_dev_role_t device_role)
```

Send a model publication message.

**Note** Before calling this function, the user needs to ensure that the model publication message (`esp_ble_mesh_model_pub_t::msg`) contains a valid message to be sent. And if users want to update the publishing message, this API should be called in `ESP_BLE_MESH_MODEL_PUBLISH_UPDATE_EVT` with the message updated.

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

Parameters
- **[in]** `model`: Mesh (client) Model publishing the message.
- **[in]** `opcode`: Message opcode.
- **[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`.

```c
esp_err_t esp_ble_mesh_server_model_update_state(esp_ble_mesh_model_t *model, esp_ble_mesh_server_state_type_t type, esp_ble_mesh_server_state_value_t *value)
```

Update a server model state value. If the model publication state is set properly (e.g. publish address is set to a valid address), it will publish corresponding status message.

**Note** Currently this API is used to update bound state value, not for all server model states.

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

Parameters
- **[in]** `model`: Server model which is going to update the state.
- **[in]** `type`: Server model state type.
- **[in]** `value`: Server model state value.

```c
esp_err_t esp_ble_mesh_node_local_reset()
```

Reset the provisioning procedure of the local BLE Mesh node.

**Note** All provisioning information in this node will be deleted and the node needs to be reprovisioned. The API function `esp_ble_mesh_node_prov_enable()` needs to be called to start a new provisioning procedure.

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

```c
esp_err_t esp_ble_mesh_provisioner_set_node_name(uint16_t index, const char *name)
```

This function is called to set the node (provisioned device) name.

**Note** index is obtained from the parameters of `ESP_BLE_MESH_PROVISIONER_PROV_COMPLETE_EVT`.

**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
Chapter 2. API

- [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: “” const esp_ble_mesh_node_t **entry = esp_ble_mesh_provisioner_get_node_table_entry(); for (int i = 0; i < CONFIG_BLE_MESH_MAX_PROV NODES; i++) { const esp_ble_mesh_node_t *node = entry[i]; if (node) { …… } } “”

**Return** Pointer to the start of the node table.

```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
esp_err_t esp_ble_mesh_provisioner_delete_node_with_addr(uint16_t unicast_addr)
This function is called to delete the provisioned node information with the node unicast address.

Return ESP_OK on success or error code otherwise.

Parameters
• [in] unicast_addr: Unicast address of the node

esp_err_t esp_ble_mesh_provisioner_add_local_app_key(const uint8_t app_key[16],
uint16_t net_idx, uint16_t app_idx)

This function is called to add a local AppKey for Provisioner.

Note app_key: If set to NULL, app_key will be generated internally. net_idx: Should be an existing one. app_idx: If it is going to be generated internally, it should be set to 0xFFFF, and the new app_idx will be reported via an event.

Return ESP_OK on success or error code otherwise.

Parameters
• [in] app_key: The app key to be set for the local BLE Mesh stack.
• [in] net_idx: The network key index.
• [in] app_idx: The app key index.

esp_err_t esp_ble_mesh_provisioner_update_local_app_key(const uint8_t app_key[16],
uint16_t net_idx, uint16_t app_idx)

This function is used to update a local AppKey for Provisioner.

Return ESP_OK on success or error code otherwise.

Parameters
• [in] app_key: Value of the AppKey.
• [in] net_idx: Corresponding NetKey Index.
• [in] app_idx: The AppKey Index

const uint8_t *esp_ble_mesh_provisioner_get_local_app_key(uint16_t net_idx, uint16_t app_idx)

This function is called by Provisioner to get the local app key value.

Return App key on success, or NULL on failure.

Parameters
• [in] app_idx: Application key index.

esp_err_t esp_ble_mesh_provisioner_bind_app_key_to_local_model(uint16_t element_addr,
uint16_t app_idx, uint16_t model_id,
uint16_t company_id)

This function is called by Provisioner to bind own model with proper app key.

Note company_id: If going to bind app_key with local vendor model, company_id should be set to 0xFFFF.

Return ESP_OK on success or error code otherwise.

Parameters
• [in] element_addr: Provisioner local element address
• [in] app_idx: Provisioner local appkey 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.

Function
```c
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.

Function
```c
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

Function
```c
const uint8_t *esp_ble_mesh_get_fast_prov_app_key(uint16_t net_idx, uint16_t app_idx)
```

This function is called to get fast provisioning application key.

Return  Application key on success, or NULL on failure.

Parameters
- [in] app_idx: Application key index.

Type Definitions
```c
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
- bt/esp_ble_mesh/api/core/include/esp_ble_mesh_provisioning_api.h

Functions
```c
esp_err_t esp_ble_mesh_provisioner_update_local_net_key(const uint8_t net_key[16],
                                                      uint16_t net_idx)
```

Register BLE Mesh provisioning callback.

Return  ESP_OK on success or error code otherwise.

Parameters
- [in] callback: Pointer to the callback function.

Function
```c
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.

Function
```c
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

Function
```c
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.

Return ESP_OK on success or error code otherwise.

Parameters
- `pub_key_x`: Unprovisioned device’s Public Key X
- `pub_key_y`: Unprovisioned device’s Public Key Y
- `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
- `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
- `string`: String input by device.

`esp_err_t esp_ble_mesh_set_unprovisioned_device_name (const char *name)`

Using this function, an unprovisioned device can set its own device name, which will be broadcasted in its advertising data.

Note This API applicable to PB-GATT mode only by setting the name to the scan response data, it doesn’t apply to PB-ADV mode.

Return ESP_OK on success or error code otherwise.

Parameters
- `name`: Unprovisioned device name

`esp_err_t esp_ble_mesh_provisioner_read_oob_pub_key (uint8_t link_idx, uint8_t pub_key_x[32], uint8_t pub_key_y[32])`

Provisioner inputs unprovisioned device’s oob public key.

Return ESP_OK on success or error code otherwise.

Parameters
- `link_idx`: The provisioning link index
- `pub_key_x`: Unprovisioned device’s Public Key X
- `pub_key_y`: Unprovisioned device’s Public Key Y

`esp_err_t esp_ble_mesh_provisioner_input_string (const char *string, uint8_t link_idx)`

Provide provisioning input OOB string.

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
- `string`: String input by Provisioner.
• [in] link_idx: The provisioning link index.

```
esp_err_t esp_ble_mesh_provisioner_input_number (uint32_t number, uint8_t link_idx)
```

Provide provisioning input OOB number.

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.

```
esp_err_t esp_ble_mesh_provisioner_prov_enable (esp_ble_mesh_prov_bearer_t bearers)
```

Enable one or more provisioning bearers.

Note PB-ADV: Enable BLE scan. PB-GATT: Initialize corresponding BLE Mesh Proxy info.

Return ESP_OK on success or error code otherwise.

Parameters
• [in] bearers: Bit-wise OR of provisioning bearers.

```
esp_err_t esp_ble_mesh_provisioner_prov_disable (esp_ble_mesh_prov_bearer_t bearers)
```

Disable one or more provisioning bearers.

Note PB-ADV: Disable BLE scan. PB-GATT: Break any existing BLE Mesh Provisioning connections.

Return ESP_OK on success or error code otherwise.

Parameters
• [in] bearers: Bit-wise OR of provisioning bearers.

```
esp_err_t esp_ble_mesh_provisioner_add_unprov_dev (esp_ble_mesh_unprov_dev_add_t *add_dev, esp_ble_mesh_dev_add_flag_t flags)
```

Add unprovisioned device info to the unprov_dev queue.

Return ESP_OK on success or error code otherwise.

Note: 1. Currently address type only supports public address and static random address.
2. 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.
3. 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.
4. 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.
2. Bearer must be equal to ESP_BLE_MESH_PROV_ADV or ESP_BLE_MESH_PROV_GATT, since Provisioner will start to provision a device immediately once this function is invoked. And the input bearer must be identical with the one within the parameters of the ESP_BLE_MESH_PROVISIONER_RECV_UNPROV_ADV_PKT_EVT event.
3. 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.
4. Recommend to use only one of the functions “esp_ble_mesh_provisioner_add_unprov_dev” and “esp_ble_mesh_provisioner_prov_device_with_addr” by a Provisioner.

**Parameters**

- `[in] uuid`: Device UUID of the unprovisioned device
- `[in] addr`: Device address of the unprovisioned device
- `[in] addr_type`: Device address type of the unprovisioned device
- `[in] bearer`: Provisioning bearer going to be used by Provisioner
- `[in] oob_info`: OOB info of the unprovisioned device
- `[in] unicast_addr`: Unicast address going to be allocated for the unprovisioned device

```c
esp_err_t esp_ble_mesh_provisioner_delete_dev(esp_ble_mesh_device_delete_t *del_dev)
```

Delete device from queue, and reset current provisioning link with the device.

**Note** If the device is in the queue, remove it from the queue; if the device is being provisioned, terminate the provisioning procedure. Either one of the device address or device UUID can be used as input.

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

**Parameters**

- `[in] del_dev`: Pointer to a struct containing the device information

```c
esp_err_t esp_ble_mesh_provisioner_set_dev_uuid_match(const uint8_t *match_val, uint8_t match_len, uint8_t offset, bool prov_after_match)
```

This function is called by Provisioner to set the part of the device UUID to be compared before starting to provision.

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

**Parameters**

- `[in] match_val`: Value to be compared with the part of the device UUID.
- `[in] match_len`: Length of the compared match value.
- `[in] offset`: Offset of the device UUID to be compared (based on zero).
• [in] prov_after_match: Flag used to indicate whether provisioner should start to provision the device immediately if the part of the UUID matches.

```c
esp_err_t esp_ble_mesh_provisioner_set_prov_data_info(esp_ble_mesh_prov_data_info_t *prov_data_info)
```
This function is called by Provisioner to set provisioning data information before starting to provision.

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

**Parameters**
- [in] prov_data_info: Pointer to a struct containing net_idx or flags or iv_index.

```c
esp_err_t esp_ble_mesh_provisioner_set_static_oob_value(const uint8_t *value, uint8_t length)
```
This function is called by Provisioner to set static oob value used for provisioning.

**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.

```c
esp_err_t esp_ble_mesh_provisioner_set_primary_elem_addr(uint16_t addr)
```
This function is called by Provisioner to set own Primary element address.

**Note** This API must be invoked when BLE Mesh initialization is completed successfully, and can be invoked before Provisioner functionality is enabled. Once this API is invoked successfully, the prov_unicast_addr value in the struct esp_ble_mesh_prov_t will be ignored, and Provisioner will use this address as its own primary element address. And if the unicast address going to assigned for the next unprovisioned device is smaller than the input address + element number of Provisioner, then the address for the next unprovisioned device will be recalculated internally.

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

**Parameters**
- [in] addr: Unicast address of the Primary element of Provisioner.

```c
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.

```c
esp_err_t esp_ble_mesh_set_fast_prov_action(esp_ble_mesh_fast_prov_action_t action)
```
This function is called to start/suspend/exit fast provisioning.

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

**Parameters**
- [in] action: fast provisioning action (i.e. enter, suspend, exit).

### Type Definitions

```c
typedef void (*esp_ble_mesh_prov_cb_t)(esp_ble_mesh_prov_cb_event_t event, esp_ble_mesh_prov_cb_param_t *param)
```
: event, event code of provisioning events; param, parameters of provisioning events

```c
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

• 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.
Chapter 2. API Reference

**esp_err_t esp_ble_mesh_proxy_client_add_filter_addr(esp_err_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(esp_err_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**

- bt/esp_ble_mesh/api/models/include/esp_ble_mesh_config_model_api.h

**Functions**

**esp_err_t esp_ble_mesh_register_config_client_callback(esp_ble_mesh_config_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.

**esp_err_t esp_ble_mesh_register_config_server_callback(esp_ble_mesh_config_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

```c
union esp_ble_mesh_cfg_client_get_state_t
```


### Public Members

```c
esp_ble_mesh_cfg_model_pub_get_t model_pub_get
```

For ESP_BLE_MESH_MODEL_OP_MODEL_PUB_GET.

```c
esp_ble_mesh_cfg_composition_data_get_t comp_data_get
```

For ESP_BLE_MESH_MODEL_OP_COMPOSITION_DATA_GET.

```c
esp_ble_mesh_cfg_sig_model_sub_get_t sig_model_sub_get
```

For ESP_BLE_MESH_MODEL_OP_SIG_MODEL_SUB_GET.

```c
esp_ble_mesh_cfg_vnd_model_sub_get_t vnd_model_sub_get
```

For ESP_BLE_MESH_MODEL_OP_VENDOR_MODEL_SUB_GET.

```c
esp_ble_mesh_cfg_app_key_get_t app_key_get
```

For ESP_BLE_MESH_MODEL_OP_APP_KEY_GET.

```c
esp_ble_mesh_cfg_node_identity_get_t node_identity_get
```

For ESP_BLE_MESH_MODEL_OP_NODE_IDENTITY_GET.

```c
esp_ble_mesh_cfg_sig_model_app_get_t sig_model_app_get
```

For ESP_BLE_MESH_MODEL_OP_SIG_MODEL_APP_GET.

```c
esp_ble_mesh_cfg_vnd_model_app_get_t vnd_model_app_get
```

For ESP_BLE_MESH_MODEL_OP_VENDOR_MODEL_APP_GET.
For ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_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 ADD ESP_BLE_MESH_MODEL_OP_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_MODEL_SUB_VIRTUAL_ADDR
ESP_BLE_MESH_MODEL_OP_NET_KEY_ADD ESP_BLE_MESH_MODEL_OP_APP_KEY_ADD
ESP_BLE_MESH_MODEL_OP_MODEL_APP_BIND ESP_BLE_MESH_MODEL_OP_NODE_RESET
ESP_BLE_MESH_MODEL_OP_FRIEND_SET ESP_BLE_MESH_MODEL_OP_HEARTBEAT_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_t default_ttl_set
For ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_SET

esp_ble_mesh_cfg_friend_set_t friend_set
For ESP_BLE_MESH_MODEL_OP_FRIEND_SET

esp_ble_mesh_cfg_gatt_proxy_set_t gatt_proxy_set
For ESP_BLE_MESH_MODEL_OP_GATT_PROXY_SET

esp_ble_mesh_cfg_relay_set_t relay_set
For ESP_BLE_MESH_MODEL_OP_RELAY_SET

esp_ble_mesh_cfg_net_key_add_t net_key_add
For ESP_BLE_MESH_MODEL_OP_NET_KEY_ADD

esp_ble_mesh_cfg_app_key_add_t app_key_add
For ESP_BLE_MESH_MODEL_OP_APP_KEY_ADD

esp_ble_mesh_cfg_model_app_bind_t model_app_bind
For ESP_BLE_MESH_MODEL_OP_APP_BIND

esp_ble_mesh_cfg_model_pub_set_t model_pub_set
For ESP_BLE_MESH_MODEL_OP_MODEL_PUB_SET

esp_ble_mesh_cfg_model_sub_add_t model_sub_add
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_ADD

esp_ble_mesh_cfg_model_sub_delete_t model_sub_delete
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_DELETE

esp_ble_mesh_cfg_model_sub_overwrite_t model_sub_overwrite
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_OVERWRITE

esp_ble_mesh_cfg_model_sub_va_add_t model_sub_va_add
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_ADD

esp_ble_mesh_cfg_model_sub_va_delete_t model_sub_va_delete
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_DELETE

esp_ble_mesh_cfg_model_sub_va_overwrite_t model_sub_va_overwrite
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_OVERWRITE
Chapter 2. API

```c
union esp_ble_mesh_cfg_client_common_cb_param_t
    #include <esp_ble_mesh_config_model_api.h> Configuration Client Model received message union.
```

### Public Members

```c
esp_ble_mesh_cfg_beacon_status_cb_t beacon_status
    The beacon status value

esp_ble_mesh_cfg_comp_data_status_cb_t comp_data_status
    The composition data status value

esp_ble_mesh_cfg_default_ttl_status_cb_t default_ttl_status
    The default_ttl status value

esp_ble_mesh_cfg_gatt_proxy_status_cb_t gatt_proxy_status
    The gatt_proxy status value

esp_ble_mesh_cfg_relay_status_cb_t relay_status
    The relay status value

esp_ble_mesh_cfg_model_pub_status_cb_t model_pub_status
    The model publication status value

esp_ble_mesh_cfg_model_sub_status_cb_t model_sub_status
    The model subscription status value

esp_ble_mesh_cfg_net_key_status_cb_t netkey_status
    The netkey status value

esp_ble_mesh_cfg_app_key_status_cb_t appkey_status
    The appkey status value
```
Chapter 2. API

```
estp_ble_mesh_cfg_mod_app_status_cb_t model_app_status
    The model app status value

estp_ble_mesh_cfg_friend_status_cb_t friend_status
    The friend status value

estp_ble_mesh_cfg_hb_pub_status_cb_t heartbeat_pub_status
    The heartbeat publication status value

estp_ble_mesh_cfg_hb_sub_status_cb_t heartbeat_sub_status
    The heartbeat subscription status value

estp_ble_mesh_cfg_net_trans_status_cb_t net_transmit_status
    The network transmit status value

estp_ble_mesh_cfg_model_sub_list_cb_t model_sub_list
    The model subscription list value

estp_ble_mesh_cfg_net_key_list_cb_t netkey_list
    The network key index list value

estp_ble_mesh_cfg_app_key_list_cb_t appkey_list
    The application key index list value

estp_ble_mesh_cfg_node_id_status_cb_t node_identity_status
    The node identity status value

estp_ble_mesh_cfg_model_app_list_cb_t model_app_list
    The model application key index list value

estp_ble_mesh_cfg_kr_phase_status_cb_t kr_phase_status
    The key refresh phase status value

estp_ble_mesh_cfg_lpn_pollto_status_cb_t lpn_timeout_status
    The low power node poll timeout status value

union esp_ble_mesh_cfg_server_state_change_t
#include <esp_ble_mesh_config_model_api.h> Configuration Server model state change value union.

Public Members

estp_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

estp_ble_mesh_state_change_cfg_model_sub_add_t mod_sub_add
    Config Model Subscription Add

estp_ble_mesh_state_change_cfg_model_sub_delete_t mod_sub_delete
    Config Model Subscription Delete

estp_ble_mesh_state_change_cfg_netkey_add_t netkey_add
    Config NetKey Add

estp_ble_mesh_state_change_cfg_netkey_update_t netkey_update
    Config NetKey Update

estp_ble_mesh_state_change_cfg_netkey_delete_t netkey_delete
    Config NetKey Delete

estp_ble_mesh_state_change_cfg_appkey_add_t appkey_add
    Config AppKey Add

estp_ble_mesh_state_change_cfg_appkey_update_t appkey_update
    Config AppKey Update

estp_ble_mesh_state_change_cfg_appkey_delete_t appkey_delete
    Config AppKey Delete
```
Chapter 2. API  參考

```c
#include <esp_ble_mesh_config_model_api.h>
```

Public Members

```c
struct esp_ble_mesh_cfg_srv
```

Configuration Server Model context

```c
Public Members
```

```c
esp_ble_mesh_model_t *model
```

Pointer to Configuration Server Model

```c
uint8_t net_transmit
```

Network Transmit state

```c
uint8_t relay
```

Relay Mode state

```c
uint8_t relay_retransmit
```

Relay Retransmit state

```c
uint8_t beacon
```

Secure Network Beacon state

```c
uint8_t gatt_proxy
```

GATT Proxy state

```c
uint8_t friend_state
```

Friend state

```c
uint8_t default_ttl
```

Default TTL

```c
struct k_delayed_work timer
```

Heartbeat Publication timer

```c
uint16_t dst
```

Destination address for Heartbeat messages

```c
uint16_t count
```

Number of Heartbeat messages to be sent

```c
uint16_t period
```

Period for sending Heartbeat messages

```c
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 App Key Get.

Public Members

uint16_t net_idx
The network key index

struct esp_ble_mesh_cfg_node_identity_get_t
Parameters of Config Node Identity Get.

Public Members

uint16_t net_idx
The network key index

struct esp_ble_mesh_cfg_sig_model_app_get_t
Parameters of Config SIG Model App Get.

Public Members

uint16_t element_addr
The element address

uint16_t model_id
The model id

struct esp_ble_mesh_cfg_vnd_model_app_get_t
Parameters of Config Vendor Model App Get.

Public Members

uint16_t element_addr
The element address

uint16_t model_id
The model id

uint16_t company_id
The company id, if not a vendor model, shall set to 0xFFFF

struct esp_ble_mesh_cfg_kr_phase_get_t
Parameters of Config Key Refresh Phase Get.
Public Members

`uint16_t net_idx`
The network key index

`struct esp_ble_mesh_cfg_lpn_polltimeout_get_t`
Parameters of Config Low Power Node PollTimeout Get.

Public Members

`uint16_t lpn_addr`
The unicast address of the Low Power node

`struct esp_ble_mesh_cfg_beacon_set_t`
Parameters of Config Beacon Set.

Public Members

`uint8_t beacon`
New Secure Network Beacon state

`struct esp_ble_mesh_cfg_default_ttl_set_t`
Parameters of Config Default TTL Set.

Public Members

`uint8_t friend_state`
The friend state value

`struct esp_ble_mesh_cfg_gatt_proxy_set_t`
Parameters of Config GATT Proxy Set.

Public Members

`uint8_t gatt_proxy`
The GATT Proxy state value

`struct esp_ble_mesh_cfg_relay_set_t`
Parameters of Config Relay Set.

Public Members

`uint8_t relay`
The relay value

`uint8_t relay_retransmit`
The relay retransmit value

`struct esp_ble_mesh_cfg_net_key_add_t`
Parameters of Config NetKey Add.
Chapter 2. API}

**Public Members**

```c
uint16_t net_idx
```

The network key index

```c
uint8_t net_key[16]
```

The network key value

```c
struct esp_ble_mesh_cfg_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
struct esp_ble_mesh_cfg_model_app_bind_t
```

Parameters of Config Model App Bind.

**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_model_pub_set_t
```

Parameters of Config Model Publication Set.

**Public Members**

```c
uint16_t element_addr
```

The element address

```c
uint16_t publish_addr
```

Value of the publish address

```c
uint16_t publish_app_idx
```

Index of the application idx

```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
uint8_t **publish_retransmit**  
Number of retransmissions and number of 50-millisecond steps between retransmissions

uint16_t model_id  
The model id

uint16_t company_id  
The company id, if not a vendor model, shall set to 0xFFFF

**struct esp_ble_mesh_cfg_model_sub_add_t**  
Parameters of Config Model Subscription Add.

**Public Members**

uint16_t element_addr  
The element address

uint16_t sub_addr  
The address to be added to the Subscription List

uint16_t model_id  
The model id

uint16_t company_id  
The company id, if not a vendor model, shall set to 0xFFFF

**struct esp_ble_mesh_cfg_model_sub_delete_t**  
Parameters of Config Model Subscription Delete.

**Public Members**

uint16_t element_addr  
The element address

uint16_t sub_addr  
The address to be removed from the Subscription List

uint16_t model_id  
The model id

uint16_t company_id  
The company id, if not a vendor model, shall set to 0xFFFF

**struct esp_ble_mesh_cfg_model_sub_overwrite_t**  
Parameters of Config Model Subscription Overwrite.

**Public Members**

uint16_t element_addr  
The element address

uint16_t sub_addr  
The address to be added to the Subscription List

uint16_t model_id  
The model id

uint16_t company_id  
The company id, if not a vendor model, shall set to 0xFFFF

**struct esp_ble_mesh_cfg_model_sub_va_add_t**  
Parameters of Config Model Subscription Virtual Address Add.
Chapter 2. API reference

Public Members

```c
uint16_t element_addr
    The element address
```n

```c
uint8_t label_uuid[16]
    The Label UUID of the virtual address to be added to the Subscription List
```n

```c
uint16_t model_id
    The model id
```n

```c
uint16_t company_id
    The company id, if not a vendor model, shall set to 0xFFFF
```n

```c
struct esp_ble_mesh_cfg_model_sub_va_delete_t
Parameters of Config Model Subscription Virtual Address Delete.
```n

Public Members

```c
uint16_t element_addr
    The element address
```n

```c
uint8_t label_uuid[16]
    The Label UUID of the virtual address to be removed from the Subscription List
```n

```c
uint16_t model_id
    The model id
```n

```c
uint16_t company_id
    The company id, if not a vendor model, shall set to 0xFFFF
```n

```c
struct esp_ble_mesh_cfg_model_sub_va_overwrite_t
Parameters of Config Model Subscription Virtual Address Overwrite.
```n

Public Members

```c
uint16_t element_addr
    The element address
```n

```c
uint8_t label_uuid[16]
    The Label UUID of the virtual address to be added to the Subscription List
```n

```c
uint16_t model_id
    The model id
```n

```c
uint16_t company_id
    The company id, if not a vendor model, shall set to 0xFFFF
```n

```c
struct esp_ble_mesh_cfg_model_pub_va_set_t
Parameters of Config Model Publication Virtual Address Set.
```n

Public Members

```c
uint16_t element_addr
    The element address
```n

```c
uint8_t label_uuid[16]
    Value of the Label UUID publish address
```n

```c
uint16_t publish_app_idx
    Index of the application key
```n
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
The app key value

```c
uint8_t app_key[16]
```

**struct esp_ble_mesh_cfg_app_key_delete_t**
Parameters of Config AppKey Delete.

**Public Members**

```c
uint16_t net_idx
   The network key index
uint16_t app_idx
   The app key index
```

**struct esp_ble_mesh_cfg_node_identity_set_t**
Parameters of Config Node Identity Set.

**Public Members**

```c
uint16_t net_idx
   The network key index
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
uint16_t model_app_idx
   Index of the app key to bind with the model
uint16_t model_id
   The model id
uint16_t company_id
   The company id, if not a vendor model, shall set to 0xFFFF
```

**struct esp_ble_mesh_cfg_kr_phase_set_t**
Parameters of Config Key Refresh Phase Set.

**Public Members**

```c
uint16_t net_idx
   The network key index
uint8_t transition
   New Key Refresh Phase Transition
```

**struct esp_ble_mesh_cfg_net_transmit_set_t**
Parameters of Config Network Transmit Set.

**Public Members**

```c
uint16_t net_idx
   The network key index
```
Chapter 2. API

Public Members

uint8_t net_transmit
Network Transmit State

struct esp_ble_mesh_cfg_heartbeat_pub_set_t
Parameters of Config Model Heartbeat Publication Set.

Public Members

uint16_t dst
Destination address for Heartbeat messages

uint8_t count
Number of Heartbeat messages to be sent

uint8_t period
Period for sending Heartbeat messages

uint8_t ttl
TTL to be used when sending Heartbeat messages

uint16_t feature
Bit field indicating features that trigger Heartbeat messages when changed

uint16_t net_idx
NetKey Index

struct esp_ble_mesh_cfg_heartbeat_sub_set_t
Parameters of Config Model Heartbeat Subscription Set.

Public Members

uint16_t src
Source address for Heartbeat messages

uint16_t dst
Destination address for Heartbeat messages

uint8_t period
Period for receiving Heartbeat messages

struct esp_ble_mesh_cfg_beacon_status_cb_t
Parameter of Config Beacon Status

Public Members

uint8_t beacon
Secure Network Beacon state value

struct esp_ble_mesh_cfg_comp_data_status_cb_t
Parameters of Config Composition Data Status

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
```c
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
StatusCode 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
Chapter 2. API 参考

uint16_t model_id
  Model ID

struct esp_ble_mesh_cfg_friend_status_cb_t
  Parameter of Config Friend Status

  Public Members

  uint8_t friend_state
    Friend state value

struct esp_ble_mesh_cfg_hb_pub_status_cb_t
  Parameters of Config Heartbeat Publication Status

  Public Members

  uint8_t status
    Status Code for the request message
  uint16_t dst
    Destination address for Heartbeat messages
  uint8_t count
    Number of Heartbeat messages remaining to be sent
  uint8_t period
    Period for sending Heartbeat messages
  uint8_t ttl
    TTL to be used when sending Heartbeat messages
  uint16_t features
    Features that trigger Heartbeat messages when changed
  uint16_t net_idx
    Index of the NetKey

struct esp_ble_mesh_cfg_hb_sub_status_cb_t
  Parameters of Config Heartbeat Subscription Status

  Public Members

  uint8_t status
    Status Code for the request message
  uint16_t src
    Source address for Heartbeat messages
  uint16_t dst
    Destination address for Heartbeat messages
  uint8_t period
    Remaining Period for processing Heartbeat messages
  uint8_t count
    Number of Heartbeat messages received
  uint8_t min_hops
    Minimum hops when receiving Heartbeat messages
  uint8_t max_hops
    Maximum hops when receiving Heartbeat messages
struct esp_ble_mesh_cfg_net_trans_status_cb_t
Parameters of Config Network Transmit Status

Public Members

uint8_t net_trans_count : 3
    Number of transmissions for each Network PDU originating from the node

uint8_t net_trans_step : 5
    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
    StatusCode for the request message

uint16_t element_addr
    Address of the element

uint16_t company_id
    Company ID

uint16_t model_id
    Model ID

struct net_buf_simple *sub_addr
    A block of all addresses from the Subscription List

struct esp_ble_mesh_cfg_net_key_list_cb_t
Parameters 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
    StatusCode 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

*params
The client common parameters

*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_mod_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_mod_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_meshCfg_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

typedef struct esp_ble_mesh_cfg_srv esp_ble_mesh_cfg_srv_t
Configuration Server Model context

typedef void (*esp_ble_mesh_cfg_client_cb_t) (esp_ble_mesh_cfg_client_cb_event_t event,
                                           esp_ble_mesh_cfg_client_cb_param_t *param)

Bluetooth Mesh Config Client and Server Model functions.

Configuration Client Model callback function type

Parameters
• event: Event type
• param: Pointer to callback parameter

typedef void (*esp_ble_mesh_cfg_server_cb_t) (esp_ble_mesh_cfg_server_cb_event_t event,
                                           esp_ble_mesh_cfg_server_cb_param_t *param)

Configuration Server Model callback function type.

Parameters
• event: Event type
• param: Pointer to callback parameter
Enumerations

enum esp_ble_mesh_cfg_client_cb_event_t

This enum value is the event of Configuration Client Model

Values:

ESP_BLE_MESH_CFG_CLIENT_GET_STATE_EVT
ESP_BLE_MESH_CFG_CLIENT_SET_STATE_EVT
ESP_BLE_MESH_CFG_CLIENT_PUBLISH_EVT
ESP_BLE_MESH_CFG_CLIENT_TIMEOUT_EVT
ESP_BLE_MESH_CFG_CLIENT_EVT_MAX

enum esp_ble_mesh_cfg_server_cb_event_t

This enum value is the event of Configuration Server model

Values:

ESP_BLE_MESH_CFG_SERVER_STATE_CHANGE_EVT
ESP_BLE_MESH_CFG_SERVER_EVT_MAX

Health Client/Server Models

Header File

- bt/esp_ble_mesh/api/models/include/esp_ble_mesh_generic_model_api.h

Functions

esp_err_t esp_ble_mesh_register_generic_client_callback(esp_ble_mesh_generic_client_cb_t callback)

Register BLE Mesh Generic Client Model callback.

Return ESP_OK on success or error code otherwise.

Parameters

- [in] callback: Pointer to the callback function.

esp_err_t esp_ble_mesh_generic_client_get_state(esp_ble_mesh_client_common_param_t *params,
                                            esp_ble_mesh_generic_client_get_state_t *get_state)

Get the value of Generic Server Model states using the Generic Client Model get messages.

Note If you want to find the opcodes and corresponding meanings accepted by this API, please refer to esp_ble_mesh_generic_message_opcode_t in esp_ble_mesh_defs.h

Return ESP_OK on success or error code otherwise.

Parameters

- [in] get_state: Pointer to generic get message value. Shall not be set to NULL.

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.
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

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

esp_ble_mesh_gen_manufacturer_property_set_t manufacturer_property_set
For ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET &
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET_UNACK

union 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
Chapter 2. API

```c
union esp_ble_mesh_gen_admin_property_status_cb_t
    admin_property_status
    ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_STATUS

union esp_ble_mesh_gen_manufacturer_properties_status_cb_t
    manufacturer_properties_status
    ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTIES_STATUS

union esp_ble_mesh_gen_manufacturer_property_status_cb_t
    manufacturer_property_status
    ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURERPROPERTY_STATUS

union 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

union esp_ble_mesh_state_change_gen_onoff_set_t
    onoff_set
    ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_SET
    Generic OnOff Set

union esp_ble_mesh_state_change_gen_level_set_t
    level_set
    ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_SET
    Generic Level Set

union esp_ble_mesh_state_change_gen_delta_set_t
    delta_set
    ESP_BLE_MESH_MODEL_OP_GEN_DELTA_SET
    Generic Delta Set

union esp_ble_mesh_state_change_gen_move_set_t
    move_set
    ESP_BLE_MESH_MODEL_OP_GEN_MOVE_SET
    Generic Move Set

union esp_ble_mesh_state_change_gen_def_trans_time_set_t
    def_trans_time_set
    ESP_BLE_MESH_MODEL_OP_GEN_DEFAULT_TRANS_TIME_SET
    Generic Default Transition Time Set

union esp_ble_mesh_state_change_gen_onpowerup_set_t
    onpowerup_set
    ESP_BLE_MESH_MODEL_OP_GEN_ONPOWER_UP_SET
    Generic OnPowerUp Set

union esp_ble_mesh_state_change_gen_power_level_set_t
    power_level_set
    ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_SET
    Generic Power Level Set

union esp_ble_mesh_state_change_gen_power_default_set_t
    power_default_set
    ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_SET
    Generic Power Default Set

union esp_ble_mesh_state_change_gen_power_range_set_t
    power_range_set
    ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_SET
    Generic Power Range Set

union esp_ble_mesh_state_change_gen_loc_global_set_t
    loc_global_set
    ESP_BLE_MESH_MODEL_OP_GEN_LOC_GLOBAL_SET
    Generic Location Global Set

union esp_ble_mesh_state_change_gen_loc_local_set_t
    loc_local_set
    ESP_BLE_MESH_MODEL_OP_GEN_LOC_LOCAL_SET
    Generic Location Local Set

union esp_ble_mesh_state_change_gen_user_property_set_t
    user_property_set
    ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_SET
    Generic User Property Set

union esp_ble_mesh_state_change_gen_admin_property_set_t
    admin_property_set
    ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_SET
    Generic Admin Property Set

union esp_ble_mesh_state_change_gen_manu_property_set_t
    manu_property_set
    ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_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

union esp_ble_mesh_server_recv_gen_user_property_get_t
    user_property
    ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_GET
    Generic User Property Get
```
# Chapter 2. API

```c
#include <esp_ble_mesh_generic_model_api.h>
```

**Generic Server Model received set message union.**

## Public Members

```c
generic_admin_property_get_t admin_property
```

Generic Admin Property Get

```c
generic_manufacturer_property_get_t manu_property
```

Generic Manufacturer Property Get

```c
generic_client_properties_get_t client_properties
```

Generic Client Properties Get

### union esp_ble_mesh_generic_server_recv_set_msg_t

#include <esp_ble_mesh_generic_model_api.h> Generic Server Model received set message union.

## Public Members

```c
generic_onoff_set_t onoff
```

Generic OnOff Set/Generic OnOff Set Unack

```c
generic_level_set_t level
```

Generic Level Set/Generic Level Set Unack

```c
generic_delta_set_t delta
```

Generic Delta Set/Generic Delta Set Unack

```c
generic_move_set_t move
```

Generic Move Set/Generic Move Set Unack

```c
def_trans_time_set_t def_trans_time
```

Generic Default Transition Time Set/Generic Default Transition Time Set Unack

```c
donpowerup_set_t onpowerup
```

Generic OnPowerUp Set/Generic OnPowerUp Set Unack

```c
generic_power_level_set_t power_level
```

Generic Power Level Set/Generic Power Level Set Unack

```c
generic_power_default_set_t power_default
```

Generic Power Default Set/Generic Power Default Set Unack

```c
generic_power_range_set_t power_range
```

Generic Power Range Set/Generic Power Range Set Unack

```c
generic_location_global_set_t location_global
```

Generic Location Global Set/Generic Location Global Set Unack

```c
generic_location_local_set_t location_local
```

Generic Location Local Set/Generic Location Local Set Unack

```c
generic_user_property_set_t user_property
```

Generic User Property Set/Generic User Property Set Unack

```c
generic_admin_property_set_t admin_property
```

Generic Admin Property Set/Generic Admin Property Set Unack

```c
generic_manufacturer_property_set_t manu_property
```

Generic Manufacturer Property Set/Generic Manufacturer Property Set Unack

### union esp_ble_mesh_generic_server_cb_value_t

#include <esp_ble_mesh_generic_model_api.h> Generic Server Model callback value union.

## Public Members

```c
generic_server_state_change_t state_change
```
structures

\textbf{Structures}

\textbf{struct esp_ble_mesh_gen_onoff_set_t}

Bluetooth Mesh Generic Client Model Get and Set parameters structure.

Parameters of Generic OnOff Set.

\textbf{Public Members}

\begin{itemize}
    \item \textbf{bool op\_en}
        Indicate if optional parameters are included
    \item \textbf{uint8\_t onoff}
        Target value of Generic OnOff state
    \item \textbf{uint8\_t tid}
        Transaction ID
    \item \textbf{uint8\_t trans\_time}
        Time to complete state transition (optional)
    \item \textbf{uint8\_t delay}
        Indicate message execution delay (C.1)
\end{itemize}

\textbf{struct esp_ble_mesh_gen_level_set_t}

Parameters of Generic Level Set.

\textbf{Public Members}

\begin{itemize}
    \item \textbf{bool op\_en}
        Indicate if optional parameters are included
    \item \textbf{int16\_t level}
        Target value of Generic Level state
    \item \textbf{uint8\_t tid}
        Transaction ID
    \item \textbf{uint8\_t trans\_time}
        Time to complete state transition (optional)
    \item \textbf{uint8\_t delay}
        Indicate message execution delay (C.1)
\end{itemize}

\textbf{struct esp_ble_mesh_gen_delta_set_t}

Parameters of Generic Delta Set.

\textbf{Public Members}

\begin{itemize}
    \item \textbf{bool op\_en}
        Indicate if optional parameters are included
    \item \textbf{int32\_t level}
        Delta change of Generic Level state
    \item \textbf{uint8\_t tid}
        Transaction ID
    \item \textbf{uint8\_t trans\_time}
        Time to complete state transition (optional)
\end{itemize}
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.
Chapter 2. API 参考

Public Members

```
uint16_t power
The value of the Generic Power Default state
```

```
struct esp_ble_mesh_gen_power_range_set_t
Parameters of Generic Power Range Set.
```

Public Members

```
uint16_t range_min
Value of Range Min field of Generic Power Range state
```

```
uint16_t range_max
Value of Range Max field of Generic Power Range state
```

```
struct esp_ble_mesh_gen_loc_global_set_t
Parameters of Generic Location Global Set.
```

Public Members

```
int32_t global_latitude
Global Coordinates (Latitude)
```

```
int32_t global_longitude
Global Coordinates (Longitude)
```

```
int16_t global_altitude
Global Altitude
```

```
struct esp_ble_mesh_gen_loc_local_set_t
Parameters of Generic Location Local Set.
```

Public Members

```
int16_t local_north
Local Coordinates (North)
```

```
int16_t local_east
Local Coordinates (East)
```

```
int16_t local_altitude
Local Altitude
```

```
uint8_t floor_number
Floor Number
```

```
uint16_t uncertainty
Uncertainty
```

```
struct esp_ble_mesh_gen_user_property_get_t
Parameter of Generic User Property Get.
```

Public Members

```
uint16_t property_id
Property ID identifying a Generic User Property
```

```
struct esp_ble_mesh_gen_user_property_set_t
Parameters of Generic User Property Set.
```

Espressif Systems 311
Release v4.3-dev-1561-g357a277603
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Public Members

```c
uint16_t property_id
    Property ID identifying a Generic User Property
```

```c
struct net_buf_simple *property_value
    Raw value for the User Property
```

```c
struct esp_ble_mesh_gen_admin_property_get_t
    Parameter of Generic Admin Property Get.
```

Public Members

```c
uint16_t property_id
    Property ID identifying a Generic Admin Property
```

```c
struct esp_ble_mesh_gen_admin_property_set_t
    Parameters of Generic Admin Property Set.
```

Public Members

```c
uint16_t property_id
    Property ID identifying a Generic Admin Property
uint8_t user_access
    Enumeration indicating user access
```

```c
struct net_buf_simple *property_value
    Raw value for the Admin Property
```

```c
struct esp_ble_mesh_gen_manufacturer_property_get_t
    Parameter of Generic Manufacturer Property Get.
```

Public Members

```c
uint16_t property_id
    Property ID identifying a Generic Manufacturer Property
```

```c
struct esp_ble_mesh_gen_manufacturer_property_set_t
    Parameters of Generic Manufacturer Property Set.
```

Public Members

```c
uint16_t property_id
    Property ID identifying a Generic Manufacturer Property
uint8_t user_access
    Enumeration indicating user access
```

```c
struct esp_ble_mesh_gen_client_properties_get_t
    Parameter of Generic Client Properties Get.
```

Public Members

```c
uint16_t property_id
    A starting Client Property ID present within an element
```
**struct esp_ble_mesh_gen_onoff_status_cb_t**


**Public Members**

- `bool op_en`
  - Indicate if optional parameters are included
- `uint8_t present_onoff`
  - Current value of Generic OnOff state
- `uint8_t target_onoff`
  - Target value of Generic OnOff state (optional)
- `uint8_t remain_time`
  - Time to complete state transition (C.1)

**struct esp_ble_mesh_gen_level_status_cb_t**

Parameters of Generic Level Status.

**Public Members**

- `bool op_en`
  - Indicate if optional parameters are included
- `int16_t present_level`
  - Current value of Generic Level state
- `int16_t target_level`
  - Target value of the Generic Level state (optional)
- `uint8_t remain_time`
  - Time to complete state transition (C.1)

**struct esp_ble_mesh_gen_def_trans_time_status_cb_t**

Parameter of Generic Default Transition Time Status.

**Public Members**

- `uint8_t trans_time`
  - The value of the Generic Default Transition Time state

**struct esp_ble_mesh_gen_onpowerup_status_cb_t**


**Public Members**

- `uint8_t onpowerup`
  - The value of the Generic OnPowerUp state

**struct esp_ble_mesh_gen_power_level_status_cb_t**

Parameters of Generic Power Level Status.

**Public Members**

- `bool op_en`
  - Indicate if optional parameters are included
uint16_t `present_power`
  Current value of Generic Power Actual state

uint16_t `target_power`
  Target value of Generic Power Actual state (optional)

uint8_t `remain_time`
  Time to complete state transition (C.1)

`struct esp_ble_mesh_gen_power_last_status_cb_t`
  Parameter of Generic Power Last Status.

**Public Members**

uint16_t `power`
  The value of the Generic Power Last state

`struct esp_ble_mesh_gen_power_default_status_cb_t`
  Parameter of Generic Power Default Status.

**Public Members**

uint16_t `power`
  The value of the Generic Default Last state

`struct esp_ble_mesh_gen_power_range_status_cb_t`
  Parameters of Generic Power Range Status.

**Public Members**

uint8_t `status_code`
  Status Code for the request message

uint16_t `range_min`
  Value of Range Min field of Generic Power Range state

uint16_t `range_max`
  Value of Range Max field of Generic Power Range state

`struct esp_ble_mesh_gen_battery_status_cb_t`
  Parameters of Generic Battery Status.

**Public Members**

u32_t `battery_level` : 8
  Value of Generic Battery Level state

u32_t `time_to_discharge` : 24
  Value of Generic Battery Time to Discharge state

u32_t `time_to_charge` : 24
  Value of Generic Battery Time to Charge state

u32_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)

int16_t global_altitude
Global Altitude

struct esp_ble_mesh_gen_loc_local_status_cb_t
Parameters of Generic Location Local Status.

Public Members

int16_t local_north
Local Coordinates (North)

int16_t local_east
Local Coordinates (East)

int16_t local_altitude
Local Altitude

uint8_t floor_number
Floor Number

uint16_t uncertainty
Uncertainty

struct esp_ble_mesh_gen_user_properties_status_cb_t
Parameter of Generic User Properties Status.

Public Members

struct net_buf_simple *property_ids
Buffer contains a sequence of N User Property IDs

struct esp_ble_mesh_gen_user_property_status_cb_t
Parameters of Generic User Property Status.

Public Members

bool op_en
Indicate if optional parameters are included

uint16_t property_id
Property ID identifying a Generic User Property

uint8_t user_access
Enumeration indicating user access (optional)

struct net_buf_simple *property_value
Raw value for the User Property (C.1)

struct esp_ble_mesh_gen_admin_properties_status_cb_t
Parameter of Generic Admin Properties Status.
Public Members

```c
struct net_buf_simple *property_ids
    Buffer contains a sequence of N Admin Property IDs
```

```c
struct esp_ble_mesh_gen_admin_property_status_cb_t
    Parameters of Generic Admin Property Status.
```

```c
bool op_en
    Indicate if optional parameters are included
```

```c
uint16_t property_id
    Property ID identifying a Generic Admin Property
```

```c
uint8_t user_access
    Enumeration indicating user access (optional)
```

```c
struct net_buf_simple *property_value
    Raw value for the Admin Property (C.1)
```

```c
struct esp_ble_mesh_gen_manufacturer_properties_status_cb_t
    Parameter of Generic Manufacturer Properties Status.
```

Public Members

```c
struct net_buf_simple *property_ids
    Buffer contains a sequence of N Manufacturer Property IDs
```

```c
struct esp_ble_mesh_gen_manufacturer_property_status_cb_t
    Parameters of Generic Manufacturer Property Status.
```

```c
bool op_en
    Indicate if optional parameters are included
```

```c
uint16_t property_id
    Property ID identifying a Generic Manufacturer Property
```

```c
uint8_t user_access
    Enumeration indicating user access (optional)
```

```c
struct net_buf_simple *property_value
    Raw value for the Manufacturer Property (C.1)
```

```c
struct esp_ble_mesh_gen_client_properties_status_cb_t
    Parameter of Generic Client Properties Status.
```

Public Members

```c
struct net_buf_simple *property_ids
    Buffer contains a sequence of N Client Property IDs
```

```c
struct esp_ble_mesh_generic_client_cb_param_t
    Generic Client Model callback parameters
```
Public Members

int error_code
Appropriate error code

`exp_ble_mesh_client_common_param_t *params`
The client common parameters.

`exp_ble_mesh_gen_client_status_cb_t status_cb`
The generic status message callback values

```c
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

```c
struct esp_ble_mesh_gen_onoff_srv_t
```
User data of Generic OnOff Server Model

Public Members

```c
exp_ble_mesh_model_t *model
```
Pointer to the Generic OnOff Server Model. Initialized internally.

```c
exp_ble_mesh_server_rsp_ctrl_t rsp_ctrl
```
Response control of the server model received messages

```c
exp_ble_mesh_gen_onoff_state_t state
```
Parameters of the Generic OnOff state

```c
exp_ble_mesh_last_msg_info_t last
```
Parameters of the last received set message

```c
exp_ble_mesh_state_transition_t transition
```
Parameters of state transition

```c
struct esp_ble_mesh_gen_level_state_t
```
Parameters of Generic Level state

Public Members

int16_t level
The present value of the Generic Level state

int16_t target_level
The target value of the Generic Level state

int16_t last_level
When a new transaction starts, level should be set to last_last, and use “level + incoming delta” to calculate the target level. In another word, “last_level” is used to record “level” of the last transaction, and “last_delta” is used to record the previously received delta_level value. The last value of the Generic Level state

int32_t last_delta
The last delta change of the Generic Level state
bool move_start
   Indicate if the transition of the Generic Level state has been started

bool positive
   Indicate if the transition is positive or negative

struct esp_ble_mesh_gen_level_srv_t
   User data of Generic Level Server Model

Public Members

   esp_ble_mesh_model_t *model
       Pointer to the Generic Level Server Model. Initialized internally.

   esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
       Response control of the server model received messages

   esp_ble_mesh_gen_level_state_t *state
       Parameters of the Generic Level state

   esp_ble_mesh_last_msg_info_t last
       Parameters of the last received set message

   esp_ble_mesh_state_transition_t *transition
       Parameters of state transition

   int32_t ttt_delta_level
       Delta change value of level state transition

struct esp_ble_mesh_gen_def_trans_time_state_t
   Parameter of Generic Default Transition Time state

Public Members

   uint8_t trans_time
       The value of the Generic Default Transition Time state

struct esp_ble_mesh_gen_def_trans_time_srv_t
   User data of Generic Default Transition Time Server Model

Public Members

   esp_ble_mesh_model_t *model
       Pointer to the Generic Default Transition Time Server Model. Initialized internally.

   esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
       Response control of the server model received messages

   esp_ble_mesh_gen_def_trans_time_state_t *state
       Parameters of the Generic Default Transition Time state

struct esp_ble_mesh_gen_onpowerup_state_t
   Parameter of Generic OnPowerUp state

Public Members

   uint8_t onpowerup
       The value of the Generic OnPowerUp state

struct esp_ble_mesh_gen_power_onoff_srv_t
   User data of Generic Power OnOff Server Model
Public Members

`esp_ble_mesh_model_t *model`
- Pointer to the Generic Power OnOff Server Model. Initialized internally.

`esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl`
- Response control of the server model received messages

`esp_ble_mesh_gen_onpowerup_state_t *state`
- Parameters of the Generic OnPowerUp state

`struct esp_ble_mesh_gen_power_onoff_setup_srv_t`
- User data of Generic Power OnOff Setup Server Model

Public Members

`esp_ble_mesh_model_t *model`
- Pointer to the Generic Power OnOff Setup Server Model. Initialized internally.

`esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl`
- Response control of the server model received messages

`esp_ble_mesh_gen_onpowerup_state_t *state`
- Parameters of the Generic OnPowerUp state

`struct esp_ble_mesh_gen_power_onoff_setup_srv_t`
- User data of Generic Power OnOff Setup Server Model

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
Chapter 2. API 参考

```c
esp_ble_mesh_gen_power_level_state_t *state
Parameters of the Generic Power Level state

esp_ble_mesh_last_msg_info_t last
Parameters of the last received set message

esp_ble_mesh_state_transition_t transition
Parameters of state transition

int32_t tt_delta_level
Delta change value of level state transition
```

```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.

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_battery_state_t
Parameters of Generic Battery state
```

**Public Members**

```c
uint32_t battery_level : 8
The value of the Generic Battery Level state

uint32_t time_to_discharge : 24
The value of the Generic Battery Time to Discharge state

uint32_t time_to_charge : 24
The value of the Generic Battery Time to Charge state

uint32_t battery_flags : 8
The value of the Generic Battery Flags state
```

```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.

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_location_state_t
Parameters of Generic Location state
```
Public Members

int32_t *global_latitude
The value of the Global Latitude field

int32_t *global_longitude
The value of the Global Longitude field

int16_t *global_altitude
The value of the Global Altitude field

int16_t *local_north
The value of the Local North field

int16_t *local_east
The value of the Local East field

int16_t *local_altitude
The value of the Local Altitude field

uint8_t *floor_number
The value of the Floor Number field

uint16_t *uncertainty
The value of the Uncertainty field

struct esp_ble_mesh_gen_location_srv_t
User data of Generic Location Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Generic Location Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages

esp_ble_mesh_gen_location_state_t *state
Parameters of the Generic Location state

struct esp_ble_mesh_gen_location_setup_srv_t
User data of Generic Location Setup Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Generic Location Setup Server Model. Initialized internally.

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
Chapter 2. API 参考

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

dale
    *model
    Pointer to the Generic User Property Server Model. Initialized internally.

dale
    *rsp_ctrl
    Response control of the server model received messages

uint8_t property_count
    Generic User Property count

dale
    *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

dale
    *model
    Pointer to the Generic Admin Property Server Model. Initialized internally.

dale
    *rsp_ctrl
    Response control of the server model received messages

uint8_t property_count
    Generic Admin Property count

dale
    *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

dale
    *model
    Pointer to the Generic Manufacturer Property Server Model. Initialized internally.

dale
    *rsp_ctrl
    Response control of the server model received messages

uint8_t property_count
    Generic Manufacturer Property count

dale
    *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

*model
Pointer to the Generic Client Property Server Model. Initialized internally.

rsp_ctrl
Response control of the server model received messages

id_count
Generic Client Property ID count

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

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

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

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

level
The value of Generic Level state

struct esp_ble_mesh_state_change_gen_def_trans_time_set_t  
Parameter of Generic Default Transition Time Set state change event

Public Members

trans_time
The value of Generic Default Transition Time state
**struct esp_ble_mesh_state_change_gen_onpowerup_set_t**  
Parameter of Generic OnPowerUp Set state change event

**Public Members**

```
uint8_t onpowerup  
```

The value of Generic OnPowerUp state

**struct esp_ble_mesh_state_change_gen_power_level_set_t**  
Parameter of Generic Power Level Set state change event

**Public Members**

```
uint16_t power  
```

The value of Generic Power Actual state

**struct esp_ble_mesh_state_change_gen_power_default_set_t**  
Parameter of Generic Power Default Set state change event

**Public Members**

```
uint16_t power  
```

The value of Generic Power Default state

**struct esp_ble_mesh_state_change_gen_power_range_set_t**  
Parameters of Generic Power Range Set state change event

**Public Members**

```
uint16_t range_min  
```

The minimum value of Generic Power Range state

```
uint16_t range_max  
```

The maximum value of Generic Power Range state

**struct esp_ble_mesh_state_change_gen_loc_global_set_t**  
Parameters of Generic Location Global Set state change event

**Public Members**

```
int32_t latitude  
```

The Global Latitude value of Generic Location state

```
int32_t longitude  
```

The Global Longitude value of Generic Location state

```
int16_t altitude  
```

The Global Altitude value of Generic Location state

**struct esp_ble_mesh_state_change_gen_loc_local_set_t**  
Parameters of Generic Location Local Set state change event

**Public Members**

```
int16_t north  
```

The Local North value of Generic Location state
int16_t east
    The Local East value of Generic Location state

int16_t altitude
    The Local Altitude value of Generic Location state

uint8_t floor_number
    The Floor Number value of Generic Location state

uint16_t uncertainty
    The Uncertainty value of Generic Location state

struct esp_ble_mesh_state_change_gen_user_property_set_t
    Parameters of Generic User Property Set state change event

    Public Members

    uint16_t id
        The property id of Generic User Property state

    struct net_buf_simple *value
        The property value of Generic User Property state

struct esp_ble_mesh_state_change_gen_admin_property_set_t
    Parameters of Generic Admin Property Set state change event

    Public Members

    uint16_t id
        The property id of Generic Admin Property state

    uint8_t access
        The property access of Generic Admin Property state

    struct net_buf_simple *value
        The property value of Generic Admin Property state

struct esp_ble_mesh_state_change_gen_manu_property_set_t
    Parameters of Generic Manufacturer Property Set state change event

    Public Members

    uint16_t id
        The property id of Generic Manufacturer Property state

    uint8_t access
        The property value of Generic Manufacturer Property state

struct esp_ble_mesh_server_recv_gen_user_property_get_t
    Context of the received Generic User Property Get message

    Public Members

    uint16_t property_id
        Property ID identifying a Generic User Property

struct esp_ble_mesh_server_recv_gen_admin_property_get_t
    Context of the received Generic Admin Property Get message

    Public Members

    uint16_t property_id
        Property ID identifying a Generic User Property
**Public Members**

```c
uint16_t property_id
```
Property ID identifying a Generic Admin Property

**struct esp_ble_mesh_server_recv_gen_manufacturer_property_get_t**
Context of the received Generic Manufacturer Property message

**Public Members**

```c
uint16_t property_id
```
Property ID identifying a Generic Manufacturer Property

**struct esp_ble_mesh_server_recv_gen_client_properties_get_t**
Context of the received Generic Client Properties Get message

**Public Members**

```c
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**

```c
bool op_en
```
Indicate if optional parameters are included

```c
uint8_t onoff
```
Target value of Generic OnOff state

```c
uint8_t tid
```
Transaction ID

```c
uint8_t trans_time
```
Time to complete state transition (optional)

```c
uint8_t delay
```
Indicate message execution delay (C.1)

**struct esp_ble_mesh_server_recv_gen_level_set_t**
Context of the received Generic Level Set message

**Public Members**

```c
bool op_en
```
Indicate if optional parameters are included

```c
int16_t level
```
Target value of Generic Level state

```c
uint8_t tid
```
Transaction ID

```c
uint8_t trans_time
```
Time to complete state transition (optional)

```c
uint8_t delay
```
Indicate message execution delay (C.1)


**struct esp_ble_mesh_server_recv_gen_delta_set_t**

Context of the received Generic Delta Set message

**Public Members**

- `bool op_en`
  Indicate if optional parameters are included
- `int32_t delta_level`
  Delta change of Generic Level state
- `uint8_t tid`
  Transaction ID
- `uint8_t trans_time`
  Time to complete state transition (optional)
- `uint8_t delay`
  Indicate message execution delay (C.1)

**struct esp_ble_mesh_server_recv_gen_move_set_t**

Context of the received Generic Move Set message

**Public Members**

- `bool op_en`
  Indicate if optional parameters are included
- `int16_t delta_level`
  Delta Level step to calculate Move speed for Generic Level state
- `uint8_t tid`
  Transaction ID
- `uint8_t trans_time`
  Time to complete state transition (optional)
- `uint8_t delay`
  Indicate message execution delay (C.1)

**struct esp_ble_mesh_server_recv_gen_def_trans_time_set_t**

Context of the received Generic Default Transition Time Set message

**Public Members**

- `uint8_t trans_time`
  The value of the Generic Default Transition Time state

**struct esp_ble_mesh_server_recv_gen_onpowerup_set_t**

Context of the received Generic OnPowerUp Set message

**Public Members**

- `uint8_t onpowerup`
  The value of the Generic OnPowerUp state

**struct esp_ble_mesh_server_recv_gen_power_level_set_t**

Context of the received Generic Power Level Set message
Public Members

bool op_en
   Indicate if optional parameters are included

uint16_t power
   Target value of Generic Power Actual state

uint8_t tid
   Transaction ID

uint8_t trans_time
   Time to complete state transition (optional)

uint8_t delay
   Indicate message execution delay (C.1)

struct esp_ble_mesh_server_recv_gen_power_default_set_t
   Context of the received Generic Power Default Set message

Public Members

uint16_t power
   The value of the Generic Power Default state

struct esp_ble_mesh_server_recv_gen_power_range_set_t
   Context of the received Generic Power Range Set message

Public Members

uint16_t range_min
   Value of Range Min field of Generic Power Range state

uint16_t range_max
   Value of Range Max field of Generic Power Range state

struct esp_ble_mesh_server_recv_gen_loc_global_set_t
   Context of the received Generic Location Global Set message

Public Members

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)
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

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
Chapter 2. API 参考

**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 Location Client Model instance.

Parameters
- cli_pub: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- cli_data: Pointer to the unique struct `esp_ble_mesh_client_t`.

`ESP_BLE_MESH_MODEL_GEN_ONOFF_SRV (srv_pub, srv_data)`
Generic Server Models related context.
Define a new Generic OnOff Server Model.

Note
1. The Generic OnOff Server Model is a root model.
   1. This model shall support model publication and model subscription.

Return New Generic OnOff Server Model instance.

Parameters
- srv_pub: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- srv_data: Pointer to the unique struct `esp_ble_mesh_gen_onoff_srv_t`.

`ESP_BLE_MESH_MODEL_GEN_LEVEL_SRV (srv_pub, srv_data)`
Define a new Generic Level Server Model.

Note
1. The Generic Level Server Model is a root model.
   1. This model shall support model publication and model subscription.

Return New Generic Level Server Model instance.

Parameters
- srv_pub: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- srv_data: Pointer to the unique struct `esp_ble_mesh_gen_level_srv_t`.

`ESP_BLE_MESH_MODEL_GEN_DEF_TRANS_TIME_SRV (srv_pub, srv_data)`
Define a new Generic Default Transition Time Server Model.

Note
1. The Generic Default Transition Time Server Model is a root model.
   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.

**Return** New Generic Power OnOff 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_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`.

**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_GEN_POWER_LEVEL_SRV`.
- `srv_data`: Pointer to the unique struct `esp_BLE_MESH_MODEL_GEN_POWER_LEVEL_SETUP_SRV`.

**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_GEN_BATTERY_SRV`.
- `srv_data`: Pointer to the unique struct `esp_BLE_MESH_MODEL_GEN_BATTERY_SRV`.

**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_GEN_LOCATION_SRV`.
- `srv_data`: Pointer to the unique struct `esp_BLE_MESH_MODEL_GEN_LOCATION_SRV`.

**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**
Chapter 2. API

- `srv_pub`: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `srv_data`: Pointer to the unique struct `esp_ble_mesh_gen_location_setup_srv_t`.

**ESP_BLE_MESH_MODEL_GEN_USER_PROP_SRV**( `srv_pub`, `srv_data` )

Define a new Generic User Property Server Model.

**Note**
1. The Generic User Property Server model is a root model.
2. This model shall support model publication and model subscription.

**Return**
New Generic User Property Server Model instance.

**Parameters**
- `srv_pub`: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `srv_data`: Pointer to the unique struct `esp_ble_mesh_gen_user_prop_srv_t`.

**ESP_BLE_MESH_MODEL_GEN_ADMIN_PROP_SRV**( `srv_pub`, `srv_data` )

Define a new Generic Admin Property Server Model.

**Note**
1. The Generic Admin Property Server model extends the Generic User Property Server model.
2. This model shall support model publication and model subscription.

**Return**
New Generic Admin Property Server Model instance.

**Parameters**
- `srv_pub`: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `srv_data`: Pointer to the unique struct `esp_ble_mesh_gen_admin_prop_srv_t`.

**ESP_BLE_MESH_MODEL_GEN_MANUFACTURER_PROP_SRV**( `srv_pub`, `srv_data` )

Define a new Generic Manufacturer Property Server Model.

**Note**
1. The Generic Manufacturer Property Server model extends the Generic User Property Server model.
2. This model shall support model publication and model subscription.

**Return**
New Generic Manufacturer Property Server Model instance.

**Parameters**
- `srv_pub`: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `srv_data`: Pointer to the unique struct `esp_ble_mesh_gen_manu_prop_srv_t`.

**ESP_BLE_MESH_MODEL_GEN_CLIENT_PROP_SRV**( `srv_pub`, `srv_data` )

Define a new Generic Client Property Server Model.

**Note**
1. The Generic Client Property Server model is a root model.
2. This model shall support model publication and model subscription.

**Return**
New Generic Client Property Server Model instance.

**Parameters**
- `srv_pub`: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `srv_data`: Pointer to the unique struct `esp_ble_mesh_gen_client_prop_srv_t`.

**Type Definitions**

```c
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

```c
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/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

Generic Client/Server Models

Header File

- bt/esp_ble_mesh/api/models/include/esp_ble_mesh_health_model_api.h

Functions

esp_err_t esp_ble_mesh_register_health_client_callback (esp_ble_mesh_health_client_cb_t callback)
Register BLE Mesh Health Model callback, the callback will report Health Client & Server Model events.
Return ESP_OK on success or error code otherwise.
Parameters
- [in] callback: Pointer to the callback function.

esp_err_t esp_ble_mesh_register_health_server_callback (esp_ble_mesh_health_server_cb_t callback)
Register BLE Mesh Health Server Model callback.
Return ESP_OK on success or error code otherwise.
Parameters
- [in] callback: Pointer to the callback function.

esp_err_t esp_ble_mesh_health_client_get_state (esp_ble_mesh_client_common_param_t *params, esp_ble_mesh_health_client_get_state_t *get_state)
This function is called to get the Health Server states using the Health Client Model get messages.
Note If you want to find the opcodes and corresponding meanings accepted by this API, please refer to
esp_ble_mesh_opcode_health_client_get_t in esp_ble_mesh_defs.h
Return ESP_OK on success or error code otherwise.
Parameters
- [in] get_state: Pointer to a union, each kind of opcode corresponds to one structure inside.
  Shall not be set to NULL.

esp_err_t esp_ble_mesh_health_client_set_state (esp_ble_mesh_client_common_param_t *params, esp_ble_mesh_health_client_set_state_t *set_state)
This function is called to set the Health Server states using the Health Client Model set messages.
Note If you want to find the opcodes and corresponding meanings accepted by this API, please refer to
esp_ble_mesh_opcode_health_client_set_t in esp_ble_mesh_defs.h
Return ESP_OK on success or error code otherwise.
Parameters
- [in] set_state: Pointer to a union, each kind of opcode corresponds to one structure inside.
  Shall not be set to NULL.

esp_err_t esp_ble_mesh_health_server_fault_update (esp_ble_mesh_elem_t *element)
This function is called by the Health Server Model to update the context of its Health Current status.
Return ESP_OK on success or error code otherwise.
Parameters
- [in] element: The element to which the Health Server Model belongs.
Unions

union esp_ble_mesh_health_client_get_state_t
#include <esp_ble_mesh_health_model_api.h>
For ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_GET
ESP_BLE_MESH_MODEL_OP_ATTENTION_GET
ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_GET
the get_state parameter in the esp_ble_mesh_health_client_get_state function should not be set to NULL.

Public Members

esp_ble_mesh_health_fault_get_t fault_get
For ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_GET.

union esp_ble_mesh_health_client_set_state_t
#include <esp_ble_mesh_health_model_api.h>
For ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR_UNACK
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST_UNACK
ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET
ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET_UNACK
ESP_BLE_MESH_MODEL_OP_ATTENTION_SET
ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_UNACK
the set_state parameter in the esp_ble_mesh_health_client_set_state function should not be set to NULL.

Public Members

esp_ble_mesh_health_attention_set_t attention_set
For ESP_BLE_MESH_MODEL_OP_ATTENTION_SET or ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_UNACK.

esp_ble_mesh_health_period_set_t period_set
For ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET or ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET_UNACK.

esp_ble_mesh_health_fault_test_t fault_test
For ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST or ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST_UNACK.

esp_ble_mesh_health_fault_clear_t fault_clear
For ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR or ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR_UNACK.

union esp_ble_mesh_health_client_common_cb_param_t
#include <esp_ble_mesh_health_model_api.h>
Health Client Model received message union.

Public Members

esp_ble_mesh_health_current_status_cb_t current_status
The health current status value.

esp_ble_mesh_health_fault_status_cb_t fault_status
The health fault status value.

esp_ble_mesh_health_period_status_cb_t period_status
The health period status value.

esp_ble_mesh_health_attention_status_cb_t attention_status
The health attention status value.

union esp_ble_mesh_health_server_cb_param_t
#include <esp_ble_mesh_health_model_api.h>
Health Server Model callback parameters union.

Public Members

esp_ble_mesh_health_fault_update_comp_cb_t fault_update_comp
ESP_BLE_MESH_HEALTH_SERVER_FAULT_UPDATE_COMP_EVT
Chapter 2. API

esp_ble_mesh_health_fault_clear_cb_t fault_clear
  ESP_BLE_MESH_HEALTH_SERVER_FAULT_CLEAR_EVT

esp_ble_mesh_health_fault_test_cb_t fault_test
  ESP_BLE_MESH_HEALTH_SERVER_FAULT_TEST_EVT

esp_ble_mesh_health_attention_on_cb_t attention_on
  ESP_BLE_MESH_HEALTH_SERVER_ATTENTION_ON_EVT

esp_ble_mesh_health_attention_off_cb_t attention_off
  ESP_BLE_MESH_HEALTH_SERVER_ATTENTION_OFF_EVT

**Structures**

struct esp_ble_mesh_health_srv_cb_t
  ESP BLE Mesh Health Server callback

**Public Members**

esp_ble_mesh_cb_t fault_clear
  Clear health registered faults. Initialized by the stack.

esp_ble_mesh_cb_t fault_test
  Run a specific health test. Initialized by the stack.

esp_ble_mesh_cb_t attention_on
  Health attention on callback. Initialized by the stack.

esp_ble_mesh_cb_t attention_off
  Health attention off callback. Initialized by the stack.

struct esp_ble_mesh_health_test_t
  ESP BLE Mesh Health Server test Context

**Public Members**

uint8_t id_count
  Number of Health self-test ID

const uint8_t * test_ids
  Array of Health self-test IDs

uint16_t company_id
  Company ID used to identify the Health Fault state

uint8_t prev_test_id
  Current test ID of the health fault test

uint8_t current_faults[ESP_BLE_MESH_HEALTH_FAULT_ARRAY_SIZE]
  Array of current faults

uint8_t registered_faults[ESP_BLE_MESH_HEALTH_FAULT_ARRAY_SIZE]
  Array of registered faults

struct esp_ble_mesh_health_srv_t
  ESP BLE Mesh Health Server Model Context

**Public Members**

esp_ble_mesh_model_t * model
  Pointer to Health Server Model

esp_ble_mesh_health_srv_cb_t health_cb
  Health callback struct
struct k_delayed_work attention_timer
    Attention Timer state

bool attention_timer_start
    Attention Timer start flag

esp_ble_mesh_health_test_t health_test
    Health Server fault test

struct esp_ble_mesh_health_fault_get_t
    Parameter of Health Fault Get

Public Members

uint16_t company_id
    Bluetooth assigned 16-bit Company ID

struct esp_ble_mesh_health_attention_set_t
    Parameter of Health Attention Set

Public Members

uint8_t attention
    Value of the Attention Timer state

struct esp_ble_mesh_health_period_set_t
    Parameter of Health Period Set

Public Members

uint8_t fast_period_divisor
    Divider for the Publish Period

struct esp_ble_mesh_health_fault_test_t
    Parameter of Health Fault Test

Public Members

uint16_t company_id
    Bluetooth assigned 16-bit Company ID

uint8_t test_id
    ID of a specific test to be performed

struct esp_ble_mesh_health_fault_clear_t
    Parameter of Health Fault Clear

Public Members

uint16_t company_id
    Bluetooth assigned 16-bit Company ID

struct esp_ble_mesh_health_current_status_cb_t
    Parameters of Health Current Status
Public Members

uint8_t *test_id
   ID of a most recently performed test

uint16_t company_id
   Bluetooth assigned 16-bit Company ID

struct net_buf_simple *fault_array
   FaultArray field contains a sequence of 1-octet fault values

struct esp_ble_mesh_health_fault_status_cb_t
   Parameters of Health Fault Status

Public Members

uint8_t *test_id
   ID of a most recently performed test

uint16_t company_id
   Bluetooth assigned 16-bit Company ID

struct net_buf_simple *fault_array
   FaultArray field contains a sequence of 1-octet fault values

struct esp_ble_mesh_health_period_status_cb_t
   Parameter of Health Period Status

Public Members

uint8_t fast_period_divisor
   Divider for the Publish Period

struct esp_ble_mesh_health_attention_status_cb_t
   Parameter of Health Attention Status

Public Members

uint8_t attention
   Value of the Attention Timer state

struct esp_ble_mesh_health_client_cb_param_t
   Health Client Model callback parameters

Public Members

int error_code
   Appropriate error code

esp_ble_mesh_client_common_param_t *params
   The client common parameters.

esp_ble_mesh_health_client_common_cb_param_t status_cb
   The health message status callback values

struct esp_ble_mesh_health_fault_update_comp_cb_t
   Parameter of publishing Health Current Status completion event
Public Members

int error_code
The result of publishing Health Current Status

exp_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

exp_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

exp_ble_mesh_model_t *model
Pointer to the Health Server Model

uint8_t test_id
ID of a specific test to be performed

uint16_t company_id
Bluetooth assigned 16-bit Company ID

struct esp_ble_mesh_health_attention_on_cb_t
Parameter of Health Attention On event

Public Members

exp_ble_mesh_model_t *model
Pointer to the Health Server Model

uint8_t time
Duration of attention timer on (in seconds)

struct esp_ble_mesh_health_attention_off_cb_t
Parameter of Health Attention Off event

Public Members

exp_ble_mesh_model_t *model
Pointer to the Health Server Model

Macros

ESP_BLE_MESH_MODEL_HEALTH_SRV (srv, pub)
Define a new Health Server Model.

Note The Health Server Model can only be included by a Primary Element.
Return New Health Server Model instance.
Parameters
Chapter 2. API

• **srv**: Pointer to the unique struct `esp_ble_mesh_health_srv_t`.
• **pub**: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.

**ESP_BLE_MESH_MODEL_HEALTH_CLI (cli_data)**
Define a new Health Client Model.

**Note** This API needs to be called for each element on which the application needs to have a Health Client Model.

**Return** New Health Client Model instance.

**Parameters**
• **cli_data**: Pointer to the unique struct `esp_ble_mesh_client_t`.

**ESP_BLE_MESH_HEALTH_PUB_DEFINE (_name, _max, _role)**
A helper to define a health publication context

**Parameters**
• **_name**: Name given to the publication context variable.
• **_max**: Maximum number of faults the element can have.
• **_role**: Role of the device which contains the model.

**ESP_BLE_MESH_HEALTH_STANDARD_TEST**
SIG identifier of Health Fault Test. 0x01 ~ 0xFF: Vendor Specific Test.

**ESP_BLE_MESH_NO_FAULT**
Fault values of Health Fault Test. 0x33 ~ 0x7F: Reserved for Future Use. 0x80 ~ 0xFF: Vendor Specific Warning/Error.

**ESP_BLE_MESH_BATTERY_LOW_WARNING**

**ESP_BLE_MESH_BATTERY_LOW_ERROR**

**ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_LOW_WARNING**

**ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_LOW_ERROR**

**ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_HIGH_WARNING**

**ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_HIGH_ERROR**

**ESP_BLE_MESH_POWER_SUPPLY_INTERRUPTED_WARNING**

**ESP_BLE_MESH_POWER_SUPPLY_INTERRUPTED_ERROR**

**ESP_BLE_MESH_NO_LOAD_WARNING**

**ESP_BLE_MESH_NO_LOAD_ERROR**

**ESP_BLE_MESH_OVERLOAD_WARNING**

**ESP_BLE_MESH_OVERLOAD_ERROR**

**ESP_BLE_MESH_OVERHEAT_WARNING**

**ESP_BLE_MESH_OVERHEAT_ERROR**

**ESP_BLE_MESH_CONDENSATION_WARNING**

**ESP_BLE_MESH_CONDENSATION_ERROR**

**ESP_BLE_MESH_VIBRATION_WARNING**

**ESP_BLE_MESH_VIBRATION_ERROR**

**ESP_BLE_MESH_CONFIGURATION_WARNING**

**ESP_BLE_MESH_CONFIGURATION_ERROR**

**ESP_BLE_MESH_ELEMENT_NOT_CALIBRATED_WARNING**

**ESP_BLE_MESH_ELEMENT_NOT_CALIBRATED_ERROR**

**ESP_BLE_MESH_MEMORY_WARNING**

**ESP_BLE_MESH_MEMORY_ERROR**
ESP_BLE_MESH_SELF_TEST_WARNING
ESP_BLE_MESH_SELF_TEST_ERROR
ESP_BLE_MESH_INPUT_TOO_LOW_WARNING
ESP_BLE_MESH_INPUT_TOO_LOW_ERROR
ESP_BLE_MESH_INPUT_TOO_HIGH_WARNING
ESP_BLE_MESH_INPUT_TOO_HIGH_ERROR
ESP_BLE_MESH_INPUT_NO_CHANGE_WARNING
ESP_BLE_MESH_INPUT_NO_CHANGE_ERROR
ESP_BLE_MESH_ACTUATOR_BLOCKED_WARNING
ESP_BLE_MESH_ACTUATOR_BLOCKED_ERROR
ESP_BLE_MESH_HOUSING_OPENED_WARNING
ESP_BLE_MESH_HOUSING_OPENED_ERROR
ESP_BLE_MESH_TAMPER_WARNING
ESP_BLE_MESH_TAMPER_ERROR
ESP_BLE_MESH_DEVICE_MOVED_WARNING
ESP_BLE_MESH_DEVICE_MOVED_ERROR
ESP_BLE_MESH_DEVICE_DROPPED_WARNING
ESP_BLE_MESH_DEVICE_DROPPED_ERROR
ESP_BLE_MESH_OVERFLOW_WARNING
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
Enumerations

enum esp_ble_mesh_health_client_cb_event_t
This enum value is the event of Health Client Model
Values:
- ESP_BLE_MESH_HEALTH_CLIENT_GET_STATE_EVT
- ESP_BLE_MESH_HEALTH_CLIENT_SET_STATE_EVT
- ESP_BLE_MESH_HEALTH_CLIENT_PUBLISH_EVT
- ESP_BLE_MESH_HEALTH_CLIENT_TIMEOUT_EVT
- ESP_BLE_MESH_HEALTH_CLIENT_EVT_MAX

enum esp_ble_mesh_health_server_cb_event_t
This enum value is the event of Health Server Model
Values:
- ESP_BLE_MESH_HEALTH_SERVER_FAULT_UPDATE_COMP_EVT
- ESP_BLE_MESH_HEALTH_SERVER_FAULT_CLEAR_EVT
- ESP_BLE_MESH_HEALTH_SERVER_FAULT_TEST_EVT
- ESP_BLE_MESH_HEALTH_SERVER_ATTENTION_ON_EVT
- ESP_BLE_MESH_HEALTH_SERVER_ATTENTION_OFF_EVT
- ESP_BLE_MESH_HEALTH_SERVER_EVT_MAX

Sensor Client/Server Models

Header File

- bt/esp_ble_mesh/api/models/include/esp_ble_mesh_lighting_model_api.h

Functions

esp_err_t esp_ble_mesh_register_light_client_callback(esp_ble_mesh_light_client_cb_t
callback)
Register BLE Mesh Light Client Model callback.

Return ESP_OK on success or error code otherwise.

Parameters

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

esp_err_t esp_ble_mesh_light_client_get_state(esp_ble_mesh_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] 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_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.
Chapter 2. API

**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.

```c
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`
  ```c
  #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`
  ```c
  #include <esp_ble_mesh_lighting_model_api.h>
  ``
  Lighting Client Model set message union.

**Public Members**

- `esp_ble_mesh_light_lc_property_get_t lc_property_get`
  ```c
  ``
  For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_GET

- `union esp_ble_mesh_light_client_get_state_t`
  ```c
  ``
  For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_GET

- `esp_ble_mesh_light_lightness_set_t lightness_set`
  ```c
  For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_SET_UNACK
  ``

- `esp_ble_mesh_light_lightness_linear_set_t lightness_linear_set`
  ```c
  For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_SET_UNACK
  ``

- `esp_ble_mesh_light_lightness_default_set_t lightness_default_set`
  ```c
  For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_SET_UNACK
  ``

- `esp_ble_mesh_light_lightness_range_set_t lightness_range_set`
  ```c
  For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_SET_UNACK
  ``

- `esp_ble_mesh_light_ctl_set_t ctl_set`
  ```c
  For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_SET_UNACK
  ``

- `esp_ble_mesh_light_ctl_temperature_set_t ctl_temperature_set`
  ```c
  For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_SET_UNACK
  ``

- `esp_ble_mesh_light_ctl_temperature_range_set_t ctl_temperature_range_set`
  ```c
  For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_SET_UNACK
  ``

- `esp_ble_mesh_light_ctl_default_set_t ctl_default_set`
  ```c
  For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET_UNACK
  ``

- `esp_ble_mesh_light_hsl_set_t hsl_set`
  ```c
  For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SET_UNACK
  ```
### Chapter 2. API

#### esp_ble_mesh_light_hsl_hue_set_t hsl_hue_set
For `ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_SET` & `ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_SET_UNACK`

#### esp_ble_mesh_light_hsl_saturation_set_t hsl_saturation_set
For `ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_SET` & `ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_SET_UNACK`

#### esp_ble_mesh_light_hsl_default_set_t hsl_default_set
For `ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_SET` & `ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_SET_UNACK`

#### esp_ble_mesh_light_hsl_range_set_t hsl_range_set
For `ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_SET` & `ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_SET_UNACK`

#### esp_ble_mesh_light_xyl_set_t xyl_set
For `ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_SET` & `ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_SET_UNACK`

#### esp_ble_mesh_light_xyl_default_set_t xyl_default_set
For `ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET` & `ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET_UNACK`

#### esp_ble_mesh_light_xyl_range_set_t xyl_range_set
For `ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_SET` & `ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_SET_UNACK`

#### esp_ble_mesh_light_lc_mode_set_t lc_mode_set
For `ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_SET` & `ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_SET_UNACK`

#### esp_ble_mesh_light_lc_om_set_t lc_om_set
For `ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_SET` & `ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_SET_UNACK`

#### esp_ble_mesh_light_lc_light_onoff_set_t lc_light_onoff_set
For `ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_SET` & `ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_SET_UNACK`

#### esp_ble_mesh_light_lc_property_set_t lc_property_set
For `ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_SET` & `ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_SET_UNACK`

union esp_ble_mesh_light_client_status_cb_t
#include <esp_ble_mesh_lighting_model_api.h> Lighting Client Model received message union.

### Public Members

#### 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`

#### 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`
**Chapter 2. API**

`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_om_status_cb_t` **lc_om_status**
For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_STATUS

`esp_ble_mesh_light_lc_light_onoff_status_cb_t` **lc_light_onoff_status**
For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_STATUS

`esp_ble_mesh_light_lc_property_status_cb_t` **lc_property_status**
For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_STATUS

union `esp_ble_mesh_lighting_server_state_change_t`

```c
#include <esp_ble_mesh_lighting_model_api.h>
```

**Public Members**

`esp_ble_mesh_state_change_light_lightness_set_t` **lightness_set**
The `recv_op` in `ctx` can be used to decide which state is changed. Light Lightness Set

`esp_ble_mesh_state_change_light_lightness_linear_set_t` **lightness_linear_set**
Light Lightness Linear Set

`esp_ble_mesh_state_change_light_lightness_default_set_t` **lightness_default_set**
Light Lightness Default Set

`esp_ble_mesh_state_change_light_lightness_range_set_t` **lightness_range_set**
Light Lightness Range Set

`esp_ble_mesh_state_change_light_ctl_set_t` **ctl_set**
Light CTL Set
EspRESSif Systems 347  Release v4.3-dev-1561-g357a277603

Chapter 2. API Reference

```

// 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_xy_l_set_t xyl_set
// Light xyL Set

// esp_ble_mesh_state_change_light_xy_l_default_set_t xyl_default_set
// Light xyL Default Set

// esp_ble_mesh_state_change_light_xy_l_range_set_t xyl_range_set
// Light xyL Range Set

// esp_ble_mesh_state_change_light_l_c_mode_set_t lc_mode_set
// Light LC Mode Set

// esp_ble_mesh_state_change_light_l_c_om_set_t lc_om_set
// Light LC Occupancy Mode Set

// esp_ble_mesh_state_change_light_l_c_light_onoff_set_t lc_light_onoff_set
// Light LC Light OnOff Set

// esp_ble_mesh_state_change_light_l_c_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_l_c_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_l_lightness_set_t lightness
// Light Lightness Set/Light Lightness Set Unack

// esp_ble_mesh_server_recv_light_l_lightness_linear_set_t lightness_linear
// Light Lightness Linear Set/Light Lightness Linear Set Unack
```
Chapter 2. API

```c
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.

Public Members

esp_ble_mesh_server_recv_sensor_status_t sensor_status
    Sensor Status

union esp_ble_mesh_lighting_server_cb_value_t
    #include <esp_ble_mesh_lighting_model_api.h> Lighting Server Model callback value union.
```
Chapter 2. API Reference

**Public Members**

```c
esp_ble_mesh_lighting_server_state_change_t state_change
    ESP_BLE_MESH_LIGHTING_SERVER_STATE_CHANGE_EVT
esp_ble_mesh_lighting_server_recv_get_msg_t get
    ESP_BLE_MESH_LIGHTING_SERVER_RECV_GET_MSG_EVT
esp_ble_mesh_lighting_server_recv_set_msg_t set
    ESP_BLE_MESH_LIGHTING_SERVER_RECV_SET_MSG_EVT
esp_ble_mesh_lighting_server_recv_status_msg_t status
    ESP_BLE_MESH_LIGHTING_SERVER_RECV_STATUS_MSG_EVT
```

**Structures**

```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

bool op_en
    Indicate if optional parameters are included

uint16_t lightness
    Target value of light lightness actual state

uint8_t tid
    Transaction ID

uint8_t trans_time
    Time to complete state transition (optional)

uint8_t delay
    Indicate message execution delay (C.1)

struct esp_ble_mesh_light_lightness_linear_set_t
    Parameters of Light Lightness Linear Set

Public Members

bool op_en
    Indicate if optional parameters are included

uint16_t lightness
    Target value of light lightness linear state

uint8_t tid
    Transaction ID

uint8_t trans_time
    Time to complete state transition (optional)

uint8_t delay
    Indicate message execution delay (C.1)

struct esp_ble_mesh_light_lightness_default_set_t
    Parameter of Light Lightness Default Set
```
Public Members

```c
uint16_t lightness
The value of the Light Lightness Default state
```

```c
struct esp_ble_mesh_light_lightness_range_set_t
Parameters of Light Lightness Range Set
```

Public Members

```c
uint16_t range_min
Value of range min field of light lightness range state
```

```c
uint16_t range_max
Value of range max field of light lightness range state
```

```c
struct esp_ble_mesh_light_ctl_set_t
Parameters of Light CTL Set
```

Public Members

```c
bool op_en
Indicate if optional parameters are included
```

```c
uint16_t ctl_lightness
Target value of light ctl lightness state
```

```c
uint16_t ctl_temperature
Target value of light ctl temperature state
```

```c
int16_t ctl_delta_uv
Target value of light ctl delta UV 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_ctl_temperature_set_t
Parameters of Light CTL Temperature Set
```

Public Members

```c
bool op_en
Indicate if optional parameters are included
```

```c
uint16_t ctl_temperature
Target value of light ctl temperature state
```

```c
int16_t ctl_delta_uv
Target value of light ctl delta UV state
```

```c
uint8_t tid
Transaction ID
```

```c
uint8_t trans_time
Time to complete state transition (optional)
```
Chapter 2. API

uint8_t delay
   Indicate message execution delay (C.1)

struct esp_ble_mesh_light_ctl_temperature_range_set_t
   Parameters of Light CTL Temperature Range Set

   Public Members

   uint16_t range_min
      Value of temperature range min field of light ctl temperature range state

   uint16_t range_max
      Value of temperature range max field of light ctl temperature range state

struct esp_ble_mesh_light_ctl_default_set_t
   Parameters of Light CTL Default Set

   Public Members

   uint16_t lightness
      Value of light lightness default state

   uint16_t temperature
      Value of light temperature default state

   int16_t delta_uv
      Value of light delta UV default state

struct esp_ble_mesh_light_hsl_set_t
   Parameters of Light HSL Set

   Public Members

   bool op_en
      Indicate if optional parameters are included

   uint16_t hsl_lightness
      Target value of light hsl lightness state

   uint16_t hsl_hue
      Target value of light hsl hue state

   uint16_t hsl_saturation
      Target value of light hsl saturation state

   uint8_t tid
      Transaction ID

   uint8_t trans_time
      Time to complete state transition (optional)

   uint8_t delay
      Indicate message execution delay (C.1)

struct esp_ble_mesh_light_hsl_hue_set_t
   Parameters of Light HSL Hue Set

   Public Members

   bool op_en
      Indicate if optional parameters are included
Chapter 2. API

**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 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_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 On state

uint8_t tid
Transaction Identifier

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)

struct esp_ble_mesh_light_lc_property_get_t
Parameter of Light LC Property Get

Public Members

uint16_t property_id
Property ID identifying a Light LC Property

struct esp_ble_mesh_light_lc_property_set_t
Parameters of Light LC Property Set

Public Members

uint16_t property_id
Property ID identifying a Light LC Property

struct net_buf_simple *property_value
Raw value for the Light LC Property

struct esp_ble_mesh_light_lightness_status_cb_t
Bluetooth Mesh Light Lightness Client Model Get and Set callback parameters structure.
Parameters of Light Lightness Status
Public Members

bool op_en
   Indicate if optional parameters are included

uint16_t present_lightness
   Current value of light lightness actual state

uint16_t target_lightness
   Target value of light lightness actual state (optional)

uint8_t remain_time
   Time to complete state transition (C.1)

struct esp_ble_mesh_light_lightness_linear_status_cb_t
   Parameters of Light Lightness Linear Status

Public Members

bool op_en
   Indicate if optional parameters are included

uint16_t present_lightness
   Current value of light lightness linear state

uint16_t target_lightness
   Target value of light lightness linear state (optional)

uint8_t remain_time
   Time to complete state transition (C.1)

struct esp_ble_mesh_light_lightness_last_status_cb_t
   Parameter of Light Lightness Last Status

Public Members

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_lightCtl_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_lightCtl_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_lightCtl_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_lightCtl_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
Chapter 2. API

### 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_light_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

```c
esp_ble_mesh_model_t *model
    Pointer to the Lighting CTL Server Model. Initialized internally.
```

```c
esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
    Response control of the server model received messages
```

```c
esp_ble_mesh_light_ctl_state_t *state
    Parameters of the Light CTL state
```

```c
esp_ble_mesh_last_msg_info_t last
    Parameters of the last received set message
```

```c
esp_ble_mesh_state_transition_t *transition
    Parameters of state transition
```

```
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
```

```c
struct esp_ble_mesh_light_ctl_setup_srv_t
    User data of Light CTL Setup Server Model
```

Public Members

```c
esp_ble_mesh_model_t *model
    Pointer to the Lighting CTL Setup Server Model. Initialized internally.
```

```c
esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
    Response control of the server model received messages
```

```c
esp_ble_mesh_light_ctl_state_t *state
    Parameters of the Light CTL state
```

```c
struct esp_ble_mesh_light_ctl_temp_srv_t
    User data of Light CTL Temperature Server Model
```

Public Members

```c
esp_ble_mesh_model_t *model
    Pointer to the Lighting CTL Temperature Server Model. Initialized internally.
```

```c
esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
    Response control of the server model received messages
```

```c
esp_ble_mesh_light_ctl_state_t *state
    Parameters of the Light CTL state
```

```c
esp_ble_mesh_last_msg_info_t last
    Parameters of the last received set message
```

```c
esp_ble_mesh_state_transition_t *transition
    Parameters of state transition
```

```
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
```c
enum 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
```
Chapter 2. API 参考

### 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

### struct esp_ble_mesh_light_xyl_state_t
Parameters of the Light xyL state

#### 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

### struct esp_ble_mesh_light_xyl_state_t
Parameters of the Light xyL state

#### Public Members

#### uint32_t mode
0b0 The controller is turned off.
- The binding with the Light Lightness state is disabled. 0b1 The controller is turned on.
- The binding with the Light Lightness state is enabled. The value of Light LC Mode state

#### uint32_t occupancy_mode
The value of Light LC Occupancy Mode state

#### uint32_t light_onoff
The present value of Light LC Light OnOff state

#### uint32_t target_light_onoff
The target value of Light LC Light OnOff state

#### uint32_t occupancy
The value of Light LC Occupancy state

#### uint32_t ambient_luxlevel
The value of Light LC Ambient LuxLevel state

#### uint16_t linear_output
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 LC Lightness Prolong state. The value of Light LC Time Fade state

uint32_t time_prolong
A timing state that determines the time the controlled lights stay at the level determined by the Light LC Lightness Prolong state. The value of Light LC Time Prolong state

uint32_t time_fade_standby_auto
A timing state that determines the time the controlled lights fade from the level determined by the Light LC Lightness Prolong state to the level determined by the Light LC Lightness Standby state when the transition is automatic. The value of Light LC Time Fade Standby Auto state

uint32_t time_fade_standby_manual
A timing state that determines the time the controlled lights fade from the level determined by the Light LC Lightness Prolong state to the level determined by the Light LC Lightness Standby state when the transition is triggered by a change in the Light LC Light OnOff state. The value of Light LC Time Fade Standby Manual state

uint16_t lightness_on
A lightness state that determines the perceptive light lightness at the Occupancy and Run internal controller states. The value of Light LC Lightness On state

uint16_t lightness_prolong
A lightness state that determines the light lightness at the Prolong internal controller state. The value of Light LC Lightness Prolong state

uint16_t lightness_standby
A lightness state that determines the light lightness at the Standby internal controller state. The value of Light LC Lightness Standby state

uint16_t ambient_luxlevel_on
A uint16 state representing the Ambient LuxLevel level that determines if the controller transitions from the Light Control Standby state. The value of Light LC Ambient LuxLevel On state

uint16_t ambient_luxlevel_prolong
A uint16 state representing the required Ambient LuxLevel level in the Prolong state. The value of Light LC Ambient LuxLevel Prolong state

uint16_t ambient_luxlevel_standby
A uint16 state representing the required Ambient LuxLevel level in the Standby state. The value of Light LC Ambient LuxLevel Standby state
float regulator_kiu
A float32 state representing the integral coefficient that determines the integral part of the equation defining the output of the Light LC PI Feedback Regulator, when Light LC Ambient LuxLevel is less than LuxLevel Out. Valid range: 0.0 ~ 1000.0. The default value is 250.0. The value of Light LC Regulator Kiu state

float regulator_kid
A float32 state representing the integral coefficient that determines the integral part of the equation defining the output of the Light LC PI Feedback Regulator, when Light LC Ambient LuxLevel is greater than or equal to the value of the LuxLevel Out state. Valid range: 0.0 ~ 1000.0. The default value is 25.0. The value of Light LC Regulator Kid state

float regulator_kpu
A float32 state representing the proportional coefficient that determines the proportional part of the equation defining the output of the Light LC PI Feedback Regulator, when Light LC Ambient LuxLevel is less than the value of the LuxLevel Out state. Valid range: 0.0 ~ 1000.0. The default value is 80.0. The value of Light LC Regulator Kpu state

float regulator_kpd
A float32 state representing the proportional coefficient that determines the proportional part of the equation defining the output of the Light LC PI Feedback Regulator, when Light LC Ambient LuxLevel is greater than or equal to the value of the LuxLevel Out state. Valid range: 0.0 ~ 1000.0. The default value is 80.0. The value of Light LC Regulator Kpd state

int8_t regulator_accuracy
A int8 state representing the percentage accuracy of the Light LC PI Feedback Regulator. Valid range: 0.0 ~ 100.0. The default value is 2.0. The value of Light LC Regulator Accuracy state

uint32_t set_occupancy_to_1_delay
If the message Raw field contains a Raw Value for the Time Since Motion Sensed device property, which represents a value less than or equal to the value of the Light LC Occupancy Delay state, it shall delay setting the Light LC Occupancy state to 0b1 by the difference between the value of the Light LC Occupancy Delay state and the received Time Since Motion value. The value of the difference between value of the Light LC Occupancy Delay state and the received Time Since Motion value

struct esp_ble_mesh_light_lc_state_machine_t
Parameters of Light LC state machine

Public Members

uint8_t fade_on
The value of transition time of Light LC Time Fade On

uint8_t fade
The value of transition time of Light LC Time Fade

uint8_t fade_standby_auto
The value of transition time of Light LC Time Fade Standby Auto

uint8_t fade_standby_manual
The value of transition time of Light LC Time Fade Standby Manual

struct esp_ble_mesh_light_lc_state_machine_t::[anonymous] trans_time
The Fade On, Fade, Fade Standby Auto, and Fade Standby Manual states are transition states that define the transition of the Lightness Out and LuxLevel Out states. This transition can be started as a result of the Light LC State Machine change or as a result of receiving the Light LC Light OnOff Set or Light LC Light Set Unacknowledged message. The value of transition time

esp_ble_mesh_lc_state_t state
The value of Light LC state machine state

struct k_delayed_work timer
Timer of Light LC state machine
struct esp_ble_mesh_light_control_t
Parameters of Light Lightness controller

Public Members

esp_ble_mesh_light_lc_state_t state
Parameters of Light LC state

esp_ble_mesh_light_lc_property_state_t prop_state
Parameters of Light LC Property state

esp_ble_mesh_light_lc_state_machine_t state_machine
Parameters of Light LC state machine

struct esp_ble_mesh_light_lc_srv_t
User data of Light LC Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Lighting LC Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages

esp_ble_mesh_light_control_t *lc
Parameters of the Light controller

esp_ble_mesh_last_msg_info_t last
Parameters of the last received set message

esp_ble_mesh_state_transition_t transition
Parameters of state transition

struct esp_ble_mesh_light_lc_setup_srv_t
User data of Light LC Setup Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Lighting LC Setup Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages

esp_ble_mesh_light_control_t *lc
Parameters of the Light controller

struct esp_ble_mesh_state_change_light_lightness_set_t
Parameter of Light Lightness Actual state change event

Public Members

uint16_t lightness
The value of Light Lightness Actual state

struct esp_ble_mesh_state_change_light_lightness_linear_set_t
Parameter of Light Lightness Linear state change event
Public Members

```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 xyL Lightness Default state

- `uint16_t x`
  The value of Light xyL x Default state

- `uint16_t y`
  The value of Light xyL y Default state

**struct esp_ble_mesh_state_change_light_xyl_range_set_t**
Parameters of Light xyL Range state change event

**Public Members**

- `uint16_t x_range_min`
  The minimum value of Light xyL x Range state

- `uint16_t x_range_max`
  The maximum value of Light xyL x Range state

- `uint16_t y_range_min`
  The minimum value of Light xyL y Range state

- `uint16_t y_range_max`
  The maximum value of Light xyL y Range state

**struct esp_ble_mesh_state_change_light_lc_mode_set_t**
Parameter of Light LC Mode state change event
Public Members

uint8_t mode
The value of Light LC Mode state

struct esp_ble_mesh_state_change_light_lc_om_set_t
Parameter of Light LC Occupancy Mode state change event

Public Members

uint8_t mode
The value of Light LC Occupancy Mode state

struct esp_ble_mesh_state_change_light_lc_light_onoff_set_t
Parameter of Light LC Light OnOff state change event

Public Members

uint8_t onoff
The value of Light LC Light OnOff state

struct esp_ble_mesh_state_change_light_lc_property_set_t
Parameters of Light LC Property state change event

Public Members

uint16_t property_id
The property id of Light LC Property state

struct net_buf_simple *property_value
The property value of Light LC Property state

struct esp_ble_mesh_state_change_sensor_status_t
Parameters of Sensor Status state change event

Public Members

uint16_t property_id
The value of Sensor Property ID

uint8_t occupancy
The value of Light LC Occupancy state

uint32_t set_occupancy_to_1_delay
The value of Light LC Set Occupancy to 1 Delay state

uint32_t ambient_luxlevel
The value of Light LC Ambient Luxlevel state

union esp_ble_mesh_state_change_sensor_status_t::[anonymous] state
Parameters of Sensor Status related state

struct esp_ble_mesh_server_recv_light_lc_property_get_t
Context of the received Light LC Property Get message
Public Members

uint16_t property_id
Property ID identifying a Light LC Property

struct esp_ble_mesh_server_recv_light_lightness_set_t
Context of the received Light Lightness Set message

Public Members

bool op_en
Indicate if optional parameters are included

uint16_t lightness
Target value of light lightness actual state

uint8_t tid
Transaction ID

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)

struct esp_ble_mesh_server_recv_light_lightness_linear_set_t
Context of the received Light Lightness Linear Set message

Public Members

bool op_en
Indicate if optional parameters are included

uint16_t lightness
Target value of light lightness linear state

uint8_t tid
Transaction ID

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)

struct esp_ble_mesh_server_recv_light_lightness_default_set_t
Context of the received Light Lightness Default Set message

Public Members

uint16_t lightness
The value of the Light Lightness Default state

struct esp_ble_mesh_server_recv_light_lightness_range_set_t
Context of the received Light Lightness Range Set message

Public Members

uint16_t range_min
Value of range min field of light lightness range state
uint16_t range_max
    Value of range max field of light lightness range state

\textbf{struct esp_ble_mesh_server_recv_light_ctl_set_t}

Context of the received Light CTL Set message

\textbf{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)

\textbf{struct esp_ble_mesh_server_recv_light_ctl_temperature_set_t}

Context of the received Light CTL Temperature Set message

\textbf{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)

\textbf{struct esp_ble_mesh_server_recv_light_ctl_temperature_range_set_t}

Context of the received Light CTL Temperature Range Set message

\textbf{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)
Chapter 2. API

**Public Members**

```c
bool op_en
   Indicate if optional parameters are included
```

```c
uint16_t saturation
   Target value of light hsl hue state
```

```c
uint8_t tid
   Transaction ID
```

```c
uint8_t trans_time
   Time to complete state transition (optional)
```

```c
uint8_t delay
   Indicate message execution delay (C.1)
```

```c
struct esp_ble_mesh_server_recv_light_hsl_default_set_t
   Context of the received Light HSL Default Set message
```

**Public Members**

```c
uint16_t lightness
   Value of light lightness default state
```

```c
uint16_t hue
   Value of light hue default state
```

```c
uint16_t saturation
   Value of light saturation default state
```

```c
struct esp_ble_mesh_server_recv_light_hsl_range_set_t
   Context of the received Light HSL Range Set message
```

**Public Members**

```c
uint16_t hue_range_min
   Value of hue range min field of light hsl hue range state
```

```c
uint16_t hue_range_max
   Value of hue range max field of light hsl hue range state
```

```c
uint16_t saturation_range_min
   Value of saturation range min field of light hsl saturation range state
```

```c
uint16_t saturation_range_max
   Value of saturation range max field of light hsl saturation range state
```

```c
struct esp_ble_mesh_server_recv_light_xyl_set_t
   Context of the received Light xyL Set message
```

**Public Members**

```c
bool op_en
   Indicate whether optional parameters included
```

```c
uint16_t lightness
   The target value of the Light xyL Lightness state
```

```c
uint16_t x
   The target value of the Light xyL x state
```
uint16_t \texttt{y} \\
\quad \text{The target value of the Light \texttt{xyL} y state}

uint8_t \texttt{tid} \\
\quad \text{Transaction Identifier}

uint8_t \texttt{trans\_time} \\
\quad \text{Time to complete state transition (optional)}

uint8_t \texttt{delay} \\
\quad \text{Indicate message execution delay (C.1)}

\textbf{struct esp\_ble\_mesh\_server\_recv\_light\_xy\_default\_set\_t} \\
Context of the received Light xyL Default Set message

\textbf{Public Members}

uint16_t \texttt{lightness} \\
\quad \text{The value of the Light Lightness Default state}

uint16_t \texttt{x} \\
\quad \text{The value of the Light xyL x Default state}

uint16_t \texttt{y} \\
\quad \text{The value of the Light xyL y Default state}

\textbf{struct esp\_ble\_mesh\_server\_recv\_light\_xy\_range\_set\_t} \\
Context of the received Light xyL Range Set message

\textbf{Public Members}

uint16_t \texttt{x\_range\_min} \\
\quad \text{The value of the xyL x Range Min field of the Light xyL x Range state}

uint16_t \texttt{x\_range\_max} \\
\quad \text{The value of the xyL x Range Max field of the Light xyL x Range state}

uint16_t \texttt{y\_range\_min} \\
\quad \text{The value of the xyL y Range Min field of the Light xyL y Range state}

uint16_t \texttt{y\_range\_max} \\
\quad \text{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}

uint8_t \texttt{mode} \\
\quad \text{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}

uint8_t \texttt{mode} \\
\quad \text{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}

uint8_t \texttt{mode} \\
\quad \text{The target value of the Light LC Occupancy Mode state}
Chapter 2. API

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)

```c
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

```c
struct net_buf_simple *property_value
```
Raw value for the Light LC Property

```c
struct esp_ble_mesh_server_recv_sensor_status_t
```
Context of the received Sensor Status message

Public Members

```c
struct net_buf_simple *data
```
Value of sensor data state (optional)

```c
struct esp_ble_mesh_lighting_server_cb_param_t
```
Lighting Server Model callback parameters

Public Members

```c
esp_ble_mesh_model_t *model
```
Pointer to Lighting Server Models

```c
esp_ble_mesh_msg_ctx_t ctx
```
Context of the received messages

```c
esp_ble_mesh_lighting_server_cb_value_t value
```
Value of the received Lighting Messages

Macros

```c
ESP_BLE_MESH_MODEL_LIGHT_LIGHTNESS_CLI(cli_pub, cli_data)
```
Define a new Light Lightness Client Model.

**Note** This API needs to be called for each element on which the application needs to have a Light Lightness Client Model.

**Return** New Light Lightness Client Model instance.

**Parameters**
- `cli_pub`: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `cli_data`: Pointer to the unique struct `esp_ble_mesh_client_t`. 
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.

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.

Return New Light CTL Temperature Server Model instance.

**Parameters**
- `srv_pub`: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `srv_data`: Pointer to the unique struct `esp_ble_mesh_light_ctl_temp_srv_t`.

**ESP_BLE_MESH_MODEL_LIGHT_HSL_SRV** (srv_pub, srv_data)

Define a new Light HSL Server Model.

**Note**
1. The Light HSL Server model extends the Light Lightness Server model. When this model is present on an Element, the corresponding Light HSL Hue Server model and the corresponding Light HSL Saturation Server model and the corresponding Light HSL Setup Server model shall also be present.
   1. This model shall support model publication and model subscription.
   2. The model requires three elements: the main element and the Hue element and the Saturation element. The Hue element contains the corresponding Light HSL Hue Server model and an instance of a Generic Level state bound to the Light HSL Hue state on the Hue element. The Saturation element contains the corresponding Light HSL Saturation Server model and an instance of a Generic Level state bound to the Light HSL Saturation state on the Saturation element. The Light HSL Hue state on the Hue element is bound to the Light HSL state on the main element and the Light HSL Saturation state on the Saturation element is bound to the Light HSL state on the main element.

Return New Light HSL Server Model instance.

**Parameters**
- `srv_pub`: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `srv_data`: Pointer to the unique struct `esp_ble_mesh_light_hsl_srv_t`.

**ESP_BLE_MESH_MODEL_LIGHT_HSL_SETUP_SRV** (srv_pub, srv_data)

Define a new Light HSL Setup Server Model.

**Note**
1. The Light HSL Setup Server model extends the Light HSL Server and the Light Lightness Setup Server.

Return New Light HSL Setup Server Model instance.

**Parameters**
- `srv_pub`: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `srv_data`: Pointer to the unique struct `esp_ble_mesh_light_hsl_setup_srv_t`.
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.
2. 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.
2. 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.
2. 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.
2. 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.
2. This model shall support model publication and model subscription.
3. 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

**Note**  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
eenum 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

eenum 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
```

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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

Time and Scenes Client/Server Models

Header File

- bt/esp_ble_mesh/api/models/include/esp_ble_mesh_sensor_model_api.h

Functions

esp_err_t esp_ble_mesh_register_sensor_client_callback(esp_ble_mesh_sensor_client_cb_t callback)

Register BLE Mesh Sensor Client Model callback.

Return ESP_OK on success or error code otherwise.

Parameters

- [in] callback: Pointer to the callback function.

esp_err_t esp_ble_mesh_sensor_client_get_state(esp_ble_mesh_client_common_param_t *params, esp_ble_mesh_sensor_client_get_state_t *get_state)

Get the value of Sensor Server Model states using the Sensor Client Model get messages.

Note If you want to know the opcodes and corresponding meanings accepted by this API, please refer to esp_ble_mesh_sensor_message_opcode_t in esp_ble_mesh_defs.h

Return ESP_OK on success or error code otherwise.

Parameters

- [in] get_state: Pointer to sensor get message value. Shall not be set to NULL.

esp_err_t esp_ble_mesh_sensor_client_set_state(esp_ble_mesh_client_common_param_t *params, esp_ble_mesh_sensor_client_set_state_t *set_state)

Set the value of Sensor Server Model states using the Sensor Client Model set messages.

Note If you want to know the opcodes and corresponding meanings accepted by this API, please refer to esp_ble_mesh_sensor_message_opcode_t in esp_ble_mesh_defs.h

Return ESP_OK on success or error code otherwise.

Parameters

- [in] set_state: Pointer to sensor set message value. Shall not be set to NULL.
**esp_err_t esp_ble_mesh_register_sensor_server_callback (esp_ble_mesh_sensor_server_cb_t callback)**

Register BLE Mesh Sensor Server Model callback.

Return ESP_OK on success or error code otherwise.

Parameters

- [in] callback: Pointer to the callback function.

**Unions**

union esp_ble_mesh_sensor_client_get_state_t

#include `<esp_ble_mesh_sensor_model_api.h>` Sensor Client Model get message union.

**Public Members**

- esp_ble_mesh_sensor_descriptor_get_t descriptor_get
  
  For ESP_BLE_MESH_MODEL_OP_SENSOR_DESCRIPTOR_GET

- esp_ble_mesh_sensor_cadence_get_t cadence_get
  
  For ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_GET

- esp_ble_mesh_sensor_settings_get_t settings_get
  
  For ESP_BLE_MESH_MODEL_OP_SENSOR_SETTINGS_GET

- esp_ble_mesh_sensor_setting_get_t setting_get
  
  For ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_GET

- esp_ble_mesh_sensor_get_t sensor_get
  
  For ESP_BLE_MESH_MODEL_OP_SENSOR_GET

- esp_ble_mesh_sensor_column_get_t column_get
  
  For ESP_BLE_MESH_MODEL_OP_SENSOR_COLUMN_GET

- esp_ble_mesh_sensor_series_get_t series_get
  
  For ESP_BLE_MESH_MODEL_OP_SENSOR_SERIES_GET

union esp_ble_mesh_sensor_client_set_state_t

#include `<esp_ble_mesh_sensor_model_api.h>` Sensor Client Model set message union.

**Public Members**

- esp_ble_mesh_sensor_cadence_set_t cadence_set
  
  For ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_SET & ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_SET_UNACK

- esp_ble_mesh_sensor_setting_set_t setting_set
  
  For ESP_BLE_MESH_MODEL_OP_SENSORSETTING_SET & ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_SET_UNACK

union esp_ble_mesh_sensor_client_status_cb_t

#include `<esp_ble_mesh_sensor_model_api.h>` Sensor Client Model received message union.

**Public Members**

- esp_ble_mesh_sensor_descriptor_status_cb_t descriptor_status
  
  For ESP_BLE_MESH_MODEL_OP_SENSOR_DESCRIPTOR_STATUS

- esp_ble_mesh_sensor_cadence_status_cb_t cadence_status
  
  For ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_STATUS

- esp_ble_mesh_sensor_settings_status_cb_t settings_status
  
  For ESP_BLE_MESH_MODEL_OP_SENSOR_SETTINGS_STATUS
Chapter 2. API

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Public Members

`esp_bluetooth_mesh_sensor_server_state_change_t state_change`
  ESP_BLE_MESH_SENSOR_SERVER_STATE_CHANGE_EVT

`esp_bluetooth_mesh_sensor_server_recv_get_msg_t get`
  ESP_BLE_MESH_SENSOR_SERVER_RECV_GET_MSG_EVT

`esp_bluetooth_mesh_sensor_server_recv_set_msg_t set`
  ESP_BLE_MESH_SENSOR_SERVER_RECV_SET_MSG_EVT

Structures

`struct esp_bluetooth_mesh_sensor_descriptor_get_t`
  Bluetooth Mesh Sensor Client Model Get and Set parameters structure.

Parameters of Sensor Descriptor Get

Public Members

`bool op_en`
  Indicate if optional parameters are included

`uint16_t property_id`
  Property ID of a sensor (optional)

`struct esp_bluetooth_mesh_sensor_cadence_get_t`
  Parameter of Sensor Cadence Get

Public Members

`uint16_t property_id`
  Property ID of a sensor

`struct esp_bluetooth_mesh_sensor_cadence_set_t`
  Parameters of Sensor Cadence Set

Public Members

`uint16_t property_id`
  Property ID for the sensor

`uint8_t fast_cadence_period_divisor : 7`
  Divisor for the publish period

`uint8_t status_trigger_type : 1`
  The unit and format of the Status Trigger Delta fields

`struct net_buf_simple *status_trigger_delta_down`
  Delta down value that triggers a status message

`struct net_buf_simple *status_trigger_delta_up`
  Delta up value that triggers a status message

`uint8_t status_min_interval`
  Minimum interval between two consecutive Status messages

`struct net_buf_simple *fast_cadence_low`
  Low value for the fast cadence range

`struct net_buf_simple *fast_cadence_high`
  Fast value for the fast cadence range
struct esp_ble_mesh_sensor_settings_get_t
  Parameter of Sensor Settings Get

Public Members

uint16_t sensor_property_id
  Property ID of a sensor

struct esp_ble_mesh_sensor_setting_get_t
  Parameters of Sensor Setting Get

Public Members

uint16_t sensor_property_id
  Property ID of a sensor

uint16_t sensor_setting_property_id
  Setting ID identifying a setting within a sensor

struct esp_ble_mesh_sensor_setting_set_t
  Parameters of Sensor Setting Set

Public Members

uint16_t sensor_property_id
  Property ID identifying a sensor

uint16_t sensor_setting_property_id
  Setting ID identifying a setting within a sensor

struct net_buf_simple *sensor_setting_raw
  Raw value for the setting

struct esp_ble_mesh_sensor_get_t
  Parameters of Sensor Get

Public Members

bool op_en
  Indicate if optional parameters are included

uint16_t property_id
  Property ID for the sensor (optional)

struct esp_ble_mesh_sensor_column_get_t
  Parameters of Sensor Column Get

Public Members

uint16_t property_id
  Property identifying a sensor

struct net_buf_simple *raw_value_x
  Raw value identifying a column

struct esp_ble_mesh_sensor_series_get_t
  Parameters of Sensor Series Get
Public Members

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
Chapter 2. API 参考

```c
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_ble_mesh_client_common_param_t *params
   The client common parameters.

esp_ble_mesh_sensor_client_status_cb_t *status_cb
   The sensor status message callback values

struct esp_ble_mesh_sensor_descriptor_t
   Parameters of Sensor Descriptor state

Public Members

uint32_t positive_tolerance
   The value of Sensor Positive Tolerance field
```
**Chapter 2. API**

```c
uint32_t negative_tolerance : 12
    The value of Sensor Negative Tolerance field

uint32_t sampling_function : 8
    The value of Sensor Sampling Function field

uint8_t measure_period
    The value of Sensor Measurement Period field

uint8_t update_interval
    The value of Sensor Update Interval field
```

`struct esp_ble_mesh_sensor_setting_t`
Parameters of Sensor Setting state

**Public Members**

```c
uint16_t property_id
    The value of Sensor Setting Property ID field

uint8_t access
    The value of Sensor Setting Access field
```

```c
struct net_buf_simple *raw
    The value of Sensor Setting Raw field
```

`struct esp_ble_mesh_sensor_cadence_t`
Parameters of Sensor Cadence state

**Public Members**

```c
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
```

```c
struct net_buf_simple *trigger_delta_down
    Note: The parameter “size” in trigger_delta_down, trigger_delta_up, fast_cadence_low & fast_cadence_high indicates the exact length of these four parameters, and they are associated with the Sensor Property ID. Users need to initialize the “size” precisely. The value of Status Trigger Delta Down field
```

```c
struct net_buf_simple *trigger_delta_up
    The value of Status Trigger Delta Up field
```

```c
uint8_t min_interval
    The value of Status Min Interval field
```

```c
struct net_buf_simple *fast_cadence_low
    The value of Fast Cadence Low field
```

```c
struct net_buf_simple *fast_cadence_high
    The value of Fast Cadence High field
```

`struct esp_ble_mesh_sensor_data_t`
Parameters of Sensor Data state

**Public Members**

```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

**Public Members**

```c
struct net_buf_simple *raw_value_x
```

The value of Sensor Raw Value X field

```c
struct net_buf_simple *column_width
```

The value of Sensor Column Width field

```c
struct net_buf_simple *raw_value_y
```

The value of Sensor Raw Value Y field

```c
struct esp_ble_mesh_sensor_state_t
```

Parameters of Sensor states

**Public Members**

```c
uint16_t sensor_property_id
```

The value of Sensor Property ID field

```c
esp_ble_mesh_sensor_descriptor_t descriptor
```

Parameters of the Sensor Descriptor state

```c
const uint8_t setting_count
```

Multiple Sensor Setting states may be present for each sensor. The Sensor Setting Property ID values shall be unique for each Sensor Property ID that identifies a sensor within an element.

```c
esp_ble_mesh_sensor_setting_t *settings
```

Parameters of the Sensor Setting state

```c
esp_ble_mesh_sensor_cadence_t *cadence
```

The Sensor Cadence state may be not supported by sensors based on device properties referencing “non-scalar characteristics” such as “histograms” or “composite characteristics”. Parameters of the Sensor Cadence state

```c
esp_ble_mesh_sensor_data_t sensor_data
```

Parameters of the Sensor Data state

```c
esp_ble_mesh_sensor_series_column_t *series_column
```

Parameters of the Sensor Series Column state

```c
struct esp_ble_mesh_sensor_srv_t
```

User data of Sensor Server Model

**Public Members**

```c
esp_ble_mesh_model_t *model
```

Pointer to the Sensor Server Model. Initialized internally.

```c
esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
```

Response control of the server model received messages
Chapter 2. API

```c
const uint8_t state_count
    Sensor state count

esp_ble_mesh_sensor_state_t *states
    Parameters of the Sensor states

struct esp_ble_mesh_sensor_setup_srv_t
    User data of Sensor Setup Server Model

Public Members

esp_ble_mesh_model_t *model
    Pointer to the Sensor Setup Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
    Response control of the server model received messages

const uint8_t state_count
    Sensor state count

esp_ble_mesh_sensor_state_t *states
    Parameters of the Sensor states

struct esp_ble_mesh_state_change_sensor_cadence_set_t
    Parameters of Sensor Cadence Set state change event

Public Members

uint16_t property_id
    The value of Sensor Property ID state

uint8_t period_divisor : 7
    The value of Fast Cadence Period Divisor state

uint8_t trigger_type : 1
    The value of Status Trigger Type state

struct net_buf_simple *trigger_delta_down
    The value of Status Trigger Delta Down state

struct net_buf_simple *trigger_delta_up
    The value of Status Trigger Delta Up state

uint8_t min_interval
    The value of Status Min Interval state

struct net_buf_simple *fast_cadence_low
    The value of Fast Cadence Low state

struct net_buf_simple *fast_cadence_high
    The value of Fast Cadence High state

struct esp_ble_mesh_state_change_sensor_setting_set_t
    Parameters of Sensor Setting Set state change event

Public Members

uint16_t property_id
    The value of Sensor Property ID state

uint16_t setting_property_id
    The value of Sensor Setting Property ID state
```
struct net_buf_simple *setting_value
   The value of Sensor Property Value state

struct esp_ble_mesh_server_recv_sensor_descriptor_get_t
   Context of the received Sensor Descriptor Get message

   Public Members

   bool op_en
      Indicate if optional parameters are included

   uint16_t property_id
      Property ID of a sensor (optional)

struct esp_ble_mesh_server_recv_sensor_cadence_get_t
   Context of the received Sensor Cadence Get message

   Public Members

   uint16_t property_id
      Property ID of a sensor

struct esp_ble_mesh_server_recv_sensor_settings_get_t
   Context of the received Sensor Settings Get message

   Public Members

   uint16_t property_id
      Property ID of a sensor

   uint16_t setting_property_id
      Setting ID identifying a setting within a sensor

struct esp_ble_mesh_server_recv_sensor_setting_get_t
   Context of the received Sensor Setting Get message

   Public Members

   bool op_en
      Indicate if optional parameters are included

   uint16_t property_id
      Property ID for the sensor (optional)

struct esp_ble_mesh_server_recv_sensor_column_get_t
   Context of the received Sensor Column Get message

   Public Members

   bool op_en
      Indicate if optional parameters are included

   uint16_t property_id
      Property ID for the sensor (optional)
Public Members

```c
uint16_t property_id
  Property identifying a sensor

struct net_buf_simple *raw_value_x
  Raw value identifying a column
```

Public Members

```c
struct esp_ble_mesh_server_recv_sensor_series_get_t
  Context of the received Sensor Series Get message
```

Public Members

```c
bool op_en
  Indicate if optional parameters are included

uint16_t property_id
  Property identifying a sensor

struct net_buf_simple *raw_value
  Raw value containing X1 and X2 (optional)
```

Public Members

```c
struct esp_ble_mesh_server_recv_sensor_cadence_set_t
  Context of the received Sensor Cadence Set message
```

Public Members

```c
uint16_t property_id
  Property ID for the sensor

struct net_buf_simple *cadence
  Value of Sensor Cadence state
```

Public Members

```c
struct esp_ble_mesh_server_recv_sensor_setting_set_t
  Context of the received Sensor Setting Set message
```

Public Members

```c
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
```

Public Members

```c
struct esp_ble_mesh_sensor_server_cb_param_t
  Sensor Server Model callback parameters
```

Public Members

```c
esp_ble_mesh_model_t *model
  Pointer to Sensor Server Models

esp_ble_mesh_msg_ctx_t *ctx
  Context of the received messages

esp_ble_mesh_sensor_server_cb_value_t *value
  Value of the received Sensor Messages
```
Chapter 2. API 参考

Macros

ESP_BLE_MESH_MODEL_SENSOR_CLI(cli_pub, cli_data)
Define a new Sensor Client Model.

Note This API needs to be called for each element on which the application needs to have a Sensor Client Model.

Return New Sensor Client Model instance.

Parameters
• cli_pub: Pointer to the unique struct esp_ble_mesh_model_pub_t.
• cli_data: Pointer to the unique struct esp_ble_mesh_client_t.

ESP_BLE_MESH_MODEL_SENSOR_SRV(srv_pub, srv_data)
Sensor Server Models related context.

Define a new Sensor Server Model.

Note 1. The Sensor Server model is a root model. When this model is present on an element, the corresponding Sensor Setup Server model shall also be present.
1. This model shall support model publication and model subscription.

Return New Sensor Server Model instance.

Parameters
• srv_pub: Pointer to the unique struct esp_ble_mesh_model_pub_t.
• srv_data: Pointer to the unique struct esp_ble_mesh_sensor_srv_t.

ESP_BLE_MESH_MODEL_SENSOR_SETUP_SRV(srv_pub, srv_data)
Define a new Sensor Setup Server Model.

Note 1. The Sensor Setup Server model extends the Sensor Server model.
1. This model shall support model publication and model subscription.

Return New Sensor Setup Server Model instance.

Parameters
• srv_pub: Pointer to the unique struct esp_ble_mesh_model_pub_t.
• srv_data: Pointer to the unique struct esp_ble_mesh_sensor_setup_srv_t.

ESP_BLE_MESH_INVALID_SENSOR_PROPERTY_ID
Invalid Sensor Property ID

ESP_BLE_MESH_SENSOR_PROPERTY_ID_LEN
Length of Sensor Property ID

ESP_BLE_MESH_SENSOR_DESCRIPTOR_LEN
Length of Sensor Descriptor state

ESP_BLE_MESH_SENSOR_UNSPECIFIED_POS_TOLERANCE
Unspecified Sensor Positive Tolerance

ESP_BLE_MESH_SENSOR_UNSPECIFIED_NEG_TOLERANCE
Unspecified Sensor Negative Tolerance

ESP_BLE_MESH_SENSOR_NOT_APPL_MEASURE_PERIOD
Not applicable Sensor Measurement Period

ESP_BLE_MESH_SENSOR_NOT_APPL_UPDATE_INTERVAL
Not applicable Sensor Update Interval

ESP_BLE_MESH_INVALID_SENSOR_SETTING_PROPERTY_ID
Invalid Sensor Setting Property ID

ESP_BLE_MESH_SENSOR_SETTING_PROPERTY_ID_LEN
Length of Sensor Setting Property ID

ESP_BLE_MESH_SENSOR_SETTING_ACCESS_LEN
Length of Sensor Setting Access

ESP_BLE_MESH_SENSOR_SETTING_ACCESS_READ
Sensor Setting Access - Read
Chapter 2. API

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.
  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**
- event: Event type
- param: Pointer to callback parameter

```c
typedef void(*esp_ble_mesh_sensor_server_cb_t)(esp_ble_mesh_sensor_server_cb_event_t event, esp_ble_mesh_sensor_server_cb_param_t *param)
```

Bluetooth Mesh Sensor Server Model function. Sensor Server Model callback function type

**Parameters**
- event: Event type
- param: Pointer to callback parameter

**Enumerations**

```c
enum esp_ble_mesh_sensor_client_cb_event_t
```
This enum value is the event of Sensor Client Model

**Values**

- **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**
# API 参考

**Chapter 2. API**

```c
enum esp_ble_mesh_sensor_sample_func
{
    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
};
```

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**

```c
enum esp_ble_mesh_sensor_server_cb_event_t
{
    ESP_BLE_MESH_SENSOR_SERVER_STATE_CHANGE_EVT,
    ESP_BLE_MESH_SENSOR_SERVER_RECV_GET_MSG_EVT,
    ESP_BLE_MESH_SENSOR_SERVER_RECV_SET_MSG_EVT,
};
```

This enum value is the event of Sensor Server Model

**Values:**

- **ESP_BLE_MESH_SENSOR_SERVER_STATE_CHANGE_EVT**
- **ESP_BLE_MESHSENSOR_SERVER_RECV_GET_MSG_EVT**
- **ESP_BLE_MESHSENSOR_SERVER_RECV_SET_MSG_EVT**

Lighting Client/Server Models

**Header File**

- `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] get_state: Pointer to time scene get message value. Shall not be set to NULL.

```c
esp_err_t esp_ble_mesh_time_scene_client_set_state(esp_ble_mesh_client_common_param_t *params,
                                                esp_ble_mesh_time_scene_client_set_state_t *set_state)
```

Set the value of Time Scene Server Model states using the Time Scene Client Model set messages.

Note If you want to know the opcodes and corresponding meanings accepted by this API, please refer to `esp_ble_mesh_time_scene_message_opcode_t` in `esp_ble_mesh_defs.h`

Return ESP_OK on success or error code otherwise.

Parameters
- [in] set_state: Pointer to time scene set message value. Shall not be set to NULL.

```c
esp_err_t esp_ble_mesh_register_time_scene_server_callback(esp_ble_mesh_time_scene_server_cb_t callback)
```

Register BLE Mesh Time and Scenes Server Model callback.

Return ESP_OK on success or error code otherwise.

Parameters
- [in] callback: Pointer to the callback function.

Unions

```c
union esp_ble_mesh_time_scene_client_get_state_t
#include <esp_ble_mesh_time_scene_model_api.h> Time Scene Client Model get message union.
```

Public Members

```c
esp_ble_mesh_scheduler_act_get_t scheduler_act_get
For ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_GET
```

```c
union esp_ble_mesh_time_scene_client_set_state_t
#include <esp_ble_mesh_time_scene_model_api.h> Time Scene Client Model set message union.
```

Public Members

```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
```
Chapter 2. API

```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

esp_ble_mesh_time_status_cb_t time_status
For ESP_BLE_MESH_MODEL_OP_TIME_STATUS

esp_ble_mesh_time_zone_status_cb_t time_zone_status
For ESP_BLE_MESH_MODEL_OP_TIME_ZONE_STATUS

esp_ble_mesh_tai_utc_delta_status_cb_t tai_utc_delta_status
For ESP_BLE_MESH_MODEL_OP_TAI.UTC_DELTA_STATUS

esp_ble_mesh_time_role_status_cb_t time_role_status
For ESP_BLE_MESH_MODEL_OP_TIME_ROLE_STATUS

esp_ble_mesh_scene_status_cb_t scene_status
For ESP_BLE_MESH_MODEL_OP_SCENE_STATUS

esp_ble_mesh_scene_register_status_cb_t scene_register_status
For ESP_BLE_MESH_MODEL_OP_SCENE_REGISTER_STATUS

esp_ble_mesh_scheduler_status_cb_t scheduler_status
For ESP_BLE_MESH_MODEL_OP_SCHEDULER_STATUS

esp_ble_mesh_scheduler_act_status_cb_t scheduler_act_status
For ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_STATUS

union esp_ble_mesh_time_scene_server_state_change_t
#include <esp_ble_mesh_time_scene_model_api.h> Time Scene Server Model state change value union.

Public Members

esp_ble_mesh_state_change_time_set_t time_set
The recv_op in ctx can be used to decide which state is changed. Time Set

esp_ble_mesh_state_change_time_status_t time_status
Time Status

esp_ble_mesh_state_change_time_zone_set_t time_zone_set
Time Zone Set

esp_ble_mesh_state_change_tai_utc_delta_set_t tai_utc_delta_set
TAI UTC Delta Set

esp_ble_mesh_state_change_time_role_set_t time_role_set
Time Role Set

esp_ble_mesh_state_change_scene_store_t scene_store
Scene Store

esp_ble_mesh_state_change_scene_recall_t scene_recall
Scene Recall

esp_ble_mesh_state_change_scene_delete_t scene_delete
Scene Delete

esp_ble_mesh_state_change_scheduler_act_set_t scheduler_act_set
Scheduler Action Set
```
union esp_ble_mesh_time_scene_server_recv_get_msg_t
#include <esp_ble_mesh_time_scene_model_api.h> Time Scene Server Model received get message union.

Public Members

  esp_ble_mesh_server_recv_scheduler_act_get_t scheduler_act
  Scheduler Action Get

union esp_ble_mesh_time_scene_server_recv_set_msg_t
#include <esp_ble_mesh_time_scene_model_api.h> Time Scene Server Model received set message union.

Public Members

  esp_ble_mesh_server_recv_time_set_t time
  Time Set
  esp_ble_mesh_server_recv_time_zone_set_t time_zone
  Time Zone Set
  esp_ble_mesh_server_recv_tai_utc_delta_set_t tai_utc_delta
  TAI-UTC Delta Set
  esp_ble_mesh_server_recv_time_role_set_t time_role
  Time Role Set
  esp_ble_mesh_server_recv_scene_store_t scene_store
  Scene Store/Scene Store Unack
  esp_ble_mesh_server_recv_scene_recall_t scene_recall
  Scene Recall/Scene Recall Unack
  esp_ble_mesh_server_recv_scene_delete_t scene_delete
  Scene Delete/Scene Delete Unack
  esp_ble_mesh_server_recv_scheduler_act_set_t scheduler_act
  Scheduler Action Set/Scheduler Action Set Unack

union esp_ble_mesh_time_scene_server_recv_status_msg_t
#include <esp_ble_mesh_time_scene_model_api.h> Time Scene Server Model received status message union.

Public Members

  esp_ble_mesh_server_recv_time_status_t time_status
  Time Status

union esp_ble_mesh_time_scene_server_cb_value_t
#include <esp_ble_mesh_time_scene_model_api.h> Time Scene Server Model callback value union.

Public Members

  esp_ble_mesh_time_scene_server_state_change_t state_change
  ESP_BLE_MESH_TIME_SCENE_SERVER_STATE_CHANGE_EVT
  esp_ble_mesh_time_scene_server_recv_get_msg_t get
  ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_GET_MSG_EVT
  esp_ble_mesh_time_scene_server_recv_set_msg_t set
  ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_SET_MSG_EVT
  esp_ble_mesh_time_scene_server_recv_status_msg_t status
  ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_STATUS_MSG_EVT
Structures

struct esp_ble_mesh_time_set_t
Bluetooth Mesh Time Scene Client Model Get and Set parameters structure.

Parameters of Time Set

    Public Members

    uint8_t tai_seconds[5]
    The current TAI time in seconds

    uint8_t sub_second
    The sub-second time in units of 1/256 second

    uint8_t uncertainty
    The estimated uncertainty in 10-millisecond steps

    uint16_t time_authority : 1
    0 = No Time Authority, 1 = Time Authority

    uint16_t tai_utc_delta : 15
    Current difference between TAI and UTC in seconds

    uint8_t time_zone_offset
    The local time zone offset in 15-minute increments

struct esp_ble_mesh_time_zone_set_t
Parameters of Time Zone Set

    Public Members

    uint8_t time_zone_offset_new
    Upcoming local time zone offset

    uint8_t tai_zone_change[5]
    TAI Seconds time of the upcoming Time Zone Offset change

struct esp_ble_mesh_tai_utc_delta_set_t
Parameters of TAI-UTC Delta Set

    Public Members

    uint16_t tai_utc_delta_new : 15
    Upcoming difference between TAI and UTC in seconds

    uint16_t padding : 1
    Always 0b0. Other values are Prohibited.

    uint8_t tai_delta_change[5]
    TAI Seconds time of the upcoming TAI-UTC Delta change

struct esp_ble_mesh_time_role_set_t
Parameter of Time Role Set

    Public Members

    uint8_t time_role
    The Time Role for the element

struct esp_ble_mesh_scene_store_t
Parameter of Scene Store
Public Members

uint16_t scene_number
The number of scenes to be stored

struct esp_ble_mesh_scene_recall_t
Parameters of Scene Recall

Public Members

bool op_en
Indicate if optional parameters are included

uint16_t scene_number
The number of scenes to be recalled

uint8_t tid
Transaction ID

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)

Public Members

uint16_t scene_number
The number of scenes to be deleted

struct esp_ble_mesh_scheduler_act_get_t
Parameter of Scheduler Action Get

Public Members

uint8_t index
Index of the Schedule Register entry to get

struct esp_ble_mesh_scheduler_act_set_t
Parameters of Scheduler Action Set

Public Members

uint64_t index: 4
Index of the Schedule Register entry to set

uint64_t year: 7
Scheduled year for the action

uint64_t month: 12
Scheduled month for the action

uint64_t day: 5
Scheduled day of the month for the action

uint64_t hour: 5
Scheduled hour for the action
uint64_t minute: 6
Scheduled minute for the action

uint64_t second: 6
Scheduled second for the action

uint64_t day_of_week: 7
Schedule days of the week for the action

uint64_t action: 4
Action to be performed at the scheduled time

uint64_t trans_time: 8
Transition time for this action

uint16_t scene_number
Transition time for this action

struct esp_ble_mesh_time_status_cb_t
Bluetooth Mesh Time Scene Client Model Get and Set callback parameters structure.

Parameters of Time Status

Public Members

uint8_t tai_seconds[5]
The current TAI time in seconds

uint8_t sub_second
The sub-second time in units of 1/256 second

uint8_t uncertainty
The estimated uncertainty in 10-millisecond steps

uint16_t time_authority: 1
0 = No Time Authority, 1 = Time Authority

uint16_t tai_utc_delta: 15
Current difference between TAI and UTC in seconds

uint8_t time_zone_offset
The local 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

struct esp_ble_mesh_tai_utc_delta_status_cb_t
Parameters of TAI-UTC Delta Status

Public Members

uint16_t tai_utc_delta_curr: 15
Current difference between TAI and UTC in seconds
### Chapter 2. API Reference

#### Public Members

```c
uint16_t padding_1: 1
    Always 0b0. Other values are Prohibited.
```

```c
uint16_t tai_utc_delta_new: 15
    Upcoming difference between TAI and UTC in seconds
```

```c
uint16_t padding_2: 1
    Always 0b0. Other values are Prohibited.
```

```c
uint8_t tai_delta_change[5]
    TAI Seconds time of the upcoming TAI-UTC Delta change
```

**struct esp_ble_mesh_time_role_status_cb_t**

Parameter of Time Role Status

**Public Members**

```c
uint8_t time_role
    The Time Role for the element
```

**struct esp_ble_mesh_scene_status_cb_t**

Parameters of Scene Status

**Public Members**

```c
bool op_en
    Indicate if optional parameters are included
```

```c
uint8_t status_code
    Status code of the last operation
```

```c
uint16_t current_scene
    Scene Number of the current scene
```

```c
uint16_t target_scene
    Scene Number of the target scene (optional)
```

```c
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**

```c
uint8_t status_code
    Status code for the previous operation
```

```c
uint16_t current_scene
    Scene Number of the current scene
```

```c
struct net_buf_simple *scenes
    A list of scenes stored within an element
```

**struct esp_ble_mesh_scheduler_status_cb_t**

Parameter of Scheduler Status

**Public Members**

```c
uint16_t schedules
    Bit field indicating defined Actions in the Schedule Register
```
**struct esp_ble_mesh_scheduler_act_status_cb_t**

Parameters of Scheduler Action Status

**Public Members**

- `uint64_t index`: 4
  Enumerates (selects) a Schedule Register entry

- `uint64_t year`: 7
  Scheduled year for the action

- `uint64_t month`: 12
  Scheduled month for the action

- `uint64_t day`: 5
  Scheduled day of the month for the action

- `uint64_t hour`: 5
  Scheduled hour for the action

- `uint64_t minute`: 6
  Scheduled minute for the action

- `uint64_t second`: 6
  Scheduled second for the action

- `uint64_t day_of_week`: 7
  Scheduled days of the week for the action

- `uint64_t action`: 4
  Action to be performed at the scheduled time

- `uint64_t trans_time`: 8
  Transition time for this action

- `uint16_t scene_number`
  Transition time for this action

**struct esp_ble_mesh_time_scene_client_cb_param_t**

Time Scene Client Model callback parameters

**Public Members**

- `int error_code`
  Appropriate error code

- `esp_ble_mesh_client_common_param_t *params`
  The client common parameters.

- `esp_ble_mesh_time_scene_client_status_cb_t status_cb`
  The scene status message callback values

**struct esp_ble_mesh_time_state_t**

Parameters of Time state

**Public Members**

- `uint8_t tai_seconds[5]`
  The value of the TAI Seconds state

- `uint8_t subsecond`
  The value of the Subsecond field
Chapter 2. API

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 Change field

uint16_t *time_authority : 1
The value of the Time Authority bit

uint16_t *tai_utc_delta_curr : 15
The value of the TAI-UTC Delta Current state

uint16_t *tai_utc_delta_new : 15
The value of the TAI-UTC Delta New state

uint8_t *tai_delta_change[5]
The value of the TAI of Delta Change field

struct esp_ble_mesh_time_state_t::[anonymous] time
Parameters of the Time state

uint8_t *time_role
The value of the Time Role state

struct esp_ble_mesh_time_srv_t
User data of Time Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Time Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages

esp_ble_mesh_time_state_t *state
Parameters of the Time state

struct esp_ble_mesh_time_setup_srv_t
User data of Time Setup Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Time Setup Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages

esp_ble_mesh_time_state_t *state
Parameters of the Time state

struct esp_ble_mesh_scene_register_t
1. Scene Store is an operation of storing values of a present state of an element.
2. The structure and meaning of the stored state is determined by a model. States to be stored are specified by each model.
3. The Scene Store operation shall persistently store all values of all states marked as Stored with Scene for all models present on all elements of a node.
4. If a model is extending another model, the extending model shall determine the Stored with Scene behavior of that model. Parameters of Scene Register state

**Public Members**

```c
uint16_t scene_number
The value of the Scene Number
```

```c
uint8_t scene_type
The value of the Scene Type
```

```c
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
```

```c
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**

```c
const uint16_t scene_count
The Scenes state’s scene count
```

```c
esp_ble_mesh_scene_register_t *scenes
Parameters of the Scenes state
```

```c
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

```c
uint16_t target_scene
The Target Scene state is a 16-bit value that contains the target Scene Number when a scene transition is in progress.

When the scene transition is in progress and the target Scene Number is deleted from a Scene Register state as a result of Scene Delete operation, the Target Scene state shall be set to 0x0000.

When the scene transition is in progress and a new Scene Number is stored in the Scene Register as a result of Scene Store operation, the Target Scene state shall be set to the new Scene Number.
When the scene transition is not in progress, the value of the Target Scene state shall be set to 0x0000. The value of the Target Scene state

```c
uint8_t status_code
```
The status code of the last scene operation

```c
bool in_progress
```
Indicate if the scene transition is in progress

```c
struct esp_ble_mesh_scene_srv_t
```
User data of Scene Server Model

**Public Members**

```c
esp_ble_mesh_model_t *model
```
Pointer to the Scene 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_scenes_state_t *state
```
Parameters of the Scenes state

```c
esp_ble_mesh_last_msg_info_t last
```
Parameters of the last received set message

```c
esp_ble_mesh_state_transition_t *transition
```
Parameters of state transition

```c
struct esp_ble_mesh_scene_setup_srv_t
```
User data of Scene Setup Server Model

**Public Members**

```c
esp_ble_mesh_model_t *model
```
Pointer to the Scene 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_scenes_state_t *state
```
Parameters of the Scenes state

```c
struct esp_ble_mesh_schedule_register_t
```
Parameters of Scheduler Register state

**Public Members**

```c
bool in_use
```
Indicate if the registered schedule is in use

```c
uint64_t year : 7
```
The value of Scheduled year for the action

```c
uint64_t month : 12
```
The value of Scheduled month for the action

```c
uint64_t day : 5
```
The value of Scheduled day of the month for the action

```c
uint64_t hour : 5
```
The value of Scheduled hour for the action
The value of Scheduled minute for the action

uint64_t \texttt{second} : 6
The value of Scheduled second for the action

uint64_t \texttt{day_of_week} : 7
The value of Schedule days of the week for the action

uint64_t \texttt{action} : 4
The value of Action to be performed at the scheduled time

uint64_t \texttt{trans_time} : 8
The value of Transition time for this action

uint16_t \texttt{scene_number}
The value of Scene Number to be used for some actions

\textbf{struct esp\_ble\_mesh\_scheduler\_state\_t}
Parameters of Scheduler state

\textbf{Public Members}

\texttt{const uint8\_t schedule\_count}
Scheduler count

\texttt{esp\_ble\_mesh\_schedule\_register\_t \*schedules}
Up to 16 scheduled entries

\textbf{struct esp\_ble\_mesh\_scheduler\_srv\_t}
User data of Scheduler Server Model

\textbf{Public Members}

\texttt{esp\_ble\_mesh\_model\_t \*model}
Pointer to the Scheduler Server Model. Initialized internally.

\texttt{esp\_ble\_mesh\_server\_rsp\_ctrl\_t \*rsp\_ctrl}
Response control of the server model received messages

\texttt{esp\_ble\_mesh\_scheduler\_state\_t \*state}
Parameters of the Scheduler state

\textbf{struct esp\_ble\_mesh\_scheduler\_setup\_srv\_t}
User data of Scheduler Setup Server Model

\textbf{Public Members}

\texttt{esp\_ble\_mesh\_model\_t \*model}
Pointer to the Scheduler Setup Server Model. Initialized internally.

\texttt{esp\_ble\_mesh\_server\_rsp\_ctrl\_t \*rsp\_ctrl}
Response control of the server model received messages

\texttt{esp\_ble\_mesh\_scheduler\_state\_t \*state}
Parameters of the Scheduler state

\textbf{struct esp\_ble\_mesh\_state\_change\_time\_set\_t}
Parameters of Time Set state change event
Public Members

- *uint8_t* `tai_seconds[5]`
  The current TAI time in seconds

- *uint8_t* `subsecond`
  The sub-second time in units of 1/256 second

- *uint8_t* `uncertainty`
  The estimated uncertainty in 10-millisecond steps

- *uint16_t* `time_authority`
  `0 = No Time Authority, 1 = Time Authority`

- *uint16_t* `tai_utc_delta_curr` : 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`
  `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

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
Chapter 2. API

```
uint64_t day_of_week : 7
    Schedule days of the week for the action

uint64_t action : 4
    Action to be performed at the scheduled time

uint64_t trans_time : 8
    Transition time for this action

uint16_t scene_number
    Scene number to be used for some actions

struct esp_ble_mesh_server_recv_scheduler_act_get_t
    Context of the received Scheduler Action Get message

Public Members

uint8_t index
    Index of the Schedule Register entry to get

struct esp_ble_mesh_server_recv_time_set_t
    Context of the received Time Set message

Public Members

uint8_t tai_seconds[5]
    The current TAI time in seconds

uint8_t subsecond
    The sub-second time in units of 1/256 second

uint8_t uncertainty
    The estimated uncertainty in 10-millisecond steps

uint16_t time_authority : 1
    0 = No Time Authority, 1 = Time Authority

uint16_t tai_utc_delta : 15
    Current difference between TAI and UTC in seconds

uint8_t time_zone_offset
    The local 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_serverRecv_tai_utc_delta_set_t
    Context of the received TAI UTC Delta Set message

Public Members

uint16_t tai_utc_delta_new : 15
    Upcoming difference between TAI and UTC in seconds
```
uint16_t padding: 1
Always 0b0. Other values are Prohibited.

uint8_t tai_delta_change[5]
TAI Seconds time of the upcoming TAI-UTC Delta change

struct esp_ble_mesh_server_recv_time_role_set_t
Context of the received Time Role Set message

Public Members

uint8_t time_role
The Time Role for the element

struct esp_ble_mesh_server_recv_scene_store_t
Context of the received Scene Store message

Public Members

uint16_t scene_number
The number of scenes to be stored

struct esp_ble_mesh_server_recv_scene_recall_t
Context of the received Scene Recall message

Public Members

bool op_en
Indicate if optional parameters are included

uint16_t scene_number
The number of scenes to be recalled

uint8_t tid
Transaction ID

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)

struct esp_ble_mesh_server_recv_scene_delete_t
Context of the received Scene Delete message

Public Members

uint16_t scene_number
The number of scenes to be deleted

struct esp_ble_mesh_server_recv_scheduler_act_set_t
Context of the received Scheduler Action Set message

Public Members

uint64_t index: 4
Index of the Schedule Register entry to set

uint64_t year: 7
Scheduled year for the action


```c
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**

```c
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_time_scene_server_cb_param_t`

Time Scene Server Model callback parameters

**Public Members**

```c
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.

ESP_BLE_MESH_MODEL_TIME_SRV (srv_pub, srv_data)
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.


Parameters
• srv_data: Pointer to the unique struct esp_ble_mesh_time_setup_srv_t.

ESP_BLE_MESH_MODEL_SCENE_SRV (srv_pub, srv_data)
Define a new Scene Server Model.

Note 1. The Scene Server model is a root model. When this model is present on an Element, the corresponding Scene Setup Server model shall also be present.
   1. This model shall support model publication and model subscription.
   2. The model may be present only on the Primary element of a node.

Return New Scene Server Model instance.
Parameters

• **srv_pub**: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
• **srv_data**: Pointer to the unique struct `esp_ble_mesh_scene_srv_t`.

**ESP_BLE_MESH_MODEL_SCENE_SETUP_SRV** *(srv_pub, srv_data)*

Define a new Scene Setup Server Model.

**Note**
1. The Scene Setup Server model extends the Scene Server model and the Generic Default Transition Time Server model.
2. This model may be present only on the Primary element of a node.

**Return**
New Scene Setup Server Model instance.

**Parameters**

• **srv_pub**: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
• **srv_data**: Pointer to the unique struct `esp_ble_mesh_scene_setup_srv_t`.

**ESP_BLE_MESH_MODEL_SCHEDULER_SRV** *(srv_pub, srv_data)*

Define a new Scheduler Server Model.

**Note**
1. The Scheduler Server model extends the Scene Server model. When this model is present on an Element, the corresponding Scheduler Setup Server model shall also be present.
2. This model shall support model publication and model subscription.
3. The model may be present only on the Primary element of a node.
4. The model requires the Time Server model shall be present on the element.

**Return**
New Scheduler Server Model instance.

**Parameters**

• **srv_pub**: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
• **srv_data**: Pointer to the unique struct `esp_ble_mesh_scheduler_srv_t`.

**ESP_BLE_MESH_MODEL_SCHEDULER_SETUP_SRV** *(srv_pub, srv_data)*

Define a new Scheduler Setup Server Model.

**Note**
1. The Scheduler Setup Server model extends the Scheduler Server and the Scene Setup Server models.
2. This model shall support model subscription.
3. The model may be present only on the Primary element of a node.

**Return**
New Scheduler Setup Server Model instance.

**Parameters**

• **srv_pub**: Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
• **srv_data**: Pointer to the unique struct `esp_ble_mesh_scheduler_setup_srv_t`.

**ESP_BLE_MESH_UNKNOWN_TAI_SECONDS**

Unknown TAI Seconds

**ESP_BLE_MESH_UNKNOWN_TAI_ZONE_CHANGE**

Unknown TAI of Zone Change

**ESP_BLE_MESH_UNKNOWN_TAI_DELTA_CHANGE**

Unknown TAI of Delta Change

**ESP_BLE_MESH_TAI_UTC_DELTA_MAX_VALUE**

Maximum TAI-UTC Delta value

**ESP_BLE_MESH_TAI_SECONDS_LEN**

Length of TAI Seconds

**ESP_BLE_MESH_TAI_OF_ZONE_CHANGE_LEN**

Length of TAI of Zone Change

**ESP_BLE_MESH_TAI_OF_DELTA_CHANGE_LEN**

Length of TAI of Delta Change

**ESP_BLE_MESH_INVALID_SCENE_NUMBER**

Invalid Scene Number

**ESP_BLE_MESH_SCENE_NUMBER_LEN**

Length of the Scene Number
Chapter 2. API Reference

ESP_BLE_MESH_SCHEDULE_YEAR_ANY_YEAR
Any year of the Scheduled year

ESP_BLE_MESH_SCHEDULE_DAY_ANY_DAY
Any day of the Scheduled day

ESP_BLE_MESH_SCHEDULE_HOUR_ANY_HOUR
Any hour of the Scheduled hour

ESP_BLE_MESH_SCHEDULE_HOUR_ONCE_A_DAY
Any hour of the Scheduled Day

ESP_BLE_MESH_SCHEDULE_SEC_ANY_OF_HOUR
Any minute of the Scheduled hour

ESP_BLE_MESH_SCHEDULE_SEC_EVERY_15_MIN
Every 15 minutes of the Scheduled hour

ESP_BLE_MESH_SCHEDULE_SEC_EVERY_20_MIN
Every 20 minutes of the Scheduled hour

ESP_BLE_MESH_SCHEDULE_SEC_ONCE_AN_HOUR
Once of the Scheduled hour

ESP_BLE_MESH_SCHEDULE_SEC_ANY_OF_MIN
Any second of the Scheduled minute

ESP_BLE_MESH_SCHEDULE_SEC_EVERY_15_SEC
Every 15 seconds of the Scheduled minute

ESP_BLE_MESH_SCHEDULE_SEC_EVERY_20_SEC
Every 20 seconds of the Scheduled minute

ESP_BLE_MESH_SCHEDULE_SEC_ONCE_AN_MIN
Once of the Scheduled minute

ESP_BLE_MESH_SCHEDULE_ACT_TURN_OFF
Scheduled Action - Turn Off

ESP_BLE_MESH_SCHEDULE_ACT_TURN_ON
Scheduled Action - Turn On

ESP_BLE_MESH_SCHEDULE_ACT_SCENE_RECALL
Scheduled Action - Scene Recall

ESP_BLE_MESH_SCHEDULE_ACT_NO_ACTION
Scheduled Action - No Action

ESP_BLE_MESH.Schedule_SCENE_NO_SCENE
Scheduled Scene - No Scene

ESP_BLE_MESH_SCHEDULE_ENTRY_MAX_INDEX
Maximum number of Scheduled entries

ESP_BLE_MESH_TIME_NONE
Time Role - None

ESP_BLE_MESH_TIME_AUTHORITY
Time Role - Mesh Time Authority

ESP_BLE_MESH_TIME_RELAY
Time Role - Mesh Time Relay

ESP_BLE_MESH_TIME_CLIENT
Time Role - Mesh Time Client

ESP_BLE_MESH_SCENE_SUCCESS
Scene operation - Success
Chapter 2. API 参考

ESP_BLE_MESH_SCENE_REG_FULL
Scene operation - Scene Register Full

ESP_BLE_MESH_SCENE_NOT_FOUND
Scene operation - Scene Not Found

Type Definitions

typedef void (*esp_ble_mesh_time_scene_client_cb_t)(esp_ble_mesh_time_scene_client_cb_event_t event,
                                                esp_ble_mesh_time_scene_client_cb_param_t *param)

Bluetooth Mesh Time Scene Client Model function.
Time Scene Client Model callback function type

Parameters
- event: Event type
- param: Pointer to callback parameter

typedef void (*esp_ble_mesh_time_scene_server_cb_t)(esp_ble_mesh_time_scene_server_cb_event_t event,
                                                  esp_ble_mesh_time_scene_server_cb_param_t *param)

Bluetooth Mesh Time and Scenes Server Model function.
Time Scene Server Model callback function type

Parameters
- event: Event type
- param: Pointer to callback parameter

Enumerations

enum esp_ble_mesh_time_scene_client_cb_event_t
This enum value is the event of Time Scene Client Model

Values:

ESP_BLE_MESH_TIME_SCENE_CLIENT_GET_STATE_EVT
ESP_BLE_MESH_TIME_SCENE_CLIENT_SET_STATE_EVT
ESP_BLE_MESH_TIME_SCENE_CLIENT_PUBLISH_EVT
ESP_BLE_MESH_TIME_SCENE_CLIENT_TIMEOUT_EVT
ESP_BLE_MESH_TIME_SCENE_CLIENT_EVT_MAX

enum esp_ble_mesh_time_scene_server_cb_event_t
This enum value is the event of Time Scene Server Model

Values:

ESP_BLE_MESH_TIME_SCENE_SERVER_STATE_CHANGE_EVT
   1. When get_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, no event will be callback to the application layer when Time Scene Get messages are received.
   2. When set_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, this event will be callback to the application layer when Time Scene Set/Set Unack messages are received.

ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_GET_MSG_EVT
When get_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, this event will be callback to the application layer when Time Scene Get messages are received.

ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_SET_MSG_EVT
When set_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, this event will be callback to the application layer when Time Scene Set/Set Unack messages are received.
ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_STATUS_MSG_EVT

When status_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, this event will be callback to the application layer when Time Status message is received.

ESP_BLE_MESH_TIME_SCENE_SERVER_EVT_MAX

请点击查看 ESP32 蓝牙架构:

Bluetooth API 的示例代码存放于 ESP-IDF bluetooth/bluedroid 示例目录下，请查看。

下面的示例给出了详细介绍:

- GATT 客户端示例
- GATT 服务端服务表格示例
- GATT 服务端示例
- GATT 客户端安全性示例
- GATT 服务端安全性示例
- GATT 客户端多连接示例

2.2 连网 API

2.2.1 Wi-Fi

Wi-Fi 库

概述  Wi-Fi 库支持配置及监控 ESP32 Wi-Fi 连网功能。

支持配置:

- 基站模式（即 STA 模式或 Wi-Fi 客户端模式），此时 ESP32 连接到接入点 (AP)。
- AP 模式（即 Soft-AP 模式或接入点模式），此时基站连接到 ESP32。
- AP-STA 共存模式（ESP32 既是接入点，同时又作为基站连接到另外一个接入点）。
- 上述模式的各种安全模式（WPA、WPA2 及 WEP 等）。
- 扫描接入点（包括主动扫描及被动扫描）。
- 使用混杂模式监控 IEEE802.11 Wi-Fi 数据包。

应用示例  ESP-IDF 示例项目的 wifi 目录下包含以下应用程序:

- Wi-Fi 示例代码;
- 另外一个简单的应用程序 esp-idf-template，演示了如何将 ESP32 模组连接到 AP。

API 参考

Header File

- esp_wifi/include/esp_wifi.h

Functions

esp_err_t esp_wifi_init (const wifi_init_config_t *config)

Init WiFi Alloc resource for WiFi driver, such as WiFi control structure, RX/TX buffer, WiFi NVS structure etc, this WiFi also start 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 init the config to default values, this can guarantee all the fields got correct value when more fields are added into wifi_init_config_t in future release. If you want to set your owner 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 init configuration structure; can point to a temporary variable.

```c
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

```c
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 soft-AP 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 esp_err.h

**Parameters**
- mode: WiFi operating mode

```c
esp_err_t esp_wifi_get_mode (wifi_mode_t *mode)
```
Get current operating mode of WiFi.

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

**Parameters**
- [out] mode: store current WiFi mode

```c
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

```c
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**
Chapter 2. API

### 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_get_auto_connect
- 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

**Attention** 2. If the ESP32 is connected to an AP, call esp_wifi_disconnect to disconnect.

**Attention** 3. The scanning triggered by esp_wifi_start_scan() will not be effective until connection between ESP32 and the AP is established. If ESP32 is scanning and connecting at the same time, ESP32 will abort scanning and return a warning message and error number ESP_ERR_WIFI_STATE. If you want to do reconnection after ESP32 received disconnect event, remember to add the maximum retry time, otherwise the called scan will not work. This is especially true when the AP doesn’t exist, and you still try reconnection after ESP32 received disconnect event with the reason code WIFI_REASON_NO_AP_FOUND.

**Return**

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start
- ESP_ERR_WIFI_CONN: WiFi internal error, station or soft-AP control block wrong
- ESP_ERR_WIFI_SSID: SSID of AP which station connect 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 is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start
- ESP_FAIL: other WiFi internal errors

### esp_err_t esp_wifi_clear_fast_connect (void)

Currently this API is just an stub API.

**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 is not started by esp_wifi_start
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_WIFI_MODE: WiFi mode is wrong

**Parameters**

- aid: when aid is 0, deauthenticate all stations, otherwise deauthenticate station whose associated id is aid
`esp_err_t esp_wifi_scan_start(const wifi_scan_config_t *config, bool block)`

Scan all available APs.

**Attention** If this API is called, the found APs are stored in WiFi driver dynamic allocated memory and the will be freed in esp_wifi_scan_get_ap_records, so generally, call esp_wifi_scan_get_ap_records to cause the memory to be freed once the scan is done.

**Attention** The values of maximum active scan time and passive scan time per channel are limited to 1500 milliseconds. Values above 1500ms may cause station to disconnect from AP and are not recommended.

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi was not started by esp_wifi_start
- ESP_ERR_WIFI_TIMEOUT: blocking scan is timeout
- ESP_ERR_WIFI_STATE: wifi still connecting when invoke esp_wifi_scan_start
- others: refer to error code in esp_err.h

**Parameters**
- config: configuration of scanning
- block: if block is true, this API will block the caller until the scan is done, otherwise it will return immediately

`esp_err_t esp_wifi_scan_stop(void)`

Stop the scan in process.

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start

`esp_err_t esp_wifi_scan_get_ap_num(uint16_t *number)`

Get number of APs found in last scan.

**Attention** This API can only be called when the scan is completed, otherwise it may get wrong value.

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start
- ESP_ERR_INVALID_ARG: invalid argument

**Parameters**
- [out] number: store number of APs found in last scan

`esp_err_t esp_wifi_scan_get_ap_records(uint16_t *number, wifi_ap_record_t *ap_records)`

Get AP list found in last scan.

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_NO_MEM: out of memory

**Parameters**
- [inout] number: As input param, it stores max AP number ap_records can hold. As output param, it receives the actual AP number this API returns.
- ap_records: wifi_ap_record_t array to hold the found APs

`esp_err_t esp_wifi_sta_get_ap_info(wifi_ap_record_t *ap_info)`

Get information of AP which the ESP32 station is associated with.

**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**
** Chapter 2. API **

- **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_1lr 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)

**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**

- **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

**Attention** 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 enable

### 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
- [out] bw: store bandwidth of interface ifx

```c
esp_err_t esp_wifi_set_channel (uint8_t primary, wifi_second_chan_t second)
```
Set primary/secondary channel of ESP32.

### Attention
1. This API should be called after esp_wifi_start()
2. When ESP32 is in STA mode, this API should not be called when STA is scanning or connecting to an external AP
3. When ESP32 is in softAP mode, this API should not be called when softAP has connected to external STAs
4. When ESP32 is in STA+softAP mode, this API should not be called when in the scenarios described above

### Return
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_IF: invalid interface
- ESP_ERR_INVALID_ARG: invalid argument

### Parameters
- primary: for HT20, primary is the channel number, for HT40, primary is the primary channel
- second: for HT20, second is ignored, for HT40, second is the second channel

```c
esp_err_t esp_wifi_get_channel (uint8_t* primary, wifi_second_chan_t* second)
```
Get the primary/secondary channel of ESP32.

### Attention
1. API return false if try to get a interface that is not enable

### Return
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

### Parameters
- primary: store current primary channel
- [out] second: store current second channel

```c
esp_err_t esp_wifi_set_country (const wifi_country_t* country)
```
configure country info

### Attention
1. The default country is [.cc=" CN", .schan=1, .nchan=13, policy=WIFI_COUNTRY_POLICY_AUTO]
2. 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.
3. When the country policy is WIFI_COUNTRY_POLICY_MANUAL, always use the configured country info.
4. 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 changed also.
5. The country configuration is stored into flash.
6. This API doesn’t validate the per-country rules, it’s up to the user to fill in all fields according to local regulations.
7. When this API is called, the PHY init data will switch to the PHY init data type corresponding to the country info.
Chapter 2. API

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)`
get the current country info

Return
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

Parameters
- country: country info

`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

`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

`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_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.

```c
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_INVALID_ARG: invalid argument

**Parameters**
- `[out]` `filter`: store the current status of subtype filter of the control packet in promiscuous mode

```c
esp_err_t esp_wifi_set_config (wifi_interface_t interface, wifi_config_t *conf)
```

Set the configuration of the ESP32 STA or AP.

**Attention 1.** This API can be called only when specified interface is enabled, otherwise, API fail

**Attention 2.** For station configuration, bssid_set needs to be 0; and it needs to be 1 only when users need to check the MAC address of the AP.

**Attention 3.** ESP32 is limited to only one channel, so when in the soft-AP+station mode, the soft-AP will adjust its channel automatically to be the same as the channel of the ESP32 station.

**Return**
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_INVALID_ARG: invalid argument
• ESP_ERR_WIFI_IF: invalid interface
• ESP_ERR_WIFI_MODE: invalid mode
• ESP_ERR_WIFI_PASSWORD: invalid password
• ESP_ERR_WIFI_NVSS: WiFi internal NVS error
• others: refer to the error code in esp_err.h

**Parameters**
- **interface**: interface
- **conf**: station or soft-AP configuration

```c
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

**Parameters**
- **interface**: interface
- **conf**: station or soft-AP configuration

```c
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**
- **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

```c
esp_err_t esp_wifi_ap_get_sta_aid(const uint8_t mac[6], uint16_t *aid)
```
Get AID of STA connected with soft-AP.

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_NOT_FOUND: Requested resource not found
- ESP_ERR_WIFI_MODE: WiFi mode is wrong
- ESP_ERR_WIFI_CONN: WiFi internal error, the station/soft-AP control block is invalid

**Parameters**
- **mac**: STA’s mac address
- **aid**: Store the AID corresponding to STA mac

```c
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**
Chapter 2. API 参考

- **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.
2. The value set by this API will be mapped to the max_tx_power of the structure wifi_country_t variable.
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}, {78, 20}}.
4. Param power unit is 0.25dBm, range is [8, 78] corresponding to 2dBm - 20dBm.

**Return**

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_START: WiFi is not started by esp_wifi_start
- ESP_ERR_WIFI_ARG: invalid argument, e.g. parameter is out of range

**Parameters**

- power: Maximum WiFi transmitting power.

**esp_err_t esp_wifi_get_max_tx_power**(int8_t *power)

Get maximum transmitting power after WiFi start.

**Return**

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_START: WiFi is not started by esp_wifi_start
- ESP_ERR_WIFI_ARG: invalid argument

**Parameters**
• **power**: Maximum WiFi transmitting power, unit is 0.25dBm.

### `esp_err_t esp_wifi_set_event_mask(uint32_t mask)`
Set mask to enable or disable some WiFi events.

**Attention** 1. Mask can be created by logical OR of various `WIFI_EVENT_MASK` constants. Events which have corresponding bit set in the mask will not be delivered to the system event handler.
**Attention** 2. Default WiFi event mask is `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.

### `esp_err_t esp_wifi_get_event_mask(uint32_t* mask)`
Get mask of WiFi events.

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by `esp_wifi_init`
- ESP_ERR_WIFI_ARG: invalid argument

**Parameters**
- **mask**: WiFi event mask.

### `esp_err_t esp_wifi_80211_tx(wifi_interface_t ifx, const void* buffer, int len, bool en_sys_seq)`
Send raw ieee80211 data.

**Attention** Currently only support for sending beacon/probe request/probe response/action and non-QoS data frame

**Return**
- ESP_OK: success
- ESP_ERR_WIFI_IF: Invalid interface
- ESP_ERR_INVALID_ARG: Invalid parameter
- ESP_ERR_WIFI_NO_MEM: out of memory

**Parameters**
- **ifx**: interface if the Wi-Fi mode is Station, the ifx should be `WIFI_IF_STA`. If the Wi-Fi mode is SoftAP, the ifx should be `WIFI_IF_AP`. If the Wi-Fi mode is Station+SoftAP, the ifx should be `WIFI_IF_STA` or `WIFI_IF_AP`. If the ifx is wrong, the API returns `ESP_ERR_WIFI_IF`.
- **buffer**: raw ieee80211 buffer
- **len**: the length of raw buffer, the len must be `<= 1500 Bytes` and `>= 24 Bytes`
- **en_sys_seq**: indicate whether use the internal sequence number. If `en_sys_seq` is false, the sequence in raw buffer is unchanged, otherwise it will be overwritten by WiFi driver with the system sequence number. Generally, if `esp_wifi_80211_tx` is called before the Wi-Fi connection has been set up, both `en_sys_seq==true` and `en_sys_seq==false` are fine. However, if the API is called after the Wi-Fi connection has been set up, `en_sys_seq` must be true, otherwise `ESP_ERR_WIFI_ARG` is returned.

### `esp_err_t esp_wifi_set_csi_rx_cb(wifi_csi_cb_t cb, void* ctx)`
Register the RX callback function of CSI data.

| Each time a CSI data is received, the callback function will be called. |

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by `esp_wifi_init`

**Parameters**
- **cb**: callback
- **ctx**: context argument, passed to callback function
**esp_err_t esp_wifi_set_csi_config(const wifi_csi_config_t *config)**

Set CSI data configuration.

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_START: WiFi is not started by esp_wifi_start or promiscuous mode is not enabled
- ESP_ERR_INVALID_ARG: invalid argument

**Parameters**

- config: configuration

**esp_err_t esp_wifi_set_csi(bool en)**

Enable or disable CSI.

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_START: WiFi is not started by esp_wifi_start or promiscuous mode is not enabled
- ESP_ERR_INVALID_ARG: invalid argument

**Parameters**

- en: true - enable, false - disable

**esp_err_t esp_wifi_set_ant_gpio(const wifi_ant_gpio_config_t *config)**

Set antenna GPIO configuration.

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_ARG: Invalid argument, e.g. parameter is NULL, invalid GPIO number etc

**Parameters**

- config: Antenna GPIO configuration.

**esp_err_t esp_wifi_get_ant_gpio(wifi_ant_gpio_config_t *config)**

Get current antenna GPIO configuration.

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_ARG: invalid argument, e.g. parameter is NULL

**Parameters**

- config: Antenna GPIO configuration.

**esp_err_t esp_wifi_set_ant(const wifi_ant_config_t *config)**

Set antenna configuration.

- 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(const wifi_ant_config_t *config)**

Get current antenna configuration.

- 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.

```c
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.

```c
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.

```c
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.

```c
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

**Structures**

```c
struct wifi_init_config_t
```
WiFi stack configuration parameters passed to esp_wifi_init call.

**Public Members**

```c
system_event_handler_t event_handler
```
WiFi event handler

```c
wifi_osi_funcs_t *osi_funcs
```
WiFi OS functions
wpa_crypto_funcs_t wpa_cryptofuncs
  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 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

int magic
  WiFi init magic number, it should be the last field

Macros

ESP_ERR_WIFI_NOT_INIT
  WiFi driver was not installed by esp_wifi_init

ESP_ERR_WIFI_NOT_STARTED
  WiFi driver was not started by esp_wifi_start

ESP_ERR_WIFI_NOT_STOPPED
  WiFi driver was not stopped by esp_wifi_stop

ESP_ERR_WIFI_IF
  WiFi interface error
ESP_ERR_WIFI_MODE
WiFi mode error

ESP_ERR_WIFI_STATE
WiFi internal state error

ESP_ERR_WIFI_CONN
WiFi internal control block of station or soft-AP error

ESP_ERR_WIFI_NVS
WiFi internal NVS module error

ESP_ERR_WIFI_MAC
MAC address is invalid

ESP_ERR_WIFI_SSID
SSID is invalid

ESP_ERR_WIFI_PASSWORD
Password is invalid

ESP_ERR_WIFI_TIMEOUT
Timeout error

ESP_ERR_WIFI_WAKE_FAIL
WiFi is in sleep state (RF closed) and wakeup fail

ESP_ERR_WIFI_WOULD_BLOCK
The caller would block

ESP_ERR_WIFI_NOT_CONNECT
Station still in disconnect status

ESP_ERR_WIFI_POST
Failed to post the event to WiFi task

ESP_ERR_WIFI_INIT_STATE
Invalid WiFi state when init/deinit is called

ESP_ERR_WIFI_STOP_STATE
Returned when WiFi is stopping

ESP_ERR_WIFI_NOT_ASSOC
The WiFi connection is not associated

ESP_ERR_WIFI_TX_DISALLOW
The WiFi TX is disallowed

WIFI_STATIC_TX_BUFFER_NUM

WIFI_CACHE_TX_BUFFER_NUM

WIFI_DYNAMIC_TX_BUFFER_NUM

WIFI_CSI_ENABLED

WIFI_AMPDU_RX_ENABLED

WIFI_AMPDU_TX_ENABLED

WIFI_NVS_ENABLED

WIFI_NANO_FORMAT_ENABLED

WIFI_INIT_CONFIG_MAGIC

WIFI_DEFAULT_RX_BA_WIN

WIFI_TASK_CORE_ID

WIFI_SOFTAP_BEACON_MAX_LEN
Chapter 2. API

WIFI_MGMT_SBUF_NUM
CONFIG_FEATURE_WPA3_SAE_BIT
CONFIG_FEATURE_CACHE_TX_BUF_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.

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
• 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
Chapter 2. API

```c
wifi_scan_time_t scan_time
  scan time per channel

struct wifi_ap_record_t
  Description of a WiFi AP.
```

**Public Members**

```c
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
```

```c
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 reserved : 27
  bit: 5..31 reserved
```

```c
wifi_country_t country
  country information of AP
```

**Public Members**

```c
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
```

```c
struct wifi_scan_threshold_t
  Structure describing parameters for a WiFi fast scan.
```
**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. Null terminated string.

uint8_t ssid_len
Optional length of SSID field.

uint8_t channel
Channel of ESP32 soft-AP

wifi_auth_mode_t authmode
Auth mode of ESP32 soft-AP. Do not support AUTH_WEP in soft-AP mode

uint8_t ssid_hidden
Broadcast SSID or not, default 0, broadcast the SSID

uint8_t max_connection
Max number of stations allowed to connect in, default 4, max 10

uint16_t beacon_interval
Beacon interval, 100 ~ 60000 ms, default 100 ms

**struct wifi_sta_config_t**
STA configuration settings for the ESP32.

**Public Members**

uint8_t ssid[32]
SSID of target AP. Null terminated string.

uint8_t password[64]
Password of target AP. Null terminated string.

wifi_scan_method_t scan_method
do all channel scan or fast scan

bool bssid_set
whether set MAC address of target AP or not. Generally, station_config.bssid_set needs to be 0; and it needs to be 1 only when users need to check the MAC address of the AP.

uint8_t bssid[6]
MAC address of target AP
uint8_t channel
channel of target AP. Set to 1~13 to scan starting from the specified channel before connecting to AP. If the channel of AP is unknown, set it to 0.

uint16_t listen_interval
Listen interval for ESP32 station to receive beacon when WIFI_PS_MAX_MODEM is set. Units: AP beacon intervals. Defaults to 3 if set to 0.

wifi_sort_method_t sort_method
sort the connect AP in the list by rssi or security mode

wifi_scan_threshold_t threshold
When sort_method is set, only APs which have an auth mode that is more secure than the selected auth mode and a signal stronger than the minimum RSSI will be used.

wifi_pmf_config_t pmf_cfg
Configuration for Protected Management Frame. Will be advertised in RSN Capabilities in RSN IE.

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 reserved : 28
bit: 4..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(MSC0 ~ 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 \texttt{sgi}: 1
\hspace{1em} \text{Short Guide Interval(SGI).} \ 0: \text{Long GI;} \ 1: \text{Short GI}

signed \texttt{noise\_floor}: 8
\hspace{1em} \text{noise floor of Radio Frequency Module(RF). unit: 0.25dBm}

unsigned \texttt{ampdu\_cnt}: 8
\hspace{1em} \text{ampdu cnt}

unsigned \texttt{channel}: 4
\hspace{1em} \text{primary channel on which this packet is received}

unsigned \texttt{secondary\_channel}: 4
\hspace{1em} \text{secondary channel on which this packet is received.} \ 0: \text{none;} \ 1: \text{above;} \ 2: \text{below}

unsigned __pad4__: 8
\hspace{1em} \text{reserved}

unsigned \texttt{timestamp}: 32
\hspace{1em} \text{timestamp. The local time when this packet is received. It is precise only if modem sleep or light sleep}
\hspace{1em} \text{is not enabled. unit: microsecond}

unsigned __pad5__: 32
\hspace{1em} \text{reserved}

unsigned __pad6__: 31
\hspace{1em} \text{reserved}

unsigned \texttt{ant}: 1
\hspace{1em} \text{antenna number from which this packet is received.} \ 0: \text{WiFi antenna 0;} \ 1: \text{WiFi antenna 1}

unsigned \texttt{sig\_len}: 12
\hspace{1em} \text{length of packet including Frame Check Sequence(FCS)}

unsigned __pad7__: 12
\hspace{1em} \text{reserved}

unsigned \texttt{rx\_state}: 8
\hspace{1em} \text{state of the packet.} \ 0: \text{no error; others: error numbers which are not public}

\textbf{struct wifi\_promiscuous\_pkt\_t}
\hspace{1em} \text{Payload passed to ‘buf’ parameter of promiscuous mode RX callback.}

\textbf{Public Members}

\texttt{wifi\_pkt\_rx\_ctrl\_t rx\_ctrl}
\hspace{1em} \text{metadata header}

\texttt{uint8\_t\ \texttt{payload}[0]}
\hspace{1em} \text{Data or management payload. Length of payload is described by rx\_ctrl.sig\_len. Type of content deter-}
\hspace{1em} \text{mined by packet type argument of callback.}

\textbf{struct wifi\_promiscuous\_filter\_t}
\hspace{1em} \text{Mask for filtering different packet types in promiscuous mode.}

\textbf{Public Members}

\texttt{uint32\_t filter\_mask}
\hspace{1em} \text{OR of one or more filter values WIFI\_PROMIS\_FILTER\_*}

\textbf{struct wifi\_csi\_config\_t}
\hspace{1em} \text{Channel state information(CSI) configuration type.}
Public Members

bool `lltf_en`
   enable to receive legacy long training field(lltf) data. Default enabled

bool `htltf_en`
   enable to receive HT long training field(htltf) data. Default enabled

bool `stbc_htltf2_en`
   enable to receive space time block code HT long training field(stbc-htltf2) data. Default enabled

bool `ltf_merge_en`
   enable to generate httf data by averaging lltf and ht_ltf data when receiving HT packet. Otherwise, use ht_ltf data directly. Default enabled

bool `channel_filter_en`
   enable to turn on channel filter to smooth adjacent sub-carrier. Disable it to keep independence of adjacent sub-carrier. Default enabled

bool `manu_scale`
   manually scale the CSI data by left shifting or automatically scale the CSI data. If set true, please set the shift bits. false: automatically. true: manually. Default false

uint8_t `shift`
   manually left shift bits of the scale of the CSI data. The range of the left shift bits is 0~15

struct `wifi_csi_info_t`
   CSI data type.

struct `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

\texttt{wifi\_ant\_gpio\_t \textit{gpio\_cfg}[4]}

The configurations of GPIOs that connect to external antenna switch

\textbf{struct wifi\_ant\_config\_t}

WiFi antenna configuration.

Public Members

\texttt{wifi\_ant\_mode\_t \textit{rx\_ant\_mode}}

WiFi antenna mode for receiving

\texttt{wifi\_ant\_t \textit{rx\_ant\_default}}

Default antenna mode for receiving, it’s ignored if \textit{rx\_ant\_mode} is not WIFI\_ANT\_MODE\_AUTO

\texttt{wifi\_ant\_mode\_t \textit{tx\_ant\_mode}}

WiFi antenna mode for transmission, it can be set to WIFI\_ANT\_MODE\_AUTO only if \textit{rx\_ant\_mode} is set to WIFI\_ANT\_MODE\_AUTO

\texttt{uint8\_t \textit{enabled\_ant0}}\ : \ 4

Index (in antenna GPIO configuration) of enabled WIFI\_ANT\_MODE\_ANT0

\texttt{uint8\_t \textit{enabled\_ant1}}\ : \ 4

Index (in antenna GPIO configuration) of enabled WIFI\_ANT\_MODE\_ANT1

\textbf{struct wifi\_event\_sta\_scan\_done\_t}

Argument structure for WIFI\_EVENT\_SCAN\_DONE event

Public Members

\texttt{uint32\_t \textit{status}}

status of scanning APs: 0 — success, 1 - failure

\texttt{uint8\_t \textit{number}}

number of scan results

\texttt{uint8\_t \textit{scan\_id}}

scan sequence number, used for block scan

\textbf{struct wifi\_event\_sta\_connected\_t}

Argument structure for WIFI\_EVENT\_STA\_CONNECTED event

Public Members

\texttt{uint8\_t \textit{ssid}[32]}

SSID of connected AP

\texttt{uint8\_t \textit{ssid\_len}}

SSID length of connected AP

\texttt{uint8\_t \textit{bssid}[6]}

BSSID of connected AP

\texttt{uint8\_t \textit{channel}}

channel of connected AP

\texttt{wifi\_auth\_mode\_t \textit{authmode}}

authentication mode used by AP

\textbf{struct wifi\_event\_sta\_disconnected\_t}

Argument structure for WIFI\_EVENT\_STA\_DISCONNECTED event
Public Members

uint8_t ssid[32]
SSID of disconnected AP

uint8_t ssid_len
SSID length of disconnected AP

uint8_t bssid[6]
BSSID of disconnected AP

uint8_t reason
reason of disconnection

struct wifi_event_sta_authmode_change_t
Argument structure for WIFI_EVENT_STA_AUTHMODE_CHANGE event

Public Members

wifi_auth_mode_t old_mode
the old auth mode of AP

wifi_auth_mode_t new_mode
the new auth mode of AP

struct wifi_event_sta_wps_er_pin_t
Argument structure for WIFI_EVENT_STA_WPS_ER_PIN event

Public Members

uint8_t pin_code[8]
PIN code of station in enrollee mode

struct wifi_event_sta_wps_er_success_t
Argument structure for WIFI_EVENT_STA_WPS_ER_SUCCESS event

Public Members

uint8_t ap_cred_cnt
Number of AP credentials received

uint8_t ssid[MAX_SSID_LEN]
SSID of AP

uint8_t passphrase[MAX_PASSPHRASE_LEN]
Passphrase for the AP

struct wifi_event_sta_wps_er_success_t::<anonymous> ap_cred[MAX_WPS_AP_CRED]
All AP credentials received from WPS handshake

struct wifi_event_ap_staconnected_t
Argument structure for WIFI_EVENT_AP_STACONNECTED event

Public Members

uint8_t mac[6]
MAC address of the station connected to ESP32 soft-AP

uint8_t aid
the aid that ESP32 soft-AP gives to the station connected to
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

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

Macros

WIFI_IF_STA
WIFI_IF_AP
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_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 esp_interface_t wifi_interface_t

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_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_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_IE_INVALID = 13
WIFI_REASON_MIC_FAILURE = 14
WIFI_REASON_4WAY_HANDSHAKE_TIMEOUT = 15
Chapter 2. API

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

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_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
WiFi event declarations

Values:

WIFI_EVENT_WIFI_READY = 0
ESP32 WiFi ready

WIFI_EVENT_SCAN_DONE
ESP32 finish scanning AP

WIFI_EVENT_STA_START
ESP32 station start

WIFI_EVENT_STA_STOP
ESP32 station stop

WIFI_EVENT_STA_CONNECTED
ESP32 station connected to AP

WIFI_EVENT_STA_DISCONNECTED
ESP32 station disconnected from AP

WIFI_EVENT_STA_AUTHMODE_CHANGE
the auth mode of AP connected by ESP32 station changed

WIFI_EVENT_STA_WPS_ER_SUCCESS
ESP32 station wps succeeds in enrollee mode

WIFI_EVENT_STA_WPS_ER_FAILED
ESP32 station wps fails in enrollee mode

WIFI_EVENT_STA_WPS_ER_TIMEOUT
ESP32 station wps timeout in enrollee mode

WIFI_EVENT_STA_WPS_ER_PIN
ESP32 station wps pin code in enrollee mode

WIFI_EVENT_STA_WPS_ER_PBC_OVERLAP
ESP32 station wps overlap in enrollee mode
Chapter 2. API

### 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_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**

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**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 API.

**Application Example** Connect ESP32 to target AP using SmartConfig: `wifi/smart_config`.

**API Reference**

**Header File**

- `esp_wifi/include/esp_smartconfig.h`

**Functions**

- `const char *esp_smartconfig_get_version (void)`
  Get the version of SmartConfig.

  **Return**
  - SmartConfig version const char.
Chapter 2. API

```c
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

```c
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.
**Attention** 2. Fast mode have corresponding APP(phone).
**Attention** 3. Two mode is compatible.

**Return**
- ESP_OK: succeed
- others: fail

**Parameters**
- enable: false-disable(default); true-enable;

**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.
```
uint8_t password[64]
    Password of the AP. Null terminated string.

bool bssid_set
    Whether set MAC address of target AP or not.

uint8_t bssid[6]
    MAC address of target AP.

smartconfig_type_t type
    Type of smartconfig (ESPTouch or AirKiss).

uint8_t token
    Token from cellphone which is used to send ACK to cellphone.

uint8_t cellphone_ip[4]
    IP address of cellphone.

struct smartconfig_start_config_t
    Configure structure for esp_smartconfig_start

Public Members

bool enable_log
    Enable smartconfig logs.

Macros
SMARTCONFIG_START_CONFIG_DEFAULT ()

Enumerations
enum smartconfig_type_t
    Values:
    SC_TYPE_ESPTOUCH = 0
        Protocol: ESPTouch
    SC_TYPE_AIRKISS
        Protocol: AirKiss
    SC_TYPE_ESPTOUCH_AIRKISS
        Protocol: ESPTouch and AirKiss

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

ESP-NOW is a communication protocol that allows devices to advertise themselves to others in the same network. It is used in a variety of applications such as smart home devices, industrial IoT systems, and other systems that require low power and low bandwidth communication.

The protocol operates on a master-slave architecture, with the master device broadcasting messages to all devices within range. Each device then responds to the master with its own unique identifier, allowing the master to identify and communicate with individual devices.

The ESP-NOW protocol is designed to be lightweight and energy-efficient, making it ideal for battery-powered devices. It is supported by several ESP32 chipsets, including the ESP32-WROOM-32.

In addition to its use in communication, ESP-NOW also has applications in security, allowing devices to authenticate each other based on the unique identifiers broadcasted in the protocol.
与 CBC-MAC 协议 (CCMP) 可用来保护动作帧的安全。ESP-NOW 广泛应用于智能家居、远程控制、传感器等领域。

帧格式  ESP-NOW 使用各个供应商的动作帧传输数据，默认比特率为 1 Mbps。各个供应商的动作帧格式为:

<table>
<thead>
<tr>
<th>MAC</th>
<th>分类</th>
<th>组标识符</th>
<th>随机</th>
<th>供应商特定内容</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 字节</td>
<td>1 字节</td>
<td>3 字节</td>
<td>4 字节</td>
<td>7~255 字节</td>
<td>4 字节</td>
</tr>
</tbody>
</table>

- 分类代码：分类代码字段可用于指示各个供应商的类别（比如 127）。
- 组标识符：组标识符包含一个唯一标识符 (比如 0x18fe34)，为乐鑫指定的 MAC 地址的前三个字节。
- 随机值：防止重放攻击。
- 供应商特定内容：供应商特定内容包含供应商特定字段，如下所示：

<table>
<thead>
<tr>
<th>元素 ID</th>
<th>长度</th>
<th>组标识符</th>
<th>类型</th>
<th>版本</th>
<th>正文</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 字节</td>
<td>1 字节</td>
<td>3 字节</td>
<td>1 字节</td>
<td>1 字节</td>
<td>0~250 字节</td>
</tr>
</tbody>
</table>

- 元素 ID：元素 ID 字段可用于指示特定于供应商的元素。
- 长度：长度是组标识符、类型、版本和正文的总长度。
- 组标识符：组标识符包含一个唯一标识符 (比如 0x18fe34)，为乐鑫指定的 MAC 地址的前三个字节。
- 类型：类型字段设置为 4，代表 ESP-NOW。
- 版本：版本字段设置为 ESP-NOW 的版本。
- 正文：正文包含 ESP-NOW 数据。

由于 ESP-NOW 是无连接的，因此 MAC 报头与标准帧略有不同。FrameControl 字段的 FromDS 和 ToDS 位均为 0。第一个地址字段用于配置目标地址。第二个地址字段用于配置源地址。第三个地址字段用于配置广播地址 (0xff:0xff:0xff:0xff:0xff:0xff)。

安全  ESP-NOW 采用 CCMP 方法保护供应商特定动作帧的安全，具体可参考 IEEE Std. 802.11-2012。Wi-Fi 设备维护一个初始化了的 PMK，其 MAC 地址对应的供应商标识为 0x18fe34。

- PMK 可使用 AES-128 算法加密 LMK。请调用 esp_now_set_pmk() 设置 PMK。如果未设置 PMK，将使用默认 PMK。
- LMK 可通过 CCMP 方法对供应商特定的动作帧进行加密，最多拥有 6 个不同的 LMK。如果未设置配对设备的 LMK，则动作帧不进行加密。

目前，不支持加密组播供应商特定的动作帧。

初始化和反初始化  调用 esp_now_init() 初始化 ESP-NOW，调用 esp_now_deinit() 反初始化 ESP-NOW。ESP-NOW 数据必须在 Wi-Fi 启动后传输，因此建议在初始化 ESP-NOW 之前启动 Wi-Fi，并在反初始化 ESP-NOW 之后停止 Wi-Fi。当调用 esp_now_deinit() 时，配对设备的所有信息都将被删除。

添加配对设备  在将数据发送到其他设备之前，请先调用 esp_now_add_peer() 将其添加到配对设备列表中。配对设备的最大数量是 20。如果启用了加密，则必须设置 LMK。ESP-NOW 数据可以从 Station 或 Softap 接口发送。确保在发送 ESP-NOW 数据之前已启用该接口。在发送广播数据之前必须添加具有广播 MAC 地址的设备。配对设备的信道范围是从 0 ~ 14。如果信道设置为 0，数据将在当前信道上发送。否则，必须使用本地设备所在的信道。

Espressif Systems  458  Release v4.3-dev-1561-g357a277603
发送 ESP-NOW 数据 调用 `esp_now_send()` 发送 ESP-NOW 数据。调用 `esp_now_register_send_cb` 注册发送回调函数。如果 MAC 层成功接收到数据，则该函数将返回 `ESP_NOW_SEND_SUCCESS` 事件。否则，它将返回 `ESP_NOW_SEND_FAIL`。ESP-NOW 数据发送失败可能有几种原因，比如目标设备不存在、设备的信道不相同、动作帧在传输过程中丢失等。应用层并不一定能总能接收到数据。如果需要，应用层可在接收 ESP-NOW 数据时发送一个应答 (ACK) 数据。如果接收 ACK 数据超时，则将重新传输 ESP-NOW 数据。可以为 ESP-NOW 数据设置序列号，从而删除重复的数据。

如果有大量 ESP-NOW 数据要发送，则调用 `esp_now_send()` 一次性发送不大于 250 字节的数据。请注意，发送 ESP-NOW 数据包的发送间隔太短可能导致回调函数返回错误。因此，建议在发送上一次回调函数返回 ACK 后再发送下次 ESP-NOW 数据。发送回调函数从高优先级的 Wi-Fi 任务中运行。因此，不要在回调函数中执行冗长的操作。相反，将必要的数据发布到队列，并交给优先级较低的处理。

接收 ESP-NOW 数据 调用 `esp_now_register_recv_cb` 注册接收回调函数。当接收 ESP-NOW 数据时，需要调用接收回调函数。接收回调函数也在 Wi-Fi 任务中运行。因此，不要在回调函数中执行冗长的操作。相反，将必要的数据发布到队列，并交给优先级较低的处理。

API 参考

Header File

- 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
Chapter 2. API

- ESP_ERR_ESPNOW_NOT_INIT: ESPNOW is not initialized

**esp_err_t esp_now_register_send_cb (esp_now_send_cb_t cb)**
Register callback function of sending ESPNOW data.

**Return**
- ESP_OK: succeed
- ESP_ERR_ESPNOW_NOT_INIT: ESPNOW is not initialized
- ESP_ERR_ESPNOW_INTERNAL: internal error

**Parameters**
- cb: callback function of sending ESPNOW data

**esp_err_t esp_now_unregister_send_cb (void)**
Unregister callback function of sending ESPNOW data.

**Return**
- ESP_OK: succeed
- ESP_ERR_ESPNOW_NOT_INIT: ESPNOW is not initialized

**esp_err_t esp_now_send (const uint8_t* peer_addr, const uint8_t* data, size_t len)**
Send ESPNOW data.

**Attention**
1. If peer_addr is not NULL, send data to the peer whose MAC address matches peer_addr
2. If peer_addr is NULL, send data to all of the peers that are added to the peer list
3. The maximum length of data must be less than ESP_NOW_MAX_DATA_LEN
4. The buffer pointed to by data argument does not need to be valid after esp_now_send returns

**Return**
- ESP_OK: succeed
- ESP_ERR_ESPNOW_NOT_INIT: ESPNOW is not initialized
- ESP_ERR_ESPNOW_ARG: invalid argument
- ESP_ERR_ESPNOW_INTERNAL: internal error
- ESP_ERR_ESPNOW_NO_MEM: out of memory
- ESP_ERR_ESPNOW_NOT_FOUND: peer is not found
- ESP_ERR_ESPNOW_IF: current WiFi interface doesn’t match that of peer

**Parameters**
- peer_addr: peer MAC address
- data: data to send
- len: length of data

**esp_err_t esp_now_add_peer (const esp_now_peer_info_t* peer)**
Add a peer to peer list.

**Return**
- ESP_OK: succeed
- ESP_ERR_ESPNOW_NOT_INIT: ESPNOW is not initialized
- ESP_ERR_ESPNOW_ARG: invalid argument
- ESP_ERR_ESPNOW_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.

**Return**
- ESP_OK: succeed
- ESP_ERR_ESPNOW_NOT_INIT: ESPNOW is not initialized
- ESP_ERR_ESPNOW_ARG: invalid argument
- ESP_ERR_ESPNOW_NOT_FOUND: peer is not found

**Parameters**
- from_head: fetch from head of list or not
- peer: peer information

**bool esp_now_is_peer_exist(const uint8_t *peer_addr)**

Peer exists or not.

**Return**
- true: peer exists
- false: peer not exists

**Parameters**
- peer_addr: peer MAC address

**esp_err_t esp_now_get_peer_num(esp_now_peer_num_t *num)**

Get the number of peers.

**Return**
- ESP_OK: succeed
- ESP_ERR_ESPNOW_NOT_INIT: ESPNOW is not initialized
- ESP_ERR_ESPNOW_ARG: invalid argument

**Parameters**
- num: number of peers

**esp_err_t esp_now_set_pmk(const uint8_t *pmk)**

Set the primary master key.

**Attention** 1. primary master key is used to encrypt local master key

**Return**
- ESP_OK: succeed
- ESP_ERR_ESPNOW_NOT_INIT: ESPNOW is not initialized
- ESP_ERR_ESPNOW_ARG: invalid argument

**Parameters**
- pmk: primary master key
**Structures**

```c
struct esp_now_peer_info
    ESPNOW peer information parameters.
```

### Public Members

- `uint8_t peer_addr[ESP_NOW_ETH_ALEN]`  
  ESPNOW peer MAC address that is also the MAC address of station or softap

- `uint8_t lmk[ESP_NOW_KEY_LEN]`  
  ESPNOW peer local master key that is used to encrypt data

- `uint8_t channel`  
  Wi-Fi channel that peer uses to send/receive ESPNOW data. If the value is 0, use the current channel which station or softap is on. Otherwise, it must be set as the channel that station or softap is on.

- `wifi_interface_t ifidx`  
  Wi-Fi interface that peer uses to send/receive ESPNOW data

- `bool encrypt`  
  ESPNOW data that this peer sends/receives is encrypted or not

- `void *priv`  
  ESPNOW peer private data

```c
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
Chapter 2. API

**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**
enum 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-MESH 編程指南**

这是 ESP-MESH 的编程指南，包括 API 参考和编码示例。本指南分为以下部分：
1. ESP-MESH 编程模型
2. 编写 ESP-MESH 应用程序
3. 自组网
4. 应用实例
5. API 参考

有关 ESP-MESH 协议的文档，请见 ESP-MESH API 指南。有关 ESP-MESH 开发框架的更多内容，请见 ESP-MESH 开发框架。
ESP-MESH 编程模型

软件栈  ESP-MESH 软件栈基于 Wi-Fi 驱动程序和 FreeRTOS 构建，某些情况下（如根节点）也会使用 LwIP 软件栈。下图展示了 ESP-MESH 软件栈。

系统事件  应用程序可通过 ESP-MESH 事件与 ESP-MESH 交互。由于 ESP-MESH 构建在 Wi-Fi 软件栈之上，因此也可以通过 Wi-Fi 事件任务与 Wi-Fi 驱动程序进行交互。下图展示了 ESP-MESH 应用程序中各种系统事件的接口。

mesh_event_id_t 定义了所有可能的 ESP-MESH 事件，并且可以指示父节点和子节点的连接或断开等事件。应用程序如需使用 ESP-MESH 事件，则必须通过 esp_event_handler_register() 将 Mesh 事件处理器程序注册在默认事件任务中。注册完成后，ESP-MESH 事件将包含与应用程序有关事件相关的处理程序。

Mesh 事件的典型应用场景包括：使用 MESH_EVENT_PARENT_CONNECTED 和 MESH_EVENT_CHILD_CONNECTED 事件来指示节点何时可以开始传输上行和下行的数据。同样，也可以使用 IP_EVENT_STA_GOT_IP 和 IP_EVENT_STA_LOST_IP 事件来指示根节点何时可以向外部 IP 网络传输数据。

警告：在自组网模式下使用 ESP-MESH 时，用户必须确保不得调用 Wi-Fi API。原因在于：自组网模式将在内部调用 Wi-Fi API 实现连接/断开/扫描等操作。此时，如果外部应用程序调用 Wi-Fi API（包括来自回调函数和 Wi-Fi 事件处理器程序的调用）都可能会干扰 ESP-MESH 的自组网行为。因此，用户不应该在 esp_mesh_start() 和 esp_mesh_stop() 之间调用 Wi-Fi API。
LwIP & ESP-MESH

应用程序无需通过LwIP层即可直接访问ESP-MESH软件栈。LwIP层仅在根节点和外部IP网络的数据发送与接收时会用到。但是，由于每个节点都有可能成为根节点（由于自动根节点选择机制的存在），每个节点仍须初始化LwIP软件栈。

每个节点都需要通过调用tcpip_adapter_init()初始化LwIP软件栈。为了防止非根节点访问LwIP，应用程序应该在LwIP初始化完成后再停止以下服务：

- SoftAP接口上的DHCP服务器服务。
- Station接口上的DHCP客户端服务。

下方代码片段展示了如何为ESP-MESH应用程序进行LwIP初始化。

```c
/* tcpip 初始化 */
tcip_adapter_init();
/*
 * 对于 MESH
 * 默认情况下，在 SoftAP接口上停止DHCP服务器
 * 默认情况下，在Station接口上停止DHCP客户端
 */
ESP_ERROR_CHECK(tcip_adapter_dhcps_stop(TCPIP_ADAPTER_IF_AP));
ESP_ERROR_CHECK(tcip_adapter_dhcpc_stop(TCPIP_ADAPTER_IF_STA));
```

注解：ESP-MESH的根节点必须与路由器连接。因此，当一个节点成为根节点时，该节点对应的处理程序必须启动DHCP客户端服务并立即获取IP地址。这样做允许其他节点开始向/从外部IP网络发送/接收数据包。但是，如果使用静态IP设置，则不需要执行此步骤。

编写ESP-MESH应用程序

ESP-MESH在正常启动前必须先初始化LwIP和Wi-Fi软件栈。下方代码展示了ESP-MESH在开始自身初始化前必须完成的步骤。

```c
tcip_adapter_init();
/*
 * 对于 MESH
 * 默认情况下，在SoftAP接口上停止DHCP服务器
 * 默认情况下，在Station接口上停止DHCP客户端
 */
ESP_ERROR_CHECK(tcip_adapter_dhcps_stop(TCPIP_ADAPTER_IF_AP));
ESP_ERROR_CHECK(tcip_adapter_dhcpc_stop(TCPIP_ADAPTER_IF_STA));

/* 事件初始化 */
ESP_ERROR_CHECK(esp_event_loop_create_default());

/*Wi-Fi 初始化 */
wifi_init_config_t config = WIFI_INIT_CONFIG_DEFAULT();
ESP_ERROR_CHECK(esp_wifi_init(&config));

/* 注册IP事件处理器 */
ESP_ERROR_CHECK(esp_event_handler_register(IP_EVENT, IP_EVENT_STA_GOT_IP, &ip_event_handler, NULL));
ESP_ERROR_CHECK(esp_wifi_set_storage(WIFI_STORAGE_FLASH));
ESP_ERROR_CHECK(esp_wifi_start());
```

在完成LwIP和Wi-Fi的初始化后，需完成以下三个步骤以启动并运行ESP-MESH。

1. 初始化Mesh
2. 配置ESP-MESH网络
3. 启动Mesh

初始化Mesh下方代码片段展示如何初始化ESP-MESH。
配置 ESP-MESH 网络 ESP-MESH 可通过 `esp_mesh_set_config()` 进行配置，并使用 `mesh_cfg_t` 构建体传递参数。该构建体包含以下 ESP-MESH 的配置参数:

<table>
<thead>
<tr>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel (信道)</td>
<td>1 到 14 信道</td>
</tr>
<tr>
<td>Mesh ID</td>
<td>ESP-MESH 网络的 ID, 见 <code>mesh_addr_t</code>。</td>
</tr>
<tr>
<td>Router (路由器)</td>
<td>路由器配置，见 <code>mesh_router_t</code>。</td>
</tr>
<tr>
<td>Mesh AP</td>
<td>Mesh AP 配置，见 <code>mesh_ap_cfg_t</code>。</td>
</tr>
<tr>
<td>Crypto Functions (加密函数)</td>
<td>Mesh IE 的加密函数，见 <code>mesh_crypto_funcs_t</code>。</td>
</tr>
</tbody>
</table>

下方代码片段展示如何配置 ESP-MESH。

```c
/* 默认启用 Mesh IE 加密 */
mesh_cfg_t cfg = MESH_INIT_CONFIG_DEFAULT();
/* Mesh ID */
memcpy((uint8_t *)&cfg.mesh_id, MESH_ID, 6);
/* 信道 (需与路由器信道匹配) */
cfg.channel = CONFIG_MESH_CHANNEL;
/* 路由器 */
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));
```

启动 Mesh 下方代码片段展示如何启动 ESP-MESH。

```c
/* 启动 Mesh */
ESP_ERROR_CHECK(esp_mesh_start());
```

启动 ESP-MESH 后，应用程序应检查 ESP-MESH 事件，以确定它是何时连接到网络的。接后，应用程序可使用 `esp_mesh_send()` 和 `esp_mesh_recv()` 在 ESP-MESH 网络中发送、接收数据包。

自组网 自组网是 ESP-MESH 的功能之一，允许节点自动扫描/选择/连接/重新连接到其他节点和路由器。此功能允许 ESP-MESH 网络具有很高的自主性，可以适应变化的动态网络拓扑结构和环境。启用自组网功能后，ESP-MESH 网络中的节点能够自主完成以下操作:

- 选择或选举根节点（见建立网络中的自动根节点选择）
- 选择首选的父节点（见建立网络中的父节点选择）
- 网络断开时自动重新连接（见管理网络中的中断父节点失败）

启用自组网功能后，ESP-MESH 软件栈将内部调用 Wi-Fi API。因此，在启用自组网功能时，应用层不得调用 Wi-Fi API，否则会干扰 ESP-MESH 的工作。

关于自组网 应用程序可以在运行时通过调用 `esp_mesh_set_self_organized()` 函数，启用或禁用自组网功能。该函数具有以下两个参数:

<table>
<thead>
<tr>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>self_organized</code></td>
<td>是否启用自组网 (true 启用, false 禁用)。</td>
</tr>
</tbody>
</table>

自组网的一个优点是其自我恢复能力。当网络中某个节点失败时，自组网会重新组织网络，确保数据的连续传输。ESP-MESH 的自组网功能还允许网络中节点的动态添加和移除，提高了网络的灵活性和可扩展性。

自组网的缺点包括可能的网络效率降低，特别是在网络负载过高的情况下。由于自组网的动态性，可能会导致网络中的数据传输延迟。

总之，ESP-MESH 的自组网功能提供了一种灵活的网络连接方式，适合于需要动态网络结构的物联网应用场景。在使用自组网时，应用程序需要根据具体需求来调整节点的配置和管理策略，以平衡网络性能和稳定性之间的关系。
Chapter 2. API 参考

- bool enable 指定启用或禁用自组网功能。
- bool select_parent 指定在启用自组网功能时是否应选择新的父节点。根据节点类型和节点当前状态，选择新的父节点具有不同的作用。在禁用自组网功能时，此参数不使用。

禁用自组网 下方代码片段展示了如何禁用自组网功能。

```c
//禁用自组网
esp_mesh_set_self_organized(false, false);
```

ESP-MESH 将在禁用自组网时尝试维护节点的当前 Wi-Fi 状态。
- 如果节点先前已连接到其他节点，则将保持连接。
- 如果节点先前已断开连接并且正在扫描父节点或路由器，则将停止扫描。
- 如果节点以前尝试重新连接到父节点或路由器，则将停止重新连接。

启用自组网 ESP-MESH 将尝试在启用自组网时保持节点的当前 Wi-Fi 状态。但是，根据节点类型以及是否选择了新的父节点，节点的 Wi-Fi 状态可能会发生变化。下表显示了启用自组网的效果。

<table>
<thead>
<tr>
<th>是否选择父节点</th>
<th>是否为根节点</th>
<th>作用</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>N</td>
<td>已连接到父节点的节点将保持连接。</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>之前扫描父节点的节点将停止扫描，调用 <code>esp_mesh_connect()</code> 重新连接。</td>
</tr>
<tr>
<td>Y</td>
<td>N</td>
<td>已连接到路由器的根节点将保持连接。</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>从路由器断开的根节点需调用 <code>esp_mesh_connect()</code> 进行重连。</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>是否选择父节点</th>
<th>是否为根节点</th>
<th>作用</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>N</td>
<td>已连接到父节点的节点将自动选择新父节点并连接。</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>重新连接父节点并进行重连。</td>
</tr>
</tbody>
</table>

下表代码片段展示了如何启用自组网功能。

```c
//启用自组网，并选择一个新的父节点
esp_mesh_set_self_organized(true, true);
...
//启用自组网并手动重新连接
esp_mesh_set_self_organized(true, false);
esp_mesh_connect();
```

调用 Wi-Fi API 在有些情况下，应用程序可能希望在使用 ESP-MESH 期间调用 Wi-Fi API，例如，应用程序可能需要手动扫描邻近的接入点 (AP)。但在应用程序调用任何 Wi-Fi API 之前，必须先禁用自组网。否则，ESP-MESH 软件栈可能会同时调用 Wi-Fi API，进而影响应用程序的正常调用。

应用程序不应在 `esp_mesh_set_self_organized()` 之间调用 Wi-Fi API。下方代码片段展示了应用程序如何在 ESP-MESH 运行期间安全地调用 `esp_wifi_scan_start()`。

```c
//禁用自组网
esp_mesh_set_self_organized(0, 0);
//停止任何正在进行的扫描
esp_wifi_scan_stop();
//手动启动扫描待完成时自动停止
esp_wifi_scan_start();
//进程扫描结果
```

(下页继续)
Chapter 2. API

```
//如果为根节点且未连接，则重新启用自组网
esp_mesh_set_self_organized(1, 0);

//如果不为根节点且未连接，则重新启用自组网
esp_mesh_set_self_organized(1, 1);

//如果为根节点且未连接，则重新启用
esp_mesh_set_self_organized(1, 0);  //不选择新的父节点
esp_mesh_connect();               //手动重新连接到路由器
```

**API 参考**

**Header File**

- esp_wifi/include/esp_mesh.h

**Functions**

- `esp_err_t esp_mesh_init(void)`
  
  Mesh initialization.

  - Check whether Wi-Fi is started.
  - Initialize mesh global variables with default values.

  **Attention** This API shall be called after Wi-Fi is started.

  **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**

Chapter 2. API 参考

- ESP_OK
- ESP_FAIL
- ESP_ERR_MESH_NOT_INIT
- ESP_ERR_MESH_NOT_CONFIG
- ESP_ERR_MESH_NO_MEMORY

**esp_err_t esp_mesh_stop(void)**

Stop mesh.

- Deinitialize mesh IE.
- Disconnect with current parent.
- Disassociate all currently associated children.
- Stop mesh network management service.
- Unregister mesh packets receive callback.
- Delete TX and RX queues.
- Release resources.
- Restore Wi-Fi softAP to default settings if Wi-Fi dual mode is enabled.
- Set Wi-Fi Power Save type to WIFI_PS_NONE.

**Return**

- ESP_OK
- ESP_FAIL

**esp_err_t esp_mesh_send(const mesh_addr_t *to, const mesh_data_t *data, int flag, const mesh_opt_t opt[], int opt_count)**

Send a packet over the mesh network.

- Send a packet to any device in the mesh network.
- Send a packet to external IP network.

**Attention** This API is not reentrant.

**Return**

- ESP_OK
- ESP_FAIL
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_START
- ESP_ERR_MESH_DISCONNECTED
- ESP_ERR_MESH_OPT_UNKNOWN
- ESP_ERR_MESH_EXCEED_MTU
- ESP_ERR_MESH_NO_MEMORY
- ESP_ERR_MESH_TIMEOUT
- 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 MESHPROTO_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-block, MESH_DATA_NONBLOCK should be set.
- 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_recv (mesh_addr_t *from, mesh_data_t *data, int timeout_ms, int *flag, mesh_opt_t opt[], int opt_count)
```

Receive a packet targeted to self over the mesh network.

flag could be MESH_DATA_FROMDS or MESH_DATA_TODS.

**Attention** Mesh RX queue should be checked regularly to avoid running out of memory.
- Use esp_mesh_get_rx_pending() to check the number of packets available in the queue waiting to be received by applications.

**Return**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_START
- ESP_ERR_MESH_TIMEOUT
- ESP_ERR_MESH_DISCARD

**Parameters**
- [out] from: the address of the original source of the packet
- [out] data: pointer to the received mesh packet
  - Field proto is the data protocol in use. Should follow it to parse the received data.
  - Field tos is the transmission tos (type of service) in use.
- [in] timeout_ms: wait time if a packet isn’t immediately available (0: no wait, port-MAX_DELAY: wait forever)
- [out] flag: bitmap for data received
  - MESH_DATA_FROMDS represents data from external IP network
  - MESH_DATA_TODS represents data directed upward within the mesh network

**Parameters**
- [out] opt: options desired to receive
  - MESH_OPT_RECV_DS_ADDR attaches the DS address
- [in] opt_count: option count desired to receive
  - Currently, this API only takes one option, so opt_count is only supported to be 1.

```
esp_err_t esp_mesh_recv_toDS (mesh_addr_t *from, mesh_addr_t *to, mesh_data_t *data, int timeout_ms, int *flag, mesh_opt_t opt[], int opt_count)
```

Receive a packet targeted to external IP network.

- Root uses this API to receive packets destined to external IP network
- Root forwards the received packets to the final destination via socket.
- If no socket connection is ready to send out the received packets and this esp_mesh_recv_toDS() hasn’t been called by applications, packets from the whole mesh network will be pending in toDS queue.

Use esp_mesh_get_rx_pending() to check the number of packets available in the queue waiting to be received
by applications in case of running out of memory in the root.

Using esp_mesh_set_xon_qsize() users may configure the RX queue size, default:32. If this size is too large, and esp_mesh_recv_toDS() isn’t called in time, there is a risk that a great deal of memory is occupied by the pending packets. If this size is too small, it will impact the efficiency on upstream. How to decide this value depends on the specific application scenarios.

flag could be MESH_DATA_TODS.

**Attention**  This API is only called by the root.

**Return**

- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_START
- ESP_ERR_MESH_TIMEOUT
- ESP_ERR_MESH_DISCARD
- ESP_ERR_MESH_RECV_RELEASE

**Parameters**

- **[out]** from: the address of the original source of the packet
- **[out]** to: the address contains remote IP address and port (IPv4:PORT)
- **[out]** data: pointer to the received packet
  - Contain the protocol and applications should follow it to parse the data.
- **[in]** timeout_ms: wait time if a packet isn’t immediately available (0:no wait, port-MAX_DELAY:wait forever)
- **[out]** flag: bitmap for data received
  - MESH_DATA_TODS represents the received data target to external IP network. Root shall forward this data to external IP network via the association with router.

**Attention**  This API is only called by the root.

**Return**

- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

**Parameters**

- **[in]** config: pointer to mesh stack configuration

### esp_err_t esp_mesh_set_config(const mesh_cfg_t *config)

Set mesh stack configuration.

- Use MESH_INIT_CONFIG_DEFAULT() to initialize the default values, mesh IE is encrypted by default.
- Mesh network is established on a fixed channel (1-14).
- Mesh event callback is mandatory.
- Mesh ID is an identifier of an MBSS. Nodes with the same mesh ID can communicate with each other.
- Regarding to the router configuration, if the router is hidden, BSSID field is mandatory.

If BSSID field isn’t set and there exists more than one router with same SSID, there is a risk that more roots than one connected with different BSSID will appear. It means more than one mesh network is established with the same mesh ID.

Root conflict function could eliminate redundant roots connected with the same BSSID, but couldn’t handle roots connected with different BSSID. Because users might have such requirements of setting up routers with same SSID for the future replacement. But in that case, if the above situations happen, please make sure applications implement forward functions on the root to guarantee devices in different mesh networks can communicate with each other. max_connection of mesh softAP is limited by the max number of Wi-Fi softAP supported (max:10).

**Attention**  This API shall be called before mesh is started after mesh is initialized.

**Return**

- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

**Parameters**

- **[in]** config: pointer to mesh stack configuration

### esp_err_t esp_mesh_get_config(mesh_cfg_t *config)

Get mesh stack configuration.
Return
• ESP_OK
• ESP_ERR_MESH_ARGUMENT

Parameters
• [out] config: pointer to mesh stack configuration

`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

`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
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

**Parameters**

- [in] pwd: pointer to the password
- [in] len: password length

### esp_err_t esp_mesh_set_ap_authmode (wifi_auth_mode_t authmode)

Set mesh softAP authentication mode.

**Attention** This API shall be called before mesh is started.

**Return**

- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

**Parameters**

- [in] authmode: authentication mode

### wifi_auth_mode_t esp_mesh_get_ap_authmode (void)

Get mesh softAP authentication mode.

**Return** authentication mode

### esp_err_t esp_mesh_set_ap_connections (int connections)

Set mesh softAP max connection value.

**Attention** This API shall be called before mesh is started.

**Return**

- ESP_OK
- ESP_ERR_MESH_ARGUMENT

**Parameters**

- [in] connections: the number of max connections

### int esp_mesh_get_ap_connections (void)

Get mesh softAP max connection configuration.

**Return** the number of max connections

### int esp_mesh_get_layer (void)

Get current layer value over the mesh network.
Attention This API shall be called after having received the event MESH_EVENT_PARENT_CONNECTED.

Return layer value

`esp_err_t esp_mesh_get_parent_bssid(mesh_addr_t *bssid)`
Get the parent BSSID.

Attention This API shall be called after having received the event MESH_EVENT_PARENT_CONNECTED.

Return

- ESP_OK
- ESP_FAIL

Parameters

- [out] bssid: pointer to parent BSSID

`bool esp_mesh_is_root(void)`
Return whether the device is the root node of the network.

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_ERR_MESH_QUEUE_FULL
- ESP_ERR_MESH_DISCARD
- ESP_FAIL
Chapter 2. API 参考

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

*esp_err_t* 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

*esp_err_t* esp_mesh_get_ap_assoc_expire (void)
Get mesh softAP associate expired time.

return seconds

*esp_err_t* 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)

*esp_err_t* esp_mesh_get_routing_table_size (void)
Get the number of devices in this device’s sub-network (including self)

Return the number of devices over this device’s sub-network (including self)

*esp_err_t* esp_mesh_get_routing_table (mesh_addr_t *mac, int len, int *size)
Get routing table of this device’s sub-network (including itself)

Return

• ESP_OK
• ESP_ERR_MESH_ARGUMENT

Parameters

• [out] mac: pointer to routing table
• [in] len: routing table size(in bytes)
• [out] size: pointer to the number of devices in routing table (including itself)

*esp_err_t* esp_mesh_post_toDS_state (bool reachable)
Post the toDS state to the mesh stack.
**Attention**  This API is only for the root.

**Return**
- ESP_OK
- ESP_FAIL

**Parameters**
- **[in]** reachable: this state represents whether the root is able to access external IP network

`esp_err_t esp_mesh_get_tx_pending(mesh_tx_pending_t *pending)`
Return the number of packets pending in the queue waiting to be sent by the mesh stack.

**Return**
- ESP_OK
- ESP_FAIL

**Parameters**
- **[out]** pending: pointer to the TX pending

`esp_err_t esp_mesh_get_rx_pending(mesh_rx_pending_t *pending)`
Return the number of packets available in the queue waiting to be received by applications.

**Return**
- ESP_OK
- ESP_FAIL

**Parameters**
- **[out]** pending: pointer to the RX pending

`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.

**Return**
the number of upQ for a certain 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.

**Return**
the number of queue

`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

```c
esp_err_t esp_mesh_delete_group_id(const mesh_addr_t *addr, int num)
```
Delete group ID addresses.

Return

- ESP_OK
- ESP_MESH_ERR_ARGUMENT

Parameters

- [in] addr: pointer to deleted group ID address
- [in] num: the number of group ID addresses

```c
int esp_mesh_get_group_num(void)
```
Get the number of group ID addresses.

Return

the number of group ID addresses

```c
esp_err_t esp_mesh_get_group_list(mesh_addr_t *addr, int num)
```
Get group ID addresses.

Return

- ESP_OK
- ESP_MESH_ERR_ARGUMENT

Parameters

- [out] addr: pointer to group ID addresses
- [in] num: the number of group ID addresses

```c
int 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

```c
int esp_mesh_get_capacity_num(void)
```
Get mesh network capacity.

Return

mesh network capacity

```c
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.

```c
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.

**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**
ture/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.

```c
esp_err_t esp_mesh_scan_get_ap_ie_len(int *len)
Get mesh networking IE length of one AP.
```

Return
- ESP_OK
- ESP_ERR_WIFI_NOT_INIT
- ESP_ERR_WIFI_ARG
- ESP_ERR_WIFI_FAIL

Parameters
- [out] len: mesh networking IE length

```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
Chapter 2. API

- [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.

- 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

**esp_err_t esp_mesh_enable_ps (void)**
Enable mesh Power Save function.

**Attention**  This API shall be called before mesh is started.

**Return**
- ESP_OK
- ESP_ERR_WIFI_NOT_INIT
- ESP_ERR_MESH_NOT_ALLOWED

**esp_err_t esp_mesh_disable_ps (void)**
Disable mesh Power Save function.

**Attention**  This API shall be called before mesh is started.

**Return**
- ESP_OK
- ESP_ERR_WIFI_NOT_INIT
- ESP_ERR_MESH_NOT_ALLOWED

**bool esp_mesh_is_ps_enabled (void)**
Check whether the mesh Power Save function is enabled.

**Return**  true/false

**bool esp_mesh_is_device_active (void)**
Check whether the device is in active state.

- If the device is not in active state, it will neither transmit nor receive frames.

**Return**  true/false

**esp_err_t esp_mesh_set_active_duty_cycle (int dev_duty, int dev_duty_type)**
Set the device duty cycle and type.

- The range of dev_duty values is 1 to 100. The default value is 12.
- 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_DUTYREQUEST, the device will use a nwk_duty provided by the network.
- If dev_duty_type is set to MESH_PSDEVICE_DUTYDEMAND, 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_PSNETWORK_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.
Chapter 2. API

- The range of nwk_duty values is 1 to 100. The default value is 12.
- 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).
- applied_rule could be MESH_PS_NETWORK_DUTY_APPLIED_ENTIRE or MESH_PS_NETWORK_DUTY_APPLIED_UPLINK.
  - 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: MESH_PS_NETWORK_DUTY_APPLIED_ENTIRE or MESH_PS_NETWORK_DUTY_APPLIED_UPLINK

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

Unions

union mesh_addr_t
    #include <esp_mesh.h> Mesh address.

Public Members

uint8_t addr[6]
    mac address

mip_t mip
    mip address

union mesh_event_info_t
    #include <esp_mesh.h> Mesh event information.

Public Members

mesh_event_channel_switch_t channel_switch
    channel switch

mesh_event_child_connected_t child_connected
    child connected

mesh_event_child_disconnected_t child_disconnected
    child disconnected

mesh_event_routing_table_change_t routing_table
    routing table change

mesh_event_connected_t connected
    parent connected

mesh_event_disconnected_t disconnected
    parent disconnected

mesh_event_no_parent_found_t no_parent
    no parent found

mesh_event_layer_change_t layer_change
    layer change

mesh_event_toDS_state_t toDS_state
    toDS state, devices shall check this state firstly before trying to send packets to external IP network. This state indicates right now whether the root is capable of sending packets out. If not, devices had better to wait until this state changes to be MESH_TODS_REACHABLE.

mesh_event_vote_started_t vote_started
    vote started

mesh_event_root_address_t root_addr
    root address

mesh_event_root_switch_req_t switch_req
    root switch request
Chapter 2. API 参考

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
Chapter 2. API

```c
uint16_t self_layer
layer

uint8_t duty
parent duty
```

```c
struct mesh_event_no_parent_found_t
No parent found information.
```

**Public Members**

- `int scan_times`
  - scan times being through

```c
struct mesh_event_layer_change_t
Layer change information.
```

**Public Members**

- `uint16_t new_layer`
  - new layer

```c
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

```c
mesh_addr_t rc_addr
root address specified by users via API esp_mesh_waive_root()
```

```c
struct mesh_event_find_network_t
find a mesh network that this device can join
```

**Public Members**

- `uint8_t channel`
  - channel number of the new found network
- `uint8_t router_bssid[6]`
  - router BSSID

```c
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()

```c
mesh_addr_t rc_addr
the address of root switch requester
```

```c
struct mesh_event_root_conflict_t
Other powerful root address.
```
Public Members

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.

Public Members

uint16_t rt_size_new
   the new value

uint16_t rt_size_change
   the changed value

struct mesh_event_root_fixed_t
   Root fixed.

Public Members

bool is_fixed
   status

struct mesh_event_scan_done_t
   Scan done event information.

Public Members

uint8_t number
   the number of APs scanned

struct mesh_event_network_state_t
   Network state information.

Public Members

bool is_rootless
   whether current mesh network has a root

struct mesh_event_ps_duty_t
   PS duty information.

Public Members

uint8_t duty
   parent or child duty

struct mesh_event_child_connected_t child_connected
   child info

struct mesh_opt_t
   Mesh option.
Public Members

- `uint8_t type`
  - option type
- `uint16_t len`
  - option length
- `uint8_t* val`
  - option value

**struct mesh_data_t**
Mesh data for `esp_mesh_send()` and `esp_mesh_recv()`

Public Members

- `uint8_t* data`
  - data
- `uint16_t size`
  - data size
  - `mesh_proto_t proto`
    - data protocol
  - `mesh_tos_t tos`
    - data type of service

**struct mesh_router_t**
Router configuration.

Public Members

- `uint8_t ssid[32]`
  - SSID
- `uint8_t ssid_len`
  - length of SSID
- `uint8_t bssid[6]`
  - BSSID, if this value is specified, users should also specify “allow_router_switch”.
  - `bool allow_router_switch`
    - if the BSSID is specified and this value is also set, when the router of this specified BSSID fails to be found after “fail” (`mesh_attempts_t`) times, the whole network is allowed to switch to another router with the same SSID. The new router might also be on a different channel. The default value is false. There is a risk that if the password is different between the new switched router and the previous one, the mesh network could be established but the root will never connect to the new switched router.

**struct mesh_ap_cfg_t**
Mesh softAP configuration.

Public Members

- `uint8_t password[64]`
  - mesh softAP password
- `uint8_t max_connection`
  - max number of stations allowed to connect in, max 10
```c
struct mesh_cfg_t
  Mesh initialization configuration.

  **Public Members**

  uint8_t channel
    channel, the mesh network on

  bool allow_channel_switch
    if this value is set, when “fail” (mesh_attempts_t) times is reached, device will change to a full channel
    scan for a network that could join. The default value is false.

  mesh_addr_t mesh_id
    mesh network identification

  mesh_router_t router
    router configuration

  mesh_ap_cfg_t mesh_ap
    mesh softAP configuration

  const mesh_crypto_funcs_t *crypto_funcs
    crypto functions

struct mesh_vote_t
  Vote.

  **Public Members**

  float percentage
    vote percentage threshold for approval of being a root

  bool is_rc_specified
    if true, rc_addr shall be specified (Unimplemented). if false, attempts value shall be specified to make
    network start root election.

  mesh_rc_config_t config
    vote address configuration

struct mesh_tx_pending_t
  The number of packets pending in the queue waiting to be sent by the mesh stack.

  **Public Members**

  int to_parent
    to parent queue

  int to_parent_p2p
    to parent (P2P) queue

  int to_child
    to child queue

  int to_child_p2p
    to child (P2P) queue

  int mgmt
    management queue

  int broadcast
    broadcast and multicast queue
```

Espressif Systems 488 Release v4.3-dev-1561-g357a277603
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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**

<table>
<thead>
<tr>
<th>Macro Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MESH_ROOT_LAYER</td>
<td>root layer value</td>
</tr>
<tr>
<td>MESH_MTU</td>
<td>max transmit unit (in bytes)</td>
</tr>
<tr>
<td>MESH_MPS</td>
<td>max payload size (in bytes)</td>
</tr>
<tr>
<td>ESP_ERR_MESH_WIFI_NOT_START</td>
<td>Mesh error code definition. Wi-Fi isn’t started</td>
</tr>
<tr>
<td>ESP_ERR_MESH_NOT_INIT</td>
<td>mesh isn’t initialized</td>
</tr>
<tr>
<td>ESP_ERR_MESH_NOT_CONFIG</td>
<td>mesh isn’t configured</td>
</tr>
<tr>
<td>ESP_ERR_MESH_NOT_START</td>
<td>mesh isn’t started</td>
</tr>
<tr>
<td>ESP_ERR_MESH_NOT_SUPPORTED</td>
<td>not supported yet</td>
</tr>
<tr>
<td>ESP_ERR_MESH_NOT_ALLOWED</td>
<td>operation is not allowed</td>
</tr>
<tr>
<td>ESP_ERR_MESH_NO_MEMORY</td>
<td>out of memory</td>
</tr>
<tr>
<td>ESP_ERR_MESH_ARGUMENT</td>
<td>illegal argument</td>
</tr>
<tr>
<td>ESP_ERR_MESH_EXCEED_MTU</td>
<td>packet size exceeds MTU</td>
</tr>
<tr>
<td>ESP_ERR_MESH_TIMEOUT</td>
<td>timeout</td>
</tr>
<tr>
<td>ESP_ERR_MESH_DISCONNECTED</td>
<td>disconnected with parent on station interface</td>
</tr>
<tr>
<td>ESP_ERR_MESH_QUEUE_FAIL</td>
<td>queue fail</td>
</tr>
<tr>
<td>ESP_ERR_MESH_QUEUE_FULL</td>
<td>queue full</td>
</tr>
<tr>
<td>ESP_ERR_MESH_NO_PARENT_FOUND</td>
<td>no parent found to join the mesh network</td>
</tr>
<tr>
<td>ESP_ERR_MESH_NO_ROUTE_FOUND</td>
<td>no route found to forward the packet</td>
</tr>
</tbody>
</table>
ESP_ERR_MESH_OPTION_NULL
    no option found

ESP_ERR_MESH_OPTION_UNKNOWN
    unknown option

ESP_ERR_MESH_XON_NO_WINDOW
    no window for software flow control on upstream

ESP_ERR_MESH_INTERFACE
    low-level Wi-Fi interface error

ESP_ERR_MESH_DISCARD_DUPLICATE
    discard the packet due to the duplicate sequence number

ESP_ERR_MESH_DISCARD
    discard the packet

ESP_ERR_MESH_VOTING
    vote in progress

ESP_ERR_MESH_XMIT
    XMIT

ESP_ERR_MESH_QUEUE_READ
    error in reading queue

ESP_ERR_MESH_PS
    mesh PS is not specified as enable or disable

ESP_ERR_MESH_RECV_RELEASE
    release esp_mesh_recv_toDS

MESH_DATA_ENC
    Flags bitmap for esp_mesh_send() and esp_mesh_recv()
    data encrypted (Unimplemented)

MESH_DATA_P2P
    point-to-point delivery over the mesh network

MESH_DATA_FROMDS
    receive from external IP network

MESH_DATA_TODS
    identify this packet is target to external IP network

MESH_DATA_NONBLOCK
    esp_mesh_send() non-block

MESH_DATA_DROP
    in the situation of the root having been changed, identify this packet can be dropped by new root

MESH_DATA_GROUP
    identify this packet is target to a group address

MESH_OPT_SEND_GROUP
    Option definitions for esp_mesh_send() and esp_mesh_recv()
    data transmission by group; used with esp_mesh_send() and shall have payload

MESH_OPT_RECV_DS_ADDR
    return a remote IP address; used with esp_mesh_send() and esp_mesh_recv()

MESH_ASSOC_FLAG_VOTE_IN_PROGRESS
    Flag of mesh networking IE.
    vote in progress
MESH_ASSOC_FLAG_NETWORK_FREE
   no root in current network
MESH_ASSOC_FLAG_ROOTS_FOUND
   root conflict is found
MESH_ASSOC_FLAG_ROOT_FIXED
   fixed root
MESH_PS_DEVICE_DUTY_REQUEST
   Mesh PS (Power Save) duty cycle type.
   requests to join a network PS without specifying a device duty cycle. After the device joins the network, a
   network duty cycle will be provided by the network
MESH_PS_DEVICE_DUTY_DEMAND
   requests to join a network PS and specifies a demanded device duty cycle
MESH_PS_NETWORK_DUTY_MASTER
   indicates the device is the NWK-DUTY-MASTER (network duty cycle master)
MESH_PS_NETWORK_DUTY_APPLIED_ENTIRE
   Mesh PS (Power Save) duty cycle applied rule.
MESH_PS_NETWORK_DUTY_APPLIED_UPLINK

Type Definitions
typedef mesh_addr_t mesh_event_root_address_t
   Root address.
typedef wifi_event_sta_disconnected_t mesh_event_disconnected_t
   Parent disconnected information.
typedef wifi_event_ap_staconnected_t mesh_event_child_connected_t
   Child connected information.
typedef wifi_event_ap_stadisconnected_t mesh_event_child_disconnected_t
   Child disconnected information.
typedef wifi_event_sta_connected_t mesh_event_router_switch_t
   New router information.

Enumerations
enum mesh_event_id_t
   Enumerated list of mesh event id.

   Values:
   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_MAX
enum mesh_type_t
Device type.

Values:

MESH_IDLE
hasn’t joined the mesh network yet

MESH_ROOT
the only sink of the mesh network. Has the ability to access external IP network

MESH_NODE
intermediate device. Has the ability to forward packets over the mesh network

MESH_LEAF
has no forwarding ability

MESH_STA
connect to router with a standalone Wi-Fi station mode, no network expansion capability

enum mesh_proto_t
Protocol of transmitted application data.

Values:

MESH_PROTO_BIN
binary

MESH_PROTO_HTTP
HTTP protocol

MESH_PROTO_JSON
JSON format

MESH_PROTO_MQTT
MQTT protocol

MESH_PROTO_AP
IP network mesh communication of node’s AP interface

MESH_PROTO_STA
IP network mesh communication of node’s STA interface

enum mesh_tos_t
For reliable transmission, mesh stack provides three type of services.

Values:

MESH_TOS_P2P
provide P2P (point-to-point) retransmission on mesh stack by default

MESH_TOS_E2E
provide E2E (end-to-end) retransmission on mesh stack (Unimplemented)

MESH_TOS_DEF
no retransmission on mesh stack

enum mesh_vote_reason_t
Vote reason.

Values:

MESH_VOTE_REASON_ROOT_INITIATED = 1
vote is initiated by the root

MESH_VOTE_REASON_CHILD_INITIATED
vote is initiated by children
enum mesh_disconnect_reason_t
Mesh disconnect reason code.

Values:
MESH_REASON_CYCLIC = 100
cyclic is detected
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

enum esp_mesh_topology_t
Mesh topology.

Values:
MESH_TOPO_TREE
tree topology
MESH_TOPO_CHAIN
chain topology

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

本部分的 Wi-Fi API 示例代码存放在 ESP-IDF 示例项目的 wifi 目录下。
ESP-MESH 的示例代码存放在 ESP-IDF 示例项目的 mesh 目录下。
2.2.2 以太网

以太网

应用示例
• 以太网基本示例：ethernet/basic.
• 以太网iperf示例：ethernet/iperf.

以太网驱动程序模型
• esp_eth/include/esp_eth.h

以太网通用接口
• esp_eth/include/esp_eth_com.h

以太网MAC接口
• esp_eth/include/esp_eth_mac.h

以太网PHY接口
• esp_eth/include/esp_eth_phy.h

以太网PHY公共寄存器
• esp_eth/include/eth_phy_regs_struct.h

API参考-驱动程序模型

Header File
• esp_eth/include/esp_eth.h

Functions

esp_err_t esp_eth_driver_install(const esp_eth_config_t *config, esp_eth_handle_t *out_hdl)
Install Ethernet driver.

Return
• ESP_OK: install esp_eth driver successfully
• ESP_ERR_INVALID_ARG: install esp_eth driver failed because of some invalid argument
• ESP_ERR_NO_MEM: install esp_eth driver failed because there’s no memory for driver
• ESP_FAIL: install esp_eth driver failed because some other error occurred

Parameters
• [in] config: configuration of the Ethernet driver
• [out] out_hdl: handle of Ethernet driver

esp_err_t esp_eth_driver_uninstall(esp_eth_handle_t hdl)
Uninstall Ethernet driver.

Note It’s not recommended to uninstall Ethernet driver unless it won’t get used any more in application code.
To uninstall Ethernet driver, you have to make sure, all references to the driver are released. Ethernet driver can only be uninstalled successfully when reference counter equals to one.

Return
• ESP_OK: uninstall esp_eth driver successfully
• ESP_ERR_INVALID_ARG: uninstall esp_eth driver failed because of some invalid argument
Chapter 2. API

- ESP_ERR_INVALID_STATE: uninstall esp_eth driver failed because it has more than one reference
- ESP_FAIL: uninstall esp_eth driver failed because some other error occurred

**Parameters**
- [in] hdl: handle of Ethernet driver

**esp_err_t** esp_eth_start(esp_eth_handle_t hdl)

Start Ethernet driver ONLY in standalone mode (i.e. without TCP/IP stack)

**Note** This API will start driver state machine and internal software timer (for checking link status).

**Return**
- ESP_OK: start esp_eth driver successfully
- ESP_ERR_INVALID_ARG: start esp_eth driver failed because of some invalid argument
- ESP_ERR.INVALID_STATE: start esp_eth driver failed because driver has started already
- ESP_FAIL: start esp_eth driver failed because some other error occurred

**Parameters**
- [in] hdl: handle of Ethernet driver

**esp_err_t** esp_eth_stop(esp_eth_handle_t hdl)

Stop Ethernet driver.

**Note** This function does the opposite operation of esp_eth_start.

**Return**
- ESP_OK: stop esp_eth driver successfully
- ESP_ERR.INVALID_ARG: stop esp_eth driver failed because of some invalid argument
- ESP_ERR.INVALID_STATE: stop esp_eth driver failed because driver has not started yet
- ESP_FAIL: stop esp_eth driver failed because some other error occurred

**Parameters**
- [in] hdl: handle of Ethernet driver

**esp_err_t** esp_eth_update_input_path(esp_eth_handle_t hdl, esp_err_t \( \text{stack_input} \) 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

**esp_err_t** esp_eth_transmit(esp_eth_handle_t hdl, void *buf, uint32_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.
Note  Before this function got invoked, the value of “length” should be 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 frame buffer successfully
- ESP_ERR_INVALID_ARG: receive frame buffer failed because of some invalid argument
- ESP_ERR_INVALID_SIZE: input buffer size is not enough to hold the incoming data. in this case, value of returned “length” indicates the real size of incoming data.
- ESP_FAIL: receive frame buffer failed because some other error occurred

Parameters

- [in] hdl: handle of Ethernet driver
- [out] buf: buffer to preserve the received packet
- [out] length: length of the received packet

```c
esp_err_t esp_eth_ioctl (esp_eth_handle_t hdl, esp_eth_io_cmd_t cmd, void *data)
```

MISC IO function of Ethernet driver.

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

Parameters

- [in] hdl: handle of Ethernet driver
- [in] cmd: IO control command
- [in] data: specified data for command

```c
esp_err_t esp_eth_increase_reference (esp_eth_handle_t hdl)
```

Increase Ethernet driver reference.

Note  Ethernet driver handle can be obtained by os timer, netif, etc. It’s dangerous when thread A is using Ethernet but thread B uninstall the driver. Using reference counter can prevent such risk, but care should be taken, when you obtain Ethernet driver, this API must be invoked so that the driver won’t be uninstalled during your using time.

Return

- ESP_OK: increase reference successfully
- ESP_ERR_INVALID_ARG: increase reference failed because of some invalid argument

Parameters

- [in] hdl: handle of Ethernet driver

```c
esp_err_t esp_eth_decrease_reference (esp_eth_handle_t hdl)
```

Decrease Ethernet driver reference.

Return

- ESP_OK: increase reference successfully
- ESP_ERR_INVALID_ARG: increase reference failed because of some invalid argument

Parameters

- [in] hdl: handle of Ethernet driver

```c
struct esp_eth_config_t
```

Configuration of Ethernet driver.

Public Members

```c
esp_eth_mac_t *mac
```

Ethernet MAC object.

```c
esp_eth_phy_t *phy
```

Ethernet PHY object.

```c
uint32_t check_link_period_ms
```

Period time of checking Ethernet link status.
# API 参考

## 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 lowlevel initialization is finished.

**Return**
- ESP_OK: process extra lowlevel initialization successfully
- ESP_FAIL: error occurred when processing extra lowlevel initialization

**Parameters**
- [in] eth_handle: handle of Ethernet driver

## esp_err_t (*on_lowlevel_deinit_done) (esp_eth_handle_t eth_handle)

Callback function invoked when lowlevel deinitialization is finished.

**Return**
- ESP_OK: process extra lowlevel deinitialization successfully
- ESP_FAIL: error occurred when processing extra lowlevel deinitialization

**Parameters**
- [in] eth_handle: handle of Ethernet driver

### Macros

**ETH_DEFAULT_CONFIG** (emac, ephy)

Default configuration for Ethernet driver.

### Type Definitions

**typedef void *esp_eth_handle_t**

Handle of Ethernet driver.

### API 参考-通用接口

#### Header File

- esp_eth/include/esp_eth_com.h

#### Functions

**esp_err_t esp_eth_detect_phy_addr (esp_eth_mediator_t *eth, uint32_t *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
Chapter 2. API

Structures

**struct esp_eth_mediator_s**

Ethernet mediator.

Public Members

```c
esp_err_t (*phy_reg_read)(esp_eth_mediator_t *eth, uint32_t phy_addr, uint32_t phy_reg, uint32_t *reg_value)
```

Read PHY register.

**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

```c
esp_err_t (*phy_reg_write)(esp_eth_mediator_t *eth, uint32_t phy_addr, uint32_t phy_reg, uint32_t reg_value)
```

Write PHY register.

**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

```c
esp_err_t (*stack_input)(esp_eth_mediator_t *eth, uint8_t *buffer, uint32_t length)
```

Deliver packet to upper stack.

**Return**
- ESP_OK: deliver packet to upper stack successfully
- ESP_FAIL: deliver packet failed because some error occurred

**Parameters**
- **[in] eth**: mediator of Ethernet driver
- **[in] buffer**: packet buffer
- **[in] length**: length of the packet

```c
esp_err_t (*on_state_changed)(esp_eth_mediator_t *eth, esp_eth_state_t state, void *args)
```

Callback on Ethernet state changed.

**Return**
- ESP_OK: process the new state successfully
- ESP_FAIL: process the new state failed because some error occurred

**Parameters**
- **[in] eth**: mediator of Ethernet driver
- **[in] state**: new state
- **[in] args**: optional argument for the new state

Macros

**ETH_MAX_PAYLOAD_LEN**

Maximum Ethernet payload size.

**ETH_MIN_PAYLOAD_LEN**

Minimum Ethernet payload size.
ETH_HEADER_LEN
Ethernet frame header size: Dest addr(6 Bytes) + Src addr(6 Bytes) + length/type(2 Bytes)

ETH_CRC_LEN
Ethernet frame CRC length.

ETH_VLAN_TAG_LEN
Optional 802.1q VLAN Tag length.

ETH_JUMBO_FRAME_PAYLOAD_LEN
Jumbo frame payload size.

ETH_MAX_PACKET_SIZE
Maximum frame size (1522 Bytes)

ETH_MIN_PACKET_SIZE
Minimum frame size (64 Bytes)

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 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_SPEED
Get Speed
API

**ETH_CMD_S_PROMISCUOUS**
Set promiscuous mode

**ETH_CMD_S_FLOW_CTRL**
Set flow control

```c
enum eth_link_t
    Ethernet link status.
    Values:
    ETH_LINK_UP
        Ethernet link is up
    ETH_LINK_DOWN
        Ethernet link is down
```

```c
enum eth_speed_t
    Ethernet speed.
    Values:
    ETH_SPEED_10M
        Ethernet speed is 10Mbps
    ETH_SPEED_100M
        Ethernet speed is 100Mbps
```

```c
enum eth_duplex_t
    Ethernet duplex mode.
    Values:
    ETH_DUPLEX_HALF
        Ethernet is in half duplex
    ETH_DUPLEX_FULL
        Ethernet is in full duplex
```

```c
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
```

**API 参考-MAC 接口**

**Header File**
- 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

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
Chapter 2. API

\[
\begin{align*}
\text{esp_err_t}(*\text{transmit})(\text{esp_eth_mac_t}*\text{mac}, \text{uint8_t}**\text{buf}, \text{uint32_t}\text{length})
\end{align*}
\]

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

\[
\begin{align*}
\text{esp_err_t}(*\text{receive})(\text{esp_eth_mac_t}*\text{mac}, \text{uint8_t}**\text{buf}, \text{uint32_t}\text{length})
\end{align*}
\]

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 be 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
- [in] buf: packet buffer which will preserve the received frame
- [out] length: length of the received packet

\[
\begin{align*}
\text{esp_err_t}(*\text{read_phy_reg})(\text{esp_eth_mac_t}*\text{mac}, \text{uint32_t}\text{phy_addr}, \text{uint32_t}\text{phy_reg}, \text{uint32_t}\text{reg_value})
\end{align*}
\]

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

\[
\begin{align*}
\text{esp_err_t}(*\text{write_phy_reg})(\text{esp_eth_mac_t}*\text{mac}, \text{uint32_t}\text{phy_addr}, \text{uint32_t}\text{phy_reg}, \text{uint32_t}\text{reg_value})
\end{align*}
\]

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
Chapter 2. API

```
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 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

**esp_err_t** (*set_peer_pause_ability*) (**esp_eth_mac_t** *mac, uint32_t ability)

Set the PAUSE ability of peer node.

**Return**
- ESP_OK: set peer pause ability successfully
- ESP_FAIL: set peer pause ability failed because some error occurred

**Parameters**
- [in] mac: Ethernet MAC instance
- [in] ability: zero indicates that pause function is supported by link partner; non-zero indicates that pause function is not supported by link partner

**esp_err_t** (*del*) (**esp_eth_mac_t** *mac)

Free memory of Ethernet MAC.

**Return**
- ESP_OK: free Ethernet MAC instance successfully
- ESP_FAIL: free Ethernet MAC instance failed because some error occurred

**Parameters**
- [in] mac: Ethernet MAC instance

**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

**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.
Chapter 2. API Reference

Type Definitions

typedef struct esp_eth_mac_s esp_eth_mac_t
    Ethernet MAC.

API 参考—PHY 接口

Header File

- esp_eth/include/esp_eth_phy.h

Functions

esp_eth_phy_t *esp_eth_phy_new_ip101(const eth_phy_config_t *config)
    Create a PHY instance of IP101.
    Return
    • instance: create PHY instance successfully
    • NULL: create PHY instance failed because some error occurred
    Parameters
    • [in] config: configuration of PHY

esp_eth_phy_t *esp_eth_phy_new_rtl8201(const eth_phy_config_t *config)
    Create a PHY instance of RTL8201.
    Return
    • instance: create PHY instance successfully
    • NULL: create PHY instance failed because some error occurred
    Parameters
    • [in] config: configuration of PHY

esp_eth_phy_t *esp_eth_phy_new_lan8720(const eth_phy_config_t *config)
    Create a PHY instance of LAN8720.
    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_ksz8041(const eth_phy_config_t *config)
    Create a PHY instance of KSZ8041.
    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(*negotiate)(esp_eth_phy_t *phy)`
Start auto negotiation.

**Return**
- ESP_OK: restart auto negotiation successfully
- ESP_FAIL: restart auto negotiation failed because some error occurred

**Parameters**
- [in] phy: Ethernet PHY instance

`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

```c
esp_err_t (*pwrctl)(esp_eth_phy_t *phy, bool enable)
```

Power control of Ethernet PHY.

**Return**

- ESP_OK: control Ethernet PHY power successfully
- ESP_FAIL: control Ethernet PHY power failed because some error occurred

**Parameters**

- **[in]** phy: Ethernet PHY instance
- **[in]** enable: set true to power on Ethernet PHY; set false to power off Ethernet PHY

```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 (*del)(esp_eth_phy_t *phy)
```

Free memory of Ethernet PHY instance.

**Return**

- ESP_OK: free PHY instance successfully
- ESP_FAIL: free PHY instance failed because some error occurred

**Parameters**

- **[in]** phy: Ethernet PHY instance

**Public Members**

- **int32_t phy_addr**
  PHY address, set -1 to enable PHY address detection at initialization stage

- **uint32_t reset_timeout_ms**
  Reset timeout value (Unit: ms)
Chapter 2. API Reference

```c
uint32_t autonego_timeout_ms
    Auto-negotiation timeout value (Unit: ms)

int reset_gpio_num
    Reset GPIO number, -1 means no hardware reset
```

**Macros**

```c
ESP_ETH_PHY_ADDR_AUTO
ETH_PHY_DEFAULT_CONFIG()
```

Default configuration for Ethernet PHY object.

**Type Definitions**

```c
typedef struct esp_eth_phy_s esp_eth_phy_t
   EthernetPHY.
```

**API Reference - esp_netif 相关使用**

**Header File**

- esp_eth/include/esp_eth_netif_glue.h

**Functions**

```c
void *esp_eth_new_netif_glue(esp_eth_handle_t eth_hdl)
Create a netif glue for Ethernet driver.

Note netif glue is used to attach io driver to TCP/IP netif
Return glue object, which inherits esp_netif_driver_base_t

Parameters
   - eth_hdl: Ethernet driver handle
```

```c
esp_err_t esp_eth_del_netif_glue(void *glue)
Delete netif glue of Ethernet driver.

Return -ESP_OK: delete netif glue successfully

Parameters
   - glue: netif glue
```

```c
esp_err_t esp_eth_set_default_handlers(void *esp_netif)
Register default IP layer handlers for Ethernet.

Note Ethernet handle might not yet properly initialized when setting up these default handlers
Return
   - ESP_ERR_INVALID_ARG: invalid parameter (esp_netif is NULL)
   - ESP_OK: set default IP layer handlers successfully
   - others: other failure occurred during register esp_event handler

Parameters
   - [in] esp_netif: esp network interface handle created for Ethernet driver
```

```c
esp_err_t esp_eth_clear_default_handlers(void *esp_netif)
Unregister default IP layer handlers for Ethernet.

Return
   - ESP_ERR_INVALID_ARG: invalid parameter (esp_netif is NULL)
   - ESP_OK: clear default IP layer handlers successfully
   - others: other failure occurred during unregister esp_event handler

Parameters
   - [in] esp_netif: esp network interface handle created for Ethernet driver
```

本部分的以太网 API 示例代码存放在 ESP-IDF 示例项目的 ethernet 目录下。
2.2.3 IP 网络层协议

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 配器迁移指南 section in case existing applications to be ported to use the esp-netif API instead.

ESP-NETIF architecture

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.
ESP-NETIF programmer’s manual Please refer to the example section for basic initialization of default interfaces:

- WiFi Station: wifi/getting_started/station/main/station_example_main.c
- WiFi Access Point: wifi/getting_started/softAP/main/softap_example_main.c
- Ethernet: ethernet/basic/main/ethernet_example_main.c

For more specific cases please consult this guide: ESP-NETIF Custom I/O Driver.

WiFi default initialization The initialization code as well as registering event handlers for default interfaces, such as softAP and station, are provided in two separate APIs to facilitate simple startup code for most applications:

- `esp_netif_create_default_wifi_ap()`  
- `esp_netif_create_default_wifi_sta()`

Please note that these functions return the `esp_netif` handle, i.e. a pointer to a network interface object allocated and configured with default settings, which as a consequence, means that:

- The created object has to be destroyed if a network de-initialization is provided by an application.
- These default interfaces must not be created multiple times, unless the created handle is deleted using `esp_netif_destroy()`.
- When using Wifi in AP+STA mode, both these interfaces has to be created.

**API Reference**

**Header File**

- `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 es-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_ioidriver_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)

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 DHCP 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:

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

```c
esp_err_t esp_netif_set_old_ip_info(esp_netif_t *esp_netif, const esp_netif_ip_info_t *ip_info)
```

Set interface old IP information.

This function is called from the DHCP client (if enabled), before a new IP is set. It is also called from the default handlers for the `SYSTEM_EVENT_STA_CONNECTED` and `SYSTEM_EVENT_ETH_CONNECTED` events.

Calling this function stores the previously configured IP, which can be used to determine if the IP changes in the future.

If the interface is disconnected or down for too long, the "IP lost timer" will expire (after the configured interval) and set the old IP information to zero.

### 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

```c
int esp_netif_get_netif_impl_index(esp_netif_t *esp_netif)
```

Get net interface index from network stack implementation.

**Note** This index could be used in `setsockopt()` to bind socket with multicast interface

### Return
- `ESP_OK`
- `ESP_ERR_ESP_NETIF_INVALID_PARAMS`

### Parameters
- `[in]` `esp_netif`: Handle to `esp-netif` instance

```c
esp_err_t esp_netif_get_netif_impl_name(esp_netif_t *esp_netif, char *name)
```

Get net interface name from network stack implementation.

**Note** This name could be used in `setsockopt()` to bind socket with appropriate interface

### 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)

```c
esp_err_t esp_netif_dhcps_option(esp_netif_t *esp_netif, esp_netif_dhcp_option_mode_t opt_op, esp_netif_dhcp_option_id_t opt_id, void *opt_val, uint32_t opt_len)
```

Set or Get DHCP server option.

### Return
- `ESP_OK`
- `ESP_ERR_ESP_NETIF_INVALID_PARAMS`
- `ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED`
- `ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED`

### Parameters
- `[in]` `esp_netif`: Handle to `esp-netif` instance
- `[in]` `opt_op`: `ESP_NETIF_OP_SET` to set an option, `ESP_NETIF_OP_GET` to get an option.
- `[in]` `opt_id`: Option index to get or set, must be one of the supported enum values.
- `[inout]` `opt_val`: Pointer to the option parameter.
- `[in]` `opt_len`: Length of the option parameter.
**esp_err_t** **esp_netif_dhcpc_option**(esp_netif_t *esp_netif, esp_netif_dhcp_option_mode_t opt_op, esp_netif_dhcp_option_id_t opt_id, void *opt_val, uint32_t opt_len)

Set or Get DHCP client option.

**Return**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [in] opt_op: ESP_NETIF_OP_SET to set an option, ESP_NETIF_OP_GET to get an option.
- [in] opt_id: Option index to get or set, must be one of the supported enum values.
- [inout] opt_val: Pointer to the option parameter.
- [in] opt_len: Length of the option parameter.

**esp_err_t** **esp_netif_dhcpc_start**(esp_netif_t *esp_netif)

Start DHCP client (only if enabled in interface object)

**Note** The default event handlers for the SYSTEM_EVENT_STA_CONNECTED and SYSTEM_EVENT_ETH_CONNECTED events call this function.

**Return**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED
- ESP_ERR_ESP_NETIF_DHCP_START_FAILED

**Parameters**
- [in] esp_netif: Handle to esp-netif instance

**esp_err_t** **esp_netif_dhcpc_stop**(esp_netif_t *esp_netif)

Stop DHCP client (only if enabled in interface object)

**Note** Calling action_netif_stop() will also stop the DHCP Client if it is running.

**Return**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED
- ESP_ERR_ESP_NETIF_IF_NOT_READY

**Parameters**
- [in] esp_netif: Handle to esp-netif instance

**esp_err_t** **esp_netif_dhcpc_get_status**(esp_netif_t *esp_netif, esp_netif_dhcp_status_t *status)

Get DHCP client status.

**Return**
- ESP_OK

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [out] status: If successful, the status of DHCP client will be returned in this argument.

**esp_err_t** **esp_netif_dhcps_get_status**(esp_netif_t *esp_netif, esp_netif_dhcp_status_t *status)

Get DHCP Server status.

**Return**
- ESP_OK

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [out] status: If successful, the status of the DHCP server will be returned in this argument.

**esp_err_t** **esp_netif_dhcps_start**(esp_netif_t *esp_netif)

Start DHCP server (only if enabled in interface object)

**Return**
• ESP_OK
• ESP_ERR_ESP_NETIF_INVALID_PARAMS
• ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED

Parameters
• [in] esp_netif: Handle to esp-netif instance

esp_err_t esp_netif_dhcps_stop(esp_netif_t* esp_netif)
Stop DHCP server (only if enabled in interface object)

Return
• ESP_OK
• ESP_ERR_ESP_NETIF_INVALID_PARAMS
• ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED
• 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.
    \textbf{Return} ip address in network order
    \textbf{Parameters}
    • \textit{addr}: IP address in ascii representation (e.g. "127.0.0.1")

esp_netif_iiodriver_handle esp_netif_get_iio_driver(esp_netif_t *esp_netif)
    Gets media driver handle for this esp-netif instance.
    \textbf{Return} opaque pointer of related IO driver
    \textbf{Parameters}
    • \textit{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.
    \textbf{Return} Handle to esp-netif instance
    \textbf{Parameters}
    • \textit{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.
    \textbf{Return} Configuration flags
    \textbf{Parameters}
    • \textit{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.
    \textbf{Return} Textual description of related interface
    \textbf{Parameters}
    • \textit{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.
    \textbf{Return} Enumerated type of this interface, such as station, AP, ethernet
    \textbf{Parameters}
    • \textit{esp_netif}: Handle to esp-netif instance

int esp_netif_get_route_prio(esp_netif_t *esp_netif)
    Returns configured routing priority number.
    \textbf{Return} Integer representing the instance’s route-prio, or -1 if invalid paramters
    \textbf{Parameters}
    • \textit{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.
    \textbf{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
    \textbf{Parameters}
    • \textit{esp_netif}: Handle to esp-netif instance
    • \textit{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.
    \textbf{Return} First netif from the list if supplied parameter is NULL, next one otherwise
    \textbf{Parameters}
    • \textit{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
  • 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 STA interface.

Return
  • ESP_OK on success, error returned from esp_event_handler_register if failed

esp_err_t esp_wifi_clear_default_wifi_driver_and_handlers (void *esp_netif)
  Clears default wifi event handlers for supplied network interface.

Return
  • ESP_OK on success, error returned from esp_event_handler_register if failed

Parameters
  • esp_netif: instance of corresponding if object
Chapter 2. API Reference

esp_netif_t *esp_netif_create_default_wifi_ap (void)
Creates default WIFI AP. In case of any init error this API aborts.

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.

Return pointer to esp-netif instance

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)

TCP/IP 配置器迁移指南

TCP/IP 配置器是在 IDF V4.1 之前使用的网络接口抽象组件。本文档概述了从 tcpip_adapter 移出至其后继者 ESP-NETIF 的过程。

更新网络连接代码

网络软件栈初始化 只需将 tcpip_adapter_init() 替换为 esp_netif_init()。请注意，ESP-NETIF 初始化 API 可返回标准错误代码，还可以使用 esp_netif_deinit() 进行去初始化。

此外，还需将 #include "tcpip_adapter.h" 替换为 #include "esp_netif.h"。

创建网络连接 TCP/IP 配置器静态定义了三个接口：
• Wi-Fi Station
• Wi-Fi AP
• 以太网

网络接口的设计应严格参考 ESP-NETIF，以使其能够连接到 TCP/IP 软件栈。例如，在 TCP/IP 软件栈和事件循环初始化完成后，Wi-Fi 的初始化代码必须调用 esp_netif_create_default_wifi_sta()；或 esp_netif_create_default_wifi_mesh_ap()。请参阅这三个接口的初始化代码示例：
• Wi-Fi Station: wifi/getting_started/station/main/station_example_main.c
• Wi-Fi AP: wifi/getting_started/softAP/main/softap_example_main.c
• 以太网: ethernet/basic/main/ethernet_example_main.c
This section outlines implementing a new I/O driver with esp-netif connection capabilities. By convention the I/O driver has to register itself as an esp-netif driver and thus holds a dependency on esp-netif component and is responsible for providing data path functions, post-attach callback and in most cases also default event handlers to define network interface actions based on driver’s lifecycle transitions.

**Packet input/output**  
As shown in the diagram, the following three API functions for the packet data path must be defined for connecting with esp-netif:

- `esp_netif_transmit()`
- `esp_netif_free_rx_buffer()`
- `esp_netif_receive()`

The first two functions for transmitting and freeing the rx buffer are provided as callbacks, i.e. they get called from esp-netif (and its underlying TCP/IP stack) and I/O driver provides their implementation.

The receiving function on the other hand gets called from the I/O driver, so that the driver’s code simply calls `esp_netif_receive()` on a new data received event.

**Post attach callback**  
A final part of the network interface initialization consists of attaching the esp-netif instance to the I/O driver, by means of calling the following API:

```c
esp_err_t esp_netif_attach(esp_netif_t *esp_netif, esp_netif_iodriver_handle_t *iodriver_handle);
```
It is assumed that the `esp_netif_iodriver_handle` is a pointer to driver’s object, a struct derived from `struct esp_netif_driver_base_s`, so that the first member of I/O driver structure must be this base structure with pointers to

- post-attach function callback
- related esp-netif instance

As a consequence the I/O driver has to create an instance of the struct per below:

```c
typedef struct my_netif_driver_s {
    esp_netif_driver_base_t base; /*!< base structure reserved as
    esp-netif driver */
    driver_impl *h; /*!< handle of driver */
    implementation */
} my_netif_driver_t;
```

with actual values of `my_netif_driver_t::base.post_attach` and the actual drivers handle `my_netif_driver_t::h`. So when the `esp_netif_attach()` gets called from the initialization code, the post-attach callback from I/O driver’s code gets executed to mutually register callbacks between esp-netif and I/O driver instances. Typically the driver is started as well in the post-attach callback. An example of a simple post-attach callback is outlined below:

```c
static esp_err_t my_post_attach_start(esp_netif_t *esp_netif, void *args)
{
    my_netif_driver_t *driver = args;
    const esp_netif_driver_ifconfig_t driver_ifconfig = {
        .driver_free_rx_buffer = my_free_rx_buf,
        .transmit = my_transmit,
        .handle = driver->driver_impl
    };
    driver->base.netif = esp_netif;
    ESP_ERROR_CHECK(esp_netif_set_driver_config(esp_netif, &driver_ifconfig));
    my_driver_start(driver->driver_impl);
    return ESP_OK;
}
```

### Default handlers

I/O drivers also typically provide default definitions of lifecycle behaviour of related network interfaces based on state transitions of I/O drivers. For example `driver start -> network start`, etc. An example of such a default handler is provided below:

```c
esp_err_t my_driver_netif_set_default_handlers(my_netif_driver_t *driver, esp_netif_t *esp_netif)
{
    driver_set_event_handler(driver->driver_impl, esp_netif_action_start, MY_DRV_EVENT_START, esp_netif);
    driver_set_event_handler(driver->driver_impl, esp_netif_action_stop, MY_DRV_EVENT_STOP, esp_netif);
    return ESP_OK;
}
```

### Network stack connection

The packet data path functions for transmitting and freeing the rx buffer (defined in the I/O driver) are called from the esp-netif, specifically from its TCP/IP stack connecting layer. The following API reference outlines these network stack interaction with the esp-netif.

#### Header File

- `esp_netif/include/esp_netif_net_stack.h`
Functions

esp_netif_t* esp_netif_get_handle_from_netif_impl (void *dev)

Returns esp-netif handle.

**Return** handle to related esp-netif instance

**Parameters**

- **[in]** dev: opaque ptr to network interface of specific TCP/IP stack

void *esp_netif_get_netif_impl (esp_netif_t *esp_netif)

Returns network stack specific implementation handle (if supported)

Note that it is not supported to acquire PPP netif impl pointer and this function will return NULL for esp_netif instances configured to PPP mode

**Return** handle to related network stack netif handle

**Parameters**

- **[in]** esp_netif: Handle to esp-netif instance

esp_err_t esp_netif_transmit (esp_netif_t *esp_netif, void *data, size_t len)

Outputs packets from the TCP/IP stack to the media to be transmitted.

This function gets called from network stack to output packets to IO driver.

**Return** ESP_OK on success, an error passed from the I/O driver otherwise

**Parameters**

- **[in]** esp_netif: Handle to esp-netif instance
- **[in]** data: Data to be transmitted
- **[in]** len: Length of the data frame

esp_err_t esp_netif_transmit_wrap (esp_netif_t *esp_netif, void *data, size_t len, void *netstack_buf)

Outputs packets from the TCP/IP stack to the media to be transmitted.

This function gets called from network stack to output packets to IO driver.

**Return** ESP_OK on success, an error passed from the I/O driver otherwise

**Parameters**

- **[in]** esp_netif: Handle to esp-netif instance
- **[in]** data: Data to be transmitted
- **[in]** len: Length of the data frame
- **[in]** netstack_buf: net stack buffer

void esp_netif_free_rx_buffer (void *esp_netif, void *buffer)

Free the rx buffer allocated by the media driver.

This function gets called from network stack when the rx buffer to be freed in IO driver context, i.e. to deallocate a buffer owned by io driver (when data packets were passed to higher levels to avoid copying)

**Parameters**

- **[in]** esp_netif: Handle to esp-netif instance
- **[in]** buffer: Rx buffer pointer

TCP/IP 套接字 API 的示例代码存放在 ESP-IDF 示例项目的 protocols/sockets 目录下。

### 2.2.4 应用层协议

应用层网络协议（IP 网络层协议之上）的相关文档存放在**应用层协议**。

### 2.3 外设 API

#### 2.3.1 Analog to Digital Converter
Chapter 2. API

Overview

Configuration and Reading ADC

Each ADC unit supports two work modes, ADC-RTC or ADC-DMA mode. ADC-RTC is controlled by the RTC controller and is suitable for low-frequency sampling operations. ADC-DMA is controlled by a digital controller and is suitable for high-frequency continuous sampling actions.

ADC-RTC mode

The ADC should be configured before reading is taken.

- For ADC1, configure desired precision and attenuation by calling functions `adc1_config_width()` and `adc1_config_channel_atten()`.
- For ADC2, configure the attenuation by `adc2_config_channel_atten()`. The reading width of ADC2 is configured every time you take the reading.

Attenuation configuration is done per channel, see `adc1_channel_t` and `adc2_channel_t`, set as a parameter of above functions.

Then it is possible to read ADC conversion result with `adc1_get_raw()` and `adc2_get_raw()`. Reading width of ADC2 should be set as a parameter of `adc2_get_raw()` instead of in the configuration functions.

Note: Since the ADC2 is shared with the WIFI module, which has higher priority, reading operation of `adc2_get_raw()` will fail between `esp_wifi_start()` and `esp_wifi_stop()`. Use the return code to see whether the reading is successful.

This API provides convenient way to configure ADC1 for reading from ULP. To do so, call function `adc1_ulp_enable()` and then set precision and attenuation as discussed above.

There is another specific function `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 Minimizing Noise.

Application Examples

Reading voltage on ADC1 channel 0 (GPIO 36):

```c
#include <driver/adc.h>

adc1_config_width(ADC_WIDTH_BIT_12);
adc1_config_channel_atten(ADC1_CHANNEL_0,ADC_ATTEN_DB_0);
int val = adc1_get_raw(ADC1_CHANNEL_0);
```

The input voltage in the above example is from 0 to 1.1 V (0 dB attenuation). The input range can be extended by setting a higher attenuation, see `adc_atten_t`. An example of using the ADC driver including calibration (discussed below) is available at esp-idf: `peripherals/adc`

Reading voltage on ADC2 channel 7 (GPIO 27):

```c
#include <driver/adc.h>

int read_raw;
adc2_config_channel_atten( ADC2_CHANNEL_7, ADC_ATTEN_0db );

esp_err_t r = adc2_get_raw(ADC2_CHANNEL_7, ADC_WIDTH_12Bit, &read_raw);
if ( r == ESP_OK ) {
    printf("%d\n", read_raw);
}
```

(下页继续)
The reading may fail due to collision with Wi-Fi, should check it. An example using the ADC2 driver to read the output of DAC is available in esp-idf: peripherals/adc2

Minimizing Noise

The ESP32 ADC can be sensitive to noise leading to large discrepancies in ADC readings. To minimize noise, users may connect a 0.1μF capacitor to the ADC input pad in use. Multisampling may also be used to further mitigate the effects of noise.

![ADC Noise Comparison](image)

**图 4:** Graph illustrating noise mitigation using capacitor and multisampling of 64 samples.

ADC Calibration

The 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 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 three sources of calibration values on ESP32, and one source on ESP32-S2. The availability of these calibration values will depend on the type and production date of the ESP32 chip/module.
**Chapter 2. API 参考**

图 5: Graph illustrating effect of differing reference voltages on the ADC voltage curve.

**Application Example**  For a full example see esp-idf: peripherals/adc

Characterizing an ADC at a particular attenuation:

```c
#include "driver/adc.h"
#include "esp_adc_cal.h"
...

// Characterize ADC at particular attenuation
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 (36);
2. ADC1_GPIO32_CHANNEL is the ADC1 channel number of GPIO 32 (ADC1 channel 4).

### API Reference

This reference covers three components:

- **ADC driver**
- **ADC Calibration**
- **GPIO Lookup Macros**

### ADC driver

#### Header File

- `driver/esp32/include/driver/adc.h`

#### Functions

- **`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

- **`int hall_sensor_read (void)`**
  
  Read Hall Sensor.

  **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.
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.

Header File

- hal/include/hal/adc_types.h

Structures

struct adc_digi_pattern_table_t
ADC digital controller (DMA mode) conversion rules setting.

Public Members

uint8_t attenu : 2
ADC sampling voltage attenuation configuration. Modification of attenuation affects the range of measurements. 0: measurement range 0 - 800mV, 1: measurement range 0 - 1100mV, 2: measurement range 0 - 1350mV, 3: measurement range 0 - 2600mV.

uint8_t bit_width : 2
ADC resolution.
- 0: 9 bit;
- 1: 10 bit;
- 2: 11 bit;
- 3: 12 bit.

uint8_t channel : 4
ADC channel index.

struct adc_digi_output_data_t
ADC digital controller (DMA mode) output data format. Used to analyze the acquired ADC (DMA) data.

Note ESP32-S2: Member channel can be used to judge the validity of the ADC data, because the role of the arbiter may get invalid ADC data.

Public Members

uint16_t data : 12
ADC real output data info. Resolution: 12 bit.

ADC real output data info. Resolution: 11 bit.

uint16_t channel : 4
ADC channel index info. For ESP32-S2: If (channel < ADC_CHANNEL_MAX), The data is valid. If (channel > ADC_CHANNEL_MAX), The data is invalid.

struct adc_digi_output_data_t::[anonymous]::[anonymous] type1
When the configured output format is 12bit. ADC_DIGI_FORMAT_12BIT

uint16_t unit : 1
ADC unit index info. 0: ADC1; 1: ADC2.

struct adc_digi_output_data_t::[anonymous]::[anonymous] type2
When the configured output format is 11bit. ADC_DIGI_FORMAT_11BIT

uint16_t val
Raw data value
struct adc_digi_config_t
CONFIG_IDF_TARGET_ESP32.

ADC digital controller (DMA mode) configuration parameters.

Example setting: When using ADC1 channel0 to measure voltage, the sampling rate is required to be 1 kHz:

<table>
<thead>
<tr>
<th>sample rate</th>
<th>1 kHz</th>
<th>1 kHz</th>
<th>1 kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>conv_mode</td>
<td>single</td>
<td>both</td>
<td>alter</td>
</tr>
<tr>
<td>adc1_pattern_len</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>dig_clk.use_apll</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>dig_clk.div_num</td>
<td>99</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>dig_clk.div_b</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>dig_clk.div_a</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>interval</td>
<td>400</td>
<td>400</td>
<td>200</td>
</tr>
<tr>
<td><code>trigger_meas_freq</code></td>
<td>1 kHz</td>
<td>1 kHz</td>
<td>2 kHz</td>
</tr>
</tbody>
</table>

Explanation of the relationship between conv_limit_num, dma_eof_num and the number of DMA outputs:

<table>
<thead>
<tr>
<th>conv_mode</th>
<th>single</th>
<th>both</th>
<th>alter</th>
</tr>
</thead>
<tbody>
<tr>
<td>trigger_meas_times</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>conv_limit_num</td>
<td>+1</td>
<td>+1</td>
<td>+1</td>
</tr>
<tr>
<td>dma_eof_num</td>
<td>+1</td>
<td>+2</td>
<td>+1</td>
</tr>
<tr>
<td>dma output (byte)</td>
<td>+2</td>
<td>+4</td>
<td>+2</td>
</tr>
</tbody>
</table>

Public Members

bool conv_limit_en
Enable the function of limiting ADC conversion times. If the number of ADC conversion trigger count is equal to the limit_num, the conversion is stopped.

uint32_t conv_limit_num
Set the upper limit of the number of ADC conversion triggers. Range: 1 ~ 255.

uint32_t adc1_pattern_len
Pattern table length for digital controller. Range: 0 ~ 16 (0: Don’t change the pattern table setting). The pattern table that defines the conversion rules for each SAR ADC. Each table has 16 items, in which channel selection, resolution and attenuation are stored. When the conversion is started, the controller reads conversion rules from the pattern table one by one. For each controller the scan sequence has at most 16 different rules before repeating itself.

uint32_t adc2_pattern_len
Refer to adc1_pattern_len

adc_digi_pattern_table_t *adc1_pattern
Pointer to pattern table for digital controller. The table size defined by adc1_pattern_len.

adc_digi_pattern_table_t *adc2_pattern
Refer to adc1_pattern

adc_digi_convert_mode_t conv_mode
ADC conversion mode for digital controller. See adc_digi_convert_mode_t.

adc_digi_output_format_t format
ADC output data format for digital controller. See adc_digi_output_format_t.
Enumerations

```plaintext
def enum adc_unit_t
    ADC unit enumeration.
    
    Note: For ADC digital controller (DMA mode), ESP32 does not support ADC_UNIT_2, ADC_UNIT_BOTH, ADC_UNIT_ALTER.
    
    Values:
    
    ADC_UNIT_1 = 1
        SAR ADC 1.
    ADC_UNIT_2 = 2
        SAR ADC 2.
    ADC_UNIT_BOTH = 3
        SAR ADC 1 and 2.
    ADC_UNIT_ALTER = 7
        SAR ADC 1 and 2 alternative mode.
    ADC_UNIT_MAX
```

```plaintext
def enum adc_channel_t
    ADC channels handle. See adc1_channel_t, adc2_channel_t.
    
    Note: For ESP32 ADC1, don’t use ADC_CHANNEL_8, ADC_CHANNEL_9. See adc1_channel_t.
    
    Values:
    
    ADC_CHANNEL_0 = 0
        ADC channel
    ADC_CHANNEL_1
        ADC channel
    ADC_CHANNEL_2
        ADC channel
    ADC_CHANNEL_3
        ADC channel
    ADC_CHANNEL_4
        ADC channel
    ADC_CHANNEL_5
        ADC channel
    ADC_CHANNEL_6
        ADC channel
    ADC_CHANNEL_7
        ADC channel
    ADC_CHANNEL_8
        ADC channel
    ADC_CHANNEL_9
        ADC channel
    ADC_CHANNEL_MAX
```

```plaintext
def enum adc_atten_t
    ADC attenuation parameter. Different parameters determine the range of the ADC. See adcl_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 to up to approx. 1100 mV.

ADC_ATTEN_DB_6 = 2
The input voltage of ADC will be attenuated, extending the range of measurement to up to approx. 1350 mV.

ADC_ATTEN_DB_11 = 3
The input voltage of ADC will be attenuated, extending the range of measurement to up to approx. 2600 mV.

ADC_ATTEN_MAX

enum adc_i2s_source_t
ESP32 ADC DMA source selection.

Values:

ADC_I2S_DATA_SRC_IO_SIG = 0
I2S data from GPIO matrix signal

ADC_I2S_DATA_SRC_ADC = 1
I2S data from ADC

ADC_I2S_DATA_SRC_MAX

enum adc_bits_width_t
ADC resolution setting option.

Note For ESP32-S2. Only 13 bit resolution is supported. For ESP32, 13 bit resolution is not supported.

Values:

ADC_WIDTH_BIT_9 = 0
ADC capture width is 9Bit. Only ESP32 is supported.

ADC_WIDTH_BIT_10 = 1
ADC capture width is 10Bit. Only ESP32 is supported.

ADC_WIDTH_BIT_11 = 2
ADC capture width is 11Bit. Only ESP32 is supported.

ADC_WIDTH_BIT_12 = 3
ADC capture width is 12Bit. Only ESP32 is supported.

ADC_WIDTH_MAX

enum adc_digi_convert_mode_t
ADC digital controller (DMA mode) work mode.

Note The conversion mode affects the sampling frequency: SINGLE_UNIT_1: When the measurement is triggered, only ADC1 is sampled once. SINGLE_UNIT_2: When the measurement is triggered, only ADC2 is sampled once. BOTH_UNIT : When the measurement is triggered, ADC1 and ADC2 are sampled at the same time. ALTER_UNIT : When the measurement is triggered, ADC1 or ADC2 samples alternately.

Values:

ADC_CONV_SINGLE_UNIT_1 = 1
SAR ADC 1.

ADC_CONV_SINGLE_UNIT_2 = 2
SAR ADC 2.

ADC_CONV_BOTH_UNIT = 3
SAR ADC 1 and 2.

ADC_CONV_ALTER_UNIT = 7
SAR ADC 1 and 2 alternative mode.
Chapter 2. API

ADC_CONV_UNIT_MAX

denum 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

Header File
- driver/include/driver/adc_common.h

Functions

void adc_power_on (void)
Enable ADC power.

void adc_power_off (void)
Power off SAR ADC This function will force power down for ADC.

esp_err_t adc_gpio_init (adc_unit_t adc_unit, adc_channel_t channel)
Initialize ADC pad.

Return
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- adc_unit: ADC unit index
- channel: ADC channel index

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 full-scale voltage is 1.1 V. To read higher voltages (up to the pin maximum voltage,
usually 3.3 V) requires setting >0 dB signal attenuation for that ADC channel.

When the analog voltage supply (VDDA) is 3.3 V:

- 0 dB attenuation (ADC_ATTEN_DB_0) gives full-scale voltage 1.1 V
- 2.5 dB attenuation (ADC_ATTEN_DB_2_5) gives full-scale voltage 1.5 V
- 6 dB attenuation (ADC_ATTEN_DB_6) gives full-scale voltage 2.2 V
- 11 dB attenuation (ADC_ATTEN_DB_11) gives full-scale voltage 3.9 V (see note below)
Due to ADC characteristics, most accurate results are obtained within the following approximate voltage ranges:

<table>
<thead>
<tr>
<th>SoC</th>
<th>attenuation</th>
<th>suggested range (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32</td>
<td>0</td>
<td>100 ~ 950</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>100 ~ 1250</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>150 ~ 1750</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>150 ~ 2450</td>
</tr>
<tr>
<td>ESP32-S2</td>
<td>0</td>
<td>100 ~ 800</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>100 ~ 1100</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>150 ~ 1350</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>150 ~ 2600</td>
</tr>
</tbody>
</table>

For maximum accuracy, use the ADC calibration APIs and measure voltages within these recommended ranges.

**Note** The full-scale voltage is the voltage corresponding to a maximum reading (depending on ADC1 configured bit width, this value in ESP32 is 4095 for 12-bits, 2047 for 11-bits, 1023 for 10-bits, 511 for 9 bits. this value in ESP32-S2 is 8191 for 13-bits.)

**Note** At 11 dB attenuation the maximum voltage is limited by VDDA, not the full scale voltage.

**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

```
void 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

```
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.

**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.
Chapter 2. API

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.

Note ESP32-S2 only supports ADC_WIDTH_BIT_13.

Return
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- adc_unit: ADC unit index
- width_bit: Bit capture width for ADC unit. ESP32-S2 only supports ADC_WIDTH_BIT_13.

```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 full-scale voltage is 1.1 V. To read higher voltages (up to the pin maximum voltage,
usually 3.3 V) requires setting >0 dB signal attenuation for that ADC channel.

When the analog voltage supply (VDDA) is 3.3 V:
### API

**adc2_config_channel_atten()**

- 0 dB attenuation (ADC_ATTEN_0db) gives full-scale voltage 1.1 V
- 2.5 dB attenuation (ADC_ATTEN_2_5db) gives full-scale voltage 1.5 V
- 6 dB attenuation (ADC_ATTEN_6db) gives full-scale voltage 2.2 V
- 11 dB attenuation (ADC_ATTEN_11db) gives full-scale voltage 3.9 V (see note below)

**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** The full-scale voltage is the voltage corresponding to a maximum reading (depending on ADC2 configured bit width, this value for ESP32 is: 4095 for 12-bits, 2047 for 11-bits, 1023 for 10-bits, 511 for 9 bits. this value for ESP32-S2 is: 8191 for 13-bits.)

**Note** At 11 dB attenuation the maximum voltage is limited by VDDA, not the full scale voltage.

**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.

**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 support 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. ESP32-S2 only supports `ADC_WIDTH_BIT_13`.
- `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**

- `adc_unit`: ADC unit index
- `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)

esp_err_t adc_digi_init (void)
ADC digital controller initialization.

Return
- ESP_OK Success

esp_err_t adc_digi_deinit (void)
ADC digital controller deinitialization.

Return
- ESP_OK Success

Parameters
- config: Pointer to digital controller parameter. Refer to adc_digi_config_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_9Bit
ADC_WIDTH_10Bit
ADC_WIDTH_11Bit
ADC_WIDTH_12Bit

Enumerations
enum adc1_channel_t
Values:

ADC1_CHANNEL_0 = 0
ADC1 channel 0 is GPIO36 (ESP32), GPIO1 (ESP32-S2)

ADC1_CHANNEL_1
ADC1 channel 1 is GPIO37 (ESP32), GPIO2 (ESP32-S2)

ADC1_CHANNEL_2
ADC1 channel 2 is GPIO38 (ESP32), GPIO3 (ESP32-S2)

ADC1_CHANNEL_3
ADC1 channel 3 is GPIO39 (ESP32), GPIO4 (ESP32-S2)

ADC1_CHANNEL_4
ADC1 channel 4 is GPIO32 (ESP32), GPIO5 (ESP32-S2)

ADC1_CHANNEL_5
ADC1 channel 5 is GPIO33 (ESP32), GPIO6 (ESP32-S2)
ADC1_CHANNEL_6
    ADC1 channel 6 is GPIO34 (ESP32), GPIO7 (ESP32-S2)

ADC1_CHANNEL_7
    ADC1 channel 7 is GPIO35 (ESP32), GPIO8 (ESP32-S2)

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

ADC Calibration

Header File
    - 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

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_TIMEOUT: Error, timed out attempting to read ADC
• ESP_ERR_INVALID_ARG: Error due to invalid arguments
Parameters

- [in] channel: ADC Channel to read
- [in] chars: Pointer to initialized ADC characteristics structure
- [out] voltage: Pointer to store converted voltage

Structures

```c
struct esp_adc_cal_characteristics_t
```
Structure storing characteristics of an ADC.

Note Call esp_adc_cal_characterize() to initialize the structure

Public Members

```c
adc_unit_t adc_num
```
ADC number

```c
adc_atten_t atten
```
ADC attenuation

```c
adc_bits_width_t bit_width
```
ADC bit width

```c
uint32_t coeff_a
```
Gradient of ADC-Voltage curve

```c
uint32_t coeff_b
```
Offset of ADC-Voltage curve

```c
uint32_t vref
```
Vref used by lookup table

```c
const uint32_t* low_curve
```
Pointer to low Vref curve of lookup table (NULL if unused)

```c
const uint32_t* high_curve
```
Pointer to high Vref curve of lookup table (NULL if unused)

Enumerations

```c
enum esp_adc_cal_value_t
```
Type of calibration value used in characterization.

Values:

```c
ESP_ADC_CAL_VAL_EFUSE_VREF = 0
```
Characterization based on reference voltage stored in eFuse

```c
ESP_ADC_CAL_VAL_EFUSE_TP = 1
```
Characterization based on Two Point values stored in eFuse

```c
ESP_ADC_CAL_VAL_DEFAULT_VREF = 2
```
Characterization based on default reference voltage

```c
ESP_ADC_CAL_VAL_MAX
```

GPIO Lookup Macros

Header File

- `soc/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_CHANNEL_6_GPIO_NUM
ADC2_GPIO27_CHANNEL
ADC2_CHANNEL_7_GPIO_NUM
ADC2_GPIO25_CHANNEL
ADC2_CHANNEL_8_GPIO_NUM
ADC2_GPIO26_CHANNEL
ADC2_CHANNEL_9_GPIO_NUM
2.3.2 Digital To Analog Converter

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, via the I2S driver when using the “built-in DAC mode”.

For other analog output options, see the Sigma-delta Modulation module and the 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

- driver/esp32/include/driver/dac.h

Functions

- `esp_err_t dac_i2s_enable (void)`
  Enable DAC output data from I2S.
  
  Return
  - ESP_OK success

- `esp_err_t dac_i2s_disable (void)`
  Disable DAC output data from I2S.
  
  Return
  - ESP_OK success

Header File

- 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
**Chapter 2. API**

**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)**

Configure 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 specify 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).

**Header File**

- soc/soc/esp32/include/soc/dac_channel.h

**Macros**

- DAC_GPIO25_CHANNEL
- DAC_CHANNEL_1_GPIO_NUM
Chapter 2. API 参考

DAC_GPIO26_CHANNEL
DAC_CHANNEL_2_GPIO_NUM

Header File
- 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.

  DAC_CW_SCALE_8 = 0x3
  1/8.

enum dac_cw_phase_t
  Set the phase of the cosine wave generator output.

  Values:
DAC_CW_PHASE_0 = 0x2
  Phase shift +0°
DAC_CW_PHASE_180 = 0x3
  Phase shift +180°

2.3.3 GPIO & RTC GPIO

Overview

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, when the Ultra Low Power co-processor is running, or when analog functions such as ADC/DAC/etc are in use.

Application Example

GPIO output and input interrupt example: peripherals/gpio.

API Reference - Normal GPIO

Header File

- driver/include/driver/gpio.h

Functions

esp_err_t gpio_config(const gpio_config_t *pGPIOConfig)
  Configure GPIO's Mode, pull-up, PullDown, IntrType

Return
  • ESP_OK success
  • ESP_ERR_INVALID_ARG Parameter error

Parameters
  • pGPIOConfig: Pointer to GPIO configure struct

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.

esp_err_t gpio_set_intr_type (gpio_num_t gpio_num, gpio_int_type_t intr_type)
  GPIO set interrupt trigger type.

Return
  • ESP_OK Success
  • ESP_ERR_INVALID_ARG Parameter error

Parameters
  • gpio_num: GPIO number. If you want to set the trigger type of e.g. of GPIO16, gpio_num should be GPIO_NUM_16 (16);
  • intr_type: Interrupt type, select from gpio_int_type_t

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. 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.

**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
gpio_set_direction (gpio_num_t gpio_num, gpio_mode_t mode)
```

GPIO set direction.

Configure GPIO direction, such as output_only, input_only, output_and_input

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO error

**Parameters**
- `gpio_num`: Configure GPIO pins number, it should be GPIO number. If you want to set direction of e.g. GPIO16, `gpio_num` should be GPIO_NUM_16 (16);
- `mode`: GPIO direction

```c
esp_err_t gpio_set_pull_mode (gpio_num_t gpio_num, gpio_pull_mode_t pull)
```

Configure GPIO pull-up/pull-down resistors.

Only pins that support both input & output have integrated pull-up and pull-down resistors. Input-only GPIOs 34-39 do not.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG : Parameter error
Parameters
- **gpio_num**: GPIO number. If you want to set pull up or down mode for e.g. GPIO16, gpio_num should be GPIO_NUM_16 (16);
- **pull**: GPIO pull up/down mode.

```c
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.

```c
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

```c
esp_err_t gpio_isr_register (void (*fn) (void *, void *, int, gpio_isr_handle_t *handle), 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.
- **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.
- **arg**: Parameter for handler function
- **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

```c
esp_err_t gpio_pullup_en (gpio_num_t gpio_num)
```
Enable pull-up on GPIO.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- **gpio_num**: GPIO number

```c
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.

esp_err_t gpio_isr_handler_remove (gpio_num_t gpio_num)

Remove ISR handler for the corresponding GPIO pin.

Return
• ESP_OK Success
• ESP_ERR_INVALID_STATE Wrong state, the ISR service has not been initialized.
Chapter 2. API 参考

- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- gpio_num: GPIO number

```c
esp_err_t gpio_set_drive_capability (gpio_num_t gpio_num, gpio_drive_cap_t strength)
```
Set GPIO pad drive capability.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- gpio_num: GPIO number, only support output GPIOs
- strength: Drive capability of the pad

```c
esp_err_t gpio_get_drive_capability (gpio_num_t gpio_num, gpio_drive_cap_t *strength)
```
Get GPIO pad drive capability.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- gpio_num: GPIO number, only support output GPIOs
- strength: Pointer to accept drive capability of the pad

```c
esp_err_t gpio_hold_en (gpio_num_t gpio_num)
```
Enable gpio pad hold function.

The gpio pad hold function works in both input and output modes, but must be output-capable gpis. 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 of the changes of input signal.

The state of digital gpio cannot be held during Deep-sleep, and it will resume the hold function when the chip wakes up from Deep-sleep. If the digital gpio also needs to be held during Deep-sleep, `gpio_deep_sleep_hold_en` should also be called.

Power down or call `gpio_hold_dis` will disable this function.

**Return**
- ESP_OK Success
- ESP_ERR_NOT_SUPPORTED Not support pad hold function

**Parameters**
- gpio_num: GPIO number, only support output-capable GPIOs

```c
esp_err_t gpio_hold_dis (gpio_num_t gpio_num)
```
Disable gpio pad hold function.

When the chip is woken up from Deep-sleep, the gpio will be set to the default mode, so, the gpio will output the default level if this function is called. If you don’t want the level changes, the gpio should be configured to a known state before this function is called. e.g. If you hold gpio18 high during Deep-sleep, after the chip is woken up and `gpio_hold_dis` is called, gpio18 will output low level (because gpio18 is input mode by default). If you don’t want this behavior, you should configure gpio18 as output mode and set it to 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

```c
void gpio_deep_sleep_hold_en (void)
```
Enable all digital gpio pad hold function during Deep-sleep.

When the chip is in Deep-sleep mode, all digital gpio will hold the state before sleep, and when the chip is woken up, the status of digital gpio will not be held. Note that the pad hold feature only works when the chip
is in Deep-sleep mode, when not in sleep mode, the digital gpio state can be changed even you have called this function.

Power down or call gpio_hold_dis will disable this function, otherwise, the digital gpio hold feature works as long as the chip enter Deep-sleep.

```c
void gpio_deep_sleep_hold_dis(void)
    Disable all digital gpio pad hold function during Deep-sleep.
```

```c
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.
```

```c
void gpio_iomux_out(uint8_t gpio_num, int func, bool oen_inv)
    Set peripheral output to an GPIO pad through the IOMUX.

Parameters
• gpio_num: gpio_num GPIO number of the pad.
• func: The function number of the peripheral pin to output pin. One of the FUNC_X_ * of specified pin (X) in soc/io_mux_reg.h.
• oen_inv: True if the output enable needs to be inverted, otherwise False.
```

Macros

```c
GPIO_PIN_COUNT
GPIO_IS_VALID_GPIO(gpio_num)
    Check whether it is a valid GPIO number.

GPIO_IS_VALID_OUTPUT_GPIO(gpio_num)
    Check whether it can be a valid GPIO number of output mode.
```

Type Definitions

```c
typedef intr_handle_t gpio_isr_handle_t
```

Header File

```c
• hal/include/hal/gpio_types.h
```

Structures

```c
struct gpio_config_t
    Configuration parameters of GPIO pad for gpio_config function.
```

Public Members

```c
uint64_t pin_bit_mask
    GPIO pin: set with bit mask, each bit maps to a GPIO

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
```
Type Definitions

typedef void (*gpio_isr_t)(void *)

Enumerations

define gpio_port_t

<table>
<thead>
<tr>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO_PORT_0 = 0</td>
</tr>
<tr>
<td>GPIO_PORT_MAX</td>
</tr>
</tbody>
</table>

define gpio_num_t

<table>
<thead>
<tr>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO_NUM_NC = -1</td>
</tr>
<tr>
<td>GPIO_NUM_0 = 0</td>
</tr>
<tr>
<td>GPIO_NUM_1 = 1</td>
</tr>
<tr>
<td>GPIO_NUM_2 = 2</td>
</tr>
<tr>
<td>GPIO_NUM_3 = 3</td>
</tr>
<tr>
<td>GPIO_NUM_4 = 4</td>
</tr>
<tr>
<td>GPIO_NUM_5 = 5</td>
</tr>
<tr>
<td>GPIO_NUM_6 = 6</td>
</tr>
<tr>
<td>GPIO_NUM_7 = 7</td>
</tr>
<tr>
<td>GPIO_NUM_8 = 8</td>
</tr>
<tr>
<td>GPIO_NUM_9 = 9</td>
</tr>
<tr>
<td>GPIO_NUM_10 = 10</td>
</tr>
<tr>
<td>GPIO_NUM_11 = 11</td>
</tr>
<tr>
<td>GPIO_NUM_12 = 12</td>
</tr>
<tr>
<td>GPIO_NUM_13 = 13</td>
</tr>
<tr>
<td>GPIO_NUM_14 = 14</td>
</tr>
<tr>
<td>GPIO_NUM_15 = 15</td>
</tr>
<tr>
<td>GPIO_NUM_16 = 16</td>
</tr>
</tbody>
</table>

Use to signal not connected to S/W

GPIO0, input and output

GPIO1, input and output

GPIO2, input and output

GPIO3, input and output

GPIO4, input and output

GPIO5, input and output

GPIO6, input and output

GPIO7, input and output

GPIO8, input and output

GPIO9, input and output

GPIO10, input and output

GPIO11, input and output

GPIO12, input and output

GPIO13, input and output

GPIO14, input and output

GPIO15, input and output

GPIO16, input and output
Chapter 2. API Reference

```c
GPIO_NUM_17 = 17
GPIO17, input and output

GPIO_NUM_18 = 18
GPIO18, input and output

GPIO_NUM_19 = 19
GPIO19, input and output

GPIO_NUM_20 = 20
GPIO20, input and output

GPIO_NUM_21 = 21
GPIO21, input and output

GPIO_NUM_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(ESP32) / input and output(ESP32-S2)

GPIO_NUM_35 = 35
GPIO35, input mode only(ESP32) / input and output(ESP32-S2)

GPIO_NUM_36 = 36
GPIO36, input mode only(ESP32) / input and output(ESP32-S2)

GPIO_NUM_37 = 37
GPIO37, input mode only(ESP32) / input and output(ESP32-S2)

GPIO_NUM_38 = 38
GPIO38, input mode only(ESP32) / input and output(ESP32-S2)

GPIO_NUM_39 = 39
GPIO39, input mode only(ESP32) / input and output(ESP32-S2)

GPIO_NUM_MAX

enum gpio_int_type_t
Values:
```

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```c
GPIO_INTR_DISABLE = 0
  Disable GPIO interrupt
GPIO_INTR_POSEDGE = 1
  GPIO interrupt type: rising edge
GPIO_INTR_NEGEDGE = 2
  GPIO interrupt type: falling edge
GPIO_INTR_ANYEDGE = 3
  GPIO interrupt type: both rising and falling edge
GPIO_INTR_LOW_LEVEL = 4
  GPIO interrupt type: input low level trigger
GPIO_INTR_HIGH_LEVEL = 5
  GPIO interrupt type: input high level trigger
GPIO_INTR_MAX

enum gpio_mode_t
  Values:
  GPIO_MODE_DISABLE = GPIO_MODE_DEF_DISABLE
    GPIO mode: disable input and output
  GPIO_MODE_INPUT = GPIO_MODE_DEF_INPUT
    GPIO mode: input only
  GPIO_MODE_OUTPUT = GPIO_MODE_DEF_OUTPUT
    GPIO mode: output only mode
  GPIO_MODE_OUTPUT_OD = ((GPIO_MODE_DEF_OUTPUT) | (GPIO_MODE_DEF_OD))
    GPIO mode: output only with open-drain mode
  GPIO_MODE_INPUT_OUTPUT_OD = ((GPIO_MODE_DEF_INPUT) | (GPIO_MODE_DEF_OUTPUT) | (GPIO_MODE_DEF_OD))
    GPIO mode: output and input with open-drain mode
  GPIO_MODE_INPUT_OUTPUT = ((GPIO_MODE_DEF_INPUT) | (GPIO_MODE_DEF_OUTPUT))
    GPIO mode: output and input mode

enum gpio_pullup_t
  Values:
  GPIO_PULLUP_DISABLE = 0x0
    Disable GPIO pull-up resistor
  GPIO_PULLUP_ENABLE = 0x1
    Enable GPIO pull-up resistor

enum gpio_pulldown_t
  Values:
  GPIO_PULLDOWN_DISABLE = 0x0
    Disable GPIO pull-down resistor
  GPIO_PULLDOWN_ENABLE = 0x1
    Enable GPIO pull-down resistor

enum gpio_pull_mode_t
  Values:
  GPIO_PULLUP_ONLY
    Pad pull up
  GPIO_PULLDOWN_ONLY
    Pad pull down
  GPIO_PULLUP_PULLDOWN
    Pad pull up + pull down
```

Chapter 2. API 参考
Chapter 2. API 参考

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

- driver/include/driver/rtc_io.h

Functions

- static 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

- static 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.
Chapter 2. API

### Return
- 1 High level
- 0 Low level
- ESP_ERR_INVALID_ARG GPIO is not an RTC IO

### Parameters
- gpio_num: GPIO number (e.g. GPIO_NUM_12)

**esp_err_t rtc_gpio_set_level** *(gpio_num_t gpio_num, uint32_t level)*

Set the RTC IO output level.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO is not an RTC IO

**Parameters**
- gpio_num: GPIO number (e.g. GPIO_NUM_12)
- level: output level

**esp_err_t rtc_gpio_set_direction** *(gpio_num_t gpio_num, rtc_gpio_mode_t mode)*

RTC GPIO set direction.

Configure RTC GPIO direction, such as output only, input only, output and input.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO is not an RTC IO

**Parameters**
- gpio_num: GPIO number (e.g. GPIO_NUM_12)
- mode: GPIO direction

**esp_err_t rtc_gpio_set_direction_in_sleep** *(gpio_num_t gpio_num, rtc_gpio_mode_t mode)*

RTC GPIO set direction in deep sleep mode or disable sleep status (default). In some application scenarios, IO needs to have another states during deep sleep.

**NOTE:** ESP32 support INPUT_ONLY mode. ESP32S2 support INPUT_ONLY, OUTPUT_ONLY, INPUT_OUTPUT mode.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO is not an RTC IO

**Parameters**
- gpio_num: GPIO number (e.g. GPIO_NUM_12)
- mode: GPIO direction

**esp_err_t rtc_gpio_pullup_en** *(gpio_num_t gpio_num)*

RTC GPIO pullup enable.

This function only works for RTC IOs. In general, call gpio_pullup_en, which will work both for normal GPIOs and RTC IOs.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO is not an RTC IO

**Parameters**
- gpio_num: GPIO number (e.g. GPIO_NUM_12)

**esp_err_t rtc_gpio_pulldown_en** *(gpio_num_t gpio_num)*

RTC GPIO pulldown enable.

This function only works for RTC IOs. In general, call gpio_pulldown_en, which will work both for normal GPIOs and RTC IOs.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO is not an RTC IO

**Parameters**
• `gpio_num`: GPIO number (e.g. GPIO_NUM_12)

```c
esp_err_t rtc_gpio_pullup_dis(gpio_num_t gpio_num)
```

RTC GPIO pullup disable.

This function only works for RTC IOs. In general, call `gpio_pullup_dis`, which will work both for normal GPIOs and RTC IOs.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO is not an RTC IO

**Parameters**
- `gpio_num`: GPIO number (e.g. GPIO_NUM_12)

```c
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)

```c
esp_err_t rtc_gpio_hold_en(gpio_num_t gpio_num)
```

Enable hold function on an RTC IO pad.

Enabling HOLD function will cause the pad to latch current values of input enable, output enable, output value, function, drive strength values. This function is useful when going into light or deep sleep mode to prevent the pin configuration from changing.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO is not an RTC IO

**Parameters**
- `gpio_num`: GPIO number (e.g. GPIO_NUM_12)

```c
esp_err_t rtc_gpio_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)

```c
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** \textit{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** \textit{rtc_gpio_force_hold_dis_all}(void)

Disable force hold signal for all RTC IOs.

**esp_err_t** \textit{rtc_gpio_set_drive_capability}(gpio_num_t \textit{gpio_num}, gpio_drive_cap_t \textit{strength})

Set RTC GPIO pad drive capability.

\textbf{Return}

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

\textbf{Parameters}

- \textit{gpio_num}: GPIO number, only support output GPIOs
- \textit{strength}: Drive capability of the pad

**esp_err_t** \textit{rtc_gpio_get_drive_capability}(gpio_num_t \textit{gpio_num}, gpio_drive_cap_t *\textit{strength})

Get RTC GPIO pad drive capability.

\textbf{Return}

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

\textbf{Parameters}

- \textit{gpio_num}: GPIO number, only support output GPIOs
- \textit{strength}: Pointer to accept drive capability of the pad

**esp_err_t** \textit{rtc_gpio_wakeup_enable}(gpio_num_t \textit{gpio_num}, gpio_int_type_t \textit{intr_type})

Enable wakeup from sleep mode using specific GPIO.

\textbf{Return}

- ESP_OK on success
- ESP_ERR_INVALID_ARG if \textit{gpio_num} is not an RTC IO, or \textit{intr_type} is not one of GPIO_INTR_HIGH_LEVEL, GPIO_INTR_LOW_LEVEL.

\textbf{Parameters}

- \textit{gpio_num}: GPIO number
- \textit{intr_type}: Wakeup on high level (GPIO_INTR_HIGH_LEVEL) or low level (GPIO_INTR_LOW_LEVEL)

**esp_err_t** \textit{rtc_gpio_wakeup_disable}(gpio_num_t \textit{gpio_num})

Disable wakeup from sleep mode using specific GPIO.

\textbf{Return}

- ESP_OK on success
- ESP_ERR_INVALID_ARG if \textit{gpio_num} is not an RTC IO

\textbf{Parameters}

- \textit{gpio_num}: GPIO number

\textbf{Macros}

\texttt{RTC_GPIO_IS_VALID_GPIO}(gpio_num)

\textbf{Header File}

- hal/include/hal/rtc_io_types.h

\textbf{Enumerations}

\texttt{enum rtc_gpio_mode_t}

RTCIO output/input mode type.
Chapter 2. API

Values:

- **RTC_GPIO_MODE_INPUT_ONLY**  
  Pad input
- **RTC_GPIO_MODE_OUTPUT_ONLY**  
  Pad output
- **RTC_GPIO_MODE_INPUT_OUTPUT**  
  Pad input + output
- **RTC_GPIO_MODE_DISABLED**  
  Pad (output + input) disable
- **RTC_GPIO_MODE_OUTPUT_OD**  
  Pad open-drain output
- **RTC_GPIO_MODE_INPUT_OUTPUT_OD**  
  Pad input + open-drain output

### 2.3.4 I2C 驱动程序

概述

I2C 是一种串行同步半双工式通信协议，在总线上可以同时挂载多个主机和从机。I2C 总线由串行数据线 (SDA) 线和串行时钟线 (SCL) 线构成。这些线都需要上拉电阻。

I2C 具有简单且制造成本低廉等优点，主要用于低速外围设备的短距离通信 (一英尺以内)。

ESP32 有两个 I2C 控制器（也称为端口），负责处理在 I2C 两根总线上的通信。每个控制器都可以设置为主机或从机。例如，可以同时让一个控制器用作主机，另一个用作从机。

驱动程序的功能

I2C 驱动程序管理在 I2C 总线上设备的通信，该驱动程序具备以下功能：

- 在主机模式下读写字节
- 支持从机模式
- 读取并写入寄存器，然后由主机读取/写入

使用驱动程序

以下部分将指导您完成 I2C 驱动程序配置和工作的基本步骤：

1. 配置驱动程序 - 设置初始化参数（如主机模式或从机模式、SDA 和 SCL 使用的 GPIO 管脚，时钟速度等）
2. 安装驱动程序 - 激活一个 I2C 控制器的驱动，该控制器可为从机也可为从机
3. 根据是为主机还是从机配置驱动程序。选择合适的项目
   a) 主机模式下通信 - 发起通信 (主机模式)
   b) 从机模式下通信 - 响应主机消息 (从机模式)
4. 中断处理 - 配置和 I2C 中断服务
5. 用户自定义配置 - 调整默认的 I2C 通信参数 (时序、位序等)
6. 错误处理 - 如何识别和处理驱动程序配置和通信错误
7. 删除驱动程序 - 在通信结束时释放 I2C 驱动程序所使用的资源

配置驱动程序：建立 I2C 通信第一步是配置驱动程序，这需要设置 i2c_config_t 结构中的几个参数：

- 设置 I2C 工作模式 - 从 i2c_mode_t 中选择主机模式或从机模式
- 设置 通信管脚
  - 指定 SDA 和 SCL 信号使用的 GPIO 管脚
– 是否启用 ESP32 的内部上拉电阻
• (仅限主机模式) 设置 I2C 时钟速度
• (仅限从机模式) 设置以下内容:
  – 是否应启用 10 位寻址模式
  – 定义从机地址

然后，初始化给定 I2C 端口的配置，请使用端口号和 `i2c_config_t` 作为函数调用参数来调用 `i2c_param_config()` 函数。

在此阶段，`i2c_param_config()` 还将其他 I2C 配置参数设置为 I2C 总线协议规范中定义的默认值。有关默认值及修改默认值的详细信息，请参考用户自定义配置。

安装驱动程序 配置好 I2C 驱动程序后，使用以下参数调用函数 `i2c_driver_install()` 安装驱动程序:

• 端口号，从 `i2c_port_t` 中二选一
• 主机或从机模式，从 `i2c_mode_t` 中选择
• (仅限从机模式) 分配用于在从机模式下发送和接收数据的缓存区大小，I2C 是一个以主机为中心的总线，数据只能根据主机的请求从从机传输到主机。因此，从机通常有一个发送缓存区，供从应用程序写入数据使用。数据保存在发送缓存区中，由主机自行读取。
• 用于分配中断的标志（请参考 ESP_INTR_FLAG_* values in `esp_system/include/esp_intr_alloc.h`）

主机模式下通信 安装 I2C 驱动程序后，ESP32 即可与其他 I2C 设备通信。

ESP32 的 I2C 控制器在主机模式下负责与 I2C 从机设备建立通信，并发送命令让从机响应，如进行测量并结果发送给主机。

为优化通信流程，驱动程序提供一个名为“命令链接”的容器，该容器应填充一系列命令，然后传递给 I2C 控制器执行。

主机写入数据 下面的示例展示如何为 I2C 主机构建命令链接，从而向从机发送 n 个字节。
c) 数据 - 一个或多个字节的数据作为\texttt{i2c_master_write()} 的实参。
d) 停止位 - \texttt{i2c_master_stop()}
   函数\texttt{i2c_master_write_byte()} 和\texttt{i2c_master_write()} 都有额外的实参，规定
   主机是否应确认其有无接受到 ACK 位。
2. 通过调用\texttt{i2c_master_cmd_begin()} 来触发 I2C 控制器执行命令链接。一旦开始执行，就不能
   再修改命令链接。
3. 命令发送后，通过调用\texttt{i2c_cmd_link_delete()} 释放命令链接使用的资源。

### 主机读取数据
下面的示例展示如何为 I2C 主机构建命令链接，以便从从机读取 n 个字节。

![I2C command link diagram]

图 7: I2C command link - master read example

在读取数据时，在上述步骤 4 中，不是用\texttt{i2c_master_write...}，而是
用\texttt{i2c_master_read_byte()} 和或\texttt{i2c_master_read()} 填充命令链接。同样，在步骤 5 中
配置最后一次的读取，以便主不提供 ACK 位。

### 指示写入或读取数据
发送从机地址后 (请参考上图第 3 步)，主机可以写入或从从机读取数据。

主机实际执行的操作信息存储在从机地址的最低有效位中。

因此，为了将数据写入从机，主机发送的命令链接应包含地址 (ESP_SLAVE_ADDR << 1) |
I2C_MASTER_WRITE，如下所示:

\begin{verbatim}
i2c_master_write_byte(cmd, (ESP_SLAVE_ADDR << 1) | I2C_MASTER_WRITE, ACK_EN);
\end{verbatim}

同理，指示从从机读取数据的命令链接如下所示:

\begin{verbatim}
i2c_master_write_byte(cmd, (ESP_SLAVE_ADDR << 1) | I2C_MASTER_READ, ACK_EN);
\end{verbatim}

### 从机模式下通信
安装 I2C 驱动程序后，ESP32 即可与其他 I2C 设备通信。

API 为从机提供以下功能:

- \texttt{i2c_slave_read_buffer()}
  当从机将数据写入从机时，从机将自动将其存储在接收缓存区中。从机应用程序可自行
  调用函数\texttt{i2c_slave_read_buffer()}。如果接收缓存区中没有数据，此函数还具有
  一个参数用于指定阻塞时间。这将允许从机程序在指定的超时设定内等待数据到达
  缓存区。

- \texttt{i2c_slave_write_buffer()} 
  发送缓存区是用于存储从机要以 FIFO 顺序发送给主机的所有数据。在主机请求接收前，
  这些数据一直存储在发送缓存区。函数\texttt{i2c_slave_write_buffer()} 有一个参数，用
于指定发送缓存区已满时的块时间。这将允许从机应用程序在指定的超时设定内等待发送缓存区中足够的可用空间。

在 peripherals/i2c 中可找到介绍如何使用这些功能的代码示例。

中断处理 安装驱动程序时，默认情况下会安装中断处理程序。但是，您可以通过调用函数 i2c_isr_register() 来注册自己的而不是默认的中断处理程序。在运行自己的中断处理程序时，可以参考 ESP32 的技术参考手册（PDF），以获取有关 I2C 控制器触发的中断描述。

调用函数 i2c_isr_free() 删除中断处理程序。

用户自定义配置 如本节末尾所述配置驱动程序，函数 i2c_param_config() 在初始化 I2C 端口的驱动程序配置时，也会将几个 I2C 通信参数设置为 I2C 总线协议规范 规定的默认值。其他一些相关参数已在 I2C 控制器的寄存器中预先配置。

通过调用下表中提供的专用函数，可以将所有这些参数更改为用户自定义值。请记住，时序值是在 APB 时钟周期中定义的。APB 的频率在 i2c_APB_CLK_FREQ 中指定。

<table>
<thead>
<tr>
<th>要更改的参数</th>
<th>函数</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCL 脉冲周期的高电平和低电平</td>
<td>i2c_set_period()</td>
</tr>
<tr>
<td>在产生信号期间使用的 SCL 和 SDA 信号时序</td>
<td>i2c_set_start_timing()</td>
</tr>
<tr>
<td>在产生停止信号期间使用的 SCL 和 SDA 信号时序</td>
<td>i2c_set_stop_timing()</td>
</tr>
<tr>
<td>从机采样以及主机切换时，SCL 和 SDA 信号之间的时序关系</td>
<td>i2c_set_data_timing()</td>
</tr>
<tr>
<td>I2C 超时</td>
<td>i2c_set_timeout()</td>
</tr>
<tr>
<td>优先发送接收最高有效位 (LSB) 或最低有效位 (MSB)，可在 i2c_trans_mode_t 定义的模式中选择</td>
<td>i2c_set_data_mode()</td>
</tr>
</tbody>
</table>

上述每个函数都有一个 _get_ 对应项来检查当前设置的值。例如，调用 i2c_get_timeout() 来检查 I2C 超时值。

要检查在驱动程序配置过程中设置的参数默认值，请参考文件 driver/i2c.c 并查找带有后缀 _DEFAULT 的定义。

通过函数 i2c_set_pin() 可以为 SDA 和 SCL 信号选择不同的管脚并改变上拉配置。如果要修改已经输入的值，请使用函数 i2c_param_config()。

注解：ESP32 的内部上拉电阻范围为几万欧姆，因此在大多数情况下，它们本身不足以用作 I2C 上拉电阻。建议用户使用阻值在 I2C 总线协议规范 规定范围内的上拉电阻。

错误处理 大多数 I2C 驱动程序的函数在成功完成时会返回 ESP_OK，或在失败时会返回特定的错误代码。实时检查返回的值并进行错误处理是一种好习惯。驱动程序也会打印日志消息，其中包含错误说明，例如检查输入配置的正确性。有关详细信息，请参考文件 driver/i2c.c 并用后缀 _ERR_STR 查找定义。

使用专用中断来捕获通信故障。例如，如果从机将数据发送回主机耗费太长时间，会触发 i2c_TIME_OUT_INT 中断。详细信息请参考中断处理。

如果出现通信失败，可以分别为发送和接收缓存区调用 i2c_reset_tx_fifo() 和 i2c_reset_rx_fifo() 来重置内部硬件缓存区。

删除驱动程序 如果使用 i2c_driver_install() 建立 I2C 通信，一段时间后不再需要 I2C 通信，则可以通过调用 i2c_driver_delete() 来移除驱动程序以释放分配的资源。

应用示例

I2C 主机和从机示例：peripherals/i2c
API 参考

Header File

- driver/include/driver/i2c.h

Functions

```c
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)
```

I2C driver install.

**Note** Only slave mode will use this value, driver will ignore this value in master mode.

**Note** Only slave mode will use this value, driver will ignore this value in master mode.

**Note** In master mode, if the cache is likely to be disabled(such as write flash) and the slave is time-sensitive, ESP_INTR_FLAG_IRAM is suggested to be used. In this case, please use the memory allocated from internal RAM in i2c read and write function, because we can not access the psram(if psram is enabled) in interrupt handle function when cache is disabled.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_FAIL Driver install error

**Parameters**

- `i2c_num`: I2C port number
- `mode`: I2C mode( master or slave )
- `slv_rx_buf_len`: receiving buffer size for slave mode

```c
esp_err_t i2c_driver_delete(i2c_port_t i2c_num)
```

I2C driver delete.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**

- `i2c_num`: I2C port number

```c
esp_err_t i2c_param_config(i2c_port_t i2c_num, const i2c_config_t *i2c_conf)
```

I2C parameter initialization.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**

- `i2c_num`: I2C port number
- `i2c_conf`: pointer to I2C parameter settings

```c
esp_err_t i2c_reset_tx_fifo(i2c_port_t i2c_num)
```

reset I2C tx hardware fifo

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**

- `i2c_num`: I2C port number

```c
esp_err_t i2c_reset_rx_fifo(i2c_port_t i2c_num)
```

reset I2C rx fifo

**Return**
Chapter 2. API

- 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 *) void *, void *arg, int intr_alloc_flags, intr_handle_t *handle)`

*12C isr handler register.*

<table>
<thead>
<tr>
<th>Return</th>
<th>ESP_OK Success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>ESP_ERR_INVALID_ARG Parameter error</td>
</tr>
</tbody>
</table>

- i2c_num: I2C port number
- fn: isr handler function
- arg: parameter for isr 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: handle return from esp_intr_alloc.

`esp_err_t i2c_isr_free(intr_handle_t handle)`

to delete and free I2C isr.

<table>
<thead>
<tr>
<th>Return</th>
<th>ESP_OK Success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>ESP_ERR_INVALID_ARG Parameter error</td>
</tr>
</tbody>
</table>

- handle: handle of isr.

`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 signal for I2C sck and sda.

<table>
<thead>
<tr>
<th>Return</th>
<th>ESP_OK Success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>ESP_ERR_INVALID_ARG Parameter error</td>
</tr>
</tbody>
</table>

- 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: Whether to enable the internal pullup for sda pin
- scl_pullup_en: Whether to enable the internal pullup for scl pin
- mode: I2C mode

`i2c_cmd_handle_t i2c_cmd_link_create(void)`

Create and init I2C command link.

**Note** Before we build I2C command link, we need to call i2c_cmd_link_create() to create a command link.

After we finish sending the commands, we need to call i2c_cmd_link_delete() to release and return the resources.

<table>
<thead>
<tr>
<th>Return</th>
<th>i2c command link handler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td></td>
</tr>
</tbody>
</table>

void `i2c_cmd_link_delete(i2c_cmd_handle_t cmd_handle)`

Free I2C command link.

**Note** Before we build I2C command link, we need to call i2c_cmd_link_create() to create a command link.

After we finish sending the commands, we need to call i2c_cmd_link_delete() to release and return the resources.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>cmd_handle: I2C command handle</th>
</tr>
</thead>
</table>

`esp_err_t i2c_master_start(i2c_cmd_handle_t cmd_handle)`

Queue command for I2C master to generate a start signal.

**Note** Only call this function in I2C master mode Call i2c_master_cmd_begin() to send all queued commands
Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `cmd_handle`: I2C cmd link

```c
esp_err_t i2c_master_write_byte(i2c_cmd_handle_t cmd_handle, uint8_t data, bool ack_en)
```
Queue command for I2C master to write one byte to I2C bus.

**Note** Only call this function in I2C master mode Call `i2c_master_cmd_begin()` to send all queued commands

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `cmd_handle`: I2C cmd link
- `data`: I2C one byte command to write to bus
- `ack_en`: enable ack check for master

```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 command for I2C master to write buffer to I2C bus.

**Note** Only call this function in I2C master mode Call `i2c_master_cmd_begin()` to send all queued commands

**Note** If the psram is enabled and intr_flag is `ESP_INTR_FLAG_IRAM`, please use the memory allocated from internal RAM.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `cmd_handle`: I2C cmd link
- `data`: data to send

```c
esp_err_t i2c_master_read_byte(i2c_cmd_handle_t cmd_handle, uint8_t *data, i2c_ack_type_t ack)
```
Queue command for I2C master to read one byte from I2C bus.

**Note** Only call this function in I2C master mode Call `i2c_master_cmd_begin()` to send all queued commands

**Note** If the psram is enabled and intr_flag is `ESP_INTR_FLAG_IRAM`, please use the memory allocated from internal RAM.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `cmd_handle`: I2C cmd link
- `data`: pointer accept the data byte

```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 command for I2C master to read data from I2C bus.

**Note** Only call this function in I2C master mode Call `i2c_master_cmd_begin()` to send all queued commands

**Note** If the psram is enabled and intr_flag is `ESP_INTR_FLAG_IRAM`, please use the memory allocated from internal RAM.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `cmd_handle`: I2C cmd link
### Chapter 2. API 参考

- **data**: data buffer to accept the data from bus

**Parameters**
- **data_len**: read data length
- **ack**: ack value for read command

**esp_err_t i2c_master_stop(i2c_cmd_handle_t cmd_handle)**
Queue command for I2C master to generate a stop signal.

**Note** Only call this function in I2C master mode Call i2c_master_cmd_begin() to send all queued commands

**Return**
- **ESP_OK**: Success
- **ESP_ERR_INVALID_ARG**: Parameter error

**Parameters**
- **cmd_handle**: I2C cmd link

**esp_err_t i2c_master_cmd_begin(i2c_port_t i2c_num, i2c_cmd_handle_t cmd_handle, TickType_t ticks_to_wait)**
I2C master send queued commands. This function will trigger sending all queued commands. 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.

**Note** Only call this function in I2C master mode

**Return**
- **ESP_OK**: Success
- **ESP_ERR_INVALID_ARG**: Parameter error
- **ESP_FAIL**: Sending command error, slave doesn’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 command handler
- **ticks_to_wait**: maximum wait ticks.

**int i2c_slave_write_buffer(i2c_port_t i2c_num, const uint8_t *data, int size, TickType_t ticks_to_wait)**
I2C slave write data to internal ringbuffer, when tx fifo empty, isr will fill the hardware fifo from the internal ringbuffer.

**Note** Only call this function in I2C slave mode

**Return**
- **ESP_FAIL**: Parameter error
- **Others**: The number of data bytes that pushed to the I2C slave buffer.

**Parameters**
- **i2c_num**: I2C port number
- **data**: pointer to write into internal buffer
- **size**: data size
- **ticks_to_wait**: Maximum waiting ticks

**int i2c_slave_read_buffer(i2c_port_t i2c_num, uint8_t *data, size_t max_size, TickType_t ticks_to_wait)**
I2C slave read data from internal buffer. When I2C slave receive data, isr will copy received data from hardware rx fifo to internal ringbuffer. Then users can read from internal ringbuffer.

**Note** Only call this function in I2C slave mode

**Return**
- **ESP_FAIL**: Parameter error
- **Others**: The number of data bytes that read from I2C slave buffer.

**Parameters**
- **i2c_num**: I2C port number
- **data**: pointer to accept data from internal buffer
- **max_size**: Maximum data size 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 broken. enable hardware filter can filter out high frequency interference and make the master more stable.

Note Enable filter will slow the SCL clock.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• i2c_num: I2C port number
• cyc_num: the APB cycles need to be filtered(0<= cyc_num <=7). When the period of a pulse is less than cyc_num * APB_cycle, the I2C controller will ignore this pulse.

esp_err_t i2c_filter_disable(i2c_port_t i2c_num)
disable filter on I2C bus

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• i2c_num: I2C port number

esp_err_t i2c_set_start_timing(i2c_port_t i2c_num, int setup_time, int hold_time)
set I2C master start signal timing

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• i2c_num: I2C port number
• setup_time: clock number between the falling-edge of SDA and rising-edge of SCL for start mark, it’s a 10-bit value.
• hold_time: clock num between the falling-edge of SDA and falling-edge of SCL for start mark, it’s a 10-bit value.

esp_err_t i2c_get_start_timing(i2c_port_t i2c_num, int *setup_time, int *hold_time)
get I2C master start signal timing

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error
Parameters

- `i2c_num`: I2C port number
- `setup_time`: pointer to get setup time
- `hold_time`: pointer to get hold time

`esp_err_t i2c_set_stop_timing(i2c_port_t i2c_num, int setup_time, int hold_time)`
set I2C master stop signal timing

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `i2c_num`: I2C port number
- `setup_time`: clock 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.

`esp_err_t i2c_get_stop_timing(i2c_port_t i2c_num, int* setup_time, int* hold_time)`
get I2C master stop signal timing

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `i2c_num`: I2C port number
- `setup_time`: pointer to get setup time.
- `hold_time`: pointer to get hold time.

`esp_err_t i2c_set_data_timing(i2c_port_t i2c_num, int sample_time, int hold_time)`
set I2C data signal timing

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `i2c_num`: I2C port number
- `sample_time`: clock number I2C used to sample data on SDA after the rising-edge of SCL, it’s a 10-bit value.
- `hold_time`: clock number I2C used to hold the data after the falling-edge of SCL, it’s a 10-bit value.

`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

```c
esp_err_t i2c_set_data_mode(i2c_port_t i2c_num, i2c_trans_mode_t tx_trans_mode, i2c_trans_mode_t rx_trans_mode)
```

set I2C data transfer mode

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- i2c_num: I2C port number
- tx_trans_mode: I2C sending data mode
- rx_trans_mode: I2C receiving data mode

```c
esp_err_t i2c_get_data_mode(i2c_port_t i2c_num, i2c_trans_mode_t *tx_trans_mode, i2c_trans_mode_t *rx_trans_mode)
```

get I2C data transfer mode

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- i2c_num: I2C port number
- tx_trans_mode: pointer to get I2C sending data mode
- rx_trans_mode: pointer to get I2C receiving data mode

Macros
- I2C_APB_CLK_FREQ: I2C source clock is APB clock, 80MHz
- I2C_NUM_0: I2C port 0
- I2C_NUM_1: I2C port 1
- I2C_NUM_MAX: I2C port max

Type Definitions
```c
typedef void *i2c_cmd_handle_t
```

I2C command handle

Header File
- hal/include/hal/i2c_types.h

Structures
```c
struct i2c_config_t
```
I2C initialization parameters.

Public Members
```c
i2c_mode_t mode
```
I2C mode
### Chapter 2. API

```c
int sda_io_num
   GPIO number for I2C sda signal

int scl_io_num
   GPIO number for I2C scl signal

bool sda_pullup_en
   Internal GPIO pull mode for I2C sda signal

bool scl_pullup_en
   Internal GPIO pull mode for I2C scl signal

uint32_t clk_speed
   I2C clock frequency for master mode, (no higher than 1MHz for now)

struct i2c_config_t::[anonymous::][anonymous::] master
   I2C master config

uint8_t addr_10bit_en
   I2C 10bit address mode enable for slave mode

uint16_t slave_addr
   I2C address for slave mode

struct i2c_config_t::[anonymous::][anonymous::] slave
   I2C slave config
```

#### 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_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

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
Values:
I2C_SCLK_REF_TICK
I2C source clock from REF_TICK
I2C_SCLK_APB
I2C source clock from APB

2.3.5 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.

An I2S bus consists of the following lines:
- 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
- Dedicated 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

注解：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

Configuration example:

```c
static const int i2s_num = 0; // I2S port number

static const i2s_config_t i2s_config = {
    .mode = I2S_MODE_MASTER | I2S_MODE_TX,
    .sample_rate = 44100,
    .bits_per_sample = 16,
    .channel_format = I2S_CHANNEL_FMT_RIGHT_LEFT,
    .communication_format = I2S_COMM_FORMAT_STAND_I2S,
    .intr_alloc_flags = 0, // default interrupt priority
    .dma_buf_count = 8,
    .dma_buf_len = 64,
    .use_apll = false
};

i2s_driver_install(I2S_NUM, &i2s_config, 0, NULL);
```

#### Setting Communication Pins

Once the driver is installed, configure physical GPIO pins to which signals will be routed. For this, call the function `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 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.
# Chapter 2: API Reference

## 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 I2S DMA Tx buffer, and then the data will be transmitted automatically.

```c
i2s_write(I2S_NUM, samples_data, ((bits+8)/16)*SAMPLE_PER_CYCLE*4, &i2s_bytes_→write, 100);
```

To retrieve received data, use the function `i2s_read()`. It will retrieve the data from the I2S DMA Rx buffer, once the data is received by the I2S controller.

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

```c
#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,
    .sample_rate = 44100,
    .bits_per_sample = 16,
    .channel_format = I2S_CHANNEL_FMT_RIGHT_LEFT,
    .communication_format = I2S_COMM_FORMAT_STAND_I2S,
    .intr_alloc_flags = 0, // default interrupt priority
    .dma_buf_count = 8,
    .dma_buf_len = 64,
    .use_apll = false
};

static const i2s_pin_config_t pin_config = {
    .bck_io_num = 26,
    .ws_io_num = 25,
    .data_out_num = 22,
    .data_in_num = I2S_PIN_NO_CHANGE
};
```
API Reference

Header File

- driver/include/driver/i2s.h

Functions

`esp_err_t i2s_set_pin(i2s_port_t i2s_num, const i2s_pin_config_t *pin)`

Set I2S pin number.

Inside the pin configuration structure, set I2S_PIN_NO_CHANGE for any pin where the current configuration should not be changed.

```c
#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 = 0, // default interrupt priority
    .dma_buf_count = 8,
    .dma_buf_len = 64,
    .use_apll = false
};

... //install and start i2s
i2s_driver_install(i2s_num, &i2s_config, 0, NULL);

//for internal DAC, this will enable both of the... internal channels
i2s_set_pin(i2s_num, NULL); //for internal DAC, this will enable both of the...

//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
```
**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_NUM_0 or I2S_NUM_1
- `pin`: I2S Pin structure, or NULL to set 2-channel 8-bit internal DAC pin configuration (GPIO25 & GPIO26)

**Note** if *pin* is set as NULL, this function will initialize both of the built-in DAC channels by default. if you don’t want this to happen and you want to initialize only one of the DAC channels, you can call `i2s_set_dac_mode` instead.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_FAIL IO error

```c
esp_err_t i2s_set_pdm_rx_down_sample(i2s_port_t i2s_num, i2s_pdm_dsr_t dsr)
```

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_NUM_0, I2S_NUM_1
- `dsr`: i2s RX down sample rate for PDM mode.

```c
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 can not be used as RTC DAC function at the same time.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `dac_mode`: DAC mode configurations - see i2s_dac_mode_t

```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_NUM_0, I2S_NUM_1
- `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

```c
esp_err_t i2s_driver_uninstall(i2s_port_t i2s_num)
```

Uninstall I2S driver.

**Return**
- ESP_OK Success
Chapter 2. API

ESP_ERR_INVALID_ARG Parameter error

Parameters
• i2s_num: I2S_NUM_0, I2S_NUM_1

**esp_err_t i2s_write**(i2s_port_t i2s_num, const void *src, size_t size, size_t *bytes_written, TickType_t ticks_to_wait)

Write data to I2S DMA transmit buffer.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• i2s_num: I2S_NUM_0, I2S_NUM_1
• 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.

**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_NUM_0, I2S_NUM_1
• src: Source address to write from
• size: Size of data in bytes
• src_bits: Source audio bit
• aim_bits: Bit wanted, no more than 32, and must be greater than src_bits
• [out] bytes_written: Number of bytes written, if timeout, the result will be less than the size passed in.
• ticks_to_wait: TX buffer wait timeout in RTOS ticks. If this many ticks pass without space becoming available in the DMA transmit buffer, then the function will return (note that if the data is written to the DMA buffer in pieces, the overall operation may still take longer than this timeout.) Pass portMAX_DELAY for no timeout.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

**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_NUM_0, I2S_NUM_1
• 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)
```

Sets 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_NUM_0, I2S_NUM_1
- `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_NUM_0, I2S_NUM_1

```
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_NUM_0, I2S_NUM_1

```
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_NUM_0, I2S_NUM_1

```
esp_err_t i2s_set_clk(i2s_port_t i2s_num, uint32_t rate, i2s_bits_per_sample_t bits, 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.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `i2s_num`: I2S_NUM_0, I2S_NUM_1
- `rate`: I2S sample rate (ex: 8000, 44100…)}
Chapter 2. API

- **bits**: I2S bit width (I2S_BITS_PER_SAMPLE_16BIT, I2S_BITS_PER_SAMPLE_24BIT, I2S_BITS_PER_SAMPLE_32BIT)
- **ch**: I2S channel, (I2S_CHANNEL_MONO, I2S_CHANNEL_STEREO)

```c
float i2s_get_clk(i2s_port_t i2s_num)
```

get clock set on particular port number.

**Return**
- actual clock set by i2s driver

**Parameters**
- i2s_num: I2S_NUM_0, I2S_NUM_1

```c
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

```c
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

```c
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

**Macros**

`I2S_PIN_NO_CHANGE`

Use in `i2s_pin_config_t` for pins which should not be changed

**Type Definitions**

`typedef intr_handler_t i2s_isr_handle_t`

**Header File**

- `hal/include/hal/i2s_types.h`
**Structures**

`struct i2s_config_t`

I2S configuration parameters for i2s_param_config function.

**Public Members**

- `i2s_mode_t mode`
  - I2S work mode

- `int sample_rate`
  - I2S sample rate

- `i2s_bits_per_sample_t bits_per_sample`
  - I2S bits per sample

- `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_buf_count`
  - I2S DMA Buffer Count

- `int dma_buf_len`
  - I2S DMA Buffer Length

- `bool use_apll`
  - I2S using APLL 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.

`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

`struct i2s_pin_config_t`

I2S pin number for i2s_set_pin.

**Public Members**

- `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

Enumerations
enum i2s_port_t
   I2S port number, the max port number is (I2S_NUM_MAX -1).
   Values:
   I2S_NUM_0 = 0
      I2S port 0
   I2S_NUM_1 = 1
      I2S port 1
   I2S_NUM_MAX
      I2S port max
enum i2s_bits_per_sample_t
   I2S bit width per sample.
   Values:
   I2S_BITS_PER_SAMPLE_8BIT = 8
      I2S bits per sample: 8-bits
   I2S_BITS_PER_SAMPLE_16BIT = 16
      I2S bits per sample: 16-bits
   I2S_BITS_PER_SAMPLE_24BIT = 24
      I2S bits per sample: 24-bits
   I2S_BITS_PER_SAMPLE_32BIT = 32
      I2S bits per sample: 32-bits
enum i2s_channel_t
   I2S channel.
   Values:
   I2S_CHANNEL_MONO = 1
      I2S 1 channel (mono)
   I2S_CHANNEL_STEREO = 2
      I2S 2 channel (stereo)
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 = 0X03
      I2S communication MSB alignment standard, data launch at first BCK
   I2S_COMM_FORMAT_STAND_PCM_SHORT = 0x04
      PCM Short standard
   I2S_COMM_FORMAT_STAND_PCM_LONG = 0x0C
      PCM Long standard
   I2S_COMM_FORMAT_STAND_MAX
      standard max
**I2S_COMM_FORMAT_I2S** = 0x01
I2S communication format I2S, correspond to I2S_COMM_FORMAT_STAND_I2S

**I2S_COMM_FORMAT_I2S_MSB** = 0x01
I2S format MSB, (I2S_COMM_FORMAT_I2S || I2S_COMM_FORMAT_I2S_MSB) correspond to I2S_COMM_FORMAT_STAND_I2S

**I2S_COMM_FORMAT_I2S_LSB** = 0x02
I2S format LSB, (I2S_COMM_FORMAT_I2S || I2S_COMM_FORMAT_I2S_LSB) correspond to I2S_COMM_FORMAT_STAND_MSB

**I2S_COMM_FORMAT_PCM** = 0x04
I2S communication format PCM, correspond to I2S_COMM_FORMAT_STAND_PCM_SHORT

**I2S_COMM_FORMAT_PCM_SHORT** = 0x04
PCM Short, (I2S_COMM_FORMAT_PCM || I2S_COMM_FORMAT_PCM_SHORT) correspond to I2S_COMM_FORMAT_STAND_PCM_SHORT

**I2S_COMM_FORMAT_PCM_LONG** = 0x08
PCM Long, (I2S_COMM_FORMAT_PCM || I2S_COMM_FORMAT_PCM_LONG) correspond to I2S_COMM_FORMAT_STAND_PCM_LONG

**enum i2s_channel_fmt_t**
I2S channel format type.

*Values:*

**I2S_CHANNEL_FMT_RIGHT_LEFT** = 0x00
**I2S_CHANNEL_FMT_ALL_RIGHT**
**I2S_CHANNEL_FMT_ALL_LEFT**
**I2S_CHANNEL_FMT_ONLY_RIGHT**
**I2S_CHANNEL_FMT_ONLY_LEFT**

**enum i2s_mode_t**
I2S Mode, default is I2S_MODE_MASTER || I2S_MODE_TX.

*Note* PDM and built-in DAC functions are only supported on I2S0 for current ESP32 chip.

*Values:*

**I2S_MODE_MASTER** = 1
Master mode

**I2S_MODE_SLAVE** = 2
Slave mode

**I2S_MODE_TX** = 4
TX mode

**I2S_MODE_RX** = 8
RX mode

**I2S_MODE_DAC_BUILT_IN** = 16
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** = 32
Input I2S data from built-in ADC, each data can be 12-bit width at most

**I2S_MODE_PDM** = 64
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

e num i2s_event_type_t
    I2S event types.
    
    Values:
    I2S_EVENT_DMA_ERROR
    I2S_EVENT_TX_DONE
        I2S DMA finish sent 1 buffer
    I2S_EVENT_RX_DONE
        I2S DMA finish received 1 buffer
    I2S_EVENT_MAX
        I2S event max index

e num i2s_dac_mode_t
    I2S DAC mode for i2s_set_dac_mode.
    
    Note  PDM and 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

e num i2s_pdm_dsr_t
    I2S PDM RX downsample mode.
    
    Values:
    I2S_PDM_DSR_8S = 0
        downampling number is 8 for PDM RX mode
    I2S_PDM_DSR_16S
        downampling number is 16 for PDM RX mode
    I2S_PDM_DSR_MAX

enum pdm_pcm_conv_t
    PDM PCM convter enable/disable.
    
    Values:
    PDM_PCM_CONV_ENABLE
        Enable PDM PCM convert
    PDM_PCM_CONV_DISABLE
        Disable PDM PCM convert
## 2.3.6 LED PWM 控制器

### 概述

LED PWM 控制器主要用于控制 LED，也可产生 PWM 信号用于其他设备的控制。该控制器有 8 路高速通道和 8 路低速通道，可以产生独立的波形来驱动 RGB LED 设备等。

LED PWM 控制器的高速通道和低速通道均支持硬件渐变功能，可在无需 CPU 干预的情况下自动改变 PWM 信号的占空比，也可由软件改变 PWM 信号的占空比，实现亮度和颜色渐变。此外，低速通道在 Sleep 模式下仍可运行。

### 功能概览

要让指定 LED PWM 控制器高速模式或低速模式 通道运行，需进行如下配置：

1. 配置定时器：指定 PWM 信号的频率和占空比分辨率。
2. 配置通道：绑定定时器和输出 PWM 信号的 GPIO。
3. 改变 PWM 信号：输出 PWM 信号来驱动 LED。可通过软件控制或使用硬件渐变功能来改变 LED 的亮度。

![ESP32 - LED PWM Controller](image)

图 8: 配置 LED PWM 控制器的关键 API

### 配置定时器

要设置定时器，可调用函数 `ledc_timer_config()`，并将其传入配置参数的数据结构 `ledc_timer_config_t` 传递给该函数：

- 定时器索引 `ledc_timer_t`
- 速度模式 `ledc_mode_t`
- PWM 信号频率
- PWM 占空比分辨率

频率和占空比分辨率相互关联。PWM 频率越高，占空比分辨率越低，反之则越高。使用该 API 用于除改变 LED 亮度以外的其他目的时，这一点很重要。更多信息请参见频率和占空比分辨率支持范围一节。

### 配置通道

定时器设置好后，请配置选定的通道 (`ledc_channel_t` 之一)。配置通道需要调用函数 `ledc_channel_config()`。

通道的配置与定时器设置类似，需向通道配置函数传递包括通道配置参数的数据结构 `ledc_channel_config_t`。
此时，通道会按照 \texttt{ledc\_channel\_config\_t} 的配置，在绑定的 GPIO 上输出具有指定频率和占空比的 PWM 信号。在通道工作过程中，可以随时通过调用函数 \texttt{ledc\_stop()} 将其暂停。

**改变 PWM 信号** 通道开始运行，生成具有恒定占空比和频率的 PWM 信号之后，有几种方式可以改变该信号。驱动 LED 时，主要通过改变占空比来变化光亮度。

以下两节介绍了如何使用软件和硬件改变占空比。如有需要，PWM 信号的频率也可更改，详见 **改变 PWM 频率** 一节。

**使用软件改变 PWM 占空比** 调用函数 \texttt{ledc\_set\_duty()} 可以设置新的占空比。之后，调用函数 \texttt{ledc\_update\_duty()} 使新配置生效。要查看当前的占空比，可使用 \_get\_ 函数 \texttt{ledc\_get\_duty()}。

另外一种设置占空比和其他通道参数的方式是调用配置通道一节提到的函数 \texttt{ledc\_channel\_config()}。

传递给函数的占空比数值范围取决于选定的 duty\_resolution。应为 0 至 2 ** duty\_resolution - 1。例如，如选定的占空比分辨率为 10，则占空比的数值范围为 0 至 1023。此时分辨率为 -0.1%。

**使用硬件渐变改变 PWM 占空比** LED PWM 控制器硬件可逐渐改变占空比的数值。要使用此功能，需用函数 \texttt{ledc\_fade\_func\_install()} 使能渐变，之后用下列可用渐变函数之一配置:

- \texttt{ledc\_set\_fade\_with\_time()}
- \texttt{ledc\_set\_fade\_with\_step()}
- \texttt{ledc\_set\_fade()}

最后用 \texttt{ledc\_fade\_start()} 开启渐变。

如不需要渐变和渐变中断，可用函数 \texttt{ledc\_fade\_func\_uninstall()} 关闭。

**改变 PWM 频率** LED PWM 控制器 API 有多种方式即时改变 PWM 频率:

- 通过调用函数 \texttt{ledc\_set\_freq()} 设置频率。可用函数 \texttt{ledc\_get\_freq()} 查看当前频率。
- 通过调用函数 \texttt{ledc\_bind\_channel\_timer()} 改变频率和占空比分辨率，将其他定时器与通道相连。
- 通过调用函数 \texttt{ledc\_channel\_config()} 改变通道的定时器。

**控制 PWM 的更多方式** 要改变 PWM 设置，可使用低电平定时器的特定功能:

- \texttt{ledc\_timer\_set()}
- \texttt{ledc\_timer\_rst()}
- \texttt{ledc\_timer\_pause()}
- \texttt{ledc\_timer\_resume()}

前两个功能可通过函数 \texttt{ledc\_channel\_config()} 在后台运行，在定时器配置后启动。

**使用中断配置** LED PWM 控制器通道时，可在 \texttt{ledc\_channel\_config\_t} 中选取参数 \texttt{ledc\_intr\_type\_t}，在渐变完成时触发中断。

要注册处理程序来处理中断，可调用函数 \texttt{ledc\_isr\_register()}。

**LED PWM 控制器高速和低速模式**

LED PWM 控制器有 8 个可用定时器和 16 路通道。其中有一半专以高速模式运行，另一半则以低速模式运行。要选取高速或低速定时器或通道，可借助所调用函数中的参数 \texttt{ledc\_mode\_t}。
急速模式的优点是可平稳地改变定时器设置。也就是说，急速模式下如定时器设置改变，此变更会自动应用于定时器的下一次溢出中断。而更改低速定时器时，设置变更应由软件显式触发。LED PWM驱动器在后台更改设置，比如在调用函数ledc_timer_config()或ledc_timer_set()时。

更多关于速度模式的详细信息请参阅ESP32技术参考手册(PDF)。注意，该手册中提到的支持SLOW_CLOCK不适用于LED PWM驱动器。

### 频率和占空比分辨率支持范围

LED PWM控制器主要用于驱动LED。该控制器PWM占空比设置的分辨率范围很广。比如，PWM频率为5kHz时，占空比分辨率最大可达13位。这意味着占空比可为0至100%之间的任意值，分辨率为~0.012%（2 ** 13 = 8192 LED亮度的离散电平）。

LED PWM控制器可用于生成频率较高的信号，足以为数码相机模组等其他设备计时。此时，最大频率可以为40MHz，占空比分辨率可达1位。也就是说，占空比固定为50%，无法调整。

LED PWM控制器API可在设定的频率和占空比分辨率超过LED PWM控制器硬件范围时报错。例如，试图将频率设置为20MHz，占空比分辨率设置为3位时，串行端口监视器会报告如下错误：

```c
E (196) ledc: requested frequency and duty resolution cannot be achieved, try _
→ reducing freq_hz or duty_resolution. div_param=128
```

此时，占空比分辨率或频率必须降低。比如，将占空比分辨率设置为2会解决这一问题，让占空比设置为25%的倍数，即25%、50%或75%。

如设置的频率和占空比分辨率低于所支持的最低值，LED PWM驱动器也会反映并报告，如：

```c
E (196) ledc: requested frequency and duty resolution cannot be achieved, try _
→ increasing freq_hz or duty_resolution. div_param=128000000
```

占空比分辨率通常用ledc_timer_bit_t设置，范围是10至15位。如需较低的占空比分辨率（上至10，下至1），可直接输入相应数值。

### 应用实例

LED PWM改变占空比和渐变控制的实例请参阅peripherals/ledc。

### API 参考

#### Header File

- driver/include/driver/ledc.h

#### Functions

- esp_err_t ledc_channel_config(const ledc_channel_config_t *ledc_conf)

  LEDC通道配置

  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定时器配置

  Configure LEDC timer with the given source timer/frequency(Hz)/duty_resolution.

  **Return**

  - ESP_OK Success
  - ESP_ERR_INVALID_ARG Parameter error
Chapter 2. API 参考

- 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

```c
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_hpoin 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 (0-7), select from ledc_channel_t

```c
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 (0-7), select from ledc_channel_t

```c
esp_err_t ledc_stop (ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t idle_level)
```

LEDC stop. Disable LEDC output, and set idle level.

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 (0-7), select from ledc_channel_t
- idle_level: Set output idle level after LEDC stops.

```c
esp_err_t ledc_set_freq (ledc_mode_t speed_mode, ledc_timer_t timer_num, uint32_t freq_hz)
```

LEDC set channel frequency (Hz)

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

```c
uint32_t ledc_get_freq (ledc_mode_t speed_mode, ledc_timer_t timer_num)
```

LEDC get channel frequency (Hz)

Return
Chapter 2. API

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`

```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 (0-7), select from `ledc_channel_t`
- **duty**: Set the LEDC duty, the range of duty setting is [0, (2**duty_resolution)]
- **hpoint**: Set the LEDC hpoint value (max: 0xffff)

```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 (0-7), 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 (0-7), select from `ledc_channel_t`
- **duty**: Set the LEDC duty, the range of duty setting is [0, (2**duty_resolution)]

```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 (0-7), select from ledc_channel_t

```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 (0-7), select from ledc_channel_t
• duty: Set the start of the gradient duty, the range of duty setting is \([0, (2^{\text{duty_resolution}})]\)
• 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 *
,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 \([0, (2^{\text{duty_resolution}})]\)
• clk_src: Select LEDC source clock.

```c
esp_err_t ledc_timer_rst(ledc_mode_t speed_mode, ledc_timer_t timer_sel)
```

Reset LEDC timer.

**Return**
• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success
Parameters
- **speed_mode**: Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **timer_sel**: LEDC timer index (0-3), select from `ledc_timer_t`

```c
esp_err_t ledc_timer_pause (ledc_mode_t speed_mode, ledc_timer_t timer_sel)
```

Pause LEDC timer counter.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- **speed_mode**: Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **timer_sel**: LEDC timer index (0-3), select from `ledc_timer_t`

```c
esp_err_t ledc_timer_resume (ledc_mode_t speed_mode, ledc_timer_t timer_sel)
```

Resume LEDC timer.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- **speed_mode**: Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **timer_sel**: LEDC timer index (0-3), select from `ledc_timer_t`

```c
esp_err_t ledc_bind_channel_timer (ledc_mode_t speed_mode, ledc_channel_t channel, ledc_timer_t timer_sel)
```

Bind LEDC channel with the selected timer.

**Return**
- 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 (0-7), select from `ledc_channel_t`
- **timer_sel**: LEDC timer index (0-3), select from `ledc_timer_t`

```c
esp_err_t ledc_set_fade_with_step (ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t target_duty, uint32_t scale, uint32_t cycle_num)
```

Set LEDC fade function.

**Note** Call `ledc_fade_func_install()` once before calling this function. Call `ledc_fade_start()` after this to start fading.

**Note** `ledc_set_fade_with_step`, `ledc_set_fade_with_time` and `ledc_fade_start` are not thread-safe, do not call these functions to control one LEDC channel in different tasks at the same time. A thread-safe version of API is `ledc_set_fade_step_and_start`.

**Note** 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 (0-7), select from `ledc_channel_t`
- **target_duty**: Target duty of fading \([0, (2^{duty\_resolution}) - 1]\)
- **scale**: Controls the increase or decrease step scale.
Chapter 2. API

- cycle_num: increase or decrease the duty every cycle_num cycles

```c
esp_err_t ledc_set_fade_with_time (ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t
                         target_duty, int max_fade_time_ms)
```

Set LEDC fade function, with a limited time.

**Note** Call ledc_fade_func_install() once before calling this function. Call ledc_fade_start() after this to start fading.

**Note** ledc_set_fade_with_step, ledc_set_fade_with_time and ledc_fade_start are not thread-safe, do not call these functions to control one LEDC channel in different tasks at the same time. A thread-safe version of API is ledc_set_fade_step_and_start

**Note** 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 (0-7), 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**

---

Espressif Systems

590

Release v4.3-dev-1561-g357a277603

Submit Document Feedback
• *speed_mode*: Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
• *channel*: LEDC channel (0-7), select from ledc_channel_t
• *duty*: Set the LEDC duty, the range of duty setting is \([0, (2^{\text{duty\_resolution}})]\)
• *hpoint*: Set the LEDC hpoint value (max: 0xffff)

```c
esp_err_t ledc_set_fade_time_and_start(ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t target_duty, uint32_t max_fade_time_ms, ledc_fade_mode_t fade_mode)
```

A thread-safe API to set and start LEDC fade function, with a limited time.

**Note** Call `ledc_fade_func_install()` once, before calling this function.

**Note** 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 (0-7), select from ledc_channel_t
• *target_duty*: Target duty of fading \((0 - (2^{\text{duty\_resolution}}) - 1))\)
• *max_fade_time_ms*: The maximum time of the fading (ms).
• *fade_mode*: choose blocking or non-blocking mode

```c
esp_err_t ledc_set_fade_step_and_start(ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t target_duty, uint32_t scale, uint32_t cycle_num, ledc_fade_mode_t fade_mode)
```

A thread-safe API to set and start LEDC fade function.

**Note** Call `ledc_fade_func_install()` once before calling this function.

**Note** 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 (0-7), select from ledc_channel_t
• *target_duty*: Target duty of fading \([0, (2^{\text{duty\_resolution}}) - 1])\)
• *scale*: Controls the increase or decrease step scale.
• *cycle_num*: increase or decrease the duty every cycle_num cycles
• *fade_mode*: choose blocking or non-blocking mode

**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
```
Header File

- hal/include/hal/ledc_types.h

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 0xffff

```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)

- `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 LDEC_USE_REF_TICK, LDEC_USE_APB_CLK or LDEC_AUTO_CLK. For low speed channels, you can also specify the source clock using LDEC_USE_RTC8M_CLK, in this case, all low speed channel’s source clock must be RTC8M_CLK

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
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_REF_TICK
LEDC timer select REF_TICK clock as source clock

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

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)

enum ledc_timer_t
Values:
```
Chapter 2. API

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
**LEDG_TIMER_9_BIT**
LEDG PWM duty resolution of 9 bits

**LEDG_TIMER_10_BIT**
LEDG PWM duty resolution of 10 bits

**LEDG_TIMER_11_BIT**
LEDG PWM duty resolution of 11 bits

**LEDG_TIMER_12_BIT**
LEDG PWM duty resolution of 12 bits

**LEDG_TIMER_13_BIT**
LEDG PWM duty resolution of 13 bits

**LEDG_TIMER_14_BIT**
LEDG PWM duty resolution of 14 bits

**LEDG_TIMER_15_BIT**
LEDG PWM duty resolution of 15 bits

**LEDG_TIMER_BIT_MAX**

**enum ledc_fade_mode_t**

*Values:*

**LEDG_FADE_NO_WAIT = 0**
LEDG fade function will return immediately

**LEDG_FADE_WAIT_DONE**
LEDG fade function will block until fading to the target duty

**LEDG_FADE_MAX**

2.3.7 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 \( \text{PWMxA / PWMxB} \).

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 \( \text{SYNC SIGNALS} \), detect \( \text{FAULT SIGNALS} \) like motor overcurrent or overvoltage, as well as obtain feedback with \( \text{CAPTURE SIGNALS} \) 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**, **Carrier** and **Interrupts**.
Chapter 2. API Reference

**图 9: MCPWM Overview**

**图 10: MCPWM Block Diagram**

Espressif Systems
Chapter 2. API

Contents

- **Configure** a basic functionality of the outputs
- **Operate** the outputs to drive a motor
- **Adjust** how the motor is driven
- **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
- Configuration and handling of **Interrupts**.

**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.

![Example of Brushed DC Motor Control with MCPWM](image)

Configuration covers the following steps:

1. Selection of a MPWn 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. 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`.

| 注解： | Call function `mcpwm_set_duty_type()` every time after `mcpwm_set_signal_high()` or `mcpwm_set_signal_low()` to resume with previously set duty cycle. |

Adjust

There are couple of ways to adjust a signal on the outputs and changing how the motor operates.

- Set specific PWM frequency by calling `mcpwm_set_frequency()`. This may be required to adjust to electrical or mechanical characteristics of particular motor and driver. To check what frequency is set, use function `mcpwm_get_frequency()`.
- Introduce a dead time between outputs A and B when they are changing the state to reverse direction of the motor rotation. This is to make up for on/off switching delay of the motor driver FETs. The dead time options are defined in `mcpwm_deadtime_type_t` and enabled by calling `mcpwm_deadtime_enable()`. To disable this functionality call `mcpwm_deadtime_disable()`.
- Synchronize outputs of operator submodules, e.g. to get raising edge of PWM0A/B and PWM1A/B to start exactly at the same time, or shift them between each other by a given phase. Synchronization is triggered by SYNC SIGNALS shown on the block diagram of the MCPWM above, and defined in `mcpwm_sync_signal_t`. To attach the signal to a GPIO call `mcpwm_gpio_init()`. You can then enable synchronization with function `mcpwm_sync_enable()`. As input parameters provide MCPWM unit, timer to synchronize, the synchronization signal and a phase to delay the timer.

| 注解： | 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_enable()` 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 please refer to ESP32 Technical Reference Manual.

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.
### Chapter 2. API 参考

#### 12: Example of Brushless DC Motor Control with MCPWM

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()`, selecting desired signal input from `mcpwm_capture_signal_t`, setting the signal edge with `mcpwm_capture_on_edge_t` and the signal count prescaler.

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 time-stamp 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()`.

If not required anymore, the capture functionality may be disabled with `mcpwm_capture_disable()`.

### Fault Handler

Each unit of the MCPWM is able to sense external signals with information about failure of the motor, the motor driver or any other device connected to the MCPWM. There are three fault inputs per unit that may be routed to user selectable GPIOs. The MCPWM may be configured to perform one of four predefined actions on A/B outputs when a fault signal is received:

- lock current state of the output
- set the output low
- set the output high
- toggle the output

The user should determine possible failure modes of the motor and what action should be performed on detection of particular fault, e.g. drive all outputs low for a brushed motor, or lock current state for a stepper motor, etc. As result of this action the motor should be put into a safe state to reduce likelihood of a damage caused by the fault.

The fault handler functionality is enabled in two steps:
1. Configuration of GPIOs to act as fault signal inputs. This is done in analogous way as described for capture signals in section above. It includes setting the signal level to trigger the fault as defined in `mcpwm_fault_input_level_t`.

2. Initialization of the fault handler by calling either `mcpwm_fault_set_oneshot_mode()` or `mcpwm_fault_set_cyc_mode()`. These functions set the mode that MCPWM should operate once fault signal becomes inactive. There are two modes possible:
   - State of MCPWM unit will be locked until reset - `mcpwm_fault_set_oneshot_mode()`.
   - The MCPWM will resume operation once fault signal becoming inactive - `mcpwm_fault_set_cyc_mode()`.

   The function call parameters include selection of one of three fault inputs defined in `mcpwm_fault_signal_t` and specific action on outputs A and B defined in `mcpwm_action_on_pwmxa_t` and `mcpwm_action_on_pwmxb_t`.

   Particular fault signal may be disabled at the runtime by calling `mcpwm_fault_deinit()`.

### Carrier

The MCPWM has a carrier submodule used if galvanic isolation from the motor driver is required by passing the A/B output signals through transformers. Any of A and B output signals may be at 100% duty and not changing whenever motor is required to run steady at the full load. Coupling of non alternating signals with a transformer is problematic, so the signals are modulated by the carrier submodule to create an AC waveform, to make the coupling possible.

To use the carrier submodule, it should be first initialized by calling `mcpwm_carrier_init()`. The carrier parameters are defined in `mcpwm_carrier_config_t` structure invoked within the function call. Then the carrier functionality may be enabled by calling `mcpwm_carrier_enable()`.

The carrier parameters may be then alerted at a runtime by calling dedicated functions to change individual fields of the `mcpwm_carrier_config_t` structure, like `mcpwm_carrier_set_period()`, `mcpwm_carrier_set_duty_cycle()`, `mcpwm_carrier_output_invert()`, etc.

This includes enabling and setting duration of the first pulse of the career with `mcpwm_carrier_oneshot_mode_enable()`. For more details please refer to “PWM Carrier Sub-module” section of the ESP32 Technical Reference Manual.

To disable carrier functionality call `mcpwm_carrier_disable()`.

### Interrupts

Registering of the MCPWM interrupt handler is possible by calling `mcpwm_isr_register()`.

### Application Example

Examples of using MCPWM for motor control: peripherals/mcpwm:

- Demonstration how to use each submodule of the MCPWM - peripherals/mcpwm/mcpwm_basic_config
- Control of BLDC (brushless DC) motor with hall sensor feedback - peripherals/mcpwm/mcpwm_bldc_control
- Brushed DC motor control - peripherals/mcpwm/mcpwm_brushed_dc_control
- Servo motor control - peripherals/mcpwm/mcpwm_servo_control

### API Reference

#### Header File

- `hal/include/hal/mcpwm_types.h`
Enumerations

enum mcpwm_intr_t
    Interrupts for MCPWM.
    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_UP_COUNTER = 1
        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_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_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**
MCPWXA = no change, MCPWMXB = falling edge delay

**MCPWM BYPASS_FED**
MCPWXA = rising edge delay, MCPWMXB = no change

**MCPWM ACTIVE_HIGH_MODE**
MCPWXA = rising edge delay, MCPWMXB = falling edge delay

**MCPWM ACTIVE_LOW_MODE**
MCPWXA = complement of rising edge delay, MCPWMXB = complement of falling edge delay

**MCPWM ACTIVE_HIGH_COMPLIMENT_MODE**
MCPWXA = rising edge delay, MCPWMXB = complement of falling edge delay

**MCPWM ACTIVE_LOW_COMPLIMENT_MODE**
MCPWXA = complement of rising edge delay, MCPWMXB = falling edge delay

**MCPWM ACTIVE_RED_FED_FROM_PWMXA**
MCPWXA = MCPWMXB = rising edge delay as well as falling edge delay, generated from MCP-WMXA

**MCPWM ACTIVE_RED_FED_FROM_PWMXB**
MCPWXA = MCPWMXB = rising edge delay as well as falling edge delay, generated from MCP-WMXB

**MCPWM DEADTIME_TYPE_MAX**

enum mcpwm_sync_signal_t
MCPWM select sync signal input.

Values:

**MCPWM_SELECT_SYNC0** = 4
Select SYNC0 as input

**MCPWM_SELECT_SYNC1**
Select SYNC1 as input

**MCPWM_SELECT_SYNC2**
Select SYNC2 as input

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

**Header File**

- driver/include/driver/mcpwm.h
**Functions**

*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

*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 can be used to initialize more then one gpio 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

*esp_err_t mcpwm_init(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, const mcpwm_config_t *mcpwm_conf)*

Initialize MCPWM parameters.

**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

*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

*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
**API**

**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 (MCPWMA/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 (MCPWMA/MCPWMXB), ‘x’ is operator number selected
- duty_in_us: set duty value in microseconds of each operator

**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 (MCPWMA/MCPWMXB), ‘x’ is operator number selected
- duty_type: set active low or active high duty type

**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

**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 (MCPWMA/MCPWMXB), ‘x’ is operator number selected

**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 (MCPWMA/MCPWMXB), ‘x’ is timer number selected

**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.
Chapter 2. 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
- gen: set the operator(MCPWMXA/MCPWMXB), ‘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

- 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)

```
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)

```
esp_err_t mcpwm_carrier_oneshot_mode_enable(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, uint8_t pulse_width)
```

Enable and set width of first pulse in carrier oneshot mode.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- mcpwm_num: set MCPWM unit (0-1)
- timer_num: set timer number (0-2) of MCPWM, each MCPWM unit has 3 timers
- pulse_width: set pulse width of first pulse in oneshot mode, width = (carrier period) * (pulse_width + 1) (pulse_width <= 15)

```
esp_err_t mcpwm_carrier_oneshot_mode_disable(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num)
```

Disable oneshot mode, width of first pulse = carrier period.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- mcpwm_num: set MCPWM unit (0-1)
- timer_num: set timer number (0-2) of MCPWM, each MCPWM unit has 3 timers
- carrier_ivt_mode: enable or disable carrier output inversion

```
esp_err_t mcpwm_carrier_output_invert(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_carrier_out_ivt_t carrier_ivt_mode)
```

Enable or disable carrier output inversion.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- mcpwm_num: set MCPWM unit (0-1)
- timer_num: set timer number (0-2) of MCPWM, each MCPWM unit has 3 timers
- carrier_ivt_mode: enable or disable carrier output inversion

```
esp_err_t mcpwm_deadtime_enable(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_deadtime_type_t dt_mode, uint32_t red, uint32_t fed)
```

Enable and initialize deadtime for each MCPWM timer.

Return

- ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• mcpwm_num: set MCPWM unit(0-1)
• timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
• dt_mode: set deadtime mode
• red: set rising edge delay = red*100ns
• fed: set rising edge delay = fed*100ns

```c
esp_err_t mcpwm_deadtime_disable (mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num)
```
Disable deadtime on MCPWM timer.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• mcpwm_num: set MCPWM unit(0-1)
• timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers

```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)
Chapter 2. API

- \( \text{timer}_\text{num} \): set timer number (0-2) of MCPWM, each MCPWM unit has 3 timers
- \( \text{fault}_\text{sig} \): set the fault pin, which needs to be enabled for cyc mode
- \( \text{action}_\text{on}_\text{pwm}_\text{xa} \): action to be taken on MCPWMA when fault occurs, either no change or high or low or toggle
- \( \text{action}_\text{on}_\text{pwm}_\text{xb} \): action to be taken on MCPWMB when fault occurs, either no change or high or low or toggle

\[
\text{esp_err_t mcpwm_fault_deinit (mcpwm_unit_t mcpwm_num, mcpwm_fault_signal_t fault_sig)}
\]
Disable fault signal.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- \( \text{mcpwm}_\text{num} \): set MCPWM unit (0-1)
- \( \text{fault}_\text{sig} \): fault pin, which needs to be disabled

\[
\text{esp_err_t mcpwm_capture_enable (mcpwm_unit_t mcpwm_num, mcpwm_capture_signal_t cap}_\text{sig},
\text{mcpwm_capture_on_edge_t cap_edge, uint32_t num_of_pulse)}
\]
Initialize capture submodule.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- \( \text{mcpwm}_\text{num} \): set MCPWM unit (0-1)
- \( \text{cap}_\text{edge} \): set capture edge, BIT(0) - negative edge, BIT(1) - positive edge
- \( \text{cap}_\text{sig} \): capture pin, which needs to be enabled
- \( \text{num_of_pulse} \): count time between rising/falling edge between 2 \(^2\) (pulses mentioned), counter uses APB_CLK

\[
\text{esp_err_t mcpwm_capture_disable (mcpwm_unit_t mcpwm_num, mcpwm_capture_signal_t cap}_\text{sig)}
\]
Disable capture signal.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- \( \text{mcpwm}_\text{num} \): set MCPWM unit (0-1)
- \( \text{cap}_\text{sig} \): capture pin, which needs to be disabled

\[
\text{uint32_t mcpwm_capture_signal_get_value (mcpwm_unit_t mcpwm_num, mcpwm_capture_signal_t cap}_\text{sig)}
\]
Get capture value.

Return Captured value

Parameters
- \( \text{mcpwm}_\text{num} \): set MCPWM unit (0-1)
- \( \text{cap}_\text{sig} \): capture pin on which value is to be measured

\[
\text{uint32_t mcpwm_capture_signal_get_edge (mcpwm_unit_t mcpwm_num, mcpwm_capture_signal_t cap}_\text{sig)}
\]
Get edge of capture signal.

Return Capture signal edge: 1 - positive edge, 2 - negative edge

Parameters
- \( \text{mcpwm}_\text{num} \): set MCPWM unit (0-1)
- \( \text{cap}_\text{sig} \): capture pin of whose edge is to be determined

\[
\text{esp_err_t mcpwm_sync_enable (mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer}_\text{num},
\text{mcpwm_sync_signal_t sync}_\text{sig, uint32_t phase_val)}
\]
Initialize sync submodule.

Return
- ESP_OK Success

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### 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 pin, which needs to be enabled
- `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_disable (mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num)
Disables 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_isr_register (mcpwm_unit_t mcpwm_num, void (*fn) (void), void *arg, int intr_alloc_flags, intr_handle_t *handle)
Register MCPWM interrupt handler, the handler is an ISR. The handler will be attached to the same CPU core that this function is running on.

**Return**
- ESP_OK Success
- ESP.ERR_INVALID_ARG Function pointer error.

**Parameters**
- `mcpwm_num`: set MCPWM unit(0-1)
- `fn`: interrupt handler function.
- `arg`: user-supplied argument passed to the handler function.
- `intr_alloc_flags`: flags used to allocate the interrupt. One or multiple (ORred) ESP_INTR_FLAG_* values. See esp_intr_alloc.h for more info.
- `handle`: pointer to return handle. If non-NULL, a handle for the interrupt will be returned here.

#### Structures

#### struct mcpwm_pin_config_t
MCPWM pin number for.

#### Public Members

- `int mcpwm0a_out_num`: MCPWM0A out pin
- `int mcpwm0b_out_num`: MCPWM0A out pin
- `int mcpwm1a_out_num`: MCPWM0A out pin
- `int mcpwm1b_out_num`: MCPWM0A out pin
- `int mcpwm2a_out_num`: MCPWM0A out pin
- `int mcpwm2b_out_num`: MCPWM0A out pin
- `int mcpwm_sync0_in_num`: SYNC0 in pin
- `int mcpwm_sync1_in_num`: SYNC1 in pin
int mcpwm_sync2_in_num
   SYNC2 in pin
int mcpwm_fault0_in_num
   FAULT0 in pin
int mcpwm_fault1_in_num
   FAULT1 in pin
int mcpwm_fault2_in_num
   FAULT2 in pin
int mcpwm_cap0_in_num
   CAP0 in pin
int mcpwm_cap1_in_num
   CAP1 in pin
int mcpwm_cap2_in_num
   CAP2 in pin

struct mcpwm_config_t
   MCPWM config structure.

Public Members

uint32_t frequency
   Set frequency of MCPWM in Hz

float cmpr_a
   Set % duty cycle for operator a(MCPWMXA), i.e for 62.3% duty cycle, duty_a = 62.3

float cmpr_b
   Set % duty cycle for operator b(MCPWMXB), i.e for 48% duty cycle, duty_b = 48.0

mcpwm_duty_type_t duty_mode
   Set type of duty cycle

mcpwm_counter_type_t counter_mode
   Set type of MCPWM counter

struct mcpwm_carrier_config_t
   MCPWM config carrier 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 oneshot mode

mcpwm_carrier_out_ivt_t carrier_ivt_mode
   Invert output of carrier
Chapter 2. API

Macros
MCPWM_OPR_A
MCPWM_OPR_B
MCPWM_OPR_MAX
MCPWM_NO_CHANGE_IN_MCPWMXA
MCPWM_FORCE_MCPWMXA_LOW
MCPWM_FORCE_MCPWMXA_HIGH
MCPWM_TOG_MCPWMXA
MCPWM_NO_CHANGE_IN_MCPWMXB
MCPWM_FORCE_MCPWMXB_LOW
MCPWM_FORCE_MCPWMXB_HIGH
MCPWM_TOG_MCPWMXB

Type Definitions
typedef mcpwm_generator_t mcpwm_operator_t
typedef mcpwm_output_action_t mcpwm_action_on_pwmxa_t
typedef mcpwm_output_action_t mcpwm_action_on_pwmxb_t

Enumerations
def mcpwm_io_signals_t
  IO signals for the MCPWM.

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

- 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.
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 = 0
MCPWM unit 0 selected

MCPWM_UNIT_1
MCPWM unit 1 selected

MCPWM_UNIT_MAX
Num of MCPWM units on ESP32

enum mcpwm_timer_t
Select MCPWM timer.
Values:

MCPWM_TIMER_0 = 0
Select MCPWM timer 0

MCPWM_TIMER_1
Select MCPWM timer 1

MCPWM_TIMER_2
Select MCPWM timer 2

MCPWM_TIMER_MAX
Num of MCPWM timers on ESP32

enum mcpwm_generator_t
Select MCPWM operator.
Values:

MCPWM_GEN_A = 0
Select MCPWM XA, where ‘X’ is operator number

MCPWM_GEN_B
Select MCPWM XB, where ‘X’ is operator number

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 = 0
Enable oneshot mode
2.3.8 Pulse Counter

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.
Chapter 2. API

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 configuration is provided separately per unit’s channel using `pcnt_config_t` and covers:

- The unit and the channel number this configuration refers to.
- GPIO numbers of the pulse input and the pulse gate input.
- Two pairs of parameters: `pcnt_ctrl_mode_t` and `pcnt_count_mode_t` to define how the counter reacts depending on the status of control signal and how counting is done positive / negative edge of the pulses.
- Two limit values (minimum / maximum) that are used to establish watchpoints and trigger interrupts when the pulse count is meeting particular limit.

Setting up of particular channel is then done by calling a function `pcnt_unit_config()` with above `pcnt_config_t` as the input parameter.

To disable the pulse or the control input pin in configuration, provide `PCNT_PIN_NOT_USED` instead of the GPIO number.

Operating the Counter

After doing setup with `pcnt_unit_config()`, the counter immediately starts to operate. The accumulated pulse count can be checked by calling `pcnt_get_counter_value()`.

There are couple of functions that allow to control the counter’s operation: `pcnt_counter_pause()`, `pcnt_counter_resume()` and `pcnt_counter_clear()`.

It is also possible to dynamically change the previously set up counter modes with `pcnt_unit_config()` by calling `pcnt_set_mode()`.

If desired, the pulse input pin and the control input pin may be changed “on the fly” using `pcnt_set_pin()`.

To disable particular input provide as a function parameter `PCNT_PIN_NOT_USED` instead of the GPIO number.

Note: For the counter not to miss any pulses, the pulse duration should be longer than one APB_CLK cycle (12.5 ns). The pulses are sampled on the edges of the APB_CLK clock and may be missed, if fall between the edges. This applies to counter operation with or without a filter.

Filtering Pulses

The PCNT unit features filters on each of the pulse and control inputs, adding the option to ignore short glitches in the signals.

The length of ignored pulses is provided in APB_CLK clock cycles by calling `pcnt_set_filter_value()`. The current filter setting may be checked with `pcnt_get_filter_value()`. The APB_CLK clock is running at 80 MHz.

The filter is put into operation / suspended by calling `pcnt_filter_enable()` / `pcnt_filter_disable()`.
Using Interrupts

There are five counter state watch events, defined in `pcnt_evt_type_t`, that are able to trigger an interrupt. The event happens on the pulse counter reaching specific values:

- Minimum or maximum count values: `counter_l_lim` or `counter_h_lim` provided in `pcnt_config_t` as discussed in Configuration
- Threshold 0 or Threshold 1 values set using function `pcnt_set_event_value()`.
- Pulse count = 0

To register, enable or disable an interrupt to service the above events, call `pcnt_isr_register()`, `pcnt_intr_enable()`, and `pcnt_intr_disable()`. To enable or disable events on reaching threshold values, you will also need to call functions `pcnt_event_enable()` and `pcnt_event_disable()`.

In order to check what are the threshold values currently set, use function `pcnt_get_event_value()`.

Application Example

- Pulse counter with control signal and event interrupt example: `peripherals/pcnt/pulse_count_event`.
- Parse the signal generated from rotary encoder: `peripherals/pcnt/rotary_encoder`.

API Reference

Header File

- `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

**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

**esp_err_t** `pcnt_event_enable (pcnt_unit_t unit, pcnt_evt_type_t evt_type)`
Enable PCNT event of PCNT unit.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `unit`: PCNT unit number
- `evt_type`: Watch point event type. All enabled events share the same interrupt (one interrupt per pulse counter unit).

**esp_err_t** `pcnt_event_disable (pcnt_unit_t unit, pcnt_evt_type_t evt_type)`
Disable PCNT event of PCNT unit.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `unit`: PCNT unit number
• evt_type: Watch point event type. All enabled events share the same interrupt (one interrupt per pulse counter unit).

```c
esp_err_t pctnt_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 pctnt_get_event_value ( pcnt_unit_t unit, pcnt_evt_type_t evt_type, int16_t* value )
```
Get PCNT event value of PCNT unit.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- unit: PCNT unit number
- evt_type: Watch point event type. All enabled events share the same interrupt (one interrupt per pulse counter unit).
- value: Pointer to accept counter value for PCNT event

```c
esp_err_t pctnt_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 pctnt_isr_unregister ( pcnt_isr_handle_t handle )
```
Unregister PCNT interrupt handler (registered by pctnt_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 pctnt_isr_service_install, please call pctnt_isr_service_unregister 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 pctnt_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 pctnt_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**

Chapter 2. API

• 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**
Chapter 2. API

- unit: PCNT unit number
- filter_val: Pointer to accept PCNT filter value.

```c
esp_err_t pcnt_set_mode(pcnt_unit_t unit, pcnt_channel_t channel, pcnt_count_mode_t pos_mode, pcnt_count_mode_t neg_mode, pcnt_ctrl_mode_t hctrl_mode, pcnt_ctrl_mode_t lctrl_mode)
```

Set PCNT counter mode.

Return
- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- unit: PCNT unit number
- channel: PCNT channel number
- pos_mode: Counter mode when detecting positive edge
- neg_mode: Counter mode when detecting negative edge
- hctrl_mode: Counter mode when control signal is high level
- lctrl_mode: Counter mode when control signal is low level

```c
esp_err_t pcnt_isr_handler_add(pcnt_unit_t unit, void(* isr_handler) void *, void *args)
```

Add ISR handler for specified unit.

Call this function after using pcnt_isr_service_install() to install the PCNT driver’s ISR handler service.

The ISR handlers do not need to be declared with IRAM_ATTR, unless you pass the ESP_INTR_FLAG_IRAM flag when allocating the ISR in pcnt_isr_service_install().

This ISR handler will be called from an ISR. So there is a stack size limit (configurable as “ISR stack size” in menuconfig). This limit is smaller compared to a global PCNT interrupt handler due to the additional level of indirection.

Return
- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- unit: PCNT unit number
- isr_handler: 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_INVALID_ARG Parameter 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.

```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
Chapter 2. API 参考

- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `unit`: PCNT unit number

**Type Definitions**

```c
typedef int isr_handle_t pcnt_isr_handle_t
```

**Header File**

- `hal/include/hal/pcnt_types.h`

**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

int ctrl_gpio_num
    Control signal input GPIO number, a negative value will be ignored

pcnt_ctrl_mode_t lctrl_mode
    PCNT low control mode

pcnt_ctrl_mode_t hctrl_mode
    PCNT high control mode

pcnt_count_mode_t pos_mode
    PCNT positive edge count mode

pcnt_count_mode_t neg_mode
    PCNT negative edge count mode

int16_t counter_h_lim
    Maximum counter value

int16_t counter_l_lim
    Minimum counter value

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

**Enumerations**

```c
enum pcnt_port_t
    PCNT port number, the max port number is (PCNT_PORT_MAX - 1).
```

**Values:**
Chapter 2. API 参考

```c
PCNT_PORT_0 = 0
PCNT port 0

PCNT_PORT_MAX
PCNT port max

enum pcnt_unit_t
Selection of all available PCNT units.

Values:

PCNT_UNIT_0 = 0
PCNT unit 0

PCNT_UNIT_1 = 1
PCNT unit 1

PCNT_UNIT_2 = 2
PCNT unit 2

PCNT_UNIT_3 = 3
PCNT unit 3

PCNT_UNIT_4 = 4
PCNT unit 4

PCNT_UNIT_5 = 5
PCNT unit 5

PCNT_UNIT_6 = 6
PCNT unit 6

PCNT_UNIT_7 = 7
PCNT unit 7

PCNT_UNIT_MAX
```

```c
e enum 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.

Values:

PCNT_MODE_KEEP = 0
Control mode: won’t change counter mode

PCNT_MODE_REVERSE = 1
Control mode: invert counter mode(increase -> decrease, decrease -> increase)

PCNT_MODE_DISABLE = 2
Control mode: Inhibit counter(counter value will not change in this condition)

PCNT_MODE_MAX
```

```c
e enum 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.

Values:

PCNT_COUNT_DIS = 0
Counter mode: Inhibit counter(counter value will not change in this condition)

PCNT_COUNT_INC = 1
Counter mode: Increase counter value

PCNT_COUNT_DEC = 2
Counter mode: Decrease counter value
```
enum pcnt_channel_t
Selection of channels available for a single PCNT unit.

Values:

PCNT_CHANNEL_0 = 0x00
    PCNT channel 0
PCNT_CHANNEL_1 = 0x01
    PCNT channel 1
PCNT_CHANNEL_MAX

enum pcnt_evt_type_t
Selection of counter’s events the may trigger an interrupt.

Values:

PCNT_EVT_THRES_1 = BIT(2)
    PCNT watch point event: threshold1 value event
PCNT_EVT_THRES_0 = BIT(3)
    PCNT watch point event: threshold0 value event
PCNT_EVT_L_LIM = BIT(4)
    PCNT watch point event: Minimum counter value
PCNT_EVT_H_LIM = BIT(5)
    PCNT watch point event: Maximum counter value
PCNT_EVT_ZERO = BIT(6)
    PCNT watch point event: counter value zero event
PCNT_EVT_MAX

2.3.9 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.

![RMT Transmitter Overview](image)

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:
Chapter 2. API 参考

### 14: RMTReceiverOverview

1. **Configure Driver**
2. **Transmit Data or Receive Data**
3. **Change Operation Parameters**
4. **Use Interrupts**

#### Configure Driver

There are several parameters that define how particular channel operates. Most of these parameters are configured by setting specific members of the `rmt_config_t` structure. Some of the parameters are common to both transmit or receive mode, and some are mode specific. They are all discussed below.

#### Common Parameters

- The **channel** to be configured, select one from the `rmt_channel_t` enumerator.
- The RMT **operation mode** - whether this channel is used to transmit or receive data, selected by setting a `rmt_mode` member to one of the values from `rmt_mode_t`.
- What is the **pin number** to transmit or receive RMT signals, selected by setting `gpio_num`.
- How many **memory blocks** will be used by the channel, set with `mem_block_num`.
- Extra miscellaneous parameters for the channel can be set in the `flags`.
  - When `RMT_CHANNEL_FLAGS_ALWAYS_ON` is set, RMT channel will take REF_TICK as source clock. The benefit is, RMT channel can continue work even when APB clock is changing. See `power_management` for more information.
- 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_ALWAYS_ON` is set in `flags`, RMT source clock is changed to REF_TICK.

#### 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`

---

**注解**：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.

![Structure of RMT items](image)

**图 15: 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**

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_pin()`
- 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 by calling `rmt_isr_register()`.
Chapter 2. API

When calling rmt_driver_install() to use the system RMT driver, a default ISR is being installed. In such a case you cannot register a generic ISR handler with rmt_isr_register().

The RMT controller triggers interrupts on four specific events described below. To enable interrupts on these events, the following functions are provided:

- The RMT receiver has finished receiving a signal - rmt_set_rx_intr_en()
- The RMT transmitter has finished transmitting the signal - rmt_set_tx_intr_en()
- The number of events the transmitter has sent matches a threshold value - rmt_set_tx_thr_intr_en()
- Ownership to the RMT memory block has been violated - rmt_set_err_intr_en()

Setting or clearing an interrupt enable mask for specific channels and events may also be done by calling rmt_set_intr_enable_mask() or rmt_clr_intr_enable_mask().

If you do not need an ISR anymore, you can deregister it by calling a function rmt_isr_deregister().

Uninstall Driver

If the RMT driver has been installed with rmt_driver_install() for some specific period of time and then not required, the driver may be removed to free allocated resources by calling rmt_driver_uninstall().

Application Examples

- A simple RMT TX example: peripherals/rmt/morse_code.
- Another RMT TX example, specific to drive a common RGB LED strip: peripherals/rmt/led_strip.
- NEC remote control TX and RX example: peripherals/rmt/ir_protocols.

API Reference

Header File

- driver/include/driver/rmt.h

Functions

esp_err_t rmt_set_clk_div(rmt_channel_t channel, uint8_t div_cnt)
Set RMT clock divider, channel clock is divided from source clock.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters
- channel: RMT channel
- div_cnt: RMT counter clock divider

esp_err_t rmt_get_clk_div(rmt_channel_t channel, uint8_t* div_cnt)
Get RMT clock divider, channel clock is divided from source clock.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters
- channel: RMT channel
- div_cnt: pointer to accept RMT counter divider

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.

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

`esp_err_t rmt_set_mem_pd(rmt_channel_t channel, bool pd_en)`

Set RMT memory in low power mode.

Return
• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters
• channel: RMT channel
• pd_en: RMT memory low power enable.

`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.

`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.

`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

```c
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

```c
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

```c
esp_err_t rmt_set_memory_owner(rmt_channel_t channel, rmt_mem_owner_t owner)
```

Set RMT memory owner.

**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.

```c
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.

```c
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.

```c
esp_err_t rmt_get_tx_loop_mode(rmt_channel_t channel, bool *loop_en)
```

Get RMT tx loop mode.
Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters
- channel: RMT channel
- loop_en: Pointer to accept RMT transmitter loop sending mode.

```
esp_err_t rmt_set_rx_filter(rmt_channel_t channel, bool rx_filter_en, uint8_t thresh)
```
Set RMT RX filter.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters
- channel: RMT channel
- rx_filter_en: To enable RMT receiver filter.
- thresh: Threshold of pulse width for receiver.

```
esp_err_t rmt_set_source_clk(rmt_channel_t channel, rmt_source_clk_t base_clk)
```
Set RMT source clock.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters
- channel: RMT channel
- base_clk: To choose source clock for RMT module.

```
esp_err_t rmt_get_source_clk(rmt_channel_t channel, rmt_source_clk_t *src_clk)
```
Get RMT source clock.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters
- channel: RMT channel
- src_clk: Pointer to accept source clock for RMT module.

```
esp_err_t rmt_set_idle_level(rmt_channel_t channel, bool idle_out_en, rmt_idle_level_t level)
```
Set RMT idle output level for transmitter.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters
- channel: RMT channel
- idle_out_en: To enable idle level output.
- level: To set the output signal’s level for channel in idle state.

```
esp_err_t rmt_get_idle_level(rmt_channel_t channel, bool *idle_out_en, rmt_idle_level_t *level)
```
Get RMT idle output level for transmitter.
Return

• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters

• channel: RMT channel
• idle_out_en: Pointer to accept value of enable idle.
• level: Pointer to accept value of output signal’s level in idle state for specified channel.

`esp_err_t rmt_get_status(rmt_channel_t channel, uint32_t *status)`
Get RMT status.

Return

• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters

• channel: RMT channel
• status: Pointer to accept channel status. Please refer to RMT_CHnSTATUS_REG(n=0~7) in rmt_reg.h for more details of each field.

`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_rx_intr_en(rmt_channel_t channel, bool en)`
Set RMT RX interrupt enable.

Return

• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters

• channel: RMT channel
• en: enable or disable RX interrupt.

`esp_err_t rmt_set_err_intr_en(rmt_channel_t channel, bool en)`
Set RMT RX error interrupt enable.

Return

• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters

• channel: RMT channel
• en: enable or disable RX err interrupt.

`esp_err_t rmt_set_tx_intr_en(rmt_channel_t channel, bool en)`
Set RMT TX interrupt enable.

Return

• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters

• channel: RMT channel
• en: enable or disable TX interrupt.

`esp_err_t rmt_set_tx_thr_intr_en(rmt_channel_t channel, bool en, uint16_t evt_thresh)`
Set RMT TX threshold event interrupt enable.

An interrupt will be triggered when the number of transmitted items reaches the threshold value.
Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters
- channel: RMT channel
- en: enable or disable TX event interrupt.
- evt_thresh: RMT event interrupt threshold value

`esp_err_t rmt_set_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.

`esp_err_t rmt_config(const rmt_config_t *rmt_param)`
Configure RMT parameters.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters
- rmt_param: RMT parameter struct

`esp_err_t rmt_isr_register(void (*fn) void * arg, int intr_alloc_flags, rmt_isr_handle_t *handle)`
Register RMT interrupt handler, the handler is an ISR.
The handler will be attached to the same CPU core that this function is running on.

Note If you already called rmt_driver_install to use system RMT driver, please do not register ISR handler again.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Function pointer error.
- ESP_FAIL System driver installed, 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.

`esp_err_t rmt_isr_deregister(rmt_isr_handle_t handle)`
Deregister previously registered RMT interrupt handler.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Handle invalid

Parameters
- handle: Handle obtained from rmt_isr_register

`esp_err_t rmt_fill_tx_items(rmt_channel_t channel, const rmt_item32_t *item, uint16_t item_num, uint16_t mem_offset)`
Fill memory data of channel with given RMT items.

Return
- ESP_ERR_INVALID_ARG Parameter error
Chapter 2. API 参考

- ESP_OK Success

**Parameters**
- channel: RMT channel
- item: Pointer of items.
- item_num: RMT sending items number.
- mem_offset: Index offset of memory.

**esp_err_t rmt_driver_install (rmt_channel_t channel, size_t rx_buf_size, int intr_alloc_flags)**

Initialize RMT driver.

**Return**
- ESP_ERR_INVALID_STATE Driver is already installed, call rmt_driver_uninstall first.
- ESP_ERR_NO_MEM Memory allocation failure
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- rx_buf_size: Size of RMT RX ringbuffer. Can be 0 if the RX ringbuffer is not used.
- intr_alloc_flags: Flags for the RMT driver interrupt handler. Pass 0 for default flags. See esp_intr_alloc.h for details. If ESP_INTR_FLAG_IRAM is used, please do not use the memory allocated from psram when calling rmt_write_items.

**esp_err_t rmt_driver_uninstall (rmt_channel_t channel)**

Uninstall RMT driver.

**Return**
- ESP_ERR_INVALID_ARG Parameter is NULL
- ESP_OK Success

**Parameters**
- channel: RMT channel

**esp_err_t rmt_get_channel_status (rmt_channel_status_result_t *channel_status)**

Get the current status of eight channels.

**Note** Do not call this function if it is possible that rmt_driver_uninstall will be called at the same time.

**Return**
- ESP_ERR_INVALID_ARG Parameter is NULL
- ESP_OK Success

**Parameters**
- [out] channel_status: store the current status of each channel

**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

**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.
Chapter 2. API Reference

Return
• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters
• channel: RMT channel
• rmt_item: head point of RMT items array. If ESP_INTR_FLAG_IRAM is used, please do not use the memory allocated from psram when calling rmt_write_items.
• item_num: RMT data item number.
• wait_tx_done:
  – If set 1, it will block the task and wait for sending done.
  – If set 0, it will not wait and return immediately.

```c
esp_err_t rmt_wait_tx_done (rmt_channel_t channel, TickType_t wait_time)
```

Wait RMT TX finished.

Return
• ESP_OK RMT TX done successfully
• ESP_ERR_TIMEOUT Exceeded the ‘wait_time’ given
• ESP_ERR_INVALID_ARG Parameter error
• ESP_FAIL Driver not installed

Parameters
• channel: RMT channel
• wait_time: Maximum time in ticks to wait for transmission to be complete. If set 0, return immediately with ESP_ERR_TIMEOUT if TX is busy (polling).

```c
esp_err_t rmt_get_ringbuf_handle (rmt_channel_t channel, RingbufHandle_t *buf_handle)
```

Get ringbuffer from RMT.

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.

```c
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.

```c
esp_err_t rmt_write_sample (rmt_channel_t channel, const uint8_t *src, size_t src_size, bool wait_tx_done)
```

Translate uint8_t type of data into rmt format and send it out. Requires rmt_translator_init to init the translator first.

Return
• ESP_FAIL Send fail
• ESP_OK Send success

Parameters
• channel: RMT channel.
• src: Pointer to the raw data.
• src_size: The size of the raw data.
• wait_tx_done: Set true to wait all data send done.
Chapter 2. API

**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.

**Structures**

**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
Chapter 2. API

**rmt_channel_t**
RMT channel

**gpio_num_t**
gpio_num
RMT GPIO number

**uint8_t clk_div**
RMT channel counter divider

**uint8_t mem_block_num**
RMT memory block number

**uint32_t flags**
RMT channel extra configurations, OR’d with RMT_CHANNEL_FLAGS_[*]

**rmt_tx_config_t tx_config**
RMT TX parameter

**rmt_rx_config_t rx_config**
RMT RX parameter

**struct rmt_tx_end_callback_t**
Structure encapsulating a RMT TX end callback.

### Public Members

**rmt_tx_end_fn_t**
Function which is called on RMT TX end

void *arg
Optional argument passed to function

### Macros

**RMT_CHANNEL_FLAGS_ALWAYS_ON**
Channel can work when APB frequency is changing (RMT channel adopts REF_TICK as clock source)

**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.
Chapter 2. API 参考

- [out] dest: Pointer to the buffer storing the rmt format data.
- src_size: The raw data size.
- wanted_num: The number of rmt format data that wanted to get.
- [out] translated_size: The size of the raw data that has been converted to rmt format, it should return 0 if no data is converted in user callback.
- [out] item_num: The number of the rmt format data that actually converted to, it can be less than wanted_num if there is not enough raw data, but cannot exceed wanted_num. it should return 0 if no data was converted.

Header File

- hal/include/hal/rmt_types.h

Structures

struct rmt_channel_status_result_t
Data struct of RMT channel status.

Public Members

rmt_channel_status_t status[RMT_CHANNEL_MAX]
Store the current status of each channel

Enumerations

denum rmt_channel_t
RMT channel ID.
Values:

RMT_CHANNEL_0
RMT channel number 0
RMT_CHANNEL_1
RMT channel number 1
RMT_CHANNEL_2
RMT channel number 2
RMT_CHANNEL_3
RMT channel number 3
RMT_CHANNEL_4
RMT channel number 4
RMT_CHANNEL_5
RMT channel number 5
RMT_CHANNEL_6
RMT channel number 6
RMT_CHANNEL_7
RMT channel number 7
RMT_CHANNEL_MAX
Number of RMT channels

denum rmt_mem_owner_t
RMT Internal Memory Owner.
Values:

RMT_MEM_OWNER_TX
RMT RX mode, RMT transmitter owns the memory block
Chapter 2. API 参考

```c
RMT_MEM_OWNER_RX
RMT RX mode, RMT receiver owns the memory block

RMT_MEM_OWNER_MAX
```

```c
enum rmt_source_clk_t
Clock Source of RMT Channel.

Values:

RMT_BASECLK_REF
RMT source clock is REF_TICK, 1MHz by default

RMT_BASECLK_APB
RMT source clock is APB CLK, 80Mhz by default

RMT_BASECLK_MAX
```

```c
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
```

```c
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
```

```c
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
```

```c
enum rmt_carrier_level_t
RMT Carrier Level.

Values:

RMT_CARRIER_LEVEL_LOW
RMT carrier wave is modulated for low Level output

RMT_CARRIER_LEVEL_HIGH
RMT carrier wave is modulated for high Level output

RMT_CARRIER_LEVEL_MAX
```
enum rmt_channel_status_t
RMT Channel Status.

Values:

RMT_CHANNEL_UNINIT
RMT channel uninitialized

RMT_CHANNEL_IDLE
RMT channel status idle

RMT_CHANNEL_BUSY
RMT channel status busy

2.3.10 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.

<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>GPIO6</td>
<td>GPIO14</td>
</tr>
<tr>
<td>D0</td>
<td>GPIO7</td>
<td>GPIO2</td>
</tr>
<tr>
<td>D1</td>
<td>GPIO8</td>
<td>GPIO4</td>
</tr>
<tr>
<td>D2</td>
<td>GPIO9</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>GPIO5</td>
<td></td>
</tr>
<tr>
<td>D7</td>
<td>GPIO18</td>
<td></td>
</tr>
<tr>
<td>CD</td>
<td>any input via GPIO matrix</td>
<td></td>
</tr>
<tr>
<td>WP</td>
<td>any input via GPIO matrix</td>
<td></td>
</tr>
</tbody>
</table>

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.

警告: 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), 4-line/1-line (with SD cards), and 8-line (with 3.3 V eMMC)
- High Speed (40 MHz), 4-line/1-line (with SD cards), and 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

• `driver/include/driver/sdmmc_host.h`

Functions

```c
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 can not be allocated
### Chapter 2. API

**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

**Parameters**

- slot: slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- slot_config: additional configuration for the slot

**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

**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 sdmme_host_do_transaction as long as other sdmme_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

```c
esp_err_t sdmme_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)

```c
esp_err_t sdmme_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

```c
esp_err_t sdmme_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 sdmme_host_init function has not been called

```c
esp_err_t sdmme_host_pullup_en (int slot, int width)
```

Enable the pull-ups of sd pins.

**Note** You should always place actual pullups on the lines instead of using this function. Internal pullup resistance are high and not sufficient, may cause instability in products. This is for debug or examples only.

**Return**
- ESP_OK: if success
- ESP_ERR_INVALID_ARG: if configured width larger than maximum the slot can support

**Parameters**
- slot: Slot to use, normally set it to 1.
- width: Bit width of your configuration, 1 or 4.

**Structures**

```c
struct sdmmc_slot_config_t
```

Extra configuration for SDMMC peripheral slot.
Public Members

- `gpio_num_t gpio_cd`
  - GPIO number of card detect signal.

- `gpio_num_t gpio_wp`
  - GPIO number of write protect signal.

- `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 default width for the slot (8 for slot 0, 4 for slot 1)

- `SDMMC_SLOT_CONFIG_DEFAULT ()`
  - Macro defining default configuration of SDMMC host slot

2.3.11 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 (by `spi_bus_initialize`).

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!

**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.

---

**API Reference**

**Header File**

- `driver/include/driver/sdspi_host.h`

**Functions**

- `esp_err_t sdspi_host_init (void)`
  Initialize SD SPI driver.
  **Note** This function is not thread safe
  **Return**
  - ESP_OK on success
  - other error codes may be returned in future versions

- `esp_err_t sdspi_host_init_device(const sdspi_device_config_t *dev_config, sdspi_dev_handle_t *out_handle)`
  Attach and initialize an SD SPI device on the specific SPI bus.
  **Note** This function is not thread safe
  **Note** Initialize the SPI bus by `spi_bus_initialize()` before calling this function.
  **Note** The SDIO over sdspi needs an extra interrupt line. Call `gpio_install_isr_service()` before this function.
  **Return**
  - ESP_OK on success
  - ESP_ERR_INVALID_ARG if sdspi_host_init_device has invalid arguments
  - ESP_ERR_NO_MEM if memory can not be allocated
  - other errors from the underlying spi_master and gpio drivers

- `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

---

注解：SD over SPI does not support speeds above `SDMMC_FREQ_DEFAULT` due to the limitations of the SPI driver.
### Chapter 2. API 参考

**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 sdsipi device
- cmdinfo: pointer to structure describing command and data to transfer

**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 sdsipi device
- freq_khz: card clock frequency, in kHz

**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

**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 sdsipi device

**esp_err_t sdspi_host_io_int_wait (sdspi_dev_handle_t handle, TickType_t timeout_ticks)**

Wait for SDIO interrupt until timeout.

**Return**
- ESP_OK on success

**Parameters**
- handle: Handle of the sdsipi 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 sdspi needs an extra interrupt line. Call gpio_install_isr_service() before this function.

**Parameters**
- slot: SPI controller to use (HSPI_HOST or VSPI_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

```c
struct sdspi_device_config_t
   Extra configuration for SD SPI device.
```

Public Members

```c
spi_host_device_t host_id
   SPI host to use, SPIx_HOST (see spi_types.h).

gpio_num_t gpio_cs
   GPIO number of CS signal.

gpio_num_t gpio_cd
   GPIO number of card detect signal.

gpio_num_t gpio_wp
   GPIO number of write protect signal.

gpio_num_t gpio_int
   GPIO number of interrupt line (input) for SDIO card.
```

```c
struct sdspi_slot_config_t
   Extra configuration for SPI host.
```

Public Members

```c
gpio_num_t gpio_cs
   GPIO number of CS signal.

gpio_num_t gpio_cd
   GPIO number of card detect signal.

gpio_num_t gpio_wp
   GPIO number of write protect signal.

gpio_num_t gpio_int
   GPIO number of interrupt line (input) for SDIO card.

gpio_num_t gpio_miso
   GPIO number of MISO signal.

gpio_num_t gpio_mosi
   GPIO number of MOSI signal.

gpio_num_t gpio_sck
   GPIO number of SCK signal.
```

```c
int dma_channel
   DMA channel to be used by SPI driver (1 or 2).
```

Macros

```c
SDSPI_HOST_DEFAULT()
```

Default sdmmc_host_t structure initializer for SD over SPI driver.

 Uses SPI mode and max frequency set to 20MHz

‘slot’ should be set to an sdspi device initialized by sdspi_host_init_device().
SDSPI_SLOT_NO_CD
indicates that card detect line is not used

SDSPI_SLOT_NO_WP
indicates that write protect line is not used

SDSPI_SLOT_NO_INT
indicates that interrupt line is not used

SDSPI_DEVICE_CONFIG_DEFAULT
Macro defining default configuration of SD SPI device.

SDSPI_SLOT_CONFIG_DEFAULT
Macro defining default configuration of SPI host

**Type Definitions**

```c
typedef int sdspi_dev_handle_t
Handle representing an SD SPI device.
```

### 2.3.12 SDIO Card Slave Driver

**Overview**

The ESP32 SDIO Card peripherals (Host, Slave) share 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 run on the second set of pins while SDIO host is not using it.

The SDIO slave can run under 3 modes: SPI, 1-bit SD and 4-bit SD modes, which is detected automatically by the hardware. According to the SDIO specification, CMD and DAT0-3 lines should be pulled up no matter in 1-bit, 4-bit or SPI mode.

<table>
<thead>
<tr>
<th>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:

Chapter 2. API

- 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.

**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)**

**Systems in Packages (SIP)**

**Modules**

**Development Boards**

**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.

   警告: 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 the 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.

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>

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.
Chapter 2. API

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.

** 注解**: Register names in ESP Technical Reference Manual 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.

** 注解**: 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 filled with 0 (sending) or discard (receiving).

- **Receiving buffer size**: The buffer size is pre-defined between the host and the slave before communication starts. Slave application has to set the buffer size during initialization by the recv_buffer_size member of sdio_slave_config_t.
- **Interrupts**: the esp32 slave support interrupts in two directions: from host to slave (called slave interrupts below) and from slave to host (called host interrupts below). See more in **Interrupts**.
- **Registers**: specific address in Function 1 access by CMD52 or CMD53.

**Communication with ESP SDIO Slave** The host should initialize the ESP32 SDIO slave according to the standard SDIO initialization process (Sector 3.1.2 of SDIO Simplified Specification), which is described briefly in **ESP SDIO Slave Initialization**.

Furthermore, there’s an ESP32-specific upper-level communication protocol upon the CMD52/CMD53 to Func 1. Please refer to **ESP SDIO Slave Protocol**. There is also a component **ESP Serial Slave Link** for ESP32 master to communicate with ESP32 SDIO slave, see example peripherals/sdio when programming your host.

**Interrupts** There are interrupts from host to slave, and from slave to host to help communicating conveniently.

**Slave Interrupts** The host can interrupt the slave by writing any one bit in the register 0x08D. Once any bit of the register is set, an interrupt is raised and the SDIO slave driver calls the callback function defined in the slave_intr_cb member in the sdio_slave_config_t structure.

** 注解**: The callback function is called in the ISR, do not use any delay, loop or spinlock in the callback.
There’s another set of functions can be used. You can call `sdio_slave_wait_int` to wait for an interrupt within a certain time, or call `sdio_slave_clear_int` to clear interrupts from host. The callback function can work with the wait functions perfectly.

**Host Interrupts** The slave can interrupt the host by an interrupt line (at certain time) which is level sensitive. When the host see the interrupt line pulled down, it may read the slave interrupt status register, to see the interrupt source. Host can clear interrupt bits, or choose to disable a interrupt source. The interrupt line will hold active until all the sources are cleared or disabled.

There are several dedicated interrupt sources as well as general purpose sources. see `sdio_slave_hostint_t` for more information.

**Shared Registers** There are 52 8-bit R/W shared registers to share information between host and slave. The slave can write or read the registers at any time by `sdio_slave_read_reg` and `sdio_slave_write_reg`. The host can access (R/W) the register by CMD52 or CMD53.

**Receiving FIFO** When the host is going to send the slave some packets, it has to check whether the slave is ready to receive by reading the buffer number of slave.

To allow the host sending data to the slave, the application has to load buffers to the slave driver by the following steps:

1. Register the buffer by calling `sdio_slave_recv_register_buf`, and get the handle of the registered buffer. The driver will allocate memory for the linked-list descriptor needed to link the buffer onto the hardware.
2. Load buffers onto the driver by passing the buffer handle to `sdio_slave_recv_load_buf`.
3. Call `sdio_slave_recv` to get the received data. If non-blocking call is needed, set `wait=0`.
4. Pass the handle of processed buffer back to the driver by `sdio_recv_load_buf` again.

*注解:* 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.

*注解:* 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,
   .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

- `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

- driver/include/driver/sdio_slave.h

Functions

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.

void sdio_slave_deinit (void)
De-initialize the sdio slave driver to release the resources.

esp_err_t sdio_slave_start (void)
Start hardware for sending and receiving, as well as set the IREADY1 to 1.

Note The driver will continue sending from previous data and PKT_LEN counting, keep data received as well
as start receiving from current TOKEN1 counting. See sdio_slave_reset.

Return
- ESP_ERR_INVALID_STATE if already started.
- ESP_OK otherwise.

void sdio_slave_stop (void)
Stop hardware from sending and receiving, also set IREADY1 to 0.

Note this will not clear the data already in the driver, and also not reset the PKT_LEN and TOKEN1 counting.
Call sdio_slave_reset to do that.

esp_err_t sdio_slave_reset (void)
Clear the data still in the driver, as well as reset the PKT_LEN and TOKEN1 counting.

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 (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.

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.

```c
sdio_slave_hostint_t sdio_slave_get_host_intena (void)
Get the interrupt enable for host.
Return the interrupt mask.
```

```c
void sdio_slave_set_host_intena (sdio_slave_hostint_t mask)
Set the interrupt enable for host.
Parameters
- **mask**: Enable mask for host interrupt.
```

```c
esp_err_t sdio_slave_send_host_int (uint8_t pos)
Interrupt the host by general purpose interrupt.
Return
- ESP_ERR_INVALID_ARG if interrupt num error
- ESP_OK otherwise
Parameters
- **pos**: Interrupt num, 0-7.
```

```c
void sdio_slave_clear_host_int (sdio_slave_hostint_t mask)
Clear general purpose interrupt to host.
Parameters
- **mask**: Interrupt bits to clear, by bit mask.
```

```c
esp_err_t sdio_slave_wait_int (int pos, TickType_t wait)
Wait for general purpose interrupt from host.
Note this clears the interrupt at the same time.
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**

```c
struct sdio_slave_config_t
Configuration of SDIO slave.
```

**Public Members**

```c
sdio_slave_timing_t timing
timing of sdio_slave. see sdio_slave_timing_t.
```

```c
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.
```

```c
int send_queue_size
max buffers that can be queued before sending.
```

```c
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).
```
Chapter 2. API

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
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.

2.3.13 Sigma-delta Modulation

Introduction

ESPD32 has a second-order sigma-delta modulation module. This driver configures the channels of the sigma-delta
module.

Functionality Overview

There are eight 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().

Application Example

Sigma-delta Modulation example: peripherals/sigmadelta.
API Reference

Header File

- driver/include/driver/sigmadelta.h

Functions

**esp_err_t sigmadelta_config (const sigmadelta_config_t *config)**
Configure Sigma-delta channel.

- **ESP_OK** Success
- **ESP_ERR_INVALID_STATE** sigmadelta driver already initialized
- **ESP_ERR_INVALID_ARG** Parameter error

**Parameters**
- **config**: Pointer of Sigma-delta channel configuration struct

**esp_err_t sigmadelta_set_duty (sigmadelta_channel_t channel, int8_t duty)**
Set Sigma-delta channel duty.

- **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.

**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.

- **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

**esp_err_t sigmadelta_set_pin (sigmadelta_channel_t channel, gpio_num_t gpio_num)**
Set Sigma-delta signal output pin.

- **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.

Header File

- hal/include/hal/sigmadelta_types.h
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.
```

Enumerations

```c
enum sigmadelta_port_t
SIGMADELTA port number, the max port number is (SIGMADELTA_NUM_MAX -1).
```

```c
SIGMADELTA_PORT_0
SIGMADELTA port 0
```

```c
SIGMADELTA_PORT_MAX
SIGMADELTA port max
```

```c
enum sigmadelta_channel_t
Sigma-delta channel list.
```

```c
SIGMADELTA_CHANNEL_0
Sigma-delta channel 0
```

```c
SIGMADELTA_CHANNEL_1
Sigma-delta channel 1
```

```c
SIGMADELTA_CHANNEL_2
Sigma-delta channel 2
```

```c
SIGMADELTA_CHANNEL_3
Sigma-delta channel 3
```

```c
SIGMADELTA_CHANNEL_4
Sigma-delta channel 4
```

```c
SIGMADELTA_CHANNEL_5
Sigma-delta channel 5
```

```c
SIGMADELTA_CHANNEL_6
Sigma-delta channel 6
```

```c
SIGMADELTA_CHANNEL_7
Sigma-delta channel 7
```

```c
SIGMADELTA_CHANNEL_MAX
Sigma-delta channel max
```

2.3.14 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 four SPI peripherals.

- SPI0 and SPI1 are used internally to access the ESP32’s attached flash memory and share an arbiter.
- 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 signal buses with the same respective names. Each bus has three CS lines to drive up to three 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. This may be the SPI2 or SPI3 peripheral. (The driver will also support the SPI1 peripheral in the future.)</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>MISO</td>
<td>Master In, Slave Out, a.k.a. Q. Data transmission from a Device to Host.</td>
</tr>
<tr>
<td>MOSI</td>
<td>Master Out, Slave In, a.k.a. D. Data transmission from a Host to Device.</td>
</tr>
<tr>
<td>SCLK</td>
<td>Serial Clock. Oscillating signal generated by a Host that keeps the transmission of data bits in sync.</td>
</tr>
<tr>
<td>CS</td>
<td>Chip Select. Allows a Host to select individual Device(s) connected to the bus in order to send or receive data.</td>
</tr>
<tr>
<td>QUADWP</td>
<td>Write Protect signal. Only used for 4-bit (qio/qout) transactions.</td>
</tr>
<tr>
<td>QUADHD</td>
<td>Hold signal. Only used for 4-bit (qio/qout) transactions.</td>
</tr>
<tr>
<td>Assertion</td>
<td>The action of activating a line. The opposite action of returning the line back to inactive (back to idle) is called de-assertion.</td>
</tr>
<tr>
<td>Transaction</td>
<td>One instance of a Host asserting a CS line, transferring data to and from a Device, and de-asserting the CS line. Transactions are atomic, which means they can never be interrupted by another transaction.</td>
</tr>
<tr>
<td>Launch edge</td>
<td>Edge of the clock at which the source register launches the signal onto the line.</td>
</tr>
<tr>
<td>Latch edge</td>
<td>Edge of the clock at which the destination register latches in the signal.</td>
</tr>
</tbody>
</table>

**Driver Features**

The SPI 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*. 

---

Submit Document Feedback
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`.

### SPI Features

### SPI Master

### SPI Bus Lock

To realize the multiplexing of different devices from different drivers (SPI Master, SPI Flash, etc.), an SPI bus lock is applied on each SPI bus. Drivers can attach their devices onto the bus with the arbitration of the lock.

Each bus lock are initialized with a BG (background) service registered, all devices request to do transactions on the bus should wait until the BG to be successfully disabled.

- For SPI1 bus, the BG is the cache, the bus lock will help to disable the cache before device operations starts, and enable it again after device releasing the lock. No devices on SPI1 is allowed using ISR (it’s meaningless for the task to yield to other tasks when the cache is disabled).
- For other buses, the driver may register its ISR as the BG. The bus lock will block a device task when it requests for exclusive use of the bus, try to disable the ISR, and unblock the device task allowed to exclusively use the bus when the ISR is successfully disabled. When the task releases the lock, the lock will also try to resume the ISR if there are pending transactions to be done in the ISR.

### SPI Transactions

An SPI bus transaction consists of five phases which can be found in the table below. Any of these phases can be skipped.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command</td>
<td>In this phase, a command (0-16 bit) is written to the bus by the Host.</td>
</tr>
<tr>
<td>Address</td>
<td>In this phase, an address (0-64 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 `rxiength` 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 intervals. 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.

**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::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::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::flags` are not set, the driver automatically sets the length of these phases to default values during Device initialization.

**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 (staring 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.
Chapter 2. API

Half-duplex transactions with both read and write phases are not supported when using DMA. For details and workarounds, see Known Issues.

**Bus Acquiring** Sometimes you might want to send SPI transactions exclusively and continuously so that it takes as little time as possible. For this, you can use bus acquiring, which helps to suspend transactions (both polling or interrupt) to other devices until the bus is released. To acquire and release a bus, use the functions `spi_device_acquire_bus()` and `spi_device_release_bus()`.

**Driver Usage**

- Initialize an SPI bus by calling the function `spi_bus_initialize()`. Make sure to set the correct I/O pins in the struct `spi_bus_config_t`. Set the signals that are not needed to -1.
- Register a Device connected to the bus with the driver by calling the function `spi_bus_add_device()`. Make sure to configure any timing requirements the device might need with the parameter `dev_config`. You should now have obtained the Device’s handle which will be used when sending a transaction to it.
- To interact with the Device, fill one or more `spi_transaction_t` structs with any transaction parameters required. Then send the structs either using a polling transaction or an interrupt transaction:
  - **Interrupt** Either queue all transactions by calling the function `spi_device_queue_trans()` and, at a later time, query the result using the function `spi_device_get_trans_result()`, or handle all requests synchronously by feeding them into `spi_device_transmit()`.
  - **Polling** Call the function `spi_device_polling_transmit()` to send polling transactions. Alternatively, if you want to insert something in between, send the transactions by using `spi_device_polling_start()` and `spi_device_polling_end()`.
- (Optional) To perform back-to-back transactions with a Device, call the function `spi_device_acquire_bus()` before sending transactions and `spi_device_release_bus()` after the transactions have been sent.
- (Optional) To unload the driver for a certain Device, call `spi_bus_remove_device()` with the Device handle as an argument.
- (Optional) To remove the driver for a bus, make sure no more drivers are attached and call `spi_bus_free()`.

The example code for the SPI master driver can be found in the `peripherals/spi_master` directory of ESP-IDF examples.

**Transactions with Data Not Exceeding 32 Bits** When the transaction data size is equal to or less than 32 bits, it will be sub-optimal to allocate a buffer for the data. The data can be directly stored in the transaction struct instead. For transmitted data, it can be achieved by using the `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 `0b000010` 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:
Chapter 2. API

- **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_polling_start()` 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**

Though the SPI Bus Lock feature makes it possible to use SPI Master driver on the SPI1 bus, it’s still tricky and needs a lot of special treatment. It’s a feature for advanced developers.

To use SPI Master driver on SPI1 bus, you have to take care of two problems:

1. The code and data, required at the meanwhile the driver is operating SPI1 bus, should be in the internal memory. SPI1 bus is shared among devices and the cache for data (code) in the Flash as well as the PSRAM. The cache should be disabled during the other drivers are operating the SPI1 bus. Hence the data (code) in the flash as well as the PSRAM cannot be fetched at the meanwhile the driver acquires the SPI1 bus by:
   - Explicit bus acquiring between `spi_device_acquire_bus()` and `spi_device_release_bus()`.
   - Implicit bus acquiring between `spi_device_polling_start()` and `spi_device_polling_end()` (or inside `spi_device_polling_transmit()`).

   During the time above, all other tasks and most ISRs will be disabled (see IRAM 安全中断处理程序). Application code and data used by current task should be placed in internal memory (DRAM or IRAM), or already in the ROM. Access to external memory (flash code, const data in the flash, and static/heap data in the PSRAM) will cause a Cache disabled but cached memory region accessed exception. For differences between IRAM, DRAM, and flash cache, please refer to the application memory layout documentation.

To place functions into the IRAM, you can either:

1. Add `IRAM_ATTR` (include “esp_attr.h”) to the function like:
   ```c
   IRAM_ATTR void foo(void) {
   }
   ```
   Please note that when a function is inlined, it will follow its caller’s segment, and the attribute will not take effect. You may need to use NOLINE_ATTR to avoid this.

2. Use the `noflash` placement in the `linker.lf`. See more in 链接脚本生成机制. Please note that, some code may be transformed into lookup table in the const data by the compiler, so `noflash_text` is not safe.

   Please do take care that the optimization level may affect the compiler behavior of inline, or transforming some code into lookup table in the const data, etc.

To place data into the DRAM, you can either:

1. Add `DRAM_ATTR` (include “esp_attr.h”) to the data definition like:
   ```c
   DRAM_ATTR int g_foo = 3;
   ```

2. Use the `noflash` placement in the `linker.lf`. See more in 链接脚本生成机制.

   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.

<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.

**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 Interval**  Transaction interval is the time that software requires to set up SPI peripheral registers and to copy data to FIFOs, or to set up DMA links.

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 interval. 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 interval timings for one byte of data are given below.

<table>
<thead>
<tr>
<th></th>
<th>Typical Transaction Time (us)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Interrupt Pipeline Polling</td>
</tr>
<tr>
<td>DMA</td>
<td>24</td>
</tr>
<tr>
<td>No DMA</td>
<td>22</td>
</tr>
</tbody>
</table>
Chapter 2. API

**SPI Clock Frequency**  Transferring each byte takes eight times the clock period \( \frac{8}{f_{spi}} \). 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 the cache miss and will need to wait until the code is read from the 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 miss.

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: \( \frac{n}{20+8n/f_{spi}} \). 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 安全中断处理程序**.

**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, and the setup timing requirement is violated, which results in the failure to perform the reading correctly.
The maximum allowed frequency is dependent on:

- \textit{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 \texttt{spi\_get\_freq\_limit()}. 

\textbf{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>

Half-duplex, no DMA allowed

If the Host only writes data, the \textit{dummy bit workaround} and the frequency check can be disabled by setting the bit \texttt{SPI\_DEVICE\_NO\_DUMMY} in the member \texttt{spi\_device\_interface\_config\_t::__flags}. When disabled, the output frequency can be 80MHz, even if the GPIO matrix is used.

\texttt{spi\_device\_interface\_config\_t::__flags}

The SPI master driver can work even if the \textit{input\_delay\_ns} in the structure \texttt{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 on an oscilloscope or logic analyzer.

Please note that the actual PCB layout design and the 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 the 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.

<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>
<tr>
<td>ESP32's slave device is on a different physical chip.</td>
<td></td>
</tr>
</tbody>
</table>

The MISO path delay (valid time) consists of a slave’s \textit{input delay} plus master’s \textit{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:

\[
\text{Freq limit [MHz]} = \frac{80}{\left\lfloor \text{MISO delay[ns]/12.5} \right\rfloor + 1}
\]

The figure below shows the relationship between frequency limit and input delay. Two extra APB clock cycle periods should be added to the MISO delay if the master uses the GPIO matrix.
Corresponding frequency limits for different Devices with different input delay times are shown in the table below.

<table>
<thead>
<tr>
<th>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

Application Example

The code example for displaying graphics on an ESP32-WROVER-KIT’s 320x240 LCD screen can be found in the peripherals/spi_master directory of ESP-IDF examples.

API Reference - SPI Common

Header File

- hal/include/hal/spi_types.h

Enumerations

enum spi_host_device_t

Enum with the three SPI peripherals that are software-accessible in it.

Values:
Chapter 2. API

SPI_HOST = 0
SPI1.
SPI2_HOST = 1
SPI2.
SPI3_HOST = 2
SPI3.

enum spi_event_t
SPI Events.

Values:
SPI_EV_BUF_TX = BIT(0)
The buffer has sent data to master, Slave HD only.
SPI_EV_BUF_RX = BIT(1)
The buffer has received data from master, Slave HD only.
SPI_EV_SEND = BIT(2)
Has sent data to master through RDDMA, Slave HD only.
SPI_EV_RECV = BIT(3)
Has received data from master through WRDMA, Slave HD only.
SPI_EV_CMD9 = BIT(4)
Received CMD9 from master, Slave HD only.
SPI_EV_CMDA = BIT(5)
Received CMDA from master, Slave HD only.
SPI_EV_TRANS = BIT(6)
A transaction has done.

Header File

- driver/include/driver/spi_common.h

Functions

esp_err_t spi_bus_initialize(spi_host_device_t host_id, const spi_bus_config_t *bus_config, int dma_chan)
Initialize a SPI bus.

Warning For now, only supports HSPI and VSPI.
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_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: Either channel 1 or 2, or 0 in the case when no DMA is required. Selecting a DMA channel for a SPI bus allows transfers on the bus to have sizes only limited by the amount of internal memory. Selecting no DMA channel (by passing the value 0) limits the amount of bytes transferred to a maximum of 64. Set to 0 if only the SPI flash uses this bus.

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` referring 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 miso_io_num
GPIO pin for Master In Slave Out (=spi_q) signal, or -1 if not used.

int sclk_io_num
GPIO pin for Spi CLoK signal, or -1 if not used.

int quadwp_io_num
GPIO pin for WP (Write Protect) signal which is used as D2 in 4-bit communication modes, or -1 if not used.

int quadhd_io_num
GPIO pin for HD (HolD) signal which is used as D3 in 4-bit communication modes, or -1 if not used.

int max_transfer_sz
Maximum transfer size, in bytes. Defaults to 4094 if 0.

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.

**API Reference - SPI Master**

**Header File**
- `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**
Chapter 2. API

- 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

`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
- ESP_ERR_TIMEOUT if there was no room in the queue before `ticks_to_wait` expired
- ESP_ERR_NO_MEM if allocating DMA-capable temporary buffer failed
- ESP_ERR_INVALID_STATE if previous transactions are not finished
- ESP_OK on success

Parameters
- handle: Device handle obtained using `spi_host_add_dev`
- trans_desc: Description of transaction to execute
- ticks_to_wait: Ticks to wait until there’s room in the queue; use `portMAX_DELAY` to never time out.

`esp_err_t spi_device_get_trans_result(spi_device_handle_t handle, spi_transaction_t *trans_desc, TickType_t ticks_to_wait)`
Get the result of a SPI transaction queued earlier by `spi_device_queue_trans()`.

This routine will wait until a transaction to the given device successfully completed. It will then return the description of the completed transaction so software can inspect the result and e.g. free the memory or re-use the buffers.

Return
- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_ERR_TIMEOUT if there was no completed transaction before `ticks_to_wait` expired
- ESP_OK on success

Parameters
- handle: Device handle obtained using `spi_host_add_dev`
- trans_desc: Pointer to variable able to contain a pointer to the description of the transaction that is executed. The descriptor should not be modified until the descriptor is returned by `spi_device_get_trans_result()`. The descriptor should be used to read the result.
- ticks_to_wait: Ticks 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.
Chapter 2. API

**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_polling_start(spi_device_handle_t handle, spi_transaction_t *trans_desc, TickType_t ticks_to_wait)
```

Immediately start a polling transaction.

**Note** Normally a device cannot start (queue) polling and interrupt transactions simultaneously. Moreover, a device cannot start a new polling transaction if another polling transaction is not finished.

**Return**
- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success
- 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_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 timeout.

```c
esp_err_t spi_device_polling_transmit(spi_device_handle_t handle, spi_transaction_t *trans_desc)
```

Send a polling transaction, wait for it to complete, and return the result.

This function is the equivalent of calling spi_device_polling_start() followed by spi_device_polling_end(). Do not use this when there is still a transaction that hasn’t been finalized.

**Note** This function is not thread safe when multiple tasks access the same SPI device. Normally a device cannot start (queue) polling and interrupt transactions simultaneously.

**Return**
- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

**Parameters**
- handle: Device handle obtained using spi_host_add_dev
- trans_desc: Description of transaction to execute

```c
esp_err_t spi_device_acquire_bus(spi_device_handle_t device, TickType_t wait)
```

Occupy the SPI bus for a device to do continuous transactions.

Transactions to all other devices will be put off until spi_device_release_bus is called.

**Note** The function will wait until all the existing transactions have been sent.
Return

- ESP_ERR_INVALID_ARG: wait is not set to portMAX_DELAY.
- ESP_OK: Success.

Parameters

- device: The device to occupy the bus.
- wait: Time to wait before the the bus is occupied by the device. Currently MUST set to portMAX_DELAY.

```c
void spi_device_release_bus(spi_device_handle_t dev)
```

Release the SPI bus occupied by the device. All other devices can start sending transactions.

Parameters

- dev: The device to release the bus.

```c
int spi_cal_clock(int fapb, int hz, int duty_cycle, uint32_t* reg_o)
```

Calculate the working frequency that is most close to desired frequency, and also the register value.

Parameters

- fapb: The frequency of apb clock, should be APB_CLK_FREQ.
- hz: Desired working frequency
- duty_cycle: Duty cycle of the spi clock
- reg_o: Output of value to be set in clock register, or NULL if not needed.

Return Actual working frequency that most fit.

```c
int spi_get_actual_clock(int fapb, int hz, int duty_cycle)
```

Calculate the working frequency that is most close to desired frequency.

Return Actual working frequency that most fit.

Parameters

- fapb: The frequency of apb clock, should be APB_CLK_FREQ.
- hz: Desired working frequency
- duty_cycle: Duty cycle of the spi clock

```c
void spi_get_timing(bool gpio_is_used, int input_delay_ns, int eff_clk, int *dummy_o, int *cycles_remain_o)
```

Calculate the timing settings of specified frequency and settings.

Note If **dummy_o** is not zero, it means dummy bits should be applied in half duplex mode, and full duplex mode may not work.

Parameters

- gpio_is_used: True if using GPIO matrix, or False if iomux pins are used.
- input_delay_ns: Input delay from SCLK launch edge to MISO data valid.
- eff_clk: Effective clock frequency (in Hz) from spi_cal_clock.
- dummy_o: Address of dummy bits used output. Set to NULL if not needed.
- cycles_remain_o: Address of cycles remaining (after dummy bits are used) output.
  - -1 If too many cycles remaining, suggest to compensate half a clock.
  - 0 If no remaining cycles or dummy bits are not used.
  - positive value: cycles suggest to compensate.

```c
int spi_get_freq_limit(bool gpio_is_used, int input_delay_ns)
```

Get the frequency limit of current configurations. SPI master working at this limit is OK, while above the limit, full duplex mode and DMA will not work, and dummy bits will be applied in the half duplex mode.

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.

```c
struct spi_device_interface_config_t
```

This is a configuration for a SPI slave device that is connected to one of the SPI buses.
Chapter 2. API

Public Members

```c
uint8_t command_bits
Default amount of bits in command phase (0-16), used when SPI_TRANS_VARIABLE_CMD is not used, otherwise ignored.
```

```c
uint8_t address_bits
Default amount of bits in address phase (0-64), used when SPI_TRANS_VARIABLE_ADDR is not used, otherwise ignored.
```

```c
uint8_t dummy_bits
Amount of dummy bits to insert between address and data phase.
```

```c
uint8_t mode
SPI mode (0-3)
```

```c
uint16_t duty_cycle_pos
Duty cycle of positive clock, in 1/256th increments (128 = 50%/50% duty). Setting this to 0 (=not setting it) is equivalent to setting this to 128.
```

```c
uint16_t cs_ena_pretrans
Amount of SPI bit-cycles the cs should be activated before the transmission (0-16). This only works on half-duplex transactions.
```

```c
uint8_t cs_ena_posttrans
Amount of SPI bit-cycles the cs should stay active after the transmission (0-16)
```

```c
int clock_speed_hz
Clock speed, divisors of 80MHz, in Hz. See SPI_MASTER_FREQ_*.
```

```c
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.
```

```c
int spics_io_num
CS GPIO pin for this device, or -1 if not used.
```

```c
uint32_t flags
Bitwise OR of SPI_DEVICE_* flags.
```

```c
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.
```

```c
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.
```

```c
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.
```

```c
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-IDF 3.0.

Example: write 0x123400 and address_bits=24 to send address of 0x12, 0x34, 0x00 (in previous version, you may have to write 0x12340000).

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.
** Макросы **

** SPI_DEVICE_TXBIT_LSBFIRST **
Transmit command/address/data LSB first instead of the default MSB first.

SPI master clock is divided by 80MHz apbclock. 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).

** 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_HALF Duplex **
Transmit data before receiving it, instead of simultaneously.

** SPI_DEVICE_CLK AS CS **
Output clock on CS line if CS is active.

** SPI_DEVICE_NO_DUMMY **
There are timing issue when reading at high frequency (the frequency is related to whether iomux pins are used, valid time after slave sees the clock).

- In half-duplex mode, the driver automatically inserts dummy bits before reading phase to fix the timing issue. Set this flag to disable this feature.
- In full-duplex mode, however, the hardware cannot use dummy bits, so there is no way to prevent data being read from getting corrupted. Set this flag to confirm that you’re going to work with output only, or read without dummy bits at your own risk.

** SPI_DEVICE_DDRCLK **

** SPI_TRANS_MODE_DIO **
Transmit/receive data in 2-bit mode.

** SPI_TRANS_MODE_QIO **
Transmit/receive data in 4-bit mode.

** SPI_TRANS_USE_RXDATA **
Receive into rx_data member of spi_transaction_t instead into memory at rx_buffer.

** SPI_TRANS_USE_TXDATA **
Transmit tx_data member of spi_transaction_t instead of data at tx_buffer. Do not set tx_buffer when using this.

** SPI_TRANS_MODE_DIOQIO_ADDR **
Also transmit address in mode selected by SPI_MODE_DIO/SPI_MODE_QIO.

** SPI_TRANS_VARIABLE_CMD **
Use the command_bits in spi_transaction_ext_t rather than default value in spi_device_interface_config_t.

** SPI_TRANS_VARIABLE_ADDR **
Use the address_bits in spi_transaction_ext_t rather than default value in spi_device_interface_config_t.

** SPI_TRANS_VARIABLE_DUMMY **
Use the dummy_bits in spi_transaction_ext_t rather than default value in spi_device_interface_config_t.

** SPI_TRANS_SET_CD **
Set the CD pin.
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.

2.3.15 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, in this case the SPI2 and SPI3 controllers. Each Device shares the MOSI, MISO and SCLK signals but is only active on the bus when the Host asserts the Device’s individual CS line.</td>
</tr>
<tr>
<td>Bus</td>
<td>A signal bus, common to all Devices connected to one Host. In general, a bus includes the following lines: MISO, MOSI, SCLK, one or more CS lines, and, optionally, QUADWP and QUADHD. So Devices are connected to the same lines, with the exception that each Device has its own CS line. Several Devices can also share one CS line if connected in the daisy-chain manner.</td>
</tr>
<tr>
<td>MISO</td>
<td>Master In, Slave Out, a.k.a. Q. Data transmission from a Device to Host.</td>
</tr>
<tr>
<td>MOSI</td>
<td>Master In, Slave Out, a.k.a. D. Data transmission from a Host to Device.</td>
</tr>
<tr>
<td>SCLK</td>
<td>Serial Clock. Oscillating signal generated by a Host that keeps the transmission of data bits in sync.</td>
</tr>
<tr>
<td>CS</td>
<td>Chip Select. Allows a Host to select individual Device(s) connected to the bus in order to send or receive data.</td>
</tr>
<tr>
<td>QUADWP</td>
<td>Write Protect signal. Only used for 4-bit (qio/qout) transactions.</td>
</tr>
<tr>
<td>QUADHD</td>
<td>Hold signal. Only used for 4-bit (qio/qout) transactions.</td>
</tr>
<tr>
<td>Assertion</td>
<td>The action of activating a line. The opposite action of returning the line back to inactive (back to idle) is called de-assertion.</td>
</tr>
<tr>
<td>Transaction</td>
<td>One instance of a Host asserting a CS line, transferring data to and from a Device, and de-asserting the CS line. Transactions are atomic, which means they can never be interrupted by another transaction.</td>
</tr>
<tr>
<td>Launch edge</td>
<td>Edge of the clock at which the source register launches the signal onto the line.</td>
</tr>
<tr>
<td>Latch edge</td>
<td>Edge of the clock at which the destination register latches in the signal.</td>
</tr>
</tbody>
</table>

**Driver Features**

The SPI slave driver allows using the SPI2 and/or SPI3 peripherals as full-duplex Devices. The driver can send/receive transactions up to 64 bytes in length, or utilize DMA to send/receive longer transactions. However, there are some known issues related to DMA.

**SPI Transactions**

A full-duplex SPI transaction begins when the Host asserts the CS line and starts sending out clock pulses on the SCLK line. Every clock pulse, a data bit is shifted from the Host to the Device on the MOSI line and back on the MISO line at the same time. At the end of the transaction, the Host de-asserts the CS line.
The attributes of a transaction are determined by the configuration structure for an SPI host acting as a slave device `spi_slave_interface_config_t`, and transaction configuration structure `spi_slave_transaction_t`.

As not every transaction requires both writing and reading data, you have a choice to configure the `spi_transaction_t` structure for TX only, RX only, or TX and RX transactions. If `spi_slave_transaction_t::rx_buffer` is set to NULL, the read phase will be skipped. If `spi_slave_transaction_t::tx_buffer` is set to NULL, the write phase will be skipped.

note: A Host should not start a transaction before its Device is ready for receiving data. It is recommended to use another GPIO pin for a handshake signal to sync the Devices. For more details, see `Transaction Interval`.

Driver Usage

- Initialize an SPI peripheral as a Device by calling the function `spi_slave_initialize`. Make sure to set the correct I/O pins in the structure `bus_config`. Set the unused signals to -1.
- Before initiating transactions, fill one or more `spi_slave_transaction_t` structs with the transaction parameters required. Either queue all transactions by calling the function `spi_slave_queue_trans()` and, at a later time, query the result by using the function `spi_slave_get_trans_result()`, or handle all requests individually by feeding them into `spi_slave_transmit()`. The latter two functions will be blocked until the Host has initiated and finished a transaction, causing the queued data to be sent and received.
- (Optional) To unload the SPI slave driver, call `spi_slave_free()`.

Transaction Data and Master/Slave Length Mismatches

Normally, the data that needs to be transferred to or from a Device is read or written to a chunk of memory indicated by the `rx_buffer` and `tx_buffer` members of the `spi_transaction_t` structure. The SPI driver can be configured to use DMA for transfers, in which case these buffers must be allocated in DMA-capable memory using `pvPortMallocCaps(size, MALLOC_CAP_DMA)`.

The amount of data that the driver can read or write to the buffers is limited by the member `spi_transaction_t::length`. However, this member does not define the actual length of an SPI transaction. A transaction’s length is determined by a Host which drives the clock and CS lines. The actual length of the transmission can be read only after a transaction is finished from the member `spi_slave_transaction_t::trans_len`.

If the length of the transmission is greater than the buffer length, only the initial number of bits specified in the `length` member will be sent and received. In this case, `trans_len` is set to `length` instead of the actual transaction length. To meet the actual transaction length requirements, set `length` to a value greater than the maximum `trans_len` expected. If the transmission length is shorter than the buffer length, only the data equal to the length of the buffer will be transmitted.

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.
Chapter 2. API 参考

注解：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.

- 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></th>
<th>Output delay of MISO (ns)</th>
<th>Freq. limit (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IO_MUX</td>
<td>43.75</td>
<td>&lt;11.4</td>
</tr>
<tr>
<td>GPIO matrix</td>
<td>68.75</td>
<td>&lt;7.2</td>
</tr>
</tbody>
</table>

Note:

1. If the frequency 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 than expected, 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:
Chapter 2. API 参考

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

- 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, int dma_chan)
```

Initialize a SPI bus as a slave interface.

Warning For now, only supports HSPI and VSPI.
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_NO_MEM if out of memory
- ESP_OK on success

Parameters

- host: SPI peripheral to use as a SPI slave interface
- bus_config: Pointer to a spi_bus_config_t struct specifying how the host should be initialized
- slave_config: Pointer to a spi_slave_interface_config_t struct specifying the details for the slave interface
- dma_chan: Either 1 or 2. A SPI bus used by this driver must have a DMA channel associated with it. The SPI hardware has two DMA channels to share. This parameter indicates which one to use.

```c
esp_err_t spi_slave_free(spi_host_device_t host)
```

Free a SPI bus claimed as a SPI slave interface.

Return

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_ERR_INVALID_STATE if not all devices on the bus are freed
- ESP_OK on success

Parameters

- host: SPI peripheral to free

```c
esp_err_t spi_slave_queue_trans(spi_host_device_t host, const spi_slave_transaction_t
*trans_desc, TickType_t ticks_to_wait)
```

Queue a SPI transaction for execution.
Queues a SPI transaction to be executed by this slave device. (The transaction queue size was specified when the slave device was initialised via spi_slave_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.

```c
esp_err_t spi_slave_get_trans_result (spi_host_device_t host, spi_slave_transaction_t **trans_desc, TickType_t ticks_to_wait)
```

Get the result of a SPI transaction queued earlier.

This routine will wait until a transaction to the given device (queued earlier with spi_slave_queue_trans) has successfully completed. It will then return the description of the completed transaction so software can inspect the result and e.g. free the memory or re-use the buffers.

It is mandatory to eventually use this function for any transaction queued by spi_slave_queue_trans.

**Return**
- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

**Parameters**
- host: SPI peripheral to that is acting as a slave
- [out] trans_desc: Pointer to variable able to contain a pointer to the description of the transaction that is executed
- ticks_to_wait: Ticks to wait until there’s a returned item; use portMAX_DELAY to never time out.

```c
esp_err_t spi_slave_transmit (spi_host_device_t host, spi_slave_transaction_t *trans_desc, TickType_t ticks_to_wait)
```

Do a SPI transaction.

Essentially does the same as spi_slave_queue_trans followed by spi_slave_get_trans_result. Do not use this when there is still a transaction queued that hasn’t been finalized using spi_slave_get_trans_result.

**Return**
- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

**Parameters**
- host: SPI peripheral to that is acting as a slave
- trans_desc: Pointer to variable able to contain a pointer to the description of the transaction that is executed. Not const because we may want to write status back into the transaction description.
- ticks_to_wait: Ticks to wait until there’s a returned item; use portMAX_DELAY to never time out.

**Structures**

```c
struct spi_slave_interface_config_t
```

This is a configuration for a SPI host acting as a slave device.
Public Members

```c
int spics_io_num
    CS GPIO pin for this device.

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 (0-3)
```

```c
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.
```

```c
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.
```

```c
struct spi_slave_transaction_t
    This structure describes one SPI transaction
```

Public Members

```c
size_t length
    Total data length, in bits.

size_t trans_len
    Transaction data length, in bits.
```

```c
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

```c
SPI_SLAVE_TXBIT_LSBFIRST
    Transmit command/address/data LSB first instead of the default MSB first.
```

```c
SPI_SLAVE_RXBIT_LSBFIRST
    Receive data LSB first instead of the default MSB first.
```

```c
SPI_SLAVE_BIT_LSBFIRST
    Transmit and receive LSB first.
```

Type Definitions

```c
typedef struct spi_slave_transaction_t spi_slave_transaction_t

typedef void (*slave_transaction_cb_t)(spi_slave_transaction_t *trans)
```
2.3.16 ESP32-WROOM-32SE (Secure Element)

Overview

The ESP32-WROOM-32SE has integrated Microchip’s ATECC608A cryptoauth chip in the module. ATECC608A is a 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.

2.3.17 定时器

简介

ESP32芯片提供两组硬件定时器，每组包含两个通用硬件定时器。所有定时器均为64位通用定时器，包括16位预分频器和64位自动重载向上/向下计数器。

功能概述

下文介绍了配置和操作定时器的常规步骤:

- 定时器初始化 - 启动定时器前应设置的参数，以及每个设置提供的具体功能。
- 定时器控制 - 如何读取定时器的值，如何暂停/启动定时器以及如何改变定时器的操作方式。
- 警报 - 如何设置和使用警报。
- 中断 - 如何使能和使用中断。

定时器初始化 两个ESP32定时器组中，每组都有两个定时器，两组共有四个定时器供使用。ESP32定时器组应使用timer_group_t识别，而每组中的个体定时器则应使用timer_idx_t识别。

首先调用timer_init()函数，并将timer_config_t结构体传递给此函数，用于定义定时器的工作方式，实现定时器初始化。特别注意以下定时器参数可设置为:

- 分频器: 设置定时器中计数器计数的速度，divider的设置将用作输入的80 MHz APB_CLK时钟的除数。
- 模式: 设置计数器是递增还是递减。可通过从timer_count_dir_t中选取一个值，后使用counter_dir来选择模式。
- 计数器使能: 如果计数器已使能，则在调用timer_init()后计数器将立即开始递增/递减。您可通过从timer_start_t中选取一个值，后使用counter_en改变此行为。
- 警报使能: 可使用alarm_en设置。
- 自动重载: 设置计数器是否应该在定时器警报上使用auto_reload自动重载首个计数值，还是继续递增或递减。
- 中断类型: 选择定时器警报上应触发的中断类型，请设置timer_intr_mode_t中定义的值。

要获取定时器设置的当前值，请使用函数timer_get_config()。
定时器控制 定时器使能后便开始计数。要使能定时器，可首先设置 counter_en 为 true，然后调用函数 timer_init()，或者直接调用函数 timer_start()。您可通过调用函数 timer_set_counter_value() 来指定定时器的首个计数值。要检查定时器的当前值，调用函数 timer_get_counter_value() 或 timer_get_counter_time_sec()。

可通过调用函数 timer_pause() 随时暂停定时器。要再次启动它，调用函数 timer_start()。

要重新配置定时器，可调用函数 timer_init()，该函数详细介绍见定时器初始化。

除此之外，还可通过使用专有函数更改个别设置来重新配置定时器：

<table>
<thead>
<tr>
<th>设置</th>
<th>专有函数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>分频器</td>
<td>timer_set_divider()</td>
<td>更改计数频率。为避免发生不可预测情况，更改分频器时应暂停定时器。如果定时器正在运行，则使用 timer_set_divider() 将其暂停后并更改设置，然后重新启动定时器。</td>
</tr>
<tr>
<td>模式</td>
<td>timer_set_counter_mode()</td>
<td>设置计数器递增还是递减</td>
</tr>
<tr>
<td>自动重载</td>
<td>timer_set_counter_auto_reload()</td>
<td>设置是否在定时器警报上重载首个计数值</td>
</tr>
</tbody>
</table>

警报 要设置警报，先调用函数 timer_set_alarm_value()，然后使用 timer_set_alarm() 使能警报。当调用函数 timer_init() 时，也可以在定时器初始化阶段使能警报。

警报已使能且定时器达到警报值后，根据配置，可能会出现以下两种行为：

- 如果先前已配置，此时将触发中断。有关如何配置中断，请参见中断。
- 如 auto_reload 已使能，定时器的计数值将重新加载，从先前配置好的值开始再次计数。应使用函数 timer_set_counter_value() 预先设置该值。

注解：

- 如果已设置警报值且定时器已超过该值，则将立即触发警报。
- 一旦触发后，警报将自动关闭，需要重新使能以再次触发。

要检查某特定的警报值，调用函数 timer_get_alarm_value()。

中断 可通过调用函数 timer_isr_register() 为特定定时器组和定时器注册中断处理程序。

调用 timer_group_intr_enable() 使能定时器组的中断程序，调用 timer_enable_intr() 使能某定时器的中断程序。调用 timer_group_intr_disable() 关闭定时器组的中断程序，调用 timer_disable_intr() 关闭某定时器的中断程序。

在中断服务程序（ISR）中处理中断时，需要明确地清除中断状态位。为此，请设置定义在 soc/soc/esp32/include/soc/timer_group_struct.h 中的 TIMERG x . int_clr_timers.tM 结构。该结构中 N 是定时器组编号 [0, 1]，M 是定时器编号 [0, 1]。例如，要清除定时器组别 0 中定时器 1 的中断状态位，请调用以下命令：

```
TIMEROG0.int_clr_timers.t1 = 1
```

有关如何使用中断，请参阅应用示例。

应用示例

64 位硬件定时器示例： peripherals/timer_group。
API 参考

Header File

- driver/include/driver/timer.h

Functions

```c
esp_err_t timer_get_counter_value(timer_group_t group_num, timer_idx_t timer_num, uint64_t *timer_val)
```

Read the counter value of hardware timer.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `group_num`: Timer group, 0 for TIMERG0 or 1 for TIMERG1
- `timer_num`: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]
- `timer_val`: Pointer to accept timer counter value.

```c
esp_err_t timer_get_counter_time_sec(timer_group_t group_num, timer_idx_t timer_num, double *time)
```

Read the counter value of hardware timer, in unit of a given scale.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `group_num`: Timer group, 0 for TIMERG0 or 1 for TIMERG1
- `timer_num`: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]
- `time`: Pointer, type of double*, to accept timer counter value, in seconds.

```c
esp_err_t timer_set_counter_value(timer_group_t group_num, timer_idx_t timer_num, uint64_t load_val)
```

Set counter value to hardware timer.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `group_num`: Timer group, 0 for TIMERG0 or 1 for TIMERG1
- `timer_num`: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]
- `load_val`: Countervalue to writeto the hardware timer.

```c
esp_err_t timer_start(timer_group_t group_num, timer_idx_t timer_num)
```

Start the counter of hardware timer.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `group_num`: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
- `timer_num`: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]

```c
esp_err_t timer_pause(timer_group_t group_num, timer_idx_t timer_num)
```

Pause the counter of hardware timer.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `group_num`: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
- `timer_num`: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]
### Chapter 2. API

#### esp_err_t timer_set_counter_mode

```c
(int) group_num, (int) timer_num,
(timer_count_dir_t) counter_dir)
```

Set counting mode for hardware timer.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- **group_num**: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
- **timer_num**: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]
- **counter_dir**: Counting direction of timer, count-up or count-down

#### esp_err_t timer_set_auto_reload

```c
(int) group_num, (int) timer_num,
(timer_autoreload_t) reload)
```

Enable or disable counter reload function when alarm event occurs.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- **group_num**: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
- **timer_num**: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]
- **reload**: Counter reload mode.

#### esp_err_t timer_set_divider

```c
(int) group_num, (int) timer_num,
(uint32_t) divider)
```

Set hardware timer source clock divider. Timer groups clock are divider from APB clock.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- **group_num**: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
- **timer_num**: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]
- **divider**: Timer clock divider value. The divider’s range is from 2 to 65536.

#### esp_err_t timer_set_alarm_value

```c
(int) group_num, (int) timer_num,
(uint64_t) alarm_value)
```

Set timer alarm value.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- **group_num**: Timer group, 0 for TIMERG0 or 1 for TIMERG1
- **timer_num**: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]
- **alarm_value**: A 64-bit value to set the alarm value.

#### esp_err_t timer_get_alarm_value

```c
(int) group_num, (int) timer_num,
(uint64_t) *alarm_value)
```

Get timer alarm value.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- **group_num**: Timer group, 0 for TIMERG0 or 1 for TIMERG1
- **timer_num**: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]
- **alarm_value**: Pointer of A 64-bit value to accept the alarm value.

#### esp_err_t timer_set_alarm

```c
(int) group_num, (int) timer_num,
(timer_alarm_t) alarm_en)
```

Enable or disable generation of timer alarm events.

**Return**
- ESP_OK Success
Chapter 2. API

• ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `group_num`: Timer group, 0 for TIMER0 or 1 for TIMER1
- `timer_num`: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]
- `alarm_en`: To enable or disable timer alarm function.

```c
esp_err_t timer_isr_callback_add(timer_group_t group_num, timer_idx_t timer_num, timer_isr_t isr_handler, void *arg, int intr_alloc_flags)
```

Add ISR handle callback for the corresponding timer.

The callback should return a bool value to determine whether need to do YIELD at the end of the ISR.

**Note** This ISR handler will be called from an ISR. This ISR handler do not need to handle interrupt status, and should be kept short. If you want to realize some specific applications or write the whole ISR, you can call timer_isr_register(…) to register ISR.

**Parameters**
- `group_num`: Timer group number
- `timer_num`: Timer index of timer group
- `isr_handler`: Interrupt handler function, it is a callback 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.

If the `intr_alloc_flags` value ESP_INTR_FLAG_IRAM is set, the handler function must be declared with IRAM_ATTR attribute and can only call functions in IRAM or ROM. It cannot call other timer APIs.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t timer_isr_callback_remove(timer_group_t group_num, timer_idx_t timer_num)
```

Remove ISR handle callback for the corresponding timer.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `group_num`: Timer group number
- `timer_num`: Timer index of timer group

```c
esp_err_t timer_isr_register(timer_group_t group_num, timer_idx_t timer_num, void (*fn)(void *arg, int intr_alloc_flags) void *, void *handle)
```

Register Timer interrupt handler, the handler is an ISR. The handler will be attached to the same CPU core that this function is running on.

If the `intr_alloc_flags` value ESP_INTR_FLAG_IRAM is set, the handler function must be declared with IRAM_ATTR attribute and can only call functions in IRAM or ROM. It cannot call other timer APIs. Use direct register access to configure timers from inside the ISR in this case.

**Note** If use this function to register ISR, you need to write the whole ISR. In the interrupt handler, you need to call timer_spinlock_take(…) before your handling, and call timer_spinlock_give(…) after your handling.

**Parameters**
- `group_num`: Timer group number
- `timer_num`: Timer index of timer group
- `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 Parameter error
**esp_err_t timer_init** *(timer_group_t group_num, timer_idx_t timer_num, const timer_config_t *config)*

Initializes and configures the timer.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `group_num`: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
- `timer_num`: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]
- `config`: Pointer to timer initialization parameters.

**esp_err_t timer_deinit** *(timer_group_t group_num, timer_idx_t timer_num)*

Deinitializes the timer.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `group_num`: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
- `timer_num`: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]

**esp_err_t timer_get_config** *(timer_group_t group_num, timer_idx_t timer_num, timer_config_t *config)*

Get timer configuration value.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `group_num`: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
- `timer_num`: Timer index, 0 for hw_timer[0] & 1 for hw_timer[1]
- `config`: Pointer of struct to accept timer parameters.

**esp_err_t timer_group_intr_enable** *(timer_group_t group_num, timer_intr_t intr_mask)*

Enable timer group interrupt, by enable mask.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `group_num`: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
- `intr_mask`: Timer interrupt enable mask.
  - TIMER_INTR_T0: t0 interrupt
  - TIMER_INTR_T1: t1 interrupt
  - TIMER_INTR_WDT: watchdog interrupt

**esp_err_t timer_group_intr_disable** *(timer_group_t group_num, timer_intr_t intr_mask)*

Disable timer group interrupt, by disable mask.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `group_num`: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
- `intr_mask`: Timer interrupt disable mask.
  - TIMER_INTR_T0: t0 interrupt
  - TIMER_INTR_T1: t1 interrupt
  - TIMER_INTR_WDT: watchdog interrupt

**esp_err_t timer_enable_intr** *(timer_group_t group_num, timer_idx_t timer_num)*

Enable timer interrupt.

**Return**
- ESP_OK Success
Chapter 2. API

• ESP_ERR_INVALID_ARG Parameter error

Parameters
• group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
• timer_num: Timer index.

\texttt{esp_err_t timer_disable_intr}(\texttt{timer_group_t group_num, timer_idx_t timer_num})

Disable timer interrupt.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
• timer_num: Timer index.

\texttt{void timer_group_intr_clr_in_isr}(\texttt{timer_group_t group_num, timer_idx_t timer_num})

Clear timer interrupt status, just used in ISR.

Parameters
• group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
• timer_num: Timer index.

\texttt{void timer_group_clr_intr_status_in_isr}(\texttt{timer_group_t group_num, timer_idx_t timer_num})

Clear timer interrupt status, just used in ISR.

Parameters
• group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
• timer_num: Timer index.

\texttt{void timer_group_enable_alarm_in_isr}(\texttt{timer_group_t group_num, timer_idx_t timer_num})

Enable alarm interrupt, just used in ISR.

Parameters
• group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
• timer_num: Timer index.

\texttt{uint64_t timer_group_get_counter_value_in_isr}(\texttt{timer_group_t group_num, timer_idx_t timer_num})

Get the current counter value, just used in ISR.

Return
• Counter value

Parameters
• group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
• timer_num: Timer index.

\texttt{void timer_group_set_alarm_value_in_isr}(\texttt{timer_group_t group_num, timer_idx_t timer_num, uint64_t alarm_val})

Set the alarm threshold for the timer, just used in ISR.

Parameters
• group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
• timer_num: Timer index.
• alarm_val: Alarm threshold.

\texttt{void timer_group_set_counter_enable_in_isr}(\texttt{timer_group_t group_num, timer_idx_t timer_num, timer_start_t counter_en})

Enable/disable a counter, just used in ISR.

Parameters
• group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
• timer_num: Timer index.
• counter_en: Enable/disable.

\texttt{timer_intr_t timer_group_intr_get_in_isr}(\texttt{timer_group_t group_num})

Get the masked interrupt status, just used in ISR.
Return
  • Interrupt status
Parameters
  • group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1

uint32_t timer_group_get_intr_status_in_isr(timer_group_t group_num)
Get interrupt status, just used in ISR.

Return
  • Interrupt status
Parameters
  • group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1

void timer_group_clr_intr_sta_in_isr(timer_group_t group_num,
                                     timer_intr_t intr_mask)
Clear the masked interrupt status, just used in ISR.

Parameters
  • group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
  • intr_mask: Masked interrupt.

bool timer_group_get_auto_reload_in_isr(timer_group_t group_num,
                                        timer_idx_t timer_num)
Get auto reload enable status, just used in ISR.

Return
  • True Auto reload enabled
  • False Auto reload disabled
Parameters
  • group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1
  • timer_num: Timer index

esp_err_t timer_spinlock_take(timer_group_t group_num)
Take timer spinlock to enter critical protect.

Return
  • ESP_OK Success
  • ESP_ERR_INVALID_ARG Parameter error
Parameters
  • group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1

esp_err_t timer_spinlock_give(timer_group_t group_num)
Give timer spinlock to exit critical protect.

Return
  • ESP_OK Success
  • ESP_ERR_INVALID_ARG Parameter error
Parameters
  • group_num: Timer group number, 0 for TIMERG0 or 1 for TIMERG1

Macros

TIMER_BASE_CLK
Frequency of the clock on the input of the timer groups

Type Definitions
typedef bool (*timer_isr_t)(void *)
Interrupt handle callback function. User need to retrun a bool value in callback.

Return
  • True Do task yield at the end of ISR
  • False Not do task yield at the end of ISR
Note If you called FreeRTOS functions in callback, you need to return true or false based on the retrun value of argument pxHigherPriorityTaskWoken. For example, xQueueSendFromISR is called in
callback, if the return value `pxHigherPriorityTaskWoken` of any FreeRTOS calls is `pdTRUE`, return true; otherwise return false.

```c
typedef intr_handle_t timer_isr_handle_t
```

Interrupt handle, used in order to free the isr after use. Aliases to an int handle for now.

Header File

- `hal/include/hal/timer_types.h`

Structures

```c
struct timer_config_t
```

Data structure with timer’s configuration settings.

### Public Members

```c
timer_alarm_t alarm_en
```

Timer alarm enable

```c
timer_start_t counter_en
```

Counter enable

```c
timer_intr_mode_t intr_type
```

Interrupt mode

```c
timer_count_dir_t counter_dir
```

Counter direction

```c
timer_autoreload_t auto_reload
```

Timer auto-reload

```c
uint32_t divider
```

Counter clock divider. The divider’s range is from 2 to 65536.

Enumerations

```c
enum timer_group_t
```

Selects a Timer-Group out of 2 available groups.

**Values:**

```c
TIMER_GROUP_0 = 0
```

Hw timer group 0

```c
TIMER_GROUP_1 = 1
```

Hw timer group 1

```c
TIMER_GROUP_MAX
```

```c
enum timer_idx_t
```

Select a hardware timer from timer groups.

**Values:**

```c
TIMER_0 = 0
```

Select timer0 of GROUPx

```c
TIMER_1 = 1
```

Select timer1 of GROUPx

```c
TIMER_MAX
```

```c
enum timer_count_dir_t
```

Decides the direction of counter.

**Values:**


```c
enum timer_start_t
   Decides whether timer is on or paused.
   Values:
   TIMER_PAUSE = 0
      Pause timer counter
   TIMER_START = 1
      Start timer counter

enum timer_intr_t
   Interrupt types of the timer.
   Values:
   TIMER_INTR_T0 = BIT(0)
      interrupt of timer 0
   TIMER_INTR_T1 = BIT(1)
      interrupt of timer 1
   TIMER_INTR_WDT = BIT(2)
      interrupt of watchdog
   TIMER_INTR_NONE = 0

enum timer_alarm_t
   Decides whether to enable alarm mode.
   Values:
   TIMER_ALARM_DIS = 0
      Disable timer alarm
   TIMER_ALARM_EN = 1
      Enable timer alarm

enum timer_intr_mode_t
   Select interrupt type if running in alarm mode.
   Values:
   TIMER_INTR_LEVEL = 0
      Interrupt mode: level mode

enum timer_autoreload_t
   Select if Alarm needs to be loaded by software or automatically reload by hardware.
   Values:
   TIMER_AUTORELOAD_DIS = 0
      Disable auto-reload: hardware will not load counter value after an alarm event
   TIMER_AUTORELOAD_EN = 1
      Enable auto-reload: hardware will load counter value after an alarm event
```

**Chapter 2. API 参考**

```
TIMER_COUNT_DOWN = 0
   Descending Count from cnt.highcnt.low

TIMER_COUNT_UP = 1
   Ascending Count from Zero

enum timer_start_t
   Decides whether timer is on or paused.
   Values:
   TIMER_PAUSE = 0
      Pause timer counter
   TIMER_START = 1
      Start timer counter

enum timer_intr_t
   Interrupt types of the timer.
   Values:
   TIMER_INTR_T0 = BIT(0)
      interrupt of timer 0
   TIMER_INTR_T1 = BIT(1)
      interrupt of timer 1
   TIMER_INTR_WDT = BIT(2)
      interrupt of watchdog
   TIMER_INTR_NONE = 0

enum timer_alarm_t
   Decides whether to enable alarm mode.
   Values:
   TIMER_ALARM_DIS = 0
      Disable timer alarm
   TIMER_ALARM_EN = 1
      Enable timer alarm

enum timer_intr_mode_t
   Select interrupt type if running in alarm mode.
   Values:
   TIMER_INTR_LEVEL = 0
      Interrupt mode: level mode

enum timer_autoreload_t
   Select if Alarm needs to be loaded by software or automatically reload by hardware.
   Values:
   TIMER_AUTORELOAD_DIS = 0
      Disable auto-reload: hardware will not load counter value after an alarm event
   TIMER_AUTORELOAD_EN = 1
      Enable auto-reload: hardware will load counter value after an alarm event
```
2.3.18 触摸传感器

概述
触摸传感器系统由保护覆盖层、触摸电极、绝缘基板和走线组成，保护覆盖层位于最上层，绝缘基板上设有电极及走线。用户触摸覆盖层将产生电容变化，根据电容变化判断是否为有效触碰行为。

ESP32 可支持最多 10 个电容式触摸板/GPIO，触摸板可以以矩阵或滑条等方式组合使用，从而覆盖更大触感区域及更多触感点。触摸传感由有限状态机 (FSM) 硬件控制，由软件或专用硬件计时器发起。

如需了解触摸传感器设计、操作及其控制寄存器等相关信息，请参考《ESP32 技术参考手册》(PDF)，您也可以在《ESP32 技术参考手册》中查看这一子系统是如何运行的。

请参考 触摸传感器应用方案简介，查看触摸传感器设计详情和固件开发指南。如果不想亲自在多种配置环境下测试触摸传感器，请查看 ESP32 触摸功能开发套件。

功能介绍
下面将 API 分解成几个函数组进行介绍，帮助您快速了解以下功能：

- 初始化触摸板驱动程序
- 配置触摸板 GPIO 管脚
- 触摸状态测量
- 调整测量参数（优化测量）
- 过滤测量数据
- 触摸监测方式
- 设置中断信号监测触摸动作
- 中断触发

请前往 API 参考 章节，查看某一函数的具体描述。应用示例 章节则介绍了此 API 的具体实现。

初始化触摸板驱动程序 使用触摸板之前，需要先调用 touch_pad_init() 函数初始化触摸板驱动程序。此函数设置了 API 参考 项下的 Macros 中列出的几项...DEFAULT 驱动程序参数，同时删除之前设置过的触摸板信息（如有），并禁用中断。

如果不再需要该驱动程序，可以调用 touch_pad_deinit() 释放已初始化的驱动程序。

配置触摸板 GPIO 管脚 调用 touch_pad_config() 使能某一 GPIO 的触感功能。

使用 touch_pad_set_fsm_mode() 选择触摸板测量（由 FSM 操作）是由硬件计时器自动启动，还是由软件自动启动。如果选择软件模式，请使用 touch_pad_sw_start() 启动 FSM。

触摸状态测量 借助以下两个函数从传感器读取原始数据或过滤后的数据：

- touch_pad_read()
- touch_pad_read_filtered()

这两个函数也可以用于检查触碰和释放触摸板时传感器读数变化范围，来评估触摸板设计，然后根据这些信息设定触碰阈值。

注解：使用 touch_pad_read_filtered() 之前，需要先调用 过滤触摸测量 中特定的滤波器函数初始化并配置该滤波器。

请参考应用示例 peripherals/touch_pad_read，查看如何使用这两个读值函数。
优化测量  触摸传感器设有数个可配置参数，以适应触摸板设计特点。例如，如果需要感知较细微的电容变化，则可以缩小触摸板充放电的参考电压范围。您可以使用 `touch_pad_set_voltage()` 函数设置电压参考低值和参考高值。

优化测量除了可以识别细微的电容变化之外，还可以降低应用程功耗，但可能会增加测量噪声干扰。如果得到的动态读数范围结果比较理想，则可以采用 `touch_pad_set_meas_time()` 函数来减少测量时间，从而进一步降低功耗。

可用的测量参数及相应的‘set’函数总结如下：

- 触摸板充放电参数：
  - 电压门限: `touch_pad_set_voltage()`
  - 速率（斜率): `touch_pad_set_cnt_mode()`
- 测量时间: `touch_pad_set_meas_time()`

电压门限（参考低值/参考高值）、速率（斜率）与测量时间的关系如下图所示:

![图16: 触摸板 - 测量参数之间的关系](image)

上图中的 Output 代表触摸传感器读值，即一个测量周期内测得的脉冲计数值。

所有函数均成对出现，用于设定某一特定参数，并获取当前参数值。例如: `touch_pad_set_voltage()` 和 `touch_pad_get_voltage()`。

过滤触摸测量  如果测量中存在噪声，可以使用提供的 API 函数对测量进行过滤。使用滤波器之前，请先调用 `touch_pad_filter_start()` 启动该滤波器。

滤波器类型为 IIR（无限脉冲响应滤波器），您可以调用 `touch_pad_set_filter_period()` 配置此类滤波器的采样周期。

如需停止滤波器，请调用 `touch_pad_filter_stop()` 函数。如果不再使用该滤波器，请调用 `touch_pad_filter_delete()` 删除此滤波器。

触摸监测  触摸监测基于用户配置的阈值和 FSM 执行的原始测量，并由 ESP32 硬件实现。你可以调用 `touch_pad_get_status()` 查看被触碰的触摸板，或调用 `touch_pad_clear_status()` 清除触摸状态信息。

您也可以将硬件触摸监测连接至中断，详细介绍见下一章节。

如果测量中存在噪声，且电容变化幅度较小，硬件触摸监测结果可能就不太理想。如需解决这一问题，不建议使用硬件监测或中断信号。建议您在自己的应用过程中采用测量过滤，并执行触摸监测。请参考 peripherals/touch_pad INTERRUPT，查看以上两种触摸监测的实现方式。
中断触发
在对触摸监测启用中断之前，请先设置一个触摸监测阈值。然后使用触摸状态测量 中所述的函数读取并显示触摸和释放触摸板时测得的结果。如果测量中存在噪声且相对电容变化较小，请使用滤波器。您也可以根据应用程序和环境条件，测试温度和电源电压变化对测量值的影响。

确定监测阈值后就可以在初始化时调用 touch_pad_config() 设置此阈值，或在运行时调用 touch_pad_set_thresh() 设置此阈值。

下一步就是设置如何触发中断。您可以设置在阈值以下或以上触发中断，具体触发模式由函数 touch_pad_set_trigger_mode() 设置。

最后您可以使用以下函数配置和管理中断调用：
- touch_pad_isr_register() / touch_pad_isr_deregister()
- touch_pad_intr_enable() / touch_pad_intr_disable()

中断配置完成后，您可以调用 touch_pad_get_status() 查看中断信号来自哪个触摸板，也可以调用 touch_pad_clear_status() 清除触摸板状态信息。

注解：触摸监测中的中断信号基于原始/未经过滤的测量值（对比用户设置的阈值），并在硬件中实现。启用软件滤波 API 并不会影响这一过程，见过滤触摸测量。

从睡眠模式唤醒
如果使用触摸板中断将芯片从睡眠模式唤醒，您可以选择配置一些触摸板，例如 SET1 或 SET1 和 SET2。触摸这些触摸板将触发中断并唤醒芯片。请调用 touch_pad_set_trigger_source() 实现上述操作。

您可以使用以下函数管理‘SET’中触摸板所需的位模式配置：
- touch_pad_set_group_mask() / touch_pad_get_group_mask()
- touch_pad_clear_group_mask()

应用示例

- 触摸传感器读值示例：peripherals/touch_pad_read
- 触摸传感器中断示例：peripherals/touch_pad_interrupt

API 参考

Header File
- 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 measure-

cnt 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,

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

Parameters
- touch_num: touch pad index
- touch_value: pointer to accept touch sensor value

\texttt{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

Parameters
- touch_num: touch pad index
- touch_value: pointer to accept touch sensor value

\texttt{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

Parameters
- touch_num: touch pad index
- touch_value: pointer to accept touch sensor value

\texttt{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

Parameters
- read_cb: Pointer to filtered callback function. If the argument passed in is NULL, the callback will stop.

\texttt{esp_err_t touch_pad_isr_register(intr_handler_t fn, void *arg)}

Register touch-pad ISR. The handler will be attached to the same CPU core that this function is running on.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO error
- ESP_ERR_NO_MEM No memory

Parameters
- fn: Pointer to ISR handler
**Chapter 2. API **

- 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. \( t_{sleep} = \text{sleep cycle} / \text{RTC SLOW_CLK frequency} \). The approximate frequency value of RTC_SLOW_CLK can be obtained using rtc_clk_slow_freq_get_hz function.
- meas_cycle: The duration of the touch sensor measurement. \( t_{meas} = \text{meas cycle} / 8M \), the maximum measure time is 0xffff / 8M = 8.19 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

```c
esp_err_t touch_pad_get_trigger_mode(touch_trigger_mode_t* mode)
```

Get touch sensor interrupt trigger mode.
chapter 2．API

Return
- ESP_OK on success

Parameters
- mode: pointer to accept touch sensor interrupt trigger mode

`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

`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

`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

`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

`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
- 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

`esp_err_t touch_pad_intr_enable (void)`
To enable touch pad interrupt.
Chapter 2. API 参考

Return
• ESP_OK on success

*esp_err_t* touch_pad_intr_disable (void)
To disable touch pad interrupt.

Return
• ESP_OK on success

*esp_err_t* touch_pad_intr_clear (void)
To clear touch pad interrupt.

Return
• ESP_OK on success

*esp_err_t* touch_pad_set_filter_period (uint32_t new_period_ms)
set touch pad filter calibration period, in ms. Need to call touch_pad_filter_start before all touch filter APIs

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

*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

*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

*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

*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**

- `driver/include/driver/touch_sensor_common.h`

**Functions**

```c
esp_err_t touch_pad_init (void)
```

Initialize touch module.

**Note** If default parameter does not match the usage scenario, it can be changed after this function.

**Return**

- ESP_OK Success
- ESP_ERR_NO_MEM Touch pad init error

```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 channel. The touch sensor measures the channel capacitance value by charging and discharging the channel. So the high threshold should be less than the supply voltage.

**Return**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong

**Parameters**

- `refh`: the value of DREFH
- `refl`: the value of DREFL
- `atten`: the attenuation on DREFH

```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

---

Submit Document Feedback
Chapter 2. API

- `refl`: pointer to accept DREFL value
- `atten`: pointer to accept the attenuation on DREFH

`esp_err_t touch_pad_set_cnt_mode(touch_pad_t touch_num, touch_cnt_slope_t slope, touch_tie_opt_t opt)`

Set touch sensor charge/discharge speed for each pad. If the slope is 0, the counter would always be zero. If the slope is 1, the charging and discharging would be slow, accordingly. If the slope is set 7, which is the maximum value, the charging and discharging would be fast.

**Note** The higher the charge and discharge current, the greater the immunity of the touch channel, but it will increase the system power consumption.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong

**Parameters**
- `touch_num`: touch pad index
- `slope`: touch pad charge/discharge speed
- `opt`: the initial voltage

`esp_err_t touch_pad_get_cnt_mode(touch_pad_t touch_num, touch_cnt_slope_t *slope, touch_tie_opt_t *opt)`

Get touch sensor charge/discharge speed for each pad.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong

**Parameters**
- `touch_num`: touch pad index
- `slope`: pointer to accept touch pad charge/discharge slope
- `opt`: pointer to accept the initial voltage

`esp_err_t touch_pad_isr_deregister(void (*fn)) void *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`)

`esp_err_t touch_pad_get_wakeup_status(touch_pad_t *pad_num)`

Get the touch pad which caused wakeup from deep sleep.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG parameter is NULL

**Parameters**
- `pad_num`: pointer to touch pad which caused wakeup

`esp_err_t touch_pad_set_fsm_mode(touch_fsm_mode_t mode)`

Set touch sensor FSM mode, the test action can be triggered by the timer, as well as by the software.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong

**Parameters**
- `mode`: FSM mode

`esp_err_t touch_pad_get_fsm_mode(touch_fsm_mode_t *mode)`

Get touch sensor FSM mode.

**Return**
- ESP_OK on success
Chapter 2. API 参考

Parameters

• mode: pointer to accept FSM mode

\texttt{esp_err_t touch_pad_clear_status (void)}

To clear the touch sensor channel active status.

\textbf{Note} The FSM automatically updates the touch sensor status. It is generally not necessary to call this API to clear the status.

\textbf{Return}

• ESP_OK on success

\texttt{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.

\textbf{Return}

• The touch sensor status. e.g. Touch1 trigger status is \texttt{status_mask & (BIT1)}.

\texttt{bool touch_pad_meas_is_done (void)}

Check touch sensor measurement status.

\textbf{Return}

• True measurement is under way
• False measurement done

\textbf{GPIO 宏查找表} 您可以使用宏定义某一触摸板通道的 GPIO，或定义某一 GPIO 的通道。例如:

1. \texttt{TOUCH_PAD_NUM5_GPIO_NUM} 定义了通道 5 的 GPIO（即 GPIO 12）;
2. \texttt{TOUCH_PAD_GPIO4_CHANNEL} 定义了 GPIO 4 的通道（即通道 0）。

\textbf{Header File}

• \texttt{soc/soc/esp32/include/soc/touch_sensor_channel.h}

\textbf{Macros}

\texttt{TOUCH_PAD_GPIO4_CHANNEL}
\texttt{TOUCH_PAD_NUM0_GPIO_NUM}
\texttt{TOUCH_PAD_GPIO0_CHANNEL}
\texttt{TOUCH_PAD_NUM1_GPIO_NUM}
\texttt{TOUCH_PAD_GPIO2_CHANNEL}
\texttt{TOUCH_PAD_NUM2_GPIO_NUM}
\texttt{TOUCH_PAD_GPIO15_CHANNEL}
\texttt{TOUCH_PAD_NUM3_GPIO_NUM}
\texttt{TOUCH_PAD_GPIO13_CHANNEL}
\texttt{TOUCH_PAD_NUM4_GPIO_NUM}
\texttt{TOUCH_PAD_GPIO12_CHANNEL}
\texttt{TOUCH_PAD_NUM5_GPIO_NUM}
\texttt{TOUCH_PAD_GPIO14_CHANNEL}
\texttt{TOUCH_PAD_NUM6_GPIO_NUM}
\texttt{TOUCH_PAD_GPIO27_CHANNEL}
\texttt{TOUCH_PAD_NUM7_GPIO_NUM}
\texttt{TOUCH_PAD_GPIO33_CHANNEL}
Chapter 2. API

### Variables

- TOUCH_PAD_NUM8_GPIO_NUM
- TOUCH_PAD_GPIO32_CHANNEL
- TOUCH_PAD_NUM9_GPIO_NUM

### Header File

- 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

### 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)
  - 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)
Chapter 2. API

**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**

```c
enum touch_high_volt_t
{
    TOUCH_HVOLT_KEEP = -1,
    TOUCH_HVOLT_2V4 = 0,
    TOUCH_HVOLT_2V5,
    TOUCH_HVOLT_2V6,
    TOUCH_HVOLT_2V7,
    TOUCH_HVOLT_MAX
};
```

**Values:**

**TOUCH_HVOLT_KEEP**
Touch sensor high reference voltage, no change

**TOUCH_HVOLT_2V4**
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**

```c
enum touch_low_volt_t
{
    TOUCH_LVOLT_KEEP = -1,
    TOUCH_LVOLT_0V5,
    TOUCH_LVOLT_0V6,
    TOUCH_LVOLT_0V7,
    TOUCH_LVOLT_0V8,
    TOUCH_LVOLT_MAX
};
```

**Values:**

**TOUCH_LVOLT_KEEP**
Touch sensor low reference voltage, no change

**TOUCH_LVOLT_0V5**
Touch sensor low reference voltage, 0.5V

**TOUCH_LVOLT_0V6**
Touch sensor low reference voltage, 0.6V

**TOUCH_LVOLT_0V7**
Touch sensor low reference voltage, 0.7V

**TOUCH_LVOLT_0V8**
Touch sensor low reference voltage, 0.8V

**TOUCH_LVOLT_MAX**

```c
enum touch_volt_atten_t
{
    TOUCH_HVOLT_ATTEN_KEEP = -1,
    TOUCH_HVOLT_ATTEN_1V5,
    TOUCH_HVOLT_ATTEN_1V
};
```

**Values:**

**TOUCH_HVOLT_ATTEN_KEEP**
Touch sensor high reference voltage attenuation, no change

**TOUCH_HVOLT_ATTEN_1V5**
Touch sensor high reference voltage attenuation, 1.5V attenuation

**TOUCH_HVOLT_ATTEN_1V**
Touch sensor high reference voltage attenuation, 1.0V attenuation
Chapter 2. API

TOUCH_HVOLT_ATTEN_0V5
Touch sensor high reference voltage attenuation, 0.5V attenuation

TOUCH_HVOLT_ATTEN_0V
Touch sensor high reference voltage attenuation, 0V attenuation

TOUCH_HVOLT_ATTEN_MAX

enum touch_cnt_slope_t
Touch sensor charge/discharge speed

Values:

TOUCH_PAD_SLOPE_0 = 0
Touch sensor charge / discharge speed, always zero

TOUCH_PAD_SLOPE_1 = 1
Touch sensor charge / discharge speed, slowest

TOUCH_PAD_SLOPE_2 = 2
Touch sensor charge / discharge speed

TOUCH_PAD_SLOPE_3 = 3
Touch sensor charge / discharge speed

TOUCH_PAD_SLOPE_4 = 4
Touch sensor charge / discharge speed

TOUCH_PAD_SLOPE_5 = 5
Touch sensor charge / discharge speed

TOUCH_PAD_SLOPE_6 = 6
Touch sensor charge / discharge speed

TOUCH_PAD_SLOPE_7 = 7
Touch sensor charge / discharge speed, fast

TOUCH_PAD_SLOPE_MAX

enum touch_tie_opt_t
Touch sensor initial charge level

Values:

TOUCH_PAD_TIE_OPT_LOW = 0
Initial level of charging voltage, low level

TOUCH_PAD_TIE_OPT_HIGH = 1
Initial level of charging voltage, high level

TOUCH_PAD_TIE_OPT_MAX

enum touch_fsm_mode_t
Touch sensor FSM mode

Values:

TOUCH_FSM_MODE_TIMER = 0
To start touch FSM by timer

TOUCH_FSM_MODE_SW
To start touch FSM by software trigger

TOUCH_FSM_MODE_MAX

enum touch_trigger_mode_t
Values:

TOUCH_TRIGGER_BELOW = 0
Touch interrupt will happen if counter value is less than threshold.
TOUCH_TRIGGER_ABOVE = 1
Touch interrupt will happen if counter value is larger than threshold.

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

2.3.19 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.

重要提示: 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).

Asyncronous: 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 to 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.
**Chapter 2. API 参考**

### Operating Modes

The TWAI driver supports the following modes of operations:

**Normal Mode:** The normal operating mode allows the TWAI controller to take part in bus activities such as transmitting and receiving messages/error frames. Acknowledgement from another node is required when transmitting a message.

**No Ack Mode:** The No Acknowledgement mode is similar to normal mode, however acknowledgements are not required for a message transmission to be considered successful. This mode is useful when self testing the TWAI controller (loopback of transmissions).

**Listen Only Mode:** This mode will prevent the TWAI controller from influencing the bus. Therefore, transmission of messages/acknowledgement/error frames will be disabled. However the TWAI controller will still be able to receive messages but will not acknowledge the message. This mode is suited for bus monitor applications.

### Alerts

The TWAI driver contains an alert feature that is used to notify the application layer of certain TWAI controller or TWAI bus events. Alerts are selectively enabled when the TWAI driver is installed, but can be reconfigured during runtime by calling `twai_reconfigure_alerts()`. The application can then wait for any enabled alerts to occur by calling `twai_read_alerts()`. The TWAI driver supports the following alerts:

<table>
<thead>
<tr>
<th>Alert Flag</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWAI_ALERT_TX_IDLE</td>
<td>No more messages queued for transmission</td>
</tr>
<tr>
<td>TWAI_ALERT_TX_SUCCESS</td>
<td>The previous transmission was successful</td>
</tr>
<tr>
<td>TWAI_ALERT_BELOW_ERR_WARN</td>
<td>Both error counters have dropped below error warning limit</td>
</tr>
<tr>
<td>TWAI_ALERT_ERR_ACTIVE</td>
<td>TWAI controller has become error active</td>
</tr>
<tr>
<td>TWAI_ALERT_RECOVERY_IN_PROGRESS</td>
<td>TWAI controller is undergoing bus recovery</td>
</tr>
<tr>
<td>TWAI_ALERT_BUS_RECOVERED</td>
<td>TWAI controller has successfully completed bus recovery</td>
</tr>
<tr>
<td>TWAI_ALERT_ARB_LOST</td>
<td>The previous transmission lost arbitration</td>
</tr>
<tr>
<td>TWAI_ALERTBOVE_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>

![Diagram of TWAI Controller](image)

**图 17: Signal lines of the TWAI controller**

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Chapter 2. API 参考

注解：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_ALERTBelow_ERR_WARN is raised when both TEC and REC return back to values below 96.

注解：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).

注解：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 bitrate 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 quanta 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 quanta
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 quanta 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.

![Bit timing configuration for 500kbit/s given BRP = 8](chart)

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.

注解：Multiple combinations of brp, tseg_1, tseg_2, and sjw can achieve the same bit rate. Users should tune these values to the physical characteristics of their bus by taking into account factors such as propagation delay, node information processing time, and phase errors.

Bit timing macro initializers are also available for commonly used bit rates. The following macro initializers are provided by the TWAI driver.

- TWAI_TIMING_CONFIG_1MBITS()
- TWAI_TIMING_CONFIG_800KBITS()
- TWAI_TIMING_CONFIG_500KBITS()
- TWAI_TIMING_CONFIG_250KBITS()
- TWAI_TIMING_CONFIG_125KBITS()
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 the 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).

![Diagram](image1.png)

**图 19: 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).

![Diagram](image2.png)

**图 20: Bit layout of dual filter mode (Right side MSBit)**

Disabling TX Queue  The TX queue can be disabled during configuration by setting the `tx_queue_len` member of `twai_general_config_t` to 0. This will allow applications that do not require message transmission to save a small amount of memory when using the TWAI driver.

Placing ISR into IRAM  The TWAI driver’s ISR (Interrupt Service Routine) can be placed into IRAM so that the ISR can still run whilst the cache is disabled. Placing the ISR into IRAM may be necessary to maintain the TWAI driver’s functionality during lengthy cache disabling operations (such as SPI Flash writes, OTA updates etc). Whilst the cache is disabled, the ISR will continue to:

- Read received messages from the RX buffer and place them into the driver’s RX queue.
- Load messages pending transmission from the driver’s TX queue and write them into the TX buffer.

To place the TWAI driver’s ISR, users must do the following:
• Enable the `CONFIG_TWAI_ISR_IN_IRAM` option using `idf.py menuconfig`.
• When calling `twai_driver_install()`, the `intr_flags` member of `twai_general_config_t` should set the `ESP_INTR_FLAG_IRAM` set.

**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)

<table>
<thead>
<tr>
<th>Label</th>
<th>Transition</th>
<th>Action/Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Uninstalled -&gt; Stopped</td>
<td><code>twai_driver_install()</code></td>
</tr>
<tr>
<td>B</td>
<td>Stopped -&gt; Uninstalled</td>
<td><code>twai_driver_uninstall()</code></td>
</tr>
<tr>
<td>C</td>
<td>Stopped -&gt; Running</td>
<td><code>twai_start()</code></td>
</tr>
<tr>
<td>D</td>
<td>Running -&gt; Stopped</td>
<td><code>twai_stop()</code></td>
</tr>
<tr>
<td>E</td>
<td>Running -&gt; Bus-Off</td>
<td>Transmit Error Counter &gt;= 256</td>
</tr>
<tr>
<td>F</td>
<td>Bus-Off -&gt; Uninstalled</td>
<td><code>twai_driver_uninstall()</code></td>
</tr>
<tr>
<td>G</td>
<td>Bus-Off -&gt; Recovering</td>
<td><code>twai_initiate_recovery()</code></td>
</tr>
<tr>
<td>H</td>
<td>Recovering -&gt; Stopped</td>
<td>128 occurrences of 11 consecutive recessive bits.</td>
</tr>
</tbody>
</table>

**Driver States**

- **Uninstalled**: In the uninstalled state, no memory is allocated for the driver and the TWAI controller is powered OFF.

- **Stopped**: In this state, the TWAI controller is powered ON and the TWAI driver has been installed. However the TWAI controller will be unable to take part in any bus activities such as transmitting, receiving, or acknowledging messages.

- **Running**: In the running state, the TWAI controller is able to take part in bus activities. Therefore messages can be transmitted/received/acknowledged. Furthermore the TWAI controller will be able to transmit error frames upon detection of errors on the bus.

- **Bus-Off**: The bus-off state is automatically entered when the TWAI controller’s Transmit Error Counter becomes greater than or equal to 256. The bus-off state indicates the occurrence of severe errors on the bus or in the TWAI controller. Whilst in the bus-off state, the TWAI controller will be unable to take part in any bus activities. To exit the bus-off state, the TWAI controller must undergo the bus recovery process.

- **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.
Chapter 2. API 参考

Message Transmission  The following code snippet demonstrates how to transmit a message via the usage of the twai_message_t type and twai_transmit() function.

```c
#include "driver/twai.h"
...
//Configure message to transmit
twai_message_t message;
message.identifier = 0xAAAA;
message.extd = 1;
message.data_length_code = 4;
for (int i = 0; i < 4; i++) {
    message.data[i] = 0;
}
//Queue message for transmission
if (twai_transmit(&message, pdMS_TO_TICKS(1000)) == ESP_OK) {
    printf("Message queued for transmission\n");
} else {
    printf("Failed to queue message for transmission\n");
}
```

Message Reception  The following code snippet demonstrates how to receive a message via the usage of the twai_message_t type and twai_receive() function.

```c
#include "driver/twai.h"
...
//Wait for message to be received
twai_message_t message;
if (twai_receive(&message, pdMS_TO_TICKS(10000)) == ESP_OK) {
    printf("Message received\n");
} else {
    printf("Failed to receive message\n");
    return;
}
//Process received message
if (message.extd) {
    printf("Message is in Extended Format\n");
} else {
    printf("Message is in Standard Format\n");
}
printf("ID is %d\n", message.identifier);
if (!(message.rtr)) {
    for (int i = 0; i < message.data_length_code; i++) {
        printf("Data byte %d = %d\n", i, message.data[i]);
    }
}
```

Reconfiguring and Reading Alerts  The following code snippet demonstrates how to reconfigure and read TWAI driver alerts via the use of the twai_reconfigure_alerts() and twai_read_alerts() functions.

```c
#include "driver/twai.h"
...
//Reconfigure alerts to detect Error Passive and Bus-Off error states
```
```c
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");
}

// 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.

```c
#include "driver/twai.h"
...

// Stop the TWAI driver
if (twai_stop() == ESP_OK) {
    printf("Driver stopped\n");
} else {
    printf("Failed to stop driver\n");
    return;
}

// Uninstall the TWAI driver
if (twai_driver_uninstall() == ESP_OK) {
    printf("Driver uninstalled\n");
} else {
    printf("Failed to uninstall driver\n");
    return;
}
```

**Multiple ID Filter Configuration**  The acceptance mask in `twai_filter_config_t` can be configured such that two or more IDs will be accepted for a single filter. For a particular filter to accept multiple IDs, the conflicting bit positions amongst the IDs must be set in the acceptance mask. The acceptance code can be set to any one of the IDs.

The following example shows how to calculate the acceptance mask given multiple IDs:

```c
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`.  

(续上页)
**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**

- hal/include/hal/twai_types.h

**Structures**

**struct twai_message_t**

Structure to store a TWAI message.

**Note** The flags member is deprecated

**Public Members**

- `uint32_t extd`: 1
  Extended Frame Format (29bit ID)
- `uint32_t rtr`: 1
  Message is a Remote Frame
- `uint32_t ss`: 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)
Chapter 2. API

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)

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
Chapter 2. API 参考

Header File
- 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

```c
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

```c
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

```c
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

```c
esp_err_t twai_transmit(const twai_message_t *message, TickType_t ticks_to_wait)
```

Transmit a TWAI message.
This function queues a TWAI message for transmission. Transmission will start immediately if no other messages are queued for transmission. If the TX queue is full, this function will block until more space becomes available or until it times out. If the TX queue is disabled (TX queue length = 0 in configuration), this function will return immediately if another message is undergoing transmission. This function can only be called when the TWAI driver is in the running state and cannot be called under Listen Only Mode.

**Note** This function does not guarantee that the transmission is successful. The TX_SUCCESS/TX_FAILED alert can be enabled to alert the application upon the success/failure of a transmission.

**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

```c
esp_err_t twai_receive(twai_message_t *message, TickType_t ticks_to_wait)
```

Receive a TWAI message.

This function receives a message from the RX queue. The flags field of the message structure will indicate the type of message received. This function will block if there are no messages in the RX queue.

**Warning** The flags field of the received message should be checked to determine if the received message contains any data bytes.

**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
Chapter 2. API

• 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

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

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

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

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

struct twai_general_config_t
Structure for general configuration of the TWAI driver.

Note Macro initializers are available for this structure

Public Members

twai_mode_t mode
Mode of TWAI controller

gpio_num_t tx_io
Transmit GPIO number


**Chapter 2. API**

### Variables

- `gpio_num_t rx_io`
  - Receive GPIO number

- `gpio_num_t clkout_io`
  - CLKOUT GPIO number (optional, set to -1 if unused)

- `gpio_num_t bus_off_io`
  - Bus off indicator GPIO number (optional, set to -1 if unused)

- `uint32_t tx_queue_len`
  - Number of messages TX queue can hold (set to 0 to disable TX Queue)

- `uint32_t rx_queue_len`
  - Number of messages RX queue can hold

- `uint32_t alerts_enabled`
  - Bit field of alerts to enable (see documentation)

- `uint32_t clkout_divider`
  - CLKOUT divider. Can be 1 or any even number from 2 to 14 (optional, set to 0 if unused)

- `int intr_flags`
  - Interrupt flags to set the priority of the driver’s ISR. Note that to use the ESP_INTR_FLAG_IRAM, the `CONFIG_TWAI_ISR_IN_IRAM` option should be enabled first.

#### Structure: `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

- `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
    TWAIdriverstates.

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

2.3.20 UART

Overview

A Universal Asynchronous Receiver/Transmitter (UART) is a hardware feature that handles communication (i.e.,
timing requirements and data framing) using widely-adapted 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.

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 int uart_num = UART2;
uart_config_t uart_config = {
    .baud_rate = 115200,
    .data_bits = UART_DATA_8_BITS,
    .parity = UART_PARITY_DISABLE,

```
Multiple Steps Configure specific parameters individually by calling a dedicated function from the table given below. These functions are also useful if re-configuring a single parameter.

<table>
<thead>
<tr>
<th>Parameter to Configure</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baudrate</td>
<td>uart_set_baudrate()</td>
</tr>
<tr>
<td>Number of transmitted bits</td>
<td>uart_set_word_length() selected out of uart_word_length_t</td>
</tr>
<tr>
<td>Parity control</td>
<td>uart_set_parity() selected out of uart_parity_t</td>
</tr>
<tr>
<td>Number of stop bits</td>
<td>uart_set_stop_bits() selected out of uart_stop_bits_t</td>
</tr>
<tr>
<td>Hardware flow control mode</td>
<td>uart_set_hw_flow_ctrl() selected out of uart_mode_t</td>
</tr>
<tr>
<td>Communication mode</td>
<td>uart_set_mode() selected out of uart_mode_t</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.

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
const int uart_buffer_size = (1024 * 2);
QueueHandle_t uart_queue;
// 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(UART2, 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));
```

The function `uart_write_bytes_with_break()` is similar to `uart_write_bytes()` but adds a serial break signal at the end of the transmission. A ‘serial break signal’ means holding the Tx line low for a period longer than one data frame.

```c
// Write data to UART, end with a break signal.
uart_write_bytes_with_break(uart_num, "test break\n", strlen("test break\n"), 100);
```

Another function for writing data to the Tx FIFO buffer is `uart_tx_chars()`. Unlike `uart_write_bytes()`, this function will not block until space is available. Instead, it will write all data which can immediately fit into the hardware Tx FIFO, and then return the number of bytes that were written.

There is a ‘companion’ function `uart_wait_tx_done()` that monitors the status of the Tx FIFO buffer and returns once it is empty.

```c
// Wait for packet to be sent
const int uart_num = UART_NUM_2;
ESP_ERROR_CHECK(uart_wait_tx_done(uart_num, 100)); // wait timeout is 100 RTOS_ticks (TickType_t)
```

**Receiving** Once the data is received by the UART and saved in the Rx FIFO buffer, it needs to be retrieved using the function `uart_read_bytes()`. Before reading data, you can check the number of bytes available in the Rx FIFO buffer by calling `uart_get_buffered_data_len()`. An example of using these functions is given below.

```c
// Read data from UART.
const int uart_num = UART2;
uint8_t data[128];
int length = 0;
ESP_ERROR_CHECK(uart_get_buffered_data_len(uart_num, (size_t*)&length));
length = uart_read_bytes(uart_num, data, length, 100);
```

If the data in the Rx FIFO buffer is no longer needed, you can clear the buffer by calling `uart_flush()`.

**Software Flow Control** If the hardware flow control is disabled, you can manually set the RTS and DTR signal levels by using the functions `uart_set_rts()` and `uart_set_dtr()` respectively.
Communication Mode Selection  The UART controller supports a number of communication modes. A mode can be selected using the function `uart_set_mode()`. Once a specific mode is selected, the UART driver will handle the behavior of a connected UART device accordingly. As an example, it can control the RS485 driver chip using the RTS line to allow half-duplex RS485 communication.

```c
// Setup UART in rs485 half duplex mode
ESP_ERROR_CHECK(uart_set_mode(uart_num, UART_MODE_RS485_HALF_DUPLEX));
```

Using Interrupts  There are many interrupts that can be generated following specific UART states or detected errors. The full list of available interrupts is provided ESP32 Technical Reference Manual (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. 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()`.

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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.

Deletion 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

**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.

Deletion 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

**注解**： The following section will use `[UART_REGISTER_NAME].[UART_FIELD_BIT]` to refer to UART register fields/bits. To find more information on a specific option bit, open the Register Summary section of the SoC Technical Reference Manual. 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_RS485_TX_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.

注解:
• The schematics below do not necessarily contain all required elements.
• The analog devices ADM483 & ADM2483 are examples of common RS485 transceivers and can be replaced with other similar transceivers.

Circuit A: Collision Detection Circuit

```
VCC ------------+  
    |     +--------x--------+  
RXD <------| R |  
           | B| ------<> B  
ESP |-------| D | ADM483 |  
     |-------| DE |  
     |--------| A| ------<> A  
     | +-----| /RE |  
     |     | +--------x--------+  
     |     |               |  
GND |     | GND  
```

This circuit is preferable because it allows for collision detection and is quite simple at the same time. The receiver
in the line driver is constantly enabled, which allows the UART to monitor the RS485 bus. Echo suppression is performed by the UART peripheral when the bit `UART_RS485_CONF_REG.UART_RS485TX_RX_EN` is enabled.

### Circuit B: Manual Switching Transmitter/Receiver Without Collision Detection

![Circuit B Diagram]

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

![Circuit C Diagram]

This galvanically isolated circuit does not require RTS pin control by a software application or driver because it controls the transceiver direction automatically. However, it requires suppressing null bytes during transmission by setting `UART_RS485_CONF_REG.UART_RS485RXBY_TX_EN` to 1 and `UART_RS485_CONF_REG.UART_RS485TX_RX_EN` to 0. This setup can work in any RS485 UART mode or even in `UART_MODE_UART`.

### Application Examples

The table below describes the code examples available in the directory `peripherals/uart/`. 

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[Release v4.3-dev-1561-g357a277603]

Espressif Systems
## Code Example

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>peripherals/uart/uart_echo</td>
</tr>
<tr>
<td>Configuring UART settings, installing the UART driver, and reading/writing</td>
</tr>
<tr>
<td>over the UART1 interface.</td>
</tr>
<tr>
<td>peripherals/uart/uart_events</td>
</tr>
<tr>
<td>Reporting various communication events, using pattern detection interrupts.</td>
</tr>
<tr>
<td>peripherals/uart/uart_async_rxtxtasks</td>
</tr>
<tr>
<td>Transmitting and receiving data in two separate FreeRTOS tasks over the</td>
</tr>
<tr>
<td>same UART.</td>
</tr>
<tr>
<td>peripherals/uart/uart_select</td>
</tr>
<tr>
<td>Using synchronous I/O multiplexing for UART file descriptors.</td>
</tr>
<tr>
<td>peripherals/uart/uart_echo_rs485</td>
</tr>
<tr>
<td>Setting up UART driver to communicate over RS485 interface in half-duplex</td>
</tr>
<tr>
<td>mode. This example is similar to peripherals/uart/uart_echo but allows</td>
</tr>
<tr>
<td>communication through an RS485 interface chip connected to ESP32 pins.</td>
</tr>
<tr>
<td>peripherals/uart/nmea0183_parser</td>
</tr>
<tr>
<td>Obtaining GPS information by parsing NMEA0183 statements received from</td>
</tr>
<tr>
<td>GPS via the UART peripheral.</td>
</tr>
</tbody>
</table>

## API Reference

### Header File

- 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 (ORred) ESP_INTR_FLAG_* values. See esp_intr_alloc.h for more info. Do not set ESP_INTR_FLAG_IRAM here (the driver’s ISR handler is not located in IRAM)

- `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).

```c
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

```c
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.

```c
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

```c
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.

```c
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

```c
esp_err_t uart_get_parity(uart_port_t uart_num, uart_parity_t *parity_mode)
```
Get the UART parity mode configuration.

Return
  • ESP_FAIL Parameter error
  • ESP_OK Success, result will be put in (*parity_mode)

Parameters
  • uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
  • parity_mode: Pointer to accept value of UART parity mode.

```c
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

`esp_err_t uart_set_hw_flow_ctrl(uart_port_t uart_num, uart_hw_flowcontrol_t flow_ctrl, uint8_t rx_thresh)`
Set hardware flow control.

Return
- ESP_OK Success
- ESP_FAIL Parameter error

Parameters
- uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
- flow_ctrl: Hardware flow control mode
- rx_thresh: Threshold of Hardware RX flow control (0 ~ UART_FIFO_LEN). Only when UART_HW_FLOWCTRL_RTS is set, will the rx_thresh value be set.

`esp_err_t uart_set_sw_flow_ctrl(uart_port_t uart_num, bool enable, uint8_t rx_thresh_xon, uint8_t rx_thresh_xoff)`
Set software flow control.

Return
- ESP_OK Success
- ESP_FAIL Parameter error

Parameters
- uart_num: UART_NUM_0, UART_NUM_1 or UART_NUM_2
- enable: switch on or off
- rx_thresh_xon: low water mark
- rx_thresh_xoff: high water mark

`esp_err_t uart_get_hw_flow_ctrl(uart_port_t uart_num, uart_hw_flowcontrol_t *flow_ctrl)`
Get the UART hardware flow control configuration.

Return
- ESP_FAIL Parameter error
- ESP_OK Success, result will be put in (*flow_ctrl)

Parameters
- uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
- flow_ctrl: Option for different flow control mode.
### Chapter 2. API

**esp_err_t uart_clear_intr_status (uart_port_t uart_num, uint32_t clr_mask)**

Clear UART interrupt status.

**Return**
- ESP_OK Success
- ESP_FAIL Parameter error

**Parameters**
- `uart_num`: UART port number, the max port number is (UART_NUM_MAX - 1).
- `clr_mask`: Bit mask of the interrupt status to be cleared.

**esp_err_t uart_enable_intr_mask (uart_port_t uart_num, uint32_t enable_mask)**

Set UART interrupt enable.

**Return**
- ESP_OK Success
- ESP_FAIL Parameter error

**Parameters**
- `uart_num`: UART port number, the max port number is (UART_NUM_MAX - 1).
- `enable_mask`: Bitmask of the enable bits.

**esp_err_t uart_disable_intr_mask (uart_port_t uart_num, uint32_t disable_mask)**

Clear UART interrupt enable bits.

**Return**
- ESP_OK Success
- ESP_FAIL Parameter error

**Parameters**
- `uart_num`: UART port number, the max port number is (UART_NUM_MAX - 1).
- `disable_mask`: Bitmask 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**
- 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_set_pin (uart_port_t uart_num, int tx_io_num, int rx_io_num, int rts_io_num, int cts_io_num)
```

Set UART pin number.

**Note** Internal signal can be output to multiple GPIO pads. Only one GPIO pad can connect with input signal.

**Note** Instead of GPIO number a macro `UART_PIN_NO_CHANGE` may be provided to keep the currently allocated pin.

**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**
Chapter 2. API

- uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
- level: 1: DTR output low; 0: DTR output high

```c
esp_err_t uart_set_tx_idle_num(uart_port_t uart_num, uint16_t idle_num)
```
Set UART idle interval after tx FIFO is empty.

**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)

```c
esp_err_t uart_param_config(uart_port_t uart_num, const uart_config_t *uart_config)
```
Set UART configuration parameters.

**Return**
- ESP_OK Success
- ESP_FAIL Parameter error

**Parameters**
- uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
- uart_config: UART parameters settings

```c
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

```c
esp_err_t uart_wait_tx_done(uart_port_t uart_num, TickType_t ticks_to_wait)
```
Wait until UART TX FIFO is empty.

**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

```c
int uart_tx_chars(uart_port_t uart_num, const char *buffer, uint32_t len)
```
Send data to the UART port from a given buffer and length.

This function will not wait for enough space in TX FIFO. It will just fill the available TX FIFO and return when the FIFO is full.

**Note** This function should only be used when UART TX buffer is not enabled.

**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

```c
int uart_write_bytes(uart_port_t uart_num, const void *src, size_t size)
```
Send data to the UART port from a given buffer and length,

If the UART driver’s parameter ‘tx_buffer_size’ is set to zero: This function will not return until all the data have been sent out, or at least pushed into TX FIFO.
Otherwise, if the \( mx_buffer_size \) > 0, this function will return after copying all the data to tx ring buffer, UART ISR will then move data from the ring buffer to TX FIFO gradually.

**Return**
- (-1) Parameter error
- OTHERS (>=0) The number of bytes pushed to the TX FIFO

**Parameters**
- \( uart_num \): UART port number, the max port number is (UART_NUM_MAX - 1).
- \( src \): data buffer address
- \( size \): data length to send

```c
int uart_write_bytes_with_break(uart_port_t uart_num, const void *src, size_t size, int brk_len)
```

Send data to the UART port from a given buffer and length.

If the UART driver’s parameter ‘tx_buffer_size’ is set to zero: This function will not return until all the data and the break signal have been sent out. After all data is sent out, send a break signal.

Otherwise, if the ‘tx_buffer_size’ > 0, this function will return after copying all the data to tx ring buffer, UART ISR will then move data from the ring buffer to TX FIFO gradually. After all data sent out, send a break signal.

**Return**
- (-1) Parameter error
- OTHERS (>=0) The number of bytes pushed to the TX FIFO

**Parameters**
- \( uart_num \): UART port number, the max port number is (UART_NUM_MAX - 1).
- \( src \): data buffer address
- \( size \): data length to send
- \( brk_len \): break signal duration (unit: the time it takes to send one bit at current baudrate)

```c
int uart_read_bytes(uart_port_t uart_num, void *buf, uint32_t length, TickType_t ticks_to_wait)
```

UART read bytes from UART buffer.

**Return**
- (-1) Error
- OTHERS (>=0) The number of bytes read from UART FIFO

**Parameters**
- \( uart_num \): UART port number, the max port number is (UART_NUM_MAX - 1).
- \( buf \): pointer to the buffer.
- \( length \): data length
- \( ticks_to_wait \): sTimeout, count in RTOS ticks

```c
esp_err_t uart_flush(uart_port_t uart_num)
```

Alias of uart_flush_input. UART ring buffer flush. This will discard all data in the UART RX buffer.

**Note** Instead of waiting the data sent out, this function will clear UART rx buffer. In order to send all the data in tx FIFO, we can use uart_wait_tx_done function.

**Return**
- ESP_OK Success
- ESP_FAIL Parameter error

**Parameters**
- \( uart_num \): UART port number, the max port number is (UART_NUM_MAX - 1).

```c
esp_err_t uart_flush_input(uart_port_t uart_num)
```

Clear input buffer, discard all the data is in the ring-buffer.

**Note** In order to send all the data in tx FIFO, we can use uart_wait_tx_done function.

**Return**
- ESP_OK Success
- ESP_FAIL Parameter error

**Parameters**
- \( uart_num \): UART port number, the max port number is (UART_NUM_MAX - 1).
**esp_err_t uart_get_buffered_data_len(uart_port_t uart_num, size_t *size)**

UART get RX ring buffer cached data length.

**Return**
- ESP_OK Success
- ESP_FAIL Parameter error

**Parameters**
- **uart_num**: UART port number, the max port number is (UART_NUM_MAX -1).
- **size**: Pointer of size_t to accept cached data length

**esp_err_t uart_disable_pattern_det_intr(uart_port_t uart_num)**

UART disable pattern detect function. Designed for applications like ‘AT commands’. When the hardware detects a series of one same character, the interrupt will be triggered.

**Return**
- ESP_OK Success
- ESP_FAIL Parameter error

**Parameters**
- **uart_num**: UART port number, the max port number is (UART_NUM_MAX -1).

**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.

**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).

```c
int uart_pattern_get_pos(uart_port_t uart_num)
```

Return the nearest detected pattern position in buffer. The positions of the detected pattern are saved in a queue, This function do nothing to the queue.

The following APIs will modify the pattern position info: `uart_flush_input`, `uart_read_bytes`, `uart_driver_delete`, `uart_pop_pattern_pos` It is the application’s responsibility to ensure atomic access to the pattern queue and the rx data buffer when using pattern detect feature.

**Note** If the RX buffer is full and flow control is not enabled, the detected pattern may not be found in the rx buffer due to overflow.

**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).

```c
esp_err_t uart_pattern_queue_reset(uart_port_t uart_num, int queue_length)
```

Allocate a new memory with the given length to save record the detected pattern position in rx buffer.

**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.

```c
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

```c
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

\texttt{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

\texttt{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.

\texttt{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.

\texttt{esp_err_t uart_set_wakeup_threshold(uart_port_t uart_num, int wakeup_threshold)}

Set the number of RX pin signal edges for light sleep wakeup.

UART can be used to wake up the system from light sleep. This feature works by counting the number of positive edges on RX pin and comparing the count to the threshold. When the count exceeds the threshold, system is woken up from light sleep. This function allows setting the threshold value.

Stop bit and parity bits (if enabled) also contribute to the number of edges. For example, letter ‘a’ with ASCII code 97 is encoded as 0100001101 on the wire (with 8n1 configuration), start and stop bits included. This sequence has 3 positive edges (transitions from 0 to 1). Therefore, to wake up the system when ‘a’ is sent, set wakeup_threshold=3.

The character that triggers wakeup is not received by UART (i.e. it can not be obtained from UART FIFO). Depending on the baud rate, a few characters after that will also not be received. Note that when the chip enters and exits light sleep mode, APB frequency will be changing. To make sure that UART has correct baud rate all the time, select REF_TICK as UART clock source, by setting use_ref_tick field in \texttt{uart_config_t} to true.
Chapter 2. API

**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.

`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.

`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

`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.

`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

```c
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
```

```c
uint8_t rx_timeout_thresh
UART timeout interrupt threshold (unit: time of sending one byte)
```

```c
uint8_t txfifo_empty_intr_thresh
UART TX empty interrupt threshold.
```

```c
uint8_t rxfifo_full_thresh
UART RX full interrupt threshold.
```

```c
struct uart_event_t
Event structure used in UART event queue.
```

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

```c
UART_NUM_0
UART port 0
```

```c
UART_NUM_1
UART port 1
```

```c
UART_NUM_2
UART port 2
```

```c
UART_NUM_MAX
UART port max
```

```c
UART_PIN_NO_CHANGE
Constant for uart_set_pin function which indicates that UART pin should not be changed
```

```c
UART_FIFO_LEN
Length of the UART HW FIFO.
```

```c
UART_BITRATE_MAX
Maximum configurable bitrate.
```

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.
```

```c
Values:
```
Chapter 2. API

UART_DATA
UART data event

UARTBREAK
UART break event

UART_BUFFER_FULL
UART RX buffer full event

UART_FIFO_OVF
UART FIFO overflow event

UART_FRAME_ERR
UART RX frame error event

UART_PARITY_ERR
UART RX parity event

UART_DATA_BREAK
UART TX data and break event

UART_PATTERN_DET
UART pattern detected

UART_EVENT_MAX
UART event max index

Header File

- hal/include/hal/uart_types.h

Structures

struct uart_at_cmd_t
UART AT cmd char configuration parameters. Note that this function may different on different chip. Please refer to the TRM at configuration.

Public Members

uint8_t cmd_char
UART AT cmd char

uint8_t char_num
AT cmd char repeat number

uint32_t gap_tout
gap time (in baud-rate) between AT cmd char

uint32_t pre_idle
the idle time (in baud-rate) between the non AT char and first AT char

uint32_t post_idle
the idle time (in baud-rate) between the last AT char and the none AT char

struct uart_sw_flowctrl_t
UART software flow control configuration parameters.

Public Members

uint8_t xon_char
Xon flow control char

uint8_t xoff_char
Xoff flow control char
uint8_t xon_thrd
If the software flow control is enabled and the data amount in rxfifo is less than xon_thrd, an xon_char will be sent

uint8_t xoff_thrd
If the software flow control is enabled and the data amount in rxfifo is more than xoff_thrd, an xoff_char will be sent

`struct uart_config_t`
UART configuration parameters for uart_param_config function.

**Public Members**

- int **baud_rate**
  UART baud rate

- `uart_word_length_t data_bits`
  UART byte size

- `uart_parity_t parity`
  UART parity mode

- `uart_stop_bits_t stop_bits`
  UART stop bits

- `uart_hw_flowcontrol_t flow_ctrl`
  UART HW flow control mode (cts/rts)

- uint8_t `rx_flow_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**

```
typedef int uart_port_t
```
UART port number, can be UART_NUM_0 ~ (UART_NUM_MAX -1).

**Enumerations**

```
enum uart_mode_t
```
UART mode selection.

**Values:**

- `UART_MODE_UART = 0x00`
  mode: regular UART mode

- `UART_MODE_RS485_HALF_DUPLEX = 0x01`
  mode: half duplex RS485 UART mode control by RTS pin

- `UART_MODE_IRDA = 0x02`
  mode: IRDA UART mode

- `UART_MODE_RS485_COLLISION_DETECT = 0x03`
  mode: RS485 collision detection UART mode (used for test purposes)

- `UART_MODE_RS485_APP_CTRL = 0x04`
  mode: application control RS485 UART mode (used for test purposes)
enum uart_word_length_t
UART word length constants.

Values:
UART_DATA_5_BITS  = 0x0
    word length: 5bits
UART_DATA_6_BITS  = 0x1
    word length: 6bits
UART_DATA_7_BITS  = 0x2
    word length: 7bits
UART_DATA_8_BITS  = 0x3
    word length: 8bits
UART_DATA_BITS_MAX = 0x4

enum uart_stop_bits_t
UART stop bits number.

Values:
UART_STOP_BITS_1    = 0x1
    stop bit: 1bit
UART_STOP_BITS_1_5  = 0x2
    stop bit: 1.5bits
UART_STOP_BITS_2    = 0x3
    stop bit: 2bits
UART_STOP_BITS_MAX  = 0x4

enum uart_parity_t
UART parity constants.

Values:
UART_PARITY_DISABLE = 0x0
    Disable UART parity
UART_PARITY_EVEN    = 0x2
    Enable UART even parity
UART_PARITY_ODD     = 0x3
    Enable UART odd parity

enum uart_hw_flowcontrol_t
UART hardware flow control modes.

Values:
UART_HW_FLOWCTRL_DISABLE   = 0x0
    disable hardware flow control
UART_HW_FLOWCTRL_RTS       = 0x1
    enable RX hardware flow control (rts)
UART_HW_FLOWCTRL_CTS       = 0x2
    enable TX hardware flow control (cts)
UART_HW_FLOWCTRL_CTS_RTS   = 0x3
    enable hardware flow control
UART_HW_FLOWCTRL_MAX       = 0x4

enum uart_signal_inv_t
UART signal bit map.
Values:

- **UART_SIGNAL_INV_DISABLE = 0**
  - Disable UART signal inverse

- **UART_SIGNAL_IRDA_TX_INV = (0x1 « 0)**
  - Inverse the UART irda_tx signal

- **UART_SIGNAL_IRDA_RX_INV = (0x1 « 1)**
  - Inverse the UART irda_rx signal

- **UART_SIGNAL_RXD_INV = (0x1 « 2)**
  - Inverse the UART 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)**
  - Inverse the UART rts signal

- **UART_SIGNAL_DTR_INV = (0x1 « 7)**
  - Inverse the UART dtr signal

**enum uart_sclk_t**

  UART source clock.

Values:

- **UART_SCLK_APB = 0x0**
  - UART source clock from APB

- **UART_SCLK_REF_TICK = 0x01**
  - 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.

**注解:** 这些宏对于需要非常高的UART波特率（超过40 MHz），意味着你需要使用IO_MUX引脚。在其他情况下，这些宏可以忽略，你可以使用GPIO矩阵，因为它允许你为任何UART功能配置任何GPIO引脚。

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**

- soc/soc/esp32/include/soc/uart_channel.h
Chapter 2. API reference

**Macros**

- UART_GPIO1_DIRECT_CHANNEL
- UART_NUM_0_TXD_DIRECT_GPIO_NUM
- UART_GPIO3_DIRECT_CHANNEL
- UART_NUM_0_RXD_DIRECT_GPIO_NUM
- UART_GPIO19_DIRECT_CHANNEL
- UART_NUM_0_CTS_DIRECT_GPIO_NUM
- UART_GPIO22_DIRECT_CHANNEL
- UART_NUM_0_RTS_DIRECT_GPIO_NUM
- UART_TXD_GPIO1_DIRECT_CHANNEL
- UART_RXD_GPIO3_DIRECT_CHANNEL
- UART_CTS_GPIO19_DIRECT_CHANNEL
- UART_RTS_GPIO22_DIRECT_CHANNEL
- UART_GPIO10_DIRECT_CHANNEL
- UART_NUM_1_TXD_DIRECT_GPIO_NUM
- UART_GPIO9_DIRECT_CHANNEL
- UART_NUM_1_RXD_DIRECT_GPIO_NUM
- UART_GPIO6_DIRECT_CHANNEL
- UART_NUM_1_CTS_DIRECT_GPIO_NUM
- UART_GPIO11_DIRECT_CHANNEL
- UART_NUM_1_RTS_DIRECT_GPIO_NUM
- UART_TXD_GPIO10_DIRECT_CHANNEL
- UART_RXD_GPIO9_DIRECT_CHANNEL
- UART_CTS_GPIO6_DIRECT_CHANNEL
- UART_RTS_GPIO11_DIRECT_CHANNEL
- UART_GPIO17_DIRECT_CHANNEL
- UART_NUM_2_TXD_DIRECT_GPIO_NUM
- UART_GPIO16_DIRECT_CHANNEL
- UART_NUM_2_RXD_DIRECT_GPIO_NUM
- UART_GPIO8_DIRECT_CHANNEL
- UART_NUM_2_CTS_DIRECT_GPIO_NUM
- UART_GPIO7_DIRECT_CHANNEL
- UART_NUM_2_RTS_DIRECT_GPIO_NUM
- UART_TXD_GPIO17_DIRECT_CHANNEL
- UART_RXD_GPIO16_DIRECT_CHANNEL
- UART_CTS_GPIO8_DIRECT_CHANNEL
- UART_RTS_GPIO7_DIRECT_CHANNEL

The API code examples are stored in the `peripherals` directory of the ESP-IDF project.
2.4 应用层协议

2.4.1 mDNS 服务

概述
mDNS 是一种组播 UDP 服务，用来提供本地网络服务和主机发现。
绝大多数的操作系统默认都会安装 mDNS 服务，或者提供单独的安装包。Mac OS 默认会安装名为 Bonjour 的服务（该服务基于 mDNS），此外 Apple 还发布了适用于 Windows 系统的安装程序，可以在官方支持找到。在 Linux 上，mDNS 服务由 avahi 提供，通常也会被默认安装。

mDNS 属性
- hostname：设备去响应的主机名。如果没有设置，会根据设备的网络接口名定义 hostname。例如，my-esp32 会被解析为 my-esp32.local。
- default_instance：默认实例名（即易记的服务名），例如 Jhon's ESP32 Thing。如果没有设置，将会使用 hostname。

以下为 STA 接口启动 mDNS 服务并设置 hostname 和 default_instance 的示例方法：

```c
void start_mdns_service()
{
    // 初始化 mDNS 服务
    esp_err_t err = mdns_init();
    if (err) {
        printf("MDNS Init failed: %d\n", err);
        return;
    }

    // 设置 hostname
    mdns_hostname_set("my-esp32");
    // 设置默认实例名
    mdns_instance_name_set("Jhon's ESP32 Thing");
}
```

mDNS 服务 mDNS 可以广播设备能够提供的网络服务的相关信息，每个服务会由以下属性构成。
- instance_name：实例名（即易记的服务名），例如 Jhon's ESP32 Web Server。如果没有定义，会使用 default_instance。
- service_type：（必需）服务类型，以下划线为前缀，这里列出了常见的类型。
- proto：（必需）服务运行所依赖的协议，以下划线为前缀，例如 _tcp 或者 _udp。
- port：（必需）服务运行所用的端口号。
- txt：形如 {var, val} 的字符串数组，用于定义服务的属性。

添加一些服务和不同属性的示例方法：

```c
void add_mdns_services()
{
    // 添加服务
    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);

    // 注意：必须先添加服务，然后才能设置其属性
    // web 服务器使用自定义的实例名
    mdns_service_instance_name_set("_http", "_tcp", "Jhon's ESP32 Web Server");

    mdns_txt_item_t serviceTxtData[3] = {
        {"board", "esp32"},
    }
```
Chapter 2. API

```c
{
    "u", "user",
    "p", "password"
};

// 设置服务的文本数据（会释放并替换当前数据）
mdns_service_txt_set("_http", ":_tcp", serviceTxtData, 3);

// 修改服务端口号
mdns_service_port_set("_myservice", ":udp", 4321);
```

mDNS 查询 mDNS 提供查询服务和解析主机 IP/IPv6 地址的方法。 服务查询的结果会作为 mdns_result_t 类型对象的链表返回。
解析主机 IP 地址的示例方法:

```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));
}
```

解析本地服务的示例方法:

```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\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");
        }
    }
}
```
使用上述方法的示例：

```c
void my_app_some_method()
{
    // 搜索 esp32-mdns.local
    resolve_mdns_host("esp32-mdns");

    // 搜索 HTTP 服务器
    find_mdns_service("_http", "_tcp");
    // 或者搜索文件服务器
    find_mdns_service("_smb", "_tcp");  // Windows 系统的共享服务
    find_mdns_service("_afpovertcp", "_tcp");  // Apple AFP 文件共享服务
    find_mdns_service("_nfs", "_tcp");  // NFS 服务器
    find_mdns_service("_ftp", "_tcp");  // FTP 服务器
    // 或者网络打印机
    find_mdns_service("_printer", "_tcp");
    find_mdns_service("_ipp", "_tcp");
}
```

应用示例

有关 mDNS 服务器和查询器的应用示例请参考 protocols/mdns。

API 参考

Header File
• 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

#### `esp_err_t mdns_instance_name_set (const char* instance_name)`
Set the default instance name for mDNS server.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM memory error

**Parameters**
- instance_name: Instance name to set

#### `esp_err_t mdns_service_add (const char* instance_name, const char* service_type, const char* proto, uint16_t port, mdns_txt_item_t txt[], size_t num_items)`
Add service to mDNS server.

**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
- service_type: service type (_http,_ftp, etc)
- proto: service protocol (_tcp,_udp)
- port: service port
- txt: string array of TXT data (eg. {{ “var”,” val” },{ “other”,” 2” }})
- num_items: number of items in TXT data

#### `esp_err_t mdns_service_remove (const char* service_type, const char* proto)`
Remove service from mDNS server.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

**Parameters**
- service_type: service type (_http,_ftp, etc)
- proto: service protocol (_tcp,_udp)
**esp_err_t** mdns_service_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_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_txt_set(const char *service_type, const char *proto, mdns_txt_item_t txt[], uint8_t num_items)

Replace all TXT items 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)
- **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.

**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

**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
**Chapter 2.** API

### 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_remove_all (void)
```
Remove and free all services from mDNS server.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error

### Parameters
- **name**: service instance or host name (NULL for PTR queries)
- **service_type**: service type (_http, _arduino, _ftp etc) (NULL for host queries)
- **proto**: service protocol (_tcp, _udp, etc) (NULL for host queries)
- **type**: type of query (MDNS_TYPE_*)
- **timeout**: time in milliseconds to wait for answers.
- **max_results**: maximum results to be collected
- **results**: pointer to the results of the query results must be freed using mdns_query_results_free below

```c
void mdns_query_results_free (mdns_result_t *results)
```
Free query results.

**Parameters**
- **results**: linked list of results to be freed

```c
esp_err_t mdns_query_ptr (const char *service_type, const char *proto, uint16_t type, 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**
- **instance_name**: 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
Chapter 2. API

- ESP_ERR_INVALID_ARG parameter error

### Parameters

- instance_name: service instance name
- service_type: service type (_http, _arduino, _ftp etc.)
- proto: service protocol (_tcp, _udp, etc.)
- timeout: time in milliseconds to wait for answer.
- result: pointer to the result of the query

```c
esp_err_t mdns_query_txt(const char *instance_name, const char *service_type, const char *proto, uint32_t timeout, mdns_result_t **result)
```

Query mDNS for TXT record.

### Return

- ESP_OK success
- ESP_ERR_INVALID_STATE mDNS is not running
- ESP_ERR_NO_MEM memory error
- ESP_ERR_INVALID_ARG parameter error

### Parameters

- instance_name: service instance name
- service_type: service type (_http, _arduino, _ftp etc.)
- proto: service protocol (_tcp, _udp, etc.)
- timeout: time in milliseconds to wait for answer.
- result: pointer to the result of the query

```c
esp_err_t mdns_query_a(const char *host_name, uint32_t timeout, esp_ip4_addr_t *addr)
```

Query mDNS for A record.

### Return

- ESP_OK success
- ESP_ERR_INVALID_STATE mDNS is not running
- ESP_ERR_NO_MEM memory error
- ESP_ERR_INVALID_ARG parameter error

### Parameters

- host_name: host name to look for
- timeout: time in milliseconds to wait for answer.
- addr: pointer to the resulting IP4 address

```c
esp_err_t mdns_query_aaaa(const char *host_name, uint32_t timeout, esp_ip6_addr_t *addr)
```

Query mDNS for A record.

### 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.

### 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

`struct mdns_ip_addr_s`
- mDNS query linked list IP item

Public Members

`esp_ip_addr_t addr`
- IP address

`struct mdns_ip_addr_s *next`
- next IP, or NULL for the last IP in the list

`struct mdns_result_s`
- mDNS query result structure

Public Members

`struct mdns_result_s *next`
- next result, or NULL for the last result in the list

`mdns_if_t tcpip_if`
- interface index

`mdns_ip_protocol_t ip_protocol`
- ip_protocol type of the interface (v4/v6)

`char *instance_name`
- instance name

`char *hostname`
- hostname

`uint16_t port`
- service port

`mdns_txt_item_t *txt`
- txt record

`size_t txt_count`
- number of txt items

`mdns_ip_addr_t *addr`
- linked list of IP addresses found

Macros

MDNS_TYPE_A
MDNS_TYPE_PTR
MDNS_TYPE_TXT
MDNS_TYPE_AAAA
MDNS_TYPE_SRV
MDNS_TYPE_OPT
MDNS_TYPE_NSEC
MDNS_TYPE_ANY

Type Definitions

```c
typedef struct mdns_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
```

Enumerations

```c
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
```

2.4.2 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_delete()`: for freeing up the connection.

Any application layer protocol like HTTP1, HTTP2 etc can be executed on top of this layer.

Application Example

Simple HTTPS example that uses ESP-TLS to establish a secure socket connection: `protocols/https_request`.

Tree structure for ESP-TLS component

```
├── esp_tls.c
├── esp_tls.h
├── esp_tls_mbedtls.c
├── esp_tls_wolfssl.c
└── private_include
```

(下頁繼續)
Chapter 2. API

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`.

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](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/Makefile 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:

```python
idf.py/make 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>
Chapter 2. API 参考

注解：These values are subject to change with change in configuration options and version of respective libraries.

ATECC608A (Secure Element) with ESP-TLS

ESP-TLS provides support for using ATECC608A cryptoauth chip with ESP32-WROOM-32SE. Use of ATECC608A is supported only when ESP-TLS is used with mbedTLS as its underlying SSL/TLS stack. ESP-TLS uses mbedtls as its underlying TLS/SSL stack by default unless changed manually.

注解：ATECC608A chip on ESP32-WROOM-32SE must be already configured and provisioned, for details refer esp_cryptoauth_utility

To enable the secure element support, and use it in your project for TLS connection, you will have to follow below steps

1) Add esp-cryptoauthlib in your project, for details please refer esp-cryptoauthlib with ESP_IDF
2) Enable following menuconfig option:
   ```
   menuconfig->Component config->ESP-TLS->Use Secure Element (ATECC608A) with ESP-TLS
   ```
3) Select type of ATECC608A chip with following option:
   ```
   menuconfig->Component config->esp-cryptoauthlib->Choose Type of ATECC608A chip
   ```
   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

- esp-tls/esp_tls.h

Functions

```
esp_tls_t *esp_tls_init (void)
Create TLS connection.
```
This function allocates and initializes esp-tls structure handle.

```
Return  tls Pointer to esp-tls as esp-tls handle if successfully initialized, NULL if allocation error
```

```
esp_tls_t *esp_tls_conn_new (const char *hostname, int hostlen, int port, const esp_tls_cfg_t *cfg)
Create a new blocking TLS/SSL connection.
```
This function establishes a TLS/SSL connection with the specified host in blocking manner.

Note: This API is present for backward compatibility reasons. Alternative function with the same functionality is esp_tls_conn_new_sync (and its asynchronous version esp_tls_conn_new_async)

```
Return pointer to esp_tls_t, or NULL if connection couldn’t be opened.
```

Parameters

- [in] hostname: Hostname of the host.
Chapter 2. API

- [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.

This function establishes a TLS/SSL connection with the specified host in blocking manner.

**Return**
- -1 If connection establishment fails.
- 1 If connection establishment is successful.
- 0 If connection state is in progress.

**Parameters**
- [in] `hostname`: Hostname of the host.
- [in] `port`: Port number of the host.
- [in] `cfg`: TLS configuration as `esp_tls_cfg_t`. If you wish to open non-TLS connection, keep this NULL. For TLS connection, a pass pointer to `esp_tls_cfg_t`. At a minimum, this structure should be zero-initialized.
- [in] `tls`: Pointer to esp-tls as esp-tls handle.

```c
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.

```c
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 true.
- [in] `tls`: pointer to esp-tls as esp-tls handle.

```c
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.
Chapter 2. API

• 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.

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.

Note This API will be removed in IDFv5.0

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.

```c
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.

```c
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 be-
fore calling esp_tls_conn_new().

Return
• ESP_OK if adding certificates was successful.
• Other if an error occurred or an action must be taken by the calling process.

Parameters
• [in] cacert_pem_buf: Buffer which has certificates in pem format. This buffer is used for
  creating a global CA store, which can be used by other tls connections.

eesp_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.

```c
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

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.

**Structures**

```c
struct esp_tls_last_error
```

Error structure containing relevant errors in case tls error occurred.

**Public Members**

```c
esp_err_t last_error
```

error code (based on ESP_ERR_ESP_TLS_BASE) of the last occurred error

```c
int esp_tls_error_code
```

`esp_tls` error code from last `esp_tls` failed api

```c
int esp_tls_flags
```

last certification verification flags

```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

```c
const size_t key_size
```

length of the key

```c
const char* hint
```

hint in PSK authentication mode in string format

```c
struct esp_tls_cfg
```

ESP-TLS configuration parameters.

**Note**

Note about format of certificates:

- This structure includes certificates of a Certificate Authority, of client or server as well as private keys, which may be of PEM or DER format. In case of PEM format, the buffer must be NULL terminated (with NULL character included in certificate size).
- Certificate Authority’s certificate may be a chain of certificates in case of PEM format, but could be only one certificate in case of DER format.
- Variables names of certificates and private key buffers and sizes are defined as unions providing backward compatibility for legacy *_pem_buf and *_pem_bytes names which suggested only PEM format was supported. It is encouraged to use generic names such as cacert_buf and cacert_bytes.

**Public Members**

```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

```c
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

```c
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 mbedtlss-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 mbedtlss-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

**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

**struct esp_tls**
ESP-TLS Connection Handle.

### Public Members

```c
mbedtls_ssl_context ssl
   TLS/SSL context

mbedtls_entropy_context entropy
   mbedtls TLS entropy context structure

mbedtls_ctr_drbg_context ctr_drbg
   mbedtls TLS 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 TLS wrapper type for sockets

mbedtls_x509_crt cacert
   Container for the X.509 CA certificate

mbedtls_x509_crt *cacert_ptr
   Pointer to the cacert being used.

mbedtls_x509_crt clientcert
   Container for the X.509 client certificate

mbedtls_pk_context clientkey
   Container for the private key of the client certificate

int sockfd
   Underlying socket file descriptor.

ssize_t (*read)(struct esp_tls *tls, char *data, size_t datalen)
   Callback function for reading data from TLS/SSL connection.

ssize_t (*write)(struct esp_tls *tls, const char *data, size_t datalen)
   Callback function for writing data to TLS/SSL connection.

**esp_tls_conn_state_t** conn_state
   ESP-TLS Connection state

fd_set rset
   read file descriptors

fd_set wset
   write file descriptors

bool is_tls
   indicates connection type (TLS or NON-TLS)

**esp_tls_role_t** role
   esp-tls role
   - ESP_TLS_CLIENT
   - ESP_TLS_SERVER

**esp_tls_error_handle_t** error_handle
   handle to error descriptor
```
Chapter 2. API 参考

Macros

ESP_ERR_ESP_TLS_BASE
Starting number of ESP-TLS error codes

ESP_ERR_ESP_TLS_CANNOT_RESOLVE_HOSTNAME
Error if hostname couldn’t be resolved upon tls connection

ESP_ERR_ESP_TLS_CANNOT_CREATE_SOCKET
Failed to create socket

ESP_ERR_ESP_TLS_UNSUPPORTED_PROTOCOL_FAMILY
Unsupported protocol family

ESP_ERR_ESP_TLS_FAILED_CONNECT_TO_HOST
Failed to connect to host

ESP_ERR_ESP_TLS_SOCKET_SETOPT_FAILED
Failed to set socket option

ESP_ERR_MBEDTLS_CERT_PARTLY_OK
mbedtls parse certificates was partly successful

ESP_ERR_MBEDTLS_CTR_DRBG_SEED_FAILED
mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_SET_HOSTNAME_FAILED
mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_CONFIG_DEFAULTS_FAILED
mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_CONF_ALPN_PROTOCOLS_FAILED
mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_X509_CRT_PARSE_FAILED
mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_CONF_OWN_CERT_FAILED
mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_SETUP_FAILED
mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_WRITE_FAILED
mbedtls api returned error

ESP_ERR_MBEDTLS_PK_PARSE_KEY_FAILED
mbedtls api returned failed

ESP_ERR_MBEDTLS_SSL_HANDSHAKE_FAILED
mbedtls api returned failed

ESP_ERR_MBEDTLS_SSL_CONF_PSK_FAILED
mbedtls api returned failed

ESP_ERR_ESP_TLS_CONNECTION_TIMEOUT
new connection in esp_tls_low_level_conn connection timedout

ESP_ERR_WOLFSSL_SSL_SET_HOSTNAME_FAILED
wolfSSL api returned error

ESP_ERR_WOLFSSL_SSL_CONF_ALPN_PROTOCOLS_FAILED
wolfSSL api returned error

ESP_ERR_WOLFSSL_CERT_VERIFY_SETUP_FAILED
wolfSSL api returned error

ESP_ERR_WOLFSSL_KEY_VERIFY_SETUP_FAILED
wolfSSL api returned error
Chapter 2. API 参考

ESP_ERR_WOLFSSL_SSL_HANDSHAKE_FAILED
wolfSSL api returned failed

ESP_ERR_WOLFSSL_CTX_SETUP_FAILED
wolfSSL api returned failed

ESP_ERR_WOLFSSL_SSL_SETUP_FAILED
wolfSSL api returned failed

ESP_ERR_WOLFSSL_SSL_WRITE_FAILED
wolfSSL api returned failed

ESP_ERR_ESP_TLS_SE_FAILED
ESP_TLS_ERR_SSL_WANT_READ
ESP_TLS_ERR_SSL_WANT_WRITE
ESP_TLS_ERR_SSL_TIMEOUT

Type Definitions

typedef struct esp_tls_last_error *esp_tls_error_handle_t
typedef struct esp_tls_last_error esp_tls_last_error_t
Error structure containing relevant errors in case tls error occurred.

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 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

define 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

define esp_tls_role
Values:
Chapter 2. API

ESP_TLS_CLIENT = 0
ESP_TLS_SERVER

2.4.3 ESP HTTP Client

Overview

*esp_http_client* provides an API for making HTTP/S requests from ESP-IDF programs. The steps to use this API for an HTTP request are:

- **esp_http_client_init():** To use the HTTP client, the first thing we must do is create an *esp_http_client* bypass into this function with the *esp_http_client_config_t* configurations. Which configuration values we do not define, the library will use default.
- **esp_http_client_perform():** The *esp_http_client* argument created from the init function is needed. This function performs all operations of the *esp_http_client*, from opening the connection, sending data, downloading data and closing the connection if necessary. All related events will be invoked in the event_handle (defined by *esp_http_client_config_t*). This function performs its job and blocks the current task until it’s done.
- **esp_http_client_cleanup():** After completing our *esp_http_client*’s task, this is the last function to be called. It will close the connection (if any) and free up all the memory allocated to the HTTP client.

Application Example

```c
esp_err_t _http_event_handle(esp_http_client_event_t *evt)
{
    switch(evt->event_id) {
    case HTTP_EVENT_ERROR:
        ESP_LOGI(TAG, "HTTP_EVENT_ERROR");
        break;
    case HTTP_EVENT_ON_CONNECTED:
        ESP_LOGI(TAG, "HTTP_EVENT_ON_CONNECTED");
        break;
    case HTTP_EVENT_HEADER_SENT:
        ESP_LOGI(TAG, "HTTP_EVENT_HEADER_SENT");
        break;
    case HTTP_EVENT_ON_HEADER:
        ESP_LOGI(TAG, "HTTP_EVENT_ON_HEADER");
        printf("%.*s", evt->data_len, (char*)evt->data);
        break;
    case HTTP_EVENT_ON_DATA:
        ESP_LOGI(TAG, "HTTP_EVENT_ON_DATA", len=%d", evt->data_len);
        if (!esp_http_client_is_chunked_response(evt->client)) {
            printf("%.*s", evt->data_len, (char*)evt->data);
        }
        break;
    case HTTP_EVENT_ON_FINISH:
        ESP_LOGI(TAG, "HTTP_EVENT_ON_FINISH");
        break;
    case HTTP_EVENT_DISCONNECTED:
        ESP_LOGI(TAG, "HTTP_EVENT_DISCONNECTED");
        break;
    }
    return ESP_OK;
}

esp_http_client_config_t config = {
    .url = "http://httpbin.org/redirect/2",
```

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Persistent Connections

Persistent connections mean that the HTTP client can re-use the same connection for several transfers. If the server does not request to close the connection with the `Connection: close` header, the new transfer with sample ip address, port, and protocol.

To allow the HTTP client to take full advantage of persistent connections, you should do as many of your file transfers as possible using the same handle.

Persistent Connections example

```c
esp_err_t err;
esp_http_client_config_t config = {
    .url = "http://httpbin.org/get",
};
esp_http_client_handle_t client = esp_http_client_init(&config);
// first request
err = esp_http_client_perform(client);
// second request
esp_http_client_set_url(client, "http://httpbin.org/anything")
esp_http_client_set_method(client, HTTP_METHOD_DELETE);
esp_http_client_set_header(client, "HeaderKey", "HeaderValue");
err = esp_http_client_perform(client);
esp_http_client_cleanup(client);
```

HTTPS

The HTTP client supports SSL connections using `mbedtl`, with the `url` configuration starting with `https` scheme (or transport_type = HTTP_TRANSPORT_OVER_SSL). HTTPS support can be configured via `CONFIG_ESP_HTTP_CLIENT_ENABLE_HTTPS` (enabled by default).

注解：By providing information using HTTPS, the library will use the SSL transport type to connect to the server. If you want to verify server, then need to provide additional certificate in PEM format, and provide to cert_pem in `esp_http_client_config_t`

HTTPS example

```c
static void https()
{
    esp_http_client_config_t config = {
        .url = "https://www.howsmyssl.com",
```
HTTP Stream

Some applications need to open the connection and control the reading of the data in an active manner. the HTTP client supports some functions to make this easier, of course, once you use these functions you should not use the `esp_http_client_perform()` function with that handle, and `esp_http_client_init()` alway called first to get the handle. Perform that functions in the order below:

- `esp_http_client_init()` : to create and handle
- `esp_http_client_set_* or esp_http_client_delete_*`: to modify the http connection information (optional)
- `esp_http_client_open()` : Open the http connection with `write_len` parameter, `write_len`=0 if we only need read
- `esp_http_client_write()` : Upload data, max length equal to `write_len` of `esp_http_client_open()` function. We may not need to call it if `write_len`=0
- `esp_http_client_fetch_headers()` : After sending the headers and write data (if any) to the server, this function will read the HTTP Server response headers. Calling this function will return the content-length from the Server, and we can call `esp_http_client_get_status_code()` for the HTTP status of the connection.
- `esp_http_client_read()` : Now, we can read the HTTP stream by this function.
- `esp_http_client_close()` : We should the connection after finish
- `esp_http_client_cleanup()` : And release the resources

Perform HTTP request as Stream reader Check the example function http_perform_as_stream_reader at protocols/esp_http_client.

HTTP Authentication

The HTTP client supports both Basic and Digest Authentication. By providing usernames and passwords in `url` or in the `username,password` of config entry. And with `auth_type`= HTTP_AUTH_TYPE_BASIC, the HTTP client takes only 1 perform to pass the authentication process. If `auth_type`= HTTP_AUTH_TYPE_NONE, but there are username and password in the configuration, the HTTP client takes 2 performs. The first time it connects to the server and receives the UNAUTHORIZED header. Based on this information, it will know which authentication method to choose, and perform it on the second.

Config authentication example 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,
};
```
Config authentication example with username, 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,
};
```

HTTP Client example: protocols/esp_http_client.

**API Reference**

**Header File**

- esp_http_client/include/esp_http_client.h

**Functions**

- `esp_http_client_handle_t esp_http_client_init(const esp_http_client_config_t *config)`
  
  Start a HTTP session. This function must be the first function to call, and it returns 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`
Chapter 2. API

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_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)

- ESP_OK
- ESP_OK
- ESP_FAIL
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, char *password)
Set http request password. The value of password parameter will be assigned to password buffer. If the password parameter is NULL then password buffer will be freed.

Return
- ESP_OK
- ESP_ERR_INVALID_ARG

Parameters
- [in] client: The esp_http_client handle
- [in] password: The password value

esp_err_t esp_http_client_set_auth_type(esp_http_client_handle_t client, esp_http_client_auth_type_t auth_type)
Set http request auth_type.

Return
- ESP_OK
- ESP_ERR_INVALID_ARG

Parameters
- [in] client: The esp_http_client handle
- [in] auth_type: The esp_http_client auth type

esp_err_t esp_http_client_set_method(esp_http_client_handle_t client, esp_http_client_method_t 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_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**
- [in] client: The `esp_http_client` handle
- [in] write_len: HTTP Content length need to write to the server

**int** `esp_http_client_write` *(esp_http_client_handle_t client, const char* buffer, int len)*

This function will write data to the HTTP connection previously opened by `esp_http_client_open()`

**Return**
- (-1) if any errors
- Length of data written

**Parameters**
- [in] client: The `esp_http_client` handle
- buffer: The buffer
- [in] len: This value must not be larger than the write_len parameter provided to `esp_http_client_open()`

**int** `esp_http_client_fetch_headers` *(esp_http_client_handle_t client)*

This function need to call after `esp_http_client_open()`, it will read from http stream, process all receive headers.

**Return**
- (0) if stream doesn’t contain content-length header, or chunked encoding (checked by `esp_http_client_is_chunked_response`)
- (-1: ESP_FAIL) if any errors
- Download data length defined by content-length header

**Parameters**
- [in] client: The `esp_http_client` handle

**bool** `esp_http_client_is_chunked_response` *(esp_http_client_handle_t client)*

Check response data is chunked.

**Return** true or false

**Parameters**
- [in] client: The `esp_http_client` handle

**int** `esp_http_client_read` *(esp_http_client_handle_t client, char* buffer, int len)*

Read data from http stream.

**Return**
- (-1) if any errors
- Length of data was read

**Parameters**
- [in] client: The `esp_http_client` handle
- buffer: The buffer
- [in] len: The length

**int** `esp_http_client_get_status_code` *(esp_http_client_handle_t client)*

Get http response status code, the valid value if this function invoke after `esp_http_client_perform`

**Return** Status code

**Parameters**
- [in] client: The `esp_http_client` handle

**int** `esp_http_client_get_content_length` *(esp_http_client_handle_t client)*

Get http response content length (from header Content-Length) the valid value if this function invoke after `esp_http_client_perform`

**Return**
- (-1) Chunked transfer
- Content-Length value as bytes
Chapter 2. API

Parameters
• [in] client: The esp_http_client handle

esp_err_t esp_http_client_close(esp_http_client_handle_t client)
Close http connection, still kept all http request resources.

Return
• ESP_OK
• ESP_FAIL

Parameters
• [in] client: The esp_http_client handle

esp_err_t esp_http_client_cleanup(esp_http_client_handle_t client)
This function must be the last function to call for an session. It is the opposite of the esp_http_client_init function and must be called with the same handle as input that a esp_http_client_init call returned. This might close all connections this handle has used and possibly has kept open until now. Don’t call this function if you intend to transfer more files, re-using handles is a key to good performance with esp_http_client.

Return
• 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

```c
esp_err_t esp_http_client_flush_response(esp_http_client_handle_t client, int *len)
```
Process all remaining response data. This uses an internal buffer to repeatedly receive, parse, and discard response data until complete data is processed. As no additional user-supplied buffer is required, this may be preferable to esp_http_client_read_response in situations where the content of the response may be ignored.

**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

```c
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

```c
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
void *user_data
    user_data context, from esp_http_client_config_t user_data

char *header_key
    For HTTP_EVENT_ON_HEADER event_id, it’s store current http header key

char *header_value
    For HTTP_EVENT_ON_HEADER event_id, it’s store current http header value

struct esp_http_client_config_t
    HTTP configuration.

Public Members

const char *url
    HTTP URL, the information on the URL is most important, it overrides the other fields below, if any

const char *host
    Domain or IP as string

int port
    Port to connect, default depend on esp_http_client_transport_t (80 or 443)

const char *username
    Using for Http authentication

const char *password
    Using for Http authentication

esp_http_client_auth_type_t auth_type
    Http authentication type, see esp_http_client_auth_type_t

const char *path
    HTTP Path, if not set, default is /

const char *query
    HTTP query

const char *cert_pem
    SSL server certification, PEM format as string, if the client requires to verify server

const char *client_cert_pem
    SSL client certification, PEM format as string, if the server requires to verify client

const char *client_key_pem
    SSL client key, PEM format as string, if the server requires to verify client

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
```c
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
```

**Macros**

- `DEFAULT_HTTP_BUF_SIZE`
- `ESP_ERR_HTTP_BASE`
  - Starting number of HTTP error codes
- `ESP_ERR_HTTP_MAX_REDIRECT`
  - The error exceeds the number of HTTP redirects
- `ESP_ERR_HTTP_CONNECT`
  - Error open the HTTP connection
- `ESP_ERR_HTTP_WRITE_DATA`
  - Error write HTTP data
- `ESP_ERR_HTTP_FETCH_HEADER`
  - Error read HTTP header from server
- `ESP_ERR_HTTP_INVALID_TRANSPORT`
  - There are no transport support for the input scheme
- `ESP_ERR_HTTP_CONNECTING`
  - HTTP connection hasn’t been established yet
- `ESP_ERR_HTTP_EAGAIN`
  - Mapping of errno EAGAIN to esp_err_t

**Type Definitions**

```c
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**

```c
typedef 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
HTTPClient 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
Chapter 2. API

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 authentiation

HTTP_AUTH_TYPE_BASIC
HTTP Basic authentication

HTTP_AUTH_TYPE_DIGEST
HTTP Disgest authentication

enum HttpStatus_Code
Enum for the HTTP status codes.

Values:

HttpStatus_MovedPermanently = 301
HttpStatus_Found = 302
HttpStatus_TemporaryRedirect = 307
HttpStatus_Unauthorized = 401
HttpStatus_Forbidden = 403
HttpStatus_NotFound = 404
HttpStatus_InternalError = 500

2.4.4 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)
Chapter 2. API 参考

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,
};
```

注解： 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 not default 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).

```bash
` 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",
};
```
The client is indifferent to the subprotocol field in the server response and will accept the connection no matter what the server replies.

For more options on `esp_websocket_client_config_t`, please refer to API reference below

**Events**

- `WEBSOCKET_EVENT_CONNECTED`: The client has successfully established a connection to the server. The client is now ready to send and receive data. Contains no event data.
- `WEBSOCKET_EVENT_DISCONNECTED`: The client has aborted the connection due to the transport layer failing to read data, e.g. because the server is unavailable. Contains no event data.
- `WEBSOCKET_EVENT_DATA`: The client has successfully received and parsed a WebSocket frame. The event data contains a pointer to the payload data, the length of the payload data as well as the opcode of the received frame. A message may be fragmented into multiple events if the length exceeds the buffer size. This event will also be posted for non-payload frames, e.g. pong or connection close frames.
- `WEBSOCKET_EVENT_ERROR`: Not used in the current implementation of the client.

If the client handle is needed in the event handler it can be accessed through the pointer passed to the event handler:

```c
esp_websocket_client_handle_t client = (esp_websocket_client_handle_t)handler_args;
```

**Limitations and Known Issues**

- The client is able to request the use of a subprotocol from the server during the handshake, but does not do any subprotocol related checks on the response from the server.

**Application Example**

A simple WebSocket example that uses `esp_websocket_client` to establish a websocket connection and send/receive data with the `websocket.org` server can be found here: `protocols/websocket`.

**Sending Text Data** The WebSocket client supports sending data as a text data frame, which informs the application layer that the payload data is text data encoded as UTF-8. Example:

```c
esp_websocket_client_send_text(client, data, len, portMAX_DELAY);
```

**API Reference**

**Header File**

- `esp_websocket_client/include/esp_websocket_client.h`

**Functions**

```c
esp_websocket_client_handle_t esp_websocket_client_init(const esp_websocket_client_config_t *config)
```

Start a Websocket session. This function must be the first function to call, and it returns a `esp_websocket_client_handle_t` that you must use as input to other functions in the interface. This call MUST have a corresponding call to `esp_websocket_client_destroy` when the operation is complete.

**Return**

- `esp_websocket_client_handle_t`
- `NULL` if any errors

**Parameters**

- `[in] config`: The configuration
**esp_err_t espwebsocket_client_set_uri (espwebsocket_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 espwebsocket_client_start (espwebsocket_client_handle_t client)**

Open the WebSocket connection.

**Return** esp_err_t

**Parameters**
- [in] client: The client

**esp_err_t espwebsocket_client_stop (espwebsocket_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 `espwebsocket_client_close()`.

**Notes:**
- Cannot be called from the websocket event handler

**Return** esp_err_t

**Parameters**
- [in] client: The client

**esp_err_t espwebsocket_client_destroy (espwebsocket_client_handle_t client)**

Destroy the WebSocket connection and free all resources. This function must be the last function to call for a session. It is the opposite of the `espwebsocket_client_init` function and must be called with the same handle as input that a `espwebsocket_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 espwebsocket_client_send (espwebsocket_client_handle_t client, const char *data, int len, TickType_t timeout)**

Generic write data to the WebSocket connection; defaults to binary send.

**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 espwebsocket_client_send_bin (espwebsocket_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
Chapter 2. API

- [in] len: The length
- [in] timeout: Write data timeout in RTOS ticks

```c
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

```c
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

```c
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.

**Return**
- true
- false

**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.
## Chapter 2. API 参考

**Return** esp_err_t

**Parameters**
- 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
c const char *data_ptr
  Data pointer

int data_len
  Data length

uint8_t op_code
  Received opcode

esp_websocket_client_handle_t client
  esp_websocket_client_handle_t context

void *user_context
  user_data context, from esp_websocket_client_config_t user_data

int payload_len
  Total payload length, payloads exceeding buffer will be posted through multiple events

int payload_offset
  Actual offset for the data associated with this event
```

```c
struct esp_websocket_client_config_t
Websocket client setup configuration.
```

**Public Members**

```c
c const char *uri
  Websocket URI, the information on the URI can be overrides the other fields below, if any

c const char *host
  Domain or IP as string

int port
  Port to connect, default depend on esp_websocket_transport_t (80 or 443)

c const char *username
  Using for Http authentication - Not supported for now

c const char *password
  Using for Http authentication - Not supported for now

c 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
```
```c
int task_prio
    Websocket task priority
int task_stack
    Websocket task stack
int buffer_size
    Websocket buffer size
const char *cert_pem
    SSL Certification, PEM format as string, if the client requires to verify server

enum esp_websocket_transport_t
transport
    Websocket transport type, see 'esp_websocket_transport_t'
char *subprotocol
    Websocket subprotocol
char *user_agent
    Websocket user-agent
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
```

**Type Definitions**

```c
typedef struct esp_websocket_client *esp_websocket_client_handle_t
```

**Enumerations**

```c
enum esp_websocket_event_id_t
    Websocket Client events id.
    Values:
    WEB_SOCKET_EVENT_ANY = -1
    WEB_SOCKET_EVENT_ERROR = 0
        This event occurs when there are any errors during execution
    WEB_SOCKET_EVENT_CONNECTED
        Once the Websocket has been connected to the server, no data exchange has been performed
    WEB_SOCKET_EVENT_DISCONNECTED
        The connection has been disconnected
    WEB_SOCKET_EVENT_DATA
        When receiving data from the server, possibly multiple portions of the packet
    WEB_SOCKET_EVENT_CLOSED
        The connection has been closed cleanly
```

```c
enum esp_websocket_transport_t
    Websocket Client transport.
    Values:
    WEB_SOCKET.Transport_UNKNOWN = 0x0
        Transport unknown
    WEB_SOCKET_TRANSPORT_OVER_TCP
        Transport over tcp
```
Chapter 2. API 参考

WEBSOCKET_TRANSPORT_OVER_SSL
Transport over ssl

2.4.5 HTTP 服务器

概述

HTTP Server组件提供了在ESP32上运行轻量级Web服务器的功能，下面介绍使用HTTP Server组件API的详细步骤：

- **httpd_start()**：创建HTTP服务器的实例，根据具体的配置为其分配内存和资源，并返回该服务器实例的句柄。服务器使用了两个套接字，一个用来监听HTTP流量（TCP类型），另一个用来处理控制信号（UDP类型），它们在服务器的任务循环中轮流使用。通过向httpd_start()传递httpd_config_t结构体，可以在创建服务器实例时配置任务的优先级和堆栈的大小。TCP流量被解析为HTTP请求，根据请求的URI来调用用户注册的处理程序，在处理程序中需要发送回HTTP响应数据包。
- **httpd_stop()**：根据传入的句柄停止服务器，并释放相关联的内存和资源。这是一个阻塞函数，首先给服务器任务发送停止信号，然后等待其终止。期间服务器任务会关闭所有已打开的连接，删除已注册的URI处理程序，并将所有会话的上下文数据重置为空。
- **httpd_register_uri_handler()**：通过传入httpd_uri_t结构体类型的对象来注册URI处理程序。该结构体包含如下成员：uri名字、method类型（比如HTTPD_GET/HTTPD_POST/HTTPD_PUT等），esp_err_t *handler (httpd_req_t *req)类型的函数指针，指向用户上下文数据的user_ctx指针。

应用示例

```c
/* URI 处理函数，在客户端发起 GET /uri 请求时被调用 */
esp_err_t get_handler(httpd_req_t *req)
{
    /* 发送简单的响应数据包 */
    const char[] resp = "URI GET Response";
    httpd_resp_send(req, resp, HTTPD_RESP_USE_STRLEN);
    return ESP_OK;
}

/* URI 处理函数，在客户端发起 POST /uri 请求时被调用 */
esp_err_t post_handler(httpd_req_t *req)
{
    /* 定义 HTTP POST 请求数据的目标缓存区 */
    httpd_req_recv() 只接收 char* 数据，但也可以是任意二进制数据（需要类型转换）
    /* 对于字符串数据，null 终止将会被省略，content_len 会给出字符串的长度 */
    char content[100];

    /* 如果内容长度大于缓存区则截断 */
    size_t recv_size = MIN(req->content_len, sizeof(content));

    int ret = httpd_req_recv(req, content, recv_size);
    if (ret <= 0) { /* 返回 0 表示连接已关闭 */
        /* 检查是否超时 */
        if (ret == HTTPD sokcERR_TIMEOUT) {
            /* 超时，可以调用 httpd_req_recv() 重试 */
            httpd_resp_send_408(req); /* 返回 408 请求超时 */
        }
    }
    return ESP_FAIL;
}
```

(下页继续)
/* 发送简单的响应数据包 */
const char[] resp = "URI POST Response";
httpd_respond_send(req, resp, HTTPD_RESP_USE_STRLEN);
return ESP_OK;
}

/* GET /uri 的 URI 处理结构 */
httpd_uri_t uri_get = {
    .uri = "/uri",
    .method = HTTP_GET,
    .handler = get_handler,
    .user_ctx = NULL
};

/* POST /uri 的 URI 处理结构 */
httpd_uri_t uri_post = {
    .uri = "/uri",
    .method = HTTP_POST,
    .handler = post_handler,
    .user_ctx = NULL
};

/* 启动 Web 服务器的函数 */
httpd_handle_t start_webserver(void)
{
    /* 生成默认的配置参数 */
    httpd_config_t config = HTTPD_DEFAULT_CONFIG();

    /* 置空 esp_http_server 的实例句柄 */
    httpd_handle_t server = NULL;

    /* 启动 httpd server */
    if (httpd_start(&server, &config) == ESP_OK) {
        /* 注册 URI 处理程序 */
        httpd_register_uri_handler(server, &uri_get);
        httpd_register_uri_handler(server, &uri_post);
    }
    else {
        /* 如果服务器启动失败，返回的句柄是 NULL */
        return server;
    }
}

/* 停止 Web 服务器的函数 */
void stop_webserver(httpd_handle_t server)
{
    if (server) {
        /* 停止 httpd server */
        httpd_stop(server);
    }
}

简单 HTTP 服务器示例 请查看位于 protocols/http_server/simple 的 HTTP 服务器示例，该示例演示了如何处理任意内容长度的数据，读取请求头和 URL 查询参数，设置响应头。

HTTP 长连接

HTTP 服务器具有长连接的功能，允许重复使用同一个连接（会话）进行多次传输，同时保持会话的上下文数据。上下文数据可由处理程序动态分配，在这种情况下需要提前指定好自定义的回调函数，以便在连接/会话被关闭时释放这部分内存资源。
长连接示例

```c
void free_ctx_func(void *ctx)
{
    /* 也可以是 free 以外的代码逻辑 */
    free(ctx);
}

esp_err_t adder_post_handler(httpd_req_t *req)
{
    /* 如果会话上下文不存在则新建一个 */
    if (!req->sess_ctx)
    {
        req->sess_ctx = malloc(sizeof(ANY_DATA_TYPE)); /* 指向上下文数据 */
        req->free_ctx = free_ctx_func; /* 释放上下文数据的函数 */
    }

    /* 访问上下文数据 */
    ANY_DATA_TYPE *ctx_data = (ANY_DATA_TYPE *)req->sess_ctx;

    /* 响应 */
    ..............
    ..............

    return ESP_OK;
}
```

详情请参考位于 protocols/http_server/persistent_sockets 的示例代码。

API 参考

Header File

```
• esp_http_server/include/esp_http_server.h
```

Functions

```
esp_err_t httpd_register_uri_handler(httpd_handle_t handle, const httpd_uri_t *uri_handler)
Registers a URI handler.
```

Example usage:

```
esp_err_t my_uri_handler(httpd_req_t *req)
{
    // Recv , Process and Send
    ....
    ....

    // Fail condition
    if (....) {
        // Return fail to close session
        return ESP_FAIL;
    }

    // On success
    return ESP_OK;
}

// URI handler structure
httpd_uri_t my_uri {
```
Chapter 2. API

Note  URI handlers can be registered in real time as long as the server handle is valid.

Return
- ESP_OK: On successfully registering the handler
- ESP_ERR_INVALID_ARG: Null arguments
- ESP_ERR_HTTPD_HANDLERS_FULL: If no slots left for new handler
- ESP_ERR_HTTPD_HANDLER_EXISTS: If handler with same URI and method is already registered

Parameters
- [in] handle: handle to HTTPD server instance
- [in] uri_handler: pointer to handler that needs to be registered

```c
esp_err_t httpd_unregister_uri_handler(httpd_handle_t handle, const char *uri, httpd_method_t method)
```

Unregister a URI handler.

Return
- ESP_OK: On successfully deregistering the handler
- ESP_ERR_INVALID_ARG: Null arguments
- ESP_ERR_NOT_FOUND: Handler with specified URI and method not found

Parameters
- [in] handle: handle to HTTPD server instance
- [in] uri: URI string
- [in] method: HTTP method

```c
esp_err_t httpd_unregister_uri(httpd_handle_t handle, const char *uri)
```

Unregister all URI handlers with the specified uri string.

Return
- ESP_OK: On successfully deregistering all such handlers
- ESP_ERR_INVALID_ARG: Null arguments
- ESP_ERR_NOT_FOUND: No handler registered with specified uri string

Parameters
- [in] handle: handle to HTTPD server instance
- [in] uri: uri string specifying all handlers that need to be deregistered

```c
esp_err_t httpd_sess_set_recv_override(httpd_handle_t hd, int sockfd, httpd_recv_func_t recv_func)
```

Override web server’s receive function (by session FD)

This function overrides the web server’s receive function. This same function is used to read HTTP request packets.

Note  This API is supposed to be called either from the context of
- an http session APIs where sockfd is a valid parameter
- a URI handler where sockfd is obtained using httpd_req_to_sockfd()

Return
- ESP_OK: On successfully registering override
- ESP_ERR_INVALID_ARG: Null arguments

Parameters
- [in] hd: HTTPD instance handle
Chapter 2. API

- [in] sockfd: Session socket FD
- [in] recv_func: The receive function to be set for this session

```c
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

```c
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 sockfd, 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

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
• 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

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”

size_t httpd_req_get_url_query_len(httpd_req_t *r)

Get Query string length from the request URL.

Note This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid

Return
• Length: Query is found in the request URL
• Zero: Query not found / Null arguments / Invalid request

Parameters
• [in] r: The request being responded to

```c
esp_err_t httpd_req_get_url_query_str(httpd_req_t *r, char *buf, size_t buf_len)
```
Get Query string from the request URL.

Note
• Presently, the user can fetch the full URL query string, but decoding will have to be performed by
  the user. Request headers can be read using httpd_req_get_hdr_value_str() to know the ‘Content-
  Type’ (eg. Content-Type: application/x-www-form-urlencoded) and then the appropriate decoding
  algorithm needs to be applied.
• This API is supposed to be called only from the context of a URI handler where httpd_req_t* request
  pointer is valid
• If output size is greater than input, then the value is truncated, accompanied by truncation error as
  return value
• Prior to calling this function, one can use httpd_req_get_url_query_len() to know the query string
  length beforehand and hence allocate the buffer of right size (usually query string length + 1 for null
  termination) for storing the query string

Return
• ESP_OK: Query is found in the request URL and copied to buffer
• ESP_ERR_NOT_FOUND: Query not found
• ESP_ERR_INVALID_ARG: Null arguments
• ESP_ERR_HTTPD_INVALID_REQ: Invalid HTTP request pointer
• ESP_ERR_HTTPD_RESULT_TRUNC: Query string truncated

Parameters
• [in] r: The request being responded to
• [out] buf: Pointer to the buffer into which the query string will be copied (if found)
• [in] buf_len: Length of output buffer

```c
esp_err_t httpd_query_key_value(const char* qry, const char* key, char* val, size_t val_size)
```
Helper function to get a URL query tag from a query string of the type param1=val1&param2=val2.

Note
• The components of URL query string (keys and values) are not URL decoded. The user must check
  for ‘Content-Type’ field in the request headers and then depending upon the specified encoding
  (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”

```c
bool httpd_uri_match_wildcard(const char *uri_template, const char *uri_to_match, size_t match_upto)
```
Test if a URI matches the given wildcard template.

Template may end with “?” to make the previous character optional (typically a slash), “*” for a wildcard
match, and “?*” to make the previous character optional, and if present, allow anything to follow.

Example:
• * matches everything
• /foo/? matches /foo and /foo/
Chapter 2. API

The special characters ‘?’ and ‘*’ anywhere else in the template will be taken literally.

Return true if a match was found

Parameters

• [in] uri_template: URI template (pattern)
• [in] uri_to_match: URI to be matched
• [in] match_upto: how many characters of the URI buffer to test (there may be trailing query string etc.)

esp_err_t httpd_resp_send(httpd_req_t *r, const char *buf, ssize_t buf_len)

API to send a complete HTTP response.

This API will send the data as an HTTP response to the request. This assumes that you have the entire response ready in a single buffer. If you wish to send response in incremental chunks use httpd_resp_send_chunk() instead.

If no status code and content-type were set, by default this will send 200 OK status code and content type as text/html. You may call the following functions before this API to configure the response headers : httpd_resp_set_status() - for setting the HTTP status string, httpd_resp_set_type() - for setting the Content Type, httpd_resp_set_hdr() - for appending any additional field value entries in the response header

Note

• This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
• Once this API is called, the request has been responded to.
• No additional data can then be sent for the request.
• Once this API is called, all request headers are purged, so request headers need be copied into separate buffers if they are required later.

Return

• ESP_OK : On successfully sending the response packet
• ESP_ERR_INVALID_ARG : Null request pointer
• ESP_ERR_HTTPD_RESP_HDR : Essential headers are too large for internal buffer
• ESP_ERR_HTTPD_RESP_SEND : Error in raw send
• ESP_ERR_HTTPD_INVALID_REQ : Invalid request

Parameters

• [in] r: The request being responded to
• [in] buf: Buffer from where the content is to be fetched
• [in] buf_len: Length of the buffer, HTTPD_RESP_USE_STRLEN to use strlen()

esp_err_t httpd_resp_send_chunk(httpd_req_t *r, const char *buf, ssize_t buf_len)

API to send one HTTP chunk.

This API will send the data as an HTTP response to the request. This API will use chunked-encoding and send the response in the form of chunks. If you have the entire response contained in a single buffer, please use httpd_resp_send() instead.

If no status code and content-type were set, by default this will send 200 OK status code and content type as text/html. You may call the following functions before this API to configure the response headers httpd_resp_set_status() - for setting the HTTP status string, httpd_resp_set_type() - for setting the Content Type, httpd_resp_set_hdr() - for appending any additional field value entries in the response header

Note

• This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
• When you are finished sending all your chunks, you must call this function with buf_len as 0.
• Once this API is called, all request headers are purged, so request headers need be copied into separate buffers if they are required later.

Return

• ESP_OK : On successfully sending the response packet chunk
• ESP_ERR_INVALID_ARG : Null request pointer
Chapter 2. API

- 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’.
Chapter 2. API 参考

Note

- This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
- This API only sets the content type to this value. The type isn’t sent out until any of the send APIs is executed.
- Make sure that the lifetime of the type string is valid till send function is called.

Return

- ESP_OK : On success
- ESP_ERR_INVALID_ARG : Null arguments
- ESP_ERR_HTTPD_INVALID_REQ : Invalid request pointer

Parameters

- [in] r: The request being responded to
- [in] type: The Content Type of the response

esp_err_t httpd_resp_set_hdr (httpd_req_t *r, const char *field, const char *value)

API to append any additional headers.

This API sets any additional header fields that need to be sent in the response.

Note

- This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
- The header isn’t sent out until any of the send APIs is executed.
- The maximum allowed number of additional headers is limited to value of max_resp_headers in config structure.
- Make sure that the lifetime of the field value strings are valid till send function is called.

Return

- ESP_OK : On successfully appending new header
- ESP_ERR_INVALID_ARG : Null arguments
- ESP_ERR_HTTPD_RESP_HDR : Total additional headers exceed max allowed
- ESP_ERR_HTTPD_INVALID_REQ : Invalid request pointer

Parameters

- [in] r: The request being responded to
- [in] field: The field name of the HTTP header
- [in] value: The value of this HTTP header

esp_err_t httpd_resp_send_err (httpd_req_t *req, httpd_err_code_t error, const char *msg)

For sending out error code in response to HTTP request.

Note

- This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
- Once this API is called, all request headers are purged, so request headers need be copied into separate buffers if they are required later.
- If you wish to send additional data in the body of the response, please use the lower-level functions directly.

Return

- ESP_OK : On successfully sending the response packet
- ESP_ERR_INVALID_ARG : Null arguments
- ESP_ERR_HTTPD_RESP_SEND : Error in raw send
- ESP_ERR_HTTPD_INVALID_REQ : Invalid request pointer

Parameters

- [in] req: Pointer to the HTTP request for which the response needs to be sent
- [in] error: Error type to send
- [in] msg: Error message string (pass NULL for default message)

static esp_err_t httpd_resp_send_404 (httpd_req_t *r)

Helper function for HTTP 404.

Send HTTP 404 message. If you wish to send additional data in the body of the response, please use the lower-level functions directly.
Chapter 2. API

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 delimiters (CRLF) will need to be placed correctly for separating sub-sections of the HTTP response packet.

If the send override function is set, this API will end up calling that function eventually to send data out.

Note
• This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
• Unless the response has the correct HTTP structure (which the user must now ensure) it is not guaranteed that it will be recognized by the client. For most cases, you wouldn’t have to call this API, but you would rather use either of: httpd_resp_send(), httpd_resp_send_chunk()

Return
• Bytes: Number of bytes that were sent successfully
• HTTPD_SOCK_ERR_INVALID : Invalid arguments
• HTTPD_SOCK_ERR_TIMEOUT : Timeout/interrupted while calling socket send()
• HTTPD_SOCK_ERR_FAIL : Unrecoverable error while calling socket send()

Parameters
• [in] r: The request being responded to
• [in] buf: Buffer from where the fully constructed packet is to be read
• [in] buf_len: Length of the buffer

int httpd_socket_send (httpd_handle_t hd, int sockfd, const char* buf, size_t buf_len, int flags)
A low level API to send data on a given socket

This internally calls the default send function, or the function registered by httpd_sess_set_send_override().

Note This API is not recommended to be used in any request handler. Use this only for advanced use cases, wherein some asynchronous data is to be sent over a socket.

Return
• Bytes: The number of bytes sent successfully
• HTTPD_SOCK_ERR_INVALID : Invalid arguments
• HTTPD_SOCK_ERR_TIMEOUT : Timeout/interrupted while calling socket send()
• HTTPD_SOCK_ERR_FAIL : Unrecoverable error while calling socket send()

Parameters
• [in] hd: server instance
• [in] sockfd: session socket file descriptor
• [in] buf: buffer with bytes to send
• [in] buf_len: data size
• [in] flags: flags for the send() function

int httpd_socket_recv (httpd_handle_t hd, int sockfd, char* buf, size_t buf_len, int flags)
A low level API to receive data from a given socket

This internally calls the default recv function, or the function registered by httpd_sess_set_recv_override().

Note This API is not recommended to be used in any request handler. Use this only for advanced use cases, wherein some asynchronous communication is required.

Return
• Bytes : The number of bytes received successfully
• 0 : Buffer length parameter is zero / connection closed by peer
• HTTPD_SOCK_ERR_INVALID : Invalid arguments
• HTTPD_SOCK_ERR_TIMEOUT : Timeout/interrupted while calling socket recv()
• HTTPD_SOCK_ERR_FAIL : Unrecoverable error while calling socket recv()

Parameters
• [in] hd: server instance
• [in] sockfd: session socket file descriptor
• [in] buf: buffer with bytes to send
• [in] buf_len: data size
• [in] flags: flags for the send() function

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
Chapter 2. API

- 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)
{
    // Ensure handle is non NULL
    if (server != NULL) {
        // Stop the httpd server
        httpd_stop(server);
    }
}
```

**Return**
- ESP_OK: Server stopped successfully
• ESP_ERR_INVALID_ARG: Handle argument is null

Parameters
- \[\text{[in]}\] 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
- \[\text{[in]}\] handle: Handle to server returned by httpd_start
- \[\text{[in]}\] work: Pointer to the function to be executed in the HTTPD’s context
- \[\text{[in]}\] 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
- \[\text{[in]}\] handle: Handle to server returned by httpd_start
- \[\text{[in]}\] 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
- \[\text{[in]}\] handle: Handle to server returned by httpd_start
- \[\text{[in]}\] sockfd: The socket descriptor for which the context should be extracted.
- \[\text{[in]}\] ctx: Context object to assign to the session
- \[\text{[in]}\] 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
- \[\text{[in]}\] handle: Handle to server returned by httpd_start
- \[\text{[in]}\] sockfd: The socket descriptor for which the context should be extracted.

void httpd_sess_set_transport_ctx (httpd_handle_t handle, int sockfd, void *ctx, httpd_free_ctx_fn_t free_fn)

Set session ‘transport’ context by socket descriptor.

See httpd_sess_set_ctx()

Parameters
- \[\text{[in]}\] handle: Handle to server returned by httpd_start
Chapter 2. API

- [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

```c
void *httpd_get_global_user_ctx (httpd_handle_t handle)
Get HTTPD global user context (it was set in the server config struct)
```

**Return** global user context

**Parameters**
- [in] handle: Handle to server returned by httpd_start

```c
void *httpd_get_global_transport_ctx (httpd_handle_t handle)
Get HTTPD global transport context (it was set in the server config struct)
```

**Return** global transport context

**Parameters**
- [in] handle: Handle to server returned by httpd_start

```c
esp_err_t httpd_sess_trigger_close (httpd_handle_t handle, int sockfd)
Trigger an httpd session close externally.
```

**Note** Calling this API is only required in special circumstances wherein some application requires to close an httpd client session asynchronously.

**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

```c
esp_err_t httpd_sess_update_lru_counter (httpd_handle_t handle, int sockfd)
Update LRU counter for a given socket.
```

LRU Counters are internally associated with each session to monitor how recently a session exchanged traffic. When LRU purge is enabled, if a client is requesting for connection but maximum number of sockets/sessions is reached, then the session having the earliest LRU counter is closed automatically.

Updating the LRU counter manually prevents the socket from being purged due to the Least Recently Used (LRU) logic, even though it might not have received traffic for some time. This is useful when all open sockets/session are frequently exchanging traffic but the user specifically wants one of the sessions to be kept open, irrespective of when it last exchanged a packet.

**Note** Calling this API is only necessary if the LRU Purge Enable option is enabled.

**Return**
- ESP_OK : Socket found and LRU counter updated
- ESP_ERR_NOT_FOUND : Socket not found
- ESP_ERR_INVALID_ARG : Null arguments

**Parameters**
- [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

```c
esp_err_t httpd_get_client_list (httpd_handle_t handle, size_t *fds, int *client_fds)
Returns list of current socket descriptors of active sessions.
```

**Return**
- ESP_OK : Successfully retrieved session list
- ESP_ERR_INVALID_ARG : Wrong arguments or list is longer than allocated

**Parameters**
- [in] handle: Handle to server returned by httpd_start
- [inout] fds: In: Number of fds allocated in the supplied structure client_fds Out: Number of valid client fds returned in client_fds,
- [out] client_fds: Array of client fds
Chapter 2. API

Structures

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.

httpd_free_ctx_fn_t global_user_ctx_free_fn
    Free function for global user context

void *global_transport_ctx
    Global transport context.
    Similar to global_user_ctx, but used for session encoding or encryption (e.g. to hold the SSL context). It will be freed using free(), unless global_transport_ctx_free_fn is specified.

httpd_free_ctx_fn_t global_transport_ctx_free_fn
    Free function for global transport context
**httpd_open_func_t open_fn**

Custom session opening callback.

Called on a new session socket just after accept(), but before reading any data.

This is an opportunity to set up e.g. SSL encryption using global_transport_ctx and the send/recv/pending session overrides.

If a context needs to be maintained between these functions, store it in the session using httpd_sess_set_transport_ctx() and retrieve it later with httpd_sess_get_transport_ctx()

Returning a value other than ESP_OK will immediately close the new socket.

**httpd_close_func_t close_fn**

Custom session closing callback.

Called when a session is deleted, before freeing user and transport contexts and before closing the socket. This is a place for custom de-init code common to all sockets.

Set the user or transport context to NULL if it was freed here, so the server does not try to free it again.

This function is run for all terminated sessions, including sessions where the socket was closed by the network stack - that is, the file descriptor may not be valid anymore.

**httpd_uri_match_func_t uri_match_fn**

URI matcher function.

Called when searching for a matching URI: 1) whose request handler is to be executed right after an HTTP request is successfully parsed 2) in order to prevent duplication while registering a new URI handler using httpd_register_uri_handler()

Available options are: 1) NULL : Internally do basic matching using strncmp() 2) httpd_uri_match_wildcard() : URI wildcard matcher

Users can implement their own matching functions (See description of the httpd_uri_match_func_t function prototype)

**struct httpd_req**

HTTP Request Data Structure.

**Public Members**

**httpd_handle_t handle**

Handle to server instance

**int method**

The type of HTTP request, -1 if unsupported method

**const char uri[HTTPD_MAX_URI_LEN + 1]**

The URI of this request (1 byte extra for null termination)

**size_t content_len**

Length of the request body

**void *aux**

Internally used members

**void *user_ctx**

User context pointer passed during URI registration.

**void *sess_ctx**

Session Context Pointer

A session context. Contexts are maintained across ‘sessions’ for a given open TCP connection. One session could have multiple request responses. The web server will ensure that the context persists across all these request and responses.

By default, this is NULL. URI Handlers can set this to any meaningful value.
If the underlying socket gets closed, and this pointer is non-NULL, the web server will free up the context by calling free(), unless free_ctx function is set.

`httpd_free_ctx_fn_t free_ctx`

Pointer to free context hook

Function to free session context

If the web server’s socket closes, it frees up the session context by calling free() on the sess_ctx member. If you wish to use a custom function for freeing the session context, please specify that here.

`bool ignore_sess_ctx_changes`

Flag indicating if Session Context changes should be ignored

By default, if you change the sess_ctx in some URI handler, the http server will internally free the earlier context (if non NULL), after the URI handler returns. If you want to manage the allocation/reallocation/freeing of sess_ctx yourself, set this flag to true, so that the server will not perform any checks on it. The context will be cleared by the server (by calling free_ctx or free()) only if the socket gets closed.

`struct httpd_uri`

Structure for URI handler.

**Public Members**

`const char *uri`  
The URI to handle

`httpd_method_t method`  
Method supported by the URI

`esp_err_t (*handler)(httpd_req_t *r)`  
Handler to call for supported request method. This must return ESP_OK, or else the underlying socket will be closed.

`void *user_ctx`  
Pointer to user context data which will be available to handler

**Macros**

`HTTPD_MAX_REQ_HDR_LEN`  
HTTPD_MAX_URI_LEN

`HTTPD_SOCK_ERR_FAIL`  
HTTPD_SOCK_ERR_INVALID

`HTTPD_SOCK_ERR_TIMEOUT`

`HTTPD_200`  
HTTP Response 200

`HTTPD_204`  
HTTP Response 204

`HTTPD_207`  
HTTP Response 207

`HTTPD_400`  
HTTP Response 400

`HTTPD_404`  
HTTP Response 404

`HTTPD_408`  
HTTP Response 408
HTTPD_500
HTTP Response 500

HTTPD_TYPE_JSON
HTTP Content type JSON

HTTPD_TYPE_TEXT
HTTP Content type text/HTML

HTTPD_TYPE_OCTET
HTTP Content type octet-stream

HTTPD_DEFAULT_CONFIG()

ESP_ERR_HTTPD_BASE
Starting number of HTTPD error codes

ESP_ERR_HTTPD_HANDLERS_FULL
All slots for registering URI handlers have been consumed

ESP_ERR_HTTPD_HANDLER_EXISTS
URI handler with same method and target URI already registered

ESP_ERR_HTTPD_INVALID_REQ
Invalid request pointer

ESP_ERR_HTTPD_RESULT_TRUNC
Result string truncated

ESP_ERR_HTTPD_RESP_HDR
Response header field larger than supported

ESP_ERR_HTTPD_RESP_SEND
Error occurred while sending response packet

ESP_ERR_HTTPD_ALLOC_MEM
Failed to dynamically allocate memory for resource

ESP_ERR_HTTPD_TASK
Failed to launch server task/thread

HTTPD_RESP_USE_STRLEN

Type Definitions
typedef struct httpd_req httpd_req_t
HTTP Request Data Structure.

typedef struct httpd_uri httpd_uri_t
Structure for URI handler.

typedef int (*httpd_send_func_t) (httpd_handle_t hd, int sockfd, const char *buf, size_t buf_len,
int flags)
Prototype for HTTPDs low-level send function.

Note User specified send function must handle errors internally, depending upon the set value of errno,
and return specific HTTPD_SOCK_ERR_ codes, which will eventually be conveyed as return value
of httpd_send() function

Return
- Bytes : The number of bytes sent successfully
- HTTPD_SOCK_ERR_INVALID : Invalid arguments
- HTTPD_SOCK_ERR_TIMEOUT : Timeout/interrupted while calling socket send()
- HTTPD_SOCK_ERR_FAIL : Unrecoverable error while calling socket send()

Parameters
- [in] hd: server instance
- [in] sockfd: session socket file descriptor
- [in] buf: buffer with bytes to send
- [in] buf_len: data size
• [in] flags: flags for the send() function

typedef int (*httpd_recv_func_t)(httpd_handle_t hd, int sockfd, char *buf, size_t buf_len, int flags)
Prototype for HTTPDs low-level recv function.

Note User specified recv function must handle errors internally, depending upon the set value of errno, and return specific HTTPD_SOCK_ERR_ codes, which will eventually be conveyed as return value of httpd_req_recv() function

Return
• Bytes : The number of bytes received successfully
• 0 : Buffer length parameter is zero / connection closed by peer
• HTTPD_SOCK_ERR_INVALID : Invalid arguments
• HTTPD_SOCK_ERR_TIMEOUT : Timeout/interrupted while calling socket recv()
• HTTPD_SOCK_ERR_FAIL : Unrecoverable error while calling socket recv()

Parameters
• [in] hd: server instance
• [in] sockfd: session socket file descriptor
• [in] buf: buffer with bytes to send
• [in] buf_len: data size
• [in] flags: flags for the send() function

typedef int (*httpd_pending_func_t)(httpd_handle_t hd, int sockfd)
Prototype for HTTPDs low-level “get pending bytes” function.

Note User specified pending function must handle errors internally, depending upon the set value of errno, and return specific HTTPD_SOCK_ERR_ codes, which will be handled accordingly in the server task.

Return
• Bytes : The number of bytes waiting to be received
• HTTPD_SOCK_ERR_INVALID : Invalid arguments
• HTTPD_SOCK_ERR_TIMEOUT : Timeout/interrupted while calling socket pending()
• HTTPD_SOCK_ERR_FAIL : Unrecoverable error while calling socket pending()

Parameters
• [in] hd: server instance
• [in] sockfd: session socket file descriptor

typedef esp_err_t (*httpd_err_handler_func_t)(httpd_req_t *req, httpd_err_code_t error)
Function prototype for HTTP error handling.

This function is executed upon HTTP errors generated during internal processing of an HTTP request. This is used to override the default behavior on error, which is to send HTTP error response and close the underlying socket.

Note
• If implemented, the server will not automatically send out HTTP error response codes, therefore, httpdRespSendErr() 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 parameter is not guaranteed as the HTTP request may be partially received/parsed.
• The function must return ESP_OK if underlying socket needs to be kept open. Any other value will ensure that the socket is closed. The return value is ignored when error is of type HTTPD_500_INTERNAL_SERVER_ERROR and the socket closed anyway.

Return
• ESP_OK : error handled successful
• ESP_FAIL : failure indicates that the underlying socket needs to be closed

Parameters
• [in] req: HTTP request for which the error needs to be handled
• [in] error: Error type

typedef void *httpd_handle_t
HTTP Server Instance Handle.

Every instance of the server will have a unique handle.
Chapter 2. API

typedef enum http_method httpd_method_t
HTTP Method Type wrapper over “enum http_method” available in “http_parser” library.

typedef void (*httpd_free_ctx_fn_t)(void *ctx)
Prototype for freeing context data (if any)

Parameters
• [in] ctx: object to free

typedef esp_err_t(*httpd_open_func_t)(httpd_handle_t hd, int sockfd)
Function prototype for opening a session.

Called immediately after the socket was opened to set up the send/recv functions and other parameters of the socket.

Return
• ESP_OK: On success
• Any value other than ESP_OK will signal the server to close the socket immediately

Parameters
• [in] hd: server instance
• [in] sockfd: session socket file descriptor

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

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)

typedef struct httpd_config httpd_config_t
HTTP Server Configuration Structure.

Note Use HTTPD_DEFAULT_CONFIG() to initialize the configuration to a default value and then modify only those fields that are specifically determined by the use case.

typedef void (*httpd_work_fn_t)(void *arg)
Prototype of the HTTPD work function Please refer to httpd_queue_work() for more details.

Parameters
• [in] arg: The arguments for this work function

Enumerations
typedef 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
Chapter 2. API

HTTPD_400_BAD_REQUEST
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

2.4.6 HTTPS server

Overview

This component is built on top of esp_http_server. The HTTPS server takes advantage of hooks and function overrides in the regular HTTP server to provide encryption using OpenSSL.

All documentation for esp_http_server applies also to a server you create this way.

Used APIs

The following API of esp_http_server should not be used with esp_https_server, as they are used internally to handle secure sessions and to maintain internal state:

- “send”, “receive” and “pending” function overrides - secure socket handling
  - httpd_sess_set_send_override()
  - httpd_sess_set_recv_override()
  - httpd_sess_set_pending_override()

- “transport context” - both global and session
  - httpd_sess_get_transport_ctx() - returns SSL used for the session
  - httpd_sess_set_transport_ctx()
  - httpd_get_global_transport_ctx() - returns the shared SSL context
  - httpd_config_t.global_transport_ctx
  - httpd_config_t.global_transport_ctx_free_fn
  - httpd_config_t.open_fn - used to set up secure sockets

Everything else can be used without limitations.

Usage

Please see the example protocols/https_server to learn how to set up a secure server.

Basically all you need is to generate a certificate, embed it in the firmware, and provide its pointers and lengths to the start function via the init struct.

The server can be started with or without SSL by changing a flag in the init struct - httpd_ssl_config.transport_mode. This could be used e.g. for testing or in trusted environments where you prefer speed over security.

Performance

The initial session setup can take about two seconds, or more with slower clock speeds or more verbose logging. Subsequent requests through the open secure socket are much faster (down to under 100 ms).
Chapter 2. API

API Reference

Header File

- 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 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 would 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

```c
size_t client_verify_cert_len
```

Client verify authority cert len

```c
const uint8_t *prvtkey_pem
```

Private key

```c
size_t prvtkey_len
```

Private key byte length

```c
httpd_ssl_transport_mode_t transport_mode
```

Transport Mode (default secure)

```c
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)

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 ~40k BRAM 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 httpd_ssl_config httpd_ssl_config_t

Enumerations
enum httpd_ssl_transport_mode_t
Values:
HTTPD_SSL_TRANSPORT_SECURE
HTTPD_SSL_TRANSPORT_INSECURE

2.4.7 ICMP Echo

Overview

ICMP (Internet Control Message Protocol) is used for diagnostic or control purposes or generated in response to errors in IP operations. The common network util ping is implemented based on the ICMP packets with the type field value of 0, also called Echo Reply.

During a ping session, the source host firstly sends out an ICMP echo request packet and wait for an ICMP echo reply with specific times. In this way, it also measures the round-trip time for the messages. After receiving a valid ICMP echo reply, the source host will generate statistics about the IP link layer (e.g. packet loss, elapsed time, etc).

It is common that IoT device needs to check whether a remote server is alive or not. The device should show the warnings to users when it got offline. It can be achieved by creating a ping session and sending/parsing ICMP echo packets periodically.

To make this internal procedure much easier for users, ESP-IDF provides some out-of-box APIs.

Create a new ping session To create a ping session, you need to fill in the esp_ping_config_t configuration structure firstly, specifying target IP address, interval times, and etc. Optionally, you can also register some callback functions with the esp_ping_callbacks_t structure.

Example method to create a new ping session and register callbacks:

```c
static void test_on_ping_success(esp_ping_handle_t hdl, void *args)
{
    // optionally, get callback arguments
    uint8_t ttl;
    uint16_t seqno;
    uint32_t elapsed_time, recv_len;
```
Chapter 2. API Reference

```c
ip_addr_t target_addr;

esp_ping_get_profile(hdl, ESP_PING_PROF_SEQNO, &seqno, sizeof(seqno));
esp_ping_get_profile(hdl, ESP_PING_PROF_TTL, &ttl, sizeof(ttl));
esp_ping_get_profile(hdl, ESP_PING_PROF_IPADDR, &target_addr, sizeof(target_addr));
esp_ping_get_profile(hdl, ESP_PING_PROF_SIZE, &recv_len, sizeof(recv_len));
esp_ping_get_profile(hdl, ESP_PING_PROF_TIMEGAP, &elapsed_time, sizeof(elapsed_time));
printf("%d bytes from %s icmp_seq=%d ttl=%d time=%d ms\n", recv_len, inet_ntoa(target_addr.u_addr.ip4), seqno, ttl, elapsed_time);
}

static void test_on_ping_timeout(esp_ping_handle_t hdl, void *args)
{
    uint16_t seqno;
    ip_addr_t target_addr;
    esp_ping_get_profile(hdl, ESP_PING_PROF_SEQNO, &seqno, sizeof(seqno));
    esp_ping_get_profile(hdl, ESP_PING_PROF_IPADDR, &target_addr, sizeof(target_addr));
    printf("From %s icmp_seq=%d timeout\n", inet_ntoa(target_addr.u_addr.ip4), seqno);
}

static void test_on_ping_end(esp_ping_handle_t hdl, void *args)
{
    uint32_t transmitted;
    uint32_t received;
    uint32_t total_time_ms;
    esp_ping_get_profile(hdl, ESP_PING_PROF_REQUEST, &transmitted, sizeof(transmitted));
    esp_ping_get_profile(hdl, ESP_PING_PROF_REPLY, &received, sizeof(received));
    esp_ping_get_profile(hdl, ESP_PING_PROF_DURATION, &total_time_ms, sizeof(total_time_ms));
    printf("%d packets transmitted, %d received, time %dms\n", transmitted, received, total_time_ms);
}

void initialize_ping()
{
    /* convert URL to IP address */
    ip_addr_t target_addr;
    struct addrinfo hint;
    struct addrinfo *res = NULL;
    memset(&hint, 0, sizeof(hint));
    memset(&target_addr, 0, sizeof(target_addr));
    getaddrinfo("www.espressif.com", NULL, &hint, &res) == 0);
    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;
```

(未完)
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 recounts 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

- `lwip/include/apps/ping/ping_sock.h`

Functions

### `esp_err_t esp_ping_new_session(const esp_ping_config_t *config, const esp_ping_callbacks_t *cbs, esp_ping_handle_t *hdl_out)`

Create a ping session.

**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

### `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

### `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

\texttt{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

\texttt{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

\texttt{struct esp_ping_callbacks_t} 
Type of “ping” callback functions.

Public Members

void *\texttt{cb_args}
arguments for callback functions

void (*\texttt{on_ping_success}(esp_ping_handle_t hdl, void *args))
Invoked by internal ping thread when received ICMP echo reply packet.

void (*\texttt{on_ping_timeout}(esp_ping_handle_t hdl, void *args))
Invoked by internal ping thread when receive ICMP echo reply packet timeout.

void (*\texttt{on_ping_end}(esp_ping_handle_t hdl, void *args))
Invoked by internal ping thread when a ping session is finished.

\texttt{struct esp_ping_config_t} 
Type of “ping” configuration.

Public Members

uint32_t \texttt{count}
A “ping” session contains count procedures

uint32_t \texttt{interval_ms}
Milliseconds between each ping procedure

uint32_t \texttt{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

Macros
ESP_PING_DEFAULT_CONFIG()
    Default ping configuration.

ESP_PING_COUNT_INFINITE
    Set ping count to zero will ping target infinitely

Type Definitions
typedef void *esp_ping_handle_t
    Type of “ping” session handle.

Enumerations
enum esp_ping_profile_t
    Profile of ping session.
    Values:
    ESP_PING_PROF_SEQNO
        Sequence number of a ping procedure
    ESP_PING_PROF_TTL
        Time to live of a ping procedure
    ESP_PING_PROF_REQUEST
        Number of request packets sent out
    ESP_PING_PROF_REPLY
        Number of reply packets received
    ESP_PING_PROF_IPADDR
        IP address of replied target
    ESP_PING_PROF_SIZE
        Size of received packet
    ESP_PING_PROF_TIMEGAP
        Elapsed time between request and reply packet
    ESP_PING_PROF_DURATION
        Elapsed time of the whole ping session

2.4.8 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/chat_client
• protocols/asio/chat_server
• protocols/asio/ssl_client_server

Please refer to the specific example README.md for details

2.4.9 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
Chapter 2. API

Configuration

URI

- Currently support mqtt, mqtts, ws, wss schemes
- MQTT over TCP samples:
  - mqtt://mqtt.eclipse.org: MQTT over TCP, default port 1883:
  - mqtt://mqtt.eclipse.org:1884 MQTT over TCP, port 1884:
  - mqtt://username:password@mqtt.eclipse.org:1884 MQTT over TCP, port 1884, with username and password
- MQTT over SSL samples:
  - mqtts://mqtt.eclipse.org: MQTT over SSL, port 8883
  - mqtts://mqtt.eclipse.org:8884: MQTT over SSL, port 8884
- MQTT over Websocket samples:
  - ws://mqtt.eclipse.org:80/mqtt
- MQTT over Websocket Secure samples:
  - wss://mqtt.eclipse.org:443/mqtt
- Minimal configurations:

```c
const esp_mqtt_client_config_t mqtt_cfg = {
    .uri = "mqtt://mqtt.eclipse.org",
    .user_context = (void *)your_context
};
esp_mqtt_client_handle_t client = esp_mqtt_client_init(&mqtt_cfg);
esp_mqtt_client_register_event(client, ESP_EVENT_ANY_ID, mqtt_event_handler,
    client);
esp_mqtt_client_start(client);
```

- Note: By default mqtt client uses event loop library to post related mqtt events (connected, subscribed, published, etc.)

SSL

- Get certificate from server, example: mqtt.eclipse.org openssl s_client -showcerts
  -connect mqtt.eclipse.org: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.eclipse.org:8883",
    .event_handle = mqtt_event_handler,
    .cert_pem = (const char *)mqtt_eclipse_org_pem_start,
};
```

If the certificate is not null-terminated then cert_len should also be set. Other SSL related configuration parameters are:

- use_global_ca_store: use the global certificate store to verify server certificate, see esp-tls.h for more information
- client_cert_pem: pointer to certificate data in PEM or DER format for SSL mutual authentication, default is NULL, not required if mutual authentication is not needed.
- client_cert_len: length of the buffer pointed to by client_cert_pem. May be 0 for null-terminated pem.
- client_key_pem: pointer to private key data in PEM or DER format for SSL mutual authentication, default is NULL, not required if mutual authentication is not needed.
- client_key_len: length of the buffer pointed to by client_key_pem. May be 0 for null-terminated pem.
- psk_hint_key: pointer to PSK struct defined in esp_tls.h to enable PSK authentication (as alternative to certificate verification). If not NULL and server/client certificates are NULL, PSK is enabled
- alpn_protos: NULL-terminated list of protocols to be used for ALPN.
Last Will and Testament  MQTT allows for a last will and testament (LWT) message to notify other clients when a client ungracefully disconnects. This is configured by the following fields in the `esp_mqtt_client_config_t` struct.

- `lwt_topic`: pointer to the LWT message topic
- `lwt_msg`: pointer to the LWT message
- `lwt_msg_len`: length of the LWT message, required if `lwt_msg` is not null-terminated
- `lwt_qos`: quality of service for the LWT message
- `lwt_retain`: specifies the retain flag of the LWT message

Other Configuration Parameters

- `disable_clean_session`: determines the clean session flag for the connect message, defaults to a clean session
- `keepalive`: determines how many seconds the client will wait for a ping response before disconnecting, default is 120 seconds.
- `disable_auto_reconnect`: enable to stop the client from reconnecting to server after errors or disconnects
- `user_context`: custom context that will be passed to the event handler
- `task_prio`: MQTT task priority, defaults to 5
- `task_stack`: MQTT task stack size, defaults to 6144 bytes, setting this will override setting from menu-config
- `buffer_size`: size of MQTT send/receive buffer, default is 1024 bytes
- `username`: pointer to the username used for connecting to the broker
- `password`: pointer to the password used for connecting to the broker
- `client_id`: pointer to the client id, defaults to `ESP32_%CHIPID%` where `%CHIPID%` are the last 3 bytes of MAC address in hex format
- `host`: MQTT broker domain (ipv4 as string), setting the uri will override this
- `port`: MQTT broker port, specifying the port in the uri will override this
- `transport`: sets the transport protocol, setting the uri will override this
- `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 menuconfig`, under Component config -> ESP-MQTT Configuration

The following settings are available:

- `CONFIG_MQTT_PROTOCOL_311`: Enables 3.1.1 version of MQTT protocol
- `CONFIG_MQTT_TRANSPORT_SSL, CONFIG_MQTT_TRANSPORT_WEBSOCKET`: Enables specific MQTT transport layer, such as SSL, WEBSOCKET, WEBSOCKET_SECURE
- `CONFIG_MQTT_CUSTOM_OUTBOX`: Disables default implementation of `mqtt_outbox`, so a specific implementation can be supplied

Events

The following events may be posted by the MQTT client:

- `MQTT_EVENT_BEFORE_CONNECT`: The client is initialized and about to start connecting to the broker.
- `MQTT_EVENT_CONNECTED`: The client has successfully established a connection to the broker. The client is now ready to send and receive data.
- `MQTT_EVENT_DISCONNECTED`: The client has aborted the connection due to being unable to read or write data, e.g., because the server is unavailable.
- `MQTT_EVENT_SUBSCRIBED`: The broker has acknowledged the client’s subscribe request. The event data will contain the message ID of the subscribe message.
• **MQTT_EVENT_UNSUBSCRIBED**: The broker has acknowledged the client’s unsubscribe request. The event data will contain the message ID of the unsubscribe message.

• **MQTT_EVENT_PUBLISHED**: The broker has acknowledged the client’s publish message. This will only be posted for Quality of Service level 1 and 2, as level 0 does not use acknowledgements. The event data will contain the message ID of the publish message.

• **MQTT_EVENT_DATA**: The client has received a publish message. The event data contains: message ID, name of the topic it was published to, received data and its length. For data that exceeds the internal buffer multiple `MQTT_EVENT_DATA` will be posted and `current_data_offset` and `total_data_len` from event data updated to keep track of the fragmented message.

• **MQTT_EVENT_ERROR**: The client has encountered an error. `esp_mqtt_error_type_t` from `error_handle` in the event data can be used to further determine the type of the error. The type of error will determine which parts of the `error_handle` struct is filled.

### API Reference

#### Header File

- `mqtt.esp-mqtt/include/mqtt_client.h`

#### Functions

`esp_mqtt_client_handle_t esp_mqtt_client_init(const esp_mqtt_client_config_t *config)`

Creates `mqtt_client_handle` based on the configuration.

- **Return**: `mqtt_client_handle` if successfully created, `NULL` on error
- **Parameters**
  - `config`: `mqtt` configuration structure

`esp_err_t esp_mqtt_client_set_uri(esp_mqtt_client_handle_t client, const char *uri)`

Sets `mqtt` connection URI. This API is usually used to overrides the URI configured in `esp_mqtt_client_init`.

- **Return**: `ESP_FAIL` if URI parse error, `ESP_OK` on success
- **Parameters**
  - `client`: `mqtt` client handle
  - `uri`:

`esp_err_t esp_mqtt_client_start(esp_mqtt_client_handle_t client)`

Starts `mqtt` client with already created client handle.

- **Return**: `ESP_OK` on success `ESP_ERR_INVALID_ARG` on wrong initialization `ESP_FAIL` on other error
- **Parameters**
  - `client`: `mqtt` client handle

`esp_err_t esp_mqtt_client_reconnect(esp_mqtt_client_handle_t client)`

This api is typically used to force reconnection upon a specific event.

- **Return**: `ESP_OK` on success `ESP_FAIL` if client is in invalid state
- **Parameters**
  - `client`: `mqtt` client handle

`esp_err_t esp_mqtt_client_disconnect(esp_mqtt_client_handle_t client)`

This api is typically used to force disconnection from the broker.

- **Return**: `ESP_OK` on success
- **Parameters**
  - `client`: `mqtt` client handle

`esp_err_t esp_mqtt_client_stop(esp_mqtt_client_handle_t client)`

 Stops `mqtt` client tasks.

  - **Notes:**
  - Cannot be called from the `mqtt` event handler

- **Return**: `ESP_OK` on success `ESP_FAIL` if client is in invalid state
- **Parameters**
**Chapter 2. API**

- **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 to send publish message (although it would drop all qos=0 messages, qos>1 messages would be enqueued)
- 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

**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

**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_OK on success

**Parameters**
- `client`: mqtt client handle
- `config`: mqtt configuration structure

```c
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_OK on success

**Parameters**
- `client`: mqtt client handle
- `event`: event type
- `event_handler`: handler callback
- `event_handler_arg`: handlers context

### Structures

**struct esp_mqtt_error_codes**

MQTT error code structure to be passed as a contextual information into ERROR event.

Important: This structure extends `esp_tls_last_error` error structure and is backward compatible with it (so might be down-casted and treated as `esp_tls_last_error` error, but recommended to update applications if used this way previously)

Use this structure directly checking error_type first and then appropriate error code depending on the source of the error:

<table>
<thead>
<tr>
<th>error_type</th>
<th>related member variables</th>
<th>note</th>
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<td>connect_return_code</td>
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</tbody>
</table>

**Public Members**

```c
esp_err_t esp_tls_last_test
```

Last esp_err code reported from esp-tls component

```c
int esp_tls_stack_err
```

Tls specific error code reported from underlying tls stack

```c
int esp_tls_cert_verify_flags
```

Tls flags reported from underlying tls stack during certificate verification

```c
esp_mqtt_error_type_t error_type
```

Error type referring to the source of the error

```c
esp_mqtt_connect_return_code_t connect_return_code
```

Connection refused error code reported from MQTT broker on connection

**struct esp_mqtt_event_t**

MQTT event configuration structure

**Public Members**

```c
esp_mqtt_event_id_t event_id
```

MQTT event type

```c
esp_mqtt_client_handle_t client
```

MQTT client handle for this event

```c
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

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

const char *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.

int reconnect_timeout_ms
Reconnect to the broker after this value in miliseconds if auto reconnect is not disabled
**const char** **alpn_protos**
NULL-terminated list of supported application protocols to be used for ALPN

**const char** **clientkey_password**
Client key decryption password string

**int** **clientkey_password_len**
String length of the password pointed to by clientkey_password

**esp_mqtt_protocol_ver_t** **protocol_ver**
MQTT protocol version used for connection, defaults to value from menuconfig

**int** **out_buffer_size**
size of MQTT output buffer. If not defined, both output and input buffers have the same size defined as buffer_size

**bool** **skip_cert_common_name_check**
Skip any validation of server certificate CN field, this reduces the security of TLS and makes the mqtt client susceptible to MITM attacks

**bool** **use_secure_element**
enable secure element for enabling SSL connection

**void** **ds_data**
carrier of handle for digital signature parameters

### Type Definitions

**typedef struct esp_mqtt_client** *esp_mqtt_client_handle_t
MQTT client handle type

**typedef struct esp_mqtt_error_codes** *esp_mqtt_error_codes_t
MQTT error code structure to be passed as a contextual information into ERROR event.

Important: This structure extends esp_tls_last_error error structure and is backward compatible with it (so might be down-casted and treated as esp_tls_last_error error, but recommended to update applications if used this way previously)

Use this structure directly checking error_type first and then appropriate error code depending on the source of the error:

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**typedef esp_mqtt_event_t** *esp_mqtt_event_handle_t

**typedef esp_err_t** (*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:**

**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

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 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

enum esp_mqtt_connect_return_code_t
MQTT connection error codes propagated via ERROR event

Values:
MQTT_CONNECTION_ACCEPTED = 0
Connection accepted

MQTT_CONNECTION_REFUSE_PROTOCOL
MQTT connection refused reason: Wrong protocol

MQTT_CONNECTION_REFUSE_ID_REJECTED
MQTT connection refused reason: ID rejected

MQTT_CONNECTION_REFUSE_SERVER_UNAVAILABLE
MQTT connection refused reason: Server unavailable

MQTT_CONNECTION_REFUSE_BAD_USERNAME
MQTT connection refused reason: Wrong user

MQTT_CONNECTION_REFUSE_NOT_AUTHORIZED
MQTT connection refused reason: Wrong username or password

enum esp_mqtt_error_type_t
MQTT connection error codes propagated via ERROR event

Values:
MQTT_ERROR_TYPE_NONE = 0

MQTT_ERROR_TYPE_ESP_TLS

MQTT_ERROR_TYPE_CONNECTION_REFUSED

enum esp_mqtt_transport_t
Values:
MQTT_TRANSPORT_UNKNOWN = 0x0

MQTT_TRANSPORT_OVER_TCP
MQTT over TCP, using scheme: mqtt
MQTT_TRANSPORT_OVER_SSL
MQTT over SSL, using scheme: mqtts

MQTT_TRANSPORT_OVER_WS
MQTT over Websocket, using scheme:: ws

MQTT_TRANSPORT_OVER_WSS
MQTT over Websocket Secure, using scheme: wss

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

2.4.10 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.

Modbus port specific API overview ESP-IDF supports Modbus Serial/TCP slave and master protocol stacks (port) and provides Modbus controller interface API to interact with user application.

The functions below are used to create and then initialize actual Modbus controller interface for Serial/TCP port accordingly:

```c
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
Chapter 2. API 参考

```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
- ESP_ERR_INVALID_STATE Initialization failure

**Parameters**
- [out] handler: handler(pointer) to master data structure
- [in] port_type: type of stack

```c
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

```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

**Modbus common interface API overview**
The function initializes the Modbus controller interface and its active context (tasks, RTOS objects and other resources).

```c
esp_err_t mbc_slave_setup(void *comm_info)
Set Modbus communication parameters for the controller.
```

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Incorrect parameter data

**Parameters**
- comm_info: Communication parameters structure.

```c
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.

The function is used to setup communication parameters of the Modbus stack. See the Modbus controller API documentation for more information. Note: The communication structure provided as a parameter is different for serial and TCP communication mode.

`mbc_slave_set_descriptor()`: Initialization of slave descriptor.

`mbc_master_set_descriptor()`: Initialization of master descriptor.
The Modbus stack uses parameter description tables (descriptors) for communication. These are different for master and slave implementation of stack and should be assigned by the API call before start of communication.

```c
esp_err_t mbc_slave_start (void)
Start Modbus communication stack.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Modbus stack start error
```

```c
esp_err_t mbc_master_start (void)
Start Modbus communication stack.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Modbus stack start error
```

Modbus controller start function. Starts stack and interface and allows communication.

```c
esp_err_t mbc_slave_destroy (void)
Destroy Modbus controller and stack.

Return
• ESP_OK Success
• ESP_ERR_INVALID_STATE Parameter error
```

```c
esp_err_t mbc_master_destroy (void)
Destroy Modbus controller and stack.

Return
• ESP_OK Success
• ESP_ERR_INVALID_STATE Parameter error
```

This function stops Modbus communication stack and destroys controller interface.

There are some configurable parameters of modbus_controller interface and Modbus stack that can be configured using KConfig values in “Modbus configuration” menu. The most important option in KConfig menu is “Enable Modbus stack support ...” for appropriate communication mode that allows to select master or slave stack for implementation. See the examples for more information about how to use these API functions.

**Modbus slave interface API overview** The slave stack requires the user defined structures which represent Modbus parameters accessed by stack. These structures should be prepared by user and be assigned to the modbus_controller interface using `mbc_slave_set_descriptor()` API call before start of communication. The interface API functions below are used for Modbus slave application:

```c
esp_err_t mbc_slave_set_descriptor (mb_register_area_descriptor_t descr_data)
Set Modbus area descriptor.

Return
• ESP_OK: The appropriate descriptor is set
• ESP_ERR_INVALID_ARG: The argument is incorrect

Parameters
• descr_data: Modbus registers area descriptor structure
```

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. See the `mb_register_area_descriptor_t` and example for more information.

```c
mb_event_group_t mbc_slave_check_event (mb_event_group_t group)
Wait for specific event on parameter change.

Return
• mb_event_group_t event bits triggered

Parameters
```

Submit Document Feedback
Chapter 2. API

- **group**: Group event bit mask to wait for change

The blocking call to function waits for event specified in the input parameter as event mask. Once master access the parameter and event mask matches the parameter the application task will be unblocked and function will return ESP_OK. See the `mb_event_group_t` for more information about Modbus event masks.

```c
esp_err_t mbc_slave_get_param_info(mb_param_info_t *reg_info, uint32_t timeout)
```

Get parameter information.

**Return**

- ESP_OK Success
- ESP_ERR_TIMEOUT Can not get data from parameter queue or queue overflow

**Parameters**

- [out] reg_info: parameter info structure
- timeout: Timeout in milliseconds to read information from parameter queue

The function gets information about accessed parameters from 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 to specify timeout for waiting notification. The `mb_param_info_t` structure contain information about accessed parameter.

**Modbus master interface API overview**

The Modbus master implementation requires parameter description table be defined before start of stack. This table describes characteristics (physical parameters like temperature, humidity, etc.) and links them to Modbus registers in specific slave device in the Modbus segment. The table has to be assigned to the modbus_controller interface using `mbc_master_set_descriptor()` API call before start of communication.

Below are the interface API functions that are used to setup and use Modbus master stack from user application and can be executed in next order:

```c
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

Assigns parameter description table for Modbus controller interface. The table has to be prepared by user according to particular implementation. Note: TCP communication stack requires to setup additional information about modbus slaves that corresponds to each address(index) used in description table. This information with IP addresses of the slaves is assigned using communication structure and interface setup call.

```c
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)
This function sends data request as defined in parameter request, waits response from corresponded slave and returns status of command execution. This function provides a standard way for read/write access to Modbus devices in the network.

```c
esp_err_t mbc_master_get_cid_info(uint16_t cid, const mb_parameter_descriptor_t **param_info)
```

Get information about supported characteristic defined as cid. Uses parameter description table to get this information. The function will check if characteristic defined as a cid parameter is supported and returns its description in param_info. Returns ESP_ERR_NOT_FOUND if characteristic is not supported.

**Return**
- esp_err_t ESP_OK - request was successful and buffer contains the supported characteristic name
- esp_err_t ESP_ERR_INVALID_ARG - invalid argument of function
- esp_err_t ESP_ERR_NOT_FOUND - the characteristic (cid) not found
- esp_err_t ESP_FAIL - unknown error during lookup table processing

**Parameters**
- [in] cid: characteristic id
- param_info: pointer to pointer of characteristic data.

The function gets information about supported characteristic defined as cid. It will check if characteristic is supported and returns its description.

```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
- 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.

The function reads data of characteristic defined in parameters from Modbus slave device and returns its data. The additional data for request is taken 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
- 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.

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.

**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.

```plaintext
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.

### 2.4.11 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
            }
        },
        .handlers = {  
            /* User defined handler functions */
            .get_prop_values = get_property_values,  
            .set_prop_values = set_property_values,  
            .usr_ctx = NULL,  
            .usr_ctx_free_fn = NULL
        },
        /* Maximum number of properties that may be set */
        .max_properties = 10
    }
};
/* Start esp_local_ctrl service */
ESP_ERROR_CHECK(esp_local_ctrl_start(&config));
```

Similarly for HTTPS transport:
/* Set the configuration */
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
    },
    .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));

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.

/* 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,
};
Also notice that there is a ctx field, which is set to point to some custom `func_get_time()`. This can be used inside the property get/set handlers to retrieve timestamp.

Here is an example of `get_prop_values()` handler, which is used for retrieving the timestamp.

```c
static esp_err_t get_property_values(size_t props_count, const esp_local_ctrl_prop_t *props, esp_local_ctrl_prop_val_t *prop_values, void *usr_ctx)
{
    for (uint32_t i = 0; i < props_count; i++) {
        ESP_LOGI(TAG, "Reading %s", props[i].name);
        if (props[i].type == TYPE_TIMESTAMP) {
            /* Obtain the timer function from ctx */
            int32_t (*func_get_time)(void) = props[i].ctx;
            /* Use static variable for saving the value. 
               * This is essential because the value has to be 
               * valid even after this function returns. 
               * Alternative is to use dynamic allocation 
               * and set the free_fn field */
            static int32_t ts = func_get_time();
            prop_values[i].data = &ts;
        }
    }
    return ESP_OK;
}
```

Here is an example of `set_prop_values()` handler. Notice how we restrict from writing to read-only properties.

```c
static esp_err_t set_property_values(size_t props_count, const esp_local_ctrl_prop_t *props, const esp_local_ctrl_prop_val_t *prop_values, void *usr_ctx)
{
    for (uint32_t i = 0; i < props_count; i++) {
        if (props[i].flags & READONLY) {
            ESP_LOGE(TAG, "Cannot write to read-only property %s", props[i].name);
            return ESP_ERR_INVALID_ARG;
        }
        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 established 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>http://&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>http://&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

- 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 could 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_reg_handler_t handler, void *user_ctx)**

Register protocomm handler for a custom endpoint.

This API can be called by the application to register a protocomm handler for an endpoint after the local control service has started.

**Note** In case of BLE transport the names and uuids of all custom endpoints must be provided beforehand as a part of the `protocomm_ble_config_t` structure set in `esp_local_ctrl_config_t`, and passed to `esp_local_ctrl_start()`.

**Return**
- ESP_OK: Success
- ESP_FAIL: Failure

**Parameters**
- `[in]` ep_name: Name of the endpoint
- `[in]` handler: Endpoint handler function
- `[in]` user_ctx: User data

**Unions**

```c
union esp_local_ctrl_transport_config_t
    #include <esp_local_ctrl.h> Transport mode (BLE / HTTPD) configuration.
```

**Public Members**

```c
esp_local_ctrl_transport_config_ble_t *ble
```

This is same as `protocomm_ble_config_t`. See `protocomm_ble.h` for available configuration parameters.


*esp_local_ctrl_transport_config_httpd_t* `httpd`

This is same as `httpd_ssl_config_t`. See `esp_https_server.h` for available configuration parameters.

**Structures**

**struct esp_local_ctrl_prop**

Property description data structure, which is to be populated and passed to the `esp_local_ctrl_add_property()` function.

Once a property is added, its structure is available for read-only access inside `get_prop_values()` and `set_prop_values()` handlers.

**Public Members**

char *`name`

Unique name of property

uint32_t `type`

Type of property. This may be set to application defined enums

size_t `size`

Size of the property value, which:

- if zero, the property can have values of variable size
- if non-zero, the property can have values of fixed size only, therefore, checks are performed internally by `esp_local_ctrl` when setting the value of such a property

uint32_t `flags`

Flags set for this property. This could be a bit field. A flag may indicate property behavior, e.g. read-only / constant

void *`ctx`

Pointer to some context data relevant for this property. This will be available for use inside the `get_prop_values()` and `set_prop_values()` handlers as a part of this property structure. When set, this is valid throughout the lifetime of a property, till either the property is removed or the `esp_local_ctrl` service is stopped.

void (*`ctx_free_fn`) (void *`ctx`)

Function used by `esp_local_ctrl` to internally free the property context when `esp_local_ctrl_remove_property()` or `esp_local_ctrl_stop()` is called.

**struct esp_local_ctrl_prop_val**

Property value data structure. This gets passed to the `get_prop_values()` and `set_prop_values()` handlers for the purpose of retrieving or setting the present value of a property.

**Public Members**

void *`data`

Pointer to memory holding property value

size_t `size`

Size of property value

void (*`free_fn`) (void *`data`)

This may be set by the application in `get_prop_values()` handler to tell `esp_local_ctrl` to call this function on the data pointer above, for freeing its resources after sending the `get_prop_values` response.

**struct esp_local_ctrl_handlers**

Handlers for receiving and responding to local control commands for getting and setting properties.
Public Members

```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 `esp_local_ctrl` service, and freed only when the service is stopped.

```c
void (*usr_ctx_free_fn)(void *usr_ctx)
```

Pointer to function which will be internally invoked on `usr_ctx` for freeing the context resources when `esp_local_ctrl_stop()` is called.

```c
struct esp_local_ctrl_config
```

Configuration structure to pass to `esp_local_ctrl_start()`

Public Members

```c
const esp_local_ctrl_transport_t *transport
```

Transport layer over which service will be provided
**esp_local_ctrl_transport_config_t** `transport_config`
Transport layer over which service will be provided

**esp_local_ctrl_handlers_t** `handlers`
Register handlers for responding to get/set requests on properties

**size_t** `max_properties`
This limits the number of properties that are available at a time

### Macros

- `ESP_LOCAL_CTRL_TRANSPORT_BLE`
- `ESP_LOCAL_CTRL_TRANSPORT_HTTPD`

### Type Definitions

**typedef struct esp_local_ctrl_prop esp_local_ctrl_prop_t**
Property description data structure, which is to be populated and passed to the `esp_local_ctrl_add_property()` function.

Once a property is added, its structure is available for read-only access inside `get_prop_values()` and `set_prop_values()` handlers.

**typedef struct esp_local_ctrl_prop_val esp_local_ctrl_prop_val_t**
Property value data structure. This gets passed to the `get_prop_values()` and `set_prop_values()` handlers for the purpose of retrieving or setting the present value of a property.

**typedef struct esp_local_ctrl_handlers esp_local_ctrl_handlers_t**
Handlers for receiving and responding to local control commands for getting and setting properties.

**typedef struct esp_local_ctrl_transport esp_local_ctrl_transport_t**
Transport 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 struct esp_local_ctrl_config esp_local_ctrl_config_t**
Configuration structure to pass to `esp_local_ctrl_start()`

### 2.4.12 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 SDIO Slave peripherals of Espressif chips are different. See the table below:

<table>
<thead>
<tr>
<th>Feature</th>
<th>ESP32</th>
<th>ESP32-S2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDIO slave</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>To host intr</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Fr host intr</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>TX DMA</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>RX DMA</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Shared registers</td>
<td>56*</td>
<td></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  CMD5arg=0x00000000
   CMD5arg=0x00ff8000 (according to the response above, poll until ready)
   Example: Arg of R4 after first CMD5(arg=0x00000000) is 0xFFF000.
   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 0x000100000.
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 Section 8.4 Register summary (table SDIO SLC Host registers) in ESP32 Technical reference manual
- 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.

**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 x buffer_num is greater than the data to write, buffer_size is pre-defined between the host and the slave before the communication starts). Otherwise, keep returning to Step 1 until the buffer size is sufficient.
3. **Write to the FIFO address with CMD53**. Note that the requested length should not exceed the length calculated at Step 2, and the FIFO address is related to requested length.
4. **Calculate used buffers**. Note that a partially used buffer at the tail is counted as used.

Sending FIFO  To read the slave’s sending FIFO, the host should complete the following steps:

1. **Wait for the interrupt line to become active** (optional, low by default).
2. **Read (poll) the interrupt bits in the INT_ST register** to monitor if new packets exist.
3. **If new packets are ready, read the PKT_LEN register**. Before reading the packets, determine the length of data to be read. As the host keeps the length of data already read from the slave, subtract this value from PKT_LEN, the result will be the maximum length of data available for reading. If no data has been added to the sending FIFO yet, wait and poll until the slave is ready and update PKT_LEN.
4. **Read from the FIFO using CMD53**. Note that the requested length should not be greater than calculated at Step 3, and the FIFO address is related to requested length.
5. **Update the read length**.

**ESP SPI Slave HD (Half Duplex) Mode Protocol**

注解：This protocol is only for ESP32-S2. The driver for other chip versions hasn’t be developed yet.

**SPI Slave Capabilities of Espressif chips**

<table>
<thead>
<tr>
<th></th>
<th>ESP32</th>
<th>ESP32-S2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPI Slave HD</td>
<td>N</td>
<td>Y (v2)</td>
</tr>
<tr>
<td>Tohost intr</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Frhost intr</td>
<td>N</td>
<td>2*</td>
</tr>
<tr>
<td>TX DMA</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>RX DMA</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Shared registers</td>
<td>72</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 consists 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 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 turn around 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 master.
- **Data**: variable length, the direction is also determined by the command.
  - This may be a data OUT phase, in which the direction is slave to master, or a data IN phase, in which the direction is master to slave.

The **direction** means which side (master or slave) controls the MOSI, MISO, WP and HD pins.

**Data IO Modes**  In some IO modes, more data wires can be use to send the data. As a result, the SPI clock cycles required for the same amount of data will be less than in 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’s the modes supported by 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 from the QPI mode.

**QPI Mode** The QPI mode is a special state of the SPI Slave. The master can send 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 the QPI mode. To exit form the QPI mode, master can send EXQPI command.

**Supported Commands**

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Command</th>
<th>Address</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRBUF</td>
<td>Write buffer</td>
<td>0x01</td>
<td>Buf addr</td>
<td>master to slave, no longer than buffer size</td>
</tr>
<tr>
<td>RDBUF</td>
<td>Read buffer</td>
<td>0x02</td>
<td>Buf addr</td>
<td>slave to master, no longer than buffer size</td>
</tr>
<tr>
<td>WRDMA</td>
<td>Write DMA</td>
<td>0x03</td>
<td>8 bits</td>
<td>master to slave, no longer than length provided by slave</td>
</tr>
<tr>
<td>RDDMA</td>
<td>Read DMA</td>
<td>0x04</td>
<td>8 bits</td>
<td>slave to master, no longer than length provided by slave</td>
</tr>
<tr>
<td>SEG_DONE</td>
<td>Segments done</td>
<td>0x05</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>ENQPI</td>
<td>Enter QPI mode</td>
<td>0x06</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>WR_DONE</td>
<td>Write segments done</td>
<td>0x07</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>CMD8</td>
<td>Interrupt</td>
<td>0x08</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>CMD9</td>
<td>Interrupt</td>
<td>0x09</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>CMDA</td>
<td>Interrupt</td>
<td>0x0A</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>EXQPI</td>
<td>Exit QPI mode</td>
<td>0xDD</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Moreover, WRBUF, RDBUF, WRDMA, RDDMA commands have their 2-bit and 4-bit version. To do transactions
in 2-bit or 4-bit mode, send the original command ORed by the corresponding command mask below. For example, command 0xA1 means WRBUF in QIO mode.

<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 large buffer as the size of data provided by the slave. After the master finish reading/writing a buffer, it has to send 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 are 512 bytes long, and reads the first 3584 bytes from the slave
3. The master do the last RDDMA transaction of 512 bytes (equal, longer or shorter than the total length loaded by the slave are all allowed). The first 508 bytes are valid data from the slave, while the last 4 bytes are meaningless bytes.
4. The master sends CMD8 to the slave
5. The slave loads another 4092 bytes of data onto the RDDMA
6. The master can start new reading transactions after it sends the CMD8

**Terminology**

- **ESSL**: Abbreviation for ESP Serial Slave Link, the component described by this document.
- **Master**: The device running the `esp_serial_slave_link` component.
- **ESSL device**: a virtual device on the master associated with an ESP slave device. The device context has the knowledge of the slave protocol above the bus, relying on some bus drivers to communicate with the slave.
- **ESSL device handle**: a handle to ESSL device context containing the configuration, status and data required by the ESSL component. The context stores the driver configurations, communication state, data shared by master and slave, etc.

   The context should be initialized before it is used, and get deinitialized if not used any more. The master application operates on the ESSL device through this handle.
- **ESP slave**: the slave device connected to the bus, which ESSL component is designed to communicate with.
- **Bus**: The bus over which the master and the slave communicate with each other.
- **Slave protocol**: The special communication protocol specified by Espressif HW/SW over the bus.
- **TX buffer num**: a counter, which is on the slave and can be read by the master, indicates the accumulated buffer numbers that the slave has loaded to the hardware to receive data from the master.
- **RX data size**: a counter, which is on the slave and can be read by the master, indicates the accumulated data size that the slave has loaded to the hardware to send to the master.

**Services provided by ESP slave**

There are some common services provided by the Espressif slaves:

1. Tohost Interrupts: The slave can inform the master about certain events by the interrupt line. (optional)
2. Frhost Interrupts: The master can inform the slave about certain events.
3. **Tx FIFO (master to slave):** the slave can send data in stream to the master. The SDIO slave can also indicate it has new data to send to master by the interrupt line. The slave updates the TX buffer num to inform the master how much data it can receive, and the master then read the TX buffer num, and take off the used buffer number to know how many buffers are remaining.

4. **Rx FIFO (slave to master):** the slave can receive data from the master in units of receiving buffers. The slave updates the RX data size to inform the master how much data it has prepared to send, and then the master read the data size, and take off the data length it has already received to know how many data is remaining.

5. **Shared registers:** the master can read some part of the registers on the slave, and also write these registers to let the slave read.

The services provided by the slave depends on the slave’s model. See [SDIO Slave Capabilities of Expressif chips](https://www.espressif.com/cn/support/software-sdk-sdkapi-esp32/esp32-sdk-api-reference/storage/sdio) and [SPI Slave Capabilities of Expressif chips](https://www.espressif.com/cn/support/software-sdk-sdkapi-esp32/esp32-sdk-api-reference/storage/spi) 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:

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**

注解：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.

### From 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_dat_size` keeps 0, until timeout.
2. Call `essl_get_packet()` to receive data from the slave.

**Reset counters (Optional)** Call `essl_reset_cnt()` to reset the internal counter if you find the slave has reset its counter.

**Application Example**

The example below shows how ESP32 SDIO host and slave communicate with each other. The host use the ESSL SDIO.

Please refer to the specific example README.md for details.

**API Reference**

**Header File**

- `esp_serial_slave_link/include/esp_serial_slave_link/essl.h`

**Functions**

```c
esp_err_t essl_init (essl_handle_t handle, uint32_t wait_ms)
```

Initialize the slave.

**Parameters**

- `handle`: Handle of a `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 a ESP32 slave device.

**Parameters**

- `handle`: Handle of a `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_num, uint32_t wait_ms)
```

Get buffer num for the host to send data to the slave. The buffers are size of `buffer_size`.

**Parameters**

- `handle`: Handle of a `essl` device.
- `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 amount of data the ESP32 slave preparing to send to host.
Return

• ESP_OK Success
• One of the error codes from SDMMC host controller

Parameters

• handle: Handle of a eSSL device.
• out_rx_size: Output of data size to read from slave.
• wait_ms: Millisecond to wait before timeout, will not wait at all if set to 0-9.

`esp_err_t essl_reset_cnt (essl_handle_t handle)`

Reset the counters of this component. Usually you don’t need to do this unless you know the slave is reset.

Parameters

• handle: Handle of a 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 ESP32 slave. The slave receive the packet into buffers whose size is buffer_size (configured during initialization).

Return

• ESP_OK Success
• ESP_ERR_TIMEOUT No buffer to use, or error from SDMMC host controller
• One of the error codes from SDMMC host controller

Parameters

• handle: Handle of a 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 ESP32 slave.

Return

• ESP_OK Success, all the data are read from the slave.
• ESP_ERR_NOT_FINISHED Read success, while there’re data remaining.
• One of the error codes from SDMMC host controller

Parameters

• handle: Handle of a 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 ESP32 slave.

Note: sdio 28-31 are reserved, the lower API helps to skip.

Return

• ESP_OK Success
• ESP_ERR_INVALID_ARG Address not valid.
• One of the error codes from SDMMC host controller

Parameters

• handle: Handle of a eSSL device.
• addr: Address of register to write. Valid address: 0-59.
• 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 ESP32 slave.
Chapter 2. API

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Address not valid.
- One of the error codes from SDMMC host controller

Parameters
- handle: Handle of a essl device.
- add: Address of register to read. Valid address: 0-27, 32-63 (28-31 reserved, return interrupt bits on read).
- 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_ERR_NOT_SUPPORTED Currently our driver does not support SDIO with SPI interface.
- ESP_OK If interrupt triggered.
- ESP_ERR_TIMEOUT No interrupts before timeout.

Parameters
- handle: Handle of a 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 ESP32 slave. All the bits set in the mask will be cleared, while other bits will stay the same.

Return
- ESP_OK Success
- One of the error codes from SDMMC host controller

Parameters
- handle: Handle of a 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 ESP32 slave.

Return
- ESP_OK Success
- ESP_INVALID_ARG if both intr_raw and intr_st are NULL.
- One of the error codes from SDMMC host controller

Parameters
- handle: Handle of a 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 ESP32 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
- One of the error codes from SDMMC host controller

Parameters
- handle: Handle of a essl device.
- ena_mask: Mask of the interrupt bits to enable.
- wait_ms: Millisecond to wait before timeout, will not wait at all if set to 0-9.

```c
esp_err_t essl_get_intr_ena (essl_handle_t handle, uint32_t* ena_mask_o, uint32_t wait_ms)
```
Get interrupt enable bits of ESP32 slave.

Return
Chapter 2. API

**ESP_OK Success**
One of the error codes from SDMMC host controller

**Parameters**
- **handle**: Handle of a eSSL device.
- **en_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**
- One of the error codes from SDMMC host controller

**Parameters**
- **handle**: Handle of a 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.

**Macros**

**ESP_ERR_NOT_FINISHED**
There is still remaining data.

**Type Definitions**

```c
typedef struct essl_dev_t* essl_handle_t
```
Handle of an ESSL device.

**Header File**

- `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.
The pre-negotiated recv buffer size used by both the host and the slave.

Header File

- `esp_serial_slave_link/include/esp_serial_slave_link/essl_spi.h`

Functions

```c
esp_err_t essl_spi_rdbuf(spi_device_handle_t spi, uint8_t* out_data, int addr, int len, uint32_t flags)
```

Read the shared buffer from the slave.

**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 `spi_device_transmit`.

**Parameters**
- `spi`: SPI device handle representing the slave
- `out_data`: Buffer for read data, strongly suggested to be in the DRAM and align 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.

**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 `spi_device_transmit`.

**Parameters**
- `spi`: SPI device handle representing the slave
- `data`: Buffer for data to send, strongly suggested to be in the DRAM and align to 4
- `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 `spi_device_transmit` and one at the end. Used when the slave is working in segment mode.

**Return**
- ESP_OK: success
- or other return value from `spi_device_transmit`.

**Parameters**
- `spi`: SPI device handle representing the slave
- `out_data`: Buffer to hold the received data, strongly suggested to be in the DRAM and align 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_rdma` instead.

**Return**
- ESP_OK: success
- or other return value from :cpp:`func:spi_device_transmit`.

**Parameters**
- *spi*: SPI device handle representing the slave
- *out_data*: Buffer to hold the received data, strongly suggested to be in the DRAM and align 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 rdda`ma_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 and align to 4
- *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 and align 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_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 `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.

2.4.13 ESP x509 Certificate Bundle

Overview

The ESP x509 Certificate Bundle API provides an easy way to include a bundle of custom x509 root certificates for TLS server verification.

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 Wed Jan 23 04:12:09 2019 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.

Trusting all root certificates means the list will have to be updated if any of the certificates are retracted. This includes removing them from `cacrt_all.pem`.

Configuration

Most configuration is done through menuconfig. Make and CMake will generate the bundle according to the configuration and embed it.

• `CONFIGMBEDTLS_CERTIFICATE_BUNDLE`: automatically build and attach the bundle.
• `CONFIGMBEDTLS_DEFAULT_CERTIFICATE_BUNDLE`: decide which certificates to include from the complete root list.
• `CONFIGMBEDTLS_CUSTOM_CERTIFICATE_BUNDLE_PATH`: specify the path of any additional certificates to embed in the bundle.

To enable the bundle when using ESP-TLS simply pass the function pointer to the bundle attach function:

```c
esp_tls_cfg_t cfg = {
    .crt_bundle_attach = esp_crt_bundle_attach,
};
```

This is done to avoid embedding the certificate bundle unless activated by the user.

If using mbedTLS directly then the bundle may be activated by directly calling the attach function during the setup process:
Generating the List of Root Certificates

The list of root certificates comes from Mozilla’s NSS root certificate store, which can be found [here](#). The list can be downloaded and created by running the script `mk-ca-bundle.pl` that is distributed as a part of curl. Another alternative would be to download the finished list directly from the curl website: CA certificates extracted from Mozilla

The common certificates bundle were made by selecting the authorities with a market share of more than 1% from w3tech’s SSL Survey. These authorities were then used to pick the names of the certificates for the filter list, `cmn_crtAuthorities.csv`, from this list provided by Mozilla.

Updating the Certificate Bundle

The bundle is embedded into the app and can be updated along with the app by an OTA update. If you want to include a more up-to-date bundle than the bundle currently included in 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

- mbedtls/esp_crt_bundle/include/esp_crt_bundle.h

Functions

```c
esp_err_t esp_crt_bundle_attach(void *conf)
```

Attach and enable use of a bundle for certificate verification.

- **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.

```c
void esp_crt_bundle_detach(mbedtls_ssl_config *conf)
```

Disable and dealloc the certification bundle.

- **Parameters**
  - `[in]` `conf`: The config struct for the SSL connection.
Chapter 2. API

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.

2.4.14 IP 网络层协议

IP 网络层协议（应用层协议之下）的文档位于连网 API。

2.5 配网 API

2.5.1 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.
### 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

3. **Configuration**
   - App specific Set Config (optional)
     - Set Config Response (optional)
   - Wi-Fi SetConfig (SSID, Passphrase...)
     - Wi-Fi SetConfig response
   - Wi-Fi ApplyConfig cmd
     - Wi-Fi ApplyConfig resp
   - Wi-Fi GetStatus cmd (repeated)
     - Wi-Fi GetStatus resp (repeated)

4. **Close connection**
   - Close Connection
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.

### Device Discovery

The advertisement and device discovery is left to the application and depending on the protocol chosen, the phone apps and device firmware application can choose appropriate method to advertise and discovery.

For the SoftAP+HTTP transport, typically the SSID (network name) of the AP hosted by the device can be used for discovery.

For the BLE transport device name or primary service included in the advertisement or combination of both can be used for discovery.

### Architecture

The below diagram shows architecture of unified provisioning.

It relies on the base layer called *Protocol Communication* (Protocol Communication) which provides a framework for security schemes and transport mechanisms. Wi-Fi Provisioning layer uses Protocomm to provide simple callbacks to the application for setting the configuration and getting the Wi-Fi status. The application has control over implementation of these callbacks. In addition 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)
图 24: Security1

---

Generate Key Pair

\[\{\text{cli\textunderscore privkey}, \text{cli\textunderscore pubkey}\} = \text{curve25519\textunderscore keygen()}\]

SessionCmd0(cli\_pubkey)

Generate Key Pair

\[\{\text{dev\textunderscore privkey}, \text{dev\textunderscore pubkey}\} = \text{curve25519\textunderscore keygen()}\]

Initialization Vector

\[\text{dev\textunderscore rand} = \text{gen\textunderscore 16\textunderscore byte\textunderscore random()}\]

Shared Key

\[\text{shared\textunderscore key}(\text{No PoP}) = \text{curve25519}(\text{dev\textunderscore privkey}, \text{cli\textunderscore pubkey})\]
\[\text{shared\textunderscore key}(\text{with PoP}) = \text{curve25519}(\text{dev\textunderscore privkey}, \text{cli\textunderscore pubkey}^\cdot \text{SHA256}(\text{pop}))\]

SessionResp0(dev\_pubkey, dev\_rand)

Shared Key

\[\text{shared\textunderscore key}(\text{No PoP}) = \text{curve25519}(\text{cli\textunderscore privkey}, \text{dev\textunderscore pubkey})\]
\[\text{shared\textunderscore key}(\text{with PoP}) = \text{curve25519}(\text{cli\textunderscore privkey}, \text{dev\textunderscore pubkey}^\cdot \text{SHA256}(\text{pop}))\]

Verification Token

\[\text{cli\textunderscore verify} = \text{aes\textunderscore ctr\textunderscore enc}(\text{key}\cdot \text{shared\textunderscore key}, \text{data}\cdot \text{dev\textunderscore pubkey}, \text{nonce}\cdot \text{dev\textunderscore rand})\]

SessionCmd1(cli\_verify)

Verify Client

\[\text{check} (\text{dev\textunderscore pubkey} == \text{aes\textunderscore ctr\textunderscore dec}(\text{cli\textunderscore verify}...))\]

Verification Token

\[\text{dev\textunderscore verify} = \text{aes\textunderscore ctr\textunderscore enc}(\text{key}\cdot \text{shared\textunderscore key}, \text{data}\cdot \text{cli\textunderscore pubkey}, \text{nonce}\cdot (\text{prev\textunderscore context}))\]

SessionResp1(dev\_verify)

Verify Device

\[\text{check} (\text{cli\textunderscore pubkey} == \text{aes\textunderscore ctr\textunderscore dec}(\text{dev\textunderscore verify}...))\]
The phone applications offer simple UI and thus more user centric, while the command line application is useful as a debugging tool for developers.

### 2.5.2 Protocol Communication

#### Overview

Protocol Communication (protocomm) component manages secure sessions and provides framework for multiple transports. The application can also use protocomm layer directly to have application specific extensions for the provisioning (or non-provisioning) use cases.

**Following features are available for provisioning:**

- **Communication security at application level** -
  - protocomm_security0 (no security)
  - protocomm_security1 (curve25519 key exchange + AES-CTR encryption)
- **Proof-of-possession** (support with protocomm_security1 only)

Protocomm internally uses protobuf (protocol buffers) for secure session establishment. Though users can implement their own security (even without using protobuf). One can even use protocomm without any security layer.

Protocomm provides framework for various transports - WiFi (SoftAP+HTTPD), BLE, console - in which case the handler invocation is automatically taken care of on the device side (see Transport Examples below for code snippets).

Note that the client still needs to establish session (only for protocomm_security1) by performing the two way handshake. See [Unified Provisioning](#) for more details about the secure handshake logic.

#### Transport Example (SoftAP + HTTP) with Security 1

For 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();
}
```

(下頁續)
/* Config for protocomm_httpd_start() */
protocomm_httpd_config_t pc_config = {
    .data = {
        .config = PROTOCOL_HTTPD_DEFAULT_CONFIG()
    }
};

/* Start protocomm server on top of HTTP */
protocomm_httpd_start(pc, &pc_config);

/* Create Proof of Possession object from pop_string. It must be valid */
/* throughout the scope of protocomm endpoint. This need not be */
/* static, */
/* ie. could be dynamically allocated and freed at the time of */
/* endpoint */
/* removal */
const static protocomm_security_pop_t pop_obj = {
    .data = (const uint8_t *) strdup(pop_string),
    .len = strlen(pop_string)
};

/* Set security for communication at application level. Just like for */
/* request handlers, setting security creates an endpoint and */
/* registers */
/* the handler provided by protocomm_security1. One can similarly use */
/* protocomm_security0. Only one type of security can be set for a */
/* protocomm instance at a time. */
/* */
/* protocomm_set_security(pc, "security_endpoint", &protocomm_security1, */
/* &pop_obj); */

/* Private data passed to the endpoint must be valid throughout the */
/* scope */
/* of protocomm endpoint. This need not be static, ie. could be */
/* dynamically */
/* allocated and freed at the time of endpoint removal */
static uint32_t priv_data = 1234;

/* Add a new endpoint for the protocomm instance, identified by a */
/* unique name */
/* and register a handler function along with private data to be */
/* passed at the */
/* time of handler execution. Multiple endpoints can be added as long */
/* as they */
/* are identified by unique names */
protocomm_add_endpoint(pc, "echo_req_endpoint",
    echo_req_handler, (void *) &priv_data);

return pc;

/* Example function for stopping a protocomm instance */
void stop_pc(protocomm_t *pc)
{
    /* Remove endpoint identified by it's unique name */
    protocomm_remove_endpoint(pc, "echo_req_endpoint");

    /* Remove security endpoint identified by it's name */
    protocomm_unset_security(pc, "security_endpoint");

    /* Stop HTTP server */
    protocomm_httpd_stop(pc);
}

(续下页)
Chapter 2. API

Transport Example (BLE) with Security 0

For complete example see provisioning/legacy/ble_prov

```c
/* Example function for launching a secure protocomm instance over BLE */
protocomm_t *start_pc()
{
    protocomm_t *pc = protocomm_new();

    /* Endpoint UUIDs */
    protocomm_ble_name_uuid_t nu_lookup_table[] = {
        {"security_endpoint", 0xFF51},
        {"echo_req_endpoint", 0xFF52}
    };

    /* Config for protocomm_ble_start() */
    protocomm_ble_config_t config = {
        .service_uuid = {
            /* LSB <---------------------------------------
             * ---------------------------------------> MSB */
            0xfb, 0x34, 0x9b, 0x5f, 0x80, 0x00, 0x00, 0x80,
            0x00, 0x10, 0x00, 0x00, 0xFF, 0xFF, 0x00, 0x00,
        },
        .nu_lookup_count = sizeof(nu_lookup_table) / sizeof(nu_lookup_table[0]),
        .nu_lookup = nu_lookup_table
    };

    /* Start protocomm layer on top of 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
Chapter 2. API

• protocomm/include/common/protocomm.h

**Functions**

```c
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

```c
void protocomm_delete (protocomm_t *pc)
```

Delete a protocomm instance.

This API will deallocate a protocomm instance that was created using `protocomm_new()`.

**Parameters**

- `[in] pc`: Pointer to the protocomm instance to be deleted

```c
esp_err_t protocomm_add_endpoint (protocomm_t *pc, const char *ep_name, protocomm_reg_handler_t h, void *priv_data)
```

Add endpoint request handler for a protocomm instance.

This API will bind an endpoint handler function to the specified endpoint name, along with any private data that needs to be pass to the handler at the time of call.

**Note**

- An endpoint must be bound to a valid protocomm instance, created using `protocomm_new()`.
- This function internally calls the registered `add_endpoint()` function of the selected transport which is a member of the protocomm_t instance structure.

**Return**

- `ESP_OK` : Success
- `ESP_FAIL` : Error adding endpoint / Endpoint with this name already exists
- `ESP_ERR_NO_MEM` : Error allocating endpoint resource
- `ESP_ERR_INVALID_ARG` : Null instance/name/handler arguments

**Parameters**

- `[in] pc`: Pointer to the protocomm instance
- `[in] ep_name`: Endpoint identifier(name) string
- `[in] h`: Endpoint handler function
- `[in] priv_data`: Pointer to private data to be passed as a parameter to the handler function on call. Pass NULL if not needed.

```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()`.
Chapter 2. API

Return
• ESP_OK : Request handled successfully
• ESP_ERR_NO_MEM : Error allocating internal resource
• ESP_ERR_INVALID_ARG : Null instance/name arguments

Parameters
• [in] pc: Pointer to the protocomm instance
• [in] session_id: Unique ID for a communication session

`esp_err_t protocomm_close_session (protocomm_t *pc, uint32_t session_id)`
Frees internal resources used by a transport session.

Note
• An endpoint must be bound to a valid protocomm instance, created using `protocomm_new()`.

Return
• ESP_OK : Request handled successfully
• ESP_ERR_INVALID_ARG : Null instance/name arguments

Parameters
• [in] pc: Pointer to the protocomm instance
• [in] session_id: Unique ID for a communication session

`esp_err_t protocomm_req_handle (protocomm_t *pc, const char *ep_name, uint32_t session_id, const uint8_t *inbuf, ssize_t inlen, uint8_t **outbuf, ssize_t *outlen)`
Calls the registered handler of an endpoint session for processing incoming data and generating the response.

Note
• An endpoint must be bound to a valid protocomm instance, created using `protocomm_new()`.
• Resulting output buffer must be deallocated by the caller.

Return
• ESP_OK : Request handled successfully
• ESP_FAIL : Internal error in execution of registered handler
• ESP_ERR_NO_MEM : Error allocating internal resource
• ESP_ERR_NOT_FOUND : Endpoint with specified name doesn’t exist
• ESP_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

```c
esp_err_t protocomm_unset_security (protocomm_t *pc, const char *ep_name)
```
Remove endpoint security for a protocomm instance.

This API will remove a registered security endpoint identified by an endpoint name.

**Return**
- ESP_OK: Success
- ESP_ERR_NOT_FOUND: Endpoint with specified name does not 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_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 does not exist
- ESP_ERR_INVALID_ARG: Null instance/name/handler 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

- protocomm/include/security/protocomm_security.h

Structures

struct protocomm_security_pop

Proof Of Possession for authenticating a secure session.

Public Members

const uint8_t *data

Pointer to buffer containing the proof of possession data

uint16_t len

Length (in bytes) of the proof of possession data

struct protocomm_security

Protocomm security object structure.

The member functions are used for implementing secure protocomm sessions.

Note This structure should not have any dynamic members to allow re-entrancy

Public Members

int ver

Unique version number of security implementation

esp_err_t (*init) (protocomm_security_handle_t *handle)

Function for initializing/allocating security infrastructure

esp_err_t (*cleanup) (protocomm_security_handle_t handle)

Function for deallocating security infrastructure

esp_err_t (*new_transport_session) (protocomm_security_handle_t handle, uint32_t session_id)

Starts new secure transport session with specified ID

esp_err_t (*close_transport_session) (protocomm_security_handle_t handle, uint32_t session_id)

Closes a secure transport session with specified ID

esp_err_t (*security_req_handler) (protocomm_security_handle_t handle, const protocomm_security_pop_t *pop, uint32_t session_id, const uint8_t *inbuf, ssize_t inlen, uint8_t **outbuf, ssize_t outlen, void *priv_data)

Handler function for authenticating connection request and establishing secure session

esp_err_t (*encrypt) (protocomm_security_handle_t handle, uint32_t session_id, const uint8_t *inbuf, ssize_t inlen, uint8_t *outbuf, ssize_t *outlen)

Function which implements the encryption algorithm

esp_err_t (*decrypt) (protocomm_security_handle_t handle, uint32_t session_id, const uint8_t *inbuf, ssize_t inlen, uint8_t *outbuf, ssize_t *outlen)

Function which implements the decryption algorithm

Type Definitions

typedef struct protocomm_security_pop protocomm_security_pop_t

Proof Of Possession for authenticating a secure session.

typedef void *protocomm_security_handle_t
Chapter 2. API 参考

**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**
- protocomm/include/security/protocomm_security0.h

**Header File**
- protocomm/include/security/protocomm_security1.h

**Header File**
- protocomm/include/transports/protocomm_httpd.h

**Functions**

```c
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

```c
esp_err_t protocomm_httpd_stop(protocomm_t *pc)
```
Stop HTTPD protocomm transport.

This API cleans up the HTTPD transport protocomm and frees all the handlers registered with the protocomm.

**Return**
- ESP_OK : Success
- ESP_ERR_INVALID_ARG : Null / incorrect protocomm instance pointer

**Parameters**
- **[in]** pc: Same protocomm instance that was passed to protocomm_httpd_start()

**Unions**

```c
union protocomm_httpd_config_data_t
#include <protocomm_httpd.h> Protocomm HTTPD Configuration Data
```

**Public Members**

```c
void *handle
HTTP Server Handle, if ext_handle_provided is set to true
```
struct protocomm_http_server_config_t
Config parameters for protocomm HTTP server.

Public Members

global uint16_t port
Port on which the HTTP server will listen

global size_t stack_size
Stack size of server task, adjusted depending upon stack usage of endpoint handler

global 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 a case, protocomm will use the same HTTP Server and not start a new one internally.

struct protocomm_httpd_config_data_t data
Protocomm HTTPD Configuration Data

Macros

PROTOCOMM_HTTPD_DEFAULT_CONFIG()

Header File

• protocomm/include/transports/protocomm_ble.h

Functions

esp_err_t protocomm_ble_start (protocomm_t *pc, const protocomm_ble_config_t *config)
Start Bluetooth Low Energy based transport layer for provisioning.

Initialize and start required BLE service for provisioning. This includes the initialization for characteristics/service for BLE.

Return

• ESP_OK: Success
• ESP_FAIL: Simple BLE start error
• ESP_ERR_NO_MEM: Error allocating memory for internal resources
• ESP_ERR_INVALID_STATE: Error in ble config
• ESP_ERR_INVALID_ARG: Null arguments

Parameters

• [in] pc: Protocomm instance pointer obtained from protocomm_new()
• [in] config: Pointer to config structure for initializing BLE

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.

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

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

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.

2.5.3 Wi-Fi Provisioning
Chapter 2. API 参考

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_ERR_CHECK( wifi_prov_mgr_init(config) );
```

The configuration structure `wifi_prov_mgr_config_t` has a few fields to specify the behavior desired of the manager:

- **scheme**: This is used to specify the provisioning scheme. Each scheme corresponds to one of the modes of transport supported by protocomm. Hence, we have three options:
  - `wifi_prov_scheme_ble`: BLE transport and GATT Server for handling provisioning commands
  - `wifi_prov_scheme_softap`: Wi-Fi SoftAP transport and HTTP Server for handling provisioning commands
  - `wifi_prov_scheme_console`: Serial transport and console for handling provisioning commands
- **scheme_event_handler**: An event handler defined along with scheme. Choosing appropriate scheme specific event handler allows the manager to take care of certain matters automatically. Presently this is not used for either SoftAP or Console based provisioning, but is very convenient for BLE. To understand how, we must recall that Bluetooth requires quite some amount of memory to function and once provisioning is finished, the main application may want to reclaim back this memory (or part of it, if it needs to use either BLE or classic BT). Also, upon every future re-boot 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)
```
Chapter 2. API

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 restored 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_ERR_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:

```c
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\nSSID : %s\nPassword : %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!\nReason : %s\nP lease reset to factory and retry\nAccess-point not found",
                     "Wi-Fi station authentication failed" : "Wi-Fi access-point not found");
            break;
        case WIFI_PROV_CRED_SUCCESS:
            ESP_LOGI(TAG, "Provisioning successful");
            break;
        case WIFI_PROV_END:
            /* De-initialize manager once provisioning is finished */
            wifi_prov_mgr_deinit();
            break;
        default:
            break;
    }
}
```
• 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.

```
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_ERR_CHECK( wifi_prov_mgr_start_provisioning(security, pop, service_name, service_key) );
```

The provisioning service will automatically finish only if it receives valid Wi-Fi AP credentials followed by successfully connection of device to the AP (IP obtained). Regardless of that, the provisioning service can be stopped at any moment by making a call to `wifi_prov_mgr_stop_provisioning()`.

注解： 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()`.

```
// Start provisioning service
ESP_ERR_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 :

```
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 protocol endpoints can be identified as follows:

<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: `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 protocol sessions as per the security scheme configured for use (this is not needed when manager is configured to use protocol 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 atleast 120ms after completing scan on a group of channels, and thus allow the driver to send out the beacons. For example, given that the total number of Wi-Fi channels is 14, then setting `group_channels` to 4, will create 5 groups, with each group having 3 channels, except the last one which will have 14 % 3 = 2 channels. So, when scan is started, the first 3 channels will be scanned, followed by a 120ms delay, and then the next 3 channels, and so on, until all the 14 channels have been scanned. One may need to adjust this parameter as having only few channels in a group may slow down the overall scan time, while having too many may again cause disconnection. Usually a value of 4 should work for most cases. Note that for any other mode of transport, e.g. BLE, this can be safely set to 0, and hence achieve the fastest overall scanning time.
  - `period_ms` (input) - Scan parameter specifying how long to wait on each channel
- **scan_status** - Gives the status of scanning process:
  - `scan_finished` (output) - When scan has finished this returns true
  - `result_count` (output) - This gives the total number of results obtained till now. If scan is yet happening this number will keep on updating
- **scan_result** - For fetching scan results. This can be called even if scan is still on going
  - `start_index` (input) - Starting index from where to fetch the entries from the results list
  - `count` (input) - Number of entries to fetch from the starting index
  - `entries` (output) - List of entries returned. Each entry consists of `ssid`, `channel` and `rssi` information

**Additional Endpoints** In case users want to have some additional protocomm endpoints customized to their requirements, this is done in two steps. First is creation of an endpoint with a specific name, and the second step is the registration of a handler for this endpoint. See `protocomm` for the function signature of an endpoint handler. A custom endpoint must be created after initialization and before starting the provisioning service. Whereas, the protocomm handler is registered for this endpoint only after starting the provisioning service.

```c
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**

- `wifi_provisioning/include/wifi_provisioning/manager.h`

**Functions**

```c
esp_err_t wifi_prov_mgr_init (wifi_prov_mgr_config_t *config)
```

Initializes 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 check 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 protocol 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.

esp_err_t wifi_prov_mgr_disable_auto_stop (uint32_t cleanup_delay)
Disable auto stopping of provisioning service upon completion.
By default, once provisioning is complete, the provisioning service is automatically stopped, and all endpoints (along with those registered by main application) are deactivated.
This API is useful in the case when main application wishes to close provisioning service only after it receives some protocomm command from the client side app. For example, after connecting to Wi-Fi, the device may want to connect to the cloud, and only once that is successfully, the device is said to be fully configured. But, then it is upto the main application to explicitly call wifi_prov_mgr_stop_provisioning() later when the device is fully configured and the provisioning service is no longer required.
Note This must be called before executing wifi_prov_mgr_start_provisioning()
Return
- ESP_OK : Success
- ESP_ERR_INVALID_STATE : Manager not initialized or provisioning service already started
Parameters
- [in] cleanup_delay: Sets the delay after which the actual cleanup of transport related resources is done after a call to wifi_prov_mgr_stop_provisioning() returns. Minimum allowed value is 100ms. If not specified, this will default to 1000ms.

esp_err_t wifi_prov_mgr_set_app_info (const char *label, const char *version, const char **capabilities, size_t total_capabilities)
Set application version and capabilities in the JSON data returned by proto-ver endpoint.
This function can be called multiple times, to specify information about the various application specific services running on the device, identified by unique labels.
The provisioning service itself registers an entry in the JSON data, by the label “prov”, containing only provisioning service version and capabilities. Application services should use a label other than “prov” so as not to overwrite this.
Note This must be called before executing wifi_prov_mgr_start_provisioning()
Return
- ESP_OK : Success
- ESP_ERR_INVALID_STATE : Manager not initialized or provisioning service already started
- ESP_ERR_NO_MEM : Failed to allocate memory for version string
Chapter 2. API 参考

- ESP_ERR_INVALID_ARG : Null argument

**Parameters**
- [in] label: String indicating the application name.
- [in] version: String indicating the application version. There is no constraint on format.
- [in] capabilities: Array of strings with capabilities. These could be used by the client side app to know the application registered endpoint capabilities
- [in] total_capabilities: Size of capabilities array

```c
esp_err_t wifi_prov_mgr_endpoint_create(const char *ep_name)
```
Create an additional endpoint and allocate internal resources for it.

This API is to be called by the application if it wants to create an additional endpoint. All additional endpoints will be assigned UUIDs starting from 0xFF54 and so on in the order of execution.

protocomm handler for the created endpoint is to be registered later using wifi_prov_mgr_endpoint_register() after provisioning has started.

**Note** This API can only be called BEFORE provisioning is started

**Note** Additional endpoints can be used for configuring client provided parameters other than Wi-Fi credentials, that are necessary for the main application and hence must be set prior to starting the application

**Note** After session establishment, the additional endpoints must be targeted first by the client side application before sending Wi-Fi configuration, because once Wi-Fi configuration finishes the provisioning service is stopped and hence all endpoints are unregistered

**Return**
- ESP_OK : Success
- ESP_FAIL : Failure

**Parameters**
- [in] ep_name: unique name of the endpoint

```c
esp_err_t wifi_prov_mgr_endpoint_register(const char *ep_name, protocomm_req_handler_t handler, void *user_ctx)
```
Register a handler for the previously created endpoint.

This API can be called by the application to register a protocomm handler to any endpoint that was created using wifi_prov_mgr_endpoint_create().

**Note** This API can only be called AFTER provisioning has started

**Note** Additional endpoints can be used for configuring client provided parameters other than Wi-Fi credentials, that are necessary for the main application and hence must be set prior to starting the application

**Note** After session establishment, the additional endpoints must be targeted first by the client side application before sending Wi-Fi configuration, because once Wi-Fi configuration finishes the provisioning service is stopped and hence all endpoints are unregistered

**Return**
- ESP_OK : Success
- ESP_FAIL : Failure

**Parameters**
- [in] ep_name: Name of the endpoint
- [in] handler: Endpoint handler function
- [in] user_ctx: User data

```c
void wifi_prov_mgr_endpoint_unregister(const char *ep_name)
```
Unregister the handler for an endpoint.

This API can be called if the application wants to selectively unregister the handler of an endpoint while the provisioning is still in progress.

All the endpoint handlers are unregistered automatically when the provisioning stops.

**Parameters**
- [in] ep_name: Name of the endpoint

```c
esp_err_t wifi_prov_mgr_event_handler(void *ctx, system_event_t *event)
```
Event handler for provisioning manager.
This is called from the main event handler and controls the provisioning manager’s internal state machine depending on incoming Wi-Fi events

**Note**: This function is DEPRECATED, because events are now handled internally using the event loop library, esp_event. Calling this will do nothing and simply return ESP_OK.

**Return**
- ESP_OK : Event handled successfully

**Parameters**
- [in] ctx: Event context data
- [in] event: Event info

```c
esp_err_t wifi_prov_mgr_get_wifi_state (wifi_prov_sta_state_t *state)
```
Get state of Wi-Fi Station during provisioning.

**Return**
- ESP_OK : Successfully retrieved Wi-Fi state
- ESP_FAIL : Provisioning app not running

**Parameters**
- [out] state: Pointer to wifi_prov_sta_state_t variable to be filled

```c
esp_err_t wifi_prov_mgr_get_wifi_disconnect_reason (wifi_prov_sta_fail_reason_t *reason)
```
Get reason code in case of Wi-Fi station disconnection during provisioning.

**Return**
- ESP_OK : Successfully retrieved Wi-Fi disconnect reason
- ESP_FAIL : Provisioning app not running

**Parameters**
- [out] reason: Pointer to wifi_prov_sta_fail_reason_t variable to be filled

```c
esp_err_t wifi_prov_mgr_configure_sta (wifi_config_t *wifi_cfg)
```
Runs Wi-Fi as Station with the supplied configuration.

Configures the Wi-Fi station mode to connect to the AP with SSID and password specified in config structure and sets Wi-Fi to run as station.

This is automatically called by provisioning service upon receiving new credentials.

If credentials are to be supplied to the manager via a different mode other than through 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

**Structures**

```c
struct wifi_prov_event_handler_t
```
Event handler that is used by the manager while provisioning service is active.

**Public Members**

```c
wifi_prov_cb_func_t event_cb
```
Callback function to be executed on provisioning events

```c
void *user_data
```
User context data to pass as parameter to callback function

```c
struct wifi_prov_scheme
```
Structure for specifying the provisioning scheme to be followed by the manager.
**Note** Ready to use schemes are available:

- `wifi_prov_scheme_ble` for provisioning over BLE transport + GATT server
- `wifi_prov_scheme_softap` for provisioning over SoftAP transport + HTTP server
- `wifi_prov_scheme_console` for provisioning over Serial UART transport + Console (for debugging)

### Public Members

**esp_err_t** (*prov_start*) *(protocomm_t *pc, void *config)*

Function which is to be called by the manager when it is to start the provisioning service associated with a protocomm instance and a scheme specific configuration.

**esp_err_t** (*prov_stop*) *(protocomm_t *pc)*

Function which is to be called by the manager to stop the provisioning service previously associated with a protocomm instance.

void *(new_config) (void)*

Function which is to be called by the manager to generate a new configuration for the provisioning service, that is to be passed to `prov_start()`.

void *(delete_config) (void *config)*

Function which is to be called by the manager to delete a configuration generated using `new_config()`.

**esp_err_t** (*set_config_service*) *(void *config, const char *service_name, const char *service_key)*

Function which is to be called by the manager to set the service name and key values in the configuration structure.

**esp_err_t** (*set_config_endpoint*) *(void *config, const char *endpoint_name, uint16_t uuid)*

Function which is to be called by the manager to set a protocomm endpoint with an identifying name and UUID in the configuration structure.

**wifi_mode_t** wifi_mode

Sets mode of operation of Wi-Fi during provisioning. This is set to:

- WIFI_MODE_APSTA for SoftAP transport
- WIFI_MODE_STA for BLE transport

**struct wifi_prov_mgr_config_t**

Structure for specifying the manager configuration.

### Public Members

**wifi_prov_scheme_t** scheme

Provisioning scheme to use. Following schemes are already available:

- `wifi_prov_scheme_ble` for provisioning over BLE transport + GATT server
- `wifi_prov_scheme_softap` for provisioning over SoftAP transport + HTTP server + mDNS (optional)
- `wifi_prov_scheme_console` for provisioning over Serial UART transport + Console (for debugging)

**wifi_prov_event_handler_t** scheme_event_handler

Event handler required by the scheme for incorporating scheme specific behavior while provisioning manager is running. Various options may be provided by the scheme for setting this field. Use WIFI_PROV_EVENT_HANDLER_NONE when not used. When using scheme `wifi_prov_scheme_ble`, the following options are available:

- WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BTDM
- WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BLE
- WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BT

**wifi_prov_event_handler_t** app_event_handler

Event handler that can be set for the purpose of incorporating application specific behavior. Use WIFI_PROV_EVENT_HANDLER_NONE when not used.
Chapter 2. API

Macros

WIFI_PROV_EVENT_HANDLER_NONE

Event handler can be set to none if not used.

Type Definitions

typedef void (*wifi_prov_cb_func_t)(void *user_data, wifi_prov_cb_event_t event, void *event_data);

typedef struct wifi_prov_scheme wifi_prov_scheme_t

Structure for specifying the provisioning scheme to be followed by the manager.

Note Ready to use schemes are available:

• wifi_prov_scheme_ble: for provisioning over BLE transport + GATT server
• wifi_prov_scheme_softap: for provisioning over SoftAP transport + HTTP server
• wifi_prov_scheme_console: for provisioning over Serial UART transport + Console (for debugging)

typedef enum wifi_prov_security wifi_prov_security_t

Security modes supported by the Provisioning Manager.

These are same as the security modes provided by protocomm

Enumerations

typedef 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

typedef enum wifi_prov_security

Security modes supported by the Provisioning Manager.

These are same as the security modes provided by protocomm

Values:

WIFI_PROV_SECURITY_0 = 0

No security (plain-text communication)

WIFI_PROV_SECURITY_1

This secure communication mode consists of X25519 key exchange
proof of possession (pop) based authentication
• AES-CTR encryption

Header File
• wifi_provisioning/include/wifi_provisioning/scheme_ble.h

Functions
void wifi_prov_scheme_ble_event_cb_free_btdm (void *user_data, wifi_prov_cb_event_t event, void *event_data)
void wifi_prov_scheme_ble_event_cb_free_ble (void *user_data, wifi_prov_cb_event_t event, void *event_data)
void wifi_prov_scheme_ble_event_cb_free_bt (void *user_data, wifi_prov_cb_event_t event, void *event_data)

esp_err_t wifi_prov_scheme_ble_set_service_uuid (uint8_t *uuid128)
Set the 128 bit GATT service UUID used for provisioning.
This API is used to override the default 128 bit provisioning service UUID, which is 0000fff-0000-1000-8000-00805f9b34fb.
This must be called before starting provisioning, i.e. before making a call to wifi_prov_mgr_start_provisioning(), otherwise the default UUID will be used.
Note The data being pointed to by the argument must be valid at least till provisioning is started. Upon start, the manager will store an internal copy of this UUID, and this data can be freed or invalidated afterwards.
Return
• ESP_OK : Success
• ESP_ERR_INVALID_ARG : Null argument
Parameters
• [in] uuid128: A custom 128 bit UUID

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
• 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
• wifi_provisioning/include/wifi_provisioning/scheme_console.h
Header File

- wifi_provisioning/include/wifi_provisioning/wifi_config.h

Functions

```c
esp_err_t wifi_prov_config_data_handler(uint32_t session_id, const uint8_t *inbuf, ssize_t inlen, uint8_t **outbuf, ssize_t *outlen, void *priv_data)
```

Handler for receiving and responding to requests from master.

This is to be registered as the wifi_config endpoint handler (protocomm protocomm_req_handler_t) using protocomm_add_endpoint()

Structures

```c
struct wifi_prov_sta_conn_info_t
```
WiFi STA connected status information.

Public Members

```c
char ip_addr[IP4ADDR_STRLEN_MAX]
```
Address received by station

```c
char bssid[6]
```
BSSID of the AP to which connection was established

```c
char ssid[33]
```
SSID of the AP to which connection was established

```c
uint8_t channel
```
Channel of the AP

```c
uint8_t auth_mode
```
Authorization mode of the AP

```c
struct wifi_prov_config_get_data_t
```
WiFi status data to be sent in response to get_status request from master.

Public Members

```c
wifi_prov_sta_state_t wifi_state
```
WiFi state of the station

```c
wifi_prov_sta_fail_reason_t fail_reason
```
Reason for disconnection (valid only when wifi_state is WIFI_STATION_DISCONNECTED)

```c
wifi_prov_sta_conn_info_t conn_info
```
Connection information (valid only when wifi_state is WIFI_STATION_CONNECTED)

```c
struct wifi_prov_config_set_data_t
```
WiFi config data received by slave during set_config request from master.

Public Members

```c
char ssid[33]
```
SSID of the AP to which the slave is to be connected

```c
char password[64]
```
Password of the AP

```c
char bssid[6]
```
BSSID of the AP
Chapter 2. API

**struct wifi_prov_config_handlers**
Internal handlers for receiving and responding to protocomm requests from master.

This is to be passed as priv_data for protocomm request handler (refer to `wifi_prov_config_data_handler()`) when calling `protocomm_add_endpoint()`.

**Public Members**

```c
esp_err_t (*get_status_handler) (wifi_prov_config_get_data_t *resp_data, wifi_prov_ctx_t *ctx)
```
Handler function called when connection status of the slave (in WiFi station mode) is requested.

```c
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.

```c
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**

```c
typedef struct wifi_prov_ctx wifi_prov_ctx_t
```
Type of context data passed to each get/set/apply handler function set in `wifi_prov_config_handlers` structure.

This is passed as an opaque pointer, thereby allowing it be defined later in application code as per requirements.

```c
typedef struct wifi_prov_config_handlers wifi_prov_config_handlers_t
```
Internal handlers for receiving and responding to protocomm requests from master.

This is to be passed as priv_data for protocomm request handler (refer to `wifi_prov_config_data_handler()`) when calling `protocomm_add_endpoint()`.

**Enumerations**

```c
enum wifi_prov_sta_state_t
```
WiFi STA status for conveying back to the provisioning master.

**Values:**

- `WIFI_PROV_STA_CONNECTING`
- `WIFI_PROV_STA_CONNECTED`
- `WIFI_PROV_STA_DISCONNECTED`

```c
enum wifi_prov_sta_fail_reason_t
```
WiFi STA connection fail reason.

**Values:**

- `WIFI_PROV_STA_AUTH_ERROR`
- `WIFI_PROV_STA_AP_NOT_FOUND`

本部分的API示例代码存放在ESP-IDF示例项目的provisioning目录下。
2.6 存储 API

2.6.1 SPI Flash API

概述

SPI Flash 组件提供外部 flash 数据读取、写入、擦除和内存映射相关的 API 函数，同时也提供了更高层级的，面向分区的 API 函数（定义在分区表中）。

与 ESP-IDF V4.0 之前的 API 不同，这一版 API 功能并不局限于主 SPI Flash 芯片（即运行程序的 SPI Flash 芯片）。使用不同的芯片指针，您可以通过 SPI0/1 或 HSPI/VSPI 总线访问外部 flash。

注解：ESP-IDF V4.0 之后的 flash API 不再是原子的。因此，如果 flash 操作地址有重叠，且写操作与读操作同时执行，读操作可能会返回一部分写入之前的读数，返回一部分写入之后的数据。

Kconfig 选项 CONFIG_SPI_FLASH_USE_LEGACY_IMPL 可将 spi_flash_* 函数切换至 ESP-IDF V4.0 之前的实现。但是，如果同时使用新旧 API，代码量可能会增多。

即便未启用 CONFIG_SPI_FLASH_USE_LEGACY_IMPL，加密读取和加密写入操作也均使用旧实现。因此，仅有主 flash 芯片支持加密操作，其他不同片选（经 SPI1 访问的 flash 芯片）则不支持加密操作。

初始化 Flash 设备

在使用 esp_flash_* API 之前，您需要在 SPI 总线上初始化芯片。

1. 调用 spi_bus_initialize() 初始化 SPI 总线，此函数将初始化总线上设备间共享的资源，如I/O、DMA 及中断等。
2. 调用 spi_bus_add_flash_device() 将 flash 设备连接到总线上。然后分配内存，填充 esp_flash_t 结构体，同时初始化 CS I/O。
3. 调用 esp_flash_init() 与芯片进行通信。后续操作会依据芯片类型不同而有差异。

注解：目前，多个 flash 芯片可连接到同一总线。但尚不支持在同一 SPI 总线上使用 esp_flash_* 和 spi_device_* 设备。

SPI Flash 访问 API

如下所示为处理 flash 中数据的函数集：

- esp_flash_read(): 将数据从 flash 读取到 RAM；
- esp_flash_write(): 将数据从 RAM 写入到 flash；
- esp_flash_erase_region(): 擦除 flash 中指定区域的数据；
- esp_flash_erase_chip(): 擦除整个 flash；
- esp_flash_get_chip_size(): 返回 menuconfig 中设置的 flash 芯片容量（以字节为单位）。

一般来说，请尽量避免对主 SPI flash 芯片直接使用原始 SPI flash 函数，如需对主 SPI flash 芯片进行操作，请使用分区专用函数。

SPI Flash 容量

SPI flash 容量存储于引导程序映像头部（烧录偏移量为 0x1000）的一个字段。

默认情况下，引导程序写入 flash 时，esptool.py 将引导程序写入 flash 时，会自动检测 SPI flash 容量，同时使用正确容量更新引导程序的头部。您也可以在工程配置中设置 CONFIG_ESPTOOLPY_FLASHSIZE，生成固定的 flash 容量。
如需在运行时覆盖已配置的 flash 容量，请配置 g_rom_flashchip 结构中的 chip_size。esp_flash_* 函数使用此容量（于软件和 ROM 中）进行边界检查。

SPI Flash 并发约束

由于 SPI flash 也被用于执行固件（通过指令 cache 或数据 cache），因此在执行读取、写入及擦除操作时，必须禁用这些 cache。这意味着在执行 flash 写操作时，两个 CPU 必须从 IRAM 运行代码，且只能从 DRAM 中读取数据。

如果您使用本文档中 API 函数，上述限制将自动生效且透明（无需您额外关注），但这些限制可能会影响系统中的其他任务的性能。

除 SPI0/1 以外的 SPI 总线上的其它 flash 芯片则不受这种限制。

请参阅应用内存分布，查看 IRAM、DRAM 和 flash cache 的区别。

为避免意外读取 flash cache，一个 CPU 在启动 flash 写入或擦除操作时，另一个 CPU 将阻塞，并且在 flash 操作完成前，两个 CPU 上的所有的非 IRAM 安全的中断都会被禁用。

IRAM 安全中断处理程序 如果您需要在 flash 操作期间运行中断处理程序（比如低延迟操作），请在注册中断处理程序时设置 ESP_INTR_FLAG_IRAM。

请确保中断处理程序访问的所有数据和函数（包括其调用的数据和函数）都存储在 IRAM 或 DRAM 中。

为函数添加 IRAM_ATTR 属性:

```c
#include "esp_attr.h"

void IRAM_ATTR gpio_isr_handler(void* arg)
{
    // ...
}
```

为常量添加 DRAM_ATTR 和 DRAM_STR 属性:

```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");
}
```

辨别哪些数据应标记为 DRAM_ATTR 可能会比较困难，除非明确标记为 DRAM_ATTR，否则编译器依然可能将某些变量或表达式当做常量（即便没有 const 标记），并将其放入 flash。

如果函数或符号未被正确放入 IRAM/DRAM 中，当中断处理程序在 flash 操作期间从 flash cache 中读取数据，则会产生非法指令异常（这是因为代码未被正确放入 IRAM）或读取垃圾数据（这是因为常数未被正确放入 DRAM），而导致崩溃。

分区表 API

ESP-IDF 工程使用分区表保存 SPI flash 各区信息，包括引导程序、各种应用程序二进制文件、数据及文件系统等，请参考 分区表，查看详细信息。

该组件在 esp_partition.h 中声明了一些 API 函数，用以枚举在分区表中找到的分区，并对这些分区执行操作:

- esp_partition_find(): 在分区表中查找特定类型的条目，返回一个不透明迭代器；
- esp_partition_get(): 返回一个结构，描述给定迭代器的分区；
- esp_partition_next(): 将迭代器移至下一个找到的分区；
- esp_partition_iterator_release(): 释放 esp_partition_find 中返回的迭代器；
- esp_partition_find_first(): 返回一个结构，描述 esp_partition_find 中找到的第一个分区；
Chapter 2. API 参考

- esp_partition_read()、esp_partition_write() 和 esp_partition_erase_range() 在分区边界内执行,等同于 spi_flash_read()、spi_flash_write() 和 spi_flash_erase_range()。

注解：请在应用程序代码中使用上述 esp_partition_* API 函数，而非低层级的 spi_flash_* API 函数。分区表 API 函数根据存储在分区表中的数据，进行边界检查并计算在 flash 中的正确偏移量。

SPI Flash 加密

您可以对 SPI flash 内容进行加密，并在硬件层对其进行透明解密。

请参阅Flash 加密，查看详细信息。

内存映射 API

ESP32 内存硬件可以将 flash 部分区域映射到指令地址空间和数据地址空间，此映射仅用于读操作。不能通过写入 flash 映射的存储区域来改变 flash 中内容。

Flash 以 64 KB 页为单位进行地址映射。内存映射硬件最多可将 4 MB flash 映射到数据地址空间，将 16 MB flash 映射到指令地址空间。请参考《ESP32 技术参考手册》查看内存映射硬件的详细信息。

请注意，有些 64 KB 页还用于将应用程序映射到内存中，因此实际可用的 64 KB 页会更少一些。

Flash 启用时，使用内存映射区域从 flash 读取数据是解密 flash 的唯一方法，解密需在硬件层进行。

内存映射 API 在 esp_spi_flash.h 和 esp_partition.h 中声明：

- spi_flash_mmap(): 将 flash 物理地址区域映射到 CPU 指令空间或数据空间；
- spi_flash_munmap(): 取消上述区域的映射；
- esp_partition_mmap(): 将分区内的一部分映射至 CPU 指令空间或数据空间；

   spi_flash_mmap() 和 esp_partition_mmap() 的区别如下:
- spi_flash_mmap(): 需要给定一个 64 KB 对齐的物理地址;
- esp_partition_mmap(): 给定分区内任意偏移量即可，此函数根据需要将返回的指针调整至指向映射内存。

内存映射在 64 KB 块中进行，如果分区内已传递给 esp_partition_mmap，则可读取分区外数据。

实现

esp_flash_t 结构包含芯片数据和该 API 的三个重要部分:

1. 主机驱动, 为访问芯片提供硬件支持;
2. 芯片驱动, 为不同芯片提供兼容性服务;
3. OS 函数, 在不同阶段（一级或二级 Boot 或者应用程序阶段）为部分 OS 函数提供支持（如一些锁、延迟）。

主机驱动 主机驱动依赖 soc/include/hal 文件夹下 spi_flash_host_drv.h 定义的 spi_flash_host_driver_t 接口。该接口提供了一些与芯片通信常用的函数。

在 SPI HAL 文件中，有些函数是基于现有的 ESP32 memory-spi 来实现的。但是，由于 ESP32 速度限制，HAL 层无法提供某些读命令的高速实现（所以这些命令根本没有在 HAL 的文件中被实现）。memapi_host_driver.h 和 .c 文件使用 HAL 提供的 common_command 函数实现上述读命令的高速版本，并将所有它实现的及 HAL 函数封装为 spi_flash_host_driver_t 供更上层调用。

您也可以实现自己的主机驱动，甚至只通过简单的 GPIO。只要实现了 spi_flash_host_driver_t 中所有函数。不管底层硬件是什么，esp_flash API 都可以访问 flash。
芯片驱动 芯片驱动在 spi_flash_chip_driver.h 中进行定义，并将主机驱动提供的基本函数进行封装以供 API 层使用。

有些操作需在执行前先发送命令，或在执行后读取状态，因此有些芯片需要不同的命令模式以及通信方式。
generic chip 芯片代表了常见的 flash 芯片，其他芯片驱动可以在通用芯片的基础上进行开发。

芯片驱动依赖主机驱动。

OS 函数 OS 函数层提供访问锁和延迟的方法。
该锁定用于解决 SPI Flash 芯片访问和其他函数之间的冲突。例如，经 SPI0/1 访问 flash 芯片时，应当禁用 cache（平时用于读取和 PSRAM 数据）。另一种情况是，一些没有 CS 线或者 CS 线受软件控制的设备（如通过 SPI 接口的 SD 卡控制）需要在一段时间内独占总线。
延时则用于某些长时操作，需要主机处于等待状态或执行轮询。
顶层 API 将芯片驱动和 OS 函数封装成一个完整的组件，并提供参数检查。

另请参考

- 分区表
- OTA API 提供了高层 API 用于更新存储在 flash 中的 app 固件。
- NVS API 提供了结构化 API 用于存储 SPI flash 中的碎片数据。

实现细节

必须确保操作期间，两个 CPU 均未从 flash 运行代码，实现细节如下：

- 单核模式下，SDK 在执行 flash 操作前将需用中断或调度算法。
- 双核模式下，实现细节更为复杂，SDK 需确保两个 CPU 均未运行 flash 代码。

如果有 SPI flash API 在 CPU A（PRO 或 APP）上调用，它使用 esp_ipc_call API 在 CPU B 上运行 spi_flash_op_block_func 函数。esp_ipc_call API 在 CPU B 上唤醒一个高优先级任务，即运行 spi_flash_op_block_func 函数。运行该函数将禁用 CPU B 上的 cache，并使用 s_flash_op_can_start 旗帜来标志 cache 已禁用。然后，CPU A 上的任务也会禁用 cache 并继续执行 flash 操作。

执行 flash 操作时，CPU A 和 CPU B 仍然可以执行中断操作。默认中断代码均存储于 RAM 中，如果新添加了中断分配 API，则应添加一个标志位以请求在 flash 操作期间禁用中断分配的中断。

Flash 操作完成后，CPU A 上的函数将设置另一标志位，即 s_flash_op_complete，用以通知 CPU B 上的任务可以重新启用 cache 并释放 CPU。接着，CPU A 上的函数也重新启用 cache，并将控制权返还给调用者。

另外，所有 API 函数均受互斥量 s_flash_op_mutex 保护。

在单核环境中（启用 CONFIG_FREERTOS_UNICORE），您需要禁用上述两个 cache 以防发生 CPU 间通信。

SPI Flash API 参考

Header File

- spi_flash/include/esp_flash_spi_init.h
Functions

`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 `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

- `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.

esp_err_t esp_flash_read_id(esp.flash_t *chip, uint32_t *out_id)
Read flash ID via the common “RDID” SPI flash command.
ID is a 24-bit value. Lower 16 bits of ‘id’ are the chip ID, upper 8 bits are the manufacturer ID.
Parameters
- chip: Pointer to identify flash chip. Must have been successfully initialised via esp.flash_init()
- [out] out_id: Pointer to receive ID value.
Return ESP_OK on success, or a flash error code if operation failed.

esp_err_t esp_flash_get_size(esp.flash_t *chip, uint32_t *out_size)
Detect flash size based on flash ID.
Note Most flash chips use a common format for flash ID, where the lower 4 bytes specify the size as a power of
2. If the manufacturer doesn’t follow this convention, the size may be incorrectly detected.
Return ESP_OK on success, or a flash error code if operation failed.
Parameters
- chip: Pointer to identify flash chip. Must have been successfully initialised via esp.flash_init()
- [out] out_size: Detected size in bytes.

esp_err_t esp_flash_erase_chip(esp.flash_t *chip)
Erase flash chip contents.
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()

esp_err_t esp_flash_erase_region(esp.flash_t *chip, uint32_t start, uint32_t len)
Erase a region of the flash chip.
Sector size is specified in chip->drv->sector_size field (typically 4096 bytes.) ESP_ERR_INVALID_ARG
will be returned if the start & length are not a multiple of this size.
Parameters
- chip: Pointer to identify flash chip. Must have been successfully initialised via esp.flash_init()
- start: Address to start erasing flash. Must be sector aligned.
- len: Length of region to erase. Must also be sector aligned.

Erase is performed using block (multi-sector) erases where possible (block size is specified in chip->drv-
>block_erase_size field, typically 65536 bytes). Remaining sectors are erased using individual sector erase
commands.
Return ESP_OK on success, or a flash error code if operation failed.

esp_err_t esp_flash_get_chip_write_protect(esp.flash_t *chip, bool *write_protected)
Read if the entire chip is write protected.
Note A correct result for this flag depends on the SPI flash chip model and chip_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.
### 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.

### 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’.

### 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.

### 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.

### 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, or a 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.
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.

Returns 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

uint32_t offset
Start address of this region.

uint32_t size
Size of the region.

struct esp_flash_os_functions_t
OS-level integration hooks for accessing flash chips inside a running OS.

It’s in the public header because some instances should be allocated statically in the startup code. May be updated according to hardware version and new flash chip feature requirements, shouldn’t be treated as public API.

For advanced developers, you may replace some of them with your implementations at your own risk.

Public Members

esp_err_t (*start)(void *arg)
Called before commencing any flash operation. Does not need to be recursive (ie is called at most once for each call to ‘end’).

esp_err_t (*end)(void *arg)
Called after completing any flash operation.

esp_err_t (*region_protected)(void *arg, size_t start_addr, size_t size)
Called before any erase/write operations to check whether the region is limited by the OS

esp_err_t (*delay_us)(void *arg, uint32_t us)
Delay for at least ‘us’ microseconds. Called in between ‘start’ and ‘end’.

void (*)(get_temp_buffer)(void *arg, size_t request_size, size_t *out_size)
Called for get temp buffer when buffer from application cannot be directly read into/write from.

void (*)(release_temp_buffer)(void *arg, void *temp_buf)
Called for release temp buffer.

esp_err_t (*yield)(void *arg)
Yield to other tasks. Called during erase operations.

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.
Chapter 2. API

Public Members

```c
spi_flash_host_inst_t *host

Pointer to hardware-specific “host_driver” structure. Must be initialized before used.
```

```c
const spi_flash_chip_t *chip_drv

Pointer to chip-model-specific “adapter” structure. If NULL, will be detected during initialisation.
```

```c
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.
```

```c
void *os_func_data

Pointer to argument for os-specific hooks. Left NULL and will be initialized with os_func.
```

```c
esp_flash_io_mode_t read_mode

Configured SPI flash read mode. Set before esp_flash_init is called.
```

```c
uint32_t size

Size of SPI flash in bytes. If 0, size will be detected during initialisation.
```

```c
uint32_t chip_id

Detected chip id.
```

Type Definitions

```c
typedef struct spi_flash_chip_t spi_flash_chip_t
```

```c
typedef struct esp_flash_t esp_flash_t
```

Header File

- hal/include/hal/spi_flash_types.h

Structures

```c
struct spi_flash_trans_t
```

Definition of a common transaction. Also holds the return value.

Public Members

```c
uint8_t command

Command to send, always 8bits.
```

```c
uint8_t mosi_len

Output data length, in bytes.
```

```c
uint8_t miso_len

Input data length, in bytes.
```

```c
uint8_t address_bitlen

Length of address in bits, set to 0 if command does not need an address.
```

```c
uint32_t address

Address to perform operation on.
```

```c
const uint8_t *mosi_data

Output data to save.
```

```c
uint8_t *miso_data

[output] Input data from slave, little endian
```

```c
struct spi_flash_host_inst_t

SPI Flash Host driver instance
```
Chapter 2. API

**Public Members**

```c
const struct spi_flash_host_driver_s *driver
```

Pointer to the implementation function table.

```c
struct spi_flash_host_driver_s
```

Host driver configuration and context structure.

**Public Members**

```c
esp_err_t (*dev_config)(spi_flash_host_inst_t *host)
```

Configure the device-related register before transactions. This saves some time to re-configure those registers when we send continuously.

```c
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.

```c
esp_err_t (*read_id)(spi_flash_host_inst_t *host, uint32_t *id)
```

Read flash ID.

```c
void (*erase_chip)(spi_flash_host_inst_t *host)
```

Erase whole flash chip.

```c
void (*erase_sector)(spi_flash_host_inst_t *host, uint32_t start_address)
```

Erase a specific sector by its start address.

```c
void (*erase_block)(spi_flash_host_inst_t *host, uint32_t start_address)
```

Erase a specific block by its start address.

```c
esp_err_t (*read_status)(spi_flash_host_inst_t *host, uint8_t*out_sr)
```

Read the status of the flash chip.

```c
esp_err_t (*set_write_protect)(spi_flash_host_inst_t *host, bool wp)
```

Disable write protection.

```c
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.

```c
bool (*supports_direct_write)(spi_flash_host_inst_t *host, const void *p)
```

Check whether given buffer can be directly used to write

```c
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

```c
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.

```c
bool (*supports_direct_read)(spi_flash_host_inst_t *host, const void *p)
```

Check whether given buffer can be directly used to read

```c
int (*read_data_slicer)(spi_flash_host_inst_t *host, uint32_t address, uint32_t len, uint32_t *align_addr, uint32_t page_size)
```

Slicer for read data. The read should be called iteratively with the return value of this function.

**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

bool (*host_idle)(spi_flash_host_inst_t *host)
Check whether the host is idle to perform new operations.

esp_err_t (*configure_host_io_mode)(spi_flash_hostInst_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.

Macros
ESP_FLASH_SPEED_MIN
 Lowest speed supported by the driver, currently 5 MHz.
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
gen 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_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.

The fastest io mode supported by the host is ESP_FLASH_READ_MODE_MAX-1.

Header File

- 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.
- 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.
- 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_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.

`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.

`void esp_partition_iterator_release (esp_partition_iterator_t iterator)`
Release partition iterator.

Parameters
  • iterator: Iterator obtained using esp_partition_find. Must be non-NULL.

`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.

`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 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_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.

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: 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 read, 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.

Note This function is essentially the same as esp_partition_write() above. It just never decrypts data but returns it as is.

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_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.
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

### 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.

### bool esp_partition_check_identity(const esp_partition_t *partition_1, const esp_partition_t *partition_2)

Check for the identity of two partitions by SHA-256 digest.

**Return**

- True: In case of the two firmware is equal.
- False: Otherwise

**Parameters**

- **[in]** `partition_1`: Pointer to info for partition 1 containing app or data. (fields: address, size and type, are required to be filled).
- **[in]** `partition_2`: Pointer to info for partition 2 containing app or data. (fields: address, size and type, are required to be filled).

### esp_err_t esp_partition_register_external(esp_flash_t *flash_chip, size_t offset, size_t size, const char *label, esp_partition_type_t type, esp_partition_subtype_t subtype, const esp_partition_t **out_partition)

Register a partition on an external flash chip.

This API allows designating certain areas of external flash chips (identified by the `esp_flash_t` structure) as partitions. This allows using them with components which access SPI flash through the `esp_partition` API.
Return

- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if CONFIG_CONFIG_SPI_FLASH_USE_LEGACY_IMPL is enabled
- ESP_ERR_NO_MEM if memory allocation has failed
- ESP_ERR_INVALID_ARG if the new partition overlaps another partition on the same flash chip
- ESP_ERR_INVALID_SIZE if the partition does’ t fit into the flash chip size

Parameters

- `flash_chip`: Pointer to the structure identifying the flash chip
- `offset`: Address in bytes, where the partition starts
- `size`: Size of the partition in bytes
- `label`: Partition name
- `type`: One of the partition types (ESP_PARTITION_TYPE_*), or an integer. Note that applications can not be booted from external flash chips, so using ESP_PARTITION_TYPE_APP is not supported.
- `subtype`: One of the partition subtypes (ESP_PARTITION_SUBTYPE_*), or an integer.
- `[out] out_partition`: Output, if non-NULL, receives the pointer to the resulting `esp_partition_t` structure

```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

```c
esp_partition_type_t type
```

Partition type (app/data)

```c
esp_partition_subtype_t subtype
```

Partition subtype

```c
uint32_t address
```

Starting address of the partition in flash

```c
uint32_t size
```

Size of the partition, in bytes

```c
char label[17]
```

Partition label, zero-terminated ASCII string

```c
bool encrypted
```

Flag is set to true if partition is encrypted
Chapter 2. API Reference

Macros

ESP_PARTITION_SUBTYPE_OTA(i)

Convenience macro to get `esp_partition_subtype_t` value for the i-th OTA partition.

Type Definitions

typedef struct esp_partition_iteratorOpaque_ *esp_partition_iterator_t

Opaque partition iterator type.

Enumerations

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.

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.
```plaintext
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_ESPHTTPD = 0x80
ESPHTTPD partition.

ESP_PARTITION_SUBTYPE_DATA_FAT = 0x81
FAT partition.

ESP_PARTITION_SUBTYPE_DATA_SPIFFS = 0x82
SPIFFS partition.

ESP_PARTITION_SUBTYPE_ANY = 0xff
Used to search for partitions with any subtype.
```

Flash 加密 API 参考

Header File

- bootloader_support/include/esp_flash_encrypt.h
Chapter 2. API

Functions

static bool esp_flash_encryption_enabled (void)

Is flash encryption currently enabled in hardware?

   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 Down-
       load Mode. If both are wanted, call esp_efuse_disable_rom_download_mode() before calling this func-
       tion.

esp_flash_enc_mode_t esp_get_flash_encryption_mode (void)

Return the flash encryption mode.

The API is called during boot process but can also be called by application to check the current flash encryption
mode of ESP32

Return

void esp_flash_encryption_init_checks (void)

Check the flash encryption mode during startup.

Verifies the flash encryption config during startup:

   Note  This function is called automatically during app startup, it doesn’t need to be called from the app.

   •  Correct any insecure flash encryption settings if hardware Secure Boot is enabled.
   •  Log warnings if the efuse config doesn’t match the project config in any way

Enumerations

enum esp_flash_enc_mode_t

Values:

   ESP_FLASH_ENC_MODE_DISABLED
   ESP_FLASH_ENC_MODE_DEVELOPMENT
   ESP_FLASH_ENC_MODE_RELEASE

2.6.2  SD/SDIO/MMC 驱动程序

概述

SD/SDIO/MMC 驱动是一种基于 SDMMC 和 SD SPI 主机驱动的协议级驱动程序，目前已支持 SD 存储器、
SDIO 卡和 eMMC 芯片。
Chapter 2. API 参考

SDMMC 主机驱动和 SD SPI 主机驱动（driver/include/driver/sdmmc_host.h）为以下功能提供 API:

- 发送命令至从设备
- 接收和发送数据
- 处理总线错误

初始化函数及配置函数:

- 如需初始化和配置 SD SPI 主机，可参阅 SD SPI 主机 API

本文档中所述的 SDMMC 协议层仅处理 SD 协议相关事项，例如卡初始化和数据传输命令。

协议层通过 sdmmc_host_t 结构体和主机协同工作，该结构体包含指向主机各类函数的指针。

应用示例

ESP-IDF storage/sd_card 目录下提供了 SDMMC 驱动与 FatFs 库组合使用的示例，演示了先初始化卡，然后使用 POSIX 和 C 库 API 向卡读写数据。请参考示例目录下 README.md 文件，查看更多详细信息。

协议层 API

协议层具备 sdmmc_host_t 结构体，此结构体描述了 SD/MMC 主机驱动，列出了其功能，并提供指向驱动程序函数的指针。协议层将卡信息储存于 sdmmc_card_t 结构体中，向 SD/MMC 主机发送命令时，协议层调用时需要一个 sdmmc_command_t 结构体来描述命令、参数、预期返回值和需传输的数据（如有）。

用于 SD 存储卡的 API

1. 初始化主卡，请调用主机驱动函数，例如 sdmmc_host_init() 和 sdmmc_host_init_slot();
2. 初始化卡，请调用 sdmmc_card_init()，并将参数 host（即主机驱动信息）和参数 card（指向 sdmmc_card_t 结构体的指针）传递给此函数。函数运行结束后，将会向 sdmmc_card_t 结构体填充该卡的信息;
3. 读取或写入卡的扇区，请分别调用 sdmmc_read_sectors() 和 sdmmc_write_sectors()，并将参数 card（指向卡信息结构的指针）传递给函数;
4. 如果不再使用该卡，请调用主机驱动函数，例如 sdmmc_host_deinit()，以禁用主机外设，并释放驱动程序分配的资源。

用于 eMMC 芯片的 API 从协议层的角度而言，eMMC 存储芯片与 SD 存储卡相同。尽管 eMMC 是芯片，不具备卡的外形，但由于协议相似（sdmmc_card_t, sdmmc_card_init()），用于 SD 卡的一些概念同样适用于 eMMC 芯片。注意，eMMC 芯片不可通过 SPI 使用，因此它与 SD API 主机驱动不兼容。

如需初始化 eMMC 内存并执行读/写操作，请参照上一章节 SD 卡操作步骤。

用于 SDIO 卡的 API  SDIO 卡初始化和检测过程与 SD 存储卡相同，唯一的区别是 SDIO 模式下数据传输命令不同。

在卡初始化和卡检测（通过运行 sdmmc_card_init()）期间，驱动仅配置 SDIO 卡如下寄存器:

1. I/O 中止 (0x06) 寄存器：在该寄存器中设置 RES 位可重置卡的 I/O 部分;
2. 总线接口控制 (0x07) 寄存器：如果主机和槽配置中启用 4 线模式，则驱动程序会尝试在该寄存器中设置总线宽度字段。如果字段设置成功，则从机支持 4 线模式，主机切换至 4 线模式;
3. 高速 (0x13) 寄存器：如果主机配置中启用高速模式，则会在该寄存器中设置 SHS 位。

注意，驱动程序不会在 (1) I/O 使能寄存器和 Int 使能寄存器，及 (2) I/O 块大小中，设置任何位。应用程序可通过调用 sdmmc_io_write_byte() 来设置相关位。

如需设置卡配置或传输数据，请根据您的具体情况选择下表中的函数:
操作 | 读函数 | 写函数
--- | --- | ---
使用 IO_RW_DIRECT (CMD52) 读写单个字节。 | sdmmc_io_read_byte() | sdmmc_io_write_byte() |
使用 IO_RW_EXTENDED (CMD53) 的字节模式读写多个字节。 | sdmmc_io_read_bytes() | sdmmc_io_write_bytes() |
块模式下，使用 IO_RW_EXTENDED (CMD53) 读写数据块。 | sdmmc_io_read_blocks() | sdmmc_io_write_blocks() |

使用 `sdmmc_io_enable_int()` 函数，应用程序可启用 SDIO 中断。
在单线模式下使用 SDIO 时，还需要连接 D1 线来启用 SDIO 中断。
如果您需要应用程序保持等待直至发生 SDIO 中断，请使用 `sdmmc_io_wait_int()` 函数。

**复合卡（存储 + SDIO）** 该驱动程序不支持 SDIO 复合卡，复合卡会被视为 SDIO 卡。

**线程安全** 多数应用程序仅需在一个任务中使用协议层。因此，协议层的 `sdmmc_card_t` 结构体或在访问 SDMMC 或 SD SPI 主机驱动程序时不使用任何类型的锁。这种锁通常在较高层级实现，例如文件系统驱动程序。

**API 参考**

**Header File**
- `sdmmc/include/sdmmc_cmd.h`

**Functions**

```c
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

```c
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`

```c
esp_err_t sdmmc_write_sectors(sdmmc_card_t *card, const void *src, size_t start_sector, size_t sector_count)
```

Write given number of sectors to SD/MMC card

**Return**
- ESP_OK on success
- One of the error codes from SDMMC host controller

**Parameters**
- `card`: pointer to card information structure previously initialized using `sdmmc_card_init`
- `src`: pointer to data buffer to read data from; data size must be equal to `sector_count * card->sdsector_size`
- `start_sector`: sector where to start writing
- `sector_count`: number of sectors to write
\textbf{esp_err_t sdmmc_read_sectors \((sdmmc_card_t *\text{card}, \text{void *} \text{dst}, \text{size_t} \text{start_sector}, \text{size_t} \text{sector_count})\)}

Write given number of sectors to SD/MMC card

\textbf{Return}
- ESP_OK on success
- One of the error codes from SDMMC host controller

\textbf{Parameters}
- \text{card}: pointer to card information structure previously initialized using \text{sdmmc_card_init}
- \text{dst}: pointer to data buffer to write into; buffer size must be at least \text{sector_count} \times \text{card-csd.sector_size}
- \text{start_sector}: sector where to start reading
- \text{sector_count}: number of sectors to read

\textbf{esp_err_t sdmmc_io_read_byte \((sdmmc_card_t *\text{card}, \text{uint32_t} \text{function}, \text{uint32_t} \text{reg}, \text{uint8_t} *\text{out_byte})\)}

Read one byte from an SDIO card using IO\_RW\_DIRECT (CMD52)

\textbf{Return}
- ESP_OK on success
- One of the error codes from SDMMC host controller

\textbf{Parameters}
- \text{card}: pointer to card information structure previously initialized using \text{sdmmc_card_init}
- \text{function}: IO function number
- \text{reg}: byte address within IO function
- \text{[out]} \text{out_byte}: output, receives the value read from the card

\textbf{esp_err_t sdmmc_io_write_byte \((sdmmc_card_t *\text{card}, \text{uint32_t} \text{function}, \text{uint32_t} \text{reg}, \text{uint8_t} \text{in_byte}, \text{uint8_t} *\text{out_byte})\)}

Write one byte to an SDIO card using IO\_RW\_DIRECT (CMD52)

\textbf{Return}
- ESP_OK on success
- One of the error codes from SDMMC host controller

\textbf{Parameters}
- \text{card}: pointer to card information structure previously initialized using \text{sdmmc_card_init}
- \text{function}: IO function number
- \text{reg}: byte address within IO function
- \text{in_byte}: value to be written
- \text{[out]} \text{out_byte}: if not NULL, receives new byte value read from the card (read-after-write).

\textbf{esp_err_t sdmmc_io_read_bytes \((sdmmc_card_t *\text{card}, \text{uint32_t} \text{function}, \text{uint32_t} \text{addr}, \text{void *} \text{dst}, \text{size_t} \text{size})\)}

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 \text{sdmmc_io_read_blocks}.

\textbf{Return}
- ESP_OK on success
- ESP\_ERR\_INVALID\_SIZE if size exceeds 512 bytes
- One of the error codes from SDMMC host controller

\textbf{Parameters}
- \text{card}: pointer to card information structure previously initialized using \text{sdmmc_card_init}
- \text{function}: IO function number
- \text{addr}: byte address within IO function where reading starts
- \text{dst}: buffer which receives the data read from card
- \text{size}: number of bytes to read

\textbf{esp_err_t sdmmc_io_write_bytes \((sdmmc_card_t *\text{card}, \text{uint32_t} \text{function}, \text{uint32_t} \text{addr}, \text{const} \text{void *} \text{src}, \text{size_t} \text{size})\)}

Write multiple bytes to an SDIO card using IO\_RW\_EXTENDED (CMD53)
This function performs write operation using CMD53 in byte mode. For block mode, see sdmmc_io_write_blocks.

Return
- ESP_OK on success
- ESP_ERR_INVALID_SIZE if size exceeds 512 bytes
- One of the error codes from SDMMC host controller

Parameters
- card: pointer to card information structure previously initialized using sdmmc_card_init
- function: IO function number
- addr: byte address within IO function where writing starts
- src: data to be written
- size: number of bytes to write

```c
esp_err_t sdmmc_io_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
- dst: buffer which receives the data read from card
- size: number of bytes to read, must be divisible by the card block size.

```c
esp_err_t sdmmc_io_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.

```c
esp_err_t sdmmc_io_enable_int (sdmmc_card_t *card)
```
Enable SDIO interrupt in the SDMMC host

Return
- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if the host controller does not support IO interrupts

Parameters
- card: pointer to card information structure previously initialized using sdmmc_card_init

```c
esp_err_t sdmmc_io_wait_int (sdmmc_card_t *card, TickType_t timeout_ticks)
```
Block until an SDIO interrupt is received

Slave uses D1 line to signal interrupt condition to the host. This function can be used to wait for the interrupt.

Return
Chapter 2. API

- 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

\[
\text{esp_err_t sdmmc_io_get_cis_data (sdmmc_card_t *card, uint8_t *out_buffer, size_t buffer_size, size_t *inout_cis_size)}
\]

Get the data of CIS region of a 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.

\[
\text{esp_err_t sdmmc_io_print_cis_info (uint8_t *buffer, size_t buffer_size, FILE *fp)}
\]

Parse and print the CIS information of a 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.

\[
\text{using sdmmc_card_init}
\]

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
- driver/include/driver/sdmmc_types.h

Structures
\[
\text{struct sdmmc_csd_t}
\]
Decoded values from SD card Card Specific Data register
Public Members

int csd_ver
CSD structure format

int mmc_ver
MMC version (for CID format)

int capacity
total number of sectors

int sector_size
sector size in bytes

int read_block_len
block length for reads

int card_command_class
Card Command Class for SD

int tr_speed
Max transfer speed

struct sdmmc_cid_t
Decoded values from SD card Card IDentification register

Public Members

int mfg_id
manufacturer identification number

int oem_id
OEM/product identification number

char name[8]
product name (MMC v1 has the longest)

int revision
product revision

int serial
product serial number

int date
manufacturing date

struct sdmmc_scr_t
Decoded values from SD Configuration Register

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
\texttt{struct sdmmc_switch_func_rsp_t}

SD SWITCH_FUNC response buffer

\textbf{Public Members}

uint32_t \texttt{data}[512 / 8 / sizeof(uint32_t)]

response data

\texttt{struct sdmmc_command_t}

SD/MMC command information

\textbf{Public Members}

uint32_t \texttt{opcode}

SD or MMC command index

uint32_t \texttt{arg}

SD/MMC command argument

\texttt{sdmmc_response_t \texttt{response}}

response buffer

void *\texttt{data}

buffer to send or read into

size_t \texttt{datalen}

length of data buffer

size_t \texttt{blklen}

block length

int \texttt{flags}

see below

\texttt{esp_err_t \texttt{error}}

error returned from transfer

int \texttt{timeout_ms}

response timeout, in milliseconds

\texttt{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.

\textbf{Public Members}

uint32_t \texttt{flags}

flags defining host properties

int \texttt{slot}

slot number, to be passed to host functions

int \texttt{max_freq_khz}

max frequency supported by the host

float \texttt{io_voltage}

I/O voltage used by the controller (voltage switching is not supported)

\texttt{esp_err_t (*init)(void)}

Host function to initialize the driver
Chapter 2. API

```c
esp_err_t (*set_bus_width)(int slot, size_t width)
host function to set bus width

size_t (*get_bus_width)(int slot)
host function to get bus width

esp_err_t (*set_bus_ddr_mode)(int slot, bool ddr_enable)
host function to set DDR mode

esp_err_t (*set_card_clk)(int slot, uint32_t freq_khz)
host function to set card clock frequency

esp_err_t (*do_transaction)(int slot, sdmmc_command_t *cmdinfo)
host function to do a transaction

esp_err_t (*deinit)(void)
host function to deinitialize the driver

esp_err_t (*deinit_p)(int slot)
host function to deinitialize the driver, called with the slot

esp_err_t (*io_int_enable)(int slot)
Host function to enable SDIO interrupt line

esp_err_t (*io_int_wait)(int slot, TickType_t timeout_ticks)
Host function to wait for SDIO interrupt line to be active

int command_timeout_ms
timeout, in milliseconds, of a single command. Set to 0 to use the default value.
```

```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

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

typedef uint32_t sdmmc_response_t[4]
    SD/MMC command response buffer

2.6.3 非易失性存储库

简介

非易失性存储 (NVS) 库主要用于在 flash 中存储键值格式的数据。本文档将详细介绍 NVS 常用的一些概念。
Chapter 2. API 参考

**底层存储**  
NVS 通过调用 `spi_flash_(read|write|erase)` API 对主 flash 的部分空间进行读、写、擦除操作，包括 data 类型和 nvs 子类型的所有分区。应用程序可调用 `nvs_open` API 选择使用带有 nvs 标签的分区，也可以通过调用 `nvs_open_from_part` API 选择使用指定名称的任意分区。

NVS 库后续版本可能会增加其他存储器后端，实际将数据保存至其他 flash 芯片 (SPI 或 I2C 接口)、RTC 或 FRAM 中。

**注解:** 如果 NVS 分区被裁剪（例如，更改分区表布局时），则应删除分区内容。可以使用 ESP-IDF 构建系统中的 `idf.py erase_flash` 命令擦除 flash 上的所有内容。

**注解:** NVS 最适合存储一些较小的数据，而非字符串或二进制大对象 (BLOB) 等较大的数据。如需存储较大的 BLOB 或者字符串，请考虑使用基于磨损均衡的 FAT 文件系统。

**键值对**  
NVS 的操作对象为键值对，其中键是 ASCII 字符串，当前支持最大键长为 15 个字符，值可以为以下几种类型：
- 整数型: `uint8_t`、`int8_t`、`uint16_t`、`int16_t`、`uint32_t`、`int32_t`、`uint64_t` 和 `int64_t`；
- 以 \0 结尾的字符串；
- 可变长度的二进制数据 (BLOB)

**注解:** 字符串值当前上限为 4000 字节，其中包括空终止符。BLOB 值上限为 508,000 字节或分区大小减去 4000 字节的 97.6%，以较低值为准。

后续可能会增加对 `float` 和 `double` 等其他类型数据的支持。

键必须唯一。为现有的键写入新的值可能产生如下结果：
- 如果新旧值数据类型相同，则更新值；
- 如果新旧值数据类型不同，则返回错误。

读取时也会执行数据类型检查。如果读取操作的数据类型与该值的数据类型不匹配，则返回错误。

**命名空间**  
为了减少不同组件之间键名的潜在冲突，NVS 将每个键值对分配给一个命名空间。命名空间的命名规则遵循键名的命名规则，即最多可占 15 个字符。命名空间的名称在调用 `nvs_open` 或 `nvs_open_from_part` 中指定，调用后将返回一个不透明句柄，用于后续调用 `nvs_get_*`、`nvs_set_*` 和 `nvs_commit` 函数。这样，一个句柄关联一个命名空间，键名不会与其他命名空间中相同键名冲突。请注意，不同 NVS 分区中具有相同名称的命名空间将被视为不同的命名空间。

**安全性、篡改性及鲁棒性**  
NVS 与 ESP32 flash 加密系统不直接兼容。但如果 NVS 加密与 ESP32 flash 加密一起使用时，数据仍可以加密形式存储。更多详情请参阅 NVS 加密。

如果未启用 NVS 加密，任何对 flash 芯片有物理访问权限的人都可以修改、擦除或添加键值对。NVS 加密启用后，如果不知道相应的 NVS 加密密钥，则无法修改或添加键值对并将其识别为有效键值。但是，针对擦除操作没有相应的防篡改功能。

当 flash 处于不一致状态时，NVS 库会尝试恢复。在任何时间点关闭设备电源，然后重新打开电源，不会导致数据丢失；但如果关闭设备电源时正在写入新的键值对，这一键值对可能会丢失。该库还应当能对 flash 中的任意数据进行正确初始化。

**内部实现**

**键值对日志**  
NVS 按顺序存储键值对，新的键值对添加在最后。因此，如需更新某一键值对，实际是在日志最后增加一对新的键值对，同时将旧的键值对标记为已擦除。
Chapter 2. API 参考

页面和条目 NVS 库在其操作中主要使用两个实体：页面和条目。页面是一个逻辑结构，用于存储部分的整体日志。逻辑页面对应 flash 的一个物理扇区，正在使用中的页面具有与之相关联的序列号。序列号赋予了页面顺序，较高的序列号对应较早创建的页面。页面有以下几种状态：

空或未初始化 页面对应的 flash 扇区为空白状态（所有字节均为 0xff）。此时，页面未存储任何数据且没有关联的序列号。

活跃状态 此时 flash 已完成初始化，页头部写入 flash，页面已具备有效序列号。页面中存在一些空条目，可写入数据。任意时刻，至多有一个页面处于活跃状态。

写满状态 Flash 已写满键值对，状态不再改变。用户无法向写满状态下的页面写入新键值对，但仍可将一些键值对标记为已擦除。

擦除状态 未擦除的键值对将移至其他页面，以便擦除当前页面。这一状态仅为暂时性状态，即 API 调用返回时，页面应脱离这一状态。如果设备突然断电，下次开机时，设备将继续把未擦除的键值对移至其他页面，并继续擦除当前页面。

损坏状态 页面包含无效数据，无法进一步解析该页面中的数据，因此之前写入该页面的所有条目均无法访问。相应的 flash 扇区并不会被立即擦除，而是与其他处于未初始化状态的扇区一起等待后续使用。这一状态可能对调试有用。

Flash 扇区映射至逻辑页面并没有特定的顺序，NVS 库会检查存储在 flash 扇区的页面序列号，并根据序列号组织页面。

| +---+ | +---+ | +---+ | +---+ | +---+ |
| Page 1 | Page 2 | Page 3 | Page 4 |
| Full | Full | Active | Empty |
| | | | |
| +---+ | +---+ | +---+ | +---+ | +---+ |
| #11 | #12 | #14 | |
| | | | |
| +---+ | +---+ | +---+ | +---+ | +---+ |
| v | v | v | v |
| | | | |
| +---+ | +---+ | +---+ | +---+ | +---+ |
| Sector 3 | Sector 0 | Sector 2 | Sector 1 |

页面结构 当前，我们假设 flash 扇区大小为 4096 字节，并且 ESP32 flash 加密硬件在 32 字节块上运行。未来有可能引入一些编译时可配置项（可通过 menuconfig 进行配置），以适应具有不同扇区大小的 flash 芯片。但目前尚不清楚 SPI flash 驱动和 SPI flash cache 之类的系统组件是否支持其他扇区大小。

页面由头部、条目状态位图和条目三部分组成。为了实现与 ESP32 flash 加密功能兼容，条目大小设置为 32 字节。如果键值为整数类型，则条目为一个键值对：如果键值为字符串或 BLOB 类型，则条目仅保存一个键值对的部分内容（更多信息详见条目结构描述）。

页面结构如下图所示，括号内表示该部分的大小（以字节为单位）：

<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>面头部 (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>/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/</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>

头部和条目状态位图写入 flash 时不加密。如果启用了 ESP32 flash 加密功能，则条目写入 flash 时将会加密。

通过将 0 写入某些位可以定义页面状态值，表示状态改变。因此，如果需要变更页面状态，并不一定要擦除页面，除非要将其更改为擦除状态。
### Chapter 2. API 参考

头部中的 version 字段反映了所用的 NVS 格式版本。为实现向后兼容，版本升级从 0xff 开始依次递减（例如，version-1 为 0xff，version-2 为 0xfe 等）。

头部中 CRC32 值是由不包含状态值的条目计算所得（4 到 28 字节）。当前未使用的条目用 0xff 字节填充。

条目结构和条目状态位图详细信息见下文描述。

#### 条目和条目状态位图
每个条目可处于以下三种状态之一，每个状态在条目状态位图中用两位表示。位图中的最后四位 (256 - 2 * 126) 未使用。

| 空 (2‘b11) | 条目还未写入任何内容，处于未初始化状态（全部字节为 0xff）。
| 写入 (2’b10) | 一个键值对（或跨多个条目的键值对的部分内容）已写入条目中。
| 擦除 (2’b00) | 条目中的键值对已丢弃，条目内容不再解析。 |

#### 条目结构
如果键值类型为基础类型，即 1-8 个字节长度的整数型，条目将保存一个键值对；如果键值类型为字符串或 BLOB 类型，条目将保存整个键值对的部分内容。另外，如果键值为字符串类型且跨多个条目，则键值所跨的所有条目均保存在同一页面。BLOB 则可以切分为多个块，实现跨多个页面。

BLOB 索引是一个附加的固定长度元数据条目，用于追踪 BLOB 块。目前条目仍支持早期 BLOB 格式（可读取可修改），但这些 BLOB 一经修改，即以新格式储存至条目。

<table>
<thead>
<tr>
<th>ChunkStart(1)</th>
<th>Rsv(2)</th>
<th>Data format</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>8+7+6+5+4+3+2+1+0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Strings, BLOB Data)</td>
</tr>
</tbody>
</table>

条目结构中各个字段含义如下：

#### 命名空间 (NS, NameSpace)
该条目的命名空间索引，详细信息见命名空间实现章节。

#### 类型 (Type)
一个字节表示此数据类型，可能的类型见 nvs_types.h 中 itemType 枚举。

#### 跨度 (Span)
该键值对所用的条目数量。如果键值为整数型，条目数量即为 1，如果键值为字符串或 BLOB，则条目数量取决于值的长度。

#### 块索引 (ChunkIndex)
用于存储 BLOB 类型数据块的索引。如果键值为其他数据类型，则此处索引应写入 0xff。

#### CRC32
对条目下所有字节进行校验，所得的校验和（CRC32 字段不计算在内）。

#### 键 (Key)
即以零结尾的 ASCII 字符串，字符串最长为 15 字节，不包含最后一个字节的 NULL (\0) 终止符。

#### 数据 (Data)
如果键值类型为整数型，则数据字段仅包含键值。如果键值小于八个字节，使用 0xff 填充未使用的部分 (右侧)。

如果键值类型为 BLOB 索引条目，该字段的八个字节将保存以下数据块信息：

- **块大小** 整个 BLOB 数据的大小（以字节为单位）。该字段仅用于 BLOB 索引类型条目。
Chapter 2. API 参考

- ChunkCount 存储过程中 BLOB 分成的数据块数量。该字段仅用于 BLOB 索引类型条目。
- ChunkStart BLOB 第一个数据块的块索引，后续数据块索引依次递增，步长为 1。该字段仅用于 BLOB 索引类型条目。

如果键值类型为字符串或 BLOB 数据块，数据字段的这八个字节将保存该键值的一些附加信息，如下所示：
- 数据大小 实际数据的大小（以字节为单位）。如果键值类型为字符串，此字段也应将零终止符包含在内。此字段仅用于字符串和 BLOB 类型条目。
- CRC32 数据所有字节的校验和，该字段仅用于字符串和 BLOB 类型条目。

可变长度值（字符串和 BLOB）写入后续条目，每个条目 32 字节。第一个条目的 span 字段将指明使用了多少条目。

命名空间 如上所述，每个键值对属于一个命名空间。命名空间标识符（字符串）也作为键值对的键，存储在索引为 0 的命名空间中。与这些键对应的值就是这些命名空间的索引。

```
| NS-0 Type=uint8_t Key="wifi" Value=1 | Entry describing namespace "wifi"
| NS-1 Type=uint32_t Key="channel" Value=6 | Key "channel" in namespace "wifi"
| NS-0 Type=uint8_t Key="pwm" Value=2 | Entry describing namespace "pwm"
| NS-2 Type=uint16_t Key="channel" Value=20 | Key "channel" in namespace "pwm"
```

条目哈希列表 为了减少对 flash 执行的读操作次数，Page 类对象均设有一个列表，包含一个数据：
条目索引和条目哈希值。该列表可大大提高检索速度。无需迭代所有条目并逐个从 flash 中读取。
Page->findItem 首先从哈希列表中检索条目哈希值。如果条目存在，则在页面内给出条目索引。由于哈希冲突，在哈希列表中检索条目哈希值可能会得到不同的条目。对 flash 中条目再次迭代可解决这一冲突。

哈希列表中每个节点均包含一个 24 位哈希值和 8 位条目索引。哈希值根据条目命名空间、键名和块索引
由 CRC32 计算所得，计算结果保留 24 位。为减少将 32 位条目存储在链表中的开销，链表采用了数组的
双向链表。每个数组占用 128 个字节，包含 29 个条目，两个链表指针和一个 32 位计数字段。因此，每
页额外需要的 RAM 最少为 128 字节，最多为 640 字节。

NVS 加密

NVS 分区内存储的数据可使用 AES-XTS 进行加密。类似于 IEEE P1619 磁盘加密标准中提到的加密方式。
为了实现加密，每个条目被均视为一个扇区，并将条目相对地址（相对于分区开头）传递给加密算法，
用作扇区号。NVS 加密所需的密钥存储于其他分区，并进行了 flash 加密。因此，在使用 NVS 加密前
应先启用 flash 加密。

NVS 密钥分区 应用程序如果想使用 NVS 加密，则需要编译进一个类型为 data，子类型为 key 的密
钥分区。该分区应标记为已加密，且最小为 4096 字节，具体结构见下表。如需了解更多信息，请参
考分区表。

```
| XTS encryption key(32) |
| XTS tweak key (32) |
| CRC32 (4) |
```

使用 NVS 分区生成程序生成上述分区表，并烧录至设备。由于分区已标记为已加密，而且启用了 flash 加密，引导程序在首次启动时将使用 flash 加密对密钥分区进行加密。您也可以在设备启动后调用
nvs_flash.h 提供的 nvs_flash_generate_keys API 生成加密密钥，然后再将密钥以加密形式写入密钥分区。

应用程序可以使用不同的密钥对不同的 NVS 分区进行加密，这样就会需要多个加密密钥分区。应用程序应为加解密操作提供正确的密钥或加密分区。

加密读取/写入 nvs_get_* 和 nvs_set_* 等 NVS API 函数同样可以对 NVS 加密分区执行读写操作。但用于初始化 NVS 非加密分区和加密分区的 API 则有所不同：初始化 NVS 非加密分区可以使用 nvs_flash_init 和 nvs_flash_init_partition，但初始化 NVS 加密分区则需调用 nvs_flash_secure_init 和 nvs_flash_secure_init_partition。上述 API 函数所需的 nvs_sec_cfg_t 结构可使用 nvs_flash_generate_keys 或者 nvs_flash_generate_keys 进行填充。

应用程序如需在加密状态下执行 NVS 读写操作，应遵循以下步骤：

1. 使用 esp_partition_find* API 查找密钥分区和 NVS 数据分区；
2. 使用 nvs_flash_read_security_cfg 或 nvs_set_security_key API 填充 nvs_sec_cfg_t 结构；
3. 使用 nvs_flash_secure_init 或 nvs_flash_secure_init_partition API 初始化 NVS flash 分区；
4. 使用 nvs_open 或 nvs_open_from_part API 打开命名空间；
5. 使用 nvs_get_* 或 nvs_set_* API 执行 NVS 读取/写入操作；
6. 使用 nvs_flash_deinit API 释放已初始化的 NVS 分区。

NVS 迭代器 迭代器允许根据指定的分区名称、命名空间和数据类型轮询 NVS 中存储的键值对。

您可以使用以下函数，执行相关操作：

- nvs_entry_find: 返回一个不透明句柄，用于后续调用 nvs_entry_next 和 nvs_entry_info 函数；
- nvs_entry_next: 返回指向下一个键值对的迭代器；
- nvs_entry_info: 返回每个键值对的信息。

如果未找到符合标准的键值对，nvs_entry_find 和 nvs_entry_next 将返回 NULL，此时不必释放迭代器。若不再需要迭代器，可使用 nvs_release_iterator 释放迭代器。

NVS 分区生成程序

NVS 分区生成程序帮助生成 NVS 分区二进制文件，使用烧录程序将二进制文件单独烧录至特定分区。

烧录至分区上的键值对由 CSV 文件提供，详情请参考 NVS 分区生成程序。

应用示例

ESP-IDF storage 目录下提供了两个代码示例：

storage/nvs_rw_value

演示如何读取及写入 NVS 单个整数值。

此示例中的值表示 ESP32 模拟重启动次数。NV 中不会因为模组重启而丢失，因此只有将这一值存储于 NVS 中，才能起到重启动次数计数器的作用。

该示例也演示了如何检测读取/写入操作是否成功，以及某个特定值是否在 NVS 中尚未初始化。诊断程序以纯文本形式提供，帮助您追踪程序流程，及时发现问题。

storage/nvs_rw_blob

演示如何读取及写入 NVS 单个整数值和 Blob（二进制大对象），并在 NVS 中存储该数值，即便 ESP32 模拟重启也不会消失。

* value - 记录 ESP32 模拟软重启次数和硬重启次数。
Chapter 2. API 参考

- blob - 内含记录模组运行次数的表格。此表格将被从 NVS 读取至动态分配的 RAM 上。每次手动重置后，表格内运行次数即增加一次，新加的运行次数被写入 NVS。下拉 GPIO0 即可手动软重启。

该示例也演示了如何执行诊断程序以检测读取/写入操作是否成功。

API 参考

Header File
- 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.
  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
  - one of the error codes from the underlying flash storage driver

- 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
  - one of the error codes from the underlying flash storage driver

- esp_err_t nvs_flash_init_partition_ptr (const esp_partition_t *partition)
  Initialize NVS flash storage for the partition specified by partition pointer.
  Parameters
  - [in] partition_label: Label of the partition. Must be no longer than 16 characters.
  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
  - one of the error codes from the underlying flash storage driver

- 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

- esp_err_t nvs_flash_deinit_partition (const char *partition_label)
  Deinitialize NVS storage for the given NVS partition.
  Return
  - ESP_OK on success
Chapter 2. API

- 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.

Erasess 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 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
- 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.

**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 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
- one of the error codes from the underlying flash storage driver

Parameters

- \[\text{partition} \]: Label of the partition. Note that internally a reference to passed value is kept and it should be accessible for future operations
- \[\text{cfg} \]: Security configuration (keys) to be used for NVS encryption/decryption. If cfg is null, no encryption/decryption is used.

```c
esp_err_t 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; -or error codes from esp_partition_write/erase APIs.

Parameters

- \[\text{partition} \]: Pointer to partition structure obtained using esp_partition_find_first or esp_partition_get. Must be non-NULL.
- \[\text{cfg} \]: Pointer to nvs security configuration structure. Pointer must be non-NULL. Generated keys will be populated in this structure.

```c
esp_err_t 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_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

- \[\text{partition} \]: Pointer to partition structure obtained using esp_partition_find_first or esp_partition_get. Must be non-NULL.
- \[\text{cfg} \]: Pointer to nvs security configuration structure. Pointer must be non-NULL.

Structures

```c
struct nvs_sec_cfg_t
```

Key for encryption and decryption.

Public Members

- \[\text{eky} \]: XTS encryption and decryption key
- \[\text{tky} \]: XTS tweak key

Macros

```c
NVS_KEY_SIZE
```

Header File

- nvs_flash/include/nvs.h

Functions

```c
esp_err_t esp_err_t nvs_set_i8 (nvs_handle_t handle, const char *key, int8_t value)
```

set 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 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.

```c
esp_err_t nvs_set_u8 (nvs_handle_t handle, const char* key, uint8_t value)
```

```c
esp_err_t nvs_set_i16 (nvs_handle_t handle, const char* key, int16_t value)
```

```c
esp_err_t nvs_set_u16 (nvs_handle_t handle, const char* key, uint16_t value)
```

```c
esp_err_t nvs_set_i32 (nvs_handle_t handle, const char* key, int32_t value)
```

```c
esp_err_t nvs_set_u32 (nvs_handle_t handle, const char* key, uint32_t value)
```

```c
esp_err_t nvs_set_i64 (nvs_handle_t handle, const char* key, int64_t value)
```

```c
esp_err_t nvs_set_u64 (nvs_handle_t handle, const char* key, uint64_t value)
```

```c
esp_err_t nvs_set_str (nvs_handle_t handle, const char* key, const char* 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.

```c
esp_err_t nvs_get_i8 (nvs_handle_t handle, const char* key, int8_t* out_value)
```

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.

All functions expect out_value to be a pointer to an already allocated variable of the given type.

```c
// Example of using nvs_get_i32:
int32_t max_buffer_size = 4096; // default value
esp_err_t err = nvs_get_i32(my_handle, "max_buffer_size", &max_buffer_size);
assert(err == ESP_OK || err == ESP_ERR_NVS_NOT_FOUND);
// if ESP_ERR_NVS_NOT_FOUND was returned, max_buffer_size will still
// have its default value.
```

**Return**
- ESP_OK if the value was retrieved successfully
- ESP_ERR_NVS_NOT_FOUND if the requested key doesn’t exist
- ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL
- ESP_ERR_NVS_INVALID_NAME if key name doesn’t satisfy constraints
- ESP_ERR_NVS_INVALID_LENGTH if length is not sufficient to store data

**Parameters**
- `[in] handle`: Handle obtained from nvs_open function.
- `[in] key`: Key name. Maximal length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
• out_value: Pointer to the output value. May be NULL for nvs_get_str and nvs_get_blob, in this case required length will be returned in length argument.

```c
esp_err_t nvs_get_u8 (nvs_handle_t handle, const char *key, uint8_t *out_value)
esp_err_t nvs_get_i16 (nvs_handle_t handle, const char *key, int16_t *out_value)
esp_err_t nvs_get_u16 (nvs_handle_t handle, const char *key, uint16_t *out_value)
esp_err_t nvs_get_i32 (nvs_handle_t handle, const char *key, int32_t *out_value)
esp_err_t nvs_get_u32 (nvs_handle_t handle, const char *key, uint32_t *out_value)
esp_err_t nvs_get_i64 (nvs_handle_t handle, const char *key, int64_t *out_value)
esp_err_t nvs_get_u64 (nvs_handle_t handle, const char *key, uint64_t *out_value)
esp_err_t nvs_get_str (nvs_handle_t handle, const char *key, char *out_value, size_t *length)
```

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);
nvs_get_str(my_handle, "server_name", server_name, &required_size);

// 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_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)
```
**esp_err_t** `nvs_open` *(const char* *name*, nvs_open_mode_t *open_mode*, nvs_handle_t *out_handle)*

Open non-volatile storage with a given namespace from the default NVS partition.

Multiple internal ESP-IDF and third party application modules can store their key-value pairs in the NVS module. In order to reduce possible conflicts on key names, each module can use its own namespace. The default NVS partition is the one that is labelled "nvs" in the partition table.

**Return**

- ESP_OK if storage handle was opened successfully
- ESP_ERR_NVS_NOT_INITIALIZED if the storage driver is not initialized
- ESP_ERR_NVS_PART_NOT_FOUND if the partition with label "nvs" is not found
- ESP_ERR_NVS_NOT_FOUND id namespace doesn’t exist yet and mode is NVS_READONLY
- ESP_ERR_NVS_INVALID_NAME if namespace name doesn’t satisfy constraints
- 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.

**esp_err_t** `nvs_open_from_partition` *(const char *part_name*, const char *name*, nvs_open_mode_t *open_mode*, nvs_handle_t *out_handle)*

Open non-volatile storage with a given namespace from specified partition.

The behaviour is same as `nvs_open()` API. However this API can operate on a specified NVS partition instead of default NVS partition. Note that the specified partition must be registered with NVS using `nvs_flash_init_partition()` API.

**Return**

- ESP_OK if storage handle was opened successfully
- ESP_ERR_NVS_NOT_INITIALIZED if the storage driver is not initialized
- ESP_ERR_NVS_PART_NOT_FOUND if the partition with specified name is not found
- ESP_ERR_NVS_NOT_FOUND id namespace doesn’t exist yet and mode is NVS_READONLY
- ESP_ERR_NVS_INVALID_NAME if namespace name doesn’t satisfy constraints
- other error codes from the underlying storage driver

**Parameters**

- [in] *part_name*: Label (name) of the partition of interest for object read/write/erase
- [in] *name*: Namespace name. Maximal length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
- [in] *open_mode*: NVS_READWRITE or NVS_READONLY. If NVS_READONLY, will open a handle for reading only. All write requests will be rejected for this handle.
- [out] *out_handle*: If successful (return code is zero), handle will be returned in this argument.

**esp_err_t** `nvs_set_blob` *(nvs_handle_t *handle*, const char *key*, const void *value*, size_t *length)*

set variable length binary value for given key

This family of functions set value for the key, given its name. Note that actual storage will not be updated until `nvs_commit` function is called.

**Return**

- ESP_OK if value was set successfully
- ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL
- ESP_ERR_NVS_READ_ONLY if storage handle was opened as read only
- ESP_ERR_NVS_INVALID_NAME if key name doesn’t satisfy constraints
- ESP_ERR_NVS_NOT_ENOUGH_SPACE if there is not enough space in the underlying storage to save the value
- ESP_ERR_NVS_REMOVE_FAILED if the value wasn’t updated because flash write operation has failed. The value was written however, and update will be finished after re-initialization of nvs, provided that flash operation doesn’t fail again.
- ESP_ERR_NVS_VALUE_TOO_LONG if the value is too long

**Parameters**
• **[in]** `handle`: Handle obtained from `nvs_open` function. Handles that were opened read only cannot be used.

• **[in]** `key`: Key name. Maximal length is `(NVS_KEY_NAME_MAX_SIZE-1)` characters. Shouldn’t be empty.

• **[in]** `value`: The value to set.

• **[in]** `length`: Length of binary value to set, in bytes; Maximum length is 508000 bytes or `(97.6%` of the partition size - 4000) bytes whichever is lower.

```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.

```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**
- **[in]** `handle`: Storage handle to close

```c
esp_err_t nvs_get_stats(const char *part_name, nvs_stats_t *nvs_stats)
```
Fill structure `nvs_stats_t`. It provides info about used memory the partition.
This function calculates to runtime the number of used entries, free entries, total entries, and amount namespace in partition.

```c
// Example of nvs_get_stats() to get the number of used entries and free_
//entries:
ns_stats_t nvs_stats;
nvs_get_stats(NULL, &nvs_stats);
printf("Count: UsedEntries = (%d), FreeEntries = (%d), AllEntries = (%d)\n",
    nvs_stats.used_entries, nvs_stats.free_entries, nvs_stats.total_
//entries);
```

**Return**

- ESP_OK if the changes have been written successfully. Return param nvs_stats will be filled.
- ESP_ERR_NVS_PART_NOT_FOUND if the partition with label “name” is not found. Return param nvs_stats will be filled 0.
- ESP_ERR_NVS_NOT_INITIALIZED if the storage driver is not initialized. Return param nvs_stats will be filled 0.
- ESP_ERR_INVALID_ARG if nvs_stats equal to NULL.
- ESP_ERR_INVALID_STATE if there is page with the status of INVALID. Return param nvs_stats will be filled not with correct values because not all pages will be counted. Counting will be interrupted at the first INVALID page.

**Parameters**

- [in] part_name: Partition name NVS in the partition table. If pass a NULL than will use NVS_DEFAULT_PART_NAME (”nvs”).
- [out] nvs_stats: Returns filled structure nvs_states_t. It provides info about used memory the partition.

```c
e.sp_err_t nvs_get_used_entry_count (nvs_handle_t handle, size_t *used_entries)
```

Calculate all entries in a namespace.

Note that to find out the total number of records occupied by the namespace, add one to the returned value used_entries (if err is equal to ESP_OK). Because the name space entry takes one entry.

```c
// Example of nvs_get_used_entry_count() to get amount of all key-value pairs_
in one namespace:
nvs_handle_t handle;
nvs_open("namespace1", NVS_READWRITE, &handle);
...
size_t used_entries;
size_t total_entries_namespace;
if(nvs_get_used_entry_count(handle, &used_entries) == ESP_OK){
    // the total number of records occupied by the namespace
    total_entries_namespace = used_entries + 1;
}
```

**Return**

- ESP_OK if the changes have been written successfully. Return param used_entries will be filled valid value.
- ESP_ERR_NVS_NOT_INITIALIZED if the storage driver is not initialized. Return param used_entries will be filled 0.
- ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL. Return param used_entries will be filled 0.
- ESP_ERR_INVALID_ARG if used_entries equal to NULL.
- Other error codes from the underlying storage driver. Return param used_entries will be filled 0.

**Parameters**

- [in] handle: Handle obtained from nvs_open function.
- [out] used_entries: Returns amount of used entries from a namespace.

```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.
Example of listing all the key-value pairs of any type under specified partition and namespace:

```c
nvs_iterator_t it = nvs_entry_find(partition, namespace, NVS_TYPE_ANY);
while (it != NULL) {
    nvs_entry_info_t info;
    nvs_entry_info(it, &info);
    it = nvs_entry_next(it);
    printf("key '%s', type '%d' \n", info.key, info.type);
}
```

// Note: no need to release iterator obtained from nvs_entry_find function when // nvs_entry_find or nvs_entry_next function return NULL, indicating no // other element for specified criteria was found.

Return Iterator used to enumerate all the entries found, or NULL if no entry satisfying criteria was found.

Parameters
- [in] part_name: Partition name
- [in] namespace_name: Set this value if looking for entries with a specific namespace. Pass NULL otherwise.
- [in] type: One of nvs_type_t values.

`nvs_iterator_t nvs_entry_next (nvs_iterator_t iterator)`

Returns next item matching the iterator criteria, NULL if no such item exists.

Note that any copies of the iterator will be invalid after this call.

Return NULL if no entry was found, valid nvs_iterator_t otherwise.

Parameters
- [in] iterator: Iterator obtained from nvs_entry_find function. Must be non-NULL.

`void nvs_entry_info (nvs_iterator_t iterator, nvs_entry_info_t *out_info)`

Fills nvs_entry_info_t structure with information about entry pointed to by the iterator.

Parameters
- [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.

`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

`struct nvs_entry_info_t`

information about entry obtained from nvs_entry_info function

Public Members

char namespace_name[16]
    Namespace to which key-value belong

char key[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_NVS_INVALID_NAME
    Namespace name doesn’t satisfy constraints

ESP_ERR_NVS_INVALID_HANDLE
    Handle has been closed or is NULL

ESP_ERR_NVS_REMOVE_FAILED
    The value wasn’t updated because flash write operation has failed. The value was written however, and update will be finished after re-initialization of nvs, provided that flash operation doesn’t fail again.

ESP_ERR_NVS_KEY_TOO_LONG
    Key name is too long

ESP_ERR_NVS_PAGE_FULL
    Internal error; never returned by nvs API functions

ESP_ERR_NVS_INVALID_STATE
    NVS is in an inconsistent state due to a previous error. Call nvs_flash_init and nvs_open again, then retry.

ESP_ERR_NVS_INVALID_LENGTH
    String or blob length is not sufficient to store data

ESP_ERR_NVS_NO_FREE_PAGES
    NVS partition doesn’t contain any empty pages. This may happen if NVS partition was truncated. Erase the whole partition and call nvs_flash_init again.

ESP_ERR_NVS_VALUE_TOO_LONG
    String or blob length is longer than supported by the implementation
Chapter 2. API

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_ENCFAILED
XTS encryption failed while writing NVS entry.

ESP_ERR_NVS_XTS_DECFAILED
XTS decryption failed while reading NVS entry.

ESP_ERR_NVS_XTS_CFGFAILED
XTS configuration setting failed.

ESP_ERR_NVS_XTS_CFGNOTFOUND
XTS configuration not found.

ESP_ERR_NVS_ENCRNOTSUPPORTED
NVS encryption is not supported in this version.

ESP_ERR_NVS.KeysNOTINITIALIZED
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.

NV.S_DEFAULT.PART.NAME
Default partition name of the NVS partition in the partition table.

NV.S_PART.NAME.MAX.SIZE
Maximum length of partition name (excluding null terminator).

NV.S.KEY.NAME.MAX.SIZE
Maximal 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

ten nvs_open_mode_t
Mode of opening the non-volatile storage.

Values:

  NVS_READONLY
  Read only

  NVS_READWRITE
  Read and write
enum nvs_type_t
Types of variables.

Values:
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 分区生成程序

介绍

NVS 分区生成程序 (nvs_flash/nvs_partition_generator/nvs_partition_gen.py) 根据 CSV 文件中的键值对生成二进制文件。该二进制文件与非易失性存储器 (NVS) 中定义的 NVS 结构兼容。NVS 分区生成程序适合用于生成二进制数据 (Blob)，其中包括设备生产时可从外部烧录的 ODM/OEM 数据。这也使得生产商在使用同一个固件的基础上，通过自定义参数，如序列号等，为每个设备生成不同配置。

准备工作

在加密模式下使用该程序，需安装下列软件包：
  • cryptography package

根目录下的 requirements.txt 包含必需 python 包，请预先安装。

CSV 文件格式

.csv 文件每行需包含四个参数，以逗号隔开。具体参数描述见下表:
### 序号 | 参数 | 描述 | 说明
--- | --- | --- | ---
1 | Key | 主键，应用程序可通过查询此键来获取数据。 | 无
2 | Type | 支持 file、data 和 namespace。 | 无
3 | Encoding | 支持 u8,i8,u16,u32,i32,string,hex2bin,base64 和 binary。决定二进制 bin 文件中 value 被编码成的类型。string 和 binary 编码的区别在于，string 数据以 NULL 字符结尾，binary 数据则不是。 | file 类型当前仅支持 hex2bin、base64、string 和 binary 编码。
4 | Value | Data value | namespace 字段的 encoding 和 value 应为空。namespace 的 encoding 和 value 为固定值，不可设置。这些单元格中的所有值都会被忽视。

**注解**：CSV 文件的第一行应为列标题，不可设置。

此类 CSV 文件的 Dump 示例如下：

```
key,type,encoding,value  <-- 列标题
namespace_name,namespace,, <-- 第一个条目为 "namespace"
key1,data,u8,1
key2,file,string,/path/to/file
```

**注解**：

请确保：
- 逗号 ‘,’ 前后无空格；
- CSV 文件每行末尾无空格。

---

**NVS 条目和命名空间 (namespace)**

如 CSV 文件中出现命名空间条目，后续条目均会被视为该命名空间的一部分，直至找到下一个命名空间条目。找到新命名空间条目后，后续所有条目都会被视为新命名空间的一部分。

**注解**：CSV 文件中第一个条目应始终为 namespace。

---

**支持多页 Blob**

默认情况下，二进制 Blob 可跨多页，格式参考[条目结构]章节。如需使用旧版格式，可在程序中禁用该功能。

**支持加密**

NVS 分区生成程序还可使用 AES-XTS 加密生成二进制加密文件。更多信息详见[NVS 加密]。

**支持解密**

如果 NVS 二进制文件采用了 AES-XTS 加密，该程序还可对此类文件进行解密，更多信息详见[NVS 加密]。
### 运行程序

#### 使用方法:

```bash
python nvs_partition_gen.py [-h] (generate,generate-key,encrypt,decrypt) ...
```

#### 可选参数:

<table>
<thead>
<tr>
<th>序号</th>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-h, -help</td>
<td>显示帮助信息并退出</td>
</tr>
</tbody>
</table>

#### 命令:

运行 `nvs_partition_gen.py {command} -h` 查看更多帮助信息

<table>
<thead>
<tr>
<th>序号</th>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>generate</td>
<td>生成 NVS 分区</td>
</tr>
<tr>
<td>2</td>
<td>generate-key</td>
<td>生成加密密钥</td>
</tr>
<tr>
<td>3</td>
<td>encrypt</td>
<td>加密 NVS 分区</td>
</tr>
<tr>
<td>4</td>
<td>decrypt</td>
<td>解密 NVS 分区</td>
</tr>
</tbody>
</table>

#### 生成 NVS 分区（默认模式）

#### 使用方法:

```bash
python nvs_partition_gen.py generate [-h] [--version {1,2}] [--outdir OUTDIR]
    input output size
```

#### 位置参数:

<table>
<thead>
<tr>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>input</td>
<td>待解析的 CSV 文件路径</td>
</tr>
<tr>
<td>output</td>
<td>NVS 二进制文件的输出路径</td>
</tr>
<tr>
<td>size</td>
<td>NVS 分区大小（以字节为单位，且为 4096 的整数倍）</td>
</tr>
</tbody>
</table>

#### 可选参数:

<table>
<thead>
<tr>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>-h, -help</td>
<td>显示帮助信息并退出</td>
</tr>
<tr>
<td>--version {1,2}</td>
<td>设置多页 Blob 版本。</td>
</tr>
<tr>
<td></td>
<td>版本 1: 禁用多页 Blob;</td>
</tr>
<tr>
<td></td>
<td>版本 2: 启用多页 Blob;</td>
</tr>
<tr>
<td></td>
<td>默认版本: 版本 2。</td>
</tr>
<tr>
<td>--outdir OUTDIR</td>
<td>输出目录，用于存储创建的文件。(默认当前目录)</td>
</tr>
</tbody>
</table>

运行如下命令创建 NVS 分区，该程序同时会提供 CSV 示例文件:

```bash
python nvs_partition_gen.py generate sample_singlepage_blob.csv sample.bin 0x3000
```

#### 仅生成加密密钥

#### 使用方法:
Chapter 2. API 参考

```
python nvs_partition_gen.py generate-key [-h] [--keyfile KEYFILE]
               [--outdir OUTDIR]
```

可选参数:

<table>
<thead>
<tr>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>-h, --help</td>
<td>显示帮助信息并退出</td>
</tr>
<tr>
<td>--keyfile</td>
<td>加密密钥文件的输出路径</td>
</tr>
<tr>
<td>--outdir</td>
<td>输出目录，用于存储创建的文件，（默认当前目录）</td>
</tr>
</tbody>
</table>

运行以下命令仅生成加密密钥:

```
python nvs_partition_gen.py generate-key
```

### 生成 NVS 加密分区 使用方法:

```
python nvs_partition_gen.py encrypt [-h] [--version {1,2}] [--keygen]
                                   [--keyfile KEYFILE] [--inputkey INPUTKEY]
                                   [--outdir OUTDIR]

input  output  size
```

位置参数:

<table>
<thead>
<tr>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>input</td>
<td>待解析 CSV 文件的路径</td>
</tr>
<tr>
<td>output</td>
<td>NVS 二进制文件的输出路径</td>
</tr>
<tr>
<td>size</td>
<td>NVS 分区大小（以字节为单位，且为 4096 的整数倍）</td>
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</tbody>
</table>

可选参数:

<table>
<thead>
<tr>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>-h, --help</td>
<td>显示帮助信息并退出</td>
</tr>
</tbody>
</table>
| --version  | • 设置多页 Blob 版本。
            | • 版本 1：禁用多页 Blob;
            | • 版本 2：启用多页 Blob;
            | • 默认版本：版本 2。 |
| --keygen   | 生成 NVS 分区加密密钥                           |
| --keyfile  | 密钥文件的输出路径                             |
| --inputkey | 内含 NVS 分区加密密钥的文件                     |
| --outdir   | 输出目录，用于存储创建的文件（默认当前目录）   |

运行以下命令加密 NVS 分区，该程序同时会提供一个 CSV 示例文件。

- 通过 NVS 分区生成程序生成加密密钥来加密:

```
python nvs_partition_gen.py encrypt sample_singlepage_blob.csv sample_encr.bin
```

- 通过 NVS 分区生成程序生成加密密钥，并将密钥存储于自定义的文件中:

```
python nvs_partition_gen.py encrypt sample_singlepage_blob.csv sample_encr.bin
```

**注解：** 创建的加密密钥格式为 `<outdir>/keys/keys-<timestamp>.bin`。

Espressif Systems 929 Release v4.3-dev-1561-g357a277603

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Chapter 2. API

```python
python nvs_partition_gen.py encrypt sample_singlepage_blob.csv sample_encr.bin --0x3000 --keygen --keyfile sample_keys.bin
```

**Note:** The created encrypted key format is `<outdir>/keys/keys-<timestamp>.bin`.

**Note:** The encrypted key is stored in the new file `keys/` directory, and is compatible with NVS key regions. More information can be found in the NVS key regions section.

- To use the encryption method,
  ```python
  python nvs_partition_gen.py encrypt sample_singlepage_blob.csv sample_encr.bin --0x3000 --inputkey sample_keys.bin
  ```

**NVS Partition Usage:**

```python
python nvs_partition_gen.py decrypt [-h] [--outdir OUTDIR] input key output
```

**Position Parameters:**

<table>
<thead>
<tr>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>input</td>
<td>待解析的 NVS 加密分区文件路径</td>
</tr>
<tr>
<td>key</td>
<td>含有解密密钥的文件路径</td>
</tr>
<tr>
<td>output</td>
<td>已解密的二进制文件输出路径</td>
</tr>
</tbody>
</table>

**Optional Parameters:**

<table>
<thead>
<tr>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>-h, --help</td>
<td>显示帮助信息并退出</td>
</tr>
<tr>
<td>--outdir OUTDIR</td>
<td>输出目录，用于存储创建的文件（默认当前目录）</td>
</tr>
</tbody>
</table>

To decrypt an encrypted NVS partition:

```python
python nvs_partition_gen.py decrypt sample_encr.bin sample_keys.bin sample_decr.bin
```

You can define custom format versions:

- Version 1: Enable multi-Blob
- Version 2: Enable multi-Blob

**Version 1: Enable Mult-Blob**

If the multi-Blob is enabled, you can use the following command to set the version parameter as 1, and execute the partition generation program. This program will generate a CSV file:

```python
python nvs_partition_gen.py generate sample_singlepage_blob.csv sample.bin 0x3000 --version 1
```

**Version 2: Enable Mult-Blob**

If the multi-Blob is enabled, you can use the following command to set the version parameter as 2, and execute the partition generation program. This program will generate a CSV file:

```python
python nvs_partition_gen.py generate sample_multipage_blob.csv sample.bin 0x4000 --version 2
```
注解：NVS 分区最小为 0x3000 字节。

注解：将二进制文件烧录至设备时，请确保与应用的 sdkconfig 设置一致。

说明

- 分区生成程序不会对重复键进行检查，而将数据同时写入这两个重复键中。请注意不要使用同名的键；
- 新页面创建后，前一页的空白处不会再写入数据。CSV 文件中的字段须按次序排列以优化内存；
- 暂不支持 64 位数据类型。

2.6.5 虚拟文件系统组件

概述

虚拟文件系统 (VFS) 组件为一些驱动提供一个统一接口。有了该接口，用户可通过操作普通文件一样操作虚拟文件。这类驱动程序可以是 FAT、SPIFFS 等真实文件系统，也可以是有文件类接口的设备驱动程序。

VFS 组件支持 C 库函数（如 fopen 和 fprintf 等）与文件系统 (FS) 驱动程序协同工作。在底层，每个 FS 驱动程序均与某些路径相关联。当一个 C 库函数需要打开文件时，VFS 组件将搜索与该文件所在文件路径相关联的 FS 驱动程序，并将调用传递给该驱动程序。针对该文件的读取、写入等其他操作的调用也将传递给这个驱动程序。

例如，您可以使用 /fat 前缀注册 FAT 文件系统驱动。之后即可调用 fopen("/fat/file.txt", "w")。之后，VFS 将调用 FAT 驱动的 open 函数，并将参数 /file.txt 和合适的打开模式传递给 open 函数；后续对返回的 FILE* 数据流使用 C 库函数也将会传递给 FAT 驱动。

注册 FS 驱动程序

如需注册 FS 驱动程序，首先要定义一个 esp_vfs_t 结构体实例，并用指向 FS API 的函数指针填充它。

```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));
```

在上述代码中需要用到 read、write 或 read_p、write_p，具体使用哪组函数由 FS 驱动程序 API 的声明方式决定。

示例 1：声明 API 函数时不带额外的上下文指针参数，即 FS 驱动程序为单例模式，此时使用 write

```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
```

(下文继续)
// When registering FS, context pointer (third argument) is NULL:
ESP_ERROR_CHECK(esp_vfs_register("/data", &myfs, NULL));

示例 2：声明 API 函数时需要一个额外的上下文指针作为参数，即可支持多个 FS 驱动程序实例，此时使用 write_p

```c
ssize_t myfs_write(myfs_t *fs, int fd, const void *data, size_t size);
```

```c
// In definition of esp_vfs_t:
.flags = ESP_VFS_FLAG_CONTEXT_PTR,
.write_p = &myfs_write,
// ... other members initialized

// When registering FS, pass the FS context pointer into the third argument
(myhypothetical 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));
```

同步输入/输出多路复用 如需通过 select() 使用同步输入/输出多路复用，首先需要把 start_select() 和 end_select() 注册到 VFS，如下所示：

```c
// In definition of esp_vfs_t:
.start_select = &uart_start_select,
.end_select = &uart_end_select,
// ... other members initialized
```

调用 start_select() 设置环境，用以检测某一 VFS 文件描述符的读取/写入/错误条件。调用 end_select() 终止、析构或释放 start_select() 设置的资源。请在 vfs/vfs_uart.c 中查看 UART 外设参考实现，esp_vfs_dev_uart_register()、uart_start_select() 和 uart_end_select() 函数。

请参考以下示例，查看如何使用 VFS 文件描述符调用 select()：

- peripherals/uart/uart_select
- system/select

如果 select() 用于套接字文件描述符，您可以启用 CONFIG_LWIP_USE_ONLY_LWIP_SELECT 选项来减少代码量，提高性能。

路径

已注册的 FS 驱动程序均有一个路径前缀与之关联，此路径前缀即为分区的挂载点。

如果挂载点中嵌套了其他挂载点，则在打开文件时使用具有最长匹配路径前缀的挂载点。例如，假设以下文件系统已在 VFS 中注册：

- 在 /data 下注册 FS 驱动程序 1
- 在 /data/static 下注册 FS 驱动程序 2

那么：

- 打开 /data/log.txt 会调用驱动程序 FS 1；
- 打开 /data/static/index.html 需调用 FS 驱动程序 2；
- 即使 FS 驱动程序 2 中没有 /index.html，也不会在 FS 驱动程序 1 中查找 /static/index.html。
挂载点名称必须以路径分隔符 (/) 开头，且分隔符后至少包含一个字符。但在以下情况中，VFS 同样支持空的挂载点名称：1. 应用程序需要提供一个”下使用的文件系统; 2. 应用程序需要同时覆盖 VFS 功能。如果没有与路径匹配的前缀，就会使用到这种文件系统。

VFS 不会对路径中的点 (.) 进行特殊处理，也不会将 .. 视为对父目录的引用。在上述示例中，使用 /data/static/.. /log.txt 路径不会调用 FS 驱动程序 1 打开 /log.txt。特定的 FS 驱动程序（如 FATFS) 可能以不同的方式处理文件名中的点。

执行打开文件操作时，FS 驱动程序仅得到文件的相对路径（挂载点前缀已经被去除）：
1. 以 /data 为路径前缀注册 myfs 驱动;
2. 应用程序调用 fopen("/data/config.json", ...);
3. VFS 调用 myfs_open("config.json", ...);
4. myfs 驱动打开 /config.json 文件。

VFS 对文件路径长度没有限制，但文件系统路径前缀受 ESP_VFS_PATH_MAX 限制，即路径前缀上限为 ESP_VFS_PATH_MAX。各个文件系统驱动则可能会对自己的文件名长度设置一些限制。

文件描述符

文件描述符是一组很小的正整数，从 0 到 FD_SETSIZE - 1，FD_SETSIZE 在 newlib sys/types.h 中定义。重大文件描述符由 CONFIG_LWIP_MAX_SOCKETS 定义，且为套接字保留。VFS 中包含一个名为 s_fd_table 的查找表，用于将全局文件描述符映射至 s_vfs 数组中注册的 VFS 驱动索引。

标准 I0 流 (stdin, stdout, stderr)

如果 menuconfig 中 UART for console output 选项没有设置为 None，则 stdin, stdout 和 stderr 将默认从 UART 读取或写入。UART0 或 UART1 可用作标准 IO。默认情况下，UART0 使用 115200 波特率，TX 管脚为 GPIO1，RX 管脚为 GPIO3。您可以在 menuconfig 中更改上述参数。

对 stdout 或 stderr 执行写入操作将会向 UART 发送 FIFO 发送字符，对 stdin 执行读取操作则会从 UART 接收 FIFO 中取出字符。

默认情况下，VFS 使用简单的函数对 UART 进行读写操作。在所有数据放进 UART FIFO 之前，写操作将处于 busy-wait 状态，读操作处于非阻塞状态，仅返回 FIFO 中已有数据。由于读操作为非阻塞，高层语言 C 库函数调用（如 fscanf("%d\n", &var);）可能获取不到所需结果。

如果应用程序使用 UART 驱动，则可以调用 esp_vfs_dev_uart_use_driver 函数来指导 VFS 使用驱动中断、读写阻塞功能等。您也可以调用 esp_vfs_dev_uart_use_nonblocking 来恢复非阻塞函数。

VFS 还为输入和输出提供换行符转换功能（可选）。多数应用程序在程序内部发送或接收以 LF（‘"n'”）结尾的行，但不同的终端程序可能需要不同的换行符，比如 CR 或 CRLF。应用程序可以通过 menuconfig 或者调用 esp_vfs_dev_uart_port_set_rx_line_endings 和 esp_vfs_dev_uart_port_set_tx_line_endings 为输入输出配置换行符。

标准流和 FreeRTOS 任务 stdin、stdout 和 stderr 的 FILE 对象在所有 FreeRTOS 任务之间共享，指向这些对象的指针分别存储在每个任务的 struct _reent 中。

预处理器把如下代码：

```c
fprintf(stderr, "%2\n");
```

解释为：

```c
fprintf(__getreent()->__stderr, "%2\n");
```

其中 __getreent () 函数将为每个任务返回一个指向 struct _reent 的指针。每个任务的 TCB 均拥有一个 struct _reent 结构体，任务初始化后，struct _reent 结构体中的__stdin、__stdout 和 __stderr 将会被赋于__GLOBAL_REENT 中__stdin、__stdout 和 __stderr 的值，__GLOBAL_REENT 即为 FreeRTOS 启动之前所用结构体。
这样设计带来的结果是:

- 允许重定向给定任务的 stdin、stdout 和 stderr，而不影响其他任务，例如通过 stdin = fopen("/dev/uart/1", "r");
- 但使用 fclose 关闭默认 stdin、stdout 或 stderr 将同时关闭相应的 FILE 流对象，因此会影响其他任务；
- 如需更改任务的默认 stdin、stdout 和 stderr 流，请在创建任务之前修改 _GLOBAL_REENT->stdin(_stdout, _stderr)。

### 应用示例

#### 指南（未完成）

**API 参考**

**Header File**

- vfs/include/esp_vfs.h

**Functions**

- ssize_t esp_vfs_write(struct_reent *r, int fd, const void *data, size_t size)
  - 这些函数是用于在 newlib 系统调用表中使用。它们将在 newlib 需要使用它们时被调用。
- off_t esp_vfs_lseek(struct_reent *r, int fd, off_t size, int mode)
- ssize_t esp_vfs_read(struct_reent *r, int fd, void *dst, size_t size)
- int esp_vfs_open(struct_reent *r, const char *path, int flags, int mode)
- int esp_vfs_close(struct_reent *r, int fd)
- int esp_vfs_fstat(struct_reent *r, int fd, struct stat *st)
- int esp_vfs_stat(struct_reent *r, const char *path, struct stat *st)
- int esp_vfs_unlink(struct_reent *r, const char *path)
- int esp_vfs_rename(struct_reent *r, const char *src, const char *dst)
- int esp_vfs_utime(const char *path, const struct utimbuf *times)

**esp_err_t esp_vfs_register(const char *base_path, const esp_vfs_t *vfs, void *ctx)**

- 注册一个虚拟文件系统给定路径前缀。

  **Return** ESP_OK if successful, ESP_ERR_NO_MEM if too many VFSes are registered.

**Parameters**

- base_path: 文件路径前缀与文件系统关联。必须是一个零终止的 C 字符串，可能为空。如果为空，内容必须是 ESP_VFS_PATH_MAX 字符长度，并且至少 2 个字符长。名称必须以“/”开头且只能以“/”结束。例如，“/data”或“/dev/spi”是有效的。这些 VFSes 将被调用来处理文件路径如“/data/myfile.txt”或“/dev/spi0”。在这种情况下，如果没有 base_path，则一个“fallback”VFS 注册。该 VFS 将处理其他 VFSes 都不匹配的路径。
- vfs: 指向 esp_vfs_t 结构，该结构映射到文件系统驱动函数。VFS 组件不能假设此指针的所有权。
- ctx: 如果 vfs->flags 包含 ESP_VFS_FLAG_CONTEXT_PTR，则指针应传递给 VFS 函数。否则，NULL。

**esp_err_t esp_vfs_register_fd_range(const esp_vfs_t *vfs, void *ctx, int min_fd, int max_fd)**

- 特殊情况函数，用于为使用 open() 方法而不是 open() 来创建新文件描述符的 VFS 注册。

---

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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_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 nfd, fd_set *readfds, fd_set *writfds, 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**
- `nfd`: Specifies the range of descriptors which should be checked. The first nfd 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.
Chapter 2. API

- **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.

```c
void esp vfs select triggered(esp vfs select sem_t sem)
```

Notification from a VFS driver about a read/write/error condition.

This function is called when the VFS driver detects a read/write/error condition as it was requested by the previous call to `start select`.

**Parameters**
- `sem`: semaphore structure which was passed to the driver by the `start select` call

```c
void esp vfs select triggered isr(esp vfs select sem_t sem, BaseType_t *woken)
```

Notification from a VFS driver about a read/write/error condition (ISR version)

This function is called when the VFS driver detects a read/write/error condition as it was requested by the previous call to `start select`.

**Parameters**
- `sem`: semaphore structure which was passed to the driver by the `start select` call
- `woken`: is set to pdTRUE if the function wakes up a task with higher priority

```c
ssize_t esp vfs pread(int fd, void *dst, size_t size, off_t offset)
```

Implements the VFS layer of POSIX `pread`

**Return**
A positive return value indicates the number of bytes read. -1 is return on failure and errno is set accordingly.

**Parameters**
- `fd`: File descriptor used for read
- `dst`: Pointer to the buffer where the output will be written
- `size`: Number of bytes to be read
- `offset`: Starting offset of the read

```c
ssize_t esp vfs pwrite(int fd, const void *src, size_t size, off_t offset)
```

Implements the VFS layer of POSIX `pwrite`

**Return**
A positive return value indicates the number of bytes written. -1 is return on failure and errno is set accordingly.

**Parameters**
- `fd`: File descriptor used for write
- `src`: Pointer to the buffer from where the output will be read
- `size`: Number of bytes to write
- `offset`: Starting offset of the write

**Structures**

```c
struct esp vfs select sem_t
VFS semaphore type for select()
```

**Public Members**

```c
bool is_sem_local
```

Type of "sem" is SemaphoreHandle_t when true, defined by socket driver otherwise

```c
void *sem
```

Semaphore instance

```c
struct esp vfs t
```

VFS definition structure.

This structure should be filled with pointers to corresponding FS driver functions.
VFS component will translate all FDs so that the filesystem implementation sees them starting at zero. The caller sees a global FD which is prefixed with an pre-filesystem-implementation.

Some FS implementations expect some state (e.g. pointer to some structure) to be passed in as a first argument. For these implementations, populate the members of this structure which have _p suffix, set flags member to ESP_VFS_FLAG_CONTEXT_PTR and provide the context pointer to esp_vfs_register function. If the implementation doesn’t use this extra argument, populate the members without _p suffix and set flags member to ESP_VFS_FLAG_DEFAULT.

If the FS driver doesn’t provide some of the functions, set corresponding members to NULL.

**Public Members**

```c
int flags
    ESP_VFS_FLAG_CONTEXT_PTR or ESP_VFS_FLAG_DEFAULT
ssize_t (*write_p)(void *p, int fd, const void *data, size_t size)
    Write with context pointer
ssize_t (*write)(int fd, const void *data, size_t size)
    Write without context pointer
off_t (*lseek_p)(void *p, int fd, off_t size, int mode)
    Seek with context pointer
off_t (*lseek)(int fd, off_t size, int mode)
    Seek without context pointer
ssize_t (*read_p)(void *ctx, int fd, void *dst, size_t size)
    Read with context pointer
ssize_t (*read)(int fd, void *dst, size_t size)
    Read without context pointer
ssize_t (*pread_p)(void *ctx, int fd, void *dst, size_t size, off_t offset)
    pread with context pointer
ssize_t (*pread)(int fd, void *dst, size_t size, off_t offset)
    pread without context pointer
ssize_t (*pwrite_p)(void *ctx, int fd, const void *src, size_t size, off_t offset)
    pwrite with context pointer
ssize_t (*pwrite)(int fd, const void *src, size_t size, off_t offset)
    pwrite without context pointer
int (*open_p)(void *ctx, const char *path, int flags, int mode)
    open with context pointer
int (*open)(const char *path, int flags, int mode)
    open without context pointer
int (*close_p)(void *ctx, int fd)
    close with context pointer
int (*close)(int fd)
    close without context pointer
int (*fstat_p)(void *ctx, int fd, struct stat *st)
    fstat with context pointer
int (*fstat)(int fd, struct stat *st)
    fstat without context pointer
int (*stat_p)(void *ctx, const char *path, struct stat *st)
    stat with context pointer
```
int (*\texttt{stat})(\texttt{const} char *path, \texttt{struct stat} *st)
    stat without context pointer
int (*\texttt{link_p})(void *ctx, \texttt{const} char *n1, \texttt{const} char *n2)
    link with context pointer
int (*\texttt{link})(\texttt{const} char *n1, \texttt{const} char *n2)
    link without context pointer
int (*\texttt{unlink_p})(void *ctx, \texttt{const} char *path)
    unlink with context pointer
int (*\texttt{unlink})(\texttt{const} char *path)
    unlink without context pointer
int (*\texttt{rename_p})(void *ctx, \texttt{const} char *src, \texttt{const} char *dst)
    rename with context pointer
int (*\texttt{rename})(\texttt{const} char *src, \texttt{const} char *dst)
    rename without context pointer
DIR *(*\texttt{opendir_p})(void *ctx, \texttt{const} char *name)
    opendir with context pointer
DIR *(*\texttt{opendir})(\texttt{const} char *name)
    opendir without context pointer
\texttt{struct dirent} *(*\texttt{readdir_p})(void *ctx, DIR *pdir)
    readdir with context pointer
\texttt{struct dirent} *(*\texttt{readdir})(DIR *pdir)
    readdir without context pointer
int (*\texttt{readdir_r_p})(void *ctx, DIR *pdir, \texttt{struct dirent} *entry, \texttt{struct dirent} **out_dirent)
    readdir_r with context pointer
int (*\texttt{readdir_r})(DIR *pdir, \texttt{struct dirent} *entry, \texttt{struct dirent} **out_dirent)
    readdir_r without context pointer
long (*\texttt{telldir_p})(void *ctx, DIR *pdir)
    telldir with context pointer
long (*\texttt{telldir})(DIR *pdir)
    telldir without context pointer
void (*\texttt{seekdir_p})(void *ctx, DIR *pdir, long offset)
    seekdir with context pointer
void (*\texttt{seekdir})(DIR *pdir, long offset)
    seekdir without context pointer
int (*\texttt{closedir_p})(void *ctx, DIR *pdir)
    closedir with context pointer
int (*\texttt{closedir})(DIR *pdir)
    closedir without context pointer
int (*\texttt{mkdir_p})(void *ctx, \texttt{const} char *name, mode_t mode)
    mkdir with context pointer
int (*\texttt{mkdir})(\texttt{const} char *name, mode_t mode)
    mkdir without context pointer
int (*\texttt{rmdir_p})(void *ctx, \texttt{const} char *name)
    rmdir with context pointer
int (*\texttt{rmdir})(\texttt{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
int (*fsync_p) (void *ctx, int fd)
    fsync with context pointer
int (*fsync) (int fd)
    fsync without context pointer
int (*access_p) (void *ctx, const char *path, int amode)
    access with context pointer
int (*access) (const char *path, int amode)
    access without context pointer
int (*truncate_p) (void *ctx, const char *path, off_t length)
    truncate with context pointer
int (*truncate) (const char *path, off_t length)
    truncate without context pointer
int (*utime_p) (void *ctx, const char *path, const struct utimbuf *times)
    utime with context pointer
int (*utime) (const char *path, const struct utimbuf *times)
    utime without context pointer
int (*tcsetattr_p) (void *ctx, int fd, int optional_actions, const struct termios *p)
    tcsetattr with context pointer
int (*tcsetattr) (int fd, int optional_actions, const struct termios *p)
    tcsetattr without context pointer
int (*tcgetattr_p) (void *ctx, int fd, struct termios *p)
    tcgetattr with context pointer
int (*tcgetattr) (int fd, struct termios *p)
    tcgetattr without context pointer
int (*tcdrain_p) (void *ctx, int fd)
    tcdrain with context pointer
int (*tcdrain) (int fd)
    tcdrain without context pointer
int (*tcflush_p) (void *ctx, int fd, int select)
    tcflush with context pointer
int (*tcflush) (int fd, int select)
    tcflush without context pointer
int (*tcflow_p) (void *ctx, int fd, int action)
    tcflow with context pointer
int (*tcflow) (int fd, int action)
    tcflow without context pointer
pid_t (*tcgetsid_p) (void *ctx, int fd)
    tcgetsid with context pointer
Chapter 2. API

pid_t (*tcgetsid)(int fd)
tcgetsid without context pointer

int (*tcsendbreak_p)(void *ctx, int fd, int duration)
tcsendbreak with context pointer

int (*tcsendbreak)(int fd, int duration)
tcsendbreak without context pointer

esp_err_t (*start_select)(int nfds, fd_set *readfds, fd_set *writefds, fd_set *exceptfds, 
estp_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
• vfs/include/esp_vfs_dev.h

Functions
void esp_vfs_dev_uart_register (void)
add /dev/uart virtual filesystem driver

This function is called from startup code to enable serial output
void esp_vfs_dev_uart_set_rx_line_endings (esp_line_endings_t mode)
Set the line endings expected to be received on UART.

This specifies the conversion between line endings received on UART and newlines (\r, LF) passed into stdin:
### ESP_LINE_ENDINGS_CRLF: convert CRLF to LF
### ESP_LINE_ENDINGS_CR: convert CR to LF
### ESP_LINE_ENDINGS_LF: no modification

**Note** this function is not thread safe w.r.t. reading from UART

**Parameters**

- `mode`: line endings expected on UART

```c
void esp_vfs_dev_uart_set_tx_line_endings (esp_line_endings_t mode)
```

Set the line endings to sent to UART.

This specifies the conversion between newlines (`\n`, LF) on stdout and line endings sent over UART:

- `ESP_LINE_ENDINGS_CRLF`: convert LF to CRLF
- `ESP_LINE_ENDINGS_CR`: convert LF to CR
- `ESP_LINE_ENDINGS_LF`: no modification

**Note** this function is not thread safe w.r.t. writing to UART

**Parameters**

- `mode`: line endings to send to UART

```c
int esp_vfs_dev_uart_port_set_rx_line_endings (int uart_num, esp_line_endings_t mode)
```

Set the line endings expected to be received on specified UART.

This specifies the conversion between line endings received on UART and newlines (`\n`, LF) passed into stdin:

- `ESP_LINE_ENDINGS_CRLF`: convert CRLF to LF
- `ESP_LINE_ENDINGS_CR`: convert LF to CRLF
- `ESP_LINE_ENDINGS_LF`: no modification

**Note** this function is not thread safe w.r.t. reading from UART

**Return** 0 if succeeded, or -1 when an error (specified by errno) have occurred.

**Parameters**

- `uart_num`: the UART number
- `mode`: line endings to send to UART

```c
int esp_vfs_dev_uart_port_set_tx_line_endings (int uart_num, esp_line_endings_t mode)
```

Set the line endings to sent to specified UART.

This specifies the conversion between newlines (`\n`, LF) on stdout and line endings sent over UART:

- `ESP_LINE_ENDINGS_CRLF`: convert LF to CRLF
- `ESP_LINE_ENDINGS_CR`: convert LF to CR
- `ESP_LINE_ENDINGS_LF`: no modification

**Note** this function is not thread safe w.r.t. writing to UART

**Return** 0 if succeeded, or -1 when an error (specified by errno) have occurred.

**Parameters**

- `uart_num`: the UART number
- `mode`: line endings to send to UART

```c
void esp_vfs_dev_uart_use_nonblocking (int uart_num)
```

set VFS to use simple functions for reading and writing UART Read is non-blocking, write is busy waiting until TX FIFO has enough space. These functions are used by default.

**Parameters**

- `uart_num`: UART peripheral number

```c
void esp_vfs_dev_uart_use_driver (int uart_num)
```

set VFS to use UART driver for reading and writing

**Note** application must configure UART driver before calling these functions With these functions, read and write are blocking and interrupt-driven.

**Parameters**

- `uart_num`: UART peripheral number
2.6.6 FAT 文件系统

ESP-IDF 使用 FatFs 库来实现 FAT 文件系统。FatFs 库位于 fatfs 组件中，您可以直接使用，也可以借助 C 标准库和 POSIX API 通过 VFS（虚拟文件系统）使用 FatFs 库的大多数功能。

此外，我们对 FatFs 库进行了扩展，新增了支持开拔磁盘 I/O 调度层，从而允许在运行时将 FatFs 驱动映射到物理磁盘。

FatFs 与 VFS 配合使用

fatfs/vfs/esp_vfs_fat.h 头文件定义了连接 FatFs 和 VFS 的函数。

函数 esp_vfs_fat_register() 分配一个 FATFS 结构，并在 VFS 中注册特定路径前缀。如果文件路径以此前缀开头，则对此文件的后续操作将转至 FatFs API。函数 esp_vfs_fat_unregister_path() 删除在 VFS 中的注册，并释放 FATFS 结构。

多数应用程序在使用 esp_vfs_fat_reg 函数时，采用如下步骤：

1. 调用 esp_vfs_fat_register(), 指定：
   • 挂载文件系统的路径前缀（例如, "/sdcard" 或 "/spiflash")
   • FatFs 驱动编号
   • 一个用于接收指向 FATFS 结构指针的变量
2. 调用 ff_diskio_register() 为上述步骤中的驱动编号注册磁盘 I/O 驱动。
3. 调用 FatFs 函数 f_mount()、_f_fdisk()、f_mkfs() 并使用与传递到 esp_vfs_fat_register() 相同的驱动编号挂载文件系统。请参考 FatFs 文档，查看更多信息。
4. 调用 C 标准库和 POSIX API 对路径中带有步骤 1 中所述前缀的文件（例如, "/sdcard/hello. txt") 执行打开、读取、写入、擦除、复制等操作。
5. 您可以选择直接调用 FatFs 函数, 但需要使用没有 VFS 前缀的路径（例如, "/hello.txt")；
6. 关闭所有打开的文件；
7. 调用 fUnmount() 并使用 NULL FATFS* 参数为与上述驱动编号相同的驱动卸载文件系统；
8. 调用 FatFs 函数 ff_diskio_unregister() 并使用 NULL ff_diskio_impl_t* 参数和相同的驱动编号来释放注册的磁盘 I/O 驱动。
9. 调用 esp_vfs_fat_unregister_path() 并使用文件系统挂载的路径将 FatFs 从 NVS 中移除，并释放步骤 1 中分配的 FatFs 结构。

esp_vfs_fat_sdmmc_mount 和 esp_vfs_fat_sdmmc_unmount 这两个便捷函数对上述步骤进行了封装，并加入对 SD 卡初始化的处理，非常便捷。我们将在下一章节详细介绍这两个函数。

esp_err_t esp_vfs_fat_register(const char *base_path, const char *fat_drive, size_t max_files, FATFS **out_fs)

Register FATFS with VFS component.

This function registers given FAT drive in VFS, at the specified base path. If only one drive is used, fat_drive argument can be an empty string. Refer to FATFS library documentation on how to specify FAT drive. This function also allocates FATFS structure which should be used for f_mount call.

Note This function doesn’t mount the drive into FATFS, it just connects POSIX and C standard library IO function with FATFS. You need to mount desired drive into FATFS separately.

Return
• ESP_OK on success
• ESP_ERR_INVALID_STATE if esp_vfs_fat_register was already called
• ESP_ERR_NO_MEM if not enough memory or too many VFSes already registered

Parameters
• base_path: path prefix where FATFS should be registered
• fat_drive: FATFS drive specification; if only one drive is used, can be an empty string
• max_files: maximum number of files which can be open at the same time
• [out] out_fs: pointer to FATFS structure which can be used for FATFS f_mount call is returned via this argument.

esp_err_t esp_vfs_fat_unregister_path(const char *base_path)

Un-register FATFS from VFS.
**Note** FATFS structure returned by esp_vfs_fat_register is destroyed after this call. Make sure to call _f_mount_ function to unmount it before calling esp_vfs_fat_unregister_ctx. Difference between this function and the one above is that this one will release the correct drive, while the one above will release the last registered one.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if FATFS is not registered in VFS

**Parameters**
- `base_path`: path prefix where FATFS is registered. This is the same used when esp_vfs_fat_register was called.

---

**FatFs 与 VFS 和 SD 卡配合使用**

Fatfs/vfs/esp_vfs_fat.h 头文件定义了两个便捷函数 `esp_vfs_fat_sdmmc_mount()`和`esp_vfs_fat_sdmmcUnmount()`。这两个函数分别执行上一节的步骤 1-3 和步骤 7-9，并初始化 SD 卡，但仅提供有限的错误处理功能。我们鼓励开发人员查看源代码并将在更多高级功能集成到产品应用中。

`esp_vfs_fat_sdmmcUnmount()` 函数用于卸载文件系统并释放从`esp_vfs_fat_sdmmcMount()`函数获取的资源。

```c
esp_err_t esp_vfs_fat_sdmmc_mount(const char *base_path, const sdmmc_host_t *host_config,
                                  const void *slot_config, const esp_vfs_fat_mount_config_t *mount_config, sdmmc_card_t **out_card)
```

Convenience function to get FAT filesystem on SD card registered in VFS.

This is an all-in-one function which does the following:
- initializes SDMMC driver or SPI driver with configuration in host_config
- initializes SD card with configuration in slot_config
- mounts FAT partition on SD card using FATFS library, with configuration in mount_config
- registers FATFS library with VFS, with prefix given by base_prefix variable

This function is intended to make example code more compact. For real world applications, developers should implement the logic of probing SD card, locating and mounting partition, and registering FATFS in VFS, with proper error checking and handling of exceptional conditions.

**Note** Use this API to mount a card through SDSPI is deprecated. Please call `esp_vfs_fat_sdspi_mount()` instead for that case.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if esp_vfs_fat_sdmmc_mount was already called
- ESP_ERR_NO_MEM if memory cannot be allocated
- ESP_FAIL if partition cannot be mounted
- other error codes from SDMMC or SPI drivers, SDMMC protocol, or FATFS drivers

**Parameters**
- `base_path`: path where partition should be registered (e.g. “/sdcard”)
- `host_config`: Pointer to structure describing SDMMC host. When using SDMMC peripheral, this structure can be initialized using SDMMC_HOST_DEFAULT() macro. When using SPI peripheral, this structure can be initialized using SDSPI_HOST_DEFAULT() macro.
- `slot_config`: Pointer to structure with slot configuration. For SDMMC peripheral, pass a pointer to `sdmmc_slot_config_t` structure initialized using SDMMC_SLOT_CONFIG_DEFAULT. (Deprecated) For SPI peripheral, pass a pointer to `sdspi_slot_config_t` structure initialized using SDSPI_SLOT_CONFIG_DEFAULT().
- `mount_config`: pointer to structure with extra parameters for mounting FATFS
- `[out] out_card`: if not NULL, pointer to the card information structure will be returned via this argument

```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.

esp_err_t esp_vfs_fat_sdmmcUnmount
---
Unmount FAT filesystem and release resources acquired using esp_vfs_fat_sdmmc_mount.

Return
---
• ESP_OK on success
• ESP_ERR_INVALID_STATE if esp_vfs_fat_sdmmc_mount hasn’t been called

FatFs \& VFS 配合使用（只读模式下）

fatfs/vfs/esp_vfs_fat.h 头文件定义了两个便捷函数 esp_vfs_fat_rawflash_mount() 和
esp_vfs_fat_rawflash_unmount()，上述两个函数分别对 FAT 只读分区执行步骤 1-3 和
步骤 7-9。有些数据分区仅在工厂时写入一次，之后在整个硬件生命周期内都不会再有任何改动。利用
上述两个函数处理这种数据分区非常方便。

esp_err_t esp_vfs_fat_rawflash_mount(const char *base_path, const char *partition_label,
const esp_vfs_fat_mount_config_t *mount_config)
---
Convenience function to initialize read-only FAT filesystem and register it in VFS.

This is an all-in-one function which does the following:

• finds the partition with defined partition_label. Partition label should be configured in the partition table.
• mounts FAT partition using FATFS library
• registers FATFS library with VFS, with prefix given by base_prefix variable

Note Wear levelling is not used when FAT is mounted in read-only mode using this function.

Return
---
• ESP_OK on success
• ESP_ERR_NOT_FOUND if the partition table does not contain FATFS partition with given label
• ESP_ERR_INVALID_STATE if esp_vfs_fat_rawflash_mount was already called for the same part-
tition
• ESP_ERR_NO_MEM if memory can not be allocated
• ESP_FAIL if partition can not be mounted
• other error codes from SPI flash driver, or FATFS drivers

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 磁盘 I/O 层

我们对 FatFs API 函数进行了扩展，实现了运行期间注册磁盘 I/O 驱动。
上述 API 为 SD/MMC 卡提供了磁盘 I/O 函数实现方式，可使用 ff_diskio_register_sdmmc() 注册指定的 FatFs 驱动编号。

```c
void ff_diskio_register (BYTE pdrv, const ff_diskio_impl_t *discio_impl)
```
Register or unregister diskio driver for given drive number.
When FATFS library calls one of disk_xxx functions for driver number pdrv, corresponding function in dis-
cio_impl for given pdrv will be called.

Parameters
- pdrv: drive number
- discio_impl: pointer to ff_diskio_impl_t structure with diskio functions or NULL to unregister
  and free previously registered drive

```c
struct ff_diskio_impl_t
```
Structure of pointers to disk IO driver functions.
See FatFs documentation for details about these functions

Public Members

DSTATUS (*init)(unsigned char pdrv)
disk initialization function

DSTATUS (*status)(unsigned char pdrv)
disk status check function

DRESULT (*read)(unsigned char pdrv, unsigned char *buff, uint32_t sector, unsigned count)
sector read function

DRESULT (*write)(unsigned char pdrv, const unsigned char *buff, uint32_t sector, unsigned count)
sector write function

DRESULT (*ioctl)(unsigned char pdrv, unsigned char cmd, void *buff)
function to get info about disk and do some misc operations

```c
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.

```c
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.

```c
esp_err_t ff_diskio_register_raw_partition (unsigned char pdrv, const esp_partition_t *part_handle)
```
Register spi flash partition

Parameters
Chapter 2. API

• pdrv: drive number
• part_handle: pointer to raw flash partition.

2.6.7 磨损均衡 API

概述

ESP32 所使用的 flash，特别是 SPI flash 多数具备扇区结构，且每个扇区仅允许有限次数的擦除/修改操作。为了避免过度使用某一扇区，乐鑫提供了磨损均衡组件，无需用户介入即可帮助用户均衡各个扇区之间的磨损。

磨损均衡组件包含了通过分区组件对外部 SPI flash 进行数据读取、写入、擦除和存储器映射相关的 API 函数。磨损均衡组件还具有软件上更高级别的 API 函数，与 FAT 文件系统协同工作。

磨损均衡组件与 FAT 文件系统组件共用 FAT 文件系统的扇区，扇区大小为 4096 字节，是标准 flash 扇区的大小，这种模式下，磨损均衡组件性能达到最佳，但需要在 RAM 中占用更多内存。

为了节省内存，磨损均衡组件还提供了另外两种模式，均使用 512 字节大小的扇区:

• 性能模式：先将数据保存在 RAM 中，擦除扇区，然后将数据存储回 flash。如果设备在扇区擦写过程中突然断电，整个扇区（4096 字节）数据将全部丢失。
• 安全模式：数据先保存在 flash 中空余扇区，擦除扇区后，数据即存储回去。如果设备断电，上电后可立即恢复数据。

设备默认设置如下:

• 定义扇区大小为 512 字节
• 默认使用性能模式

您可以使用配置菜单更改设置。

磨损均衡组件不会将数据缓存在 RAM 中，写入和擦除函数直接修改 flash，函数返回后，flash 即完成修改。

磨损均衡访问 API

处理 flash 数据常用的 API 如下所示:

• wl-mount - 为指定分区挂载并初始化磨损均衡模块
• wl-unmount - 卸载分区并释放磨损均衡模块
• wl-erase-range - 擦除 flash 中指定的地址范围
• wl-write - 将数据写入分区
• wl-read - 从分区读取数据
• wl-size - 返回可用内存的大小（以字节为单位）
• wl-sector-size - 返回一个扇区的大小

请尽量避免直接使用原始磨损均衡函数，建议您使用文件系统特定的函数。

内存大小

内存大小是根据分区参数在磨损均衡模块中计算所得，由于模块使用 flash 部分扇区存储内部数据，因此计算所得内存大小有少许偏差。

另请参阅

• FAT 文件系统
• 分区表
**Chapter 2. API 参考**

**应用示例**

`storage/wear_levelling` 中提供了一款磨损均衡驱动与 FatFs 库结合使用的示例。该示例初始化磨损均衡驱动，挂载 `FAT` 文件系统分区，并使用 POSIX（可移植操作系统接口）和 C 库 API 从中写入和读取数据。

如需了解更多信息，请参考 `storage/wear_levelling/README.md`。

**高级 API 参考**

**头文件**

- `fatfs/vfs/esp_vfs_fat.h`

**函数**

```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 cannot be mounted
- other error codes from wear levelling library, SPI flash driver, or FATFS drivers

**Parameters**

- `base_path`: path where FATFS partition should be mounted (e.g. `/spiflash`
- `partition_label`: label of the partition which should be used
- `mount_config`: pointer to structure with extra parameters for mounting FATFS
- `[out] wl_handle`: wear levelling driver handle

**struct esp_vfs_fat_mount_config_t**

Configuration arguments for `esp_vfs_fat_sdmmc_mount` and `esp_vfs_fat_spiflash_mount` functions.

**Public Members**

- `bool format_if_mount_failed`
  If FAT partition can not be mounted, and this parameter is true, create partition table and format the filesystem.

- `int max_files`
  Max number of open files.

- `size_t allocation_unit_size`
  If format_if_mount_failed is set, and mount fails, format the card with given allocation unit size. Must be a power of 2, between sector size and 128 * sector size. For SD cards, sector size is always 512 bytes. For wear_levelling, sector size is determined by `CONFIG_WL_SECTOR_SIZE` option.

  Using larger allocation unit size will result in higher read/write performance and higher overhead when storing small files.

  Setting this field to 0 will result in allocation unit set to the sector size.
esp_err_t esp_vfs_fat_spiflashUnmount (const char *base_path, wl_handle_t wl_handle)

Unmount FAT filesystem and release resources acquired using esp_vfs_fat_spiflash_mount.

Return
• ESP_OK on success
• ESP_ERR_INVALID_STATE if esp_vfs_fat_spiflash_mount hasn’t been called

Parameters
• base_path: path where partition should be registered (e.g. “/spiflash”) 
• wl_handle: wear levelling driver handle returned by esp_vfs_fat_spiflash_mount

Header File
• wear_levelling/include/wear_levelling.h

Functions
esp_err_t wl_mount (const esp_partition_t *partition, wl_handle_t *out_handle)

Mount WL for defined partition.

Return
• ESP_OK, if the allocation was successfully;
• ESP_ERR_INVALID_ARG, if WL allocation was unsuccessful;
• ESP_ERR_NO_MEM, if there was no memory to allocate WL components;

Parameters
• partition: that will be used for access
• out_handle: handle of the WL instance

esp_err_t wlUnmount (wl_handle_t handle)

Unmount WL for defined partition.

Return
• ESP_OK, if the operation completed successfully;
• or one of error codes from lower-level flash driver.

Parameters
• handle: WL partition handle

esp_err_t 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;
Chapter 2. API

- 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.

```c
esp_err_t wl_write(wl_handle_t handle, size_t dest_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.

```c
size_t wl_size(wl_handle_t handle)
```
Get size of the WL storage.

**Return** usable size, in bytes

**Parameters**
- `handle`: WL module handle that was initialized before

```c
size_t wl_sector_size(wl_handle_t handle)
```
Get sector size of the WL instance.

**Return** sector size, in bytes

**Parameters**
- `handle`: WL module handle that was initialized before

**Macros**
- `WL_INVALID_HANDLE`

**Type Definitions**

```c
typedef int32_t wl_handle_t
    wear levelling handle
```

### 2.6.8 SPIFFS 文件系统

**概述**

SPIFFS 是一个用于 SPI NOR flash 设备的嵌入式文件系统，支持磨损均衡、文件系统一致性检查等功能。

**说明**

- 目前，SPIFFS 尚不支持目录, 但可以生成扁平结构。如果 SPIFFS 挂载在 `/spiffs` 下，在 `/spiffs/tmp/myfile.txt` 路径下创建一个文件则会在 SPIFFS 中生成一个名为 `/tmp/myfile.txt` 的文件；而不是在 `/spiffs/tmp` 下生成名为 `myfile.txt` 的文件。
- SPIFFS 并非实时栈，每次写操作耗时不等。
- 目前，SPIFFS 尚不支持检测或处理已损坏的块。
工具

spiffsgen.py  spiffsgen.py:

```
python spiffsgen.py <image_size> <base_dir> <output_file>
```

参数（选）说明如下:

- **image_size**: 分区大小，用于烧录生成的 SPIFFS 映像;
- **base_dir**: 创建 SPIFFS 映像的目录;
- **output_file**: SPIFFS 映像输出文件。

其他参数（选）也参与控制映像的生成，您可以运行以下帮助命令，查看这些参数的具体信息:

```
python spiffsgen.py -help
```

上述可选参数对应 SPIFFS 构建配置选项。若想顺利生成可用的映像，请确保使用的参数或配置与构建 SPIFFS 时所用的参数或配置相同。运行帮助命令将显示参数所对应的 SPIFFS 构建配置。如未指定参数，将使用帮助信息中的默认值。

映像生成后，您可以使用 esptool.py 或 parttool.py 烧录映像。

您可以在命令行或脚本中单独调用 spiffsgen.py，也可以直接从构建系统调用 spiffs_create_partition_image 来使用 spiffsgen.py。

在 Make 构建系统中运行:

```
SPIFFS_IMAGE_FLASH_IN_PROJECT := ...
SPIFFS_IMAGE_DEPENDS := ...
$(eval $(call spiffs_create_partition_image,<partition>,<base_dir>))
```

在 CMake 构建系统中运行:

```
spiffs_create_partition_image(<partition> <base_dir> [FLASH_IN_PROJECT] [DEPENDS_ ->dep dep dep...])
```

在构建系统中使用 spiffsgen.py 更为方便，构建配置自动传递给 spiffsgen.py 工具。确保生成的映像可用于构建。比如，单独调用 spiffsgen.py 时需要用到 **image_size** 参数。但在构建系统中调用 spiffs_create_partition_image 时，仅需要 **partition** 参数，映像大小将直接从工程分区表中获取。

Make 构建系统和 CMake 构建系统结构有所不同，请注意以下几点:

- 在 Make 构建系统中使用 spiffs_create_partition_image，需在工程 Makefile 中调用；
- 在 CMake 构建系统中使用 spiffs_create_partition_image，需从组件 CMakeLists.txt 文件调用。

您也可以指定 FLASH_IN_PROJECT，然后使用 idf.py flash 或 make flash 将映像与应用程序二进制文件、分区表等一起自动烧录至设备，例如:

在 Make 构建系统中运行:

```
SPIFFS_IMAGE_FLASH_IN_PROJECT := 1
$(eval $(call spiffs_create_partition_image,<partition>,<base_dir>))
```

在 CMake 构建系统中运行:

```
spiffs_create_partition_image(my_spiffs_partition my_folder FLASH_IN_PROJECT)
```

不指定 **FLASH_IN_PROJECT** 或 SPIFFS_IMAGE_FLASH_IN_PROJECT 也可以生成映像，但须使用 esptool.py, parttool.py 或自定义构建系统目标手动烧录。

有时基本目录中的内容是在构建时生成的，您可以使用 **DEPENDS** 或 SPIFFS_IMAGE_DEPENDS 指定目标，因此可以在生成映像之前执行此目标。

在 Make 构建系统中运行:
```c
SPIFFS_IMAGE_DEPENDS := dep
$(eval $(call spiffs_create_partition_image,<partition>,<base_dir>))
```

在 CMake 构建系统中运行:

```c
add_custom_target(dep COMMAND ...
spiffs_create_partition_image(my_spiffs_partition my_folder DEPENDS dep)
```

请参考 `storage/spiffsgen`，查看示例。

**mkspiffs** 您也可以使用 mkspiffs 工具创建 SPIFFS 分区映像。与 spiffsgen.py 相似，mkspiffs 也可以用于从指定文件夹中生成映像，然后使用 esptool.py 烧录映像。

该工具需要获取以下参数:

- **Block Size**: 4096（SPI flash 标准）
- **Page Size**: 256（SPI flash 标准）
- **Image Size**: 分区大小（以字节为单位，可从分区表中获取）
- **Partition Offset**: 分区起始地址（可从分区表中获取）

运行以下命令，将文件夹打包成 1 MB 大小的映像:

```
mkspiffs -c [src_folder] -b 4096 -p 256 -s 0x10000 spiffs.bin
```

运行以下命令，将映像烧录到 ESP32（偏移量: 0x110000）:

```
python esptool.py --chip esp32 --port [port] --baud [baud] write_flash -z 0x110000..
```

### 选择合适的 SPIFFS 工具

上面介绍的两款 SPIFFS 工具功能相似，需根据实际情况，选择合适的一款。

以下情况优先选用 spiffsgen.py 工具:

1. 仅需在构建时简单生成 SPIFFS 映像，请选择使用 spiffsgen.py，spiffsgen.py 可以直接在构建系统中使用函数或命令生成 SPIFFS 映像。
2. 主机没有可用的 C/C++ 编译器时，可以选择使用 spiffsgen.py 工具，spiffsgen.py 不需要编译。

以下情况优先选用 mkspiffs 工具:

1. 如果您除了需要生成映像外，还需要打包 SPIFFS 映像，请选择使用 mkspiffs 工具。spiffsgen.py 目前尚不支持此功能。
2. 如果您当前环境中 Python 解释器不可用，或主机编译器不可用，或者有预编译的 mkspiffs 二进制文件，此时请选择使用 mkspiffs 工具。但是，mkspiffs 没有集成到构建系统，用户必须自己完成以下工作: 在构建期间编译 mkspiffs（如果未使用预编译的二进制文件），为输出文件创建构建规则或目标，将适当的参数传递给工具等。

另请参阅

- 分区表

### 应用示例

`storage/spiffs` 目录下提供了 SPIFFS 应用示例。该示例初始化并挂载了一个 SPIFFS 分区，然后使用 POSIX 和 C 库 API 与之和读取数据。请参考 example 目录下的 README.md 文件，查看详细信息。
Chapter 2. API 参考

高级 API 参考

Header File

- spiffs/include/esp_spiffs.h

Functions

`esp_err_t esp_vfs_spiffs_register(const esp_vfs_spiffs_conf_t *conf)`
Register and mount SPIFFS to VFS with given path prefix.

Return
- ESP_OK if success
- ESP_ERR_NO_MEM if objects could not be allocated
- ESP_ERR_INVALID_STATE if already mounted or partition is encrypted
- ESP_ERR_NOT_FOUND if partition for SPIFFS was not found
- ESP_FAIL if mount or format fails

Parameters
- `conf`: Pointer to `esp_vfs_spiffs_conf_t` configuration structure

`esp_err_t esp_vfs_spiffs_unregister(const char *partition_label)`
Unregister and unmount SPIFFS from VFS

Return
- ESP_OK if successful
- ESP_ERR_INVALID_STATE already unregistered

Parameters
- `partition_label`: Same label as passed to esp_vfs_spiffs_register.

`bool esp_spiffs_mounted(const char *partition_label)`
Check if SPIFFS is mounted

Return
- true if mounted
- false if not mounted

Parameters
- `partition_label`: Optional, label of the partition to check. If not specified, first partition with subtype=spiffs is used.

`esp_err_t esp_vfs_spiffs_format(const char *partition_label)`
Format the SPIFFS partition

Return
- ESP_OK if successful
- ESP_FAIL on error

Parameters
- `partition_label`: Same label as passed to esp_vfs_spiffs_register.

`esp_err_t esp_vfs_spiffs_info(const char *partition_label, size_t *total_bytes, size_t *used_bytes)`
Get information for SPIFFS

Return
- ESP_OK if success
- ESP_ERR_INVALID_STATE if not mounted

Parameters
- `partition_label`: Same label as passed to esp_vfs_spiffs_register
- `[out] total_bytes`: Size of the file system
- `[out] used_bytes`: Current used bytes in the file system

Structures

`struct esp_vfs_spiffs_conf_t`
Configuration structure for esp_vfs_spiffs_register.
Public Members

`const char* base_path`
File path prefix associated with the filesystem.

`const char* partition_label`
Optional, label of SPIFFS partition to use. If set to NULL, first partition with subtype=spiffs will be used.

`size_t max_files`
Maximum files that could be open at the same time.

`bool format_if_mount_failed`
If true, it will format the file system if it fails to mount.

2.6.9 量产程序

介绍

这一程序主要用于量产时为每一设备创建工厂NVS（非易失性存储器）分区映像。NVS 分区映像由 CSV（逗号分隔值）文件生成，文件中包含了用户提供的配置项及配置值。

注意，该程序仅创建用于量产的二进制映像。您需要使用以下工具将映像烧录到设备上：

- esptool.py
- Flash 下载工具（仅适用于 Windows）
- 直接烧录程序

准备工作

该程序需要用到分区公用程序。

- 操作系统要求：
  - Linux、MacOS 或 Windows（标准版）
- 安装依赖包：
  - Python：https://www.python.org/downloads/。

注释：

使用该程序之前，请确保：

- Python 路径已添加到 PATH 环境变量中；
  - 已经安装 requirement.txt 中的软件包。requirement.txt 在 esp-idf 根目录下。

具体流程

- CSV 配置文件
- 主 CSV 文件
- 二进制 bin 文件
CSV 配置文件

CSV 配置文件中包含设备待烧录的配置信息，定义了待烧录的配置项。例如定义 firmware_key(key)的 type 为 data，encoding 为 hex2bin。

配置文件中数据格式如下（REPEAT 标签可选）：

| name1,namespace,  | key1,type1,encoding1 |
| name2,namespace,  | key2,type2,encoding2,REPEAT |
| name3,namespace,  | key3,type3,encoding3 |
| key4,type4,encoding4 |

**注解**：文件第一行应始终为 namespace 条目。

每行应包含三个参数：key、type 和 encoding，并以逗号分隔。如果有 REPEAT 标签，则主 CSV 文件中所有设备此键值均相同。

有关各个参数的详细说明，请参阅 NVS 分区生成程序的 README 文件。

CSV 配置文件示例如下：

| app,namespace,  | firmware_key, data, hex2bin |
| serial_no, data, string, REPEAT  | "serial_no" 被标记为 "REPEAT" |
| device_no, data, i32 |

**注解**：

请确保：
- 只号 ‘，’ 前后无空格；
- CSV 文件每行末尾无空格。

主 CSV 文件

主 CSV 文件中包含设备待烧录的详细信息，文件中每行均对应一个设备实体。主 CSV 文件中的 key 应首先在 CSV 配置文件中定义。

主 CSV 文件的数据格式如下：

| key1,key2,key3..... | value1,value2,value3..... | key4,key5,key6..... | value4,value5,value6..... | value7,value8,value9..... |

**注解**：文件中键 (key) 名应始终置于文件首行。从配置文件中获取的键，在此文件中的排列顺序应与在其配置文件中的排列顺序相同。主 CSV 文件同时可以包含其它列 (键)，这些列将被视为元数据，而不会编译进最终二进制文件。

每行应包含相应键的键值 (value)，并用逗号隔开。如果某键带有 REPEAT 标签，则仅需在第二行（即第一个条目）输入对应的值，后面其他行为空。

参数描述如下：

value Data value
value 是与键对应的键值。

主 CSV 文件示例如下:

<table>
<thead>
<tr>
<th>id,firmware_key,serial_no,device_no</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,1a2b3c4d5e6faabb,A1,101</td>
</tr>
<tr>
<td>2,1a2b3c4d5e6fccdd,,102</td>
</tr>
<tr>
<td>3,1a2b3c4d5e6feeff,,103</td>
</tr>
</tbody>
</table>

注解：如果出现 REPEAT 标签，则会在相同目录下生成一个新的主 CSV 文件用作主输入文件，并在每行为带有 REPEAT 标签的键插入键值。

量产程序还会创建中间 CSV 文件，NVS 分区程序将使用此 CSV 文件作为输入，然后生成二进制文件。中间 CSV 文件的格式如下:

<table>
<thead>
<tr>
<th>key,type,encoding,value</th>
</tr>
</thead>
<tbody>
<tr>
<td>key,namespace,</td>
</tr>
<tr>
<td>key1,type1,encoding1,value1</td>
</tr>
<tr>
<td>key2,type2,encoding2,value2</td>
</tr>
</tbody>
</table>

此步骤将为每一设备生成一个中间 CSV 文件。

运行量产程序

使用方法:

```
python mfg_gen.py [-h] {generate,generate-key} ...
```

可选参数:

<table>
<thead>
<tr>
<th>序号</th>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-h,-help</td>
<td>显示帮助信息并退出</td>
</tr>
</tbody>
</table>

命令:

运行 mfg_gen.py {command} -h 查看更多帮助信息

<table>
<thead>
<tr>
<th>序号</th>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>generate</td>
<td>生成 NVS 分区</td>
</tr>
<tr>
<td>2</td>
<td>generate-key</td>
<td>生成加密密钥</td>
</tr>
</tbody>
</table>

为每个设备生成工厂映像（默认）

使用方法:

```
python mfg_gen.py generate [-h] [--fileid FILEID] [--version {1,2}] [--keygen] [--keyfile KEYFILE] [--inputkey INPUTKEY] [--outdir OUTDIR] conf values prefix size
```

位置参数:

<table>
<thead>
<tr>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>conf</td>
<td>待解析的 CSV 配置文件路径</td>
</tr>
<tr>
<td>values</td>
<td>待解析的主 CSV 文件路径</td>
</tr>
<tr>
<td>prefix</td>
<td>每个输出文件名前缀的唯一名称</td>
</tr>
<tr>
<td>size</td>
<td>NVS 分区大小（以字节为单位，且为 4096 的整数倍）</td>
</tr>
</tbody>
</table>
可选参数:

<table>
<thead>
<tr>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>-h, --help</td>
<td>显示帮助信息并退出</td>
</tr>
<tr>
<td>--fileid FILEID</td>
<td>每个文件名后缀的唯一文件标识符（主 CSV 文件中的任意键），默认为数值 1, 2, 3…</td>
</tr>
<tr>
<td>--version [1,2]</td>
<td>• 设置多页 Blob 版本。</td>
</tr>
<tr>
<td></td>
<td>• 版本 1 - 禁用多页 Blob；</td>
</tr>
<tr>
<td></td>
<td>• 版本 2 - 启用多页 Blob；</td>
</tr>
<tr>
<td></td>
<td>• 默认版本: 版本 2</td>
</tr>
<tr>
<td>--keygen</td>
<td>生成 NVS 分区加密密钥</td>
</tr>
<tr>
<td>--inputkey INPUTKEY</td>
<td>内含 NVS 分区加密密钥的文件</td>
</tr>
<tr>
<td>--outdir OUTDIR</td>
<td>输出目录，用于存储创建的文件（默认当前目录）</td>
</tr>
</tbody>
</table>

请运行以下命令为每个设备生成工厂映像，量产程序同时提供了一个 CSV 示例文件:

```
python mfg_gen.py generate samples/sample_config.csv samples/sample_values_--singlepage_blob.csv Sample 0x3000
```

主 CSV 文件应在 file 类型下设置一个相对路径，指向运行该程序的当前目录。

每个设备生成工厂密钥映像

运行以下命令为每一设备生成工厂密钥映像，量产程序同时提供了一个 CSV 示例文件。

- 通过量产程序生成加密密钥来进行加密:

```
python mfg_gen.py generate samples/sample_config.csv samples/sample_values_--singlepage_blob.csv Sample 0x3000 --keygen
```

**注释:** 创建的加密密钥格式为 <outdir>/keys/keys-<prefix>-<fileid>.bin。

**注释:** 加密密钥存储于新建文件的 keys/ 目录下，与 NVS 密钥分区结构兼容。更多信息请参考 NVS 密钥分区。

- 提供加密密钥用作二进制输入文件来进行加密:

```
python mfg_gen.py generate samples/sample_config.csv samples/sample_values_--singlepage_blob.csv Sample 0x3000 --inputkey keys/sample_keys.bin
```

仅生成加密密钥

**使用方法:**

```
python mfg_gen.py generate-key [-h] [--keyfile KEYFILE] [--outdir OUTDIR]
```

可选参数:

<table>
<thead>
<tr>
<th>参数</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>-h, --help</td>
<td>显示帮助信息并退出</td>
</tr>
<tr>
<td>--keyfile KEYFILE</td>
<td>加密密钥文件的输出路径</td>
</tr>
<tr>
<td>--outdir OUTDIR</td>
<td>输出目录，用于存储创建的文件（默认当前目录）</td>
</tr>
</tbody>
</table>

运行以下命令仅生成加密密钥:
Chapter 2. API

```python
python mfg_gen.py generate-key
```

### Note

The generated key format is `<outdir>/keys/keys-<timestamp>.bin`.

### Note

The fileid parameter default values are 1, 2, 3…, with CSV files corresponding one-to-one. It contains device configuration.

When building a project, create a folder named `outdir` under the project directory to store the following files:

- bin/ : The generated application image
- csv/ : The generated CSV file
- keys/ : The generated key file

This part of the API code example can be found in the ESP-IDF storage directory.

## 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:

```bash
esptool.py --chip esp32 image_info build/app.bin
```

```
esptool.py v2.3.1
Image version: 1
Entry point: 40080ea4
13 segments
Segment 1: len 0x13ce0 load 0x3f400020 file_offs 0x00000018 SOC_DROM
Segment 2: len 0x00000 load 0x3ff80000 file_offs 0x00013d00 SOC_RTC_DRAM
Segment 3: len 0x00000 load 0x3ff80000 file_offs 0x00013d08 SOC_RTC_DRAM
Segment 4: len 0x028e0 load 0x3fbb28e0 file_offs 0x000165f8 DRAM
Segment 5: len 0x00000 load 0x3ff80000 file_offs 0x00013d10 SOC_IRAM
Segment 6: len 0x00000 load 0x40080000 file_offs 0x00016600 SOC_IRAM
Segment 7: len 0x09600 load 0x40080400 file_offs 0x00016a08 SOC_IRAM
Segment 8: len 0x62e4c load 0x400d0018 file_offs 0x00020010 SOC_IROM
Segment 9: len 0x06ce0 load 0x40089a00 file_offs 0x00082e64 SOC_IROM
```

(continued)
You can also see the information on segments in the IDF logs while your application is booting:

```
I (443) esp_image: segment 0: paddr=0x00000000 vaddr=0x3f400000 size=0x13ce0 (=)
→81120) map
I (489) esp_image: segment 1: paddr=0x000033d0 vaddr=0x3f800000 size=0x000000 (0)=
→load
I (530) esp_image: segment 2: paddr=0x000033d10 vaddr=0x3f800000 size=0x000000 (0)=
→load
I (571) esp_image: segment 3: paddr=0x000033d18 vaddr=0x3f8b0000 size=0x028e0 (=)
→10464) load
I (612) esp_image: segment 4: paddr=0x000036600 vaddr=0x3f8b28e0 size=0x000000 (0)=
→load
I (654) esp_image: segment 5: paddr=0x000036608 vaddr=0x40080000 size=0x00400 (=)
→1024) load
I (695) esp_image: segment 6: paddr=0x0000366a10 vaddr=0x40080400 size=0x09600 (=)
→38400) load
I (737) esp_image: segment 7: paddr=0x0000400018 vaddr=0x400d0018 size=0x62e4c (=)
→(405068) map
I (847) esp_image: segment 8: paddr=0x0000a2e6c vaddr=0x4008a000 size=0x06ce0 (=)
→27884) load
I (888) esp_image: segment 9: paddr=0x0000a9b60 vaddr=0x400c0000 size=0x000000 (0)=
→load
I (929) esp_image: segment 10: paddr=0x0000a9b68 vaddr=0x50000000 size=0x00004 (=)
→load
I (971) esp_image: segment 11: paddr=0x0000a9b74 vaddr=0x50000004 size=0x00000 (=)
→load
I (1012) esp_image: segment 12: paddr=0x0000a9b7c vaddr=0x50000008 size=0x00000 (=)
→0) load
```

For more details on the type of memory segments and their address ranges, see the ESP32 Technical Reference Manual, Section 1.3.2 Embedded Memory.

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 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:

- `secure_version` - see Anti-rollback.
- `version` - see App version. *
- `project_name` is filled from PROJECT_NAME. *
- `time and date` - compile time and date.
- `idf_ver` - version of ESP-IDF. *
Chapter 2. API 參考

- **app_elf_sha256** - contains sha256 for the elf application file.

* - The maximum length is 32 characters, including null-termination character. For example, if the length of PROJECT_NAME exceeds 32 characters, the excess characters will be disregarded.

This structure is useful for identification of images uploaded OTA because it has a fixed offset = sizeof(esp_image_header_t) + sizeof(esp_image_segment_header_t). As soon as a device receives the first fragment containing this structure, it has all the information to determine whether the update should be continued or not.

### Adding a Custom Structure to an Application

Customer also has the opportunity to have similar structure with a fixed offset relative to the beginning of the image. The following pattern can be used to add a custom structure to your image:

```c
const __attribute__((section(".rodata_custom_desc"))) esp_custom_app_desc_t custom_app_desc = {
    ...}
```

Offset for custom structure is sizeof(esp_image_header_t) + sizeof(esp_image_segment_header_t) + sizeof(esp_app_desc_t).

To guarantee that the custom structure is located in the image even if it is not used, you need to add:

- For **Make**: add `COMPONENT_ADD_LDFLAGS += -u custom_app_desc` into `component.mk`
- For **Cmake**: add `target_link_libraries(${COMPONENT_TARGET} "-u custom_app_desc")` into `CMakeLists.txt`

### API Reference

**Header File**

- **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)
Chapter 2. API

gॉ

**uint8_t spi_pin_drv[3]**
Drive settings for the SPI flash pins (read by ROM bootloader)

**esp_chip_id_t chip_id**
Chip identification number

**uint8_t min_chip_rev**
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
Chapter 2. API 参考

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_ESP32S3 = 0x0004
chip ID: ESP32-S3

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

ESP_IMAGE_SPI_SPEED_20M
SPI clock frequency 20 MHz

ESP_IMAGE_SPI_SPEED_80M = 0xF
SPI clock frequency 80 MHz
```c
enum esp_image_flash_size_t
    Supported SPI flash sizes.

Values:

ESP_IMAGE_FLASH_SIZE_1MB = 0
    SPI flash size 1 MB
ESP_IMAGE_FLASH_SIZE_2MB
    SPI flash size 2 MB
ESP_IMAGE_FLASH_SIZE_4MB
    SPI flash size 4 MB
ESP_IMAGE_FLASH_SIZE_8MB
    SPI flash size 8 MB
ESP_IMAGE_FLASH_SIZE_16MB
    SPI flash size 16 MB
ESP_IMAGE_FLASH_SIZE_MAX
    SPI flash size MAX
```

### 2.7.2 Application Level Tracing

**Overview**

IDF provides useful feature for program behaviour analysis: application level tracing. It is implemented in the corresponding library and can be enabled via menuconfig. This feature allows to transfer arbitrary data between host and ESP32 via JTAG interface with small 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 特定应用程序的跟踪
2. Lightweight logging to the host, see 记录日志到主机
3. System behaviour analysis, see 基于SEGGER SystemView的系统行为分析

**API Reference**

**Header File**

- `app_trace/include/esp_app_trace.h`

**Functions**

```c
esp_err_t esp_apptrace_init(void)
    Initializes application tracing module.

Note  Should be called before any esp_aptrace_xxx call.
Return ESP_OK on success, otherwise see esp_err_t
```

```c
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_aptrace_buffer_get and esp_aptrace_write. This function does not protect internal data by lock.
```

```c
uint8_t *esp_aptrace_buffer_get(esp_aptrace_dest_t dest, uint32_t size, uint32_t tmo)
    Allocates buffer for trace data. After data in buffer are ready to be sent off esp_aptrace_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.

```c
esp_err_t esp_apptrace_buffer_put (esp_apptrace_dest_t dest, uint8_t *ptr, uint32_t tmo)
```

Indicates that the data in buffer are ready to be sent off. This function is a counterpart of and must be preceded by esp_apptrace_buffer_get.

Return ESP_OK on success, otherwise see esp_err_t

Parameters
- **dest**: Indicates HW interface to send data. Should be identical to the same parameter in call to esp_apptrace_buffer_get.
- **ptr**: Address of trace buffer to release. Should be the value returned by call to esp_apptrace_buffer_get.
- **tmo**: Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

```c
esp_err_t esp_apptrace_write (esp_apptrace_dest_t dest, 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.

```c
int esp_apptrace_vprintf_to (esp_apptrace_dest_t dest, uint32_t tmo, const char *fmt, va_list ap)
```

vprintf-like function to sent log messages to host via specified HW interface.

Return Number of bytes written.

Parameters
- **fmt**: Address of format string.
- **ap**: List of arguments.

```c
int esp_apptrace_vprintf (const char *fmt, va_list ap)
```

vprintf-like function to sent log messages to host.

Return Number of bytes written.

Parameters
- **fmt**: Address of format string.
- **ap**: List of arguments.

```c
esp_err_t esp_apptrace_flush (esp_apptrace_dest_t dest, uint32_t tmo)
```

Flushes remaining data in trace buffer to host.

Return ESP_OK on success, otherwise see esp_err_t

Parameters
- **dest**: Indicates HW interface to flush data on.
- **tmo**: Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

```c
esp_err_t esp_apptrace_flush_nolock (esp_apptrace_dest_t dest, uint32_t min_sz, uint32_t tmo)
```

Flushes remaining data in trace buffer to host without locking internal data. This is special version of esp_apptrace_flush which should be called from panic handler.

Return ESP_OK on success, otherwise see esp_err_t

Parameters
- **dest**: Indicates HW interface to flush data on.
- **min_sz**: Threshold for flushing data. If current filling level is above this value, data will be flushed. TRAX destinations only.
• tmo: Timeout for operation (in us). Use ESP_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. After data in buffer are 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 down buffer are 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 completed. 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_TRAX = 0x1
JTAG destination.

ESP_APPTRACE_DEST_UART0 = 0x2
UART destination.
Header File

- app_trace/include/esp_sysview_trace.h

Functions

static esp_err_t esp_sysview_flush(uint32_t tmo)
Flushes remaining data in SystemView trace buffer to host.

Return ESP_OK.
Parameters
- tmo: Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

int esp_sysview_vprintf(const char *format, va_list args)
vprintf-like function to send log messages to the host.

Return Number of bytes written.
Parameters
- format: Address of format string.
- args: List of arguments.

esp_err_t esp_sysview_heap_trace_start(uint32_t tmo)
Starts SystemView heap tracing.

Return ESP_OK on success, ESP_ERR_TIMEOUT if operation has been timed out.
Parameters
- tmo: Timeout (in us) to wait for the host to be connected. Use -1 to wait forever.

esp_err_t esp_sysview_heap_trace_stop(void)
Stops SystemView heap tracing.

Return ESP_OK.

void esp_sysview_heap_trace_alloc(void *addr, uint32_t size, const void *callers)
Sends heap allocation event to the host.

Parameters
- addr: Address of allocated block.
- size: Size of allocated block.
- callers: Pointer to array with callstack addresses. Array size must be CONFIG_HEAP_TRACING_STACK_DEPTH.

void esp_sysview_heap_trace_free(void *addr, const void *callers)
Sends heap de-allocation event to the host.

Parameters
- addr: Address of de-allocated block.
- callers: Pointer to array with callstack addresses. Array size must be CONFIG_HEAP_TRACING_STACK_DEPTH.

2.7.3 控制台终端

ESP-IDF 提供了 console 组件，它包含了开发基于串口的交互式控制终端所需要的所有模块，主要支持以下功能：
- 行编辑，由 linenoise 库具体实现，它支持处理退格键和方向键，支持回看命令的历史纪录，支持命令的自动补全和参数提示。
- 将命令行拆分为参数列表。
- 参数解析，由 argtable3 库具体实现，它支持解析 GNU 样式的命令行参数。
- 用于注册和调度命令的函数。
- 帮助创建 REPL (Read-Evaluate-Print-Loop) 环境的函数。
注解：这些功能模块可以一起使用也可以独立使用，例如仅使用行编辑和命令注册的功能，然后使用getopt函数或者自定义的函数来实现参数解析，而不是直接使用argtable3库。同样地，还可以使用更简单的命令输入方法（比如fgets函数）和其他用于命令分割和参数解析的方法。

行编辑

行编辑功能允许用户通过按键输入来编辑命令，使用退格键删除符号，使用左/右键在命令中移动光标，使用上/下键导航到之前输入的命令，使用制表键（“Tab”）来自动补全命令。

注解：此功能依赖于终端应用程序对ANSI转移符的支持。显示原始UART数据的串口监视器不能与行编辑库一同使用。如果运行system/console示例程序的时候观察到的输出结果是\n或者类似的转移字符而不是命令行提示符esp>`时，就表明当前的串口监视器不支持ANSI转移字符。已知可用的串口监视程序有GNUscreen，minicom和idf_monitor.py（可以通过在项目目录下执行`idf.pymonitor`来调用）。

往前这里可以查看linenoise库提供的所有函数的描述。

配置 Linenoise库不需要显式地初始化，但是在调用行编辑函数之前，可能需要对某些配置的默认值稍作修改。

linenoiseClearScreen()

使用转移字符清除终端屏幕，并将光标定位在左上角。

linenoiseSetMultiLine()

在单行和多行编辑模式之间进行切换。单行模式下，如果命令的长度超过终端的宽度，会在行内滚动命令文本以显示文本的结尾。在这种情况下，文本的开头部分会被隐藏。单行模式在每次按下按键时发送到屏幕刷新的数据较少，与多行模式相比更容易发生故障。另一方面，在单行模式下编辑命令和复制命令将变得更加困难。默认情况下开启的是单行模式。

主循环 linenoise()

在大多数情况下，控制台应用程序都会具有相同的工作形式——在某个循环中不断读取输入的内容，然后解析再处理。linenoise()是专门用来获取用户按键输入的函数，当回车键被按下后便会返回完整的一行内容。因此可以用它来完成前面循环中的“读取”任务。

linenoiseFree()

必须调用此函数才能释放从linenoise()函数获取的命令行缓冲。

提示和补全 linenoiseSetCompletionCallback()

当用户按下制表键时，linenoise会调用补全回调函数，该回调函数会检查当前已经输入的内容，然后调用linenoiseAddCompletion()函数来提供所有可能的补全后的命令列表。启用补全功能，需要事先调用linenoiseSetCompletionCallback()函数来注册补全回调函数。

console组件提供了一个成熟的功能来为注册的命令提供补全功能esp_console_get_completion()（见下文）。

linenoiseAddCompletion()

补全回调函数会通过调用此函数来通知linenoise库当前键入命令所有可能的补全结果。

linenoiseSetHintsCallback()
每当用户的输入改变时，linenoise 就会调用此回调函数，检查到目前为止输入的命令行内容，然后提供带有提示信息的字符串（例如命令参数列表），然后会在同一行上用不同的颜色显示
出该文本。

### linenoiseSetFreeHintsCallback()

如果提示回调函数返回的提示字符串是动态分配的或者需要以其它方式回收，就需要使用
linenoiseSetFreeHintsCallback() 注册具体的清理函数。

### 历史记录  linenoiseHistorySetMaxLen()

该函数设置要保留在内存中的最近输入的命令的数量。用户通过使用向上/向下箭头来导航历史记录。

### linenoiseHistoryAdd()

Linenoise 不会自动向历史记录中添加命令，应用程序需要调用此函数来将命令字符串添加到
历史记录中。

### linenoiseHistorySave()

该函数将命令的历史记录从 RAM 中保存为文本文件，例如保存到 SD 卡或者 Flash 的文件系
统中。

### linenoiseHistoryLoad()

与 linenoiseHistorySave 相对应，从文件中加载历史记录。

### linenoiseHistoryFree()

释放用于存储命令历史记录的内存。当使用完 linenoise 库后需要调用此函数。

### 将命令行拆分成参数列表

console 组件提供 esp_console_split_argv() 函数来将命令行字符串拆分为参数列表。该函数会
返回参数的数量 (argc) 和一个指针数组，该指针数组可以作为 argv 参数传递给任何接受 argc, argv
格式参数的函数。

根据以下规则来将命令行拆分成参数列表：

- 参数由空格分隔
- 如果参数本身需要使用空格，可以使用 `\` (反斜杠) 对它们进行转义
- 其它能被识别的转义字符有 `\` (显示反斜杠本身) 和 `"` (显示双引号)
- 可以使用双引号来引用参数，引号只可能出现在参数的开头和结尾，参数中的引号必须如上所述进
行转移。参数周围的引号会被 esp_console_split_argv() 函数删除

示例:

- `abc def 1 20 .3` → `[abc, def, 1, 20, .3]`
- `abc "123 456" def` → `[abc, 123 456, def]`
- `'a\ b\c"` → `['a b\c"]`

### 参数解析

对于参数解析，console 组件使用 argtable3 库。有关 argtable3 的介绍请查看 教程 或者 Github 仓库中的
示例代码。

### 命令的注册与调度

console 组件包含了一些工具函数，用来注册命令，将用户输入的命令和已经注册的命令进行匹配，使
用命令行输入的参数调用命令。

Submit Document Feedback
应用程序首先调用 `esp_console_init()` 来初始化命令注册模块，然后调用 `esp_console_cmd_register()` 函数注册命令处理程序。

对于每个命令，应用程序需要提供以下信息（需要以 `esp_console_cmd_t` 结构体的形式给出）：

- 命令名字（不含空格的字符串）
- 帮助文档，解释该命令的用途
- 可选的提示文本，列出命令的参数。如果应用程序使用 Artable3 库来解析参数，则可以通过提供指向 Artable 参数定义结构体的指针来自动生成提示文本
- 命令处理函数

命令注册模块还提供了其它函数：

`esp_console_run()`

该函数接受命令行字符串，使用 `esp_console_split_argv()` 函数将其拆分为 `argv` 形式的参数列表，在已经注册的组件列表中查找命令，如果找到，则执行其对应的处理程序。

`esp_console_register_help_command()`

将 `help` 命令添加到已注册命令列表中，此命令将会以列表的方式打印所有注册的命令及其参数和帮助文本。

`esp_console_get_completion()`

与 `linenoise` 库中的 `linenoiseSetCompletionCallback()` 一同使用的回调函数，根据已经注册的命令列表为 `linenoise` 提供补全功能。

`esp_console_get_hint()`

与 `linenoise` 库中 `linenoiseSetHintsCallback()` 一同使用的回调函数，为 `linenoise` 提供已经注册的命令的参数提示功能。

初始化 REPL 环境

`console` 组件还提供了一些 API 来帮助创建一个基本的 REPL 环境。

在一个典型的 `console` 应用中，你只需要调用 `esp_console_new_repl_uart()`，它会为你初始化好构建在 UART 基础上的 REPL 环境，其中包括安装 UART 驱动，基本的 console 配置，创建一个新的线程来执行 REPL 任务，注册一些基本的命令（比如 `help` 命令）。

完成了之后你可以使用 `esp_console_cmd_register()` 来注册其它命令。REPL 环境在初始化后需要再调用 `esp_console_start_repl()` 函数才能开始运行。

应用程序示例

`system/console` 目录下提供了 `console` 组件的示例应用程序，展示了具体的使用方法。该示例介绍了如何初始化 UART 和 VFS 的功能，设置 `linenoise` 库。从 UART 中读取命令并加以处理，然后将历史命令存储到 Flash 中。更多信息，请参阅示例代码目录中的 README.md 文件。

此外，ESP-IDF 还提供了基于 `console` 组件的示例程序，它们可以辅助应用程序的开发。例如，`peripherals/i2c/i2c_tools`，`wifi/iperf` 等等。

API 参考

Header File

- `console/esp_console.h`
**Functions**

`esp_err_t esp_console_init(const esp_console_config_t *config)`
initialize console module

**Note** Call this once before using other console module features

**Return**
- ESP_OK on success
- ESP_ERR_NO_MEM if out of memory
- ESP_ERR_INVALID_STATE if already initialized
- ESP_ERR_INVALID_ARG if the configuration is invalid

**Parameters**
- config: console configuration

`esp_err_t esp_console_deinit(void)`
de-initialize console module

**Note** Call this once when done using console module functions

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if not initialized yet

`esp_err_t esp_console_cmd_register(const esp_console_cmd_t *cmd)`
Register console command.

**Return**
- ESP_OK on success
- ESP_ERR_NO_MEM if out of memory
- ESP_ERR_INVALID_ARG if command description includes invalid arguments

**Parameters**
- cmd: pointer to the command description; can point to a temporary value

`esp_err_t esp_console_run(const char *cmdline, int *cmd_ret)`
Run command line.

**Return**
- ESP_OK, if command was run
- ESP_ERR_INVALID_ARG, if the command line is empty, or only contained whitespace
- ESP_ERR_NOT_FOUND, if command with given name wasn’t registered
- ESP_ERR_INVALID_STATE, if esp_console_init wasn’t called

**Parameters**
- cmdline: command line (command name followed by a number of arguments)
- [out] cmd_ret: return code from the command (set if command was run)

`size_t esp_console_split_argv(char *line, char **argv, size_t argv_size)`
Split command line into arguments in place.

```
* - 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**
Chapter 2. API 参考

- 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, linenoiseCompleteitions *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`: linenoiseCompleteitions 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. linenoiseSetFree-HintsCallback 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

```c
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 a 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
- `dev_config`: UART device configuration
- `repl_config`: REPL configuration
- `ret_repl`: return REPL handle after initialization succeed, return NULL otherwise

```c
esp_err_t esp_console_start_repl(esp_console_repl_t *repl)
```

Start REPL environment.

#### Note
Once the REPL got started, it won’t be stopped until user call 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**

- `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.

```c
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> “)

```c
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`
  - Comunication 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.
Chapter 2. API Reference

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 the `help` output.

**const char* hint**
Hint text, usually lists possible arguments. If set to NULL, and argument 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()**

Type Definitions

**typedef struct linenoiseCompletions linenoiseCompletions**
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 Chapter eFuse Controller of ESP32 Technical Reference Manual. Some eFuse bits are available for user applications.

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:

- \texttt{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 \texttt{idf.py efuse_common_table}). Note that changes in this file can lead to incorrect operation.
- \texttt{custom} (optional and can be enabled by \texttt{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 \texttt{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:

\textbf{field_name} Name of field. The prefix \texttt{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 name, and expand the field as well (see \texttt{MAC_FACTORY} field in the common table).

\textbf{efuse_block} Block number. It determines where the eFuse bits will be placed for this field. Available \texttt{EFUSE_BLK0..EFUSE_BLK3}.

\textbf{bit_start} Start bit number (0..255). The bit_start field can be omitted. In this case, it will be set to bit_start + bit_count from the previous record, if it has the same efuse_block. Otherwise (if efuse_block is different, or this is the first entry), an error will be generated.
**bit_count** The number of bits to use in this field (1.-). This parameter cannot 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_MAX_BLK_LEN`, 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`.

**efuse_table_gen.py tool**

The tool is designed to generate C-source files from CSV file and validate fields. First of all, the check is carried out on the uniqueness of the names and overlaps of the field bits. If an additional custom file is used, it will be checked with the existing common file (esp_efuse_table.csv). In case of errors, a message will be displayed and the string that caused the error. C-source files contain structures of type `esp_efuse_desc_t`.

To generate a common files, use the following command `idf.py efuse_common_table` or:

```
cd $IDF_PATH/components/efuse/
./efuse_table_gen.py esp32.esp_efuse_table.csv
```

After generation in the folder esp32 create:

- `esp_efuse_table.c` file.
- In `include` folder `esp_efuse_table.h` file.

To generate a custom files, use the following command `idf.py efuse_custom_table` or:

```
cd $IDF_PATH/components/efuse/
./efuse_table_gen.py 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.h` 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"
```

**Support 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 are not used.

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 `espelfuse.py -p COM4 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 `EFUSE_CODE_SCHEME_SELECTOR` option to select the coding type for tables in a Kconfig. When generating source files, if your tables do not follow the coding scheme, an error message will be displayed. Adjust the length or offset fields. If your program was compiled with `None` encoding and 3/4 is used in the chip, then the `ESP_ERR_CODING` error may occur when calling the eFuse API (the field is outside the block boundaries). If the field matches the new block boundaries, then the API will work without errors.

Also, 3/4 coding scheme imposes restrictions on writing bits belonging to one coding unit. The whole block with a length of 256 bits is divided into 4 coding units, and in each coding unit there are 6 bytes of useful data and 2 service bytes. These 2 service bytes contain the checksum of the previous 6 data bytes.

It turns out that only one field can be written into one coding unit. Repeated rewriting in one coding unit is prohibited. But if the record was made in advance or through a `esp_efuse_write_block()` function, then reading the fields belonging to one coding unit is possible.

In case 3/4 coding scheme, the writing process is divided into the coding units and we can not use the usual mode of writing some fields. We can prepare all the data for writing and burn it in one time. You can also use this mode for `None` coding scheme but it is not necessary. It is important for 3/4 coding scheme. To write some fields in one time need to use the batch writing mode. Firstly set this mode through `esp_efuse_batch_write_begin()` function then write some fields as usual use the `esp_efuse_write_...` functions. At the end to burn they, need to call the `esp_efuse_batch_write_commit()` function. It burns prepared data to the efuse blocks and disable the batch recording mode. The batch writing mode blocks `esp_efuse_read_...` operations.

After changing the coding scheme, run `efuse_common_table` and `efuse_custom_table` commands to check the tables of the new coding scheme.

eFuse API

Access to the fields is via a pointer to the description structure. API functions have some basic operation:

- `esp_efuse_read_field_blob()` - returns an array of read eFuse bits.
- `esp_efuse_read_field_cnt()` - returns the number of bits programmed as “1”.
- `esp_efuse_write_field_blob()` - writes an array.
- `esp_efuse_write_field_cnt()` - writes a required count of bits as “1”.
- `esp_efuse_get_field_size()` - returns the number of bits by the field name.
- `esp_efuse_read_reg()` - returns value of eFuse register.
- `esp_efuse_write_reg()` - writes value to eFuse register.
- `esp_efuse_get_coding_scheme()` - returns eFuse coding scheme for blocks.
- `esp_efuse_read_block()` - reads key to eFuse block starting at the offset and the required size.
- `esp_efuse_write_block()` - writes key to eFuse block starting at the offset and the required size.
- `esp_efuse_batch_write_begin()` - set the batch mode of writing fields.
- `esp_efuse_batch_write_commit()` - writes all prepared data for batch writing mode and reset the batch writing mode.
Chapter 2. API

- `esp_efuse_batch_write_cancel()` - reset the batch writing mode and prepared data.

For frequently used fields, special functions are made, like this `esp_efuse_get_chip_ver()`, `esp_efuse_get_pkg_ver()`.

**How add a new field**

1. Find a free bits for field. Show `esp_efuse_table.csv` file or run `idf.py show_efuse_table` or the next command:

   ```bash
   $ ./efuse_table_gen.py esp32/esp_efuse_table.csv --info
   eFuse coding scheme: NONE
   # field_name  efuse_block       bit_start  bit_count
   1 WR_DIS_FLASH_CRYPT_CNT  EFUSE_BLK0   2          1
   2 WR_DIS_BLK1              EFUSE_BLK0   7          1
   3 WR_DIS_BLK2              EFUSE_BLK0   8          1
   4 WR_DIS_BLK3              EFUSE_BLK0   9          1
   5 RD_DIS_BLK1              EFUSE_BLK0   16         1
   6 RD_DIS_BLK2              EFUSE_BLK0   17         1
   7 RD_DIS_BLK3              EFUSE_BLK0   18         1
   8 FLASH_CRYPT_CNT          EFUSE_BLK0   20         7
   9 MAC_FACTORY              EFUSE_BLK0   32         8
   10 MAC_FACTORY             EFUSE_BLK0   40         8
   11 MAC_FACTORY             EFUSE_BLK0   48         8
   12 MAC_FACTORY             EFUSE_BLK0   56         8
   13 MAC_FACTORY             EFUSE_BLK0   64         8
   14 MAC_FACTORY             EFUSE_BLK0   72         8
   15 MAC_FACTORY_CRC         EFUSE_BLK0   80         8
   16 CHIP_VER_DIS_APP_CPU    EFUSE_BLK0   96         1
   17 CHIP_VER_DIS_BT         EFUSE_BLK0   97         1
   18 CHIP_VER_PKG            EFUSE_BLK0  105        3
   19 CHIP_CPU_FREQ_LOW       EFUSE_BLK0  108        1
   20 CHIP_CPU_FREQ_RATED     EFUSE_BLK0  109        1
   21 CHIP_VER_REV1           EFUSE_BLK0  111        1
   22 ADC_VREF_AND_SDIO_DREF  EFUSE_BLK0  136        6
   23 XPD_SDIO_REG            EFUSE_BLK0  142        1
   24 SDIO_TIEH               EFUSE_BLK0  143        1
   25 SDIO_FORCE              EFUSE_BLK0  144        1
   26 ENCRYPT_CONFIG          EFUSE_BLK0  188        4
   27 CONSOLE_DEBUG_DISABLE   EFUSE_BLK0  194        1
   28 ABS_DONE_0              EFUSE_BLK0  196        1
   29 DISABLE_JTAG            EFUSE_BLK0  198        1
   30 DISABLE_DL_ENCRYPT      EFUSE_BLK0  199        1
   31 DISABLE_DL_DECRYPT      EFUSE_BLK0  200        1
   32 DISABLE_DL_CACHE        EFUSE_BLK0  201        1
   33 ENCRYPT_FLASH_KEY       EFUSE_BLK1  0          256
   34 SECURE_BOOT_KEY         EFUSE_BLK2  0          256
   35 MAC_CUSTOM_CRC          EFUSE_BLK3  0          8
   36 MAC_CUSTOM              EFUSE_BLK3  8          48
   37 ADC1_TP_LOW             EFUSE_BLK3  96         7
   38 ADC1_TP_HIGH            EFUSE_BLK3  103        9
   39 ADC2_TP_LOW             EFUSE_BLK3  112        7
   40 ADC2_TP_HIGH            EFUSE_BLK3  119        9
   41 SECURE_VERSION          EFUSE_BLK3  128       32
   42 MAC_CUSTOM_VER          EFUSE_BLK3  184        8
   
   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
Chapter 2. API 参考

| 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.

1. Fill a line for field: field_name, efuse_block, bit_start, bit_count, comment.
2. 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.

esefuse.py  esptool includes a useful tool for reading/writing ESP32 eFuse bits - esefuse.py.
Flash voltage (VDD_SDIO) determined by GPIO12 on reset (High for 1.8V, Low/NC for ~3.3V).

To get a dump for all eFuse registers.
Header File

- 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.

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

Return

- true: The field parameter is valid and the bit is set.
- false: The bit is not set, or the parameter is invalid and assertions are disabled.

Parameters

- [in] field: A pointer to the structure describing the fields of efuse.

```c
esp_err_t esp_efuse_read_field_cnt(const esp_efuse_desc_t *field[], size_t *out_cnt)
```
Reads bits from EFUSE field and returns number of bits programmed as “1”.

If the bits are set not sequentially, they will still be counted.

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_protection** (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_protection** (esp_efuse_block_t blk)

Sets a read protection for the whole block.
Chapter 2. API

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.

Return  Returns the number of bits used by field.

Parameters
- [in] field: A pointer to the structure describing the fields of efuse.

uint32_t esp_efuse_read_reg(esp_efuse_block_t blk, unsigned int num_reg)

Returns value of efuse register.

This is a thread-safe implementation. Example: EFUSE_BLK2_RDATA3_REG where (blk=2, num_reg=3)

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.

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.

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] dst_key: A pointer to array that will contain the result of reading.
- [in] size_bits: The number of bits required to read.
### `esp_err_t esp_efuse_write_block` (esp_efuse_block_t blk, const void *src_key, size_t offset_in_bits, size_t size_bits)

Write key to efuse block starting at the offset and the required size.

**Return**
- ESP_OK: The operation was successfully completed.
- ESP_ERR_INVALID_ARG: Error in the passed arguments.
- ESP_ERR_CODING: Error range of data does not match the coding scheme.
- ESP_ERR_EFUSE_REPEATED_PROG: Error repeated programming of programmed bits

**Parameters**
- [in] blk: Block number of eFuse.
- [in] src_key: A pointer to array that contains the key for writing.
- [in] size_bits: The number of bits required to write.

### `uint8_t esp_efuse_get_chip_ver` (void)

Returns chip version from efuse.

**Return** chip version

### `uint32_t esp_efuse_get_pkg_ver` (void)

Returns chip package from efuse.

**Return** chip package

### `void esp_efuse_burn_new_values` (void)

### `void esp_efuse_reset` (void)

### `void esp_efuse_disable_basic_rom_console` (void)

### `esp_err_t esp_efuse_disable_rom_download_mode` (void)

### `void esp_efuse_write_random_key` (uint32_t blk_wdata0_reg)

### `uint32_t esp_efuse_read_secure_version` (void)

### `bool esp_efuse_check_secure_version` (uint32_t secure_version)

### `esp_err_t esp_efuse_update_secure_version` (uint32_t secure_version)

### `void esp_efuse_init` (uint32_t offset, uint32_t size)

### `esp_err_t esp_efuse_batch_write_begin` (void)

### `esp_err_t esp_efuse_batch_write_cancel` (void)

### `esp_err_t esp_efuse_batch_write_commit` (void)

### Structures

**struct esp_efuse_desc_s**

Structure eFuse field.

### Public Members

- esp_efuse_block_t efuse_block: 8
  - Block of eFuse

- uint8_t bit_start
  - Start bit [0..255]

- uint16_t bit_count
  - Length of bit field [1..-]
Macros

**ESP_ERR_EFUSE**
Base error code for efuse api.

**ESP_OK_EFUSE_CNT**
OK the required number of bits is set.

**ESP_ERR_EFUSE_CNT_IS_FULL**
Error field is full.

**ESP_ERR_EFUSE_REPEATED_PROG**
Error repeated programming of programmed bits is strictly forbidden.

**ESP_ERR_CODING**
Error while an encoding operation.

Type Definitions

typedef struct esp_efuse_desc_s esp_efuse_desc_t
Type definition for an eFuse field.

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

- esp_common/include/esp_err.h

Functions

**const char* esp_err_to_name (esp_err_t code)**
Returns string for esp_err_t error codes.

This function finds the error code in a pre-generated lookup-table and returns its string representation.

The function is generated by the Python script tools/gen_esp_err_to_name.py which should be run each time an esp_err_t error is modified, created or removed from the IDF project.

**Return** string error message

**Parameters**

- **code**: esp_err_t error code

**const char* esp_err_to_name_r (esp_err_t code, char* buf, size_t buflen)**
Returns string for esp_err_t and system error codes.

This function finds the error code in a pre-generated lookup-table of esp_err_t errors and returns its string representation. If the error code is not found then it is attempted to be found among system errors.

The function is generated by the Python script tools/gen_esp_err_to_name.py which should be run each time an esp_err_t error is modified, created or removed from the IDF project.

**Return** buf containing the string error message

**Parameters**

- **code**: esp_err_t error code
- **buf**: buffer where the error message should be written
- **buflen**: Size of buffer buf. At most buflen bytes are written into the buf buffer (including the terminating null byte).
Macros

ESP_OK
   esp_err_t value indicating success (no error)
ESP_FAIL
   Generic esp_err_t code indicating failure
ESP_ERR_NO_MEM
   Out of memory
ESP_ERR_INVALID_ARG
   Invalid argument
ESP_ERR_INVALID_STATE
   Invalid state
ESP_ERR_INVALID_SIZE
   Invalid size
ESP_ERR_NOT_FOUND
   Requested resource not found
ESP_ERR_NOT_SUPPORTED
   Operation or feature not supported
ESP_ERR_TIMEOUT
   Operation timed out
ESP_ERR_INVALID_RESPONSE
   Received response was invalid
ESP_ERR_INVALID_CRC
   CRC or checksum was invalid
ESP_ERR_INVALID_VERSION
   Version was invalid
ESP_ERR_INVALID_MAC
   MAC address was invalid
ESP_ERR_WIFI_BASE
   Starting number of WiFi error codes
ESP_ERR_MESH_BASE
   Starting number of MESH error codes
ESP_ERR_FLASH_BASE
   Starting number of flash error codes
ESP_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 int32_t 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;
}
```

Signature Verification

For additional security, signature of OTA firmware images can be verified. For that, refer to the documentation.

API Reference

Header File

- `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 OTA_VALIDATE FAILED: Invalid app image
- ESP_ERR_NO_MEM: Cannot allocate memory for OTA operation.
- ESP_ERR FLASH_OP_TIMEOUT or ESP_ERR FLASH_OP_FAIL: Flash write failed.
- For other return codes, refer OTA documentation in esp-idf’s app_update component.

Parameters

- [in] `config`: pointer to `esp_http_client_config_t` structure.
Chapter 2. API

**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 initialized and HTTPS connection established
- ESP_FAIL: For generic failure.
- ESP_ERR_INVALID_ARG: Invalid argument (missing/incorrect config, certificate, etc.)
- For other return codes, refer documentation in app_update component and esp_http_client component in esp-idf.

**Parameters**

- **[in]** ota_config: pointer to esp_https_ota_config_t structure
- **[out]** handle: pointer to an allocated data of type esp_https_ota_handle_t which will be initialized 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_ERROTALVALIDATEFAILED: Invalid app image
- ESP_ERR_NO_MEM: Cannot allocate memory for OTA operation.
- ESP_ERR_FLASH_OP_TIMEOUT or ESP_ERR_FLASH_OP_FAIL: Flash write failed.
- For other return codes, refer OTA documentation in esp-idf’s app_update component.

**Parameters**

- **[in]** https_ota_handle: pointer to esp_https_ota_handle_t structure

**bool esp_https_ota_is_complete_data_received** *(esp_https_ota_handle_t https_ota_handle)*

Checks if complete data was received or not.

**Note** This API can be called just before esp_https_ota_finish() to validate if the complete image was indeed received.

**Return**

- false
- true

**Parameters**

- **[in]** https_ota_handle: pointer to esp_https_ota_handle_t structure

**esp_err_t esp_https_ota_finish** *(esp_https_ota_handle_t https_ota_handle)*

Clean-up HTTPS OTA Firmware upgrade and close HTTPS connection.

This function closes the HTTP connection and frees the ESP HTTPS OTA context. This function switches the boot partition to the OTA partition containing the new firmware image.

**Note** If this API returns successfully, esp_restart() must be called to boot from the new firmware image.

**Return**

- ESP_OK: Clean-up successful
Chapter 2. API

- ESP_ERR_INVALID_STATE
- ESP_ERR_INVALID_ARG: Invalid argument
- ESP_ERR_OTA_VALIDATE_FAILED: Invalid app image

**Parameters**

- [in] https_ota_handle: pointer to esp_https_ota_handle_t structure

```c
esp_err_t esp_https_ota_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

```c
int esp_https_ota_get_image_len_read(esp_https_ota_handle_t https_ota_handle)
```

This function returns OTA image data read so far.

**Note** This API should be called only if esp_https_ota_perform() has been called at least once or if esp_https_ota_get_img_desc has been called before.

**Return**

- -1 On failure
- total bytes read so far

**Parameters**

- [in] https_ota_handle: pointer to esp_https_ota_handle_t structure

**Structures**

```c
struct esp_https_ota_config_t
```

ESP HTTPS OTA configuration.

**Public Members**

```c
const esp_http_client_config_t *http_config
```

ESP HTTP client configuration

```c
http_client_init_cb_t http_client_init_cb
```

Callback after ESP HTTP client is initialised

```c
bool bulk_flash_erase
```

Erase entire flash partition during initialization. By default flash partition is erased during write operation and in chunk of 4K sector size

**Macros**

```c
ESP_ERR_HTTPS_OTA_BASE
ESP_ERR_HTTPS_OTA_IN_PROGRESS
```

**Type Definitions**

```c
typedef void *esp_https_ota_handle_t
typedef esp_err_t (*http_client_init_cb_t)(esp_http_client_handle_t)
```
2.7.7 ESP-pthread

Overview

This module offers Espressif specific extensions to the pthread library that can be used to influence the behaviour of pthreads.

- Stack size of the pthreads
- Priority of the created pthreads
- Inheriting this configuration across threads
- Thread name
- Core affinity / core pinning.

Example to tune the stack size of the pthread:

```c
void * thread_func(void * p)
{
    printf("In thread_func\n");
    return NULL;
}

void app_main(void)
{
    pthread_t t1;
    esp_pthread_cfg_t cfg = esp_create_default_pthread_config();
    cfg.stack_size = (4 * 1024);
    esp_pthread_set_cfg(&cfg);
    pthread_create(&t1, NULL, thread_func);
}
```

The API can also be used for inheriting the settings across threads. For example:

```c
void * my_thread2(void * p)
{
    /* This thread will inherit the stack size of 4K */
    printf("In my_thread2\n");
    return NULL;
}

void * my_thread1(void * p)
{
    printf("In my_thread1\n");
    pthread_t t2;
    pthread_create(&t2, NULL, my_thread2);
    return NULL;
}

void app_main(void)
{
    pthread_t t1;
    esp_pthread_cfg_t cfg = esp_create_default_pthread_config();
    cfg.stack_size = (4 * 1024);
    cfg.inherit_cfg = true;
    esp_pthread_set_cfg(&cfg);
    pthread_create(&t1, NULL, my_thread1);
}```
API Reference

Header File

- 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_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_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_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.

- `bool inherit_cfg`
  Inherit this configuration further.

- `const char *thread_name`
  The thread name.
int pin_to_core
    The core id to pin the thread to. Has the same value range as xCoreId argument of xTaskCreatePinnedToCore.

Macros
PTHREAD_STACK_MIN

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 wifi 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 WiFi, a successful connection to the access point may be an event. Events are referenced using a two part identifier which are discussed more here. Event loops are the vehicle by which events get posted by event sources and handled by event handler functions. These two appear prominently in the event loop library APIs.

Using this library roughly entails the following flow:

1. A user defines a function that should run when an event is posted to a loop. This function is referred to as the event handler. It should have the same signature as esp_event_handler_t.
2. An event loop is created using esp_event_loop_create(), which outputs a handle to the loop of type esp_event_loop_handle_t. Event loops created using this API are referred to as user event loops. There is, however, a special type of event loop called the default event loop which are discussed here.
3. Components register event handlers to the loop using esp_event_handler_register_with(). Handlers can be registered with multiple loops, more on that here.
4. Event sources post an event to the loop using esp_event_post_to().
5. Components wanting to remove their handlers from being called can do so by unregistering from the loop using esp_event_handler_unregister_with().
6. Event loops which are no longer needed can be deleted using esp_event_loop_delete().

In code, the flow above may look like as follows:

```c
// 1. Define the event handler
void run_on_event (void *handler_arg, esp_event_base_t base, int32_t id, void *event_data)
{
    // Event handler logic
}

void app_main()
{
    // 2. A configuration structure of type esp_event_loop_args_t is needed to
    // specify the properties of the loop to be
    // created. A handle of type esp_event_loop_handle_t is obtained, which is
    // needed by the other APIs to reference the loop
    // to perform their operations on.
    esp_event_loop_args_t loop_args = {
        .queue_size = ...,  
```
Declaring and defining events

As mentioned previously, events consists of two-part identifiers: the event base and the event ID. The event base identifies an independent group of events; the event ID identifies the event within that group. Think of the event base and event ID as a person’s last name and first name, respectively. A last name identifies a family, and the first name identifies a person within that family.

The event loop library provides macros to declare and define the event base easily.

Event base declaration:

```
ESP_EVENT_DECLARE_BASE(EVENT_BASE)
```

Event base definition:

```
ESP_EVENT_DEFINE_BASE(EVENT_BASE)
```

注解：In IDF, the base identifiers for system events are uppercase and are postfixed with _EVENT. For example, the base for wifi 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 (WiFi 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><code>esp_event_loop_create()</code></td>
<td><code>esp_event_loop_create_default()</code></td>
</tr>
<tr>
<td><code>esp_event_loop_delete()</code></td>
<td><code>esp_event_loop_delete_default()</code></td>
</tr>
<tr>
<td><code>esp_event_handler_register_with()</code></td>
<td><code>esp_event_handler_register()</code></td>
</tr>
<tr>
<td><code>esp_event_handler_unregister_with()</code></td>
<td><code>esp_event_handler_unregister()</code></td>
</tr>
<tr>
<td><code>esp_event_post_to()</code></td>
<td><code>esp_event_post()</code></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. `<event base>, <event ID>` - handler executes when the event with base `<event base>` and event ID `<event ID>` gets posted to the loop
2. `<event base>, ESP_EVENT_ANY_ID` - handler executes when any event with base `<event base>` gets posted to the loop
3. ESP_EVENT_ANY_BASE, ESP_EVENT_ANY_ID - handler executes when any event gets posted to the loop

As an example, suppose the following handler registrations were performed:
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**

- `esp_event/include/esp_event.h`

**Functions**

```
 esp_err_t esp_event_loop_create(const esp_event_loop_args_t *event_loop,
                                 esp_event_loop_handle_t *event_loop)
```

Create a new 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
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

**esp_err_t esp_event_loop_create_default** (void)

Create default event loop.

Return

- ESP_OK: Success
- ESP_ERR_NO_MEM: Cannot allocate memory for event loops list
- ESP_FAIL: Failed to create task loop
- Others: Fail

**esp_err_t esp_event_loop_delete_default** (void)

Delete the default event loop.

Return

- ESP_OK: Success
- Others: Fail

**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 of the allotted time waiting on the event queue. Once an event has been unqueued, 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 unqueued event, and (2) during dispatch of the unqueued 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 unqueued 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
- [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_handle_t event_loop, esp_event_base_t event_base, int32_t event_id, esp_event_handler_t event_handler, void *event_handler_arg)
```

Register an event handler to a specific loop (legacy).

This function behaves in the same manner as `esp_event_handler_register`, except the additional specification of the event loop to register the handler to.

**Note** 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
- `[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_handle_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
• [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_instance_register_with, except that it registers the handler.

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).
This function can be used to unregister a handler so that it no longer gets called during dispatch. Handlers can be unregistered 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_unregister()` 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`

This function ignores unregistration of handler instance that has not been previously registered.

**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
- `[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.

This function can be used to unregister a handler so that it no longer gets called during dispatch. Handlers can be unregistered 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`

This function ignores unregistration of handler instances that have not been previously registered.

**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
• [in] event_base: the base of the event with which to unregister the handler
• [in] event_id: the id of the event with which to unregister the handler
• [in] instance: the instance object of the registration to be unregistered

**esp_err_t** esp_event_handler_instance_unregister (esp_event_base_t event_base, int32_t event_id, esp_event_handler_instance_t instance)

Unregister a handler from the system event loop.

This function does the same as esp_event_handler_instance_unregister_with, except that it unregisters the handler instance from the default event loop.

Return
• ESP_OK: Success
• ESP_ERR_INVALID_ARG: Invalid combination of event base and event id
• Others: Fail

Parameters
• [in] event_base: the base of the event with which to unregister the handler
• [in] event_id: the id of the event with which to unregister the handler
• [in] instance: the instance object of the registration to be unregistered

**esp_err_t** esp_event_post (esp_event_base_t event_base, int32_t event_id, 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

**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
• [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

`esp_err_t esp_event_isr_post` event_data_size

`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.

`esp_err_t esp_event_isr_post_to` event_data_size

`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
• [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.

`esp_err_t esp_event_dump` event_data_size

`esp_event_dump` (FILE *file)

Dumps statistics of all event loops.

Dumps event loop info in the format:

```
  event loop
  handler
  handler
  ...
  event loop
  handler
  handler
```

(下页继续)
Chapter 2. API

... where:

event loop
  format: address, name rx: total_recieved dr: total_dropped
  where:
  address - memory address of the event loop
  name - name of the event loop, 'none' if no dedicated task
  total_recieved - number of successfully posted events
  total_dropped - number of events unsuccessfully posted due to queue being full

handler
  format: address ev: base, id inv: total_invoked run: total_runtime
  where:
  address - address of the handler function
  base, id - the event specified by event base and id this handler executes
  total_invoked - number of times this handler has been invoked
  total_runtime - total amount of time used for invoking this handler

Note this function is a noop when CONFIG_ESP_EVENT_LOOP_PROFILING is disabled

Return
  • ESP_OK: Success
  • ESP_ERR_NO_MEM: Cannot allocate memory for event loops list
  • Others: Fail

Parameters
  • [in] file: the file stream to output to

Structures

struct esp_event_loop_args_t
  Configuration for creating event loops.

Public Members

int32_t queue_size
  size of the event loop queue

const char *task_name
  name of the event loop task; if NULL, a dedicated task is not created for event loop

UBaseType_t task_priority
  priority of the event loop task, ignored if task name is NULL

uint32_t task_stack_size
  stack size of the event loop task, ignored if task name is NULL

BaseType_t task_core_id
  core to which the event loop task is pinned to, ignored if task name is NULL

Header File

  • 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**

```c
typedef void *esp_event_loop_handle_t
```
- a number that identifies an event with respect to a base

```c
typedef void (*esp_event_handler_t)(void *event_handler_arg, esp_event_base_t event_base, int32_t event_id, void *event_data)
```
- function called when an event is posted to the queue

```c
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**
- esp_event/include/esp_event_legacy.h

**Functions**

```c
esp_err_t esp_event_send(system_event_t *event)
```
- Send a 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
- others: fail

**Parameters**
- *[in]* event: Event to send

```c
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 a 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 WiFi Driver only.

**Return**
- ESP_OK: succeed
- 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

void esp_event_set_default_eth_handlers (void)
Install default event handlers for Ethernet interface.

Note This API is part of the legacy event system. New code should use event library API in esp_event.h.

void esp_event_set_default_wifi_handlers (void)
Install default event handlers for Wi-Fi interfaces (station and AP)

Note This API is part of the legacy event system. New code should use event library API in esp_event.h.

esp_err_t esp_event_loop_init (system_event_cb_t cb, void *ctx)
Initialize event loop.

Create the event handler and task

Note This API is part of the legacy event system. New code should use event library API in esp_event.h.

Return
• ESP_OK: succeed
• others: fail

Parameters
• cb: application specified event callback, it can be modified by call esp_event_set_cb
• ctx: reserved for user

system_event_cb_t esp_event_loop_set_cb (system_event_cb_t cb, void *ctx)
Set application specified event callback function.

Note This API is part of the legacy event system. New code should use event library API in esp_event.h.

Attention 1. If cb is NULL, means application 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
union system_event_info_t
#include <esp_event_legacy.h> Union of all possible system_event argument structures

Public Members

system_event_sta_connected_t connected
ESP32 station connected to AP

system_event_sta_disconnected_t disconnected
ESP32 station disconnected to AP

system_event_sta_scan_done_t scan_done
ESP32 station scan (APs) done

system_event_sta_authmode_change_t auth_change
the auth mode of AP ESP32 station connected to changed

system_event_sta_got_ip_t got_ip
ESP32 station got IP, first time got IP or when IP is changed
Chapter 2. API 参考

```c
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_probereqrecvd
    ESP32 soft-AP receive probe request packet

system_event_ap_staipassigned_t ap_staipassigned
    ESP32 soft-AP assign an IP to the station

system_event_got_ip6_t got_ip6
    ESP32 station or ap or ethernet ipv6 addr state change to preferred
```

### Structures

```c
struct system_event_t
    Event, as a tagged enum

Public Members

```c
system_event_id_t event_id
    event ID

system_event_info_t event_info
    event information
```

### Macros

```c
SYSTEM_EVENT_AP_STA_GOT_IP6
```

### Type Definitions

```c
typedef wifi_event_sta_wps_fail_reason_t system_event_sta_wps_fail_reason_t
    Argument structure of SYSTEM_EVENT_STA_WPS_ER_FAILED event

typedef wifi_event_sta_scan_done_t system_event_sta_scan_done_t
    Argument structure of SYSTEM_EVENT_SCAN_DONE event

typedef wifi_event_sta_connected_t system_event_sta_connected_t
    Argument structure of SYSTEM_EVENT_STA_CONNECTED event

typedef wifi_event_sta_disconnected_t system_event_sta_disconnected_t
    Argument structure of SYSTEM_EVENT_STA_DISCONNECTED event

typedef wifi_event_sta_authmode_change_t system_event_sta_authmode_change_t
    Argument structure of SYSTEM_EVENT_STA_AUTHMODE_CHANGE event

typedef wifi_event_sta_wps_er_pin_t system_event_sta_wps_er_pin_t
    Argument structure of SYSTEM_EVENT_STA_WPS_ER_PIN event

typedef wifi_event_sta_wps_er_success_t system_event_sta_wps_er_success_t
    Argument structure of SYSTEM_EVENT_STA_WPS_ER_SUCCESS event

typedef wifi_event_ap_staconnected_t system_event_ap_staconnected_t
    Argument structure of event
```
typedef wifi_event_ap_stadisconnected_t system_event_ap_stadisconnected_t
    Argument structure of event

typedef wifi_event_ap_probe_req_rx_t system_event_ap_probe_req_rx_t
    Argument structure of event

typedef ip_event_ap_staipassigned_t system_event_ap_staipassigned_t
    Argument structure of event

typedef ip_event_got_ip_t system_event_sta_got_ip_t
    Argument structure of event

typedef ip_event_got_ip6_t system_event_got_ip6_t
    Argument structure of event

typedef esp_err_t (*system_event_handler_t)(esp_event_base_t event_base, int32_t event_id,
    void *event_data, size_t event_data_size, TickType_t ticks_to_wait)

    Event handler function type

typedef esp_err_t (*system_event_cb_t)(void *ctx, system_event_t *event)
    Application specified event callback function.

    Note  This API is part of the legacy event system. New code should use event library API in esp_event.h

    Return
    •  ESP_OK: succeed
    •  others: fail

    Parameters
    •  ctx: reserved for user
    •  event: event type defined in this file

Enumerations
enum system_event_id_t
    System event types enumeration

    Values:

    SYSTEM_EVENT_WIFI_READY = 0
    ESP32 WiFi 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_WPS_ER_SUCCESS
    ESP32 station wps succeeds in enrollee mode
Chapter 2. API 参考

```c
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_GOT_IP6
  ESP32 station or ap or ethernet interface v6IP addr is preferred
SYSTEM_EVENT_ETH_START
  ESP32 ethernet start
SYSTEM_EVENT_ETH_STOP
  ESP32 ethernet stop
SYSTEM_EVENT_ETH_CONNECTED
  ESP32 ethernet phy link up
SYSTEM_EVENT_ETH_DISCONNECTED
  ESP32 ethernet phy link down
SYSTEM_EVENT_ETH_GOT_IP
  ESP32 ethernet got IP from connected AP
SYSTEM_EVENT_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.

注解：ESP-IDF FreeRTOS is based on the Xtensa port of FreeRTOS v10.2.0,

For more information about FreeRTOS features specific to ESP-IDF, see ESP-IDF FreeRTOS SMP Changes and ESP-IDF FreeRTOS Additions.
Task API

Header File

- freertos/include/freertos/task.h

Functions

```c
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 xTaskCreate, but allows setting task affinity in SMP system.

**Return**  
`pdPASS` if the task was successfully created and added to a ready list, otherwise an error code defined in the file projdefs.h

**Parameters**

- `pvTaskCode`: Pointer to the task entry function. Tasks must be implemented to never return (i.e. continuous loop).
- `pcName`: A descriptive name for the task. This is mainly used to facilitate debugging. Max length defined by configMAX_TASK_NAME_LEN - default is 16.
- `usStackDepth`: The size of the task stack specified as the number of bytes. Note that this differs from vanilla FreeRTOS.
- `pvParameters`: Pointer that will be used as the parameter for the task being created.
- `uxPriority`: The priority at which the task should run. Systems that include MPU support can optionally create tasks in a privileged (system) mode by setting bit portPRIVILEGE_BIT of the priority parameter. For example, to create a privileged task at priority 2 the uxPriority parameter should be set to `(2 | portPRIVILEGE_BIT)`.
- `pvCreatedTask`: Used to pass back a handle by which the created task can be referenced.
- `xCoreID`: If the value is tskNO_AFFINITY, the created task is not pinned to any CPU, and the scheduler can run it on any core available. Values 0 or 1 indicate the index number of the CPU which the task should be pinned to. Specifying values larger than (portNUM_PROCESSORS - 1) will cause the function to fail.

```c
static BaseType_t xTaskCreate( TaskFunction_t pvTaskCode, const char *const pcName, const uint32_t usStackDepth, void *const pvParameters, UBaseType_t uxPriority, TaskHandle_t *const pvCreatedTask)
```

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.

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.
    }
}
```

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Function that creates a task.

```c
void vOtherFunction( void )
{
static uint8_t ucParameterToPass;
TaskHandle_t xHandle = NULL;

// Create the task, storing the handle. Note that the passed parameter...
--ucParameterToPass
// must exist for the lifetime of the task, so in this case is declared...
--static. If it was just an
// an automatic stack variable it might no longer exist, or at least have...
--been corrupted, by the time
// the new task attempts to access it.
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).
- 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 *const pcName, const uint32_t ulStackDepth, void *const pvParameters, UBaseType_t uxPriority, StackType_t *const pxStackBuffer, StaticTask_t *const pxTaskBuffer, const BaseType_t xCoreID)

Create a new task with a specified affinity.

This function is similar to xTaskCreateStatic, but allows specifying task affinity in an SMP system.

Return If neither pxStackBuffer or pxTaskBuffer are NULL, then the task will be created and pdPASS is returned. If either pxStackBuffer or pxTaskBuffer are NULL then the task will not be created and errCOULDNOT_ALLOCATE_REQUIRED_MEMORY is returned.

Parameters
- pvTaskCode: Pointer to the task entry function. Tasks must be implemented to never return (i.e. continuous loop).
• 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 *const pcName, const uint32_t ulStackDepth, void *const pvParameters, UBaseType_t uxPriority, StackType_t *const pxStackBuffer, StaticTask_t *const pxTaskBuffer)
```

Create a new task and add it to the list of tasks that are ready to run.

Internally, within the FreeRTOS implementation, tasks use two blocks of memory. The first block is used to hold the task’s data structures. The second block is used by the task as its stack. If a task is created using xTaskCreate() then both blocks of memory are automatically dynamically allocated inside the xTaskCreate() function. (see http://www.freertos.org/a00111.html). 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:

```
// Dimensions the buffer that the task being created will use as its stack.
// NOTE: This is the number of bytes the stack will hold, not the number of
// words as found in vanilla FreeRTOS.
#define STACK_SIZE 200

// Structure that will hold the TCB of the task being created.
StaticTask_t xTaskBuffer;

// Buffer that the task being created will use as its stack. Note this is
// an array of StackType_t variables. The size of StackType_t is dependent on
// the RTOS port.
StackType_t xStack[ STACK_SIZE ];

// Function that implements the task being created.
void vTaskCode( void * pvParameters )
{
    // The parameter value is expected to be 1 as 1 is passed in the
    // pvParameters value in the call to xTaskCreateStatic().
    configASSERT( ( uint32_t ) pvParameters == 1UL );

    for( ;; )
    {
        // Task code goes here.
    }
}

// Function that creates a task.
void vOtherFunction( void )
{
    TaskHandle_t xHandle = NULL;
}
```
Create the task without using any dynamic memory allocation.

```c
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.
    &xStackBuffer ); // Variable to hold the task's data structure.
```

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).
- 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.

```c
void vTaskAllocateMPURegions ( TaskHandle_t xTask, const MemoryRegion_t * const pxRegions )
void vTaskDelete ( TaskHandle_t xTaskToDelete )
```

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.

INCLUDE_vTaskDelete must be defined as 1 for this function to be available. See the configuration section for more information.

NOTE: The idle task is responsible for freeing the kernel allocated memory from tasks that have been deleted. It is therefore important that the idle task is not starved of microcontroller processing time if your application makes any calls to vTaskDelete(). Memory allocated by the task code is not automatically freed, and should be freed before the task is deleted.

See the demo application file death.c for sample code that utilises vTaskDelete().

Example usage:

```c
void vOtherFunction( void )
{
    TaskHandle_t xHandle;
}
```
Chapter 2. API

Parameters

- **xTaskToDelete**: The handle of the task to be deleted. Passing NULL will cause the calling task to be deleted.

```c
void vTaskDelete ( xHandle );
```

**Parameters**

- **xTaskToDelay**: The amount of time, in tick periods, that the calling task should block.

```c
void vTaskDelayUntil ( TickType_t *const pxPreviousWakeTime, const TickType_t xTimeIncrement );
```

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, vTaskDe-
layUntil () specifies the absolute (exact) time at which it wishes to unblock.

The constant portTICK_PERIOD_MS can be used to calculate real time from the tick rate - with the resolution
of one tick period.

Example usage:

```c
void vTaskFunction( void * pvParameters )
{
    TickType_t xLastWakeTime;
    const TickType_t xFrequency = 10;

    // Initialise the xLastWakeTime variable with the current time.
    xLastWakeTime = xTaskGetTickCount ();
    for (;; )
    {
        // Wait for the next cycle.
        vTaskDelayUntil( &xLastWakeTime, xFrequency );
        // Perform action here.
    }
}
```

Parameters

- pxPreviousWakeTime: Pointer to a variable that holds the time at which the task was last
  unblocked. The variable must be initialised with the current time prior to its first use (see the example
  below). Following this the variable is automatically updated within vTaskDelayUntil ()
- xTimeIncrement: The cycle time period. The task will be unblocked at time *pxPreviousWake-
  Time + xTimeIncrement. Calling vTaskDelayUntil with the same xTimeIncrement parameter value
  will cause the task to execute with a fixed interface period.

```
BaseType_t xTaskAbortDelay ( TaskHandle_t xTask )
```

```
UBaseType_t uxTaskPriorityGet ( const TaskHandle_t xTask )
```

Obtain the priority of any task.

INCLUDE uxTaskPriorityGet must be defined as 1 for this function to be available. See the configuration
section for more information.

Example usage:

```c
void vAFunction( void )
{
    TaskHandle_t xHandle;

    // Create a task, storing the handle.
    xTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, &xHandle );

    // ...

    // Use the handle to obtain the priority of the created task.
    // It was created with tskIDLE_PRIORITY, but may have changed
    // it itself.
    if( uxTaskPriorityGet( xHandle ) != tskIDLE_PRIORITY )
    {
        // The task has changed it's priority.
    }

    // ...

    // Is our priority higher than the created task?
```
if( uxTaskPriorityGet( xHandle ) < uxTaskPriorityGet( NULL ) )
{
    // Our priority (obtained using NULL handle) is higher.
}

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)
Obtain the state of any task.
States are encoded by the eTaskState enumerated type.
#include_eTaskGetState must be defined as 1 for this function to be available. See the configuration section for more information.
Return  The state of the task 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)
Populates a TaskStatus_t structure with information about a task.
#include_USE_TRACE_FACILITY must be defined as 1 for this function to be available. See the configuration section for more information.

Example usage:

void vAFunction( void )
{
    TaskHandle_t xHandle;
    TaskStatus_t xTaskDetails;

    // Obtain the handle of a task from its name.
    xHandle = xTaskGetHandle( "Task_Name" );

    // Check the handle is not NULL.
    configASSERT( xHandle );

    // Use the handle to obtain further information about the task.
    vTaskGetInfo( xHandle,
                 &xTaskDetails,
                 pdTRUE, // Include the high water mark in xTaskDetails.
                 eInvalid ); // Include the task state in xTaskDetails.
}

Parameters
• xTask: Handle of the task being queried. If xTask is NULL then information will be returned
about the calling task.
• pxTaskStatus: A pointer to the TaskStatus_t structure that will be filled with information about
the task referenced by the handle passed using the xTask parameter.
• xGetFreeStackSpace: The TaskStatus_t structure contains a member to report the stack high
water mark of the task being queried. Calculating the stack high water mark takes a relatively long
time, and can make the system temporarily unresponsive - so the xGetFreeStackSpace parameter is
provided to allow the high water mark checking to be skipped. The high water mark value will only
be written to the TaskStatus_t structure if xGetFreeStackSpace is not set to pdFALSE;
• eState: The TaskStatus_t structure contains a member to report the state of the task being queried.
Obtaining the task state is not as fast as a simple assignment - so the eState parameter is provided to
allow the state information to be omitted from the TaskStatus_t structure. To obtain state information
then set eState to eInvalid - otherwise the value passed in eState will be reported as the task state in
the TaskStatus_t structure.

void vTaskPrioritySet( TaskHandle_t xTask, UBaseType_t uxNewPriority )
Set the priority of any task.

INCLUDE_vTaskPrioritySet must be defined as 1 for this function to be available. See the configuration
section for more information.

A context switch will occur before the function returns if the priority being set is higher than the currently
executing task.

Example usage:

```c
void vAFunction( void )
{
    TaskHandle_t xHandle;

    // Create a task, storing the handle.
    xTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, &xHandle... );
    // ...

    // Use the handle to raise the priority of the created task.
    vTaskPrioritySet( xHandle, tskIDLE_PRIORITY + 1 );
    // ...

    // Use a NULL handle to raise our priority to the same value.
    vTaskPrioritySet( NULL, tskIDLE_PRIORITY + 1 );
}
```

Parameters
• xTask: Handle to the task for which the priority is being set. Passing a NULL handle results in the
  priority of the calling task being set.
• uxNewPriority: The priority to which the task will be set.

void vTaskSuspend( TaskHandle_t xTaskToSuspend )
Suspend a task.

INCLUDE_vTaskSuspend must be defined as 1 for this function to be available. See the configuration section
for more information.

Suspend any task. When suspended a task will never get any microcontroller processing time, no matter what
its priority.

Calls to vTaskSuspend are not accumulative - i.e. calling vTaskSuspend () twice on the same task still only
requires one call to vTaskResume () to ready the suspended task.

Example usage:

```c
void vAFunction( void )
{
    TaskHandle_t xHandle;

    // Create a task, storing the handle.
    xTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, &xHandle... );
}
```
// ...  
// Use the handle to suspend the created task.  
vTaskSuspend( xHandle );  
// ...  
// The created task will not run during this period, unless  
// another task calls vTaskResume( xHandle ).  
// ...  

// Suspend ourselves.  
vTaskSuspend( NULL );  
// We cannot get here unless another task calls vTaskResume  
// with our handle as the parameter.  

Parameters  
• xTaskToSuspend: Handle to the task being suspended. Passing a NULL handle will cause the  
calling task to be suspended.

void vTaskResume( TaskHandle_t xTaskToResume)  
Resumes a suspended task.

INCLUDE_vTaskSuspend must be defined as 1 for this function to be available. See the configuration section  
for more information.

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:

void vAFunction( void )  
{  
TaskHandle_t xHandle;  

// Create a task, storing the handle.  
xBTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, &xHandle...  
);  
// ...  

// Use the handle to suspend the created task.  
vTaskSuspend( xHandle );  
// ...  

// The created task will not run during this period, unless  
// another task calls vTaskResume( xHandle ).  
// ...  

// Resume the suspended task ourselves.  
vTaskResume( xHandle );  

// The created task will once again get microcontroller processing  
// time in accordance with its priority within the system.
Chapter 2. API 参考

Parameters

- xTaskToResume: Handle to the task being readied.

BaseType_t xTaskResumeFromISR (TaskHandle_t xTaskToResume)

An implementation of vTaskResume() that can be called from within an ISR.

INCLUDE_xTaskResumeFromISR must be defined as 1 for this function to be available. See the configuration section for more information.

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 vTaskSuspendAll (void)

Suspends the scheduler without disabling interrupts.

Context switches will not occur while the scheduler is suspended.

After calling vTaskSuspendAll() the calling task will continue to execute without risk of being swapped out until a call to xTaskResumeAll() has been made.

API functions that have the potential to cause a context switch (for example, vTaskDelayUntil(), xQueueSend(), etc.) must not be called while the scheduler is suspended.

Example usage:

```c
void vTask1( void * pvParameters )
{
    for( ;; )
    {
        // Task code goes here.
        // ...

        // At some point the task wants to perform a long operation during
        // which it does not want to get swapped out. It cannot use
        // taskENTER_CRITICAL ()/taskEXIT_CRITICAL () as the length of the
        // operation may cause interrupts to be missed - including the
        // ticks.

        // Prevent the real time kernel swapping out the task.
        vTaskSuspendAll ();

        // Perform the operation here. There is no need to use critical
        // sections as we have all the microcontroller processing time.
        // During this time interrupts will still operate and the kernel
        // tick count will be maintained.

        // ...

        // The operation is complete. Restart the kernel.
        xTaskResumeAll ();
    }
}
```
BaseType_t `xTaskResumeAll` (void)
Resumes scheduler activity after it was suspended by a call to `vTaskSuspendAll()`.

`xTaskResumeAll()` only resumes the scheduler. It does not unsuspend tasks that were previously suspended by a call to `vTaskSuspend()`.

Example usage:

```c
void vTask1( void * pvParameters )
{
    for( ;; )
    {
        // Task code goes here.
        
        // ... 
        
        // At some point the task wants to perform a long operation during
        // which it does not want to get swapped out. It cannot use
        // taskENTER_CRITICAL ()/taskEXIT_CRITICAL () as the length of the
        // operation may cause interrupts to be missed - including the
        // ticks.
        
        // Prevent the real time kernel swapping out the task.
        vTaskSuspendAll ();
        
        // Perform the operation here. There is no need to use critical
        // sections as we have all the microcontroller processing time.
        // During this time interrupts will still operate and the real
        // time kernel tick count will be maintained.
        
        // ... 
        
        // The operation is complete. Restart the kernel. We want to force
        // a context switch - but there is no point if resuming the scheduler
        // caused a context switch already.
        if( !xTaskResumeAll () )
        {
            taskYIELD ();
            
        }
    }
}
```

**Return** If resuming the scheduler caused a context switch then `pdTRUE` is returned, otherwise `pdFALSE` is returned.

TickType_t `xTaskGetTickCount` (void)
Get tick count

**Return** The count of ticks since `vTaskStartScheduler` was called.

TickType_t `xTaskGetTickCountFromISR` (void)
Get tick count from ISR

This is a version of `xTaskGetTickCount()` that is safe to be called from an ISR - provided that TickType_t is the natural word size of the microcontroller being used or interrupt nesting is either not supported or not being used.

**Return** The count of ticks since `vTaskStartScheduler` was called.

UBaseType_t `uxTaskGetNumberOfTasks` (void)
Get current number of tasks

**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)
Get task name

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 words, so on a 32 bit machine a value of 1 means 4 bytes) since the task started. The smaller the returned number the closer the task has come to overflowing its stack.
uxTaskGetStackHighWaterMark() and uxTaskGetStackHighWaterMark2() are the same except for their return type. Using configSTACK_DEPTH_TYPE allows the user to determine the return type. It gets around the problem of the value overflowing on 8-bit types without breaking backward compatibility for applications that expect an 8-bit return type.

Return The smallest amount of free stack space there has been (in words, so actual spaces on the stack rather than bytes) since the task referenced by xTask was created.
Parameters
• xTask: Handle of the task associated with the stack to be checked. Set xTask to NULL to check the stack of the calling task.

configSTACK_DEPTH_TYPE uxTaskGetStackHighWaterMark2 (TaskHandle_t xTask)
Returns the start of the stack associated with xTask.
INCLUDE_uxTaskGetStackHighWaterMark2 must be set to 1 in FreeRTOSConfig.h for this function to be available.

Returns the high water mark of the stack associated with xTask. That is, the minimum free stack space there has been (in words, so on a 32 bit machine a value of 1 means 4 bytes) since the task started. The smaller the returned number the closer the task has come to overflowing its stack.
uxTaskGetStackHighWaterMark() and uxTaskGetStackHighWaterMark2() are the same except for their return type. Using configSTACK_DEPTH_TYPE allows the user to determine the return type. It gets around the problem of the value overflowing on 8-bit types without breaking backward compatibility for applications that expect an 8-bit return type.

Return The smallest amount of free stack space there has been (in words, so actual spaces on the stack rather than bytes) since the task referenced by xTask was created.
Parameters
• xTask: Handle of the task associated with the stack to be checked. Set xTask to NULL to check the stack of the calling task.

uint8_t *pxTaskGetStackStart (TaskHandle_t xTask)
Returns the start of the stack associated with xTask.
INCLUDE_pxTaskGetStackStart must be set to 1 in FreeRTOSConfig.h for this function to be available.

Returns the highest stack memory address on architectures where the stack grows down from high memory, and the lowest memory address on architectures where the stack grows up from low memory.

Return A pointer to the start of the stack.
Parameters
• xTask: Handle of the task associated with the stack returned. Set xTask to NULL to return the stack of the calling task.
void vTaskSetApplicationTaskTag (TaskHandle_t xTask, TaskHookFunction_t pxHookFunction)
Sets pxHookFunction to be the task hook function used by the task xTask.

Parameters
• xTask: Handle of the task to set the hook function for. Passing xTask as NULL has the effect of
  setting the calling tasks hook function.
• pxHookFunction: Pointer to the hook function.

TaskHookFunction_t xTaskGetApplicationTaskTag (TaskHandle_t xTask)
Returns the pxHookFunction value assigned to the task xTask. Do not call from an interrupt service routine -
call xTaskGetApplicationTaskTagFromISR() instead.

TaskHookFunction_t xTaskGetApplicationTaskTagFromISR (TaskHandle_t xTask)
Returns the pxHookFunction value assigned to the task xTask. Can be called from an interrupt service routine.

void vTaskSetThreadLocalStoragePointer (TaskHandle_t xTaskToSet, BaseType_t xIndex, void *pvValue)
Set local storage pointer specific to the given task.

Each task contains an array of pointers that is dimensioned by the configNUM_THREAD_LOCAL_STORAGE_POINTERS setting in FreeRTOSConfig.h. The kernel does not use the pointers itself, so the application writer can use the pointers for any purpose they wish.

Parameters
• xTaskToSet: Task to set thread local storage pointer for
• xIndex: The index of the pointer to set, from 0 to configNUM_THREAD_LOCAL_STORAGE_POINTERS - 1.
• pvValue: Pointer value to set.

void *pvTaskGetThreadLocalStoragePointer (TaskHandle_t xTaskToQuery, BaseType_t xIndex)
Get local storage pointer specific to the given task.

Each task contains an array of pointers that is dimensioned by the configNUM_THREAD_LOCAL_STORAGE_POINTERS setting in FreeRTOSConfig.h. The kernel does not use the pointers itself, so the application writer can use the pointers for any purpose they wish.

Return Pointer value

Parameters
• xTaskToQuery: Task to get thread local storage pointer for
• xIndex: The index of the pointer to get, from 0 to configNUM_THREAD_LOCAL_STORAGE_POINTERS - 1.

void vTaskSetThreadLocalStoragePointerAndDelCallback (TaskHandle_t xTaskToSet, BaseType_t xIndex, void *pvValue, TlsDeleteCallbackFunction_t pvDelCallback)
Set local storage pointer and deletion callback.

Each task contains an array of pointers that is dimensioned by the configNUM_THREAD_LOCAL_STORAGE_POINTERS setting in FreeRTOSConfig.h. The kernel does not use the pointers itself, so the application writer can use the pointers for any purpose they wish.

Local storage pointers set for a task can reference dynamically allocated resources. This function is similar to vTaskSetThreadLocalStoragePointer, but provides a way to release these resources when the task gets deleted. For each pointer, a callback function can be set. This function will be called when task is deleted, with the local storage pointer index and value as arguments.

Parameters
• xTaskToSet: Task to set thread local storage pointer for
• xIndex: The index of the pointer to set, from 0 to configNUM_THREAD_LOCAL_STORAGE_POINTERS - 1.
• pvValue: Pointer value to set.
• pvDelCallback: Function to call to dispose of the local storage pointer when the task is deleted.
BaseType_t xTaskCallApplicationTaskHook(TaskHandle_t xTask, void *pvParameter)
Calls the hook function associated with xTask. Passing xTask as NULL has the effect of calling the Running
tasks (the calling task) hook function.

Parameters
• xTask: Handle of the task to call the hook for.
• pvParameter: Parameter passed to the hook function for the task to interpret as it wants. The
  return value is the value returned by the task hook function registered by the user.

TaskHandle_t xTaskGetIdleTaskHandle(void)
xTaskGetIdleTaskHandle() is only available if INCLUDE_xTaskGetIdleTaskHandle is set to 1 in FreeRTOSConfig.h.

Simply returns the handle of the idle task. It is not valid to call xTaskGetIdleTaskHandle() before the scheduler
has been started.

BaseType_t uxTaskGetSystemState(TaskStatus_t *pxTaskStatusArray, const UBaseType_t uxArraySize, uint32_t* const pulTotalRunTime)

configUSE_TRACE_FACILITY must be defined as 1 in FreeRTOSConfig.h for uxTaskGetSystemState() to
be available.

uxTaskGetSystemState() populates an TaskStatus_t structure for each task in the system. TaskStatus_t structures
contain, among other things, members for the task handle, task name, task priority, task state, and total
amount of run time consumed by the task. See the TaskStatus_t structure definition in this file for the full
member list.

Example usage:

```c
// This example demonstrates how a human readable table of run time stats
// information is generated from raw data provided by uxTaskGetSystemState().
// The human readable table is written to pcWriteBuffer.
void vTaskGetRunTimeStats( char *pcWriteBuffer )
{
    TaskStatus_t *pxTaskStatusArray;
    volatile UBaseType_t uxArraySize, x;
    uint32_t ulTotalRunTime, ulStatsAsPercentage;

    // Make sure the write buffer does not contain a string.
    *pcWriteBuffer = 0x00;

    // Take a snapshot of the number of tasks in case it changes while this
    // function is executing.
    uxArraySize = uxTaskGetNumberOfTasks();

    // Allocate a TaskStatus_t structure for each task. An array could be
    // allocated statically at compile time.
    pxTaskStatusArray = pvPortMalloc( uxArraySize * sizeof( TaskStatus_t ) );
    if( pxTaskStatusArray != NULL )
    {
        // Generate raw status information about each task.
        uxArraySize = uxTaskGetSystemState( pxTaskStatusArray, uxArraySize, &ulTotalRunTime);

        // For percentage calculations.
        ulTotalRunTime /= 100UL;

        // Avoid divide by zero errors.
        if( ulTotalRunTime > 0 )
        {
            // For each populated position in the pxTaskStatusArray array,
            // format the raw data as human readable ASCII data
            for( x = 0; x < uxArraySize; x++ )
            {
```
Chapter 2. API

void vTaskList (char *pcWriteBuffer)

List all the current tasks.

cfgUSE_TRACE_FACILITY and cfgUSE_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.

Lists all the current tasks, along with their current state and stack usage high watermark.

Note This function will disable interrupts for its duration. It is not intended for normal application runtime use but as a debug aid.

Tasks are reported as blocked (‘B’), ready (‘R’), deleted (‘D’) or suspended (‘S’).

vTaskList() calls uxTaskGetSystemState(), then formats part of the uxTaskGetSystemState() output into a
human readable table that displays task names, states and stack usage.

**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()` 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.

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** This function will disable interrupts for its duration. It is not intended for normal application runtime use but as a debug aid.

`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.

**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.

`vTaskGetRunTimeStats()` has a dependency on the `sprintf()` C library function that might bloat the code size, use a lot of stack, and provide different results on different platforms. An alternative, tiny, third party, and limited functionality implementation of `sprintf()` is provided in many of the FreeRTOS/Demo sub-directories in a file called `printf-stdarg.c` (note `printf-stdarg.c` does not provide a full `snprintf()` implementation!).

It is recommended that production systems call `uxTaskGetSystemState()` directly to get access to raw stats data, rather than indirectly through a call to `vTaskGetRunTimeStats()`.

**Parameters**

- `pcWriteBuffer`: A buffer into which the execution times will be written, in ASCII form. This buffer is assumed to be large enough to contain the generated report. Approximately 40 bytes per task should be sufficient.

```c
uint32_t ulTaskGetIdleRunTimeCounter (void)
```

`configGENERATE_RUN_TIME_STATS` and `configUSE_STATS_FORMATTING_FUNCTIONS` must both be defined as 1 for this function to be available. The application must also then provide definitions for `portCONFIGURE_TIMER_FOR_RUN_TIME_STATS()` and `portGET_RUN_TIME_COUNTER_VALUE()` to configure a peripheral timer/counter and return the timers current count value respectively. The counter should be at least 10 times the frequency of the tick count.

Setting `configGENERATE_RUN_TIME_STATS` to 1 will result in a total accumulated execution time being stored for each task. The resolution of the accumulated time value depends on the frequency of the timer configured by the `portCONFIGURE_TIMER_FOR_RUN_TIME_STATS()` macro. While `uxTaskGetSystemState()`...
State() 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 portCONFIG_TIMER_FOR_RUN_TIME_STATS() and portGET_RUN_TIME_COUNTER_VALUE() macros.

BaseType_t xTaskGenericNotify(TaskHandle_t xTaskToNotify, uint32_t ulValue, eNotifyAction eAction, uint32_t* pulPreviousNotificationValue)

`configUSE_TASK_NOTIFICATIONS` must be undefined or defined as 1 for this function to be available.

When `configUSE_TASK_NOTIFICATIONS` is set to one each task has its own private “notification value”, which is a 32-bit unsigned integer (uint32_t).

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 the task’s notification value. 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 xTaskNotifyWait() or ulTaskNotifyTake(). 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 xTaskNotifyWait() to [optionally] block to wait for a notification to be pending, or ulTaskNotifyTake() to [optionally] block to wait for its notification value to have a non-zero value. The task does not consume any CPU time while it is in the Blocked state.


eSetBits - The task’s notification value is bitwise ORed with ulValue. xTaskNotify() 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().
- ulValue: Data that can be sent with the notification. How the data is used depends on the value of the eAction parameter.
- eAction: Specifies how the notification updates the task’s notification value, if at all. Valid values for eAction are as follows:
  - eIncrement - The task’s notification value is incremented. ulValue is not used and xTaskNotify() always returns pdPASS in this case.
  - eSetValueWithOverwrite - The task’s notification value is set to the value of ulValue, even if the task being notified had not yet processed the previous notification (the task already had a notification pending). xTaskNotify() always returns pdPASS in this case.
  - eSetValueWithoutOverwrite - If the task being notified did not already have a notification pending then the task’s notification value is set to ulValue and xTaskNotify() will return pdPASS. If the task being notified already had a notification pending then no action is performed and pdFAIL is returned.
  - eNoAction - The task receives a notification without its notification value being updated. ulValue is not used and xTaskNotify() always returns pdPASS in this case.

**Return** Dependent on the value of eAction. See the description of the eAction parameter.

**Parameters**

- pulPreviousNotificationValue: Can be used to pass out the subject task’s notification value before any bits are modified by the notify function.
BaseType_t \texttt{xTaskGenericNotifyFromISR} (TaskHandle_t xTaskToNotify, uint32_t ulValue, eNotifyAction eAction, uint32_t *pulPreviousNotificationValue, BaseType_t *pxHigherPriorityTaskWoken)

Send task notification from an ISR.

configUSE_TASK_NOTIFICATIONS must be undefined or defined as 1 for this function to be available.

When configUSE_TASK_NOTIFICATIONS is set to one each task has its own private “notification value”, which is a 32-bit unsigned integer (uint32_t).

A version of \texttt{xTaskNotify()} that can be used from an interrupt service routine (ISR).

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 the task’s notification value. 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 \texttt{xTaskNotifyWait()} or \texttt{ulTaskNotifyTake()}. 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 \texttt{xTaskNotifyWait()} to [optionally] block to wait for a notification to be pending, or \texttt{ulTaskNotifyTake()} to [optionally] block to wait for its notification value to have a non-zero value. The task does not consume any CPU time while it is in the Blocked state.

See \url{http://www.FreeRTOS.org/RTOS-task-notifications.html} for details.

eSetBits - The task’s notification value is bitwise ORed with ulValue. \texttt{xTaskNotify()} always returns \texttt{pdPASS} in this case.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{xTaskToNotify}: The handle of the task being notified. The handle to a task can be returned from the \texttt{xTaskCreate()} API function used to create the task, and the handle of the currently running task can be obtained by calling \texttt{xTaskGetCurrentTaskHandle()}.
  \item \texttt{ulValue}: Data that can be sent with the notification. How the data is used depends on the value of the \texttt{eAction} parameter.
  \item \texttt{eAction}: Specifies how the notification updates the task’s notification value, if at all. Valid values for \texttt{eAction} are as follows:
     \begin{itemize}
       \item \texttt{eIncrement} - The task’s notification value is incremented. \texttt{ulValue} is not used and \texttt{xTaskNotify()} always returns \texttt{pdPASS} in this case.
       \item \texttt{eSetValueWithOverwrite} - The task’s notification value is set to the value of \texttt{ulValue}, even if the task being notified had not yet processed the previous notification (the task already had a notification pending). \texttt{xTaskNotify()} always returns \texttt{pdPASS} in this case.
       \item \texttt{eSetValueWithoutOverwrite} - If the task being notified did not already have a notification pending then the task’s notification value is set to \texttt{ulValue} and \texttt{xTaskNotify()} will return \texttt{pdPASS}. If the task being notified already had a notification pending then no action is performed and \texttt{pdFAIL} is returned.
       \item \texttt{eNoAction} - The task receives a notification without its notification value being updated. \texttt{ulValue} is not used and \texttt{xTaskNotify()} always returns \texttt{pdPASS} in this case.
     \end{itemize}
   \end{itemize}

\textbf{Return} Dependent on the value of \texttt{eAction}. See the description of the \texttt{eAction} parameter.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{pulPreviousNotificationValue}: Can be used to pass out the subject task’s notification value before any bits are modified by the notify function.
  \item \texttt{pxHigherPriorityTaskWoken}: \texttt{xTaskNotifyFromISR()} will set \texttt{*pxHigherPriorityTaskWoken} to \texttt{pdTRUE} if sending the notification caused the task to which the notification was sent to leave the Blocked state, and the unblocked task has a priority higher than the currently running task. If \texttt{xTaskNotifyFromISR()} sets this value to \texttt{pdTRUE} then a context switch should be requested before
the interrupt is exited. How a context switch is requested from an ISR is dependent on the port - see the documentation page for the port in use.

```c
BaseType_t xTaskNotifyWait (uint32_t ulBitsToClearOnEntry, uint32_t ulBitsToClearOnExit, uint32_t *pulNotificationValue, TickType_t xTicksToWait)
```

Wait for task notification

configUSE_TASK_NOTIFICATIONS must be undefined or defined as 1 for this function to be available.

When configUSE_TASK_NOTIFICATIONS is set to one each task has its own private “notification value”, which is a 32-bit unsigned integer (uint32_t).

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 the task’s notification value. 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 xTaskNotifyWait() or ulTaskNotifyTake(). 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 xTaskNotifyWait() to [optionally] block to wait for a notification to be pending, or ulTaskNotifyTake() to [optionally] block to wait for its notification value to have a non-zero value. The task does not consume any CPU time while it is in the Blocked state.


**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**

- **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 vTaskNotifyGiveFromISR (TaskHandle_t xTaskToNotify, BaseType_t *pxHigherPriorityTaskWoken)
```

Simplified macro for sending task notification from ISR.

configUSE_TASK_NOTIFICATIONS must be undefined or defined as 1 for this macro to be available.
When configUSE_TASK_NOTIFICATIONS is set to one each task has its own private "notification value", which is a 32-bit unsigned integer (uint32_t).

A version of xTaskNotifyGive() that can be called from an interrupt service routine (ISR).

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 the task’s notification value. 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.

vTaskNotifyGiveFromISR() 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 vTaskNotifyGiveFromISR().

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 ulTaskNotifyTake() API function rather than the xTaskNotifyWait() API function.


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().
- 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 ulTaskNotifyTake(BaseType_t xClearCountOnExit, TickType_t xTicksToWait)

Simplified macro for receiving task notification.

configUSE_TASK_NOTIFICATIONS must be undefined or defined as 1 for this function to be available.

When configUSE_TASK_NOTIFICATIONS is set to one each task has its own private "notification value", which is a 32-bit unsigned integer (uint32_t).

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 the task’s notification value. 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.

ulTaskNotifyTake() 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 ulTaskNotifyTake().

When a task is using its notification value as a binary or counting semaphore other tasks should send notifications to it using the xTaskNotifyGive() macro, or xTaskNotify() function with the eAction parameter set to eIncrement.

ulTaskNotifyTake() can either clear the task’s notification value to zero on exit, in which case the notification value acts like a binary semaphore, or decrement the task’s notification value on exit, in which case the notification value acts like a counting semaphore.

A task can use ulTaskNotifyTake() to [optionally] block to wait for a 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 xTaskNotifyWait() will return when a notification is pending, ulTaskNotifyTake() will return when the task’s notification value is not zero.


**Return** The task’s notification count before it is either cleared to zero or decremented (see the xClearCountOnExit parameter).

**Parameters**

- **xClearCountOnExit**: if xClearCountOnExit is pdFALSE then the task’s notification value is decremented when the function exits. In this way the notification value acts like a counting semaphore. If xClearCountOnExit is not pdFALSE then the task’s notification value is cleared to zero when the function exits. In this way the notification value acts like a binary semaphore.
- **xTicksToWait**: The maximum amount of time that the task should wait in the Blocked state for the task’s notification value to be greater than zero, should the count not already be greater than zero when ulTaskNotifyTake() was called. The task will not consume any processing time while it is in the Blocked state. This is specified in kernel ticks, the macro pdMS_TO_TICKS(value_in_ms) can be used to convert a time specified in milliseconds to a time specified in ticks.

BaseType_t xTaskNotifyStateClear(TaskHandle_t xTask)

If the notification state of the task referenced by the handle xTask is eNotified, then set the task’s notification state to eNotWaitingNotification. The task’s notification value is not altered. Set xTask to NULL to clear the notification state of the calling task.

**Return** pdTRUE if the task’s notification state was set to eNotWaitingNotification, otherwise pdFALSE.

**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
tskNO_AFFINITY
tskIDLE_PRIORITY

Defines the priority used by the idle task. This must not be modified.

taskYIELD()

Macro for forcing a context switch.

taskENTER_CRITICAL(x)

Macro to mark the start of a critical code region. Preemptive context switches cannot occur when in a critical region.

**Note** This may alter the stack (depending on the portable implementation) so must be used with care!

taskENTER_CRITICAL_FROM_ISR()

taskENTER_CRITICAL_ISR(mux)

taskEXIT_CRITICAL(x)

Macro to mark the end of a critical code region. Preemptive context switches cannot occur when in a critical region.

**Note** This may alter the stack (depending on the portable implementation) so must be used with care!

taskEXIT_CRITICAL_FROM_ISR(x)
taskEXIT_CRITICAL_ISR (mux)

taskDISABLE_INTERRUPTS ()
    Macro to disable all maskable interrupts.

taskENABLE_INTERRUPTS ()
    Macro to enable microcontroller interrupts.

taskSCHEDULER_SUSPENDED

taskSCHEDULER_NOT_STARTED

taskSCHEDULER_RUNNING

xTaskNotify (xTaskToNotify, ulValue, eAction)

xTaskNotifyAndQuery (xTaskToNotify, ulValue, eAction, pulPreviousNotifyValue)

xTaskNotifyFromISR (xTaskToNotify, ulValue, eAction, pxHigherPriorityTaskWoken)

xTaskNotifyAndQueryFromISR (xTaskToNotify, ulValue, eAction, pulPreviousNotificationValue, pxHigherPriorityTaskWoken)

xTaskNotifyGive (xTaskToNotify, ulValue, eAction)
    Simplified macro for sending task notification.
    configUSE_TASK_NOTIFICATIONS must be undefined or defined as 1 for this macro to be available.
    When configUSE_TASK_NOTIFICATIONS is set to one each task has its own private “notification value”,
    which is a 32-bit unsigned integer (uint32_t).
    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
    the task’s notification value. 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.
    xTaskNotifyGive() 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 xTaskNotifyGive().
    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 ulTaskNotificationTake() API function rather than the xTaskNotifyWait() API
    function.


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().

Type Definitions

typedef void *TaskHandle_t

typedef BaseType_t(*TaskHookFunction_t)(void *)
    Defines the prototype to which the application task hook function must conform.

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**

- `freertos/include/freertos/queue.h`

**Functions**

BaseType_t xQueueGenericSendFromISR(QueueHandle_t xQueue, const void *const pvItemToQueue, BaseType_t *const pxHigherPriorityTaskWoken, const BaseType_t xCopyPosition)

It is preferred that the macros xQueueSendFromISR(), xQueueSendToFrontFromISR() and xQueueSendToBackFromISR() be used in place of calling this function directly. xQueueGiveFromISR() is an equivalent for use by semaphores that don’t actually copy any data.

Post an item on a queue. It is safe to use this function from within an interrupt service routine.

Items are queued by copy not reference so it is preferable to only queue small items, especially when called from an ISR. In most cases it would be preferable to store a pointer to the item being queued.

Example usage for buffered IO (where the ISR can obtain more than one value per call):

```c
void vBufferISR( void )
{
    char cIn;
    BaseType_t xHigherPriorityTaskWokenByPost;
```
We have not woken a task at the start of the ISR.

// 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...
// 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 *pxHigher-
  priorityTaskWoken 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 pxHigherPriority-
                             TaskWoken)

BaseType_t xQueueGenericSend(QueueHandle_t xQueue, const *const pvItemToQueue, Tick-
                             Type_t xTicksToWait, const BaseType_t xCopyPosition)
It is preferred that the macros xQueueSend(), xQueueSendToFront() and xQueueSendToBack() are used in
place of calling this function directly.

Post an item on a queue. The item is queued by copy, not by reference. This function must not be called from
an interrupt service routine. See xQueueSendFromISR () for an alternative which may be used in an ISR.

Example usage:

```c
struct AMessage
{
    char ucMessageID;
    char ucData[ 20 ];
} xMessage;

uint32_t ulVar = 10UL;

void vATask( void *pvParameters )
{
    QueueHandle_t xQueue1, xQueue2;
    ```
struct AMessage *pxMessage;

// Create a queue capable of containing 10 uint32_t values.
xQueue1 = xQueueCreate( 10, sizeof( uint32_t ) );

// Create a queue capable of containing 10 pointers to AMessage structures.
// These should be passed by pointer as they contain a lot of data.
xQueue2 = xQueueCreate( 10, sizeof( struct AMessage * ) );

if( xQueue1 != 0 )
{
   // 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:
struct AMessage
{
char ucMessageID;
char ucData[ 20 ];
} xMessage;

QueueHandle_t xQueue;

// Task to create a queue and post a value.
void vATask( void *pvParameters )
{
struct AMessage *pxMessage;

// Create a queue capable of containing 10 pointers to AMessage structures.
// These should be passed by pointer as they contain a lot of data.
xQueue = xQueueCreate( 10, sizeof( struct AMessage * ) );
if( xQueue == 0 )
{
    // Failed to create the queue.
}

// Send a pointer to a struct AMessage object. Don't block if the
// queue is already full.
pxMessage = & xMessage;
xQueueSend( xQueue, ( void * ) &pxMessage, ( TickType_t ) 0 );

// ... Rest of task code.
}

// Task to 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.
    }
}

// ... Rest of task code.
}

Return  pdTRUE if an item was successfully received from the queue, otherwise pdFALSE.

Parameters
  • xQueue: The handle to the queue from which the item is to be received.
  • pvBuffer: Pointer to the buffer into which the received item will be copied.
  • xTicksToWait: The maximum amount of time the task should block waiting for an item to
    receive should the queue be empty at the time of the call. The time is defined in tick periods so
    the constant portTICK_PERIOD_MS should be used to convert to real time if this is required.
    xQueuePeek() will return immediately if xTicksToWait is 0 and the queue is empty.

BaseType_t xQueuePeekFromISR( QueueHandle_t xQueue, void *const pvBuffer )

A version of xQueuePeek() that can be called from an interrupt service routine (ISR).

Receive an item from a queue without removing the item from the queue. The item is received by copy so a
buffer of adequate size must be provided. The number of bytes copied into the buffer was defined when the queue was created.

Successfully received items remain on the queue so will be returned again by the next call, or a call to xQueueReceive().

**Return** pdTRUE if an item was successfully received from the queue, otherwise pdFALSE.

**Parameters**

- **xQueue**: The handle to the queue from which the item is to be received.
- **pvBuffer**: Pointer to the buffer into which the received item will be copied.

```c
BaseType_t xQueueReceive(QueueHandle_t xQueue, void *const pvBuffer, TickType_t xTicksToWait)
```

Receive an item from a queue. The item is received by copy so a buffer of adequate size must be provided. The number of bytes copied into the buffer was defined when the queue was created.

Successfully received items are removed from the queue.

This function must not be used in an interrupt service routine. See xQueueReceiveFromISR for an alternative that can.

**Example usage:**

```c
struct AMessage
{
    char ucMessageID;
    char ucData[20];
} xMessage;

QueueHandle_t xQueue;

// Task to create a queue and post a value.
void vATask( void *pvParameters )
{
    struct AMessage *pxMessage;

    // Create a queue capable of containing 10 pointers to AMessage structures.
    // These should be passed by pointer as they contain a lot of data.
    xQueue = xQueueCreate( 10, sizeof( struct AMessage * ) );
    if( xQueue == 0 )
    {
        // Failed to create the queue.
    }
    ...

    // Send a pointer to a struct AMessage object. Don't block if the queue is already full.
    pxMessage = & xMessage;
    xQueueSend( xQueue, ( void * ) &pxMessage, ( TickType_t ) 0 );

    // ... Rest of task code.
}

// Task to receive from the queue.
void vADifferentTask( void *pvParameters )
{
    struct AMessage *pxRxedMessage;

    if( xQueue != 0 )
    {
        // Receive a message on the created queue. Block for 10 ticks if a message is not immediately available.
        xQueueReceive( xQueue, &{ pxRxedMessage }, ( TickType_t ) 10 );
    }
```

(下页继续)
Chapter 2. API 参考

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.

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.

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 xQueueReceiveFromISR(QueueHandle_t xQueue, void *const pvBuffer, BaseType_t *const pxHigherPriorityTaskWoken)

Receive an item from a queue. It is safe to use this function from within an interrupt service routine.

Example usage:

```c
QueueHandle_t xQueue;

// Function to create a queue and post some values.
void vAFunction( void *pvParameters )
{
    char cValueToPost;
    const TickType_t xTicksToWait = ( TickType_t )0xff;

    // Create a queue capable of containing 10 characters.
    xQueue = xQueueCreate( 10, sizeof( char ) );
    if( xQueue == 0 )
    {
        // Failed to create the queue.
    }

    // Post some characters that will be used within an ISR. If the queue
```
is full then this task will block for xTicksToWait ticks.
cValueToPost = 'a';
xQueueSend( xQueue, ( void *) &cValueToPost, xTicksToWait );
cValueToPost = 'b';
xQueueSend( xQueue, ( void *) &cValueToPost, xTicksToWait );

... keep posting characters ... this task may block when the queue becomes full.
cValueToPost = 'c';
xQueueSend( xQueue, ( void *) &cValueToPost, xTicksToWait );

ISR that outputs all the characters received on the queue.
void vISR_Routine( void )
{
    BaseType_t xTaskWokenByReceive = pdFALSE;
    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)
```

lint!e971 Unqualified chartypes are allowed for strings and single characters only. 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 BaseType_t uxQueueLength, const BaseType_t uxItemSize, const uint8_t ucQueueType)
```

lint!e971 Unqualified chartypes are allowed for strings and single characters only. 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 BaseType_t uxQueueLength, const BaseType_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 BaseType_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 http://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.
Chapter 2. API 参考

Parameters

- uxEventQueueLength: Queue sets store events that occur on the queues and semaphores contained in the set. uxEventQueueLength specifies the maximum number of events that can be queued at once. To be absolutely certain that events are not lost uxEventQueueLength should be set to the total sum of the length of the queues added to the set, where binary semaphores and mutexes have a length of 1, and counting semaphores have a length set by their maximum count value. Examples:
  - If a queue set is to hold a queue of length 5, another queue of length 12, and a binary semaphore, then uxEventQueueLength should be set to \((5 + 12 + 1)\), or 18.
  - If a queue set is to hold three binary semaphores then uxEventQueueLength should be set to \((1 + 1 + 1)\), or 3.
  - If a queue set is to hold a counting semaphore that has a maximum count of 5, and a counting semaphore that has a maximum count of 3, then uxEventQueueLength should be set to \((5 + 3)\), or 8.

BaseType_t xQueueAddToSet (QueueSetMemberHandle_t xQueueOrSemaphore, QueueSetHandle_t xQueueSet)

Adds a queue or semaphore to a queue set that was previously created by a call to xQueueCreateSet().

See FreeRTOS/Source/Demo/Common/Minimal/QueueSet.c for an example using this function.

Note 1: A receive (in the case of a queue) or take (in the case of a semaphore) operation must not be performed on a member of a queue set unless a call to xQueueSelectFromSet() has first returned a handle to that set member.

Return If the queue or semaphore was successfully added to the queue set then pdPASS is returned. If the queue could not be successfully added to the queue set because it is already a member of a different queue set then pdFAIL is returned.

Parameters

- xQueueOrSemaphore: The handle of the queue or semaphore being added to the queue set (cast to an QueueSetMemberHandle_t type).
- xQueueSet: The handle of the queue set to which the queue or semaphore is being added.

BaseType_t xQueueRemoveFromSet (QueueSetMemberHandle_t xQueueOrSemaphore, QueueSetHandle_t xQueueSet)

Removes a queue or semaphore from a queue set. A queue or semaphore can only be removed from a set if the queue or semaphore is empty.

See FreeRTOS/Source/Demo/Common/Minimal/QueueSet.c for an example using this function.

Return If the queue or semaphore was successfully removed from the queue set then pdPASS is returned. If the queue was not in the queue set, or the queue (or semaphore) was not empty, then pdFAIL is returned.

Parameters

- xQueueOrSemaphore: The handle of the queue or semaphore being removed from the queue set (cast to an QueueSetMemberHandle_t type).
- xQueueSet: The handle of the queue set in which the queue or semaphore is included.

QueueSetMemberHandle_t xQueueSelectFromSet (QueueSetHandle_t xQueueSet, const TickType_t xTicksToWait)

xQueueSelectFromSet() selects from the members of a queue set a queue or semaphore that either contains data (in the case of a queue) or is available to take (in the case of a semaphore). xQueueSelectFromSet() effectively allows a task to block (pend) on a read operation on all the queues and semaphores in a queue set simultaneously.

See FreeRTOS/Source/Demo/Common/Minimal/QueueSet.c for an example using this function.

Note 1: See the documentation on http://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 the specified block time expires.

Parameters
- xQueueSet: The queue set on which the task will (potentially) block.
- xTicksToWait: The maximum time, in ticks, that the calling task will remain in the Blocked state (with other tasks executing) to wait for a member of the queue set to be ready for a successful queue read or semaphore take operation.

QueueSetMemberHandle_t xQueueSelectFromSetFromISR (QueueSetHandle_t xQueueSet)
A version of xQueueSelectFromSet() that can be used from an ISR.

Macros

xQueueCreate (uxQueueLength, uxItemSize)

Creates a new queue instance. This allocates the storage required by the new queue and returns a handle for the queue.

Example usage:

```c
struct AMessage
{
    char ucMessageID;
    char ucData[20];
};

void vATask( void *pvParameters )
{
    QueueHandle_t xQueue1, xQueue2;

    // Create a queue capable of containing 10 uint32_t values.
    xQueue1 = xQueueCreate( 10, sizeof( uint32_t ) );
    if( xQueue1 == 0 )
    {
        // Queue was not created and must not be used.
    }

    // Create a queue capable of containing 10 pointers to AMessage structures. // These should be passed by pointer as they contain a lot of data.
    xQueue2 = xQueueCreate( 10, sizeof( struct AMessage * ) );
    if( xQueue2 == 0 )
    {
        // Queue was not created and must not be used.
    }

    // ... Rest of task code.
}
```

Return  If the queue is successfully create then a handle to the newly created queue is returned. If the queue cannot be created then 0 is returned.

Parameters
- uxQueueLength: The maximum number of items that the queue can contain.
- uxItemSize: The number of bytes each item in the queue will require. Items are queued by copy, not by reference, so this is the number of bytes that will be copied for each posted item. Each item on the queue must be the same size.

xQueueCreateStatic (uxQueueLength, uxItemSize, pucQueueStorage, pxQueueBuffer)

Creates a new queue instance, and returns a handle by which the new queue can be referenced.

Internally, within the FreeRTOS implementation, queues use two blocks of memory. The first block is used to hold the queue’s data structures. The second block is used to hold items placed into the queue. If a queue is created using xQueueCreate() then both blocks of memory are automatically dynamically allocated.
inside the xQueueCreate() function. (see http://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. http://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 )

// 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 hold.
                          ITEM_SIZE  // The size of each item in the queue
                        & ucQueueStorage[ 0 ], // The buffer that will hold the
                        & xQueueBuffer ); // The buffer that will hold the
                        // queue structure.

  // The queue is guaranteed to be created successfully as no dynamic memory
  // allocation is used. Therefore xQueue1 is now a handle to a valid queue.
  // ... Rest of task code.
}
```

Return If the queue is created then a handle to the created queue is returned. If pxQueueBuffer is NULL then NULL is returned.

Parameters

- `uxQueueLength`: The maximum number of items that the queue can contain.
- `uxItemSize`: The number of bytes each item in the queue will require. Items are queued by copy, not by reference, so this is the number of bytes that will be copied for each posted item. Each item on the queue must be the same size.
- `pucQueueStorage`: If uxItemSize is not zero then pucQueueStorageBuffer must point to a uint8_t array that is at least large enough to hold the maximum number of items that can be in the queue at any one time - which is (uxQueueLength * uxItemSize) bytes. If uxItemSize is zero then pucQueueStorageBuffer can be NULL.
- `pxQueueBuffer`: Must point to a variable of type StaticQueue_t, which will be used to hold the queue’s data structure.

`xQueueSendToFront` (xQueue, pvItemToQueue, xTicksToWait)

Post an item to the front of a queue. The item is queued by copy, not by reference. This function must not be called from an interrupt service routine. See xQueueSendFromISR() for an alternative which may be used in an ISR.

Example usage:
struct AMessage
{
    char ucMessageID;
    char ucData[20];
} xMessage;

uint32_t ulVar = 10UL;

void vATask( void *pvParameters )
{
    QueueHandle_t xQueue1, xQueue2;
    struct AMessage *pxMessage;

    // Create a queue capable of containing 10 uint32_t values.
    xQueue1 = xQueueCreate( 10, sizeof( uint32_t ) );

    // Create a queue capable of containing 10 pointers to AMessage structures.
    // These should be passed by pointer as they contain a lot of data.
    xQueue2 = xQueueCreate( 10, sizeof( struct AMessage * ) );

    ... if( xQueue1 != 0 )
    {
        // Send an uint32_t. Wait for 10 ticks for space to become
        // available if necessary.
        if( xQueueSendToFront( xQueue1, ( void * ) &ulVar, ( TickType_t ) 10 ) !=
          pdPASS )
            // Failed to post the message, even after 10 ticks.
        }
    }

    if( xQueue2 != 0 )
    {
        // Send a pointer to a struct AMessage object. Don't block if the
        // queue is already full.
        pxMessage = &xMessage;
        xQueueSendToFront( xQueue2, ( void * ) &pxMessage, ( TickType_t ) 0 );
    }

    // ... Rest of task code. 
}

Return  pdTRUE if the item was successfully posted, otherwise errQUEUE_FULL.
Parameters
  • xQueue: The handle to the queue on which the item is to be posted.
  • pvItemToQueue: A pointer to the item that is to be placed on the queue. The size of the items
    the queue will hold was defined when the queue was created, so this many bytes will be copied from
    pvItemToQueue into the queue storage area.
  • xTicksToWait: The maximum amount of time the task should block waiting for space to become
    available on the queue, should it already be full. The call will return immediately if this is set to 0
    and the queue is full. The time is defined in tick periods so the constant portTICK_PERIOD_MS
    should be used to convert to real time if this is required.

xQueueSendToBack (xQueue, pvItemToQueue, xTicksToWait)
This is a macro that calls xQueueGenericSend().

Post an item to the back of a queue. The item is queued by copy, not by reference. This function must not be
called from an interrupt service routine. See xQueueSendFromISR () for an alternative which may be used in
an ISR.

Example usage:
struct AMessage
{
    char ucMessageID;
    char ucData[20];
} xMessage;

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 xQueueSendToFront().

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, pvItemToQueue)

Only for use with queues that have a length of one - so the queue is either empty or full.

Post an item on a queue. If the queue is already full then overwrite the value held in the queue. The item is queued by copy, not by reference.

This function must not be called from an interrupt service routine. See xQueueOverwriteFromISR () for an
Chapter 2. API

An alternative which may be used in an ISR.

Example usage:

```c
void vFunction( void *pvParameters )
{
    QueueHandle_t xQueue;
    uint32_t ulVarToSend, ulValReceived;

    // Create a queue to hold one uint32_t value. It is strongly
    // recommended *not* to use xQueueOverwrite() on queues that can
    // contain more than one value, and doing so will trigger an assertion
    // if configASSERT() is defined.
    xQueue = xQueueCreate( 1, sizeof( uint32_t ) );

    // Write the value 10 to the queue using xQueueOverwrite().
    ulVarToSend = 10;
    xQueueOverwrite( xQueue, &ulVarToSend );

    // Peeking the queue should now return 10, but leave the value 10 in
    // the queue. A block time of zero is used as it is known that the
    // queue holds a value.
    ulValReceived = 0;
    xQueuePeek( xQueue, &ulValReceived, 0 );

    if( ulValReceived != 10 )
    {
        // Error unless the item was removed by a different task.
    }

    // The queue is still full. Use xQueueOverwrite() to overwrite the
    // value held in the queue with 100.
    ulVarToSend = 100;
    xQueueOverwrite( xQueue, &ulVarToSend );

    // This time read from the queue, leaving the queue empty once more.
    // A block time of 0 is used again.
    xQueueReceive( xQueue, &ulValReceived, 0 );

    // The value read should be the last value written, even though the
    // queue was already full when the value was written.
    if( ulValReceived != 100 )
    {
        // Error!
    }

    // ...
}
```

Return: xQueueOverwrite() is a macro that calls xQueueGenericSend(), and therefore has the same return
values as xQueueSendToFront(). However, pdPASS is the only value that can be returned because
xQueueOverwrite() will write to the queue even when the queue is already full.

Parameters:
- **xQueue**: The handle of the queue to which the data is being sent.
- **pvItemToQueue**: A pointer to the item that is to be placed on the queue. The size of the items
  the queue will hold was defined when the queue was created, so this many bytes will be copied from
  pvItemToQueue into the queue storage area.

**xQueueSendToFrontFromISR(xQueue, pvItemToQueue, pxHigherPriorityTaskWoken)**

This is a macro that calls xQueueGenericSendFromISR().

Post an item to the front of a queue. It is safe to use this macro from within an interrupt service routine.

Items are queued by copy not reference so it is preferable to only queue small items, especially when called
from an ISR. In most cases it would be preferable to store a pointer to the item being queued.

Example usage for buffered IO (where the ISR can obtain more than one value per call):

```c
void vBufferISR( void )
{
    char cIn;
    BaseType_t xHigherPriorityTaskWoken;

    // We have not woken a task at the start of the ISR.
    xHigherPriorityTaskWoken = pdFALSE;

    // Loop until the buffer is empty.
    do
    {
        // Obtain a byte from the buffer.
        cIn = portINPUT_BYTE( RX_REGISTER_ADDRESS );

        // Post the byte.
        xQueueSendToFrontFromISR( xRxQueue, &cIn, &xHigherPriorityTaskWoken );
    } while( portINPUT_BYTE( BUFFER_COUNT ) );

    // Now the buffer is empty we can switch context if necessary.
    if( xHigherPriorityTaskWoken )
    {
        portYIELD_FROM_ISR();
    }
}
```

Return pdTRUE if the data was successfully sent to the queue, otherwise errQUEUE_FULL.

Parameters

- **xQueue**: The handle to the queue on which the item is to be posted.
- **pvItemToQueue**: A pointer to the item that is to be placed on the queue. The size of the items the queue will hold was defined when the queue was created, so this many bytes will be copied from pvItemToQueue into the queue storage area.
- **[out]** pxHigherPriorityTaskWoken: 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 xQueueSendToFrontFromISR() sets this value to pdTRUE then a context switch should be requested before the interrupt is exited.

**xQueueSendToBackFromISR(xQueue, pvItemToQueue, pxHigherPriorityTaskWoken)**

This is a macro that calls xQueueGenericSendFromISR() post an item to the back of a queue. It is safe to use this macro from within an interrupt service routine.

Items are queued by copy not reference so it is preferable to only queue small items, especially when called from an ISR. In most cases it would be preferable to store a pointer to the item being queued.

Example usage for buffered IO (where the ISR can obtain more than one value per call):

```c
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();
    }
}
```
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:

```c
QueueHandle_t xQueue;

void vFunction(void *pvParameters)
{
    // Create a queue to hold one uint32_t value. It is strongly
    // recommended *not* to use _xQueueOverwriteFromISR() on queues that can
    // contain more than one value, and doing so will trigger an assertion
    // if configASSERT() is defined.
    xQueue = _xQueueCreate(1, sizeof(uint32_t));
}

void vAnInterruptHandler(void)
{
    // 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, (void*)&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, (void*)&ulVarToSend, &xHigherPriorityTaskWoken);
}
```
Chapter 2. API

Reading from the queue will now return 100.

...  

if( xHigherPriorityTaskWoken == pdTRUE )
{
    // Writing to the queue caused a task to unblock and the unblocked task
    // has a priority higher than or equal to the priority of the currently
    // executing task (the task this interrupt interrupted). Perform a...
    context
    // switch so this interrupt returns directly to the unblocked task.
    portYIELD_FROM_ISR(); // or portEND_SWITCHING_ISR() depending on the...
    --port.
}

Return  xQueueOverwriteFromISR() is a macro that calls xQueueGenericSendFromISR(), and therefore has
the same return values as xQueueSendToFrontFromISR(). However, pdPASS is the only value that can
be returned because xQueueOverwriteFromISR() will write to the queue even when the queue is already
full.

Parameters

• xQueue: The handle to the queue on which the item is to be posted.
• pvItemToQueue: A pointer to the item that is to be placed on the queue. The size of the items
the queue will hold was defined when the queue was created, so this many bytes will be copied from
pvItemToQueue into the queue storage area.
• [out] pxHigherPriorityTaskWoken: xQueueOverwriteFromISR() will set *pxHigher-
PriorityTaskWoken to pdTRUE if sending to the queue caused a task to unblock, and the unblocked
task has a priority higher than the currently running task. If xQueueOverwriteFromISR() sets this
value to pdTRUE then a context switch should be requested before the interrupt is exited.

xQueueSendFromISR (xQueue, pvItemToQueue, pxHigherPriorityTaskWoken)

This is a macro that calls xQueueGenericSendFromISR(). It is included for backward compatibility with
versions of FreeRTOS.org that did not include the xQueueSendToBackFromISR() and xQueueSendToFront-
FromISR() macros.

Post an item to the back of a queue. It is safe to use this function from within an interrupt service routine.

Items are queued by copy not reference so it is preferable to only queue small items, especially when called
from an ISR. In most cases it would be preferable to store a pointer to the item being queued.

Example usage for buffered IO (where the ISR can obtain more than one value per call):

```c
void vBufferISR( void )
{
    char cIn;
    BaseType_t xHigherPriorityTaskWoken;

    // We have not woken a task at the start of the ISR.
    xHigherPriorityTaskWoken = pdFALSE;

    // Loop until the buffer is empty.
    do
    {
       // Obtain a byte from the buffer.
       cIn = portINPUT_BYTE( RX_REGISTER_ADDRESS );

       // Post the byte.
       xQueueSendFromISR( xRxQueue, &cIn, &xHigherPriorityTaskWoken );
    } while( portINPUT_BYTE( BUFFER_COUNT ) );
```

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Now the buffer is empty we can switch context if necessary.

```c
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 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 `*pxHigherPriorityTaskWoken` to `pdTRUE` if sending to the queue caused a task to unblock, and the unblocked task has a priority higher than the currently running task. If `xQueueSendFromISR()` sets this value to `pdTRUE` then a context switch should be requested before the interrupt is exited.

`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**

```c
typedef struct QueueDefinition *QueueHandle_t
typedef struct QueueDefinition *QueueSetHandle_t
```

Type by which queue sets are referenced. For example, a call to `xQueueCreateSet()` returns an `xQueueSet` variable that can then be used as a parameter to `xQueueSelectFromSet()`, `xQueueAddToSet()`, etc.

```c
typedef struct QueueDefinition *QueueSetMemberHandle_t
```

Queuesets can contain both queues and semaphores, so the `QueueSetMemberHandle_t` is defined as a type to be used where a parameter or return value can be either a `QueueHandle_t` or an `SemaphoreHandle_t`.

**Semaphore API**

**Header File**
- `freertos/include/freertos/semphr.h`

**Macros**

```c
semBINARY_SEMAPHORE_QUEUE_LENGTH
semSEMAPHORE_QUEUE_ITEM_LENGTH
semGIVE_BLOCK_TIME
```

`xSemaphoreCreateBinary()`
- Creates a new binary semaphore instance, and returns a handle by which the new semaphore can be referenced.

In many usage scenarios it is faster and more memory efficient to use a direct to task notification in place of a binary semaphore! [http://www.freertos.org/RTOS-task-notifications.html](http://www.freertos.org/RTOS-task-notifications.html)

Internally, within the FreeRTOS implementation, binary semaphores use a block of memory, in which the semaphore structure is stored. If a binary semaphore is created using `xSemaphoreCreateBinary()` then the required memory is automatically dynamically allocated inside the `xSemaphoreCreateBinary()` function. (see [http://www.freertos.org/a00111.html](http://www.freertos.org/a00111.html)). If a binary semaphore is created using `xSemaphoreCreateBinaryStatic()` then the application writer must provide the memory. `xSemaphoreCreateBinaryStatic()` therefore allows a binary semaphore to be created without using any dynamic memory allocation.
The old vSemaphoreCreateBinary() macro is now deprecated in favour of this xSemaphoreCreateBinary() function. Note that binary semaphores created using the vSemaphoreCreateBinary() macro are created in a state such that the first call to ‘take’ the semaphore would pass, whereas binary semaphores created using xSemaphoreCreateBinary() are created in a state such that the semaphore must first be ‘given’ before it can be ‘taken’.

This type of semaphore can be used for pure synchronisation between tasks or between an interrupt and a task. The semaphore need not be given back once obtained, so one task/interrupt can continuously ‘give’ the semaphore while another continuously ‘takes’ the semaphore. For this reason this type of semaphore does not use a priority inheritance mechanism. For an alternative that does use priority inheritance see xSemaphoreCreateMutex().

Example usage:

```c
SemaphoreHandle_t xSemaphore = NULL;

void vATask( void * pvParameters )
{
    // Semaphore cannot be used before a call to vSemaphoreCreateBinary ().
    // This is a macro so pass the variable in directly.
    xSemaphore = xSemaphoreCreateBinary();

    if( xSemaphore != NULL )
    {
        // The semaphore was created successfully.
        // The semaphore can now be used.
    }
}
```

**Return** Handle to the created semaphore, or NULL if the memory required to hold the semaphore’s data structures could not be allocated.

**xSemaphoreCreateBinaryStatic** (pxStaticSemaphore)

Creates a new binary semaphore instance, and returns a handle by which the new semaphore can be referenced.

**NOTE:** In many usage scenarios it is faster and more memory efficient to use a direct to task notification in place of a binary semaphore! [http://www.freertos.org/RTOS-task-notifications.html](http://www.freertos.org/RTOS-task-notifications.html)

Internally, within the FreeRTOS implementation, binary semaphores use a block of memory, in which the semaphore structure is stored. If a binary semaphore is created using xSemaphoreCreateBinary() then the required memory is automatically dynamically allocated inside the xSemaphoreCreateBinary() function. (see [http://www.freertos.org/a00111.html](http://www.freertos.org/a00111.html)). If a binary semaphore is created using xSemaphoreCreateBinaryStatic() then the application writer must provide the memory. xSemaphoreCreateBinaryStatic() therefore allows a binary semaphore to be created without using any dynamic memory allocation.

This type of semaphore can be used for pure synchronisation between tasks or between an interrupt and a task. The semaphore need not be given back once obtained, so one task/interrupt can continuously ‘give’ the semaphore while another continuously ‘takes’ the semaphore. For this reason this type of semaphore does not use a priority inheritance mechanism. For an alternative that does use priority inheritance see xSemaphoreCreateMutex().

Example usage:

```c
SemaphoreHandle_t xSemaphore = NULL;
StaticSemaphore_t xSemaphoreBuffer;

void vATask( void * pvParameters )
{
    // Semaphore cannot be used before a call to xSemaphoreCreateBinary() or xSemaphoreCreateBinaryStatic().
    // The semaphore's data structures will be placed in the xSemaphoreBuffer variable, the address of which is passed into the function. The function's parameter is not NULL, so the function will not attempt any...
    xSemaphore = xSemaphoreCreateBinary();
}
```
Chapter 2. API

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/**
 * dynamic memory allocation, and therefore the function will **not return**
 * return NULL.
 * xSemaphore = xSemaphoreCreateBinaryStatic( &xSemaphoreBuffer );
 */

// Rest of task code goes here.

<table>
<thead>
<tr>
<th>Return</th>
<th>If the semaphore is created then a handle to the created semaphore is returned. If pxSemaphoreBuffer is NULL then NULL is returned.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>• 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.</td>
</tr>
</tbody>
</table>

xSemaphoreTake(xSemaphore, xBlockTime)

*Macro* to obtain a semaphore. The semaphore must have previously been created with a call to xSemaphoreCreateBinary(), xSemaphoreCreateMutex() or xSemaphoreCreateCounting().

Example usage:

```c
SemaphoreHandle_t xSemaphore = NULL;

// A task that creates a semaphore.
void vATask( void * pvParameters )
{
    // Create the semaphore to guard a shared resource.
    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.
        }
    }
}
```

<table>
<thead>
<tr>
<th>Return</th>
<th>pdTRUE if the semaphore was obtained. pdFALSE if xBlockTime expired without the semaphore becoming available.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>• xSemaphore: A handle to the semaphore being taken - obtained when the semaphore was created.</td>
</tr>
</tbody>
</table>
xBlockTime: The time in ticks to wait for the semaphore to become available. The macro portTICK_PERIOD_MS can be used to convert this to a real time. A block time of zero can be used to poll the semaphore. A block time of portMAX_DELAY can be used to block indefinitely (provided INCLUDE_vTaskSuspend is set to 1 in FreeRTOSConfig.h).

\texttt{xSemaphoreTakeRecursive}(xMutex, xBlockTime)  
\textit{Macro} to recursively obtain, or ‘take’, a mutex type semaphore. The mutex must have previously been created using a call to \texttt{xSemaphoreCreateRecursiveMutex();}

\texttt{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 \texttt{xSemaphoreCreateMutex().}

A mutex used recursively can be ‘taken’ repeatedly by the owner. The mutex doesn’t become available again until the owner has called \texttt{xSemaphoreGiveRecursive()} for each successful ‘take’ request. For example, if a task successfully ‘takes’ the same mutex 5 times then the mutex will not be available to any other task until it has also ‘given’ the mutex back exactly five times.

Example usage:

```c
SemaphoreHandle_t xMutex = NULL;

// A task that creates a mutex.
void vATask( void *pvParameters )
{
    // Create the mutex to guard a shared resource.
    xMutex = xSemaphoreCreateRecursiveMutex();
}

// A task that uses the mutex.
void vAnotherTask( void *pvParameters )
{
    // ... Do other things.

    if( xMutex != NULL )
    {
        // See if we can obtain the mutex. If the mutex \textbf{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 \textbf{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 \textbf{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 \textbf{not} be
            // available to another task until it has also been given back
            // three times. Again it \textbf{is} unlikely that real code would have
            // these calls sequentially, but instead buried in a more complex
            // call structure. This \textbf{is} just for illustrative purposes.
            xSemaphoreGiveRecursive( xMutex );
            xSemaphoreGiveRecursive( xMutex );
            xSemaphoreGiveRecursive( xMutex );

            // Now the mutex can be taken by other tasks.
        }
    } else
```

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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:

```c
SemaphoreHandle_t xSemaphore = NULL;
void vATask( void * pvParameters )
{
    // Create the semaphore to guard a shared resource.
    vSemaphoreCreateBinary( xSemaphore );

    if( xSemaphore != NULL )
    {
        if( xSemaphoreGive( xSemaphore ) != pdTRUE )
        {
            // We would expect this call to fail because we cannot give
            // a semaphore without first "taking" it!
        }

        // Obtain the semaphore - don't block if the semaphore is not
        // immediately available.
        if( xSemaphoreTake( xSemaphore, ( TickType_t ) 0 ) )
        {
            // We now have the semaphore and can access the shared resource.
            // ...

            // We have finished accessing the shared resource so can free the
            // semaphore.
            if( xSemaphoreGive( xSemaphore ) != pdTRUE )
            {
                // We would not expect this call to fail because we must have
                // obtained the semaphore to get here.
            }
        }
    }
}
```
Return pdTRUE if the semaphore was released. pdFALSE if an error occurred. Semaphores are implemented using queues. An error can occur if there is no space on the queue to post a message - indicating that the semaphore was not first obtained correctly.

Parameters
• xSemaphore: A handle to the semaphore being released. This is the handle returned when the semaphore was created.

**xSemaphoreGiveRecursive**(xMutex)

SEMPhr. h

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.
            xSemaphoreTakeRecursive( xMutex, (TickType_t)10 );
            xSemaphoreTakeRecursive( xMutex, (TickType_t)10 );

            // The mutex has now been 'taken' three times, so will not be
            // available to another task until it has also been given back
            // three times. Again it is unlikely that real code would have
            // these calls sequentially, it would be more likely that the calls
            // to xSemaphoreGiveRecursive() would be called as a call stack
            // unwound. This is just for demonstrative purposes.
            xSemaphoreGiveRecursive( xMutex );
            xSemaphoreGiveRecursive( xMutex );
        }
    }
```

(未完待续)
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 given.

Parameters
• xMutex: A handle to the mutex being released, or ‘given’. This is the handle returned by
  xSemaphoreCreateMutex();

xSemaphoreGiveFromISR(xSemaphore, pxHigherPriorityTaskWoken)
Macro to release a semaphore. The semaphore must have previously been created with a call to
  xSemaphoreCreateBinary() or xSemaphoreCreateCounting().

Mutex type semaphores (those created using a call to xSemaphoreCreateMutex()) must not be used with this
macro.

This macro can be used from an ISR.

Example usage:

```c
#define LONG_TIME 0xffff
#define TICKS_TO_WAIT 10
SemaphoreHandle_t xSemaphore = NULL;

// Repetitive task.
void vATask( void * pvParameters )
{
    for( ;; )
    {
        // We want this task to run every 10 ticks of a timer. The semaphore
        // was created before this task was started.

        // Block waiting for the semaphore to become available.
        if( xSemaphoreTake( xSemaphore, LONG_TIME ) == pdTRUE )
        {
            // It is time to execute.

            // ...

            // We have finished our task. Return to the top of the loop where
            // we will block on the semaphore until it is time to execute
            // again. Note when using the semaphore for synchronisation with an
            // ISR in this manner there is no need to 'give' the semaphore back.
        }
    }
}

// Timer ISR
void vTimerISR( void * pvParameters )
{
    static uint8_t ucLocalTickCount = 0;
    static BaseType_t xHigherPriorityTaskWoken;

    // A timer tick has occurred.
```
// ... 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 *pxHigherPriority-
  TaskWoken to pdTRUE if giving the semaphore caused a task to unblock, and the unblocked task
  has a priority higher than the currently running task. If xSemaphoreGiveFromISR() sets this value
  to pdTRUE then a context switch should be requested before the interrupt is exited.

xSemaphoreTakeFromISR (xSemaphore, pxHigherPriorityTaskWoken)

Macro to take a semaphore from an ISR. The semaphore must have previously been created with a call to
xSemaphoreCreateBinary() or xSemaphoreCreateCounting().

Mutex type semaphores (those created using a call to xSemaphoreCreateMutex()) must not be used with this
macro.

This macro can be used from an ISR, however taking a semaphore from an ISR is not a common operation. It
is likely to only be useful when taking a counting semaphore when an interrupt is obtaining an object from a
resource pool (when the semaphore count indicates the number of resources available).

Return pdTRUE if the semaphore was successfully taken, otherwise pdFALSE

Parameters

• xSemaphore: A handle to the semaphore being taken. This is the handle returned when the
  semaphore was created.

• [out] pxHigherPriorityTaskWoken: xSemaphoreTakeFromISR() will set *pxHigher-
  PriorityTaskWoken to pdTRUE if taking the semaphore caused a task to unblock, and the unblocked task
  has a priority higher than the currently running task. If xSemaphoreTakeFromISR() sets this value
  to pdTRUE then a context switch should be requested before the interrupt is exited.

xSemaphoreCreateMutex ()

Macro that implements a mutex semaphore by using the existing queue mechanism.

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 http://www.freertos.
.org/a00111.html). If a mutex is created using xSemaphoreCreateMutexStatic() then the application writer
must provided the memory. xSemaphoreCreateMutexStatic() therefore allows a mutex to be created without
using any dynamic memory allocation.
Mutexes created using this function can be accessed using the xSemaphoreTake() and xSemaphoreGive() macros. The xSemaphoreTakeRecursive() and xSemaphoreGiveRecursive() macros must not be used.

This type of semaphore uses a priority inheritance mechanism so a task ‘taking’ a semaphore MUST ALWAYS ‘give’ the semaphore back once the semaphore it is no longer required.

Mutex type semaphores cannot be used from within interrupt service routines.

See xSemaphoreCreateBinary() for an alternative implementation that can be used for pure synchronisation (where one task or interrupt always ‘gives’ the semaphore and another always ‘takes’ the semaphore) and from within interrupt service routines.

Example usage:

```c
SemaphoreHandle_t xSemaphore;

void vATask( void * pvParameters )
{
    // Semaphore cannot be used before a call to xSemaphoreCreateMutex().
    // This is a macro so pass the variable in directly.
    xSemaphore = xSemaphoreCreateMutex();

    if( xSemaphore != NULL )
    {
        // The semaphore was created successfully.
        // The semaphore can now be used.
    }
}
```

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 [http://www.freertos.org/a00111.html](http://www.freertos.org/a00111.html)). If a mutex is created using xSemaphoreCreateMutexStatic() then the application writer must provided the memory. xSemaphoreCreateMutexStatic() therefore allows a mutex to be created without using any dynamic memory allocation.

Mutexes created using this function can be accessed using the xSemaphoreTake() and xSemaphoreGive() macros. The xSemaphoreTakeRecursive() and xSemaphoreGiveRecursive() macros must not be used.

This type of semaphore uses a priority inheritance mechanism so a task ‘taking’ a semaphore MUST ALWAYS ‘give’ the semaphore back once the semaphore it is no longer required.

Mutex type semaphores cannot be used from within interrupt service routines.

See xSemaphoreCreateBinary() for an alternative implementation that can be used for pure synchronisation (where one task or interrupt always ‘gives’ the semaphore and another always ‘takes’ the semaphore) and from within interrupt service routines.

Example usage:

```c
SemaphoreHandle_t xSemaphore;
StaticSemaphore_t xMutexBuffer;

void vATask( void * pvParameters )
{
    // 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.

xSemaphoreCreateCounting(uxMaxCount, uxInitialCount)

Creates a new recursive mutex type semaphore instance, and returns a handle by which the new recursive mutex can be referenced.

Internally, within the FreeRTOS implementation, recursive mutexes use a block of memory, in which the mutex structure is stored. If a recursive mutex is created using xSemaphoreCreateRecursiveMutex() then the required memory is automatically dynamically allocated inside the xSemaphoreCreateRecursiveMutex() function. (see http://www.freertos.org/a00111.html). If a recursive mutex is created using xSemaphoreCreateRecursiveMutexStatic() then the application writer must provide the memory that will get used by the mutex. xSemaphoreCreateRecursiveMutexStatic() therefore allows a recursive mutex to be created without using any dynamic memory allocation.

 Mutexes created using this macro can be accessed using the xSemaphoreTakeRecursive() and xSemaphoreGiveRecursive() macros. The xSemaphoreTake() and xSemaphoreGive() macros must not be used.

A mutex used recursively can be ‘taken’ repeatedly by the owner. The mutex doesn’t become available again until the owner has called xSemaphoreGiveRecursive() for each successful ‘take’ request. For example, if a task successfully ‘takes’ the same mutex 5 times then the mutex will not be available to any other task until it has also ‘given’ the mutex back exactly five times.

This type of semaphore uses a priority inheritance mechanism so a task ‘taking’ a semaphore MUST ALWAYS ‘give’ the semaphore back once the semaphore it is no longer required.

Mutex type semaphores cannot be used from within interrupt service routines.

See vSemaphoreCreateBinary() for an alternative implementation that can be used for pure synchronisation (where one task or interrupt always ‘gives’ the semaphore and another always ‘takes’ the semaphore) and from within interrupt service routines.

Example usage:

SemaphoreHandle_t xSemaphore;
void vATask( void * pvParameters )
{
    // Semaphore cannot be used before a call to xSemaphoreCreateMutex().
    // This is a macro so pass the variable in directly.
    xSemaphore = xSemaphoreCreateRecursiveMutex();

    if( xSemaphore != NULL )
    {
        // The semaphore was created successfully.
        // The semaphore can now be used.
    }
}

Creates a new recursive mutex type semaphore instance, and returns a handle by which the new recursive mutex can be referenced.

Return xSemaphore Handle to the created mutex semaphore. Should be of type SemaphoreHandle_t.

Internally, within the FreeRTOS implementation, recursive mutexes use a block of memory, in which the mutex structure is stored. If a recursive mutex is created using xSemaphoreCreateRecursiveMutex() then the
required memory is automatically dynamically allocated inside the xSemaphoreCreateRecursiveMutex() function. (see http://www.freertos.org/a00111.html). If a recursive mutex is created using xSemaphoreCreateRecursiveMutexStatic() then the application writer must provide the memory that will get used by the mutex. xSemaphoreCreateRecursiveMutexStatic() therefore allows a recursive mutex to be created without using any dynamic memory allocation.

Mutexes created using this macro can be accessed using the xSemaphoreTakeRecursive() and xSemaphoreGiveRecursive() macros. The xSemaphoreTake() and xSemaphoreGive() macros must not be used.

A mutex used recursively can be ‘taken’ repeatedly by the owner. The mutex doesn’t become available again until the owner has called xSemaphoreGiveRecursive() for each successful ‘take’ request. For example, if a task successfully ‘takes’ the same mutex 5 times then the mutex will not be available to any other task until it has also ‘given’ the mutex back exactly five times.

This type of semaphore uses a priority inheritance mechanism so a task ‘taking’ a semaphore MUST ALWAYS ‘give’ the semaphore back once the semaphore it is no longer required.

Mutex type semaphores cannot be used from within interrupt service routines.

See xSemaphoreCreateBinary() for an alternative implementation that can be used for pure synchronisation (where one task or interrupt always ‘gives’ the semaphore and another always ‘takes’ the semaphore) and from within interrupt service routines.

Example usage:

```c
SemaphoreHandle_t xSemaphore;
StaticSemaphore_t xMutexBuffer;

void vATask( void *pvParameters )
{
    // A recursive semaphore cannot be used before it is created. Here a recursive mutex is created using xSemaphoreCreateRecursiveMutexStatic().
    // The address of xMutexBuffer is passed into the function, and will hold the mutexes data structures - so no dynamic memory allocation will be attempted.
    xSemaphore = xSemaphoreCreateRecursiveMutexStatic( &xMutexBuffer );

    // As no dynamic memory allocation was performed, xSemaphore cannot be NULL, so there is no need to check it.
}
```

Creates a new counting semaphore instance, and returns a handle by which the new counting semaphore can be referenced.

**Return** If the recursive mutex was successfully created then a handle to the created recursive mutex is returned. If pxMutexBuffer was NULL then NULL is returned.

**Parameters**

- **pxStaticSemaphore**: Must point to a variable of type StaticSemaphore_t, which will then be used to hold the recursive mutex’s data structure, removing the need for the memory to be allocated dynamically.

In many usage scenarios it is faster and more memory efficient to use a direct to task notification in place of a counting semaphore! http://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 http://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! [http://www.freertos.org/RTOS-task-notifications.html](http://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 [http://www.freertos.org/a00111.html](http://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.
}
```

Returns If the counting semaphore was successfully created then a handle to the created counting semaphore is returned. If pxSemaphoreBuffer was NULL then NULL is returned.

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)`
semphr.h
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
typedef QueueHandle_t SemaphoreHandle_t

Timer API

Header File

- freertos/include/freertos/timers.h

Functions

TimerHandle_t xTimerCreate(const char *const pcTimerName, const TickType_t xTimerPeriodInTicks, const UBaseType_t uxAutoReload, void *const pvTimerID, TimerCallbackFunction_t pxCallbackFunction)

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 http://www.freertos.org/a00111.html). If a software timer is created using xTimerCreateStatic() then the application writer must provide the memory that will get used by the software timer. xTimerCreateStatic() therefore allows a software timer to be created without using any dynamic memory allocation.

Timers are created in the dormant state. The xTimerStart(), xTimerReset(), xTimerStartFromISR(), xTimerResetFromISR(), xTimerChangePeriod() and xTimerChangePeriodFromISR() API functions can all be used to transition a timer into the active state.

Example usage:

```c
#define NUM_TIMERS 5

// An array to hold handles to the created timers.
TimerHandle_t xTimers[NUM_TIMERS];

// An array to hold a count of the number of times each timer expires.
int32_t lExpireCounters[NUM_TIMERS] = { 0 };

// Define a callback function that will be used by multiple timer instances.
// The callback function does nothing but count the number of times the
// associated timer expires, and stop the timer once the timer has expired
// 10 times.
void vTimerCallback( TimerHandle_t pxTimer )
{
    int32_t lArrayIndex;
    const int32_t xMaxExpiryCountBeforeStopping = 10;

    // Optionally do something if the pxTimer parameter is NULL.
    configASSERT( pxTimer );

    // Which timer expired?
    lArrayIndex = ( int32_t ) pvTimerGetTimerID( pxTimer );

    // Increment the number of times that pxTimer has expired.
    lExpireCounters[ lArrayIndex ] += 1;

    // If the timer has expired 10 times then stop it from running.
    if( lExpireCounters[ lArrayIndex ] == xMaxExpiryCountBeforeStopping )
    {
        // Do not use a block time if calling a timer API function from a
        // timer callback function, as doing so could cause a deadlock!
        xTimerStop( pxTimer, 0 );
    }
```
void main( void )
{
int32_t x;

// Create then start some timers. Starting the timers before the scheduler has been started means the timers will start running immediately that the scheduler starts.
for( x = 0; x < NUM_TIMERS; x++ )
{
    xTimers[ x ] = xTimerCreate( "Timer", // Just a text name,
        not used by the kernel.
        ( 100 * x ), // The timer period in...
        ticks.
        pdTRUE, // The timers will auto-
        reload themselves when they expire.
        ( void * ) x, // Assign each timer a...
        unique id equal to its array index.
        vTimerCallback // Each timer calls the...
        same callback when it expires.
        )
;
    if( xTimers[ x ] == NULL )
    {
        // The timer was not created.
        } else
    {
        // Start the timer. No block time is specified, and even if one...
        // it would be ignored because the scheduler has not yet been // started.
        if( xTimerStart( xTimers[ x ], 0 ) != pdPASS )
        {
            // The timer could not be set into the Active state.
            } }
    }
}

// ... // Create tasks here. // ...

// Starting the scheduler will start the timers running as they have...// already
// been set into the active state.
vTaskStartScheduler();

// Should not reach here.
for(;; );

Return If the timer is successfully created then a handle to the newly created timer is returned. If the timer cannot be created (because either there is insufficient FreeRTOS heap remaining to allocate the timer structures, or the timer period was set to 0) then NULL is returned.

Parameters
• pcTimerName: A text name that is assigned to the timer. This is done purely to assist debugging. The kernel itself only ever references a timer by its handle, and never by its name.
• xTimerPeriodInTicks: The timer period. The time is defined in tick periods so the con-
stant 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.

• 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);”.

Timers are created in the dormant state. The xTimerStart(), xTimerReset(), xTimerStartFromISR(), xTimerResetFromISR(), xTimerChangePeriod() and xTimerChangePeriodFromISR() API functions can all be used to transition a timer into the active state.

Example usage:

```c
// The buffer used to hold the software timer's data structure.
static StaticTimer_t xTimerBuffer;

// A variable that will be incremented by the software timer's callback function.
UBaseType_t uxVariableToIncrement = 0;

// A software timer callback function that increments a variable passed to it when the software timer was created. After the 5th increment the callback function stops the software timer.
static void prvTimerCallback( TimerHandle_t xExpiredTimer )
{
    UBaseType_t *puxVariableToIncrement;
    BaseType_t xReturned;
    puxVariableToIncrement = (UBaseType_t *) pvTimerGetTimerID(xExpiredTimer);
    *puxVariableToIncrement = *puxVariableToIncrement + 1;
    #if *puxVariableToIncrement == 5
        xTimerStop( xExpiredTimer, staticDONT_BLOCK );
    #endif
}
```
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...
    --allocated dynamically, just as if xTimerCreate() had been called.
    xTimer = xTimerCreateStatic( "T1", // Text name for the task. _
    --Helps debugging only. Not used by FreeRTOS.
    xTimerPeriod, // The period of the timer...
    --in ticks.
    pdTRUE, // This is an auto-reload_.
    --timer.
    ( void * ) &uxVariableToIncrement, // A_
    --variable incremented by the software timer’s callback function
    prvTimerCallback, // The function to execute_
    --when the timer expires.
    &xTimerBuffer ); // The buffer that will...
    --hold the software timer structure.

    // The scheduler has not started yet so a block time is not used.
    xReturned = xTimerStart( xTimer, 0 );

    // ...
    // Create tasks here.
    // ...

    // Starting the scheduler will start the timers running as they have_
    --already
    // been set into the active state.
    vTaskStartScheduler();

    // Should not reach here.
    for( ;; );
}

Return If the timer is created then a handle to the created timer is returned. If pxTimerBuffer was NULL
then NULL is returned.

Parameters

- pcTimerName: A text name that is assigned to the timer. This is done purely to assist debugging.
  The kernel itself only ever references a timer by its handle, and never by its name.
- xTimerPeriodInTicks: The timer period. The time is defined in tick periods so the constant
  portTICK_PERIOD_MS can be used to convert a time that has been specified in milliseconds.
  For example, if the timer must expire after 100 ticks, then xTimerPeriodInTicks should be
  set to 100. Alternatively, if the timer must expire after 500ms, then xPeriod can be set to
  ( 500 / portTICK_PERIOD_MS ) provided configTICK_RATE_HZ is less than or equal to 1000.
- 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( Timer-
  Handle_t xTimer );”.
- pxTimerBuffer: Must point to a variable of type StaticTimer_t, which will be then be used
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:

Parameters
• xTimer: The timer being updated.
• pvNewID: The ID to assign to the timer.

See the xTimerCreate() API function example usage scenario.

BaseType_t xTimerIsTimerActive ( TimerHandle_t xTimer )

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
// 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.
    }
}
```
Return pdFALSE will be returned if the timer is dormant. A value other than pdFALSE will be returned if
the timer is active.

Parameters
- xTimer: The timer being queried.

TaskHandle_t xTimerGetTimerDaemonTaskHandle(void)
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 xTimerGetTimerDaemon-
TaskHandle() before the scheduler has been started.

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 xTimerPendFunc-
tionCallFromISR() 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:

```
// The callback function that will execute in the context of the daemon task.
// Note callback functions must all use this same prototype.
void vProcessInterface( void *pvParameter1, uint32_t ulParameter2 )
{
    BaseType_t xInterfaceToService;
    // The interface that requires servicing is passed in the second
    // parameter. The first parameter is not used in this case.
    xInterfaceToService = ( BaseType_t ) ulParameter2;
    // ...Perform the processing here...
}

// An ISR that receives data packets from multiple interfaces
void vAnISR( void )
{
    BaseType_t xInterfaceToService, xHigherPriorityTaskWoken;
    // Query the hardware to determine which interface needs processing.
    xInterfaceToService = prvCheckInterfaces();
    // The actual processing is to be deferred to a task. Request the
    // vProcessInterface() callback function is executed, passing in the
    // number of the interface that needs processing. The interface to
    // service is passed in the second parameter. The first parameter is
    // not used in this case.
    xHigherPriorityTaskWoken = pdFALSE;
    xTimerPendFunctionCallFromISR( vProcessInterface, NULL, ( uint32_t )-
xInterfaceToService, &xHigherPriorityTaskWoken );
    // If xHigherPriorityTaskWoken is now set to pdTRUE then a context
    // switch should be requested. The macro used is port specific and will
    // be either portYIELD_FROM_ISR() or portEND_SWITCHING_ISR() - refer to
    // the documentation page for the port being used.
    portYIELD_FROM_ISR( xHigherPriorityTaskWoken );
```

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Return pdPASS is returned if the message was successfully sent to the timer daemon task, otherwise pdFALSE is returned.

Parameters
- xFunctionToPend: The function to execute from the timer service/daemon task. The function must conform to the PendedFunction_t prototype.
- pvParameter1: The value of the callback function’s first parameter. The parameter has a void *
  type to allow it to be used to pass any type. For example, unsigned longs can be cast to a void *,
  or the void * can be used to point to a structure.
- ulParameter2: The value of the callback function’s second parameter.
- pxHigherPriorityTaskWoken: As mentioned above, calling this function will result in a message being sent to the timer daemon task. If the priority of the timer daemon task (which is set using configTIMER_TASK_PRIORITY in FreeRTOSConfig.h) is higher than the priority of the currently running task (the task the interrupt interrupted) then *pxHigherPriorityTaskWoken will be set to pdTRUE within xTimerPendFunctionCallFromISR(), indicating that a context switch should be requested before the interrupt exits. For that reason *pxHigherPriorityTaskWoken must be initialised to pdFALSE. See the example code below.

BaseType_t xTimerPendFunctionCall (PendedFunction_t xFunctionToPend, void *pvParameter1, uint32_t ulParameter2, TickType_t xTicksToWait)

Used to defer the execution of a function to the RTOS daemon task (the timer service task, hence this function is implemented in timers.c and is prefixed with ‘Timer’).

Return pdPASS is returned if the message was successfully sent to the timer daemon task, otherwise pdFALSE is returned.

Parameters
- xFunctionToPend: The function to execute from the timer service/daemon task. The function must conform to the PendedFunction_t prototype.
- pvParameter1: The value of the callback function’s first parameter. The parameter has a void *
  type to allow it to be used to pass any type. For example, unsigned longs can be cast to a void *,
  or the void * can be used to point to a structure.
- ulParameter2: The value of the callback function’s second parameter.
- xTicksToWait: Calling this function will result in a message being sent to the timer daemon task
  on a queue. xTicksToWait is the amount of time the calling task should remain in the Blocked state
  (so not using any processing time) for space to become available on the timer queue if the queue is
  found to be full.

const char *pcTimerGetName (TimerHandle_t xTimer)

const char *const pcTimerGetName(TimerHandle_t xTimer);

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 autoreload 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.
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.

Macros
    tmrCOMMAND_EXECUTE_CALLBACK_FROM_ISR
    tmrCOMMAND_EXECUTE_CALLBACK
    tmrCOMMAND_START_DONT_TRACE
    tmrCOMMAND_START
    tmrCOMMAND_RESET
    tmrCOMMAND_STOP
    tmrCOMMAND_CHANGE_PERIOD
    tmrCOMMAND_DELETE
    tmrFIRST_FROM_ISR_COMMAND
    tmrCOMMAND_START_FROM_ISR
    tmrCOMMAND_RESET_FROM_ISR
    tmrCOMMAND_STOP_FROM_ISR
    tmrCOMMAND_CHANGE_PERIOD_FROM_ISR

xTimerStart (xTimer, xTicksToWait)
    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)
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)
Timer functionality is provided by a timer service/daemon task. Many of the public FreeRTOS timer API functions send commands to the timer service task through a queue called the timer command queue. The timer command queue is private to the kernel itself and is not directly accessible to application code. The length of the timer command queue is set by the configTIMER_QUEUE_LENGTH configuration constant.

xTimerChangePeriod() changes the period of a timer that was previously created using the xTimerCreate() API function.

xTimerChangePeriod() can be called to change the period of an active or dormant state timer.

The configUSE_TIMERS configuration constant must be set to 1 for xTimerChangePeriod() to be available.

Example usage:

```c
// This function assumes xTimer has already been created. If the timer
// referenced by xTimer is already active when it is called, then the timer
// is deleted. If the timer referenced by xTimer is not active when it is
// called, then the period of the timer is set to 500ms and the timer is
```
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.
        }
    }
}

Returns  pdFAIL will be returned if the change period command could not be sent to the timer command queue
even after xTicksToWait ticks had passed. pdPASS will be returned if the command was successfully
sent to the timer command queue. When the command is actually processed will depend on the priority
of the timer service/daemon task relative to other tasks in the system. The timer service/daemon task
priority is set by the 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 )

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:

Returns  pdFAIL will be returned if the delete command could not be sent to the timer command queue even
after xTicksToWait ticks had passed. pdPASS will be returned if the command was successfully sent to
the timer command queue. When the command is actually processed will depend on the priority of the
timer service/daemon task relative to other tasks in the 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)

Timer functionality is provided by a timer service/daemon task. Many of the public FreeRTOS timer API functions send commands to the timer service task through a queue called the timer command queue. The length of the timer command queue is set by the configTIMER_QUEUE_LENGTH configuration constant.

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.
    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.
}
```

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Chapter 2. API

```c
void main( void )
{
    int32_t x;

    // Create then start the one-shot timer that is responsible for turning
    // the back-light off if no keys are pressed within a 5 second period.
    xBacklightTimer = xTimerCreate( "BacklightTimer",     // Just a text_
            ( 5000 / portTICK_PERIOD_MS), // The timer_
            period in ticks.                    // The timer_
            is a one-shot timer.                // The timer_
            not used by the callback so can take any value.          // The id is.
            vBacklightTimerCallback              // The_
            callback function that switches the LCD back-light off.
    );

    if ( xBacklightTimer == NULL )
    {
        // The timer was not created.
    }
    else
    {
        // Start the timer. No block time is specified, and even if one was
        // it would be ignored because the scheduler has not yet been
        // started.
        if ( xTimerStart( xBacklightTimer, 0 ) != pdPASS )
        {
            // The timer could not be set into the Active state.
        }
    }

    // ... 
    // Create tasks here. 
    // ...

    // Starting the scheduler will start the timer running as it has already
    // been set into the active state.
    vTaskStartScheduler();

    // Should not reach here.
    for( ; ; );
}
```

**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)
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
        // depends on the FreeRTOS port being used).
    }
}
```

**Return**  pdFAIL will be returned if the start command could not be sent to the timer command queue. pdPASS will be returned if the command was successfully sent to the timer command queue. When the command is actually processed will depend on the priority of the timer service/daemon task relative to other tasks in the system, although the timers expiry time is relative to when xTimerStartFromISR() is actually called. The timer service/daemon task priority is set by the configTIMER_TASK_PRIORITY configuration constant.

**Parameters**
- xTimer: The handle of the timer being started/restarted.
- pxHigherPriorityTaskWoken: The timer service/daemon task spends most of its time in
the Blocked state, waiting for messages to arrive on the timer command queue. Calling xTimerStartFromISR() writes a message to the timer command queue, so has the potential to transition the timer service/daemon task out of the Blocked state. If calling xTimerStartFromISR() causes the timer service/daemon task to leave the Blocked state, and the timer service/daemon task has a priority equal to or greater than the currently executing task (the task that was interrupted), then *pxHigherPriorityTaskWoken will get set to pdTRUE internally within the xTimerStartFromISR() function. If xTimerStartFromISR() sets this value to pdTRUE then a context switch should be performed before the interrupt exits.

\textbf{xTimerStopFromISR (xTimer, 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).
    }
}
```

\textbf{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.

\textbf{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.

\textbf{xTimerChangePeriodFromISR (xTimer, xNewPeriod, pxHigherPriorityTaskWoken)}
A version of xTimerChangePeriod() that can be called from an interrupt service routine.

Example usage:

```c
// This scenario assumes xTimer has already been created and started. When an interrupt occurs, the period of xTimer should be changed to 500ms.

// The interrupt service routine that changes the period of xTimer.
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).
    }
}
```

**Return**

pdFAIL will be returned if the command to change the timers period could not be sent to the timer command queue. pdPASS will be returned if the command was successfully sent to the timer command queue. When the command is actually processed will depend on the priority of the timer service/daemon task relative to other tasks in the system. The timer service/daemon task priority is set by the 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.
- **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)

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.

```c
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.

```c
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.
    }

    // The rest of the key processing here.

    // If xHigherPriorityTaskWoken equals pdTRUE, then a context switch should be performed. The syntax required to perform a context switch from inside an ISR varies from port to port, and from compiler to compiler. Inspect the demos for the port you are using to find the actual syntax required.
    if( xHigherPriorityTaskWoken != pdFALSE )
    {
        // Call the interrupt safe yield function here (actual function depends on the FreeRTOS port being used).
    }
}
```

Return pdFAIL will be returned if the reset command could not be sent to the timer command queue. pdPASS will be returned if the command was successfully sent to the timer command queue. When the command is actually processed will depend on the priority of the timer service/daemon task relative to other tasks in the system, although the timers expiry time is relative to when xTimerResetFromISR() is actually called. The timer service/daemon task priority is set by the configTIMER_TASK_PRIORITY configuration constant.

Parameters

- xTimer: The handle of the timer that is to be started, reset, or restarted.
- pxHigherPriorityTaskWoken: The timer service/daemon task spends most of its time in the Blocked state, waiting for messages to arrive on the timer command queue. Calling xTimer-
ResetFromISR() 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**

```c
typedef void *TimerHandle_t
typedef void (*)(TimerHandle_t xTimer)
typedef void (*)(PendedFunction_t)(void *, uint32_t)
```

**Event Group API**

**Header File**

- freertos/include/freertos/event_groups.h

**Functions**

```c
EventGroupHandle_t xEventGroupCreate(void)
```

Create a new event group.

Internally, within the FreeRTOS implementation, event groups use a [small] block of memory, in which the event group’s structure is stored. If an event group is created using xEventGroupCreate() then the required memory is automatically dynamically allocated inside the xEventGroupCreate() function. (see [http://www.freertos.org/a00111.html](http://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 [http://www.freertos.org/a00111.html](http://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 group is created using xEventGroupCreate() then the required memory is automatically dynamically allocated inside the xEventGroupCreate() function. (see [http://www.freertos.org/a00111.html](http://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, // The event group being tested.
                                  BIT_0 | BIT_4, // The bits within the event group to wait...
                                 xClearOnExit, pdTRUE, // BIT_0 and BIT_4 should be cleared before...
                                 xTicksToWait );
}
```
pdFALSE, // Don’t wait for both bits, either bit will...
→do.
  xTicksToWait }; // Wait a maximum of 100ms for either bit to...
→be set.

  if( ( uxBits & ( BIT_0 | BIT_4 ) ) == ( BIT_0 | BIT_4 ) )
  {
    // xEventGroupWaitBits() returned because both bits were set.
  }
  else if( ( uxBits & BIT_0 ) != 0 )
  {
    // xEventGroupWaitBits() returned because just BIT_0 was set.
  }
  else if( ( uxBits & BIT_4 ) != 0 )
  {
    // xEventGroupWaitBits() returned because just BIT_4 was set.
  }
  else
  {
    // xEventGroupWaitBits() returned because xTicksToWait ticks passed
    // without either BIT_0 or BIT_4 becoming set.
  }
}

[c]

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().
- uxBitsToWaitFor: A bitwise value that indicates the bit or bits to test inside the event group. For example, to wait for bit 0 and/or bit 2 set uxBitsToWaitFor to 0x05. To wait for bits 0 and/or bit 1 and/or bit 2 set uxBitsToWaitFor to 0x07. Etc.
- xClearOnExit: If xClearOnExit is set to pdTRUE then any bits within uxBitsToWaitFor that are set within the event group will be cleared before xEventGroupWaitBits() returns if the wait condition was met (if the function returns for a reason other than a timeout). If xClearOnExit is set to pdFALSE then the bits set in the event group are not altered when the call to xEventGroupWaitBits() returns.
- xWaitForAllBits: If xWaitForAllBits is set to pdTRUE then xEventGroupWaitBits() will return when either all the bits in uxBitsToWaitFor are set or the specified block time expires. If xWaitForAllBits is set to pdFALSE then xEventGroupWaitBits() will return when any one of the bits set in uxBitsToWaitFor is set or the specified block time expires. The block time is specified by the xTicksToWait parameter.
- xTicksToWait: The maximum amount of time (specified in ‘ticks’) to wait for one/all (depending on the xWaitForAllBits value) of the bits specified by uxBitsToWaitFor to become set.

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, BIT_0 | BIT_4 );

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( EventGroupHandle_t xEventGroup, const EventBits_t uxBitsToSet )
Set bits within an event group. This function cannot be called from an interrupt. xEventGroupSetBits-FromISR() is a version that can be called from an interrupt.

Setting bits in an event group will automatically unblock tasks that are blocked waiting for the bits.
Example usage:

#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 );

    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()). Sec-  
ond, 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 xEvent-  
GroupSetBits() 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.
    }
}

Return  The value of the event group at the time either the bits being waited for became set, or the block time
expired. Test the return value to know which bits were set. If xEventGroupSync() returned because its timeout expired then not all the bits being waited for will be set. If xEventGroupSync() returned because all the bits it was waiting for were set then the returned value is the event group value before any bits were automatically cleared.

**Parameters**

- **xEventGroup**: The event group in which the bits are being tested. The event group must have previously been created using a call to xEventGroupCreate().
- **uxBitsToSet**: The bits to set in the event group before determining if, and possibly waiting for, all the bits specified by the uxBitsToWait parameter are set.
- **uxBitsToWaitFor**: A bitwise value that indicates the bit or bits to test inside the event group. For example, to wait for bit 0 and bit 2 set uxBitsToWaitFor to 0x05. To wait for bits 0 and bit 1 and bit 2 set uxBitsToWaitFor to 0x07. Etc.
- **xTicksToWait**: The maximum amount of time (specified in ‘ticks’) to wait for all of the bits specified by uxBitsToWaitFor to become set.

**EventBits_t xEventGroupGetBitsFromISR (EventGroupHandle_t xEventGroup)**

A version of xEventGroupGetBits() that can be called from an ISR.

**Return**

The event group bits at the time xEventGroupGetBitsFromISR() was called.

**Parameters**

- **xEventGroup**: The event group being queried.

**void vEventGroupDelete (EventGroupHandle_t xEventGroup)**

Delete an event group that was previously created by a call to xEventGroupCreate(). Tasks that are blocked on the event group will be unblocked and obtain 0 as the event group’s value.

**Parameters**

- **xEventGroup**: The event group being deleted.

**Macros**

**xEVENTGROUPCLEARBITSFROMISR (xEVENTGROUPHANDLE, uxBITS TO CLEAR)**

A version of xEventGroupClearBits() that can be called from an interrupt.

Setting bits in an event group is not a deterministic operation because there are an unknown number of tasks that may be waiting for the bit or bits being set. FreeRTOS does not allow nondeterministic operations to be performed while interrupts are disabled, so protects event groups that are accessed from tasks by suspending the scheduler rather than disabling interrupts. As a result event groups cannot be accessed directly from an interrupt service routine. Therefore xEventGroupClearBitsFromISR() sends a message to the timer task to have the clear operation performed in the context of the timer task.

Example usage:

```c
#define BIT_0  ( 1 << 0 )
#define BIT_4  ( 1 << 4 )

// An event group which it is assumed has already been created by a call to
// xEventGroupCreate().
EventGroupHandle_t xEventGroup;

void anInterruptHandler( void )
{
    // Clear bit 0 and bit 4 in xEventGroup.
    xResult = xEventGroupClearBitsFromISR(
        xEventGroup,   // The event group being updated.
        BIT_0 | BIT_4 ); // The bits being set.

    if( xResult == pdPASS )
    {
        // The message was posted successfully.
    }
}
```
**Return** If the request to execute the function was posted successfully then pdPASS is returned, otherwise pdFALSE is returned. pdFALSE will be returned if the timer service queue was full.

**Parameters**
- xEventGroup: The event group in which the bits are to be cleared.
- uxBitsToClear: A bitwise value that indicates the bit or bits to clear. For example, to clear bit 3 only, set uxBitsToClear to 0x08. To clear bit 3 and bit 0 set uxBitsToClear to 0x09.

**xEventGroupSetBitsFromISR** (xEventGroup, uxBitsToSet, pxHigherPriorityTaskWoken)
A version of xEventGroupSetBits() that can be called from an interrupt.

Setting bits in an event group is not a deterministic operation because there are an unknown number of tasks that may be waiting for the bit or bits being set. FreeRTOS does not allow nondeterministic operations to be performed in interrupts or from critical sections. Therefore xEventGroupSetBitsFromISR() sends a message to the timer task to have the set operation performed in the context of the timer task - where a scheduler lock is used in place of a critical section.

**Example usage:**

```c
#define BIT_0  ( 1 << 0 )
#define BIT_4  ( 1 << 4 )

// An event group which it is assumed has already been created by a call to
// xEventGroupCreate().
EventGroupHandle_t xEventGroup;

void anInterruptHandler( void )
{
    BaseType_t xHigherPriorityTaskWoken, xResult;

    // xHigherPriorityTaskWoken must be initialised to pdFALSE.
    xHigherPriorityTaskWoken = pdFALSE;

    // Set bit 0 and bit 4 in xEventGroup.
    xResult = xEventGroupSetBitsFromISR(
        xEventGroup,  // The event group being updated.
        BIT_0 | BIT_4 // The bits being set.
        &xHigherPriorityTaskWoken );

    // Was the message posted successfully?
    if( xResult == pdPASS )
    {
        // If xHigherPriorityTaskWoken is now set to pdTRUE then a context
        // switch should be requested. The macro used is port specific and
        // will be either portYIELD_FROM_ISR() or portEND_SWITCHING_ISR() -
        // refer to the documentation page for the port being used.
        portYIELD_FROM_ISR( xHigherPriorityTaskWoken );
    }
}
```

**Return** If the request to execute the function was posted successfully then pdPASS is returned, otherwise pdFALSE is returned. pdFALSE will be returned if the timer service queue was full.

**Parameters**
- xEventGroup: The event group in which the bits are to be set.
- uxBitsToSet: A bitwise value that indicates the bit or bits to set. For example, to set bit 3 only, set uxBitsToSet to 0x08. To set bit 3 and bit 0 set uxBitsToSet to 0x09.
- pxHigherPriorityTaskWoken: As mentioned above, calling this function will result in a message being sent to the timer daemon task. If the priority of the timer daemon task is higher than the priority of the currently running task (the task the interrupt interrupted) then *pxHigherPriorityTaskWoken will be set to pdTRUE by xEventGroupSetBitsFromISR(), indicating that a context switch should be requested before the interrupt exits. For that reason *pxHigherPriorityTaskWoken must be initialised to pdFALSE. See the example code below.

**xEventGroupGetBits** (xEventGroup)
Chapter 2. API

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**

```c
typedef void *EventGroupHandle_t
typedef TickType_t EventBits_t
```

**Stream Buffer API**

**Header File**

- freertos/include/freertos/stream_buffer.h

**Functions**

```c
size_t xStreamBufferSend(StreamBufferHandle_t xStreamBuffer, const void *pvTxData, size_t xDataLengthBytes, TickType_t xTicksToWait)
```

Sends bytes to a stream buffer. The bytes are copied into the stream buffer.

: Uniquely among FreeRTOS objects, the stream buffer implementation (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 xStreamBufferRead()) inside a critical section and set the receive block time to 0.

Use xStreamBufferSend() to write to a stream buffer from a task. Use xStreamBufferSendFromISR() to write to a stream buffer from an interrupt service routine (ISR).

**Example use:**

```c
void vAFunction( StreamBufferHandle_t xStreamBuffer )
{
  size_t xBytesSent;
  uint8_t ucArrayToSend[] = { 0, 1, 2, 3 };  
  char *pcStringToSend = "String to send";
  const TickType_t x100ms = pdMS_TO_TICKS( 100 );

  /\ Send an array to the stream buffer, blocking for a maximum of 100ms to \ 
  /\ wait for enough space to be available in the stream buffer. \ 
  xBytesSent = xStreamBufferSend( xStreamBuffer, ( void * ) ucArrayToSend, \ 
  sizeof( ucArrayToSend ), x100ms );

  if( xBytesSent != sizeof( ucArrayToSend ) )
  {
    // The call to xStreamBufferSend() times out before there was enough \ 
    // space in the buffer for the data to be written, but it did \ 
    // successfully write xBytesSent bytes.
  }

  /\ Send the string to the stream buffer. Return immediately if there is\ 
  /\ not \ 
  // enough space in the buffer. \ 
  xBytesSent = xStreamBufferSend( xStreamBuffer, ( void * ) pcStringToSend, \ 
  strlen( pcStringToSend ), 0 );
```

(下页继续)
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 bytes to 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.

```
size_t xStreamBufferSendFromISR( StreamBufferHandle_t xStreamBuffer, const void *pvTxData, size_t xDataLengthBytes, BaseType_t *const pxHigherPriorityTaskWoken )
```

Interrupt safe version of the API function that sends a stream of bytes to the stream buffer.

: 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 xStreamBufferRead()) inside a critical section and set the receive block time to 0.

Use xStreamBufferSend() to write to a stream buffer from a task. Use xStreamBufferSendFromISR() to write to a stream buffer from an interrupt service routine (ISR).

**Example use:**

```c
//A stream buffer that has already been created.
StreamBufferHandle_t xStreamBuffer;

void vAnInterruptServiceRoutine( void )
{
    size_t xBytesSent;
    char *pcStringToSend = "String to send";
    BaseType_t xHigherPriorityTaskWoken = pdFALSE; // Initialised to pdFALSE.

    // Attempt to send the string to the stream buffer.
    xBytesSent = xStreamBufferSendFromISR( xStreamBuffer,
        ( void * ) pcStringToSend,
        strlen( pcStringToSend ),
        &xHigherPriorityTaskWoken );
```

![](ESpressif Systems 1085 Release v4.3-dev-1561-g357a277603  Submit Document Feedback)
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 Blocked 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.

: Uniquely among FreeRTOS objects, the stream buffer implementation (so also the message buffer implement-
ation, 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 xStreamBufferRead()) 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:

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.
size_t xReceivedBytes = xStreamBufferReceive( xStreamBuffer,
    ( void * ) ucRxData,
    sizeof( ucRxData ),
    xBlockTime );

if( xReceivedBytes > 0 )
{
    // ucRxData contains another xRecievedBytes 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 IN-
  CLUDE_vTaskSuspend is set to 1 in FreeRTOSConfig.h. A task does not use any CPU time when
  it is in the Blocked state.

size_t xStreamBufferReceiveFromISR(StreamBufferHandle_t xStreamBuffer,
    void *pvRxData,
    size_t xBufferLengthBytes,
    BaseType_t *const pxHigherPriorityTaskWoken)

An interrupt safe version of the API function that receives bytes from a stream buffer.

Use xStreamBufferReceive() to read bytes from a stream buffer from a task. Use xStreamBufferReceive-
FromISR() to read bytes from a stream buffer from an interrupt service routine (ISR).

Example use:

// A stream buffer that has already been created.
StreamBuffer_t xStreamBuffer;

void vAnInterruptServiceRoutine( void )
{
    uint8_t ucRxData[ 20 ];
    size_t xReceivedBytes;
    BaseType_t xHigherPriorityTaskWoken = pdFALSE;  // Initialised to pdFALSE.

    // Receive the next stream from the stream buffer.
    xReceivedBytes = xStreamBufferReceiveFromISR( xStreamBuffer,
        ( void * ) ucRxData,
        sizeof( ucRxData ),
        &xHigherPriorityTaskWoken );

    if( xReceivedBytes > 0 )
    {
        // ucRxData contains xReceivedBytes read from the stream buffer.
Process the stream here.

void vStreamBufferDelete(StreamBufferHandle_t xStreamBuffer)

Deletes a stream buffer that was previously created using a call to xStreamBufferCreate() or xStreamBufferCreateStatic(). If the stream buffer was created using dynamic memory (that is, by xStreamBufferCreate()), then the allocated memory is freed.

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.

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.

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)**

**size_t xStreamBufferBytesAvailable (StreamBufferHandle_t xStreamBuffer)**

**BaseType_t xStreamBufferSetTriggerLevel (StreamBufferHandle_t xStreamBuffer, size_t xTriggerLevel)**

A stream buffer's trigger level is the number of bytes that must be in the stream buffer before a task that is blocked on the stream buffer to wait for data is moved out of the blocked state. For example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 1 then the task will be unblocked when a single byte is written to the buffer or the task's block time expires. As another example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 10 then the task will not be unblocked until the stream buffer contains at least 10 bytes or the task's block time expires. If a reading task's block time expires before the trigger level is reached then the task will still receive however many bytes are actually available. Setting a trigger level of 0 will result in a trigger level of 1 being used. It is not valid to specify a trigger level that is greater than the buffer size.

A trigger level is set when the stream buffer is created, and can be modified using xStreamBufferSetTriggerLevel().

**Return** If xTriggerLevel was less than or equal to the stream buffer's length then the trigger level will be updated and pdTRUE is returned. Otherwise pdFALSE is returned.

**Parameters**

- xStreamBuffer: The handle of the stream buffer being updated.
- xTriggerLevel: The new trigger level for the stream buffer.

**BaseType_t xStreamBufferSendCompletedFromISR (StreamBufferHandle_t xStreamBuffer, BaseType_t *pxHigherPriorityTaskWoken)**

For advanced users only.

The sbSEND_COMPLETED() macro is called from within the FreeRTOS APIs when data is sent to a message buffer or stream buffer. If there was a task that was blocked on the message or stream buffer waiting for data to arrive then the sbSEND_COMPLETED() macro sends a notification to the task to remove it from the Blocked state. xStreamBufferSendCompletedFromISR() does the same thing. It is provided to enable application writers to implement their own version of sbSEND_COMPLETED(), and MUST NOT BE USED AT ANY OTHER TIME.

See the example implemented in FreeRTOS/Demo/Minimal/MessageBufferAMP.c for additional information.

**Return** If a task was removed from the Blocked state then pdTRUE is returned. Otherwise pdFALSE is returned.

**Parameters**

- xStreamBuffer: The handle of the stream buffer to which data was written.
- pxHigherPriorityTaskWoken: *pxHigherPriorityTaskWoken should be initialised to pdFALSE before it is passed into xStreamBufferSendCompletedFromISR(). If calling xStreamBufferSendCompletedFromISR() removes a task from the Blocked state, and the task has a priority above the priority of the currently running task, then *pxHigherPriorityTaskWoken will get set to pdTRUE indicating that a context switch should be performed before exiting the ISR.

**BaseType_t xStreamBufferReceiveCompletedFromISR (StreamBufferHandle_t xStreamBuffer, BaseType_t *pxHigherPriorityTaskWoken)**

For advanced users only.

The sbRECEIVE_COMPLETED() macro is called from within the FreeRTOS APIs when data is read out of a message buffer or stream buffer. If there was a task that was blocked on the message or stream buffer waiting for data to arrive then the sbRECEIVE_COMPLETED() macro sends a notification to the task to remove it from the Blocked state. xStreamBufferReceiveCompletedFromISR() does the same thing. It is provided to enable application writers to implement their own version of sbRECEIVE_COMPLETED(), and MUST NOT BE USED AT ANY OTHER TIME.

See the example implemented in FreeRTOS/Demo/Minimal/MessageBufferAMP.c for additional information.
Return If a task was removed from the Blocked state then pdTRUE is returned. Otherwise pdFALSE is returned.

Parameters
- **xStreamBuffer**: The handle of the stream buffer from which data was read.
- **pxHigherPriorityTaskWoken**: *pxHigherPriorityTaskWoken* should be initialised to pdFALSE before it is passed into xStreamBufferReceiveCompletedFromISR(). If calling xStreamBufferReceiveCompletedFromISR() removes a task from the Blocked state, and the task has a priority above the priority of the currently running task, then *pxHigherPriorityTaskWoken* will get set to pdTRUE indicating that a context switch should be performed before exiting the ISR.

Macros

**xStreamBufferCreate**(xBufferSizeBytes, xTriggerLevelBytes)

Creates a new stream buffer using dynamically allocated memory. See xStreamBufferCreateStatic() for a version that uses statically allocated memory (memory that is allocated at compile time).

`configSUPPORT_DYNAMIC_ALLOCATION` must be set to 1 or left undefined in FreeRTOSConfig.h for xStreamBufferCreate() to be available.

Example use:

```c
void vAFunction( void )
{
    StreamBufferHandle_t xStreamBuffer;
    const size_t xStreamBufferSizeBytes = 100, xTriggerLevel = 10;

    // Create a stream buffer that can hold 100 bytes. The memory used to
    // hold both the stream buffer structure and the data in the stream buffer
    // is allocated dynamically.
    xStreamBuffer = xStreamBufferCreate( xStreamBufferSizeBytes, ...
    //xTriggerLevel );

    if( xStreamBuffer == NULL )
    {
        // There was not enough heap memory space available to create the
        // stream buffer.
    }
    else
    {
        // The stream buffer was created successfully and can now be used.
    }
}
```

Return If NULL is returned, then the stream buffer cannot be created because there is insufficient heap memory available for FreeRTOS to allocate the stream buffer data structures and storage area. A non-NULL value being returned indicates that the stream buffer has been created successfully - the returned value should be stored as the handle to the created stream buffer.

Parameters
- **xBuffSizeBytes**: The total number of bytes the stream buffer will be able to hold at any one time.
- **xTriggerLevelBytes**: The number of bytes that must be in the stream buffer before a task that is blocked on the stream buffer to wait for data is moved out of the blocked state. For example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 1 then the task will be unblocked when a single byte is written to the buffer or the task’s block time expires. As another example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 10 then the task will not be unblocked until the stream buffer contains at least 10 bytes or the task’s block time expires. If a reading task’s block time expires before the trigger level is reached then the task will still receive however many bytes are actually available. Setting a trigger level of 0 will result in a trigger level of 1 being used. It is not valid to specify a trigger level that is greater than the buffer size.
**xStreamBufferCreateStatic** (xBufferSizeBytes, xTriggerLevelBytes, pucStreamBufferStorageArea, pxStaticStreamBuffer)

Creates a new stream buffer using statically allocated memory. See xStreamBufferCreate() for a version that uses dynamically allocated memory.

configSUPPORT_STATIC_ALLOCATION must be set to 1 in FreeRTOSConfig.h for xStreamBufferCreateStatic() to be available.

Example use:

```c
// Used to dimension the array used to hold the streams. The available space will actually be one less than this, so 999.
#define STORAGE_SIZE_BYTES 1000

// Defines the memory that will actually hold the streams within the stream buffer.
static uint8_t ucStorageBuffer[ STORAGE_SIZE_BYTES ];

// The variable used to hold the stream buffer structure.
StaticStreamBuffer_t xStreamBufferStruct;

void MyFunction( void )
{
    StreamBufferHandle_t xStreamBuffer;
    const size_t xTriggerLevel = 1;

    xStreamBuffer = xStreamBufferCreateStatic( sizeof( ucBufferStorage ),
                                      xTriggerLevel,
                                      ucBufferStorage,
                                      &xStreamBufferStruct );

    // As neither the pucStreamBufferStorageArea or pxStaticStreamBuffer parameters were NULL, xStreamBuffer will not be NULL, and can be used to reference the created stream buffer in other stream buffer API calls.

    // Other code that uses the stream buffer can go here.
}
```

**Return** If the stream buffer is created successfully then a handle to the created stream buffer is returned. If either pucStreamBufferStorageArea or pxStaticStreamBuffer are NULL then NULL is returned. **Parameters**

- **xBufferSizeBytes**: The size, in bytes, of the buffer pointed to by the pucStreamBufferStorageArea parameter.
- **xTriggerLevelBytes**: The number of bytes that must be in the stream buffer before a task that is blocked on the stream buffer to wait for data is moved out of the blocked state. For example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 1 then the task will be unblocked when a single byte is written to the buffer or the task’s block time expires. As another example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 10 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
```

---

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**Release v4.3-dev-1561-g357a277603**
Message Buffer API

Header File

- freertos/include/freertos/message_buffer.h

Macros

\texttt{xMessageBufferCreate}(\texttt{xBufferSizeBytes})

Creates a new message buffer using dynamically allocated memory. See \texttt{xMessageBufferCreateStatic()} for a version that uses statically allocated memory (memory that is allocated at compile time).

\texttt{configSUPPORT_DYNAMIC_ALLOCATION} must be set to 1 or left undefined in \texttt{FreeRTOSConfig.h} for \texttt{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 \textbf{and} the messages themselves \textbf{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 \textbf{not} enough heap memory space available to create the
        // message buffer.
    }
    else
        // The message buffer was created successfully \textbf{and} can now be used.
}
```

Return If NULL is returned, then the message buffer cannot be created because there is insufficient heap memory available for FreeRTOS to allocate the message buffer data structures and storage area. A non-NULL value being returned indicates that the message buffer has been created successfully - the returned value should be stored as the handle to the created message buffer.

Parameters

- \texttt{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(\texttt{size_t}) bytes are also written to store the message’s length. sizeof(\texttt{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.

\texttt{xMessageBufferCreateStatic}(\texttt{xBufferSizeBytes, pucMessageBufferStorageArea, pxStaticMessageBuffer})

Creates a new message buffer using statically allocated memory. See \texttt{xMessageBufferCreate()} for a version that uses dynamically allocated memory.

Example use:

```c
// Used to dimension the array used to hold the messages. The available space
// will actually be one less than this, so 999.
#define STORAGE_SIZE_BYTES 1000

// Defines the memory that will actually hold the messages within the message
// buffer.
static uint8_t ucStorageBuffer[ STORAGE_SIZE_BYTES ];
```
The variable used to hold the message buffer structure.
StaticMessageBuffer_t xMessageBufferStruct;

void MyFunction( void )
{
    MessageBufferHandle_t xMessageBuffer;

    xMessageBuffer = xMessageBufferCreateStatic( sizeof( ucBufferStorage ),
        ucBufferStorage,
        &xMessageBufferStruct );

    // As neither the pucMessageBufferStorageArea or pxStaticMessageBuffer
    // parameters were NULL, xMessageBuffer will not be NULL, and can be used to
    // reference the created message buffer in other message buffer API calls.

    // Other code that uses the message buffer can go here.
}

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 pucMessageBufferStor-
ageArea parameter. When a message is written to the message buffer an additional sizeof( size_t )
bytes are also written to store the message’s length. sizeof( size_t ) is typically 4 bytes on a 32-bit
architecture, so on most 32-bit architecture a 10 byte message will take up 14 bytes of message
buffer space. The maximum number of bytes that can be stored in the message buffer is actually
(xBufferSizeBytes - 1).
• pucMessageBufferStorageArea: Must point to a uint8_t array that is at least xBufferSize-
Bytes + 1 big. This is the array to which messages are copied when they are written to the message
buffer.
• pxStaticMessageBuffer: Must point to a variable of type StaticMessageBuffer_t, which will
be used to hold the message buffer’s data structure.

xMessageBufferSend(xMessageBuffer, pvTxData, xDataLengthBytes, xTicksToWait)
Sends a discrete message to the message buffer. The message can be any length that fits within the buffer’s
free space, and is copied into the buffer.

: Uniquely among FreeRTOS objects, the stream buffer implementation (so also the message buffer implement-
station, as message buffers are built on top of stream buffers) assumes there is only one task or interrupt that
will write to the buffer (the writer), and only one task or interrupt that will read from the buffer (the reader). It
is safe for the writer and reader to be different tasks or interrupts, but, unlike other FreeRTOS objects, it is not
safe to have multiple different writers or multiple different readers. If there are to be multiple different writers
then the application writer must place each call to a writing API function (such as xMessageBufferSend())
inside a critical section and set the send block time to 0. Likewise, if there are to be multiple different readers
then the application writer must place each call to a reading API function (such as xMessageBufferRead())
inside a critical section and set the receive block time to 0.

Use xMessageBufferSend() to write to a message buffer from a task. Use xMessageBufferSendFromISR() to
write to a message buffer from an interrupt service routine (ISR).

Example use:

void vAFunction( MessageBufferHandle_t xMessageBuffer )
{
    size_t xBytesSent;
    uint8_t ucArrayToSend[] = { 0, 1, 2, 3 };
    char *pcStringToSend = "String to send";
    const TickType_t x100ms = pdMS_TO_TICKS( 100 );
}

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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.

```c
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.

```c
xBytesSent = xMessageBufferSend( xMessageBuffer, ( void * ) pcStringToSend, strlen( pcStringToSend ), 0 );
```

If `xBytesSent != strlen( pcStringToSend )`

- The string could not be added to the message buffer because there was not enough free space in the buffer.

Return The number of bytes written to the message buffer. If the call to `xMessageBufferSend()` times out before there was enough space to write the message into the message buffer then zero is returned. If the call did not time out then `xDataLengthBytes` is returned.

Parameters
- `xMessageBuffer`: The handle of the message buffer to which a message is being sent.
- `pvTxData`: A pointer to the message that is to be copied into the message buffer.
- `xDataLengthBytes`: The length of the message. That is, the number of bytes to copy from `pvTxData` into the message buffer. When a message is written to the message buffer an additional `sizeof(size_t)` bytes are also written to store the message’s length. `sizeof(size_t)` is typically 4 bytes on a 32-bit architecture, so on most 32-bit architecture setting `xDataLengthBytes` to 20 will reduce the free space in the message buffer by 24 bytes (20 bytes of message data and 4 bytes to hold the message length).
- `xTicksToWait`: The maximum amount of time the calling task should remain in the Blocked state to wait for enough space to become available in the message buffer, should the message buffer have insufficient space when `xMessageBufferSend()` is called. The calling task will never block if `xTicksToWait` is zero. The block time is specified in tick periods, so the absolute time it represents is dependent on the tick frequency. The macro `pdMS_TO_TICKS()` can be used to convert a time specified in milliseconds into a time specified in ticks. Setting `xTicksToWait` to `portMAX_DELAY` will cause the task to wait indefinitely (without timing out), provided `INCLUDE_vTaskSuspend` is set to 1 in `FreeRTOSConfig.h`. Tasks do not use any CPU time when they are in the Blocked state.

`xMessageBufferSendFromISR(xMessageBuffer, pvTxData, xDataLengthBytes, pxHigherPriorityTaskWoken)`

Interrupt safe version of the API function that sends a discrete message to the message buffer. The message can be any length that fits within the buffer’s free space, and is copied into the buffer.

: Uniquely among FreeRTOS objects, the stream buffer implementation (so also the message buffer implementation, as message buffers are built on top of stream buffers) assumes there is only one task or interrupt that will write to the buffer (the writer), and only one task or interrupt that will read from the buffer (the reader). It is safe for the writer and reader to be different tasks or interrupts, but, unlike other FreeRTOS objects, it is not safe to have multiple different writers or multiple different readers. If there are to be multiple different writers then the application writer must place each call to a writing API function (such as `xMessageBufferSend()` inside a critical section and set the send block time to 0. Likewise, if there are to be multiple different readers then the application writer must place each call to a reading API function (such as `xMessageBufferRead()` inside a critical section and set the receive block time to 0.

Use `xMessageBufferSend()` to write to a message buffer from a task. Use `xMessageBufferSendFromISR()` to
write to a message buffer from an interrupt service routine (ISR).

Example use:

```c
// A message buffer that has already been created.
MessageBufferHandle_t xMessageBuffer;

void vAnInterruptServiceRoutine( void )
{
    size_t xBytesSent;
    char *pcStringToSend = "String to send";
    BaseType_t xHigherPriorityTaskWoken = pdFALSE; // Initialised to pdFALSE.

    // Attempt to send the string to the message buffer.
    xBytesSent = xMessageBufferSendFromISR( xMessageBuffer,
                                             ( void * ) pcStringToSend,
                                             strlen( pcStringToSend ),
                                             &xHigherPriorityTaskWoken );

    if( xBytesSent != strlen( pcStringToSend ) )
    {
        // The string could not be added to the message buffer because there was
        // not enough free space in the buffer.
    }

    // If xHigherPriorityTaskWoken was set to pdTRUE inside
    // xMessageBufferSendFromISR() then a task that has a priority above the
    // priority of the currently executing task was unblocked and a context
    // switch should be performed to ensure the ISR returns to the unblocked
    // task. In most FreeRTOS ports this is done by simply passing
    // xHigherPriorityTaskWoken into portYIELD_FROM_ISR(), which will test the
    // variables value, and perform the context switch if necessary. Check the
    // documentation for the port in use for port specific instructions.
    portYIELD_FROM_ISR( xHigherPriorityTaskWoken );
}
```

**Return** The number of bytes actually written to the message buffer. If the message buffer didn’t have enough free space for the message to be stored then 0 is returned, otherwise `xDataLengthBytes` is returned.

**Parameters**
- `xMessageBuffer`: The handle of the message buffer to which a message is being sent.
- `pvTxData`: A pointer to the message that is to be copied into the message buffer.
- `xDataLengthBytes`: The length of the message. That is, the number of bytes to copy from `pvTxData` into the message buffer. When a message is written to the message buffer an additional `sizeof(size_t)` bytes are also written to store the message 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** *(MessageBuffer, pvRxData, xBufferLengthBytes, xTicksToWait)*

Receives a discrete message from a message buffer. Messages can be of variable length and are copied out of the buffer.
Uniquely among FreeRTOS objects, the stream buffer implementation (so also the message buffer implementation, as message buffers are built on top of stream buffers) assumes there is only one task or interrupt that will write to the buffer (the writer), and only one task or interrupt that will read from the buffer (the reader). It is safe for the writer and reader to be different tasks or interrupts, but, unlike other FreeRTOS objects, it is not safe to have multiple different writers or multiple different readers. If there are to be multiple different writers then the application writer must place each call to a writing API function (such as xMessageBufferSend()) inside a critical section and set the send block time to 0. Likewise, if there are to be multiple different readers then the application writer must place each call to a reading API function (such as xMessageBufferRead()) inside a critical section and set the receive block time to 0.

Use xMessageBufferReceive() to read from a message buffer from a task. Use xMessageBufferReceiveFromISR() to read from a message buffer from an interrupt service routine (ISR).

Example use:

```c
void vAFunction( MessageBuffer_t xMessageBuffer )
{
uint8_t ucRxData[ 20 ];
size_t xReceivedBytes;
const TickType_t xBlockTime = pdMS_TO_TICKS( 20 );

// Receive the next message from the message buffer. Wait in the Blocked
// state (so not using any CPU processing time) for a maximum of 100ms for
// a message to become available.
xReceivedBytes = xMessageBufferReceive( xMessageBuffer,
    (void *) ucRxData,
    sizeof( ucRxData ),
    xBlockTime );

if( xReceivedBytes > 0 )
{
    // A ucRxData contains a message that is xReceivedBytes long. Process
    // the message here....
}
}
```

Return The length, in bytes, of the message read from the message buffer, if any. If xMessageBufferReceive() times out before a message became available then zero is returned. If the length of the message is greater than xBufferLengthBytes then the message will be left in the message buffer and zero is returned.

Parameters

- **xMessageBuffer**: The handle of the message buffer from which a message is being received.
- **pvRxData**: A pointer to the buffer into which the received message is to be copied.
- **xBufferLengthBytes**: The length of the buffer pointed to by the pvRxData parameter. This sets the maximum length of the message that can be received. If xBufferLengthBytes is too small to hold the next message then the message will be left in the message buffer and 0 will be returned.
- **xTicksToWait**: The maximum amount of time the task should remain in the Blocked state to wait for a message, should the message buffer be empty. xMessageBufferReceive() will return immediately if xTicksToWait is zero and the message buffer is empty. The block time is specified in tick periods, so the absolute time it represents is dependent on the tick frequency. The macro pdMS_TO_TICKS() can be used to convert a time specified in milliseconds into a time specified in ticks. Setting xTicksToWait to portMAX_DELAY will cause the task to wait indefinitely (without timing out), provided INCLUDE_vTaskSuspend is set to 1 in FreeRTOSConfig.h. Tasks do not use any CPU time when they are in the Blocked state.

xMessageBufferReceiveFromISR(xMessageBuffer, pvRxData, xBufferLengthBytes, pxHigherPriorityTaskWoken) An interrupt safe version of the API function that receives a discrete message from a message buffer. Messages can be of variable length and are copied out of the buffer.
is safe for the writer and reader to be different tasks or interrupts, but, unlike other FreeRTOS objects, it is not safe to have multiple different writers or multiple different readers. If there are to be multiple different writers then the application writer must place each call to a writing API function (such as xMessageBufferSend()) inside a critical section and set the send block time to 0. Likewise, if there are to be multiple different readers then the application writer must place each call to a reading API function (such as xMessageBufferRead()) inside a critical section and set the receive block time to 0.

Use xMessageBufferReceive() to read from a message buffer from a task. Use xMessageBufferReceiveFromISR() to read from a message buffer from an interrupt service routine (ISR).

Example use:

```c
// A message buffer that has already been created.
MessageBuffer_t xMessageBuffer;

void vAnInterruptServiceRoutine( void )
{
    uint8_t ucRxData[20];
    size_t xReceivedBytes;
    BaseType_t xHigherPriorityTaskWoken = pdFALSE; // Initialised to pdFALSE.

    // Receive the next message from the message buffer.
    xReceivedBytes = xMessageBufferReceiveFromISR( xMessageBuffer,
                                                ( void * ) ucRxData,
                                                sizeof( ucRxData ),
                                                &xHigherPriorityTaskWoken );

    if( xReceivedBytes > 0 )
    {
        // 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.

xMessageBufferIsFull(xMessageBuffer)

Tests to see if a message buffer is full. A message buffer is full if it cannot accept any more messages, of any size, until space is made available by a message being removed from the message buffer.

Return If the message buffer referenced by xMessageBuffer is full then pdTRUE is returned. Otherwise pdFALSE is returned.

Parameters

• xMessageBuffer: The handle of the message buffer being queried.

xMessageBufferIsEmpty(xMessageBuffer)

Tests to see if a message buffer is empty (does not contain any messages).

Return If the message buffer referenced by xMessageBuffer is empty then pdTRUE is returned. Otherwise pdFALSE is returned.

Parameters

• xMessageBuffer: The handle of the message buffer being queried.

xMessageBufferReset(xMessageBuffer)

Resets a message buffer to its initial empty state, discarding any message it contained.

A message buffer can only be reset if there are no tasks blocked on it.

Return If the message buffer was reset then pdPASS is returned. If the message buffer could not be reset because either there was a task blocked on the message queue to wait for space to become available, or to wait for a message to be available, then pdFAIL is returned.

Parameters

• xMessageBuffer: The handle of the message buffer being reset.

xMessageBufferSpaceAvailable(xMessageBuffer)

Returns the number of bytes of free space in the message buffer.

Return The number of bytes that can be written to the message buffer before the message buffer would be full. When a message is written to the message buffer an additional sizeof(size_t) bytes are also written to store the message’s length. sizeof(size_t) is typically 4 bytes on a 32-bit architecture, so if xMessageBufferSpaceAvailable() returns 10, then the size of the largest message that can be written to the message buffer is 6 bytes.

Parameters

• xMessageBuffer: The handle of the message buffer being queried.

xMessageBufferSpacesAvailable(xMessageBuffer)

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**

```c
typedef void *MessageBufferHandle_t
```

Type by which message buffers are referenced. For example, a call to `xBUFF C R E A T E()` returns an `MessageBufferHandle_t` variable that can then be used as a parameter to `xBUFFER Send()`, `xBUFFER Receive()`, etc.

### 2.7.10 FreeRTOS Additions

**Overview**

ESP-IDF FreeRTOS is based on the Xtensa port of FreeRTOS v8.2.0 with significant modifications for SMP compatibility (see [ESP-IDF FreeRTOS SMP Changes](#)). However various features specific to ESP-IDF FreeRTOS have been added. The features are as follows:

- **Ring Buffers:** Ring buffers were added to provide a form of buffer that could 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 amongst both CPUs.
- **Component Specific Properties:** Currently added only one component specific property `ORIG_INCLUDE_PATH`.

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Ring Buffers

The ESP-IDF FreeRTOS ring buffer is a strictly FIFO buffer that supports arbitrarily sized items. Ring buffers are a more memory efficient alternative to FreeRTOS queues in situations where the size of items is variable. The capacity of a ring buffer is not measured by the number of items it can store, but rather by the amount of memory used for storing items. The ring buffer provides API to send an item, or to allocate space for an item in the ring buffer to be filled manually by the user. For efficiency reasons, items are always retrieved from the ring buffer by reference. As a result, all retrieved items must also be returned to the ring buffer by using vRingbufferReturnItem() or vRingbufferReturnItemFromISR(), in order for them to be removed from the ring buffer completely. The ring buffers are split into the three following types:

No-Split buffers will guarantee that an item is stored in contiguous memory and will not attempt to split an item under any circumstances. Use no-split buffers when items must occupy contiguous memory. Only this buffer type allows you getting the data item address and writing to the item by yourself.

Allow-Split buffers will allow an item to be split when wrapping around if doing so will allow the item to be stored. 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 and be sent or retrieved each time. Use byte buffers when separate items do not need to be maintained (e.g. a byte stream).

Usage The following example demonstrates the usage of xRingbufferCreate() and xRingbufferSend() to create a ring buffer 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 apply for the memory on the ring buffer (of type RINGBUF_TYPE_NOSPLIT) and then send an item to it. This way 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 _copy
dma_item_t item;
UBaseType_t res = xRingbufferSendAcquire(buf_handle, &item, DMA_ITEM_SIZE(buffer_size), pdMS_TO_TICKS(1000));
if (res != pdTRUE) {
    printf("Failed to acquire memory for item\n");
} else {
    item->dma_desc = (lldesc_t) {
        .size = buffer_size,
        .length = buffer_size,
        .eof = 0,
        .owner = 1,
        .buf = &item->buf,
    };
    //Actually send to the ring buffer for consumer to use
    res = xRingbufferSendComplete(buf_handle, &item);
    if (res != pdTRUE) {
        printf("Failed to send item\n");
    }
}
```

The following example demonstrates retrieving and returning an item from a no-split ring buffer using `xRingbufferReceive()` and `vRingbufferReturnItem()`

```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
```
Chapter 2. API 代码示例

//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);
}
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().

注解：两份使用RingbufferReceive[UpTo][FromISR]()示例，如果的字节环绕环缓冲。
**Sending to Ring Buffer** The following diagrams illustrate the differences between no-split/allow-split buffers and byte buffers with regards 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 25: Sending items to no-split/allow-split ring buffers](image)

For no-split/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.

![Diagram 26: Sending items to byte buffers](image)

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 the earliest acquired item will prevent the subsequent items from being received.

The following diagrams illustrate what will happen when SendAcquire/SendComplete don’t happen in the same order. At the beginning, there is already an 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.

![Diagram for SendAcquire and SendComplete](image)

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. Due to the usage if 20 bytes item is not complete, it’s not available, nor the following data items.

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/byte buffers do not allow using SendAcquire/SendComplete since acquired buffers are required to be complete (not wrapped).
Chapter 2. API 参考

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 assumes 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.

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.

注解:  Allow-split buffers treats the both parts of the split item as two separate items, therefore call `xRingbufferReceiveSplit()` instead of `xRingbufferReceive()` to receive both parts of a split item.
in a thread safe manner.

Byte buffers will store as much data as possible into the free space at the tail of buffer. The remaining data will then be stored in the free space at the head of the buffer. No overhead is incurred when wrapping around in byte buffers.

Referring to the diagram above, the 16 bytes of free space at the tail of the buffer is insufficient to completely store the 28 bytes of data. Therefore the 16 bytes of free space is filled with data, and the remaining 12 bytes are written to the free space at the head of the buffer. The buffer now contains data in two separate continuous parts, and each part continuous will be treated as a separate item by the byte buffer.

**Retrieving/Returning** The following diagrams illustrates the differences between no-split/allow-split and byte buffers in retrieving and returning data.

Items in no-split/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 they were retrieved (20, 8, 16). As such, the space is not freed until the first item (16 byte) is returned.

Byte buffers do not allow multiple retrievals before returning (every retrieval must be followed by a return before another retrieval is permitted). When using `xRingbufferReceive()` or `xRingbufferReceiveFromISR()`, all continuous stored data will be retrieved. `xRingbufferReceiveUpTo()` or `xRingbufferReceiveUpToFromISR()` can be used to restrict the maximum number of bytes retrieved. Since every retrieval must be followed by a return, the space will be freed as soon as the data is returned.

Referring to the diagram above, the 38 bytes of continuous stored data at the tail of the buffer is retrieved, returned, and freed. The next call to `xRingbufferReceive()` or `xRingbufferReceiveFromISR()` then wraps around and does the same to the 30 bytes of continuous stored data at the head of the buffer.
Chapter 2. API

32: Retrieving/Returning data in byte buffers

Ring Buffers with Queue Sets

Ring buffers can be added to FreeRTOS queue sets using `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 `xQueueSelectFromSet()`. To check whether the selected queue set member is the ring buffer, call `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);
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 \( x\text{BufferSize} \). Note that \( x\text{BufferSize} \) must be 32-bit aligned for no-split/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).

**注解:** The `CONFIG_FREERTOS_SUPPORT_STATIC_ALLOCATION` option must be enabled in `menuconfig` for statically allocated ring buffers to be available.

**注解:** When deleting a ring buffer created via `xRingbufferCreateStatic()`, the function `vRingbufferDelete()` will not free any of the memory blocks. This must be done manually by the user after `vRingbufferDelete()` is called.

The code snippet below demonstrates a ring buffer being allocated entirely in external RAM.

```c
#include "freertos/ringbuf.h"
#include "freertos/semphr.h"
#include "esp_heap_caps.h"

#define BUFFER_SIZE 400 //32-bit aligned size
#define BUFFER_TYPE RINGBUF_TYPE_NOSPLIT
...

//Allocate ring buffer data structure and storage area into external RAM
StaticRingbuffer_t *buffer_struct = (StaticRingbuffer_t *)heap_caps_malloc(sizeof(StaticRingbuffer_t), MALLOC_CAP_SPIRAM);
uint8_t *buffer_storage = (uint8_t *)heap_caps_malloc(sizeof(uint8_t)*BUFFER_SIZE, __MALLOC_CAP_SPIRAM);

//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);
```

### Ring Buffer API Reference

**注解:** 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.

### Header File

- `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 overhead 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** The CONFIG_FREERTOS_SUPPORT_STATIC_ALLOCATION option must be enabled for this to be available

**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 of 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**
Chapter 2. API

- [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.

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 timeout.

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.

```c
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 retried. If the item is split, both parts will be retrieved. This function will block until an item is available or until it times out.

**Note** Call(s) to vRingbufferReturnItem() is required after this to free up the item(s) retrieved.

**Note** This function should only be called on allow-split buffers

**Return**
- pdTRUE if an item (split or unsplit) was retrieved
- pdFALSE when no item was retrieved

**Parameters**
- **[in]** xRingbuffer: Ring buffer to retrieve the item from
- **[out]** ppvHeadItem: Double pointer to first part (set to NULL if no items were retrieved)
- **[out]** ppvTailItem: Double pointer to second part (set to NULL if item is not split)
- **[out]** pxHeadItemSize: Pointer to size of first part (unmodified if no items were retrieved)
- **[out]** pxTailItemSize: Pointer to size of second part (unmodified if item is not split)
- **[in]** xTicksToWait: Ticks to wait for items in the ring buffer.

```c
BaseType_t xRingbufferReceiveSplitFromISR(RingbufHandle_t xRingbuffer, void **ppvHeadItem, void **ppvTailItem, size_t *pxHeadItemSize, size_t *pxTailItemSize)
```

Retrieve a split item from an allow-split ring buffer in an ISR.

Attempt to retrieve a split item from an allow-split ring buffer. If the item is not split, only a single item is retried. 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)

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 the 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
Chapter 2. API

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 the a ring buffer’s current status such as free/read/write 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

void xRingbufferPrintInfo(RingbufHandle_t xRingbuffer)

Debugging function to print the internal pointers in the ring buffer.

Parameters
- xRingbuffer: Ring buffer to show

Structures

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.

Note The CONFIG_FREERTOS_SUPPORT_STATIC_ALLOCATION option must be enabled for this structure to be available.

Type Definitions

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.

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.

Note The CONFIG_FREERTOS_SUPPORT_STATIC_ALLOCATION option must be enabled for this structure to be available.
Enumerations

```c
enum RingbufferType_t
{
    RINGBUF_TYPE_NOSPLIT = 0,
    RINGBUF_TYPE_ALLOWSPLIT,
    RINGBUF_TYPE_BYTEBUF,
    RINGBUF_TYPE_MAX,
}
```

**Values:**

- **RINGBUF_TYPE_NOSPLIT**
  - No-split buffers will only store an item in contiguous memory and will never split an item. Each item requires an 8 byte overhead for a header and will always internally occupy a 32-bit aligned size of space.

- **RINGBUF_TYPE_ALLOWSPLIT**
  - 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

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**

Due to the the dual core nature of the ESP32, it may be necessary for some applications to have separate hooks for each core. Furthermore, it may be necessary for the Idle Tasks or Tick Interrupts to execute multiple hooks that are configurable at run time. Therefore the ESP-IDF provides it’s own hooks API in addition to the legacy hooks provided by Vanilla FreeRTOS.

The ESP-IDF tick/idle hooks are registered at run time, and each tick/idle hook must be registered to a specific CPU. When the idle task runs/tick Interrupt occurs on a particular CPU, the CPU will run each of its registered idle/tick hooks in turn.

Hooks API Reference

**Header File**

- `esp_common/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

`esp_err_t esp_register_freertos_idle_hook(esp_freertos_idle_cb_t new_idle_cb)`

Register a callback to the idle hook of the core that calls this function. The callback should return true if it should be called by the idle hook once per interrupt (or FreeRTOS tick), and return false if it should be called repeatedly as fast as possible by the idle hook.

**Warning** Idle callbacks MUST NOT, UNDER ANY CIRCUMSTANCES, CALL A FUNCTION THAT MIGHT BLOCK.

Return
- ESP_OK: Callback registered to the calling core’s idle hook
- ESP_ERR_NO_MEM: No more space on the calling core’s idle hook to register callback

**Parameters**
- [in] new_idle_cb: Callback to be called

`esp_err_t esp_register_freertos_tick_hook_for_cpu(esp_freertos_tick_cb_t new_tick_cb, UBaseType_t cpuid)`

Register a callback to be called from the specified core’s tick hook.

Return
- ESP_OK: Callback registered to specified core’s tick hook
- ESP_ERR_NO_MEM: No more space on the specified core’s tick hook to register the callback
- ESP_ERR_INVALID_ARG: cpuid is invalid

**Parameters**
- [in] new_tick_cb: Callback to be called
- [in] cpuid: id of the core

`esp_err_t esp_register_freertos_tick_hook(esp_freertos_tick_cb_t new_tick_cb)`

Register a callback to be called from the calling core’s tick hook.

Return
- ESP_OK: Callback registered to the calling core’s tick hook
- ESP_ERR_NO_MEM: No more space on the calling core’s tick hook to register the callback

**Parameters**
- [in] new_tick_cb: Callback to be called

`void esp_deregister_freertos_idle_hook_for_cpu(esp_freertos_idle_cb_t old_idle_cb, UBaseType_t cpuid)`

Unregister an idle callback from the idle hook of the specified core.

**Parameters**
- [in] old_idle_cb: Callback to be unregistered
- [in] cpuid: id of the core

`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

```c
typedef bool (*esp_freertos_idle_cb_t)(void)
typedef void (*esp_freertos_tick_cb_t)(void)
```

Component Specific Properties

Besides standard component variables that could be gotten with basic cmake build properties FreeRTOS component also provides an 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"`.

### 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 应用程序的内存布局.

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 3FFAE5E0 len 00001920 (6 KiB): DRAM |
| I (265) heap_init: At 3FFB2EC8 len 0002D138 (180 KiB): DRAM |
| I (272) heap_init: At 3FFE0440 len 0003AE0 (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 配置片外 RAM for more details.

**API Reference - Heap Allocation**

**Header File**

- `heap/include/esp_heap_caps.h`

**Functions**

```c
esp_err_t heap_caps_register_failed_alloc_callback (esp_alloc_failed_hook_t callback)
```

registers a callback function to be invoked if a memory allocation operation fails

- **Return** ESP_OK if callback was registered.
- **Parameters**
  - `callback`: caller defined callback to be invoked

```c
void *heap_caps_malloc (size_t size, uint32_t caps)
```

Allocate a chunk of memory which has the given capabilities.

- **Equivalent semantics to libc malloc(), for capability-aware memory.**
- **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

```c
void heap_caps_free (void *ptr)
```

Free memory previously allocated via `heap_caps_malloc()` or `heap_caps_realloc()`.

- **Equivalent semantics to libc free(), for capability-aware memory.**
- **In IDF, free(p) is equivalent to heap_caps_free(p).**
- **Parameters**
  - `ptr`: Pointer to memory previously returned from `heap_caps_malloc()` or `heap_caps_realloc()`. Can be NULL.

```c
void *heap_caps_realloc (void *ptr, size_t size, int caps)
```

Reallocates 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, int caps)
```

Allocate a aligned chunk of memory which has the given capabilities.

- **Equivalent semantics to libc aligned_alloc(), for capability-aware memory.**
- **Return** A pointer to the memory allocated on success, NULL on failure
- **Parameters**
  - `alignment`: How the pointer received needs to be aligned must be a power of two
Chapter 2. API

- **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 a 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_capscalloc(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_capscalloc(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 that because of heap fragmentation it is probably not possible to allocate a single block of memory of this size. Use heap_caps_get_largest_free_block() for this purpose.

**Return**: Amount of free bytes in the regions

**Parameters**
- **caps**: Bitwise OR of MALLOC_CAP_* flags indicating the type of memory

```c
size_t heap_caps_get_minimum_free_size(uint32_t caps)
```

Get the total minimum free memory of all regions with the given capabilities.

This adds all the low water marks of the regions capable of delivering the memory with the given capabilities.

Note the result may be less than the global all-time minimum available heap of this kind, as “low water marks” are tracked per-region. Individual regions’ heaps may have reached their “low water marks” 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.

Parameters

- **caps**: Bitwise OR of MALLOC_CAP_* flags indicating the type of memory

**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

**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

**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.

**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.

**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, ...)
Allocate a chunk of memory as preference in decreasing order.
Return Pointer to a new buffer of size ‘size’, or NULL if allocation failed.
Parameters
• ptr: Pointer to previously allocated memory, or NULL for a new allocation.
• size: Size of the new buffer requested, or 0 to free the buffer.
• num: Number of variable parameters

void *heap_capscalloc_prefer(size_t n, size_t size, size_t num, ...)
Allocate a chunk of memory as preference in decreasing order.
Return A pointer to the memory allocated on success, NULL on failure
Parameters
• n: Number of continuing chunks of memory to allocate
• size: Size, in bytes, of a chunk of memory to allocate
• num: Number of variable parameters

void heap_caps_dump(uint32_t caps)
Dump the full structure of all heaps with matching capabilities.
Prints a large amount of output to serial (because of locking limitations, the output bypasses stdout/stderr). For each (variable sized) block in each matching heap, the following output is printed on a single line:
• Block address (the data buffer returned by malloc is 4 bytes after this if heap debugging is set to Basic, or 8 bytes otherwise).
• Data size (the data size may be larger than the size requested by malloc, either due to heap fragmentation or because of heap debugging level).
• Address of next block in the heap.
• If the block is free, the address of the next free block is also printed.
Parameters
• caps: Bitwise OR of MALLOC_CAP_* flags indicating the type of memory

void heap_caps_dump_all(void)
Dump the full structure of all heaps.
Covers all registered heaps. Prints a large amount of output to serial.

Output is the same as for heap_caps_dump.

```c
size_t heap_caps_get_allocated_size(void *ptr)
```

Return the size that a particular pointer was allocated with.

**Note** The app will crash with an assertion failure if the pointer is not valid.

**Return** Size of the memory allocated at this block.

**Parameters**

- `ptr`: Pointer to currently allocated heap memory. Must be a pointer value previously returned by heap_caps_malloc, malloc, calloc, etc. and not yet freed.

**Macros**

**MALLOC_CAP_EXEC**

Flags to indicate the capabilities of the various memory systems.

- Memory must be able to run executable code

**MALLOC_CAP_32BIT**

Memory must allow for aligned 32-bit data accesses.

**MALLOC_CAP_8BIT**

Memory must allow for 8/16-bit data accesses.

**MALLOC_CAP_DMA**

Memory must be able to accessed by DMA.

**MALLOC_CAP_PID2**

Memory must be mapped to PID2 memory space (PIIDs are not currently used)

**MALLOC_CAP_PID3**

Memory must be mapped to PID3 memory space (PIIDs are not currently used)

**MALLOC_CAP_PID4**

Memory must be mapped to PID4 memory space (PIIDs are not currently used)

**MALLOC_CAP_PID5**

Memory must be mapped to PID5 memory space (PIIDs are not currently used)

**MALLOC_CAP_PID6**

Memory must be mapped to PID6 memory space (PIIDs are not currently used)

**MALLOC_CAP_PID7**

Memory must be mapped to PID7 memory space (PIIDs are not currently used)

**MALLOC_CAP_SPIRAM**

Memory must be in SPI RAM.

**MALLOC_CAP_INTERNAL**

Memory must be internal; specifically it should not disappear when flash/spiram cache is switched off.

**MALLOC_CAP_DEFAULT**

Memory can be returned in a non-capability-specific memory allocation (e.g. malloc(), calloc()) call.

**MALLOC_CAP_IRAM_8BIT**

Memory must be in IRAM and allow unaligned access.

**MALLOC_CAP_INVALID**

Memory can’t be used / list end marker.

**Type Definitions**

```c
typedef void (*esp_alloc_failed_hook_t)(size_t size, uint32_t caps, const char *function_name)
```

Callback called when a allocation operation fails, if registered.

**Parameters**
Chapter 2. API

**Thread Safety**

Heap functions are thread safe, meaning they can be called from different tasks simultaneously without any limitations.

It is technically possible to call malloc, free, and related functions from interrupt handler (ISR) context. 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**

- heap/include/esp_heap_caps_init.h

**Functions**

- **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.

- **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.

- **heap_caps_add_region**( intptr_t start, intptr_t end)

  Add a region of memory to the collection of heaps at runtime.

  Most memory regions are defined in soc_memory_layout.c for the SoC, and are registered via heap_caps_init(). Some regions can’t be used immediately and are later enabled via heap_caps_enable_nonos_stack_heaps(). Call this function to add a region of memory to the heap at some later time.

  This function does not consider any of the “reserved” regions or other data in soc_memory_layout, caller needs to consider this themselves.

  All memory within the region specified by start & end parameters must be otherwise unused.

  The capabilities of the newly registered memory will be determined by the start address, as looked up in the regions specified in soc_memory_layout.c.

  Use heap_caps_add_region_with_caps() to register a region with custom capabilities.

  **Return** ESP_OK on success, ESP_ERR_INVALID_ARG if a parameter is invalid, ESP_ERR_NOT_FOUND if the specified start address doesn’t reside in a known region, or any error returned by heap_caps_add_region_with_caps().

  **Parameters**

  - **start**: Start address of new region.
  - **end**: End address of new region.
**esp_err_t heap_caps_add_region_with_caps(const uint32_t caps[], intptr_t start, intptr_t end)**

Add a region of memory to the collection of heaps at runtime, with custom capabilities.

Similar to heap_caps_add_region(), only custom memory capabilities are specified by the caller.

**Return**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if a parameter is invalid
- ESP_ERR_NO_MEM if no memory to register new heap.
- ESP_ERR_INVALID_SIZE if the memory region is too small to fit a heap
- ESP_FAIL if region overlaps the start and/or end of an existing region

**Parameters**

- *caps*: Ordered array of capability masks for the new region, in order of priority. Must have length SOC_MEMORY_TYPE_NO_PRIOS. Does not need to remain valid after the call returns.
- *start*: Start address of new region.
- *end*: End address of new region.

**Implementation Notes**

Knowledge about the regions of memory in the chip comes from the “soc” component, which contains memory layout information for the chip, and the different capabilities of each region. Each region’s capabilities are prioritised, so that (for example) dedicated DRAM and IRAM regions will be used for allocations ahead of the more versatile D/IRAM regions.

Each contiguous region of memory contains its own memory heap. The heaps are created using the multi_heap functionality. multi_heap allows any contiguous region of memory to be used as a heap.

The heap capabilities allocator uses knowledge of the memory regions to initialize each individual heap. Allocation functions in the heap capabilities API will find the most appropriate heap for the allocation (based on desired capabilities, available space, and preferences for each region’s use) and then calling multi_heap_malloc() or multi_heap_calloc() for the heap situated in that particular region.

Calling `free()` involves finding the particular heap corresponding to the freed address, and then calling `multi_heap_free()` on that particular multi_heap instance.

**API Reference - Multi Heap API**

(Note: The multi heap API is used internally by the heap capabilities allocator. Most IDF programs will never need to call this API directly.)

**Header File**

- `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.

```c
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.

```c
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.

```c
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.

```c
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.

```c
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.

```c
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.
Chapter 2. API 参考

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 the lifetime minimum free heap size.

Equivalent to the minimum_free_bytes member returned by multi_heap_get_info().

Returns the lifetime “low water mark” 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

**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 largest free block in the heap. This is the largest malloc-able size.

size_t minimum_free_bytes
Lifetime minimum free heap size. Equivalent to multi_minimum_free_heap_size().

size_t allocated_blocks
Number of (variable size) blocks allocated in the heap.

size_t free_blocks
Number of (variable size) free blocks in the heap.

size_t total_blocks
Total number of (variable size) blocks in the heap.

Type Definitions

typedef struct multi_heap_info *multi_heap_handle_t
Opaque handle to a registered heap.

2.7.12 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 water mark” 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 a allocation operation fails.

Additionally user can enable a generation of a system abort if 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 show how to register a 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_set_watchpoint()`. A fatal exception will occur when the watchpoint triggers. For example `esp_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 0xe9b7384 caller...
    0x4000276d: leak_some_memory at /path/to/idf/examples/get-started/blink/main/./
    →/blink.c:27
0x400027dc: blink_task at /path/to/idf/examples/get-started/blink/main/./blink.c:52
8 bytes (@ 0x3ffaf804) allocated CPU 0 ccount 0xe9b79c0 caller...
    0x40002776: leak_some_memory at /path/to/idf/examples/get-started/blink/main/./
    →/blink.c:29
0x400027dc: 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 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.  
- ccoun 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_SYSVIEW_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 argument to this function is ignored and heap tracing module behaves like **HEAP_TRACE_ALL** was passed: all allocations and deallocations are sent to the host.  
- Call the function `heap_trace_stop()` to stop the trace once the suspect piece of code has finished executing.

An example:

```c
#include "esp_heap_trace.h"

...

void app_main()
{
    ...
    ESP_ERROR_CHECK( heap_trace_init_tohost() );
    ...
}

void some_function()
{
    ESP_ERROR_CHECK( heap_trace_start(HEAP_TRACE_LEAKS) );
    do_something_you_suspect_is_leaking();
    ESP_ERROR_CHECK( heap_trace_stop() );
    ...
}
```
To gather and analyse heap trace do the following on the host:

1. Build the program and download it to the target as described in Getting Started Guide.
2. Run OpenOCD (see JTAG Debugging).

### 注解：
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:

```bash
target remote :3333
mon reset halt
flushregs
tb heap_trace_start
commands
mon esp32 sysview start file:///tmp/heap.svdat
c
end
tb heap_trace_stop
commands
mon esp32 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_log.svdat. Tracing will be stopped when program hits breakpoint at `heap_trace_stop()`.

4. Run GDB using the following command `xtensa-esp32-elf-gdb -x gdbinit </path/to/program/elf>`

5. Quit GDB when program stops at `heap_trace_stop()`. Trace data are saved in `/tmp/heap.svdat`

6. Run processing script `$/IDF_PATH/tools/esp_app_trace/sysviewtrace_proc.py -p -b </path/to/program/elf> /tmp/heap_log.svdat`

The output from the heap trace will look something like this:

```bash
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
```

(下页继续)
Chapter 2. API参考

[0.002798700] HEAP: Freed bytes @ 0x3ffbb50bc 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 @ 0x3ffaff80 from task "alloc" on core 0 by:
/home/user/projects/esp/esp-idf/components/freertos/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 @ 0x3ffaff80 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 @ 0x3ffaff80 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 @ 0x3ffaff80 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 @ 0x3ffaff80 from task "alloc" on core 0 by:
/home/user/projects/esp/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:48
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)

[0.202667075] HEAP: Freed bytes @ 0x3ffaff80 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 @ 0x3ffaff80 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)
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)

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 @ 0x3ffaff80 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)
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 of 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 stdio - 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, WiFi, 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

- `heap/include/esp_heap_trace.h`
Chapter 2. API 参考

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.
- 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.

```c
esp_err_t heap_trace_get (size_t index, heap_trace_record_t *record)
```

Return a raw record from the heap trace buffer.

**Note** It is safe to call this function while heap tracing is running, however in HEAP_TRACE_LEAK mode record indexing may skip entries unless heap tracing is stopped first.

**Return**
- ESP_ERR_NOT_SUPPORTED Project was compiled without heap tracing enabled in menuconfig.
- ESP_ERR_INVALID_STATE Heap tracing was not initialised.
- ESP_ERR_INVALID_ARG Index is out of bounds for current heap trace record count.
- ESP_OK Record returned successfully.

**Parameters**
- index: Index (zero-based) of the record to return.
- [out] record: Record where the heap trace record will be copied.

```c
void heap_trace_dump (void)
```

Dump heap trace record data to stdout.

**Note** It is safe to call this function while heap tracing is running, however in HEAP_TRACE_LEAK mode the dump may skip entries unless heap tracing is stopped first.

**Structures**

```c
struct heap_trace_record_t
```
Trace record data type. Stores information about an allocated region of memory.

**Public Members**

- `uint32_t ccound`
  
  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
```

**Values:**

- `HEAP_TRACE_ALL`
- `HEAP_TRACE_LEAKS`

### 2.7.13 High Resolution Timer

**Overview**

Although FreeRTOS provides software timers, these timers have a few limitations:
Chapter 2. API

- 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.

`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 `CONFIG_ESP_TIMER_IMPL`:

- LAC timer (ESP32)
- (legacy) FRC2 timer (ESP32)
- SYSTIMER for (ESP32-S2)

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 a SPI Flash operation is in progress.

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.

**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

- esp_timer/include/esp_timer.h

Functions

**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.

**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.

**esp_err_t esp_timer_start_once** (esp_timer_handle_t timer, uint64_t timeout_us)

Start one-shot timer.

Timer should not be running when this function is called.

**Return**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if the handle is invalid
- ESP_ERR_INVALID_STATE if the timer is already running

**Parameters**

- timer: timer handle created using esp_timer_create
- timeout_us: timer timeout, in microseconds relative to the current moment

**esp_err_t esp_timer_start_periodic** (esp_timer_handle_t timer, uint64_t period)

Start a periodic timer.
Timer should not be running when this function is called. This function will start the timer which will trigger every ‘period’ microseconds.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if the handle is invalid
- ESP_ERR_INVALID_STATE if the timer is already running

**Parameters**
- `timer`: timer handle created using esp_timer_create
- `period`: timer period, in microseconds

```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 esp_timer_init was called (this normally happens early during application startup).

```c
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.

```c
esp_err_t esp_timer_dump(FILE *stream)
```

Dump the list of timers to a stream.

If CONFIG_ESP_TIMER_PROFILING option is enabled, this prints the list of all the existing timers. Otherwise, only the list active timers is printed.

The format is:

```
name period alarm times_armed times_triggered total_callback_run_time
```

where:

- `name`:—timer name (if CONFIG_ESP_TIMER_PROFILING is defined), or timer pointer
- `period`:—period of timer, in microseconds, or 0 for one-shot timer
- `alarm`:—time of the next alarm, in microseconds since boot, or 0 if the timer is not started

The following fields are printed if CONFIG_ESP_TIMER_PROFILING is defined:

- `times_armed`:—number of times the timer was armed via esp_timer_start
- `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
Chapter 2. API 参考

- ESP_ERR_NO_MEM if can not allocate temporary buffer for the output

**Parameters**
- stream: stream (such as stdout) to dump the information to

**Structures**

```c
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.

**Type Definitions**

```c
typedef struct esp_timer *esp_timer_handle_t
```

Opaque type representing a single esp_timer.

```c
typedef void (*)(esp_timer_cb_t)(void *arg)
```

Timer callback function type.

**Parameters**
- `arg`: pointer to opaque user-specific data

**Enumerations**

```c
enum esp_timer_dispatch_t
```

Method for dispatching timer callback.

**Values:**

- `ESP_TIMER_TASK`
  Callback is called from timer task.

### 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**

- `esp32/include/esp32/himem.h`

**Functions**

- `esp_err_t esp_himem_alloc(size_t size, esp_himem_handle_t *handle_out)`
  Allocate a block in high memory.
  
  **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

```c
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 succesfully 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

```c
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 succesfully 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

```c
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 succesfully 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)

```c
size_t esp_himem_get_phys_size (void)
```
Get total amount of memory under control of himem API.

**Return**  Amount of memory, in bytes

```c
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

```c
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**

```c
typedef struct esp_himem_ramdata_t *esp_himem_handle_t
```
```c
typedef struct esp_himem_rangedata_t *esp_himem_rangehandle_t
```
2.7.15 Inter-Processor Call

Overview

Due to the dual core nature of the ESP32, there are instances where a certain function must be run in the context of a particular core (e.g. allocating ISR to an interrupt source of a particular core). The IPC (Inter-Processor Call) feature allows for the execution of functions on a particular CPU.

A given function can be executed on a particular core by calling `esp_ipc_call()` or `esp_ipc_call_blocking()`. IPC is implemented via two high priority FreeRTOS tasks pinned to each CPU known as the IPC Tasks. The two IPC Tasks remain inactive (blocked) until `esp_ipc_call()` or `esp_ipc_call_blocking()` is called. When an IPC Task of a particular core is unblocked, it will preempt the current running task on that core and execute a given function.

Usage

`esp_ipc_call()` unblocks the IPC task on a particular core to execute a given function. The task that calls `esp_ipc_call()` will be blocked until the IPC Task begins execution of the given function. `esp_ipc_call_blocking()` is similar but will block the calling task until the IPC Task has completed execution of the given function.

Functions executed by IPCs must be functions of type `void func(void *arg)`. To run more complex functions which require a larger stack, the IPC tasks’ stack size can be configured by modifying `CONFIG_ESP_IPC_TASK_STACK_SIZE` inmenuconfig. The IPC API is protected by a mutex hence simultaneous IPC calls are not possible.

Care should taken to avoid deadlock when writing functions to be executed by IPC, especially when attempting to take a mutex within the function.

API Reference

Header File

- esp_ipc/include/esp_ipc.h

Functions

`esp_err_t esp_ipc_call (uint32_t cpu_id, esp_ipc_func_t func, void *arg)`

Execute a function on the given CPU.

Run a given function on a particular CPU. The given function must accept a void* argument and return void. The given function is run in the context of the IPC task of the CPU specified by the cpu_id parameter. The calling task will be blocked until the IPC task begins executing the given function. If another IPC call is ongoing, the calling task will block until the other IPC call completes. The stack size allocated for the IPC task can be configured in the “Inter-Processor Call (IPC) task stack size” setting in menuconfig. Increase this setting if the given function requires more stack than default.

Note In single-core mode, returns ESP_ERR_INVALID_ARG for cpu_id 1.

Return

- ESP_ERR_INVALID_ARG if cpu_id is invalid
- ESP_ERR_INVALID_STATE if the FreeRTOS scheduler is not running
- ESP_OK otherwise

Parameters

- [in] cpu_id: CPU where the given function should be executed (0 or 1)
- [in] func: Pointer to a function of type void func(void* arg) to be executed
- [in] arg: Arbitrary argument of type void* to be passed into the function

`esp_err_t esp_ipc_call_blocking (uint32_t cpu_id, esp_ipc_func_t func, void *arg)`

Execute a function on the given CPU and blocks until it completes.

Run a given function on a particular CPU. The given function must accept a void* argument and return void. The given function is run in the context of the IPC task of the CPU specified by the cpu_id parameter. The
calling task will be blocked until the IPC task completes execution of the given function. If another IPC call is
ongoing, the calling task will block until the other IPC call completes. The stack size allocated for the IPC
task can be configured in the “Inter-Processor Call (IPC) task stack size” setting in menuconfig. Increase this
setting if the given function requires more stack than default.

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 void(void* arg) to be executed
- [in] arg: Arbitrary argument of type void* to be passed into the function

2.7.16 Call function with external stack

Overview

A given function can be executed with a user allocated stack space which is independent of current task stack, this
mechanism can be used to save stack space wasted by tasks which call a common function with intensive stack usage
such as `printf`. The given function can be called inside the shared stack space which is a callback function deferred
by calling `esp_execute_shared_stack_function()`, passing that function as parameter

Usage

`esp_execute_shared_stack_function()` takes four arguments, a mutex object allocated by the caller,
which is used to protect if the same function shares its allocated stack, a pointer to the top of stack used to that
fuction, the size in bytes of stack and, a pointer to a user function where the shared stack space will reside, after
calling the function, the user defined function will be deferred as a callback where functions can be called using the
user allocated space without taking space from current task stack.

The usage may looks like the code below:

```c
void external_stack_function(void)
{
  printf("Executing this printf from external stack! \n");
}

// Let's suppose we wanting to call printf using a separated stack space
// allowing 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);
}
```
API Reference

Header File

- esp_common/include/esp_expression_with_stack.h

Functions

void esp_execute_shared_stack_function (SemaphoreHandle_t lock, void *stack, size_t stack_size, shared_stack_function function)

Calls user defined shared stack space function.

Note if either lock, stack or stack size is invalid, the expression will be called using the current stack.

Parameters

- lock: Mutex object to protect in case of shared stack
- stack: Pointer to user allocated stack
- stack_size: Size of current stack in bytes
- function: pointer to the shared stack function to be executed

Macros

ESP_EXECUTE_EXPRESSION_WITH_STACK (lock, stack, stack_size, expression)

Type Definitions

typedef void (*shared_stack_function) (void)

2.7.17 Interrupt allocation

Overview

A driver can allocate an interrupt for a certain peripheral by calling esp_intr_alloc (or esp_intr_alloc_sintrstatus). It can use the flags passed to this function to set the type of interrupt allocated, specifying a specific 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 has two different types of interrupts it handles differently: Shared interrupts and non-shared interrupts. The simplest of the two 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. Shared interrupts can have multiple peripherals triggering it, 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 see if any action is required.

Non-shared interrupts can be either level- or edge-triggered. Shared interrupts can only be level interrupts (because of the chance of missed interrupts when edge interrupts are used.) (The logic behind this: DevA and DevB share an int. DevB signals an int. Int line goes high. ISR handler calls code for DevA -&gt; does nothing. ISR handler calls code for DevB, but while doing that, DevA signals an int. ISR DevB is done, clears int for DevB, exits interrupt code. Now an interrupt for DevA is still pending, but because the int line never went low (DevA kept it high even when the int for DevB was cleared) the interrupt is never serviced.)

Multicore issues

Peripherals that can generate interrupts can be divided in two types:
• External peripherals, within the ESP32 but outside the Xtensa cores themselves. Most ESP32 peripherals are of this type.
• Internal peripherals, part of the Xtensa CPU cores themselves.

Interrupt handling differs slightly between these two types of peripherals.

**Internal peripheral interrupts** Each Xtensa CPU core has its own set of six internal peripherals:

- Three timer comparators
- A performance monitor
- Two software interrupts.

Internal interrupt sources are defined in `esp_intr_alloc.h` as `ETS_INTERNAL_*_INTR_SOURCE`.

These peripherals can only be configured from the core they are associated with. When generating an interrupt, the interrupt they generate is hard-wired to their associated core; it’s not possible to have e.g. 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](https://docs.esp32.com) 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’ll be all 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 supports this feature, you have to use it very carefully. There usually exist 2 ways to stop an interrupt from being triggered: *disable the source or mask peripheral interrupt status*. IDF only handles the enabling and disabling of the source itself, leaving status and mask bits to be handled by users. *Status bits should always be masked before the handler responsible for it is disabled, or the status should be handled in other enabled interrupt properly.* You may leave some status bits unhandled if you just disable one of all the handlers without masking the status bits, which causes the interrupt to trigger infinitely resulting in a system crash.

**API Reference**

**Header File**

- esp_system/include/esp_intr_alloc.h

**Functions**

- **esp_err_t esp_intr_mark_shared** (int intno, int cpu, bool is_in_iram)

  Mark an interrupt as a shared interrupt.

  This will mark a certain interrupt on the specified CPU as an interrupt that can be used to hook shared interrupt handlers to.

  **Return** ESP_ERR_INVALID_ARG if cpu or intno is invalid ESP_OK otherwise

  **Parameters**
  - intno: The number of the interrupt (0-31)
  - cpu: CPU on which the interrupt should be marked as shared (0 or 1)
  - is_in_iram: Shared interrupt is for handlers that reside in IRAM and the int can be left enabled while the flash cache is disabled.

- **esp_err_t esp_intr_reserve** (int intno, int cpu)

  Reserve an interrupt to be used outside of this framework.

  This will mark a certain interrupt on the specified CPU as reserved, not to be allocated for any reason.

  **Return** ESP_ERR_INVALID_ARG if cpu or intno is invalid ESP_OK otherwise

  **Parameters**
  - intno: The number of the interrupt (0-31)
  - cpu: CPU on which the interrupt should be marked as shared (0 or 1)

- **esp_err_t esp_intr_alloc** (int source, int flags, intr_handler_t handler, void *arg, intr_handle_t *ret_handle)

  Allocate an interrupt with the given parameters.

  This finds an interrupt that matches the restrictions as given in the flags parameter, maps the given interrupt source to it and hooks up the given interrupt handler (with optional argument) as well. If needed, it can return a handle for the interrupt as well.

  The interrupt will always be allocated on the core that runs this function.

  If ESP_INTR_FLAG_IRAM flag is used, and handler address is not in IRAM or RTC_FAST_MEM, then ESP_ERR_INVALID_ARG is returned.

  **Return** ESP_ERR_INVALID_ARG if the combination of arguments is invalid. ESP_ERR_NOT_FOUND if no free interrupt found with the specified flags ESP_OK otherwise

  **Parameters**
  - source: The interrupt source. One of the ETS_*_INTR_SOURCE interrupt mux sources, as defined in soc/soc.h, or one of the internal ETS_INTERNAL_*_INTR_SOURCE sources as defined in this header.
  - flags: An ORred mask of the ESP_INTR_FLAG_* defines. These restrict the choice of interrupts that this routine can choose from. If this value is 0, it will default to allocating a non-shared interrupt of level 1, 2 or 3. If this is ESP_INTR_FLAG_SHARED, it will allocate a shared interrupt of level 1. Setting ESP_INTR_FLAG_INTRDISABLED will return from this function with the interrupt disabled.
  - handler: The interrupt handler. Must be NULL when an interrupt of level >3 is requested, because these types of interrupts aren’t C-callable.
**Chapter 2. API**

- 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_alloc_intrstatus(int source, int flags, uint32_t intrstatusreg, uint32_t intrstatusmask, intr_handler_t handler, void *arg, intr_handle_t *ret_handle)
```

Allocate an interrupt with the given parameters.

This essentially does the same as esp_intr_alloc, but allows specifying a register and mask combo. For shared interrupts, the handler is only called if a read from the specified register, ANDeed 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 No free interrupt found with the specified flags
- ESP_OK otherwise

**Parameters**
- source: The interrupt source. One of the ETS_*_INTR_SOURCE interrupt mux sources, as defined in soc/soc.h, or one of the internal ETS_INTERNAL_*_INTR_SOURCE sources as defined in this header.
- flags: An ORred mask of the ESP_INTR_FLAG_* defines. These restrict the choice of interrupts that this routine can choose from. If this value is 0, it will default to allocating a non-shared interrupt of level 1, 2 or 3. If this is ESP_INTR_FLAG_SHARED, it will allocate a shared interrupt of level 1. Setting ESP_INTR_FLAG_INTRDISABLED will return from this function with the interrupt disabled.
- intrstatusreg: The address of an interrupt status register
- intrstatusmask: A mask. If a read of address intrstatusreg has any of the bits that are 1 in the mask set, the ISR will be called. If not, it will be skipped.
- handler: The interrupt handler. Must be NULL when an interrupt of level >3 is requested, because these types of interrupts aren’t C-callable.
- arg: Optional argument for passed to the interrupt handler
- ret_handle: Pointer to an intr_handle_t to store a handle that can later be used to request details or free the interrupt. Can be NULL if no handle is required.

```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
**esp_err_t esp_intr_disable (intr_handle_t handle)**

Disable the interrupt associated with the handle.

**Note**
1. For local interrupts (ESP_INTERNAL_* sources), this function has to be called on the CPU the interrupt is allocated on. Other interrupts have no such restriction.
2. When several handlers sharing a same interrupt source, interrupt status bits, which are handled in the handler to be disabled, should be masked before the disabling, or handled in other enabled interrupts properly. Miss of interrupt status handling will cause infinite interrupt calls and finally system crash.

**Return** ESP_ERR_INVALID_ARG if the combination of arguments is invalid. ESP_OK otherwise

**Parameters**
- handle: The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus

**esp_err_t esp_intr_enable (intr_handle_t handle)**

Enable the interrupt associated with the handle.

**Note** For local interrupts (ESP_INTERNAL_* sources), this function has to be called on the CPU the interrupt is allocated on. Other interrupts have no such restriction.

**Return** ESP_ERR_INVALID_ARG if the combination of arguments is invalid. ESP_OK otherwise

**Parameters**
- handle: The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus

**esp_err_t esp_intr_set_in_iram (intr_handle_t handle, bool is_in_iram)**

Set the “in IRAM” status of the handler.

**Note** Does not work on shared interrupts.

**Return** ESP_ERR_INVALID_ARG if the combination of arguments is invalid. ESP_OK otherwise

**Parameters**
- handle: The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus
- is_in_iram: Whether the handler associated with this handle resides in IRAM. Handlers residing in IRAM can be called when cache is disabled.

**void esp_intr_noniram_disable (void)**

Disable interrupts that aren’t specifically marked as running from IRAM.

**void esp_intr_noniram_enable (void)**

Re-enable interrupts disabled by esp_intr_noniram_disable.

**void esp_intr_enable_source (int inum)**

Enable the interrupt source based on its number

**Parameters**
- inum: interrupt number from 0 to 31

**void esp_intr_disable_source (int inum)**

Disable the interrupt source based on its number

**Parameters**
- inum: interrupt number from 0 to 31

**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.
Chapter 2. API

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 priio interrupts. These can be handled in C.

ESP_INTR_FLAG_HIGH
High level interrupts. Need to be handled in assembly.

ESP_INTR_FLAG_LEVELMASK
Mask for all level flags.

ETS_INTERNAL_TIMER0_INTR_SOURCE
Platform timer 0 interrupt source.
The esp_intr_alloc* functions can allocate an int for all ETS_*_INTR_SOURCE interrupt sources that are routed through the interrupt mux. Apart from these sources, each core also has some internal sources that do not pass through the interrupt mux. To allocate an interrupt for these sources, pass these pseudo-sources to the functions.

ETS_INTERNAL_TIMER1_INTR_SOURCE
Platform timer 1 interrupt source.

ETS_INTERNAL_TIMER2_INTR_SOURCE
Platform timer 2 interrupt source.

ETS_INTERNAL_SW0_INTR_SOURCE
Software int source 1.

ETS_INTERNAL_SW1_INTR_SOURCE
Software int source 2.

ETS_INTERNAL_PROFILING_INTR_SOURCE
Int source for profiling.

ETS_INTERNAL_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`. All logging statements for verbosity levels higher than `CONFIG_LOG_DEFAULT_LEVEL` will be removed by the preprocessor.
- **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)

### Notes

The function `esp_log_level_set()` cannot set logging levels higher than specified by `CONFIG_LOG_DEFAULT_LEVEL`. To increase log level for a specific file 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", err...
```

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.

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"
```
Chapter 2. API

At component scope, define it in the component makefile:

CFLAGS += -D LOG_LOCAL_LEVEL=ESP_LOG_DEBUG

To configure logging output per module at runtime, add calls to the function `esp_log_level_set()` as follows:

```
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
```

**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 记录日志到主机.

**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**

- 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 that this function can not raise log level above the level set using CONFIG_LOG_DEFAULT_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
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.

**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 WiFi & 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
log sink.

**See** esp_log_write()

**Macros**

**ESP_LOG_BUFFER_HEX_LEVEL** (tag, buffer, buff_len, level)

Log a buffer of hex bytes at specified level, separated into 16 bytes each line.

**Parameters**

- **tag**: description tag
- **buffer**: Pointer to the buffer array
- **buff_len**: length of buffer in bytes
- **level**: level of the log

**ESP_LOG_BUFFER_CHAR_LEVEL** (tag, buffer, buff_len, level)

Log a buffer of characters at specified level, separated into 16 bytes each line. Buffer should contain only
printable characters.

**Parameters**

- **tag**: description tag
- **buffer**: Pointer to the buffer array
- **buff_len**: length of buffer in bytes
- **level**: level of the log

**ESP_LOG_BUFFER_HEXDUMP** (tag, buffer, buff_len, level)

Dump a buffer to the log at specified level.

The dump log shows just like the one below:
It is highly recommend to use terminals with over 102 text width.

Parameters

- **tag**: description tag
- **buffer**: Pointer to the buffer array
- **buff_len**: length of buffer in bytes
- **level**: level of the log

`ESP_LOG_BUFFER_HEX (tag, buffer, buff_len)`

Log a buffer of hex bytes at Info level.

See `esp_log_buffer_hex_level`

Parameters

- **tag**: description tag
- **buffer**: Pointer to the buffer array
- **buff_len**: length of buffer in bytes

`ESP_LOG_BUFFER_CHAR (tag, buffer, buff_len)`

Log a buffer of characters at Info level. Buffer should contain only printable characters.

See `esp_log_buffer_char_level`

Parameters

- **tag**: description tag
- **buffer**: Pointer to the buffer array
- **buff_len**: length of buffer in bytes

`ESP_EARLY_LOGE (tag, format, ...)`

Macro to output logs in startup code, before heap allocator and syscalls have been initialized. Log at ESP_LOG_ERROR level.

See `printf, ESP_LOGE`

`ESP_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_IMPL (tag, format, log_level, log_tag_letter, ...)`

`ESP_LOGE (tag, format, ...)`

`ESP_LOGW (tag, format, ...)`

`ESP_LOGI (tag, format, ...)`

`ESP_LOGD (tag, format, ...)`
Chapter 2. API

**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 **ESP_EARLY_LOGE**, the log level cannot be changed by *esp_log_level_set*.

Usage: **ESP_DRAM_LOGE**(DRAM_STR("my_tag"), "format", or **ESP_DRAM_LOGE**(TAG, "format", ", ..") where TAG is a char* that points to a str in the DRAM.

**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**

defined **esp_log_level_t**

Log level.

Values:

**ESP_LOG_NONE**

No log output

**ESP_LOG_ERROR**

Critical errors, software module cannot recover on its own

**ESP_LOG_WARN**

Error conditions from which recovery measures have been taken
### Chapter 2. API Reference

**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](#).

**Random number generation**

ESP32 contains a hardware random number generator, values from it can be obtained using `esp_random()`.

When Wi-Fi or Bluetooth are enabled, numbers returned by hardware random number generator (RNG) can be considered true random numbers. Without Wi-Fi or Bluetooth enabled, hardware RNG is a pseudo-random number generator. At startup, ESP-IDF bootloader seeds the hardware RNG with entropy, but care must be taken when reading random values between the start of `app_main` and initialization of Wi-Fi or Bluetooth drivers.

**MAC Address**

These APIs allow querying and customizing MAC addresses for different network interfaces that supported (e.g. Wi-Fi, Bluetooth, Ethernet).

In ESP-IDF these addresses are calculated from `Base MAC address`. Base MAC address can be initialized with factory-programmed value from internal eFuse, or with a user-defined value. In addition to setting the base MAC address, applications can specify the way in which MAC addresses are allocated to devices. See [Number of universally administered MAC address](#) section for more details.
**Base MAC address**  To fetch MAC address for a specific interface (e.g. Wi-Fi, Bluetooth, Ethernet), you can simply use `esp_read_mac()` function.

By default, this function takes the eFuse value burned at a pre-defined block (e.g. BLK0 for ESP32, BLK1 for ESP32-S2) as the base MAC address. Per-interface MAC addresses will be calculated according to the table above.

Applications who want to customize base MAC address (not the one provided by Espressif) should call `esp_base_mac_addr_set()` before `esp_read_mac()`. The customized MAC address can be stored in any supported storage device (e.g. Flash, NVS, etc).

Note that, calls to `esp_base_mac_addr_set()` should take place before the initialization of network stack, for example, early in `app_main`.

**Custom MAC address in eFuse**  To facilitate the usage of custom MAC addresses, ESP-IDF provides `esp_efuse_mac_get_custom()` function, which loads MAC address from internal pre-defined eFuse block (e.g. BLK3 for ESP32). This function assumes that custom 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>

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.

**Number of universally administered MAC address**  Several MAC addresses (universally administered by IEEE) are uniquely assigned to the networking interfaces (Wi-Fi/BT/Ethernet). The final octet of each universally administered MAC address increases by one. Only the first one of them (which is called base MAC address) is stored in eFuse or external storage, the others are generated from it. Here, ‘generate’ means adding 0, 1, 2 and 3 (respectively) to the final octet of the base MAC address.

If the universally administered MAC addresses are not enough for all of the networking interfaces, locally administered MAC addresses which are derived from universally administered MAC addresses are assigned to the rest of networking interfaces.

See this article for the definition of local and universally administered MAC addresses.

**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.
App version

Application version is stored in \texttt{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 \texttt{esp_image_header_t} and \texttt{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 \texttt{PROJECT_VER} variable in your project CMakeLists.txt/Makefile:

- In application CMakeLists.txt put \texttt{set(PROJECT_VER "0.1.0.1")} before including \texttt{project.cmake}.

(For legacy GNU Make build system: in application Makefile put \texttt{PROJECT_VER = "0.1.0.1"} before including \texttt{project.mk}.)

If \texttt{CONFIG_APP_PROJECT_VER_FROM_CONFIG} option is set, the value of \texttt{CONFIG_APP_PROJECT_VER} will be used. Otherwise if \texttt{PROJECT_VER} variable is not set in the project then it will be retrieved from either \texttt{$(PROJECT_PATH)/version.txt} file (if present) else using git command \texttt{git describe}. If neither is available then \texttt{PROJECT_VER} will be set to “1”. Application can make use of this by calling \texttt{esp_ota_get_app_description()} or \texttt{esp_ota_get_partition_description()} functions.

API Reference

Header File

- \texttt{esp_system/include/esp_system.h}

Functions

\texttt{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 \texttt{esp_restart} function.

\textbf{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

\textbf{Parameters}

- \texttt{handle}: function to execute on restart

\texttt{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 \texttt{esp_register_shutdown_handler} function.

- ESP_OK on success
- ESP_ERR_INVALID_STATE if the given handler hasn’t been registered before

\textbf{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 WiFi, 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 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 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

**uint32_t esp_random (void)**
Get one random 32-bit word from hardware RNG.

The hardware RNG is fully functional whenever an RF subsystem is running (ie Bluetooth or WiFi is enabled). For random values, call this function after WiFi or Bluetooth are started.

If the RF subsystem is not used by the program, the function bootloader_random_enable() can be called to enable an entropy source. bootloader_random_disable() must be called before RF subsystem or I2S peripheral are used. See these functions’ documentation for more details.

Any time the app is running without an RF subsystem (or bootloader_random) enabled, RNG hardware should be considered a PRNG. A very small amount of entropy is available due to pre-seeding while the IDF bootloader is running, but this should not be relied upon for any use.

**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 has the same restrictions regarding available entropy as esp_random()

**Parameters**
- **buf**: Pointer to buffer to fill with random numbers.
- **len**: Length of buffer in bytes

**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 the networking interfaces. If using base MAC address stored in BLK3 of EFUSE or external storage, call this API to set base MAC address with the MAC address which is stored in BLK3 of EFUSE or external storage before initializing WiFi/BT/Ethernet.

**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.

**esp_err_t esp_base_mac_addr_get (uint8_t *mac)**
Return base MAC address which is set using esp_base_mac_addr_set.

**Return** ESP_OK on success ESP_ERR_INVALID_MAC base MAC address has not been set

**Parameters**
- **mac**: base MAC address, length: 6 bytes.
**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 BLK3 of EFUSE. 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.

**Return** ESP_OK on success ESP_ERR_INVALID_VERSION An invalid MAC version field was read from BLK3 of EFUSE ESP_ERR_INVALID_CRC An invalid MAC CRC was read from BLK3 of EFUSE

**Parameters**
- mac: base MAC address, length: 6 bytes.

**esp_err_t esp_efuse_mac_get_default (uint8_t *mac)**

Return base MAC address which is factory-programmed by Espressif in BLK0 of EFUSE.

**Return** ESP_OK on success

**Parameters**
- mac: base MAC address, length: 6 bytes.

**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 or reads base MAC address from BLK0 of EFUSE. Then set the MAC address of the interface including wifi station, wifi softap, bluetooth and ethernet.

**Return** ESP_OK on success

**Parameters**
- mac: MAC address of the interface, length: 6 bytes.
- type: type of MAC address, 0:wifi station, 1:wifi softap, 2:bluetooth, 3:ethernet.

**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 derives a local MAC address from an universal MAC address. A definition of local vs universal MAC address can be found on Wikipedia <#Universal_vs._local>. In ESP32, universal MAC address is generated from base MAC address in EFUSE or other external storage. Local MAC address is derived from the universal MAC address.

**Return** ESP_OK on success

**Parameters**
- local_mac: Derived local MAC address, length: 6 bytes.
- universal_mac: Source universal MAC address, length: 6 bytes.

void esp_system_abort (const char *details)

Trigger a software abort.

**Parameters**
- details: Details that will be displayed during panic handling.

void esp_chip_info (esp_chip_info_t *out_info)

Fill an esp_chip_info_t structure with information about the chip.

**Parameters**
- [out] out_info: structure to be filled

**Structures**

**struct esp_chip_info_t**

The structure represents information about the chip.
Chapter 2. API

Public Members

```c
esp_chip_model_t model
    chip model, one of esp_chip_model_t
```

```c
uint32_t features
    bit mask of CHIP_FEATURE_x feature flags
```

```c
uint8_t cores
    number of CPU cores
```

```c
uint8_t revision
    chip revision number
```

Macros

```c
CHIP_FEATURE_EMB_FLASH
    Chip has embedded flash memory.
```

```c
CHIP_FEATURE_WIFI_BGN
    Chip has 2.4GHz WiFi.
```

```c
CHIP_FEATURE_BLE
    Chip has Bluetooth LE.
```

```c
CHIP_FEATURE_BT
    Chip has Bluetooth Classic.
```

Type Definitions

```c
typedef void (*shutdown_handler_t)(void)
    Shutdown handler type
```

Enumerations

```c
enum esp_mac_type_t
    Values:
    ESP_MAC_WIFI_STA
    ESP_MAC_WIFI_SOFTAP
    ESP_MAC_BT
    ESP_MAC_ETH
```

```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.

enum esp_chip_model_t
Chip models.

Values:

CHIP_ESP32 = 1
ESP32.

CHIP_ESP32S2 = 2
ESP32-S2.

CHIP_ESP32S3 = 4
ESP32-S3.

Header File
- esp_common/include/esp_idf_version.h

Functions

const char* esp_get_idf_version (void)
Return full IDF version string, same as `git describe’ output.

Note If you are printing the ESP-IDF version in a log file or other information, this function provides more information than using the numerical version macros. For example, numerical version macros don’t differentiate between development, pre-release and release versions, but the output of this function does.

Return constant string from IDF_VER

Macros

ESP_IDF_VERSION_MAJOR
Major version number (X.x.x)

ESP_IDF_VERSION_MINOR
Minor version number (x.X.x)

ESP_IDF_VERSION_PATCH
Patch version number (x.x.X)

ESP_IDF_VERSION_VAL (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)
2.7.20 空中升级 (OTA)

OTA 流程概览

OTA 升级机制可以让设备在固件正常运行时根据接收数据更新（如通过 Wi-Fi 或蓝牙）。

要运行 OTA 机制，需配置设备的分区表 `<./api-guides/partition-tables>`，该分区表至少包括两个 OTA 应用程序分区（即 `ota_0` 和 `ota_1`）和一个 OTA 数据分区。

OTA 功能启动后，向当前未用于启动的 OTA 应用分区写入新的应用固件镜像。镜像验证后，OTA 数据分区更新，指定在下一次启动时使用该镜像。

OTA 数据分区

所有使用 OTA 功能的项目，其分区表 `<./api-guides/partition-tables>` 必须包含一个 OTA 数据分区（类型为 data，子类型为 ota）。

工厂启动设置下，OTA 数据分区中应没有数据（所有字节擦写成 0xFF）。如果分区表中有工厂应用程序，ESP-IDF 软件启动加载器会启动工厂应用程序。如果分区表中没有工厂应用程序，则启动第一个可用的 OTA 分区（通常是 `ota_0`）。

第一次 OTA 升级后，OTA 数据分区更新，指定下一次启动哪个 OTA 应用程序分区。

OTA 数据分区是两个 0x2000 字节大小的 flash 空间，防止写入时电源故障引发问题。两个扇区单独擦除，写入匹配数据，若存在不一致，则用计数器字段判定哪个扇区为最新数据。

应用程序回滚

应用程序回滚的主要目的是确保设备更新后正常运转。该功能可使设备在更新新版本后出现严重错误时，回滚到之前正常运行的应用版本。回滚使能，OTA 升级，应用更新至新版本，之后可能有以下三种情况：

- 应用程序运行正常，`esp_ota_mark_app_valid_cancel_rollback()` 将应用程序状态标记为 `ESP OTA IMG VALID`，启动无限期。
- 应用程序出错，无法继续工作，必须回滚到此前的版本，`esp_ota_mark_app_invalid_rollback_and_reboot()` 将正在运行的版本标记为 `ESP OTA IMG INVALID` 然后复位。启动加载器不会选取此版本，而是此前正常运行的版本。
- 如果 `CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE` 使能，则无需调用函数便可复位，回滚至之前的应用版本。

注解：应用程序的状态不是写到程序的二进制镜像，而是写到 `ota_data` 分区。该分区有一个 `ota_seq` 计数器，该计数器是 OTA 应用分区的指针，指向下次启动时选取应用所在的分区 (`ota_0, ota_1, …`)。

应用程序 OTA 状态

状态控制了选取启动应用程序的过程：

<table>
<thead>
<tr>
<th>状态</th>
<th>启动加载器选取启动应用程序的限制</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>ESP OTA IMG VALID</code></td>
<td>启动无限期，可选择。</td>
</tr>
<tr>
<td><code>ESP OTA IMG UNINITIALIZED</code></td>
<td>启动无限期，可选择。</td>
</tr>
<tr>
<td><code>ESP OTA IMG INVALID</code></td>
<td>启动无限期，可选择。</td>
</tr>
<tr>
<td><code>ESP OTA IMG ABORTED</code></td>
<td>启动无限期，可选择。</td>
</tr>
</tbody>
</table>
| `ESP OTA IMG NEW`                        | 如使能 `CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE`，则仅会选取一次。在启动加载器中，状态立即变为 `ESP OTA IMG_PENDING_VERIFY`。
| `ESP OTA IMG PENDING_VERIFY`             | 如使能 `CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE`，则不会选取，状态变为“`ESP OTA IMG_ABORTED`”。

如果 `CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE` 没有使能（默认情况），则 `esp_ota_mark_app_valid_cancel_rollback()` 和 `esp_ota_mark_app_invalid_rollback_and_reboot()` 为可选功能，`ESP OTA IMG NEW` 和 `ESP OTA IMG_PENDING_VERIFY` 不会使用。
Kconfig 中的 CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE 可以帮助用户追踪新版应用程序的第一次启动。应用程序需调用 esp_ota_mark_app_valid_cancel_rollback() 函数确认可以运行，否则将会在重启时回滚至旧版本。该功能可让用户在启动阶段控制应用程序的可操作性。新版应用程序仅有一次机会尝试是否能成功启动。

**回滚过程 CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE 使能时，回滚过程如下：**

- 新版应用程序下载成功，esp_ota_set_boot_partition() 函数将分区设为可启动，状态设为 ESP OTA_IMG_NEW。该状态表示应用程序为新版本，第一次启动需要监测。
- 重新启动 esp_restart()。
- 启动加载器检查新版应用程序，若状态设置为 ESP OTA_IMG_PENDING_VERIFY，则写入 ESP OTA_IMG_ABORTED。
- 启动加载器选取新版应用程序启动，应用程序状态不设置为 ESP OTA_IMG_INVALID 或 ESP OTA_IMG_ABORTED。
- 启动加载器检查所选取的新版应用程序，若状态设置为 ESP OTA_IMG_NEW，则写入 ESP OTA_IMG_PENDING_VERIFY。该状态表示，需确认应用程序的可操作性，如不确认，发生重启，则状态会重写为 ESP OTA_IMG_ABORTED（见上文），该应用程序不可再启动，将回滚至上一版本。
- 新版应用程序启动，应进行自测。
- 若通过自测，则必须调用函数 esp_ota_mark_app_valid_cancel_rollback()，因为新版应用程序在等待确认其可操作性（ESP OTA_IMG_PENDING_VERIFY 状态）。
- 若未通过自测，则调用函数 esp_ota_mark_app_invalid_rollback_and_reboot()，回滚至之前版本，同时无效的新版本设为 ESP OTA_IMG_INVALID。
- 如果新版应用程序可操作性没有确认，则状态一直为 ESP OTA_IMG_PENDING_VERIFY。下一次启动时，状态变更为 ESP OTA_IMG_ABORTED，阻止其再次启动，之后回滚到之前的版本。

**意外复位** 如果在新版应用第一次启动时发生断电或意外崩溃，则会回滚至之前正常运行的版本。

建议：尽快完成自测，防止因断电回滚。

只有 OTA 分区可以回滚。工厂分区不会回滚。

**启动无效/中止的应用程序** 用户可以启动先前设置为 ESP OTA_IMG_INVALID 或 ESP OTA_IMG_ABORTED 的应用程序：

- 获取最后一个无效应用分区 esp_ota_get_last_invalid_partition()。
- 将获取的分区传递给 esp_ota_set_boot_partition()，更新 otadata。
- 重启 esp_restart()。启动加载器会启动指定应用程序。

要确定是否在应用程序启动时进行自测，可以调用 esp_ota_get_state_partition() 函数。如果结果为 ESP OTA_IMG_PENDING_VERIFY，则需要自测，后续确认应用程序的可操作性。

**如何设置状态** 下文简单描述了如何设置应用程序状态：

- ESP OTA_IMG_VALID 由函数 esp_ota_mark_app_valid_cancel_rollback() 设置。
- 如果 CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE 没有使能，ESP OTA_IMG_UNDEFINED 由函数 esp_ota_set_boot_partition() 设置。
- 如果 CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE 没有使能，ESP OTA_IMG_NEW 由函数 esp_ota_set_boot_partition() 设置。
- ESP OTA_IMG_INVALID 由函数 esp_ota_mark_app_invalid_rollback_and_reboot() 设置。
- 如果应用程序的可操作性无法确认，发生重启（CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE 使能），则设置 ESP OTA_IMG_ABORTED。
- 如果 CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE 使能，取出的应用程序状态为 ESP OTA_IMG_NEW，则在启动加载器中设置 ESP OTA_IMG_PENDING_VERIFY。
防回滚

防回滚机制可以防止回滚到安全版本号低于芯片 eFuse 中烧录程序的应程序版本。

设置 `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK` 启动防回滚机制，在启动加载器中选取可启动的应用程序，会额外检查芯片和应用程序镜像的安全版本号。可启动固件中的应用安全版本号必须等于或高于芯片中的应用安全版本号。

`CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK` 和 `CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE` 一起使用。此时，只有安全版本号等于或高于芯片中的应用安全版本号时才会回滚。

典型的防回滚机制

- 新发布的固件解决了此前版本的安全问题。
- 开发者在确保固件可以运行之后，增加安全版本号，发布固件。
- 下载新版应用程序。
- 运行函数 `esp_ota_set_boot_partition()`，将新版应用程序设为可启动。如果新版应用程序的安全版本号低于芯片中的应用安全版本号，新版应用程序会被擦除，无法更新到新固件。
- 重新启动。
- 在启动加载器中选取安全版本号等于或高于芯片中应用安全版本号的应用程序。如果 `otadata` 处于初始化阶段，通过串行通道加载了安全版本号高于芯片中应用安全版本号的固件，则启动加载器中 eFuse 的安全版本号会立即更新。
- 新版应用程序启动，之后进行可操作性检测，如果通过检测，则调用函数 `esp_ota_mark_app_valid_cancel_rollback()`，将应用程序标记为 `ESP_OTA_IMG_VALID`，更新芯片中应用程序的安全版本号。注意，如果调用函数 `esp_ota_mark_app_invalid_rollback_and_reboot()`，可能会因为设备中没有可启动的应用程序而回滚失败，返回 `ESP_ERR_OTA_ROLLBACK_FAILED` 错误，应用程序状态一直为 `ESP_OTA_IMG_PENDING_VERIFY`。
- 如果运行的应用程序处于 `ESP_OTA_IMG_VALID` 状态，则可再次更新。

建议:

如果想避免因服务器应用程序的安全版本号低于运行的应用程序，造成不必要的下载和擦除，必须从镜像的第一个包中获取 `new_app_info.secure_version`，和 eFuse 的安全版本号比较。如果 `esp_efuse_check_secure_version(new_app_info.secure_version)` 函数为真，则下载继续，反之则中断。

```c
bool image_header_was_checked = false;
while (1) {
    int data_read = esp_http_client_read(client, ota_write_data, BUFFSIZE);
...
    if (data_read > 0) {
        if (image_header_was_checked == false) {
            esp_app_desc_t new_app_info;
            if (data_read > sizeof(esp_image_header_t) + sizeof(esp_image_segment_header_t) + sizeof(esp_app_desc_t)) {  // check current version with downloading
                if (esp_efuse_check_secure_version(new_app_info.secure_version) == false) {
                    ESP_LOGE(TAG, "This a new app can not be downloaded due to a secure version is lower than stored in efuse.");
                    http_cleanup(client);
                    task_fatal_error();
                }
                image_header_was_checked = true;
                esp_ota_begin(update_partition, OTA_SIZE_UNKNOWN, &update_handle);
            }
        }
    }
}
```

(下转续页)
限值：
  - secure_version 字段最多有 32 位。也就是说，防回滚最多可以做 32 次。用户可以使用
    `CONFIG_BOOTLOADER_APP_SEC_VER_SIZE_EFUSE_FIELD` 减少该 eFuse 字段的长度。
  - 防回滚仅在 eFuse 编码机制设置为 NONE 时生效。
  - 分区表不应有工具分区，应仅有两个应用程序分区。

security_version:
  - 存储在应用程序镜像中的 esp_app_desc 里。版本号
    用`CONFIG_BOOTLOADER_APP_SECURE_VERSION`设置。

没有安全启动的安全 OTA 升级

即便硬件安全启动没有使能，也可验证已签名的 OTA 升级，具体可参考Signed App Verification Without
Hardware Secure Boot。

OTA 工具 (otatool.py)

`app_update` 组件中有 otatool.py 工具，用于在目标设备上完成下列 OTA 分区相关操作：
  - 读取 otadata 分区 (read_otadata)
  - 擦除 otadata 分区，将设备复位至工厂应用程序 (erase_otadata)
  - 切换 OTA 分区 (switch_ota_partition)
  - 擦除 OTA 分区 (erase_ota_partition)
  - 写入 OTA 分区 (write_ota_partition)
  - 读取 OTA 分区 (read_ota_partition)

用户若想通过编程方式完成相关操作，可从另一个 Python 脚本导出并使用分区工具，或者从 Shell 脚本
调用分区工具。前者可使用工具的 Python API，后者则使用命令行界面。

Python API

首先，确保已导入 otatool 模块。

```python
import sys
import os

idf_path = os.environ["IDF_PATH"]  # 从环境中获取 IDF_PATH 的值
otatool_dir = os.path.join(idf_path, "components", "app_update")  # otatool.py 位于
sys.path.append(otatool_dir)  # 使 Python 寻找 otatool 模块
from otatool import *  # 导入 otatool 模块内的所有名称
```

要使用 OTA 工具的 Python API，第一步是创建 OtatoolTarget:

```python
# 创建 partool.py 的目标设备，并将目标设备连接到串行端口 /dev/ttyUSB1
target = OtatoolTarget("/dev/ttyUSB1")
```

现在，可使用创建的 OtatoolTarget 在目标设备上完成操作:

```python
# 擦除 otadata，将设备复位至工厂应用程序
target.erase_otadata()
```
要操作的 OTA 分区通过应用程序分区序号或分区名称指定。
更多关于 Python API 的信息，请查看 OTA 工具的代码注释。

命令行界面  otatool.py 的命令行界面具有如下结构：

```
otatool.py [command-args] [subcommand] [subcommand-args]
```

- **command-args** - 执行主命令 (otatool.py) 所需的实际参数，多与目标设备有关
- **subcommand** - 要执行的操作
- **subcommand-args** - 所选操作的实际参数

更多信息可用 -help 指令查看：

```
# 显示可用的子命令和主命令描述
otatool.py --help

# 显示子命令的描述
otatool.py [subcommand] --help
```

相关文档

- 分区表
- SPI Flash 和分区 API
- ESP HTTPS OTA

应用程序示例

端对端的 OTA 固件升级示例请参考 system/ota。

API 参考

Header File

```
* 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_PENDING_VERIFY state then it will lead to the ESP_ERR_OTA_ROLLBACK_INVALID_STATE error. Confirm the running app before to run download a new app, use esp_ota_mark_app_valid_cancel_rollback() function for it (this should be done as early as possible when you first download a new application).

Return
• ESP_OK: OTA operation commenced successfully.
• ESP_ERR_INVALID_ARG: partition or out_handle arguments were NULL, or partition doesn’t point to an OTA app partition.
• ESP_ERR_NO_MEM: Cannot allocate memory for OTA operation.
• ESP_ERR_OTA_PARTITION_CONFLICT: Partition holds the currently running firmware, cannot update in place.
• ESP_ERR_NOT_FOUND: Partition argument not found in partition table.
• ESP_ERR_OTA_SELECT_INFO_INVALID: The OTA data partition contains invalid data.
• ESP_ERR_OTA_SIZE_INVALID: 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.

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.
Chapter 2. API

- **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.

This function can write data in non-contiguous manner. If flash encryption is enabled, data should be 16 byte 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
const esp_partition_t *esp_ota_get_boot_partition (void)
```

Get partition info of currently configured boot app.

**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.
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.

**Return**
- ESP_OK Successful.
- ESP_ERR_NOT_FOUND `app_desc` structure is not found. Magic word is incorrect.
- ESP_ERR_NOT_SUPPORTED Partition is not application.
- ESP_ERR_INVALID_ARG Arguments is NULL or if partition’s offset exceeds partition size.
- ESP_ERR_INVALID_SIZE Read would go out of bounds of the partition.
- or one of error codes from lower-level flash driver.

**Parameters**
- `[in]` `partition`: Pointer to app partition. (only app partition)
- `[out]` `app_desc`: Structure of info about app.

```c
esp_err_t esp_ota_mark_app_valid_cancel_rollback(void)
```

This function is called to indicate that the running app is working well.

**Return**
- ESP_OK: if successful.
**esp_err_t esp_ota_mark_app_invalid_rollback_and_reboot**(void)
This function is called to roll back to the previously workable app with reboot.

If rollback is successful then device will reset else API will return with error code. Checks applications on a flash drive that can be booted in case of rollback. If the flash does not have at least one app (except the running app) then rollback is not possible.

**Return**
- ESP_FAIL: if not successful.
- ESP_ERR_OTA_ROLLBACK_FAILED: The rollback is not possible due to flash does not have any apps.

**const esp_partition_t *esp_ota_get_last_invalid_partition**(void)
Returns last partition with invalid state (ESP_OTA_IMG_INVALID or ESP_OTA_IMG_ABORTED).

**Return**
- partition.

**esp_err_t esp_ota_get_state_partition**(const esp_partition_t *partition, esp_ota_img_states_t *ota_state)
Returns state for given partition.

**Return**
- ESP_OK: Successful.
- ESP_ERR_INVALID_ARG: partition or ota_state arguments were NULL.
- ESP_ERR_NOT_SUPPORTED: partition is not ota.
- ESP_ERR_NOT_FOUND: Partition table does not have otadata or state was not found for given partition.

**Parameters**
- [in] partition: Pointer to partition.
- [out] ota_state: state of partition (if this partition has a record in otadata).

**esp_err_t esp_ota_erase_last_boot_app_partition**(void)
Erase previous boot app partition and corresponding otadata select for this partition.

When current app is marked to as valid then you can erase previous app partition.

**Return**
- ESP_OK: Successful, otherwise ESP_ERR.

**bool esp_ota_check_rollback_is_possible**(void)
Checks applications on the slots which can be booted in case of rollback.

These applications should be valid (marked in otadata as not UNDEFINED, INVALID or ABORTED and crc is good) and be able booted, and secure_version of app >= secure_version of efuse (if anti-rollback is enabled).

**Return**
- True: Returns true if the slots have at least one app (except the running app).
- False: The rollback is not possible.

**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
Chapter 2. API参考

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().

2.7.21 Performance Monitor

The Performance Monitor component provides APIs to use ESP32 internal performance counters to profile functions and applications.

Application Example

An example which combines performance monitor is provided in examples/system/perfmon directory. This example initializes the performance monitor structure and execute them with printing the statistics.

High level API Reference

Header Files

- perfmon/include/perfmon.h

API Reference

Header File

- 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
**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

**xtensa_perfmon_start** (void)
Start PM counters.

Start all PM counters synchronously. Write 1 to the PGM register

**xtensa_perfmon_stop** (void)
Stop PM counters.

Stop all PM counters synchronously. Write 0 to the PGM register

**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 occurs (overflow = 1)

**Parameters**
- [in] id: performance counter number

**xtensa_perfmon_dump** (void)
Dump PM values.

Dump all PM register to the console.

**Header File**
- 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
void 
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

struct xtensa_perfmon_config

Performance monitor configuration structure.

Structure to configure performance counter to measure dedicated function

Public Members

int repeat_count

how much times function will be called before the callback will be repeated

float max_deviation

Difference between min and max counter number 0..1, 0 - no difference, 1 - not used

void *call_params

This pointer will be passed to the call_function as a parameter

void (*call_function)(void *params)

pointer to the function that have to be called

void (*callback)(void *params, uint32_t select, uint32_t mask, uint32_t value)

pointer to the function that will be called with result parameters

void *callback_params

parameter that will be passed to the callback

int tracelevel

trace level for all counters. In case of negative value, the filter will be ignored. If it’s >=0, then the perfmon will count only when interrupt level > tracelevel. It’s useful to monitor interrupts.

uint32_t counters_size

amount of counter in the list

const uint32_t *select_mask

list of the select/mask parameters

Type Definitions

typedef struct xtensa_perfmon_config xtensa_perfmon_config_t

Performance monitor configuration structure.

Structure to configure performance counter to measure dedicated function

2.7.22 电源管理
Chapter 2. API 参考

概述

ESP-IDF 中集成的电源管理算法可以根据应用程序组件的需求，调整外围总线 (APB) 频率、CPU 频率，并使芯片进入 Light-sleep 模式，尽可能减少运行应用程序的功耗。

应用程序组件可以通过创建和获取电源管理锁来控制功耗。

例如:
- 对于从 APB 获得时钟频率的外设，其驱动可以要求在使用该外设时，将 APB 频率设置为 80 MHz。
- RTOS 可以要求 CPU 在有任务准备开始运行时以最高配置频率工作。
- 一些外设可能需要中断才能启用，因此其驱动也会要求禁用 Light-sleep 模式。

因为请求较高的 APB 频率或 CPU 频率，以及禁用 Light-sleep 模式会增加功耗，请将组件使用的电源管理锁降到最少。

电源管理配置

编译时可使用 CONFIG_PM_ENABLE 选项启用电源管理功能。

启用电源管理功能将会增加中断延迟。额外延迟与多个因素有关，例如：CPU 频率，单/双核模式，是否需要进行频率切换等。CPU 频率为 240 MHz 且未启用频率调节时，最小额外延迟为 0.2 us；如果启用频率调节，且在中断入口将频率由 40 MHz 调节至 80 MHz，则最大额外延迟为 40 us。

应用程序可以通过调用 esp_pm_configure() 函数启用动态调频 (DFS) 功能和自动 Light-sleep 模式。此函数的参数为 esp_pm_config_esp32_t，定义了频率调节的相关设置。在此参数结构中，需要初始化下面三个字段：

- max_freq_mhz: 最大 CPU 频率 (MHz)，即获取 ESP_PM_CPU_FREQ_MAX 锁后所使用的频率。该字段通常设置为 CONFIG_ESP32_DEFAULT_CPU_FREQ_MHZ。
- min_freq_mhz: 最小 CPU 频率 (MHz)，即仅获取 ESP_PM_APB_FREQ_MAX 锁后所使用的频率。该字段可设置为晶振 (XTAL) 频率值，或者 XTAL 频率值除以整数。注意，10 MHz 是生成 1 MHz 的 REF_TICK 默认时钟所需的最小频率。
- light_sleep_enable: 没有获取任何管理锁时，决定系统是否需要自动进入 Light-sleep 状态 (true/false)。

或者，如果在 menuconfig 中启用了 CONFIG_PM_DFS_INIT_AUTO 选项，最大 CPU 频率将由 CONFIG_ESP32_DEFAULT_CPU_FREQ_MHZ 设置决定，最小 CPU 频率将设定为 XTAL 频率。

注释:

1. 自动 Light-sleep 模式基于 FreeRTOS Tickless Idle 功能，因此如果在 menuconfig 中没有启用 CONFIG_FREERTOS_USE_TICKLESS_IDLE 选项，在自动 Light-sleep 时，esp_pm_configure() 将会返回 ESP_ERR_NOT_SUPPORTED 错误。
2. 在 Light-sleep 状态下，外设设有时钟控制，不会产生来自 GPIO 和内部外设的中断。Sleep Modes 文档中提到的唤醒源可用于从 Light-sleep 状态触发唤醒。例如，EXT0 和 EXT1 唤醒源就可以通过 GPIO 唤醒芯片。

电源管理锁

应用程序可以通过获取或释放管理锁来控制电源管理算法。应用程序获取电源管理锁后，电源管理算法的操作将受到下面的限制。释放电源管理锁后，限制解除。

电源管理锁设有获取/释放计数器，如果已多次获取电源管理锁，则需要将电源管理锁释放相同次数以解除限制。

ESP32 支持下表中所述的三种电源管理锁。
### ESP32 电源管理算法

下表列出了启用动态调频时如何切换 CPU 频率和 APB 频率。您可以使用 `esp_pm_configure()` 函数或 `CONFIG_ESP32_DEFAULT_CPU_FREQ_MHZ` 选项来设置 CPU 频率。

如果没有获得任何管理锁，调用 `esp_pm_configure()` 将启动 Light-sleep 模式。Light-sleep 模式持续时间由以下因素决定：

- 处于阻塞状态的 FreeRTOS 任务数（例如超时）
- 高分辨率定时器 API 注册的计数器数量

您也可以设置 Light-sleep 模式在最近事件（任务解除阻塞，或计时器超时）之前持续多久才唤醒芯片。

### 动态调频和外设驱动

启用动态调频后，APB 频率在一个 RTOS 滴答周期内多次更改。有些外设不受 APB 频率变更的影响，但有些外设可能会出现问题。例如，Timer Group 外设定时器会继续计数，但定时器计数的速度将随 APB 频率的变更而变更。

下面的外设不受 APB 频率变更的影响：

- UART：如果 REF_TICK 用作时钟源，则 UART 不受 APB 频率变更影响。请查看 `uart_config_t` 中的 `use_ref_tick`。
- LEDC：如果 REF_TICK 用作时钟源，则 LEDC 不受 APB 频率变更影响。请查看 `ledc_timer_config()` 函数。
- RMT：如果 REF_TICK 用作时钟源，则 RMT 不受 APB 频率变更影响。请查看 `rmt_config_t` 结构体中的 `flags` 成员以及 `RMT_CHANNEL_FLAGS_ALWAYS_ON` 宏。

目前以下外设驱动程序可感知动态调频，并在调频期间使用 `ESP_PM_APB_FREQ_MAX` 锁：

- SPI master
- I2C
- I2S（如果 APLL 锁在使用中，I2S 则会启用 `ESP_PM_NO_LIGHT_SLEEP` 锁）
- SDMMC

启用以下驱动程序时，将占用 `ESP_PM_APB_FREQ_MAX` 锁：

- SPI slave：从调用 `spi_slave_initialize()` 至 `spi_slave_free()` 期间。
- Ethernet：从调用 `esp_eth_driver_install()` 至 `esp_eth_driver_uninstall()` 期间。
- WiFi：从调用 `esp_wifi_start()` 至 `esp_wifi_stop()` 期间。如果启用了调制解调器睡眠模式，广播关闭时将释放此管理锁。
- TWAI：从调用 `twai_driver_install()` 至 `twai_driver_uninstall()` 期间。
- Bluetooth：从调用 `esp_bt_controller_enable()` 至 `esp_bt_controller_disable()` 期间。如果启用了蓝牙调制解调器，广播关闭时将释放此管理锁。但仍然占用 `ESP_PM_NO_LIGHT_SLEEP` 锁。

以下外设驱动程序无法感知动态调频，应用程序需自己获取/释放管理锁：

- PCNT
- Sigma-delta
- Timer group
- MCPWM
API 参考

Header File

- esp_pm/include/esp_pm.h

Functions

\texttt{esp_err_t esp\_pm\_configure(const void *\text{config})}  
Set implementation-specific power management configuration.

\begin{itemize}
  \item ESP_OK on success
  \item ESP\_ERR\_INVALID\_ARG if the configuration values are not correct
  \item ESP\_ERR\_NOT\_SUPPORTED if certain combination of values is not supported, or if CONFIG\_PM\_ENABLE is not enabled in sdkconfig
\end{itemize}

\textbf{Parameters}

- \text{config}: pointer to implementation-specific configuration structure (e.g. esp\_pm\_config\_esp32)

\texttt{esp_err_t esp\_pm\_lock\_create(esp\_pm\_lock\_type\_t \text{lock\_type}, int \text{arg}, const char *\text{name}, esp\_pm\_lock\_handle\_t *\text{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.

\begin{itemize}
  \item ESP_OK on success
  \item ESP\_ERR\_NO\_MEM if the lock structure cannot be allocated
  \item ESP\_ERR\_INVALID\_ARG if out\_handle is NULL or type argument is not valid
  \item ESP\_ERR\_NOT\_SUPPORTED if CONFIG\_PM\_ENABLE is not enabled in sdkconfig
\end{itemize}

\textbf{Parameters}

- \text{lock\_type}: Power management constraint which the lock should control
- \text{arg}: argument, value depends on lock\_type, see esp\_pm\_lock\_type\_t
- \text{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] \text{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.

\texttt{esp_err_t esp\_pm\_lock\_acquire(esp\_pm\_lock\_handle\_t \text{handle})}  
Take a power management lock.

Once the lock is taken, power management algorithm will not switch to the mode specified in a call to esp\_pm\_lock\_create, or any of the lower power modes (higher numeric values of ‘mode’).

The lock is recursive, in the sense that if esp\_pm\_lock\_acquire is called a number of times, esp\_pm\_lock\_release has to be called the same number of times in order to release the lock.

This function may be called from an ISR.

This function is not thread-safe w.r.t. calls to other esp\_pm\_lock\_* functions for the same handle.

\begin{itemize}
  \item ESP_OK on success
  \item ESP\_ERR\_INVALID\_ARG if the handle is invalid
  \item ESP\_ERR\_NOT\_SUPPORTED if CONFIG\_PM\_ENABLE is not enabled in sdkconfig
\end{itemize}

\textbf{Parameters}

- \text{handle}: handle obtained from esp\_pm\_lock\_create function

\texttt{esp_err_t esp\_pm\_lock\_release(esp\_pm\_lock\_handle\_t \text{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

```c
esp_err_t esp_pm_dump_locks(FILE *stream)
```

Dump the list of all locks to stderr

This function dumps debugging information about locks created using esp_pm_lock_create to an output stream.

This function must not be called from an ISR. If esp_pm_lock_acquire/release are called while this function is running, inconsistent results may be reported.

**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 fmempoen/open_memstream to print to a string buffer.

**Type Definitions**

```c
typedef struct esp_pm_lock *esp_pm_lock_handle_t
```

Opaque handle to the power management lock.

**Enumerations**

```c
enum esp_pm_lock_type_t
```

Power management constraints.

**Values:**

- **ESP_PM_CPU_FREQ_MAX**
  - Require CPU frequency to be at the maximum value set via esp_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
- 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 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 (including ULP coprocessor), and RTC memories (slow and fast).
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.

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.
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.

**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. See chapter “Reset and Clock” of the ESP32 Technical Reference Manual for details about RTC clock options.

This wakeup mode doesn’t require RTC peripherals or RTC memories to be powered on during sleep.  
`esp_sleep_enable_timer_wakeup()` function can be used to enable deep sleep wakeup using a timer.

**Touch pad**  
RTC IO module contains logic to trigger wakeup when a touch sensor interrupt occurs. You need to configure the touch pad interrupt before the chip starts deep sleep.  
`esp_sleep_enable_touchpad_wakeup()` function can be used to enable this wakeup source.

**External wakeup (ext0)**  
RTC IO module contains logic to trigger wakeup when one of RTC GPIOs is set to a predefined logic level. RTC IO is part of RTC peripherals power domain, so RTC peripherals will be kept powered on during 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()`.

`esp_sleep_enable_ext0_wakeup()` function can be used to enable this wakeup source.

**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/p pulldown resistors using `rtc_gpio_` functions, before entering sleep:

```c
esp_sleep_pd_config(ESP_PD_DOMAIN_RTC_PERIPH, ESP_PD_OPTION_ON);
gpio_pullup_dis(gpio_num);
gpio_pulldown_en(gpio_num);
```

**警告:** 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.

**esp_sleep_enable_ext1_wakeup()** function can be used to enable this wakeup source.
ULP coprocessor wakeup  ULP coprocessor can run while the chip is in sleep mode, and may be used to poll sensors, monitor ADC or touch sensor values, and wake up the chip when a specific event is detected. ULP coprocessor is part of RTC peripherals power domain, and it runs the program stored in RTC slow memory. RTC slow memory will be powered on during sleep if this wakeup mode is requested. RTC peripherals will be automatically powered on before ULP coprocessor starts running the program; once the program stops running, RTC peripherals are automatically powered down again.

`esp_sleep_enable_ulp_wakeup()` function can be used to enable this wakeup source.

GPIO wakeup (light sleep only) In addition to EXT0 and EXT1 wakeup sources described above, one more method of wakeup from external inputs is available in light sleep mode. With this wakeup source, each pin can be individually configured to trigger wakeup on high or low level using `gpio_wakeup_enable()` function. Unlike EXT0 and EXT1 wakeup sources, which can only be used with RTC IOs, this wakeup source can be used with any IO (RTC or digital).

`esp_sleep_enable_gpio_wakeup()` function can be used to enable this wakeup source.

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.

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 \texttt{esp\_deep\_sleep\_start()} to remove this extra current:

\begin{verbatim}
  rtc\_gpio\_isolate(GPIO\_NUM\_12);
\end{verbatim}

\textbf{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.

\textbf{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 and ext1 wakeup sources, it is possible to identify pin or touch pad which has caused wakeup using \texttt{esp\_sleep\_get\_touchpad\_wakeup\_status()} and \texttt{esp\_sleep\_get\_ext1\_wakeup\_status()} functions.

\textbf{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}.

\textbf{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 co-processor programming.

\textbf{API Reference}

\textbf{Header File}

- \texttt{esp\_system\_include/esp\_sleep.h}

\textbf{Functions}

\begin{verbatim}
  esp\_err\_t esp\_sleep\_disable\_wakeup\_source(esp\_sleep\_source\_t source)
\end{verbatim}

Disable wakeup source.

This function is used to deactivate wake up trigger for source defined as parameter of the function.

See docs/sleep-modes.rst for details.

**Note** This function does not modify wake up configuration in RTC. It will be performed in \texttt{esp\_sleep\_start} function.

**Return**

- ESP\_OK on success
- ESP\_ERR\_INVALID\_STATE if trigger was not active
Parameters

- **source**: number of source to disable of type esp_sleep_source_t

### esp_err_t esp_sleep_enable_ulp_wakeup (void)
Enable wake up by ULP coprocessor.

**Note** On ESP32, ULP wakeup source cannot be used when RTC_PERIPH power domain is forced to be powered on (ESP_PD_OPTION_ON) or when ext0 wakeup source is used.

**Return**
- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if additional current by touch (CONFIG_ESP32_RTC_EXT_CRYST_ADDIT_CURRENT) is enabled.
- ESP_ERR_INVALID_STATE if ULP co-processor is not enabled or if wakeup triggers conflict.

### esp_err_t esp_sleep_enable_timer_wakeup (uint64_t time_in_us)
Enable wake up by timer.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if value is out of range (TBD)

**Parameters**

- **time_in_us**: time before wake up, in microseconds

### esp_err_t esp_sleep_enable_touchpad_wakeup (void)
Enable wake up 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.

**Note** The FSM mode of the touch button should be configured as the timer trigger mode.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if value is out of range (TBD)
- ESP_ERR_INVALID_STATE if wakeup triggers conflict.

### touch_pad_t esp_sleep_get_touchpad_wakeup_status (void)
Get the touch pad which caused wake up.

If wakeup was caused by another source, this function will return TOUCH_PAD_MAX;

**Return**
- touch_pad which caused wake up

### esp_err_t esp_sleep_enable_ext0_wakeup (gpio_num_t gpio_num, int level)
Enable wake up using a pin.

This function uses external wake up 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 wake up source. Only GPIOs which 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 wake up 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 are have RTC functionality can be used in this bitmap: 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

```c
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 wake up 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

```c
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

```c
esp_err_t esp_sleep_enable_wifi_wakeup (void)
```

Enable wakeup by WiFi MAC.

**Return**
- ESP_OK on success

```c
uint64_t esp_sleep_get_ext1_wakeup_status (void)
```

Get the bit mask of GPIOs which caused wakeup (ext1)

If wakeup was caused by another source, this function will return 0.

**Return** bit mask, if GPIOn caused wakeup, BIT(n) will be set
**esp_err_t esp_sleep_pd_config**(esp_sleep_pd_domain_t domain, esp_sleep_pd_option_t option)

Set power down mode for an RTC power domain in sleep mode.
If not set set using this API, all power domains default to ESP_PD_OPTION_AUTO.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if either of the arguments is out of range

**Parameters**
- domain: power domain to configure
- option: power down option (ESP_PD_OPTION_OFF, ESP_PD_OPTION_ON, or ESP_PD_OPTION_AUTO)

void **esp_deep_sleep_start**(void)
Enter deep sleep with the configured wakeup options.
This function does not return.

**esp_err_t esp_light_sleep_start**(void)
Enter light sleep with the configured wakeup options.

**Return**
- ESP_OK on success (returned after wakeup)
- ESP_ERR_INVALID_STATE if WiFi or BT is not stopped

void **esp_deep_sleep**(uint64_t time_in_us)
Enter deep-sleep mode.
The device will automatically wake up after the deep-sleep time. Upon waking up, the device calls deep sleep
wake stub, and then proceeds to load application.
Call to this function is equivalent to a call to esp_deep_sleep_enable_timer_wakeup followed by a call to
esp_deep_sleep_start.

esp_deep_sleep does not shut down WiFi, BT, and higher level protocol connections gracefully. Make sure
relevant WiFi and BT stack functions are called to close any connections and deinitialize the peripherals. These
include:
- esp_bluedroid_disable
- esp_bt_controller_disable
- esp_wifi_stop

This function does not return.

**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.

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.

**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_MAX`  
  Number of domains.

```c
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.

2.7.24 Watchdogs

Overview

The ESP-IDF has support for two types of watchdogs: The Interrupt Watchdog Timer and the Task Watchdog Timer (TWDT). The Interrupt Watchdog Timer and the TWDT can both be enabled using Project Configuration Menu, however the TWDT can also be enabled during runtime. The Interrupt Watchdog is responsible for detecting instances where FreeRTOS task switching is blocked for a prolonged period of time. The TWDT is responsible for detecting instances of tasks running without yielding for a prolonged period.

Interrupt watchdog The interrupt watchdog makes sure the FreeRTOS task switching interrupt isn’t blocked for a long time. This is bad because no other tasks, including potentially important ones like the WiFi task and the idle task, can’t get any CPU runtime. A blocked task switching interrupt can happen because a program runs into an infinite loop with interrupts disabled or hangs in an interrupt.

The default action of the interrupt watchdog is to invoke the panic handler, causing a register dump and an opportunity for the programmer to find out, using either OpenOCD or gdbstub, what bit of code is stuck with interrupts disabled. Depending on the configuration of the panic handler, it can also blindly reset the CPU, which may be preferred in a production environment.
The interrupt watchdog is built around the hardware watchdog in timer group 1. If this watchdog for some reason cannot execute the NMI handler that invokes the panic handler (e.g. because IRAM is overwritten by garbage), it will hard-reset the SOC. If the panic handler executes, it will display the panic reason as “Interrupt wdt timeout on CPU0” or “Interrupt wdt timeout on CPU1” (as applicable).

**Configuration**  The interrupt watchdog is enabled by default via the `CONFIG_ESP_INT_WDT` configuration flag. The timeout is configured by setting `CONFIG_ESP_INT_WDT_TIMEOUT_MS`. The default timeout is higher if PSRAM support is enabled, as a critical section or interrupt routine that accesses a large amount of PSRAM will take longer to complete in some circumstances. The INT WDT timeout should always be longer than the period between FreeRTOS ticks (see `CONFIG_FREERTOS_HZ`).

**Tuning**  If you find the Interrupt watchdog timeout is triggering because an interrupt or critical section is running longer than the timeout period, consider rewriting the code: critical sections should be made as short as possible, with non-critical computation happening outside the critical section. Interrupt handlers should also perform the minimum possible amount of computation, consider pushing data into a queue from the ISR and processing it in a task instead. Neither critical sections or interrupt handlers should ever block waiting for another event to occur.

If changing the code to reduce the processing time is not possible or desirable, it’s possible to increase the `CONFIG_ESP_INT_WDT_TIMEOUT_MS` setting instead.

**Task Watchdog Timer**  The Task Watchdog Timer (TWDT) is responsible for detecting instances of tasks running for a prolonged period of time without yielding. This is a symptom of CPU starvation and is usually caused by a higher priority task looping without yielding to a lower-priority task thus starving the lower priority task from CPU time. This can be an indicator of poorly written code that spinloops on a peripheral, or a task that is stuck in an infinite loop.

By default the TWDT will watch the Idle 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 form 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_common/include/esp_int_wdt.h

**Functions**

```c
void esp_int_wdt_init(void)
```

Initialize the non-CPU-specific parts of interrupt watchdog. This is called in the init code if the interrupt watchdog is enabled in menuconfig.

**Task Watchdog API Reference**

A full example using the Task Watchdog is available in esp-idf: system/task_watchdog

**Header File**

- esp_common/include/esp_task_wdt.h

**Functions**

```c
esp_err_t esp_task_wdt_init(uint32_t timeout, bool panic)
```

Initialize the Task Watchdog Timer (TWDT)

This function configures and initializes the TWDT. If the TWDT is already initialized when this function is called, this function will update the TWDT’s timeout period and panic configurations instead. After initializing the TWDT, any task can elect to be watched by the TWDT by subscribing to it using esp_task_wdt_add().

**Return**

- ESP_OK: Initialization was successful
- ESP_ERR_NO_MEM: Initialization failed due to lack of memory

**Note** esp_task_wdt_init() must only be called after the scheduler started

**Parameters**

- `[in]` timeout: Timeout period of TWDT in seconds
- `[in]` panic: Flag that controls whether the panic handler will be executed when the TWDT times out

```c
esp_err_t esp_task_wdt_deinit(void)
```

Deinitialize the Task Watchdog Timer (TWDT)

This function will deinitialize the TWDT. Calling this function whilst tasks are still subscribed to the TWDT, or when the TWDT is already deinitialized, will result in an error code being returned.

**Return**

- ESP_OK: TWDT successfully deinitialized
- ESP_ERR_NO_MEM: TWDT successfully deinitialized
- ESP_ERR_TASK: Error, tasks are still subscribed to the TWDT
- ESP_ERR_NOT_FOUND: Error, TWDT has already been deinitialized

```c
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.

### 2.7.25 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 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 < 0.5Vamp, 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
cftime
```

(下页继续)
Chapter 2. API

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**

```
• lwip/include/apps/sntp/sntp.h
```

**Functions**

```c
void sntp_sync_time (struct timeval *tv)
```

This function updates the system time. This is a weak-linked function. It is possible to replace all SNTP update functionality by placing a `sntp_sync_time()` function in the app firmware source. If the default implementation is used, calling `sntp_set_sync_mode()` allows the time synchronization mode to be changed to instant or smooth. If a callback function is registered via `sntp_set_time_sync_notification_cb()`, it will be called following time synchronization.

**Parameters**

```
• tv: Time received from SNTP server.
```

```c
void sntp_set_sync_mode (sntp_sync_mode_t sync_mode)
```

Set the sync mode.

Allowable two mode: SNTP_SYNC_MODE_IMMED and SNTP_SYNC_MODE_SMOOTH.

**Parameters**

```
• sync_mode: Sync mode.
```

```c
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.
**Chapter 2. API**

```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 through SNTP. To apply the new sync interval call the sntp_restart() function, otherwise, it will be applied after the last interval expired.

Parameters
  • interval_ms: The sync interval in ms. It cannot be lower than 15 seconds, otherwise 15 seconds will be set.
```

```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.
```

```c
enum sntp_sync_status_t
SNTP sync status.

Values:
  SNTP_SYNC_STATUS_RESET
  SNTP_SYNC_STATUS_COMPLETED
  SNTP_SYNC_STATUS_IN_PROGRESS
```
2.7.26 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

- esp_rom/include/esp_rom_sys.h

Functions

int esp_rom_printf(const char *fmt, ...)
Print formatted string to console device.

Note float and long long data are not supported!

Return int: Total number of characters written on success; A negative number on failure.

Parameters
- fmt: Format string
- ...: Additional arguments, depending on the format string

void esp_rom_delay_us (uint32_t us)
Pauses execution for us microseconds.

Parameters
- us: Number of microseconds to pause

void esp_rom_install_channel_putc (int channel, void (*putc)) char c
esp_rom_printf can print message to different channels simultaneously. This function can help install the low level putc function for esp_rom_printf.

Parameters
- channel: Channel number (starting from 1)
- putc: Function pointer to the putc implementation. Set NULL can disconnect esp_rom_printf with putc.

void esp_rom_disable_logging (void)
Disable logging from the ROM code.

Code examples for this API section are provided in the system directory of ESP-IDF examples.

2.8 Project Configuration

2.8.1 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.

2.8.2 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.
(For the legacy GNU Make build system, the project configuration menu is opened with `make menuconfig`.)

### 2.8.3 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 must be created manually. It can contain all the options which matter for the given application. The format is the same as that of the `sdkconfig` file. 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 自定义 `sdkconfig` 的默认值.

### 2.8.4 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.
- Lines cannot be wrapped by backslash (because there is a bug in earlier versions of `conf-idf` which causes that Windows line endings are not recognized after a backslash).

**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.

### 2.8.5 Backward Compatibility of Kconfig Options

The standard Kconfig tools ignore unknown options in `sdkconfig`. So if a developer has custom settings for options which are renamed in newer ESP-IDF releases then the given setting for the option would be silently ignored. Therefore, several features have been adopted to avoid this:

1. `confgen.py` is used by the tool chain to pre-process `sdkconfig` files before anything else, for example `menuconfig`, would read them. As the consequence, the settings for old options will be kept and not ignored.
2. `confgen.py` recursively finds all `sdkconfig.rename` files in ESP-IDF directory which contain old and new Kconfig option names. Old options are replaced by new ones in the `sdkconfig` file.
3. `confgen.py` post-processes `sdkconfig` files and generates all build outputs (`sdkconfig.h`, `sdkconfig.cmake`, `auto.conf`) by adding a list of compatibility statements, i.e. value of the old option is set the value of the new option (after modification). This is done in order to not break customer codes where old option might still be used.
4. **Deprecated options and their replacements** are automatically generated by `confgen.py`. 

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2.8.6 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_PYTHON`
- `CONFIG_SDK_MAKE_WARN_UNDEFINED_VARIABLES`
- `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.

**CONFIG_SDK_PYTHON**

Python interpreter

*Found in: SDK tool configuration*

The executable name/path that is used to run python.

(Note: This option is used with the legacy GNU Make build system only.)

**CONFIG_SDK_MAKE_WARN_UNDEFINED_VARIABLES**

‘make’ warns on undefined variables

*Found in: SDK tool configuration*

Adds –warn-undefined-variables to MAKEFLAGS. This causes make to print a warning any time an undefined variable is referenced.

This option helps find places where a variable reference is misspelled or otherwise missing, but it can be unwanted if you have Makefiles which depend on undefined variables expanding to an empty string.

(Note: this option is used with the legacy GNU Make build system only.)

**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.
Chapter 2. API

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.

Build type

Contains:

- `CONFIG_APP_BUILD_TYPE`

**CONFIG_APP_BUILD_TYPE**

Application build type

`Found in: Build type`

Select the way the application is built.

By default, the application is built as a binary file in a format compatible with the ESP32 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:

```
# 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 *0x40007901c # Load the application into RAM load # Run till app_main tb
app_main c
```

Execute this gdbinit file as follows:

```
xtensa-esp32-elf-gdb build/app-name.elf -x gdbinit
```

Recommended sdkconfig.defaults for building loadable ELF files is as follows. `CONFIG_APP_BUILD_TYPE_ELF_RAM` is required, other options help reduce application memory footprint.

```
CONFIG_APP_BUILD_TYPE_ELF_RAM=y
CONFIG_VFS_SUPPORT_TERMIOS=y
CONFIG_NEWLIB_NANO_FORMAT=y
CONFIG_ESP_SYSTEM_PANIC_PRINT_HALT=y
CONFIG_ESP_DEBUG_STUBS_ENABLE=y
CONFIG_ESP_ERR_TO_NAME_LOOKUP=y
```

Available options:

- Default (binary application + 2nd stage bootloader) (APP_BUILD_TYPE_APP_2NDBOOT)
- ELF file, loadable into RAM (EXPERIMENTAL) (APP_BUILD_TYPE_ELF_RAM)

Application manager

Contains:

- `CONFIG_APP_COMPILE_TIME_DATE`
- `CONFIG_APP_EXCLUDE_PROJECT_VER_VAR`
- `CONFIG_APP_EXCLUDE_PROJECT_NAME_VAR`
- `CONFIG_APP_PROJECT_VER_FROM_CONFIG`
- `CONFIG_APP_RETRIEVE_LEN_ELF_SHA`
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.

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.

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.

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.

CONFIG_APP_PROJECT_VER

Project version

*Found in: Application manager > CONFIG_APP_PROJECT_VER_FROM_CONFIG*

Project version

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.

**Bootloader config**

Contains:

- `CONFIG_BOOTLOADER_COMPILER_OPTIMIZATION`
- `CONFIG_BOOTLOADER_LOG_LEVEL`
- `CONFIG_BOOTLOADER_SPI_CUSTOM_WP_PIN`


- **CONFIG_BOOTLOADER_SPI_WP_PIN**
- **CONFIG_BOOTLOADER_VDDSIO_BOOST**
- **CONFIG_BOOTLOADER_FACTORY_RESET**
- **CONFIG_BOOTLOADER_APP_TEST**
- **CONFIG_BOOTLOADER_HOLD_TIME_GPIO**
- **CONFIG_BOOTLOADER_WDT_ENABLE**
- **CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE**
- **CONFIG_BOOTLOADER_SKIP_VALIDATE_IN_DEEP_SLEEP**
- **CONFIG_BOOTLOADER_CUSTOM_RESERVE_RTC**

**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.
**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.

**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 pulled low while device starts up. See settings below.

**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. To trigger a factory reset, this GPIO must be pulled low on reset. Note that GPIO34-39 do not have an internal pullup and an external one must be provided.

**CONFIG_BOOTLOADER_OTA_DATA_ERASE**

Clear OTA data on factory reset (select factory partition)

*Found in: Bootloader config > CONFIG_BOOTLOADER_FACTORY_RESET*

The device will boot from “factory” partition (or OTA slot 0 if no factory partition is present) after a factory reset.

**CONFIG_BOOTLOADER_DATA_FACTORY_RESET**

Comma-separated names of partitions to clear on factory reset

*Found in: Bootloader config > CONFIG_BOOTLOADER_FACTORY_RESET*

Allows customers to select which data partitions will be erased while factory reset.
Specify the names of partitions as a comma-delimited with optional spaces for readability. (Like this: “nvs, phy_init, …”) Make sure that the name specified in the partition table and here are the same. Partitions of type “app” cannot be specified here.

**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.

**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.

**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.

**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).

**CONFIG_BOOTLOADER_WDT_DISABLE_IN_USER_CODE**

Allows RTC watchdog disable in user code

*Found in: Bootloader config > CONFIG_BOOTLOADER_WDT_ENABLE*

If it is set, the client must itself reset or disable rtc_wdt in their code (app_main()). Otherwise rtc_wdt will be disabled before calling app_main function. Use function rtc_wdt_feed() for resetting counter of rtc_wdt. Use function rtc_wdt_disable() for disabling rtc_wdt.
Chapter 2. API Reference

**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.

**CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE**

Enable app rollback support

*Found in: Bootloader config*

After updating the app, the bootloader runs a new app with the “ESP_OOTA_IMG_PENDING_VERIFY” state set. This state prevents the re-run of this app. After the first boot of the new app in the user code, the function should be called to confirm the operability of the app or vice versa about its non-operability. If the app is working, then it is marked as valid. Otherwise, it is marked as not valid and rolls back to the previous working app. A reboot is performed, and the app is booted before the software update. Note: If during the first boot a new app the power goes out or the WDT works, then roll back will happen. Rollback is possible only between the apps with the same security versions.

**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.

**CONFIG_BOOTLOADER_APP_SECURE_VERSION**

eFuse secure version of app

*Found in: Bootloader config > CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE > CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK*

The secure version is the sequence number stored in the header of each firmware. The security version is set in the bootloader, version is recorded in the eFuse field as the number of set ones. The allocated number of bits in the efuse field for storing the security version is limited (see BOOTLOADER_APP_SEC_VER_SIZE_EFUSE_FIELD option).

Bootloader: When bootloader selects an app to boot, an app is selected that has a security version greater or equal that recorded in eFuse field. The app is booted with a higher (or equal) secure version.

The security version is worth increasing if in previous versions there is a significant vulnerability and their use is not acceptable.

Your partition table should has a scheme with ota_0 + ota_1 (without factory).

**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.
**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 emulating read/write operations with efuse secure version. It allows testing anti-rollback implementation without permanent write eFuse bits. In the partition table, there should be an existing partition `emul_efuse, data, 5, , 0x2000`.

**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 wake-up 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.

**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.

**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.

**Security features**

Contains:

- `CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT`
- `CONFIG_SECURE_SIGNED_APPS_SCHEME`
- `CONFIG_SECURE_SIGNED_ON_BOOT_NO_SECURE_BOOT`
- `CONFIG_SECURE_SIGNED_ON_UPDATE_NO_SECURE_BOOT`
- `CONFIG_SECURE_BOOT`
- `CONFIG_SECURE_BOOTLOADER_MODE`
- `CONFIG_SECURE_BOOT_BUILD_SIGNED_BINARIES`
- `CONFIG_SECURE_BOOT_VERIFICATION_KEY`
- `CONFIG_SECURE_BOOTLOADER_KEY_ENCODING`
- `CONFIG_SECURE_BOOT_INSECURE`
- `CONFIG_SECURE_FLASH_ENC_ENABLED`
• Potentially insecure options
  • CONFIG_SECURE_DISABLE_ROM_DL_MODE

CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT

Require signed app images

Found in: Security features

Require apps to be signed to verify their integrity.

This option uses the same app signature scheme as hardware secure boot, but unlike hardware secure boot it does not prevent the bootloader from being physically updated. This means that the device can be secured against remote network access, but not physical access. Compared to using hardware Secure Boot this option is much simpler to implement.

CONFIG_SECURE_SIGNED_APPS_SCHEME

App Signing Scheme

Found in: Security features

Select the Secure App signing scheme. Depends on the Chip Revision. There are two options: 1. ECDSA based secure boot scheme. (Only choice for Secure Boot V1) Supported in ESP32 and ESP32-ECO3. 2. The RSA based secure boot scheme. (Only choice for Secure Boot V2) Supported in ESP32-ECO3. (ESP32 Chip Revision 3 onwards)

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.

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.
**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.

**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 re-flashing of any device that uses it.

**CONFIG_SECURE_BOOT_BUILD_SIGNED_BINARIES**

Sign binaries during build

*Found in: Security features*

Once secure boot or signed app requirement is enabled, app images are required to be signed.

If enabled (default), these binary files are signed as part of the build process. The file named in “Secure boot private signing key” will be used to sign the image.
If disabled, unsigned app/partition data will be built. They must be signed manually using espsecure.py. Version 1 to enable ECDSA Based Secure Boot and Version 2 to enable RSA based Secure Boot. (for example, on a remote signing server.)

**CONFIG_SECURE_BOOT_SIGNING_KEY**

Secure boot private signing key

*Found in: Security features > CONFIG_SECURE_BOOT_BUILD_SIGNED_BINARIES*

Path to the key file used to sign app images.

Key file is an ECDSA private key (NIST256p curve) in PEM format for Secure Boot V1. Key file is an RSA private key in PEM format for Secure Boot V2.

Path is evaluated relative to the project directory.

You can generate a new signing key by running the following command: espsecure.py generate_signing_key secure_boot_signing_key.pem

See the Secure Boot section of the ESP-IDF Programmer’s Guide for this version for details.

**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 reflasable 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.

**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* before enabling.

**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 UART bootloader to perform flash encryption operations.

Select Release mode only for production or manufacturing. Once enabled you can not reflash using UART bootloader.

Refer to the Secure Boot section of the ESP-IDF Programmer’s Guide for this version and *Flash* 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_ALLOW_ROM_BASIC
- CONFIG_SECURE_BOOT_ALLOW_JTAG
- CONFIG_SECURE_BOOT_ALLOW_SHORT_APP_PARTITION
- CONFIG_SECURE_BOOT_V2_ALLOW_EFUSE_RD_DIS
- CONFIG_SECURE_INSECURE_ALLOW_DL_MODE
- CONFIG_SECURE_FLASH_UART_BOOTLOADER_ALLOW_ENC
- CONFIG_SECURE_FLASH_UART_BOOTLOADER_ALLOW_DEC
- 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.
**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.

**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 holding the public key digest, causing an immediate denial of service and possibly allowing an additional fault injection attack to bypass the signature protection.

**CONFIG_SECURE_INSECURE_ALLOW_DL_MODE**

Don’t automatically restrict UART download mode

*Found in: Security features > Potentially insecure options*

By default, enabling either flash encryption in release mode or secure boot will automatically disable UART download mode on ESP32 ECO3, or enable secure download mode on newer chips. This is recommended to reduce the attack surface of the chip.

To allow the full UART download mode to stay enabled, enable this option and ensure the options SECURE_DISABLE_ROM_DL_MODE and SECURE_ENABLE_SECURE_ROM_DL_MODE are disabled as applicable. This is not recommended.

**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.

**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.

**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.

**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 espefuse.py.

**CONFIG_SECURE_DISABLE_ROM_DL_MODE**
Permanently disable ROM Download Mode

*Found in: Security features*

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, espefuse.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.
Serial flasher config

Contains:

- `CONFIG_ESPTOOLPY_PORT`
- `CONFIG_ESPTOOLPY_BAUD`
- `CONFIG_ESPTOOLPY_BAUD_OTHER_VAL`
- `CONFIG_ESPTOOLPY_COMPRESSED`
- `CONFIG_ESPTOOLPY_NO_STUB`
- `CONFIG_ESPTOOLPY_FLASHMODE`
- `CONFIG_ESPTOOLPY_FLASHFREQ`
- `CONFIG_ESPTOOLPY_FLASHSIZE`
- `CONFIG_ESPTOOLPY_FLASHSIZE_DETECT`
- `CONFIG_ESPTOOLPY_BEFORE`
- `CONFIG_ESPTOOLPY_AFTER`
- `CONFIG_ESPTOOLPY_MONITOR_BAUD`
- `CONFIG_ESPTOOLPY_MONITOR_BAUD_OTHER_VAL`

**CONFIG_ESPTOOLPY_PORT**

Default serial port

*Found in: Serial flasher config*

The serial port that’s connected to the ESP chip. This can be overridden by setting the `ESPPORT` environment variable.

This value is ignored when using the CMake-based build system or `idf.py`.

**CONFIG_ESPTOOLPY_BAUD**

Default baud rate

*Found in: Serial flasher config*

Default baud rate to use while communicating with the ESP chip. Can be overridden by setting the `ESPBAUD` variable.

This value is ignored when using the CMake-based build system or `idf.py`.

**Available options:**

- 115200 baud (`ESPTOOLPY_BAUD_115200B`)
- 230400 baud (`ESPTOOLPY_BAUD_230400B`)
- 921600 baud (`ESPTOOLPY_BAUD_921600B`)
- 2Mbaud (`ESPTOOLPY_BAUD_2MB`)
- Other baud rate (`ESPTOOLPY_BAUD_OTHER`)

**CONFIG_ESPTOOLPY_BAUD_OTHER_VAL**

Other baud rate value

*Found in: Serial flasher config*

**CONFIG_ESPTOOLPY_COMPRESSED**

Use compressed upload

*Found in: Serial flasher config*

The flasher tool can send data compressed using zlib, letting the ROM on the ESP chip decompress it on the fly before flashing it. For most payloads, this should result in a speed increase.
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.

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)

CONFIG_ESPTOOLPY_FLASHFREQ

Flash SPI speed

*Found in: Serial flasher config*

The SPI flash frequency to be used.

Available options:

- 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.
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)
- 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*
Partition Table

Contains:

- `CONFIG_PARTITION_TABLE_TYPE`
- `CONFIG_PARTITION_TABLE_CUSTOM_FILENAME`
- `CONFIG_PARTITION_TABLE_OFFSET`
- `CONFIG_PARTITION_TABLE_MD5`

**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. Otherwise it’s possible to create a new custom partition CSV for your application.

*Available options:*

- Single factory app, no OTA (PARTITION_TABLE_SINGLE_APP)
- Factory app, two OTA definitions (PARTITION_TABLE_TWO_OTA)
- Custom partition table CSV (PARTITION_TABLE_CUSTOM)

**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.

**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.

**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.
Compiler options

Contains:

- CONFIG_COMPILER_OPTIMIZATION
- CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL
- CONFIG_COMPILER_CXX_EXCEPTIONS
- CONFIG_COMPILER_CXX_RTTI
- CONFIG_COMPILER_STACK_CHECK_MODE
- CONFIG_COMPILER_WARN_WRITE_STRINGS
- CONFIG_COMPILER_DISABLE_GCC8_WARNINGS
- CONFIG_COMPILER_DUMP_RTL_FILES

**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 (-O0) (COMPILER_OPTIMIZATION_NONE)

**CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL**

Assertion level

*Found in: Compiler options*

Assertions can be:

- Enabled. Failure will print verbose assertion details. This is the default.
- Set to “silent” to save code size (failed assertions will abort() but user needs to use the aborting address to find the line number with the failed assertion.)
- Disabled entirely (not recommended for most configurations.) -DNDEBUG is added to CPPFLAGS in this case.

**Available options:**

- Enabled (COMPILER_OPTIMIZATION_ASSERTIONS_ENABLE)
- Silent (saves code size) (COMPILER_OPTIMIZATION_ASSERTIONS_SILENT)

Enable assertions. Assertion content and line number will be printed on failure.

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_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.

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.

**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.

**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

**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 *`.

**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.

**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:

• Application Level Tracing
• ESP-ASIO
• Bluetooth
• CONFIG_BLE_MESH
• CoAP Configuration
• Driver configurations
• eFuse Bit Manager
• ESP-TLS
• ESP32-specific
• ADC-Calibration
• Common ESP-related
• Ethernet
• Event Loop Library
• GDB Stub
• ESP HTTP client
• HTTP Server
• ESP HTTPS OTA
• ESP HTTPS server
• ESP NETIF Adapter
• Power Management
• ESP System Settings
• High resolution timer (esp_timer)
• Wi-Fi
• PHY
• Core dump
• FAT Filesystem support
• Modbus configuration
• FreeRTOS
• Heap memory debugging
• jsmn
• Log output
• LWIP
• mbedtls
• mDNS
• ESP-MQTT Configurations
• Newlib
• NVS
• OpenSSL
• PThreads
• SPI Flash driver
• SPIFFS Configuration
• TCP Transport
• TinyUSB
• Unity unit testing library
• Virtual file system
• Wear Levelling
• Wi-Fi Provisioning Manager
• Supplicant

**Application Level Tracing**  Contains:

- `CONFIG_APPTRACE_DESTINATION`
- `CONFIG_APPTRACE_ONPANIC_HOST_FLUSH_TMO`
- `CONFIG_APPTRACE_POSTMORTEM_FLUSH_THRESH`
- `CONFIG_APPTRACE_PENDING_DATA_SIZE_MAX`
- `FreeRTOS SystemView Tracing`
- `CONFIG_APPTRACE_GCOV_ENABLE`

**CONFIG_APPTRACE_DESTINATION**

Data Destination

*Found in: Component config > Application Level Tracing*

Select destination for application trace: trace memory or none (to disable).

**Available options:**

- Trace memory (`APTRACE_DEST_TRAX`)
- None (`APTRACE_DEST_NONE`)

**CONFIG_APPTRACE_ONPANIC_HOST_FLUSH_TMO**

Timeout for flushing last trace data to host on panic

*Found in: Component config > Application Level Tracing*

Timeout for flushing last trace data to host in case of panic. In ms. Use -1 to disable timeout and wait forever.
CONFIG_APPTRACE_POSTMORTEM_FLUSH_THRESH

Threshold for flushing last trace data to host on panic

*Found in: Component config > Application Level Tracing*

Threshold for flushing last trace data to host on panic in post-mortem mode. This is minimal amount of data needed to perform flush. In bytes.

CONFIG_APPTRACE_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_SYSVIEW_ENABLE`

CONFIG_SYSVIEW_ENABLE

SystemView Tracing Enable

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables support for SEGGER SystemView tracing functionality.

CONFIG_SYSVIEW_TS_SOURCE

Timer to use as timestamp source

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_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) (`SYSVIEW_TS_SOURCE_CCOUNT`)
- Timer 0, Group 0 (`SYSVIEW_TS_SOURCE_TIMER_00`)
- Timer 1, Group 0 (`SYSVIEW_TS_SOURCE_TIMER_01`)
- Timer 0, Group 1 (`SYSVIEW_TS_SOURCE_TIMER_10`)
- Timer 1, Group 1 (`SYSVIEW_TS_SOURCE_TIMER_11`)
- `esp_timer` high resolution timer (`SYSVIEW_TS_SOURCE_ESP_TIMER`)

CONFIG_SYSVIEW_MAX_TASKS

Maximum supported tasks

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Configures maximum supported tasks in sysview debug
CONFIG_SYSVIEW_BUF_WAIT_TMO

Trace buffer wait timeout

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Configures timeout (in us) to wait for free space in trace buffer. Set to -1 to wait forever and avoid lost events.

CONFIG_SYSVIEW_EVT_OVERFLOW_ENABLE

Trace Buffer Overflow Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Enables “Trace Buffer Overflow” event.

CONFIG_SYSVIEW_EVT_ISR_ENTER_ENABLE

ISR Enter Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Enables “ISR Enter” event.

CONFIG_SYSVIEW_EVT_ISR_EXIT_ENABLE

ISR Exit Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Enables “ISR Exit” event.

CONFIG_SYSVIEW_EVT_ISR_TO_SCHEDULER_ENABLE

ISR Exit to Scheduler Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Enables “ISR to Scheduler” event.

CONFIG_SYSVIEW_EVT_TASK_START_EXEC_ENABLE

Task Start Execution Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Enables “Task Start Execution” event.

CONFIG_SYSVIEW_EVT_TASK_STOP_EXEC_ENABLE

Task Stop Execution Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Enables “Task Stop Execution” event.
**CONFIG_SYSVIEW_EVT_TASK_START_READY_ENABLE**

Task Start Ready State Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Enables “Task Start Ready State” event.

**CONFIG_SYSVIEW_EVT_TASK_STOP_READY_ENABLE**

Task Stop Ready State Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Enables “Task Stop Ready State” event.

**CONFIG_SYSVIEW_EVT_TASK_CREATE_ENABLE**

Task Create Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Enables “Task Create” event.

**CONFIG_SYSVIEW_EVT_TASK_TERMINATE_ENABLE**

Task Terminate Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Enables “Task Terminate” event.

**CONFIG_SYSVIEW_EVT_IDLE_ENABLE**

System Idle Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Enables “System Idle” event.

**CONFIG_SYSVIEW_EVT_TIMER_ENTER_ENABLE**

Timer Enter Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Enables “Timer Enter” event.

**CONFIG_SYSVIEW_EVT_TIMER_EXIT_ENABLE**

Timer Exit Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_SYSVIEW_ENABLE*

Enables “Timer Exit” event.
CONFIG_APTRACE_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.

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)

Bluetooth Contains:

- **CONFIG_BT_ENABLED**
- Bluetooth controller
- **CONFIG_BT_HOST**
- Bluedroid Options
- 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_MODE**
- **CONFIG_BTDM_CTRL_BLE_MAXCONN**
- **CONFIG_BTDM_CTRL_BR_EDR_MAX_ACL_CONN**
- **CONFIG_BTDM_CTRL_BR_EDR_MAX_SYNC_CONN**
- **CONFIG_BTDM_CTRL_BR_EDR_SCO_DATA_PATH**
- **CONFIG_BTDM_CTRL_PCM_ROLE_EDGE_CONFIG**
- **CONFIG_BTDM_CTRL_AUTO_LATENCY**
- **CONFIG_BTDM_CTRL_LEGACY_AUTH_VENDOR_EVT**
Chapter 2. API

- CONFIG_BTDM_CTRL_PINNED_TO_CORE_CHOICE
- CONFIG_BTDM_CTRL_HCI_MODE_CHOICE
- HCI UART(H4) Options
- MODEM SLEEP Options
- CONFIG_BTDM_BLE_SLEEP_CLOCK_ACCURACY
- CONFIG_BTDM_BLE_SCAN_DUPL
- CONFIG_BTDM_CTRL_FULL_SCAN_SUPPORTED
- CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP
- CONFIG_BTDM_COEX_BT_OPTIONS

**CONFIG_BTDM_CTRL_MODE**

Bluetooth controller mode (BR/EDR/BLE/DUALMODE)

*Found in: Component config > Bluetooth > 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 > Bluetooth controller*

BLE maximum connections of bluetooth controller. Each connection uses 1KB static DRAM whenever the BT controller is enabled.

**CONFIG_BTDM_CTRL_BR_EDR_MAX_ACL_CONN**

BR/EDR ACL Max Connections

*Found in: Component config > Bluetooth > Bluetooth controller*

BR/EDR ACL maximum connections of bluetooth controller. Each connection uses 1.2KB static DRAM whenever the BT controller is enabled.

**CONFIG_BTDM_CTRL_BR_EDR_MAX_SYNC_CONN**

BR/EDR Sync(SCO/eSCO) Max Connections

*Found in: Component config > Bluetooth > Bluetooth controller*

BR/EDR Synchronize maximum connections of bluetooth controller. Each connection uses 2KB static DRAM whenever the BT controller is enabled.

**CONFIG_BTDM_CTRL_BR_EDR_SCO_DATA_PATH**

BR/EDR Sync(SCO/eSCO) default data path

*Found in: Component config > Bluetooth > 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 > Bluetooth controller

Contains:

- CONFIG_BTDM_CTRL_PCM_ROLE
- CONFIG_BTDM_CTRL_PCM_POLAR

CONFIG_BTDM_CTRL_PCM_ROLE

PCM Role

*Found in:* Component config > Bluetooth > 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 > 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 > Bluetooth controller

BLE auto latency, used to enhance classic BT performance while classic BT and BLE are enabled at the same time.

CONFIG_BTDM_CTRL_LEDISGENCY_AUTH_VENDOR_EVT

Legacy Authentication Vendor Specific Event Enable

*Found in:* Component config > Bluetooth > Bluetooth controller

To protect from BIAS attack during Legacy authentication, Legacy authentication Vendor specific event should be enabled.

CONFIG_BTDM_CTRL_PINNED_TO_CORE_CHOICE

The cpu core which bluetooth controller run

*Found in:* Component config > Bluetooth > 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 > 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 runs on ESP32, too.
- UART(H4) (BTDM_CTRL_HCI_MODE_UART_H4)
  - If using an external Bluetooth host which runs on other hardware and uses UART as the HCI interface, choose this option.

**HCI UART(H4) Options**

Contains:

- `CONFIG_BT_HCI_UART_NO`
- `CONFIG_BT_HCI_UART_BAUDRATE`

**CONFIG_BT_HCI_UART_NO**

UART Number for HCI

*Found in: Component config > Bluetooth > Bluetooth controller > HCI UART(H4) Options*

Uart number for HCI. The available uart is UART1 and UART2.

**CONFIG_BT_HCI_UART_BAUDRATE**

UART Baudrate for HCI

*Found in: Component config > Bluetooth > Bluetooth controller > HCI UART(H4) Options*

UART Baudrate for HCI. Please use standard baudrate.

**MODEM SLEEP Options**

Contains:

- `CONFIG_BTDM_MODEM_SLEEP`
- `CONFIG_BTDM_LOW_POWER_CLOCK`

**CONFIG_BTDM_MODEM_SLEEP**

Bluetooth modem sleep

*Found in: Component config > Bluetooth > Bluetooth controller > MODEM SLEEP Options*

Enable/disable Bluetooth controller low power mode.

**CONFIG_BTDM_MODEM_SLEEP_MODE**

Bluetooth modem sleep mode

*Found in: Component config > Bluetooth > Bluetooth controller > MODEM SLEEP Options > CONFIG_BTDM_MODEM_SLEEP*

To select which strategy to use for modem sleep

**Available options:**

- ORIG Mode (sleep with low power clock) (BTDM_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_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_LOW_POWER_CLOCK**

Bluetooth low power clock

*Found in: Component config > Bluetooth > 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_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_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 > 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 > Bluetooth controller*

This select enables parameters setting of BLE scan duplicate.
CONFIG_BTDM_SCAN_DUPL_TYPE

Scan Duplicate Type

*Found in: Component config > Bluetooth > 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 > 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.

CONFIG_BTDM_BLE_MESH_SCAN_DUPL_EN

Special duplicate BLE Mesh scan mechanism for BLE Mesh scan

*Found in: Component config > Bluetooth > Bluetooth controller > CONFIG_BTDM_BLE_SCAN_DUPL > CONFIG_BTDM_BLE_MESH_SCAN_DUPL_EN*

This enables the BLE scan duplicate for special BLE Mesh scan.

CONFIG_BTDM_MESH_DUPL_SCAN_CACHE_SIZE

Maximum number of Mesh adv packets in scan duplicate filter

*Found in: Component config > Bluetooth > 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.

CONFIG_BTDM_CTRL_FULL_SCAN_SUPPORTED

BLE full scan feature supported

*Found in: Component config > Bluetooth > 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.
Chapter 2. API 参考

**CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP**

BLE adv report flow control supported

*Found in: Component config > Bluetooth > 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.

**CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_NUM**

BLE adv report flow control number

*Found in: Component config > Bluetooth > 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.

**CONFIG_BTDM_BLE_ADV_REPORT_DISCARD_THRESHOLD**

BLE adv lost event threshold value

*Found in: Component config > Bluetooth > 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.

**CONFIG_BTDM_COEX_BT_OPTIONS**

Coexistence Bluetooth Side Options

*Found in: Component config > Bluetooth > Bluetooth controller*

Options of Bluetooth Side of WiFi and bluetooth coexistence.

Contains:

- `CONFIG_BTDM_COEX_BLE_ADV_HIGH_PRIORITY`

**CONFIG_BTDM_COEX_BLE_ADV_HIGH_PRIORITY**

Improve BLE ADV priority for WiFi & BLE coexistence

*Found in: Component config > Bluetooth > Bluetooth controller > CONFIG_BTDM_COEX_BT_OPTIONS*

Improve BLE ADV coexistence priority to make it better performance. For example, BLE mesh need to enable this option to improve BLE adv performance.

**CONFIG_BT_HOST**

Bluetooth Host

*Found in: Component config > Bluetooth*

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 use cases
- NimBLE - BLE only (BT_NIMBLE_ENABLED)
  This option is recommended for BLE only use cases 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_BTC_TASK_STACK_SIZE
- CONFIG_BT_BLUEDROID_PINNED_TO_CORE_CHOICE
- CONFIG_BT_BTU_TASK_STACK_SIZE
- CONFIG_BT_BLUEDROID_MEM_DEBUG
- CONFIG_BT_CLASSIC_ENABLED
- CONFIG_BT_HFP_WBS_ENABLE
- CONFIG_BT_HID_HOST_ENABLED
- CONFIG_BT_SSP_ENABLED
- CONFIG_BT_BLE_ENABLED
- CONFIG_BT_STACK_NO_LOG
- BT_DEBUG_LOG_LEVEL
- CONFIG_BT_ACL_CONNECTIONS
- CONFIG_BT_ALLOCATION_FROM_SPIRAM_FIRST
- CONFIG_BT_BLE_DYNAMIC_ENV_MEMORY
- CONFIG_BT_BLE_HOST_QUEUE_CONG_CHECK
- CONFIG_BT_BLE_ACT_SCAN_REP_ADV_SCAN
- CONFIG_BT_BLE_ESTAB_LINK_CONN_TOUT

CONFIG_BT_BTC_TASK_STACK_SIZE

Bluetooth event (callback to application) task stack size

Found in: Component config > Bluetooth > Bluedroid Options

This select btc task stack size

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
CONFIG_BT_BLUEDROID_MEM_DEBUG

Bluedroid memory debug

*Found in:* Component config > Bluetooth > Bluedroid Options

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

CONFIG_BT_A2DP_ENABLE

A2DP

*Found in:* Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED

Advanced Audio Distributation Profile

CONFIG_BT_SPP_ENABLED

SPP

*Found in:* Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED

This enables the Serial Port Profile

CONFIG_BT_HFP_ENABLE

Hands Free/Handset Profile

*Found in:* Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_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 > Bluez

This enables Wide Band Speech. Should disable it when SCO data path is PCM. Otherwise there will be no data transmitted via GPIOs.

CONFIG_BT_HID_HOST_ENABLED
Classic BT HID Host

Found in: Component config > Bluetooth > Bluez

This enables the BT HID Host

CONFIG_BT_SSP_ENABLED
Secure Simple Pairing

Found in: Component config > Bluetooth > Bluez

This enables the Secure Simple Pairing. If disable this option, Bluez will only support Legacy Pairing

CONFIG_BT_BLE_ENABLED
Bluetooth Low Energy

Found in: Component config > Bluetooth > Bluez

This enables Bluetooth Low Energy

CONFIG_BT_GATTS_ENABLE
Include GATT server module(GATTS)

Found in: Component config > Bluetooth > Bluez > Bluez Options > CONFIG_BT_BLE_ENABLED

This option can be disabled when the app work only on gatt client mode

CONFIG_BT_GATTS_PPP_CP_CHAR_GAP
Enable Peripheral Preferred Connection Parameters characteristic in GAP service

Found in: Component config > Bluetooth > Bluez Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTS_ENABLED

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

CONFIG_BT_GATTS_SEND_SERVICE_CHANGE_MODE
GATTS Service Change Mode

Found in: Component config > Bluetooth > Bluez Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTS_ENABLED

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

**CONFIG_BT_GATTC_CACHE_NVS_FLASH**

Save gatt cache data to nvs flash

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTC_ENABLE*

This select can save gattc cache data to nvs flash

**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.

**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.

**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

**BT DEBUG LOG LEVEL**  Contains:

- **CONFIG_BT_LOG_HCI_TRACE_LEVEL**
- **CONFIG_BT_LOG_BTM_TRACE_LEVEL**
- **CONFIG_BT_LOG_L2CAP_TRACE_LEVEL**
- **CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL**
- **CONFIG_BT_LOG_SDPA_TRACE_LEVEL**
- **CONFIG_BT_LOG_GAP_TRACE_LEVEL**
- **CONFIG_BT_LOG_BNEP_TRACE_LEVEL**
- **CONFIG_BT_LOG_PAN_TRACE_LEVEL**
- **CONFIG_BT_LOG_A2D_TRACE_LEVEL**
- **CONFIG_BT_LOG_AVDT_TRACE_LEVEL**
- **CONFIG_BT_LOG_AVCT_TRACE_LEVEL**
- **CONFIG_BT_LOG_AVRC_TRACE_LEVEL**
- **CONFIG_BT_LOG_MCA_TRACE_LEVEL**
- **CONFIG_BT_LOG_HID_TRACE_LEVEL**
**Chapter 2. API**

- `CONFIG_BT_LOG_APPL_TRACE_LEVEL`
- `CONFIG_BT_LOG_GATT_TRACE_LEVEL`
- `CONFIG_BT_LOG_SMP_TRACE_LEVEL`
- `CONFIG_BT_LOG_BTIF_TRACE_LEVEL`
- `CONFIG_BT_LOG_BTIF_TRACE_LEVEL`
- `CONFIG_BT_LOG_OSI_TRACE_LEVEL`
- `CONFIG_BT_LOG_BTM_TRACE_LEVEL`
- `CONFIG_BT_LOG_HCI_TRACE_LEVEL`
- `CONFIG_BT_LOG_BTM_TRACE_LEVEL`

**CONFIG_BT_LOG_HCI_TRACE_LEVEL**

HCl 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)
Chapter 2. API

• EVENT (BT_LOG_BNEP_TRACE_LEVEL_EVENT)
• DEBUG (BT_LOG_BNEP_TRACE_LEVEL_DEBUG)
• VERBOSE (BT_LOG_BNEP_TRACE_LEVEL_VERBOSE)

CONFIG_BT_LOG_PAN_TRACE_LEVEL

PAN layer

Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL

Define BT trace level for PAN layer

Available options:
• NONE (BT_LOG_PAN_TRACE_LEVEL_NONE)
• ERROR (BT_LOG_PAN_TRACE_LEVEL_ERROR)
• WARNING (BT_LOG_PAN_TRACE_LEVEL_WARNING)
• API (BT_LOG_PAN_TRACE_LEVEL_API)
• EVENT (BT_LOG_PAN_TRACE_LEVEL_EVENT)
• DEBUG (BT_LOG_PAN_TRACE_LEVEL_DEBUG)
• VERBOSE (BT_LOG_PAN_TRACE_LEVEL_VERBOSE)

CONFIG_BT_LOG_A2D_TRACE_LEVEL

A2D layer

Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL

Define BT trace level for A2D layer

Available options:
• NONE (BT_LOG_A2D_TRACE_LEVEL_NONE)
• ERROR (BT_LOG_A2D_TRACE_LEVEL_ERROR)
• WARNING (BT_LOG_A2D_TRACE_LEVEL_WARNING)
• API (BT_LOG_A2D_TRACE_LEVEL_API)
• EVENT (BT_LOG_A2D_TRACE_LEVEL_EVENT)
• DEBUG (BT_LOG_A2D_TRACE_LEVEL_DEBUG)
• VERBOSE (BT_LOG_A2D_TRACE_LEVEL_VERBOSE)

CONFIG_BT_LOG_AVDT_TRACE_LEVEL

AVDT layer

Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL

Define BT trace level for AVDT layer

Available options:
• NONE (BT_LOG_AVDT_TRACE_LEVEL_NONE)
• ERROR (BT_LOG_AVDT_TRACE_LEVEL_ERROR)
• WARNING (BT_LOG_AVDT_TRACE_LEVEL_WARNING)
• API (BT_LOG_AVDT_TRACE_LEVEL_API)
• EVENT (BT_LOG_AVDT_TRACE_LEVEL_EVENT)
• DEBUG (BT_LOG_AVDT_TRACE_LEVEL_DEBUG)
• VERBOSE (BT_LOG_AVDT_TRACE_LEVEL_VERBOSE)

CONFIG_BT_LOG_AVCT_TRACE_LEVEL

AVCT layer

Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL

Define BT trace level for AVCT layer

Available options:
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 > Bluedroid 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 > Bluedroid 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_LEVELVERBOSE)
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_ACLgetConnections

BT/BLE MAX ACL CONNECTIONS(1~7)

*Found in:* Component config > Bluetooth > Bluedroid Options

Maximum BT/BLE connection count
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

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

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.

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

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.

NimBLE Options
Contains:

- CONFIG_BT_NIMBLE_MEM_ALLOC_MODE
- CONFIG_BT_NIMBLE_MAX_CONNECTIONS
- CONFIG_BT_NIMBLE_MAX_BONDS
- CONFIG_BT_NIMBLE_MAX_CCCDS
- CONFIG_BT_NIMBLE_L2CAP_COC_MAX_NUM
- CONFIG_BT_NIMBLE_PINNED_TO_CORE_CHOICE
- CONFIG_BT_NIMBLE_TASK_STACK_SIZE
- CONFIG_BT_NIMBLE_ROLE_CENTRAL
- CONFIG_BT_NIMBLE_ROLE_PERIPHERAL
- CONFIG_BT_NIMBLE_ROLE_BROADCASTER
- CONFIG_BT_NIMBLE_ROLE_OBSERVER
- CONFIG_BT_NIMBLE_NVS_PERSIST
- CONFIG_BT_NIMBLE_SM_LEGACY
- CONFIG_BT_NIMBLE_SM_SC
• CONFIG_BT_NIMBLE_DEBUG
• CONFIG_BT_NIMBLE_SM_SC_DEBUG_KEYS
• CONFIG_BT_NIMBLE_SVC_GAP_DEVICE_NAME
• CONFIG_BT_NIMBLE_GAP_DEVICE_NAME_MAX_LEN
• CONFIG_BT_NIMBLE_ATT_PREFERRED_MTU
• CONFIG_BT_NIMBLE_SVC_GAP_APPEARANCE
• CONFIG_BT_NIMBLE_ACL_BUF_COUNT
• CONFIG_BT_NIMBLE_ACL_BUF_SIZE
• 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_MSYS1_BLOCK_COUNT
• CONFIG_BT_NIMBLE_HS_FLOW_CTRL
• CONFIG_BT_NIMBLE_RPA_TIMEOUT
• CONFIG_BT_NIMBLE_MESH
• CONFIG_BT_NIMBLE_CRYPTO_STACK_MBEDTLS

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

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.

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_MAX_CONNECTIONS
Maximum number of concurrent connections

Found in: Component config > Bluetooth > NimBLE Options

Defines maximum number of concurrent BLE connections

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
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

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

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

CONFIG_BT_NIMBLE_ROLE_CENTRAL
Enable BLE Central role

*Found in: Component config > Bluetooth > NimBLE Options*

CONFIG_BT_NIMBLE_ROLE_PERIPHERAL
Enable BLE Peripheral role

*Found in: Component config > Bluetooth > NimBLE Options*

CONFIG_BT_NIMBLE_ROLE_BROADCASTER
Enable BLE Broadcaster role

*Found in: Component config > Bluetooth > NimBLE Options*

CONFIG_BT_NIMBLE_ROLE_OBSERVER
Enable BLE Observer role

*Found in: Component config > Bluetooth > NimBLE Options*
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

CONFIG_BT_NIMBLE_SM_LEGACY
Security manager legacy pairing
*Found in: Component config > Bluetooth > NimBLE Options*
Enable security manager legacy pairing

CONFIG_BT_NIMBLE_SM_SC
Security manager secure connections (4.2)
*Found in: Component config > Bluetooth > NimBLE Options*
Enable security manager secure connections

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

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.

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()

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
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()

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

CONFIG_BT_NIMBLE_ACL_BUF_COUNT

ACL Buffer count

*Found in: Component config > Bluetooth > NimBLE Options*

The number of ACL data buffers.

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)

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

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

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
**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.

**CONFIG_BT_NIMBLE_HS_FLOW_CTRL**

Enable Host Flow control

*Found in: Component config > Bluetooth > NimBLE Options*

Enable Host Flow control

**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

**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

**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

**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

**CONFIG_BT_NIMBLE_MESH**

Enable BLE mesh functionality

*Found in: Component config > Bluetooth > NimBLE Options*

Enable BLE Mesh functionality

Contains:

- `CONFIG_BT_NIMBLE_MESH_PROXY`
- `CONFIG_BT_NIMBLE_MESH_PROV`
- `CONFIG_BT_NIMBLE_MESH_GATT_PROXY`
- `CONFIG_BT_NIMBLE_MESH_RELAY`
- `CONFIG_BT_NIMBLE_MESH_LOW_POWER`
- `CONFIG_BT_NIMBLE_MESH_FRIEND`
- `CONFIG_BT_NIMBLE_MESH_DEVICE_NAME`

**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.

**CONFIG_BT_NIMBLE_MESH_PROV**

Enable BLE mesh provisioning

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH*

Enable mesh provisioning.

**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.

**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.

**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.

**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.

**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.
**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

**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

**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.

**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:

- `CONFIG_BLE_MESH_HCI_5_0`
- `CONFIG_BLE_MESH_USE_DUPLICATE_SCAN`
- `CONFIG_BLE_MESH_MEM_ALLOC_MODE`
- `CONFIG_BLE_MESH_FREERTOS_STATIC_ALLOC`
- `CONFIG_BLE_MESH_FAST_PROV`
- `CONFIG_BLE_MESH_NODE`
- `CONFIG_BLE_MESH_PROVISIONER`
- `CONFIG_BLE_MESH_PROV`
- `CONFIG_BLE_MESH_PB_ADV`
- `CONFIG_BLE_MESH_PB_GATT`
- `CONFIG_BLE_MESH_PROXY`
- `CONFIG_BLE_MESH_GATT_PROXY_SERVER`
- `CONFIG_BLE_MESH_GATT_PROXY_CLIENT`
- `CONFIG_BLE_MESH_SETTINGS`
- `CONFIG_BLE_MESH_SUBNET_COUNT`
- `CONFIG_BLE_MESH_APP_KEY_COUNT`
- `CONFIG_BLE_MESH_MODEL_KEY_COUNT`
- `CONFIG_BLE_MESH_MODEL_GROUP_COUNT`
- `CONFIG_BLE_MESH_LABEL_COUNT`
- `CONFIG_BLE_MESH_CRPL`
- `CONFIG_BLE_MESH_MSG_CACHE_SIZE`
- `CONFIG_BLE_MESH_ADV_BUF_COUNT`
- `CONFIG_BLE_MESH_SUPPORT_BLE_ADV`
- `CONFIG_BLE_MESH_IVU_DIVIDER`
- `CONFIG_BLE_MESH_TX_SEG_MSG_COUNT`
- `CONFIG_BLE_MESH_RX_SEG_MSG_COUNT`
- `CONFIG_BLE_MESH_RX_SDU_MAX`
Chapter 2. API

- `CONFIG_BLE_MESH_TX_SEG_MAX`
- `CONFIG_BLE_MESH_RELAY`
- `CONFIG_BLE_MESH_LOW_POWER`
- `CONFIG_BLE_MESH_FRIEND`
- `CONFIG_BLE_MESH_NO_LOG`
- `BLE Mesh STACK DEBUG LOG LEVEL`
- `BLE Mesh NET BUF DEBUG LOG LEVEL`
- `CONFIG_BLE_MESH_CLIENT_MSG_TIMEOUT`
- Support for BLE Mesh Client Models
- `CONFIG_BLE_MESH_IV_UPDATE_TEST`
- BLE Mesh specific test option

**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.

**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”.

**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.

**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.

**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_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.

**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).

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.

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.

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.

CONFIG_BLE_MESH_PROVISIONER_SUBNET_COUNT

Maximum number of mesh subnets that can be created by Provisioner

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_PROVISIONER*

This option specifies how many subnets per network a Provisioner can create. Indeed, this value decides the number of network keys which can be added by a Provisioner.

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.
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.

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.

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.

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.

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.
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.

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.

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.

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.

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.

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.
**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.

**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.

**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.

**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.

**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.
**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.

**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.

**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.

**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.

**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.

**CONFIG_BLE_MESH_ADV_BUF_COUNT**

Number of advertising buffers

*Found in: Component config > CONFIG_BLE_MESH*

Number of advertising buffers available. The transport layer reserves ADV_BUF_COUNT - 3 buffers for outgoing segments. The maximum outgoing SDU size is 12 times this value (out of which 4 or 8 bytes are used for the Transport Layer MIC). For example, 5 segments means the maximum SDU size is 60 bytes, which leaves 56 bytes for application layer data using a 4-byte MIC, or 52 bytes using an 8-byte MIC.
CONFIG_BLE_MESH_SUPPORT_BLE_ADV

Support sending normal BLE advertising packets

*Found in: Component config > CONFIG_BLE_MESH*

When selected, users can send normal BLE advertising packets with specific API.

CONFIG_BLE_MESH_BLE_ADV_BUF_COUNT

Number of advertising buffers for BLE advertising packets

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_SUPPORT_BLE_ADV*

Number of advertising buffers for BLE packets available.

CONFIG_BLE_MESH_IVU_DIVIDER

Divider for IV Update state refresh timer

*Found in: Component config > CONFIG_BLE_MESH*

When the IV Update state enters Normal operation or IV Update in Progress, we need to keep track of how many hours has passed in the state, since the specification requires us to remain in the state at least for 96 hours (Update in Progress has an additional upper limit of 144 hours).

In order to fulfill the above requirement, even if the node might be powered off once in a while, we need to store persistently how many hours the node has been in the state. This doesn’t necessarily need to happen every hour (thanks to the flexible duration range). The exact cadence will depend a lot on the ways that the node will be used and what kind of power source it has.

Since there is no single optimal answer, this configuration option allows specifying a divider, i.e. how many intervals the 96 hour minimum gets split into. After each interval the duration that the node has been in the current state gets stored to flash. E.g. the default value of 4 means that the state is saved every 24 hours (96 / 4).

CONFIG_BLE_MESH_TX_SEG_MSG_COUNT

Maximum number of simultaneous outgoing segmented messages

*Found in: Component config > CONFIG_BLE_MESH*

Maximum number of simultaneous outgoing multi-segment and/or reliable messages. The default value is 1, which means the device can only send one segmented message at a time. And if another segmented message is going to be sent, it should wait for the completion of the previous one. If users are going to send multiple segmented messages at the same time, this value should be configured properly.

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.
**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.

**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.

**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.

**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.

**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.

**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.

**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.

**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.

**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.

**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.

**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.
**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 PDU that the Friend node can store in its Friend Queue. As an example, MinQueueSizeLog value 1 gives \( N = 2 \), and value 7 gives \( N = 128 \).

**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.

**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.

**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.

**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.

**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.
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.

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.

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.

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.

CONFIG_BLE_MESH_FRIEND_SEG_RX
Number of incomplete segment lists per LPN

*Found in:* Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_FRIEND

Number of incomplete segment lists tracked for each Friends’ LPN. In other words, this determines from how many elements can segmented messages destined for the Friend queue be received simultaneously.

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.
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.

Support for BLE Mesh Client Models  Contains:
  •  CONFIG_BLE_MESH_CFG_CLI
  •  CONFIG_BLE_MESH_HEALTH_CLI
  •  CONFIG_BLE_MESH_GENERIC_ONOFF_CLI
  •  CONFIG_BLE_MESH_GENERIC_LEVEL_CLI
  •  CONFIG_BLE_MESH_GENERIC_DEF_TRANS_TIME_CLI
  •  CONFIG_BLE_MESH_GENERIC_POWER_ONOFF_CLI
  •  CONFIG_BLE_MESH_GENERIC_POWER_LEVEL_CLI
  •  CONFIG_BLE_MESH_GENERIC_BATTERY_CLI
  •  CONFIG_BLE_MESH_GENERIC_LOCATION_CLI
Chapter 2. API

- CONFIG_BLE_MESH_GENERICPROPERTY_CLI
- CONFIG_BLE_MESH_SENSORENCLI
- CONFIG_BLE_MESH_TIMELCLI
- CONFIG_BLE_MESH_SCENE_CLI
- CONFIG_BLE_MESH_SCHEDULER_CLI
- CONFIG_BLE_MESH_LIGHT_LIGHTNESS_CLI
- CONFIG_BLE_MESH_LIGHT_CTL_CLI
- CONFIG_BLE_MESH_LIGHT_HSL_CLI
- CONFIG_BLE_MESH_LIGHT_XYL_CLI
- CONFIG_BLE_MESH_LIGHT_LC_CLI

CONFIG_BLE_MESH_CFG_CLI
Configuration Client Model

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client 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 Client Models*

Enable support for Health client model.

CONFIG_BLE_MESH_GENERIC_ONOFF_CLI
Generic OnOff Client Model

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client 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 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 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 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 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 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 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 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 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 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 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 Models
Enable support for Scheduler client model.
Chapter 2. API Reference

**CONFIG_BLE_MESH_LIGHT_LIGHTNESS_CLI**
Light Lightness Client Model

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client 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 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 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 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 Models*
Enable support for Light LC client model.

**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.

**BLE Mesh specific test option**
Contains:

- **CONFIG_BLE_MESH_SELF_TEST**
- **CONFIG_BLE_MESH_SHELL**
- **CONFIG_BLE_MESH_DEBUG**

**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.
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 enter the 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.

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.

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.

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.

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.

**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)
**Driver configurations**  Contains:

- *ADC configuration*
- *SPI configuration*
- *TWAI configuration*
- *UART configuration*
- *RTCIO configuration*

**ADC configuration**  Contains:

- *CONFIG_ADC_FORCE_XPD_FSM*
- *CONFIG_ADC_DISABLE_DAC*

**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.

**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.

**SPI configuration**  Contains:

- *CONFIG_SPI_MASTER_IN_IRAM*
- *CONFIG_SPI_MASTER_ISR_IN_IRAM*
- *CONFIG_SPI_SLAVE_IN_IRAM*
- *CONFIG_SPI_SLAVE_ISR_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.

**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.

**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.

**CONFIG_SPI_SLAVE_ISR_IN_IRAM**

Place SPI slave ISR function into IRAM

*Found in: Component config > Driver configurations > SPI configuration*

Place the SPI slave ISR in to IRAM to avoid possible cache miss.

Also you can forbid the ISR being disabled during flash writing access, by add ESP_INTR_FLAG_IRAM when initializing the driver.

**TWAI configuration** Contains:

- **CONFIG_TWAI_ISR_IN_IRAM**

**CONFIG_TWAI_ISR_IN_IRAM**

Place TWAI ISR function into IRAM

*Found in: Component config > Driver configurations > TWAI configuration*

Place the TWAI ISR in to IRAM. This will allow the ISR to avoid cache misses, and also be able to run whilst the cache is disabled (such as when writing to SPI Flash). Note that if this option is enabled: - Users should also set the ESP_INTR_FLAG_IRAM in the driver configuration structure when installing the driver (see docs for specifics). - Alert logging (i.e., setting of the TWAI_ALERT_AND_LOG flag) will have no effect.

**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.

**RTCIO configuration** Contains:

- **CONFIG_RTCIO_SUPPORT_RTC_GPIO_DESC**
CONFIG_RTCIO_SUPPORT_RTC_GPIO_DESC

Support array \texttt{rtc_gpio_desc} for ESP32

*Found in: Component config \textgreater{} Driver configurations \textgreater{} RTCIO configuration*

The array \texttt{rtc_gpio_desc} will not compile by default. If this option is selected, the array \texttt{rtc_gpio_desc} can be compiled. If user use this array, please enable this configuration.

eFuse Bit Manager   \hspace{1cm} \text{Contains:}

- \texttt{CONFIG_EFUSE_CUSTOM_TABLE}
- \texttt{CONFIG_EFUSE_VIRTUAL}
- \texttt{CONFIG_EFUSE_CODE_SCHEME_SELECTOR}

CONFIG_EFUSE_CUSTOM_TABLE

Use custom eFuse table

*Found in: Component config \textgreater{} eFuse Bit Manager*

Allows to generate a structure for eFuse from the CSV file.

CONFIG_EFUSE_CUSTOM_TABLE_FILENAME

Custom eFuse CSV file

*Found in: Component config \textgreater{} eFuse Bit Manager \textgreater{} CONFIG_EFUSE_CUSTOM_TABLE*

Name of the custom eFuse CSV filename. This path is evaluated relative to the project root directory.

CONFIG_EFUSE_VIRTUAL

Simulate eFuse operations in RAM

*Found in: Component config \textgreater{} eFuse Bit Manager*

All read and write operations are redirected to RAM instead of eFuse registers. If this option is set, all permanent changes (via eFuse) are disabled. Log output will state changes which would be applied, but they will not be.

CONFIG_EFUSE_CODE_SCHEME_SELECTOR

Coding Scheme Compatibility

*Found in: Component config \textgreater{} eFuse Bit Manager*

Selector eFuse code scheme.

**Available options:**
- None Only (EFUSE_CODE_SCHEME_COMPAT_NONE)
- 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   \hspace{1cm} \text{Contains:}

- \texttt{CONFIG_ESP_TLS_LIBRARY_CHOOSE}
- \texttt{CONFIG_ESP_TLS_USE_SECURE_ELEMENT}
- \texttt{CONFIG_ESP_TLS_SERVER}
- \texttt{CONFIG_ESP_TLS_PSK_VERIFICATION}
- \texttt{CONFIG_ESP_WOLFSSL_SMALL_CERT_VERIFY}
- \texttt{CONFIG_ESP_DEBUG_WOLFSSL}
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_USINGMBEDTLS)
- wolfSSL (License info in wolfSSL directory README) (ESP_TLS_USINGWOLFSSL)

CONFIG_ESP_TLS_USE_SECURE_ELEMENT
Use Secure Element (ATECC608A) with ESP-TLS

Found in: Component config > ESP-TLS

Enable use of Secure Element for ESP-TLS, this enables internal support for ATECC608A peripheral on ESPWROOM32SE, which can be used for TLS connection.

CONFIG_ESP_TLS_SERVER
Enable ESP-TLS Server

Found in: Component config > ESP-TLS

Enable support for creating server side SSL/TLS session, available for mbedTLS as well as wolfSSL TLS library.

CONFIG_ESP_TLS_PSK_VERIFICATION
Enable PSK verification

Found in: Component config > ESP-TLS

Enable support for pre shared key ciphers, supported for both mbedTLS as well as wolfSSL TLS library.

CONFIG_ESP_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).

CONFIG_ESP_DEBUG_WOLFSSL
Enable debug logs for wolfSSL

Found in: Component config > ESP-TLS

Enable detailed debug prints for wolfSSL SSL library.
**ESP32-specific** Contains:

- `CONFIG_ESP32_REV_MIN`
- `CONFIG_ESP32_DEFAULT_CPU_FREQ_MHZ`
- `CONFIG_ESP32_SPIRAM_SUPPORT`
- `CONFIG_ESP32_TRAX`
- `CONFIG_ESP32_UNIVERSAL_MAC_ADDRESSES`
- `CONFIG_ESP32_ULP_COPROC_ENABLED`
- `CONFIG_ESP32_DEBUG_OCDAware`
- `CONFIG_ESP32_BROWNOUT_DET`
- `CONFIG_ESP32_REDUCE_PHY_TX_POWER`
- `CONFIG_ESP32_TIME_SYSCALL`
- `CONFIG_ESP32_RTC_CLK_SRC`
- `CONFIG_ESP32_RTC_EXT_CRYST_ADDIT_CURRENT`
- `CONFIG_ESP32_RTC_CLK_CAL_CYCLES`
- `CONFIG_ESP32_RTC_XTAL_CAL_RETRY`
- `CONFIG_ESP32_DEEP_SLEEP_WAKEUP_DELAY`
- `CONFIG_ESP32_XTAL_FREQ_SEL`
- `CONFIG_ESP32_DISABLE_BASIC_ROM_CONSOLE`
- `CONFIG_ESP32_NO_BLOBS`
- `CONFIG_ESP32_COMPATIBLE_PRE_V2_1_BOOTLOADERS`
- `CONFIG_ESP32_RTCDATA_IN_FAST_MEM`
- `CONFIG_ESP32_USE_FIXED_STATIC_RAM_SIZE`
- `CONFIG_ESP32_DPORT_DIS_INTERRUPT_LVL`
- `CONFIG_ESP32_IRAM_AS_8BIT_ACCESSIBLE_MEMORY`
- `CONFIG_ESP32_ALLOW_RTC_FAST_MEM_AS_HEAP`

**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:*
- 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.
**SPI RAM config**

Contains:

- `CONFIG_SPIRAM_TYPE`
- `CONFIG_SPIRAM_SPEED`
- `CONFIG_SPIRAM_BOOT_INIT`
- `CONFIG_SPIRAM_USE`
- `CONFIG_SPIRAM_MEMTEST`
- `CONFIG_SPIRAM_MALLOC_ALWAYSINTERNAL`
- `CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP`
- `CONFIG_SPIRAM_MALLOC_RESERVE_INTERNAL`
- `CONFIG_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY`
- `CONFIG_SPIRAM_CACHE_WORKAROUND`
- `SPIRAM cache workaround debugging`
- `CONFIG_SPIRAM_BANKSWITCH_ENABLE`
- `CONFIG_SPIRAM_OCCUPY_SPI_HOST`
- `PSRAM clock and cs IO for ESP32-DOWD`
- `PSRAM clock and cs IO for ESP32-D2WD`
- `PSRAM clock and cs IO for ESP32-PICO`
- `CONFIG_SPIRAM_CUSTOM_SPIWP_SD3_PIN`
- `CONFIG_SPIRAM_SPIWP_SD3_PIN`
- `CONFIG_SPIRAM_2T_MODE`

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**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)

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**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.

**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.

**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(…, MALLOC_CAP_SPIRAM) (SPIRAM_USE_CAPS_ALLOC)
- Make RAM allocatable using malloc() as well (SPIRAM_USE_MALLOC)

**CONFIG_SPIRAM_MEMTEST**

Run memory test on SPI RAM initialization

*Found in: Component config > 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.

**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.

**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.
CONFIG_SPIRAM_MALLOC_RESERVE_INTERNAL
Reserve this amount of bytes for data that specifically needs to be in DMA or internal memory

*Found in:* Component config > 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.

Set this to 0 to disable this feature.

Note that because FreeRTOS stacks are forced to internal memory, they will also use this memory pool; be sure to keep this in mind when adjusting this value.

Note also that the DMA reserved pool may not be one single contiguous memory region, depending on the configured size and the static memory usage of the app.

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 the option, and add EXT_RAM_ATTR defined your variable, then your variable will be placed in PSRAM instead of internal memory, and placed most of variables of lwip, net802.11, pp, bluedroid library to external memory defaultly.

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.

**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 DULPLDST 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) (SPI-ROM CACHE WORKAROUND STRATEGY_MEMW)
- Duplicate LD/ST for 32-bit, `memw` for 8/16 bit (SPI-ROM CACHE WORKAROUND STRATEGY DUPLDST)
- Insert `nops` between vulnerable loads/stores (old strategy, obsolete) (SPI-ROM CACHE WORKAROUND STRATEGY_NOPS)

**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 psrcam will be changed as 32Mbit, so himem will be unusable.

**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`.

**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 friends 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 to disable this and use `xTaskCreateStatic` to create the tasks stack in external memory.

**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) (SPI_RAM_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.

**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.

**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.

**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.

**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)

**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.

**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.

**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.

**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.

**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

**CONFIG_ESP32_UNIVERSAL_MAC_ADDRESSES**

Number of universally administered (by IEEE) MAC address

*Found in: Component config > ESP32-specific*

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)

**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.

**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.
CONFIG_ESP32_DEBUG_OCD_AWARE

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.

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.

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_REDUCE_PHY_TX_POWER

Reduce PHY TX power when brownout reset

*Found in: Component config > ESP32-specific*

When brownout reset occurs, reduce PHY TX power to keep the code running

#Note about the use of “FRC1” name: currently FRC1 timer is not used for high resolution time-keeping anymore. Instead the esp_timer API is used. #FRC1 name in the option name is kept for compatibility.

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.
Chapter 2. API

- If only RTC timer is used, timekeeping will continue in deep sleep, but time will be measured at 6.6 microsecond resolution. Also the gettimeofday function itself may take longer to run.
- If no timers are used, gettimeofday and time functions return -1 and set errno to ENOSYS.
- When RTC is used for timekeeping, two RTC_STORE registers are used to keep time in deep sleep mode.

Available options:
- RTC and high-resolution timer (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

Additional current for external 32kHz crystal

Found in: Component config > ESP32-specific

Choose which additional current is used for rtc external crystal.

- With some 32kHz crystal configurations, the X32N and X32P pins may not have enough drive strength to keep the crystal oscillating during deep sleep. If this option is enabled, additional current from touchpad 9 is provided internally to drive the 32kHz crystal. If this option is enabled, deep sleep current is slightly higher (4-5uA) and the touchpad and ULP wakeup sources are not available.

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.

**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.

**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.

**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)

**CONFIG_ESP32_DISABLE_BASIC_ROM_CONSOLE**
Chapter 2. API

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.)

**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.

**CONFIG_ESP32_COMPATIBLE_PRE_V2_1_BOOTLOADERS**

App compatible with bootloaders before IDF v2.1

*Found in: Component config > ESP32-specific*

Bootloaders before 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 SRAM usage.

**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.

**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
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 BT_RESERVE_DRAM if Bluetooth controller is enabled.

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.

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.

CONFIG_ESP32_ALLOW_RTC_FAST_MEM_AS_HEAP

Enable RTC fast memory for dynamic allocations

*Found in: Component config > ESP32-specific*

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. RTC fast memory is accessible to PRO cpu only and hence this is allowed for single core configuration only for ESP32.

ADC-Calibration  
Contains:

- `CONFIG_ADC_CAL_EFUSE_TP_ENABLE`
- `CONFIG_ADC_CAL_EFUSE_VREF_ENABLE`
- `CONFIG_ADC_CAL_LUT_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.
**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.

**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.

**Common ESP-related** Contains:

- `CONFIG_ESP_ERR_TO_NAME_LOOKUP`
- `CONFIG_ESP_SYSTEM_EVENT_QUEUE_SIZE`
- `CONFIG_ESP_SYSTEM_EVENT_TASK_STACK_SIZE`
- `CONFIG_ESP_MAIN_TASK_STACK_SIZE`
- `CONFIG_ESP_IPC_TASK_STACK_SIZE`
- `CONFIG_ESP_IPC_USES_CALLERS_PRIORITY`
- `CONFIG_ESP_MINIMAL_SHARED_STACK_SIZE`
- `CONFIG_ESP_CONSOLE_UART`
- `CONFIG_ESP_CONSOLE_UART_NUM`
- `CONFIG_ESP_CONSOLE_UART_TX_GPIO`
- `CONFIG_ESP_CONSOLE_UART_RX_GPIO`
- `CONFIG_ESP_CONSOLE_UART_BAUDRATE`
- `CONFIG_ESP_INT_WDT`
- `CONFIG_ESP_TASK_WDT`
- `CONFIG_ESP_PANIC_HANDLER_IRAM`

**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.

**CONFIG_ESP_SYSTEM_EVENT_QUEUE_SIZE**

System event queue size

*Found in: Component config > Common ESP-related*

Config system event queue size in different application.

**CONFIG_ESP_SYSTEM_EVENT_TASK_STACK_SIZE**

Event loop task stack size

*Found in: Component config > Common ESP-related*

Config system event task stack size in different application.
CHAPTER 2. API

**CONFIG_ESP_MAIN_TASK_STACK_SIZE**

Main task stack size

*Found in: Component config > Common ESP-related*

Configure the “main task” stack size. This is the stack of the task which calls `app_main()`. If `app_main()` returns then this task is deleted and its stack memory is freed.

**CONFIG_ESP_IPC_TASK_STACK_SIZE**

Inter-Processor Call (IPC) task stack size

*Found in: Component config > Common ESP-related*

Configure the IPC tasks stack size. One 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 stack size should be enough for most common use cases. It can be shrunk if you are sure that you do not use any custom IPC functionality.

**CONFIG_ESP_IPC_USES_CALLERS_PRIORITY**

IPC runs at caller’s priority

*Found in: Component config > Common ESP-related*

If this option is not enabled then the IPC task will keep behavior same as prior to that of ESP-IDF v4.0, and hence IPC task will run at (configMAX_PRIORITIES - 1) priority.

**CONFIG_ESP_MINIMAL_SHARED_STACK_SIZE**

Minimal allowed size for shared stack

*Found in: Component config > Common ESP-related*

Minimal value of size, in bytes, accepted to execute a expression with shared stack.

**CONFIG_ESP_CONSOLE_UART**

Channel for console output

*Found in: Component config > Common ESP-related*

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 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.

Available options:

- Default: UART0 (ESP_CONSOLE_UART_DEFAULT)
- USB CDC (ESP_CONSOLE_USB_CDC)
- 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 > Common ESP-related*

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 > Common ESP-related*

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.

**CONFIG_ESP_CONSOLE_UART_RX_GPIO**

UART RX on GPIO#

*Found in: Component config > Common ESP-related*

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.

**CONFIG_ESP_CONSOLE_UART_BAUDRATE**

UART console baud rate

*Found in: Component config > Common ESP-related*

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.
**CONFIG_ESP_INT_WDT**

Interrupt watchdog

*Found in: Component config > Common ESP-related*

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.

**CONFIG_ESP_INT_WDT_TIMEOUT_MS**

Interrupt watchdog timeout (ms)

*Found in: Component config > Common ESP-related > CONFIG_ESP_INT_WDT*

The timeout of the watchdog, in milliseconds. Make this higher than the FreeRTOS tick rate.

**CONFIG_ESP_INT_WDT_CHECK_CPU1**

Also watch CPU1 tick interrupt

*Found in: Component config > Common ESP-related > CONFIG_ESP_INT_WDT*

Also detect if interrupts on CPU 1 are disabled for too long.

**CONFIG_ESP_TASK_WDT**

Initialize Task Watchdog Timer on startup

*Found in: Component config > Common ESP-related*

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)

**CONFIG_ESP_TASK_WDT_PANIC**

Invoke panic handler on Task Watchdog timeout

*Found in: Component config > Common ESP-related > 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)

**CONFIG_ESP_TASK_WDT_TIMEOUT_S**

Task Watchdog timeout period (seconds)

*Found in: Component config > Common ESP-related > 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)

**CONFIG_ESP_TASK_WDT_CHECK_IDLE_TASK_CPU0**

Watch CPU0 Idle Task

*Found in: Component config > Common ESP-related > 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.
CONFIG_ESP_TASK_WDT_CHECK_IDLE_TASK_CPU1

Watch CPU1 Idle Task

*Found in: Component config > Common ESP-related > CONFIG_ESP_TASK_WDT*

If this option is enabled, the Task Watchdog Timer will watch the CPU1 Idle Task.

CONFIG_ESP_PANIC_HANDLER_IRAM

Place panic handler code in IRAM

*Found in: Component config > Common ESP-related*

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 is placed in IRAM. This allows the panic handler to run without needing to re-enable cache first. This may be necessary to debug some complex issues with crashes while flash cache is disabled (for example, when writing to SPI flash.)

Ethernet  Contains:

- CONFIG_ETH_USE_ESP32_EMAC
- CONFIG_ETH_USE_SPI_ETHERNET
- CONFIG_ETH_USE_OPENETH

CONFIG_ETH_USE_ESP32_EMAC

Support ESP32 internal EMAC controller

*Found in: Component config > Ethernet*

ESP32 integrates a 10/100M Ethernet MAC controller.

Contains:

- CONFIG_ETH_PHY_INTERFACE
- CONFIG_ETH_RMII_CLK_MODE
- CONFIG_ETH_RMII_CLK_OUTPUT_GPIO0
- CONFIG_ETH_RMII_CLK_OUT_GPIO
- CONFIG_ETH_DMA_BUFFER_SIZE
- CONFIG_ETH_DMA_RX_BUFFER_NUM
- CONFIG_ETH_DMA_TX_BUFFER_NUM

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)
- Media Independent Interface (MII) (ETH_PHY_INTERFACE_MII)
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.

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.

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.

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.

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.
**CONFIG_ETH_USE_SPI_ETHERNET**

Support SPI to Ethernet Module

*Found in: Component config > Ethernet*

ESP-IDF can also support some SPI-Ethernet modules.

Contains:

- `CONFIG_ETH_SPI_ETHERNET_DM9051`

**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 to enable DM9051 driver.

**CONFIG_ETH_USE_OPENETH**

Support OpenCores Ethernet MAC (for use with QEMU)

*Found in: Component config > Ethernet*

OpenCores Ethernet MAC driver can be used when an ESP-IDF application is executed in QEMU. This driver is not supported when running on a real chip.

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.

**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.

**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/received 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.
CONFIG_ESP_EVENT_POST_FROM_ISR

Support posting events from ISRs

*Found in: Component config > Event Loop Library*

Enable posting events from interrupt handlers.

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.

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.

ESP HTTP client  Contains:

- `CONFIG_ESP_HTTP_CLIENT_ENABLE_HTTPS`
- `CONFIG_ESP_HTTP_CLIENT_ENABLE_BASIC_AUTH`

CONFIG_ESP_HTTP_CLIENT_ENABLE_HTTPS

Enable https

*Found in: Component config > ESP HTTP client*

This option will enable https protocol by linking mbedtls library and initializing SSL transport

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
HTTP Server  Contains:

- `CONFIG_HTTPD_MAX_REQ_HDR_LEN`
- `CONFIG_HTTPD_MAX_URI_LEN`
- `CONFIG_HTTPD_ERR_RESP_NO_DELAY`
- `CONFIG_HTTPD_PURGE_BUF_LEN`
- `CONFIG_HTTPD_LOG_PURGE_DATA`
- `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.

**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.

**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.

**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.

**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.

**CONFIG_HTTPD_WS_SUPPORT**

WebSocket server support

*Found in: Component config > HTTP Server*

This sets the WebSocket server support.
Chapter 2. API

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

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

ESP NETIF Adapter  Contains:

  • CONFIG_ESP_NETIF_IP_LOST_TIMER_INTERVAL
  • CONFIG_ESP_NETIF_USE_TCPIP_STACK_LIB
  • CONFIG_ESP_NETIF_TCPIP_ADAPTER_COMPATIBLE_LAYER

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.

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_TCP/IP_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.

**Power Management**

Contains:

- **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.

**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.

**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.

**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.
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.

ESP System Settings  Contains:

- `CONFIG_ESP_SYSTEM_PANIC`
- `CONFIG_ESP_SYSTEM_RTC_EXT_XTAL_BOOTSTRAP_CYCLES`

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
- Invoke GDBStub (ESP_SYSTEM_PANIC_GDBSTUB)
  Invoke gdbstub on the serial port, allowing for gdb to attach to it to do a postmortem of the crash.

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).

High resolution timer (esp_timer)  Contains:

- `CONFIG_ESP_TIMER_PROFILES`
- `CONFIG_ESP_TIMER_TASK_STACK_SIZE`
- `CONFIG_ESP_TIMER_IMPL`
**CONFIG_ESP_TIMER_PROFILING**

Enable esp_timer profiling features

*Found in: Component config > High resolution timer (esp_timer)*

If enabled, esp_timer_dump will dump information such as number of times the timer was started, number of times the timer has triggered, and the total time it took for the callback to run. This option has some effect on timer performance and the amount of memory used for timer storage, and should only be used for debugging/testing purposes.

**CONFIG_ESP_TIMER_TASK_STACK_SIZE**

High-resolution timer task stack size

*Found in: Component config > High resolution timer (esp_timer)*

Configure the stack size of “timer_task” task. This task is used to dispatch callbacks of timers created using ets_timer and esp_timer APIs. If you are seeing stack overflow errors in timer task, increase this value.

Note that this is not the same as FreeRTOS timer task. To configure FreeRTOS timer task size, see “FreeRTOS timer task stack size” option in “FreeRTOS” menu.

**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 ESP32-S2 chip.

**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_SW_COEXIST_ENABLE
- CONFIG_ESP32_WIFI_STATIC_RX_BUFFER_NUM
- CONFIG_ESP32_WIFI_DYNAMIC_RX_BUFFER_NUM
- CONFIG_ESP32_WIFI_TX_BUFFER
- CONFIG_ESP32_WIFI_STATIC_TX_BUFFER_NUM
- CONFIG_ESP32_WIFI_DYNAMIC_TX_BUFFER_NUM
- CONFIG_ESP32_WIFI_CSI_ENABLED
- CONFIG_ESP32_WIFI_AMPDPU_TX_ENABLED
- CONFIG_ESP32_WIFI_AMPDPU_RX_ENABLED
- CONFIG_ESP32_WIFI_NV5S_ENABLED
- CONFIG_ESP32_WIFI_TASK_CORE_ID
- CONFIG_ESP32_WIFI_SOFTAP_BEACON_MAX_LEN
- CONFIG_ESP32_WIFI_MGMT_SBUF_NUM
- CONFIG_ESP32_WIFI_DEBUG_LOG_ENABLE
- CONFIG_ESP32_WIFI_IRAM_OPT
- CONFIG_ESP32_WIFI_RX_IRAM_OPT
- CONFIG_ESP32_WIFI_ENABLE_WPA3_SAE
**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.

**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.

**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.

**CONFIG_ESP32_WIFI_TXBUFFER**

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.

**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.

**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.

**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.

**CONFIG_ESP32_WIFI_AMPDU_TX_ENABLED**

WiFi AMPDU TX

*Found in: Component config > Wi-Fi*

Select this option to enable AMPDU TX feature

**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.

**CONFIG_ESP32_WIFI_AMPDU_RX_ENABLED**

WiFi AMPDU RX

*Found in: Component config > Wi-Fi*

Select this option to enable AMPDU RX feature

**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 time we should NOT change the default value unless special reason, e.g. test the maximum UDP RX throughput with iperf etc. For iperf test in shieldbox, the recommended value is 9~12. If PSRAM is used and WiFi memory is prefered to allocat in PSRAM first, the default and minimum value should be 16 to achieve better throughput and compatibility with both stations and APs.

**CONFIG_ESP32_WIFI_NVS_ENABLED**

WiFi NVS flash

*Found in: Component config > Wi-Fi*

Select this option to enable WiFi NVS flash

**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 occurence 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 ontop 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.

**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.

**CONFIG_ESP32_WIFI_DEBUG_LOG_ENABLE**

Enable WiFi debug log

*Found in: Component config > Wi-Fi*

Select this option to enable WiFi debug log

**CONFIG_ESP32_WIFI_DEBUG_LOG_LEVEL**

WiFi debug log level

*Found in: Component config > Wi-Fi > CONFIG_ESP32_WIFI_DEBUG_LOG_ENABLE*

The WiFi log is divided into the following levels: ERROR, WARNING, INFO, DEBUG, VERBOSE. The ERROR, WARNING, INFO levels are enabled by default, and the DEBUG, VERBOSE levels can be enabled here.

**Available options:**
- WiFi Debug Log Debug (ESP32_WIFI_DEBUG_LOG_DEBUG)
- WiFi Debug Log Verbosel (ESP32_WIFI_DEBUG_LOG_VERBOSE)

**CONFIG_ESP32_WIFI_DEBUG_LOG_MODULE**

WiFi debug log module

*Found in: Component config > Wi-Fi > CONFIG_ESP32_WIFI_DEBUG_LOG_ENABLE*

The WiFi log module contains three parts: WIFI, COEX, MESH. The WIFI module indicates the logs related to WiFi, the COEX module indicates the logs related to WiFi and BT (or BLE) coexist, the MESH module indicates the logs related to Mesh. When ESP32_WIFI_LOG_MODULE_ALL is enabled, all modules are selected.

**Available options:**
- WiFi Debug Log Module All (ESP32_WIFI_DEBUG_LOG_MODULE_ALL)
- WiFi Debug Log Module WiFi (ESP32_WIFI_DEBUG_LOG_MODULE_WIFI)
- WiFi Debug Log Module Coex (ESP32_WIFI_DEBUG_LOG_MODULE_COEX)
- WiFi Debug Log Module Mesh (ESP32_WIFI_DEBUG_LOG_MODULE_MESH)

**CONFIG_ESP32_WIFI_DEBUG_LOG_SUBMODULE**

WiFi debug log submodule

*Found in: Component config > Wi-Fi > CONFIG_ESP32_WIFI_DEBUG_LOG_ENABLE*

Enable this option to set the WiFi debug log submodule. Currently the log submodule contains the following parts: INIT, IOCTL, CONN, SCAN. The INIT submodule indicates the initialization process. The IOCTL submodule indicates the API calling process. The CONN submodule indicates the connecting process. The SCAN submodule indicates the scanning process.
CONFIG_ESP32_WIFI_DEBUG_LOG_SUBMODULE_ALL
WiFi Debug Log Submodule All

*Found in:* Component config > Wi-Fi > CONFIG_ESP32_WIFI_DEBUG_LOG_ENABLE > CONFIG_ESP32_WIFI_DEBUG_LOG_SUBMODULE_ALL

When this option is enabled, all debug submodules are selected.

CONFIG_ESP32_WIFI_DEBUG_LOG_SUBMODULE_INIT
WiFi Debug Log Submodule Init

*Found in:* Component config > Wi-Fi > CONFIG_ESP32_WIFI_DEBUG_LOG_ENABLE > CONFIG_ESP32_WIFI_DEBUG_LOG_SUBMODULE_INIT

CONFIG_ESP32_WIFI_DEBUG_LOG_SUBMODULE_IOCTL
WiFi Debug Log Submodule IOCTL

*Found in:* Component config > Wi-Fi > CONFIG_ESP32_WIFI_DEBUG_LOG_ENABLE > CONFIG_ESP32_WIFI_DEBUG_LOG_SUBMODULE_IOCTL

CONFIG_ESP32_WIFI_DEBUG_LOG_SUBMODULE_CONN
WiFi Debug Log Submodule Conn

*Found in:* Component config > Wi-Fi > CONFIG_ESP32_WIFI_DEBUG_LOG_ENABLE > CONFIG_ESP32_WIFI_DEBUG_LOG_SUBMODULE_CONN

CONFIG_ESP32_WIFI_DEBUG_LOG_SUBMODULE_SCAN
WiFi Debug Log Submodule Scan

*Found in:* Component config > Wi-Fi > CONFIG_ESP32_WIFI_DEBUG_LOG_ENABLE > CONFIG_ESP32_WIFI_DEBUG_LOG_SUBMODULE_SCAN

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.

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.
**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.

**PHY**  
Contains:

- **CONFIG_ESP32_PHY_CALIBRATION_AND_DATA_STORAGE**
- **CONFIG_ESP32_PHY_INIT_DATA_IN_PARTITION**
- **CONFIG_ESP32_PHY_MAX_WIFI_TX_POWER**

**CONFIG_ESP32_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’.

**CONFIG_ESP32_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’.

Contains:

- **CONFIG_ESP32_SUPPORT_MULTIPLE_PHY_INIT_DATA_BIN**

**CONFIG_ESP32_SUPPORT_MULTIPLE_PHY_INIT_DATA_BIN**

Support multiple PHY init data bin

*Found in: Component config > PHY > CONFIG_ESP32_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.
**CONFIG_ESP32_PHY_INIT_DATA_ERROR**

Terminate operation when PHY init data error

*Found in: Component config > PHY > CONFIG_ESP32_PHY_INIT_DATA_IN_PARTITION > CONFIG_ESP32_SUPPORT_MULTIPLE_PHY_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.

**CONFIG_ESP32_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.

**Core dump**

Contains:

- CONFIG_ESP_COREDUMP_TO_FLASH_OR_UART
- CONFIG_ESP_COREDUMP_DATA_FORMAT
- CONFIG_ESP_COREDUMP_CHECKSUM
- CONFIG_ESP_COREDUMP_MAX_TASKS_NUM
- CONFIG_ESP_COREDUMP_UART_DELAY
- CONFIG_ESP_COREDUMP_STACK_SIZE
- CONFIG_ESP_COREDUMP_DECODE

**CONFIG_ESP_COREDUMP_TO_FLASH_OR_UART**

Data destination

*Found in: Component config > Core dump*

Select place to store core dump: flash, uart or none (to disable core dumps generation).

Core dumps to Flash are not available if PSRAM is used for task stacks.

If core dump is configured to be stored in flash and custom partition table is used add corresponding entry to your CSV. For examples, please see predefined partition table CSV descriptions in the components/partition_table directory.

**Available options:**

- Flash (ESP_COREDUMP_ENABLE_TO_FLASH)
- UART (ESP_COREDUMP_ENABLE_TO_UART)
- None (ESP_COREDUMP_ENABLE_TO_NONE)

**CONFIG_ESP_COREDUMP_DATA_FORMAT**

Core dump data format

*Found in: Component config > Core dump*

Select the data format for core dump.

**Available options:**

- Binary format (ESP_COREDUMP_DATA_FORMAT_BIN)
- ELF format (ESP_COREDUMP_DATA_FORMAT_ELF)
CONFIG_ESP_COREDUMP_CHECKSUM

Core dump data integrity check

Found in: Component config > Core dump

Select the integrity check for the core dump.

Available options:
- Use CRC32 for integrity verification (ESP_COREDUMP_CHECKSUM_CRC32)
- Use SHA256 for integrity verification (ESP_COREDUMP_CHECKSUM_SHA256)

CONFIG_ESP_COREDUMP_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.

CONFIG_ESP_COREDUMP_STACK_SIZE

Reserved stack size

Found in: Component config > Core dump

Size of the memory to be reserved for core dump stack. If 0 core dump process will run on the stack of crashed task/ISR, otherwise special stack will be allocated. To ensure that core dump itself will not overflow task/ISR stack set this to the value above 800. NOTE: It eats DRAM.

CONFIG_ESP_COREDUMP_DECODE

Handling of UART core dumps in IDF Monitor

Found in: Component config > Core dump

Available options:
- Decode and show summary (info_corefile) (ESP_COREDUMP_DECODE_INFO)
- Don’t decode (ESP_COREDUMP_DECODE_DISABLE)

FAT Filesystem support

Contains:
- CONFIG_FATFS_CHOOSE_CODEPAGE
- CONFIG_FATFS_LONG_FILENAMES
- CONFIG_FATFS_MAX_LFN
- CONFIG_FATFS_API_ENCODING
- CONFIG_FATFS_FS_LOCK
- CONFIG_FATFS_TIMEOUT_MS
- CONFIG_FATFS_PER_FILE_CACHE
- CONFIG_FATFS_ALLOC_PREFER_EXTRAM
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)
- Portugese (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.

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.

**CONFIG_FATFS_TIMEOUT_MS**

Timeout for acquiring a file lock, ms

* Found in: *Component config > FAT Filesystem support*

This option sets FATFS configuration value _FS_TIMEOUT, scaled to milliseconds. Sets the number of milliseconds FATFS will wait to acquire a mutex when operating on an open file. For example, if one task is performing a lengthy operation, another task will wait for the first task to release the lock, and timeout after amount of time set by this option.

**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.

**CONFIG_FATFS_ALLOC_PREFER_EXTRAM**

Perfer external RAM when allocating FATFS buffers

* Found in: *Component config > FAT Filesystem support*

When the option is enabled, internal buffers used by FATFS will be allocated from external RAM. If the allocation from external RAM fails, the buffer will be allocated from the internal RAM. Disable this option if optimizing for performance. Enable this option if optimizing for internal memory size.
Modbus configuration  Contains:

- CONFIG_FMB_COMM_MODE_TCP_EN
- CONFIG_FMB_COMM_MODE_RTU_EN
- CONFIG_FMB_COMM_MODE_ASCII_EN
- CONFIG_FMB_MASTER_TIMEOUT_MS_RESPOND
- CONFIG_FMB_MASTER_DELAY_MS_CONVERT
- CONFIG_FMB_QUEUE_LENGTH
- CONFIG_FMB_PORT_TASK_STACK_SIZE
- CONFIG_FMB_SERIAL_BUF_SIZE
- CONFIG_FMB_SERIAL_ASCII_BITS_PER_SYMB
- CONFIG_FMB_SERIAL_ASCII_TIMEOUT_RESPOND_MS
- CONFIG_FMB_PORT_TASK_PRIO
- CONFIG_FMB_CONTROLLER_SLAVE_ID_SUPPORT
- CONFIG_FMB_CONTROLLER_NOTIFY_TIMEOUT
- CONFIG_FMB_CONTROLLER_NOTIFY_QUEUE_SIZE
- CONFIG_FMB_CONTROLLER_STACK_SIZE
- CONFIG_FMB_EVENT_QUEUE_TIMEOUT
- CONFIG_FMB_TIMER_PORT_ENABLED
- CONFIG_FMB_TIMER_GROUP
- CONFIG_FMB_TIMER_INDEX
- CONFIG_FMB_TIMER_ISR_IN_IRAM

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.

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.

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).

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.
**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.

**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.

**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.

**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.

**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.

**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).

**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.
**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.

**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).

**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.

**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.

**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.

**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.
CONFIG_FMB_CONTROLLER_STACK_SIZE

Modbus controller stack size

*Found in: Component config > Modbus configuration*

Modbus controller task stack size. The Stack size may be adjusted when debug mode is used which requires more stack size (for example).

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.

CONFIG_FMB_TIMER_PORT_ENABLED

Modbus slave 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.

CONFIG_FMB_TIMER_GROUP

Modbus Timer group number

*Found in: Component config > Modbus configuration*

Modbus Timer group number that is used for timeout measurement.

CONFIG_FMB_TIMER_INDEX

Modbus Timer index in the group

*Found in: Component config > Modbus configuration*

Modbus Timer Index in the group that is used for timeout measurement.

CONFIG_FMB_TIMER_ISR_IN_IRAM

Place timer interrupt handler into IRAM

*Found in: Component config > Modbus configuration*

This option places Modbus timer IRQ handler into IRAM. This allows to avoid delays related to processing of non-IRAM-safe interrupts during a flash write operation (NVS updating a value, or some other flash API which has to perform an read/write operation and disable CPU cache). 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.

**FreeRTOS** Contains:

- `CONFIG_FREERTOS_UNICORE`
- `CONFIG_FREERTOS_CORETIMER`
- `CONFIG_FREERTOS_OPTIMIZED_SCHEDULER`
- `CONFIG_FREERTOS_HZ`
- `CONFIG_FREERTOS_ASSERT_ON_UNTESTED_FUNCTION`
- `CONFIG_FREERTOS_CHECK_STACKOVERFLOW`
Chapter 2. API

• CONFIG_FREERTOS_WATCHPOINT_END_OF_STACK
• CONFIG_FREERTOS_INTERRUPT_BACKTRACE
• CONFIG_FREERTOS_THREAD_LOCAL_STORAGE_POINTERS
• CONFIG_FREERTOS_ASSERT
• CONFIG_FREERTOS_IDLE_TASK_STACKSIZE
• CONFIG_FREERTOS_ISR_STACKSIZE
• CONFIG_FREERTOS_LEGACY_HOOKS
• CONFIG_FREERTOS_MAX_TASK_NAME_LEN
• CONFIG_FREERTOS_SUPPORT_STATIC_ALLOCATION
• CONFIG_FREERTOS_TIMER_TASK_PRIORITY
• CONFIG_FREERTOS_TIMER_TASK_STACK_DEPTH
• CONFIG_FREERTOS_TIMER_QUEUE_LENGTH
• CONFIG_FREERTOS_QUEUE_REGISTRY_SIZE
• CONFIG_FREERTOS_GENERATE_RUN_TIME_STATS
• CONFIG_FREERTOS_USE_TICKLESS_IDLE
• CONFIG_FREERTOS_TASK_FUNCTION_WRAPPER
• CONFIG_FREERTOS_CHECK_MUTEX_GIVEN_BY_OWNER
• CONFIG_FREERTOS_CHECK_PORT_CRITICAL_COMPLIANCE
• CONFIG_FREERTOS_PLACE_FUNCTIONS_INTO_FLASH
• CONFIG_FREERTOS_FPU_IN_ISR

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

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.
**CONFIG_FREERTOS_HZ**

Tick rate (Hz)

*Found in: Component config > FreeRTOS*

Select the tick rate at which FreeRTOS does pre-emptive context switching.

**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().

**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 debug memory watchpoint 1 (the second one) 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 only have one watchpoint; the 2nd one is overwritten as soon as a task switch happens.

This check only triggers if the stack overflow writes within 4 bytes of 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.
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.

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.

CONFIG_FREERTOS_ASSERT

FreeRTOS assertions

*Found in: Component config > FreeRTOS*

Failed FreeRTOS configASSERT() assertions can be configured to behave in different ways.

*Available options:*

- abort() on failed assertions (FREERTOS_ASSERT_FAIL_ABORT)
  If a FreeRTOS configASSERT() fails, FreeRTOS will abort() and halt execution. The panic handler can be configured to handle the outcome of an abort() in different ways.
- Print and continue failed assertions (FREERTOS_ASSERT_FAIL_PRINT_CONTINUE)
  If a FreeRTOS assertion fails, print it out and continue.
- Disable FreeRTOS assertions (FREERTOS_ASSERT_DISABLE)
  FreeRTOS configASSERT() will not be compiled into the binary.

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.

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.
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.

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.

CONFIG_FREERTOS_SUPPORT_STATIC_ALLOCATION

Enable FreeRTOS static allocation API

*Found in: Component config > FreeRTOS*

FreeRTOS gives the application writer the ability to instead provide the memory themselves, allowing the following objects to optionally be created without any memory being allocated dynamically:

- Tasks
- Software Timers (Daemon task is still dynamic. See documentation)
- Queues
- Event Groups
- Binary Semaphores
- Counting Semaphores
- Recursive Semaphores
- Mutexes

Whether it is preferable to use static or dynamic memory allocation is dependent on the application, and the preference of the application writer. Both methods have pros and cons, and both methods can be used within the same RTOS application.

Creating RTOS objects using statically allocated RAM has the benefit of providing the application writer with more control: RTOS objects can be placed at specific memory locations. The maximum RAM footprint can be determined at link time, rather than run time. The application writer does not need to concern themselves with graceful handling of memory allocation failures. It allows the RTOS to be used in applications that simply don’t allow any dynamic memory allocation (although FreeRTOS includes allocation schemes that can overcome most objections).

CONFIG_FREERTOS_ENABLE_STATIC_TASK_CLEAN_UP

Enable static task clean up hook

*Found in: Component config > FreeRTOS > CONFIG_FREERTOS_SUPPORT_STATIC_ALLOCATION*

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
}
```
Chapter 2. API 参考

**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.

**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.

**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.

**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.

**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().

**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().
**CONFIG_FREERTOS_VTASKLIST_INCLUDE_COREID**

Enable display of xCoreID in vTaskList

*Found in: Component config > FreeRTOS > CONFIG_FREERTOS_USE_TRACE_FACILITY > CONFIG_FREERTOS_USE_STATS_FORMATTING_FUNCTIONS*

If enabled, this will include an extra column when vTaskList is called to display the CoreID the task is pinned to (0,1) or -1 if not pinned.

**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)

**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 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.

If disabled, automatic light sleep support will be disabled.
### 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.

### 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.

### 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.

### 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.

### CONFIG_FREERTOS_PLACE_FUNCTIONS_INTO_FLASH

Place FreeRTOS functions into Flash

*Found in: Component config > FreeRTOS*

When enabled these 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.

### 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.

**Heap memory debugging**

Contains:

- `CONFIG_HEAP_CORRUPTION_DETECTION`
- `CONFIG_HEAP_TRACING_DEST`
- `CONFIG_HEAP_TRACING_STACK_DEPTH`
- `CONFIG_HEAP_TASK_TRACKING`
- `CONFIG_HEAP_ABORT_WHEN_ALLOCATION_FAILS`
**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.
**jsmn** Contains:

- `CONFIG_JSMN_PARENT_LINKS`
- `CONFIG_JSMN_STRICT`

**CONFIG_JSMN_PARENT_LINKS**

Enable parent links

*Found in: Component config > jsmn*

You can access to parent node of parsed json

**CONFIG_JSMN_STRICT**

Enable strict mode

*Found in: Component config > jsmn*

In strict mode primitives are: numbers and booleans

**libsodium** Contains:

- `CONFIG_LIBSODIUM_USE_MBEDTLS_SHA`

**CONFIG_LIBSODIUM_USE_MBEDTLS_SHA**

Use mbedTLS SHA256 & SHA512 implementations

*Found in: Component config > libsodium*

If this option is enabled, libsodium will use thin wrappers around mbedTLS for SHA256 & SHA512 operations.

This saves some code size if mbedTLS is also used. However it is incompatible with hardware SHA acceleration (due to the way libsodium’s API manages SHA state).

**Log output** Contains:

- `CONFIG_LOG_DEFAULT_LEVEL`
- `CONFIG_LOG_COLORS`
- `CONFIG_LOG_TIMESTAMP_SOURCE`

**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.

Note that this setting limits which log statements are compiled into the program. So setting this to, say, “Warning” would mean that changing log level to “Debug” at runtime will not be possible.

**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_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.

**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:

- CONFIG_LWIP_LOCAL_HOSTNAME
- CONFIG_LWIP_DNS_SUPPORT_MDNS_QUERIES
- CONFIG_LWIP_L2_TO_L3_COPY
- CONFIG_LWIP_IRAM_OPTIMIZATION
- CONFIG_LWIP_TIMERS_ONDEMAND
- CONFIG_LWIP_MAX_SOCKETS
- CONFIG_LWIP_USE_ONLY_LWIP_SELECT
- CONFIG_LWIP_SO_LINGER
- CONFIG_LWIP_SO_REUSE
- CONFIG_LWIP_SO_RCVBUF
- CONFIG_LWIP_NETBUF_RECVINFO
- CONFIG_LWIP_IP4_FRAG
- CONFIG_LWIP_IP6_FRAG
- CONFIG_LWIP_IP4_REASSMBLY
- CONFIG_LWIP_IP6_REASSMBLY
- CONFIG_LWIP_IP_FORWARD
- CONFIG_LWIP_STATS
- CONFIG_LWIP_ETHARP_TRUST_IP_MAC
- CONFIG_LWIP_ESP_GRATUITOUS_ARP
- CONFIG_LWIP_TCP_IP_RECVMBOX_SIZE
- CONFIG_LWIP_DHCP_DOES_ARP_CHECK
- CONFIG_LWIP_DHCP_RESTORE_LAST_IP
- DHCP server
- CONFIG_LWIP_AUTOIP
- CONFIG_LWIP_IPV6_AUTOCONFIG
- CONFIG_LWIP_NETIF_LOOPBACK
- TCP
- UDP
- CONFIG_LWIP_TCPIP_TASK_STACK_SIZE
Chapter 2. API

- CONFIG_LWIP_TCPIP_TASK_AFFINITY
- CONFIG_LWIP_PPP_SUPPORT
- CONFIG_LWIP_IPV6_MEMP_NUM_ND6_QUEUE
- CONFIG_LWIP_IPV6 ND6_NUM_NEIGHBORS
- CONFIG_LWIP_PPP_NOTIFY_PHASE_SUPPORT
- CONFIG_LWIP_PPP_PAP_SUPPORT
- CONFIG_LWIP_PPP_CHAP_SUPPORT
- CONFIG_LWIP_PPP_MSMAP_SUPPORT
- CONFIG_LWIP_PPP_MPPE_SUPPORT
- CONFIG_LWIP_PPP_DEBUG_ON
- CONFIG_LWIP_SLIP_SUPPORT
- ICMP
- LWIP RAW API
- SNTP
- CONFIG_LWIP_ESP_LWIP_ASSERT
- Debug

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()

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

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.

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.
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.

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.

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.

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.

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.

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.
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.

**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.

**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.

**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.

**CONFIG_LWIP_IP4_REASSEMBLY**
Enable reassembly incoming fragmented IP4 packets

*Found in: Component config > LWIP*

Enabling this option allows reassembling incoming fragmented IP4 packets.

**CONFIG_LWIP_IP6_REASSEMBLY**
Enable reassembly incoming fragmented IP6 packets

*Found in: Component config > LWIP*

Enabling this option allows reassembling incoming fragmented IP6 packets.

**CONFIG_LWIP_IP_FORWARD**
Enable IP forwarding

*Found in: Component config > LWIP*

Enabling this option allows packets forwarding across multiple interfaces.

**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.
Chapter 2. API

**CONFIG_LWIP_STATS**

Enable LWIP statistics

*Found in: Component config > LWIP*

Enabling this option allows LWIP statistics

**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.

**CONFIG_LWIP_ESP_GRATUITOUS_ARP**

Send gratuitous ARP periodically

*Found in: Component config > LWIP*

Enable this option allows to send gratuitous ARP periodically.

This option solve the compatibility issues. If the ARP table of the AP is old, and the AP doesn’t send ARP request to update it’s ARP table, this will lead to the STA sending IP packet fail. Thus we send gratuitous ARP periodically to let AP update it’s ARP table.

**CONFIG_LWIP_GARP_TMR_INTERVAL**

GARP timer interval(seconds)

*Found in: Component config > LWIP > CONFIG_LWIP_ESP_GRATUITOUS_ARP*

Set the timer interval for gratuitous ARP. The default value is 60s

**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.
**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.

**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.

**DHCP server**

Contains:

- **CONFIG_LWIP_DHCPS_LEASE_UNIT**
- **CONFIG_LWIP_DHCPS_MAX_STATION_NUM**

**CONFIG_LWIP_DHCPS_LEASE_UNIT**

Multiplier for lease time, in seconds

*Found in: Component config > LWIP > DHCP server*

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.

**CONFIG_LWIP_DHCPS_MAX_STATION_NUM**

Maximum number of stations

*Found in: Component config > LWIP > DHCP server*

The maximum number of DHCP clients that are connected to the server. After this number is exceeded, DHCP server removes of the oldest device from its address pool, without notification.

**CONFIG_LWIP_AUTOIP**

Enable IPV4 Link-Local Addressing (AUTOIP)

*Found in: Component config > LWIP*

Enabling this option allows the device to self-assign an address in the 169.256/16 range if none is assigned statically or via DHCP.

See RFC 3927.

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.)

**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.

**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.

**CONFIG_LWIP_IPV6_AUTOCONFIG**

Enable IPV6 stateless address autoconfiguration

*Found in: Component config > LWIP*

Enabling this option allows the devices to IPV6 stateless address autoconfiguration.

See RFC 4862.

**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.

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.
Chapter 2. API

TCP   Contains:

- CONFIG_LWIP_MAX_ACTIVE_TCP
- CONFIG_LWIP_MAX_LISTENING_TCP
- CONFIG_LWIP_TCP_MAXRTX
- CONFIG_LWIP_TCP_SYNMAXRTX
- CONFIG_LWIP_TCP_MSS
- CONFIG_LWIP_TCP_TMR_INTERVAL
- CONFIG_LWIP_TCP_MSL
- CONFIG_LWIP_TCP_SND_BUF_DEFAULT
- CONFIG_LWIP_TCP_WND_DEFAULT
- CONFIG_LWIP_TCP_RECVMBOX_SIZE
- CONFIG_LWIP_TCP_QUEUE_OOSEQ
- CONFIG_LWIP_TCP_SACK_OUT
- CONFIG_LWIP_TCP_KEEP_CONNECTION_WHEN_IP_CHANGES
- CONFIG_LWIP_TCP_OVERSIZE
- CONFIG_LWIP_WND_SCALE
- CONFIG_LWIP_TCP_RTO_TIME

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.

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.

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.

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.
Chapter 2. API Reference

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

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.

CONFIG_LWIP_TCP_MSL

Maximum segment lifetime (MSL)

Found in: Component config > LWIP > TCP

Set maximum segment lifetime in milliseconds.

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.

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.

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_RECCVMBOX_SIZE packets for each TCP socket, so the maximum possible cached TCP packets for all TCP sockets is LWIP_TCP_RECCVMBOX_SIZE multiples the maximum TCP socket number. In other words, the bigger LWIP_TCP_RECCVMBOX_SIZE means more memory. On the other hand, if the receive mail box is too small, the mail box may be full. If the mail box is full, the LWIP drops the packets. So generally we need to make sure the TCP receive mail box is big enough to avoid packet drop between LWIP core and application.

**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.

**CONFIG_LWIP_TCP_SACK_OUT**
Support sending selective acknowledgements

*Found in: Component config > LWIP > TCP*
TCP will support sending selective acknowledgements (SACKs).

**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.

**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.

**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.

**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.

**UDP**

Contains:

- `CONFIG_LWIP_MAX_UDP_PCBS`
- `CONFIG_LWIP_UDP_RECVMBOX_SIZE`

**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.

**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 receiv mail box is too small, the mail box may be full. If the mail box is full, the LWIP drops the packets. So generally we need to make sure the UDP receive mail box is big enough to avoid packet drop between LWIP core and application.
**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.

**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.

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.

**CONFIG_LWIP_IPV6_MEMP_NUM_ND6_QUEUE**

Max number of IPv6 packets to queue during MAC resolution

*Found in: Component config > LWIP*

Config max number of IPv6 packets to queue during MAC resolution.

**CONFIG_LWIP_IPV6_NUM_ELEMENT_ND6_NEIGHBORS**

Max number of entries in IPv6 neighbor cache

*Found in: Component config > LWIP*

Config max number of entries in IPv6 neighbor cache.
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.

CONFIG_LWIP_PPP_PAP_SUPPORT
Enable PAP support
*Found in: Component config > LWIP*
Enable Password Authentication Protocol (PAP) support

CONFIG_LWIP_PPP_CHAP_SUPPORT
Enable CHAP support
*Found in: Component config > LWIP*
Enable Challenge Handshake Authentication Protocol (CHAP) 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

CONFIG_LWIP_PPP_MPPE_SUPPORT
Enable MPPE support
*Found in: Component config > LWIP*
Enable Microsoft Point-to-Point Encryption (MPPE) support

CONFIG_LWIP_PPP_DEBUG_ON
Enable PPP debug log output
*Found in: Component config > LWIP*
Enable PPP debug log output

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.
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

ICMP Contains:
• CONFIG_LWIP_MULTICAST_PING
• CONFIG_LWIP_BROADCAST_PING

CONFIG_LWIP_MULTICAST_PING
Respond to multicast pings

Found in: Component config > LWIP > ICMP

CONFIG_LWIP_BROADCAST_PING
Respond to broadcast pings

Found in: Component config > LWIP > ICMP

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.

SNTP Contains:
• CONFIG_LWIP_DHCP_MAX_NTP_SERVERS
• CONFIG_LWIP_SNTP_UPDATE_DELAY

CONFIG_LWIP_DHCP_MAX_NTP_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/snntp_setservername functions is limited to this value.

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).
CONFIG_LWIP_ESP_LWIP_ASSERT
Enable LWIP ASSERT checks

*Found in: Component config > LWIP*

Enable this option allows lwip to check assert. It is recommended to keep it open, do not close it.

**Debug** Contains:

- `CONFIG_LWIP_NETIF_DEBUG`
- `CONFIG_LWIP_PBUF_DEBUG`
- `CONFIG_LWIP_ETHARP_DEBUG`
- `CONFIG_LWIP_API_LIB_DEBUG`
- `CONFIG_LWIP_SOCKETS_DEBUG`
- `CONFIG_LWIP_IP_DEBUG`
- `CONFIG_LWIP_ICMP_DEBUG`
- `CONFIG_LWIP_IP6_DEBUG`
- `CONFIG_LWIP_ICMP6_DEBUG`

CONFIG_LWIP_NETIF_DEBUG
Enable netif debug messages

*Found in: Component config > LWIP > Debug*

CONFIG_LWIP_PBUF_DEBUG
Enable pbuf debug messages

*Found in: Component config > LWIP > Debug*

CONFIG_LWIP_ETHARP_DEBUG
Enable etharp debug messages

*Found in: Component config > LWIP > Debug*

CONFIG_LWIP_API_LIB_DEBUG
Enable api lib debug messages

*Found in: Component config > LWIP > Debug*

CONFIG_LWIP_SOCKETS_DEBUG
Enable socket debug messages

*Found in: Component config > LWIP > Debug*

CONFIG_LWIP_IP_DEBUG
Enable IP debug messages

*Found in: Component config > LWIP > Debug*

CONFIG_LWIP_ICMP_DEBUG
Enable ICMP debug messages

*Found in: Component config > LWIP > Debug*
Chapter 2. API 参考

CONFIG_LWIP_IP6_DEBUG
Enable IP6 debug messages

*Found in:* Component config > LWIP > Debug

CONFIG_LWIP_ICMP6_DEBUG
Enable ICMP6 debug messages

*Found in:* Component config > LWIP > Debug

**mbedTLS** Contains:

- CONFIG_MBEDTLS_MEM_ALLOC_MODE
- CONFIG_MBEDTLS_SSL_MAX_CONTENT_LEN
- CONFIG_MBEDTLSASYMMETRIC_CONTENT_LEN
- CONFIG_MBEDTLS_DYNAMIC_BUFFER
- CONFIG_MBEDTLS_DEBUG
- Certificate Bundle
- CONFIG_MBEDTLS_ECP_RESTARTABLE
- CONFIG_MBEDTLS_CMAC_C
- CONFIG_MBEDTLS_HARDWARE_AES
- CONFIG_MBEDTLS_HARDWARE_MPI
- CONFIG_MBEDTLS_HARDWARE_SHA
- CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY
- CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN
- CONFIG_MBEDTLS_HAVE_TIME
- CONFIG_MBEDTLS_ECDSA_DETERMINISTIC
- CONFIG_MBEDTLS_SHA512_C
- CONFIG_MBEDTLS_TLS_MODE
- TLS Key Exchange Methods
- CONFIG_MBEDTLS_SSL_RENEGOTIATION
- CONFIG_MBEDTLS_SSL_PROTO_SSL3
- CONFIG_MBEDTLS_SSL_PROTO_TLS1
- CONFIG_MBEDTLS_SSL_PROTO_TLS1_1
- CONFIG_MBEDTLS_SSL_PROTO_TLS1_2
- CONFIG_MBEDTLS_SSL_PROTO_DTLS
- CONFIG_MBEDTLS_SSL_ALPN
- CONFIG_MBEDTLS_CLIENT_SSL_SESSION_TICKETS
- CONFIG_MBEDTLS_SERVER_SSL_SESSION_TICKETS
- Symmetric Ciphers
- CONFIG_MBEDTLS_RIPEMD160_C
- Certificates
- CONFIG_MBEDTLS_ECP_C
- CONFIG_MBEDTLS_POLY1305_C
- CONFIG_MBEDTLS_CHACHA20_C
- CONFIG_MBEDTLS_HKDF_C
- CONFIG_MBEDTLS_THREADING_C
- CONFIG_MBEDTLS_SECURITY_RISKS

**CONFIG_MBEDTLS_MEM_ALLOC_MODE**
Memory allocation strategy

*Found in:* Component config > mbedTLS

Allocation strategy for mbedTLS, essentially provides ability to allocate all required dynamic allocations from,
• Internal DRAM memory only
• External SPIRAM memory only
• Either internal or external memory based on default malloc() behavior in ESP-IDF
• Custom allocation mode, by overwriting calloc()/free() using mbedtls_platform_set_calloc_free() function
• Internal IRAM memory wherever applicable else internal DRAM

Recommended mode here is always internal, since that is most preferred from security perspective. But if application requirement does not allow sufficient free internal memory then alternate mode can be selected.

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).

CONFIG_MBEDTLS_ASYMMETRIC_CONTENT_LEN
Asymmetric in/out fragment length

Found in: Component config > mbedTLS

If enabled, this option allows customizing TLS in/out fragment length in asymmetric way. Please note that enabling this with default values saves 12KB of dynamic memory per TLS connection.

CONFIG_MBEDTLS_SSL_INgetContent_LEN
TLS maximum incoming fragment length

Found in: Component config > mbedTLS

This defines maximum incoming fragment length, overriding default maximum content length (MBEDTLS_SSL_MAX_CONTENT_LEN).

CONFIG_MBEDTLS_SSL_OUTCONTENT_LEN
TLS maximum outgoing fragment length

Found in: Component config > mbedTLS

This defines maximum outgoing fragment length, overriding default maximum content length (MBEDTLS_SSL_MAX_CONTENT_LEN).

**CONFIG_MBEDTLS_DYNAMIC_BUFFER**

Using dynamic TX/RX buffer

*Found in: Component config > mbedTLS*

Using dynamic TX/RX buffer. After enabling this option, mbedTLS will allocate TX buffer when need to send data and then free it if all data is sent, allocate RX buffer when need to receive data and then free it when all data is used or read by upper layer.

By default, when SSL is initialized, mbedTLS also allocate TX and RX buffer with the default value of “MBEDTLS_SSL_OUT_CONTENT_LEN” or “MBEDTLS_SSL_IN_CONTENT_LEN”, so to save more heap, users can set the options to be an appropriate value.

**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.

**CONFIG_MBEDTLS_DYNAMIC_FREE_CONFIG_DATA**

Free certificate, key and DHM data after its usage

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_DYNAMIC_BUFFER*

Free certificate, 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.

**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.

**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.

**CONFIG_MBEDTLS_DEFAULT_CERTIFICATE_BUNDLE**

Default certificate bundle options

*Found in: Component config > mbedTLS > Certificate Bundle > CONFIG_MBEDTLS_CERTIFICATE_BUNDLE*

**Available options:**

- Use the full default certificate bundle (MBEDTLS_CERTIFICATE_BUNDLE_DEFAULT_FULL)
- Use only the most common certificates from the default bundles (MBEDTLS_CERTIFICATE_BUNDLE_DEFAULT_CMN)
  Use only the most common certificates from the default bundles, reducing the size with 50%, while still having around 99% coverage.
- Do not use the default certificate bundle (MBEDTLS_CERTIFICATE_BUNDLE_DEFAULT_NONE)

**CONFIG_MBEDTLS_CUSTOM_CERTIFICATE_BUNDLE**

Add custom certificates to the default bundle

*Found in: Component config > mbedTLS > Certificate Bundle > CONFIG_MBEDTLS_CERTIFICATE_BUNDLE*

**CONFIG_MBEDTLS_CUSTOM_CERTIFICATE_BUNDLE_PATH**

Custom certificate bundle path

*Found in: Component config > mbedTLS > Certificate Bundle > CONFIG_MBEDTLS_CERTIFICATE_BUNDLE > CONFIG_MBEDTLS_CUSTOM_CERTIFICATE_BUNDLE*

Name of the custom certificate directory or file. This path is evaluated relative to the project root directory.

**CONFIG_MBEDTLS_ECP_RESTARTABLE**

Enable mbedTLS ecp restartable

*Found in: Component config > mbedTLS*

Enable “non-blocking” ECC operations that can return early and be resumed.

**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.
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.

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 4096 bit results.

These operations are used by RSA.

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.

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)

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)

CONFIG_MBEDTLS_HAVE_TIME
Enable mbedtls time

*Found in: Component config > mbedTLS*

System has time.h and timer(). The time does not need to be correct, only time differences are used.
CONFIG_MBEDTLS_HAVE_TIME_DATE
Enable mbedtls certificate expiry check

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_HAVE_TIME*

System has time.h and time(), gmtime() and the clock is correct. The time needs to be correct (not necessarily very accurate, but at least the date should be correct). This is used to verify the validity period of X.509 certificates.

It is suggested that you should get the real time by “SNTP”.

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.

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.

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_PSK_MODES
- CONFIG_MBEDTLS_KEY_EXCHANGE_RSA
- CONFIG_MBEDTLS_KEY_EXCHANGE_DHE_RSA
- CONFIG_MBEDTLS_KEY_EXCHANGE_ELLIPTIC_CURVE
- CONFIG_MBEDTLS_KEY_EXCHANGE_ECJPAKE

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.
Chapter 2. API 参考

**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.

**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.

**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.

**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.

**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-

**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-

**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.
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-

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-

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-

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-

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-

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.

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.
Chapter 2. API

CONFIG_MBEDTLS_SSL_PROTO_TLS1
Support TLS 1.0 protocol
*Found in: Component config > mbedTLS*

CONFIG_MBEDTLS_SSL_PROTO_TLS1_1
Support TLS 1.1 protocol
*Found in: Component config > mbedTLS*

CONFIG_MBEDTLS_SSL_PROTO_TLS1_2
Support TLS 1.2 protocol
*Found in: Component config > mbedTLS*

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

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.

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.

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.

**Symmetric Ciphers**
Contains:
- **CONFIG_MBEDTLS_AES_C**
- **CONFIG_MBEDTLS_CAMELLIA_C**
- **CONFIG_MBEDTLS_DES_C**
- **CONFIG_MBEDTLS_RC4_MODE**
- **CONFIG_MBEDTLS_BLOWFISH_C**
- **CONFIG_MBEDTLS_XTEA_C**
- **CONFIG_MBEDTLS_CCM_C**
- **CONFIG_MBEDTLS_GCM_C**
**CONFIG_MBEDTLS_AES_C**

AES block cipher

*Found in: Component config > mbedTLS > Symmetric Ciphers*

**CONFIG_MBEDTLS_CAMELLIA_C**

Camellia block cipher

*Found in: Component config > mbedTLS > Symmetric Ciphers*

**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.

**CONFIG_MBEDTLS_RC4_MODE**

RC4 Stream Cipher (legacy, insecure)

*Found in: Component config > mbedTLS > Symmetric Ciphers*

ARCFOUR (RC4) stream cipher can be disabled entirely, enabled but not added to default ciphersuites, or enabled completely.

Please consider the security implications before enabling RC4.

**Available options:**

- Disabled (MBEDTLS_RC4_DISABLED)
- Enabled, not in default ciphersuites (MBEDTLS_RC4_ENABLED_NO_DEFAULT)
- Enabled (MBEDTLS_RC4_ENABLED)

**CONFIG_MBEDTLS_BLOWFISH_C**

Blowfish block cipher (read help)

*Found in: Component config > mbedTLS > Symmetric Ciphers*

Enables the Blowfish block cipher (not used for TLS sessions.)

The Blowfish cipher is not used for mbedTLS TLS sessions but can be used for other purposes. Read up on the limitations of Blowfish (including Sweet32) before enabling.

**CONFIG_MBEDTLS_XTEA_C**

XTEA block cipher

*Found in: Component config > mbedTLS > Symmetric Ciphers*

Enables the XTEA block cipher.

**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.
Chapter 2. API参考

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.

CONFIG_MBEDTLS_RIPEMD160_C
Enable RIPEMD-160 hash algorithm

*Found in: Component config > mbedTLS*

Enable the RIPEMD-160 hash algorithm.

Certificates  Contains:

- **CONFIG_MBEDTLS_PEM_PARSE_C**
- **CONFIG_MBEDTLS_PEM_WRITE_C**
- **CONFIG_MBEDTLS_X509_CRL_PARSE_C**
- **CONFIG_MBEDTLS_X509_CSR_PARSE_C**

CONFIG_MBEDTLS_PEM_PARSE_C
Read & Parse PEM formatted certificates

*Found in: Component config > mbedTLS > Certificates*

Enable decoding/parsing of PEM formatted certificates.
If your certificates are all in the simpler DER format, disabling this option will save some code size.

CONFIG_MBEDTLS_PEM_WRITE_C
Write PEM formatted certificates

*Found in: Component config > mbedTLS > Certificates*

Enable writing of PEM formatted certificates.
If writing certificate data only in DER format, disabling this option will save some code size.

CONFIG_MBEDTLS_X509_CRL_PARSE_C
X.509 CRL parsing

*Found in: Component config > mbedTLS > Certificates*


CONFIG_MBEDTLS_X509_CSR_PARSE_C
X.509 CSR parsing

*Found in: Component config > mbedTLS > Certificates*

Support for parsing X.509 Certificate Signing Requests
CONFIG_MBEDTLS_ECP_C
Elliptic Curve Ciphers

*Found in: Component config > mbedTLS*

Contains:

- CONFIG_MBEDTLS_ECDH_C
- CONFIG_MBEDTLS_ECJPAKE_C
- CONFIG_MBEDTLS_ECP_DP_SECP192R1_ENABLED
- CONFIG_MBEDTLS_ECP_DP_SECP224R1_ENABLED
- CONFIG_MBEDTLS_ECP_DP_SECP256R1_ENABLED
- CONFIG_MBEDTLS_ECP_DP_SECP384R1_ENABLED
- CONFIG_MBEDTLS_ECP_DP_SECP521R1_ENABLED
- CONFIG_MBEDTLS_ECP_DP_SECP192K1_ENABLED
- CONFIG_MBEDTLS_ECP_DP_SECP224K1_ENABLED
- CONFIG_MBEDTLS_ECP_DP_SECP256K1_ENABLED
- CONFIG_MBEDTLS_ECP_DP_BP256R1_ENABLED
- CONFIG_MBEDTLS_ECP_DP_BP384R1_ENABLED
- CONFIG_MBEDTLS_ECP_DP_BP512R1_ENABLED
- CONFIG_MBEDTLS_ECP_DP_CURVE25519_ENABLED
- CONFIG_MBEDTLS_ECP_NIST_OPTIM

CONFIG_MBEDTLS_ECDH_C
Elliptic Curve Diffie-Hellman (ECDH)

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C*

Enable ECDH. Needed to use ECDHE-xxx TLS ciphersuites.

CONFIG_MBEDTLS_ECDSA_C
Elliptic Curve DSA

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C > CONFIG_MBEDTLS_ECDH_C*

Enable ECDSA. Needed to use ECDSA-xxx TLS ciphersuites.

CONFIG_MBEDTLS_ECJPAKE_C
Elliptic curve J-PAKE

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C*

Enable ECJPAKE. Needed to use ECJPAKE-xxx TLS ciphersuites.

CONFIG_MBEDTLS_ECP_DP_SECP192R1_ENABLED
Enable SECP192R1 curve

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C*

Enable support for SECP192R1 Elliptic Curve.

CONFIG_MBEDTLS_ECP_DP_SECP224R1_ENABLED
Enable SECP224R1 curve

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C*

Enable support for SECP224R1 Elliptic Curve.
CONFIG_MBEDTLS_ECP_DP_SECP256R1_ENABLED
Enable SECP256R1 curve
*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C*
Enable support for SECP256R1 Elliptic Curve.

CONFIG_MBEDTLS_ECP_DP_SECP384R1_ENABLED
Enable SECP384R1 curve
*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C*
Enable support for SECP384R1 Elliptic Curve.

CONFIG_MBEDTLS_ECP_DP_SECP521R1_ENABLED
Enable SECP521R1 curve
*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C*
Enable support for SECP521R1 Elliptic Curve.

CONFIG_MBEDTLS_ECP_DP_SECP192K1_ENABLED
Enable SECP192K1 curve
*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C*
Enable support for SECP192K1 Elliptic Curve.

CONFIG_MBEDTLS_ECP_DP_SECP224K1_ENABLED
Enable SECP224K1 curve
*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C*
Enable support for SECP224K1 Elliptic Curve.

CONFIG_MBEDTLS_ECP_DP_SECP256K1_ENABLED
Enable SECP256K1 curve
*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C*
Enable support for SECP256K1 Elliptic Curve.

CONFIG_MBEDTLS_ECP_DP_BP256R1_ENABLED
Enable BP256R1 curve
*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C*
support for DP Elliptic Curve.

CONFIG_MBEDTLS_ECP_DP_BP384R1_ENABLED
Enable BP384R1 curve
*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C*
support for DP Elliptic Curve.
CONFIG_MBEDTLS_ECP_DP_BP512R1_ENABLED
Enable BP512R1 curve

*Found in:* Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C

Support for DP Elliptic Curve.

CONFIG_MBEDTLS_ECP_DP_CURVE25519_ENABLED
Enable CURVE25519 curve

*Found in:* Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C

Enable support for CURVE25519 Elliptic Curve.

CONFIG_MBEDTLS_ECP_NIST_OPTIM
NIST ‘modulo p’ optimisations

*Found in:* Component config > mbedTLS > CONFIG_MBEDTLS_ECP_C

NIST ‘modulo p’ optimisations increase Elliptic Curve operation performance.
Disabling this option saves some code size.

# end of Elliptic Curve options

CONFIG_MBEDTLS_POLY1305_C
Poly1305 MAC algorithm

*Found in:* Component config > mbedTLS

Enable support for Poly1305 MAC algorithm.

CONFIG_MBEDTLS_CHACHA20_C
Chacha20 stream cipher

*Found in:* Component config > mbedTLS

Enable support for Chacha20 stream cipher.

CONFIG_MBEDTLS_CHACHAPOLY_C
ChaCha20-Poly1305 AEAD algorithm

*Found in:* Component config > mbedTLS > CONFIG_MBEDTLS_CHACHA20_C

Enable support for ChaCha20-Poly1305 AEAD algorithm.

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).
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.

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.

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.

CONFIG_MBEDTLS SECURITY_RISKS

Show configurations with potential security risks

Found in: Component config > mbedtls

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

mDNS

Contains:

• CONFIG_MDNS_MAX_SERVICES
• CONFIG_MDNS_TASK_PRIORITY
• CONFIG_MDNS_TASK_STACK_SIZE
• CONFIG_MDNS_TASK_AFFINITY
• CONFIG_MDNS_SERVICE_ADD_TIMEOUT_MS
• CONFIG_MDNS_TIMER_PERIOD_MS

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.
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.

CONFIG_MDNS_TASK_STACK_SIZE

mDNS task stack size

*Found in: Component config > mDNS*

Allows setting mDNS task stacksize.

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.

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.

ESP-MQTT Configurations Contains:

- CONFIG_MQTT_PROTOCOL_311
- CONFIG_MQTT_TRANSPORT_SSL
- CONFIG_MQTT_TRANSPORT_WEBSOCKET
- CONFIG_MQTT_USE_CUSTOM_CONFIG
- CONFIG_MQTT_TASK_CORE_SELECTION_ENABLED
- CONFIG_MQTT_CUSTOM_OUTBOX
- CONFIG_MQTT_OUTBOX_EXPIRED_TIMEOUT_MS
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

CONFIG_MQTT_TRANSPORT_SSL
Enable MQTT over SSL

*Found in: Component config > ESP-MQTT Configurations*
Enable MQTT transport over SSL with mbedTLS

CONFIG_MQTT_TRANSPORT_WEBSOCKET
Enable MQTT over Websocket

*Found in: Component config > ESP-MQTT Configurations*
Enable MQTT transport over Websocket.

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_USE_CUSTOM_CONFIG
MQTT Using custom configurations

*Found in: Component config > ESP-MQTT Configurations*
Custom MQTT configurations.

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

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

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
Chapter 2. API Reference

**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

**CONFIG_MQTT_BUFFER_SIZE**
Default MQTT Buffer Size

*Found in:* Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG

This buffer size is used for both transmit and receive.

**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

**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.

**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.

**CONFIG_MQTT_TASK_CORE_SELECTION_ENABLED**
Enable MQTT task core selection

*Found in:* Component config > ESP-MQTT Configurations

This will enable core selection

**CONFIG_MQTT_TASK_CORE_SELECTION**
Core to use?

*Found in:* Component config > ESP-MQTT Configurations > CONFIG_MQTT_TASK_CORE_SELECTION_ENABLED

**Available options:**
- Core 0 (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. persistant outbox in NVM or similar).

**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.

**Newlib** Contains:

- **CONFIG_NEWLIB_STDOUT_LINE_ENDING**
- **CONFIG_NEWLIB_STDIN_LINE_ENDING**
- **CONFIG_NEWLIB_NANO_FORMAT**

**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.

**NVS**
Contains:
- **CONFIG_NVS_ENCRYPTION**

**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.

**OpenSSL**
Contains:
- **CONFIG_OPENSSL_DEBUG**
- **CONFIG_OPENSSL_ERROR_STACK**
- **CONFIG_OPENSSL_DEBUG_LEVEL**
- **CONFIG_OPENSSL_LOWLEVEL_DEBUG**
- **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.

**CONFIG_OPENSSL_ERROR_STACK**
Enable OpenSSL error structure

*Found in: Component config > OpenSSL*

Enable OpenSSL Error reporting
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.

CONFIG_OPENSSL_LOWWLEVEL_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.

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);”.

PThreads Contains:

- CONFIG_PTHREAD_TASK_PRIO_DEFAULT
- CONFIG_PTHREAD_TASK_STACK_SIZE_DEFAULT
- CONFIG_PTHREAD_STACK_MIN
- CONFIG_PTHREAD_TASK_CORE_DEFAULT
- CONFIG_PTHREAD_TASK_NAME_DEFAULT

CONFIG_PTHREAD_TASK_PRIO_DEFAULT

Default task priority

*Found in:* Component config > PThreads

Priority used to create new tasks with default pthread parameters.
**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.

**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

**CONFIG_PTHREAD_TASK_CORE_DEFAULT**

Default pthread core affinity

*Found in: Component config > PThreads*

The default core to which pthreads are pinned.

**Available options:**

- No affinity (PTHREAD_DEFAULT_CORE_NO_AFFINITY)
- Core 0 (PTHREAD_DEFAULT_CORE_0)
- Core 1 (PTHREAD_DEFAULT_CORE_1)

**CONFIG_PTHREAD_TASK_NAME_DEFAULT**

Default name of pthreads

*Found in: Component config > PThreads*

The default name of pthreads.

**SPI Flash driver**

Contains:

- CONFIG_SPI_FLASH_VERIFY_WRITE
- CONFIG_SPI_FLASH_ENABLE_COUNTERS
- CONFIG_SPI_FLASH_ROM_DRIVER_PATCH
- CONFIG_SPI_FLASH_DANGEROUS_WRITE
- CONFIG_SPI_FLASH_USE_LEGACY_IMPL
- CONFIG_SPI_FLASH_SHARE_SPI1_BUS
- CONFIG_SPI_FLASH_BYPASS_BLOCK_ERASE
- CONFIG_SPI_FLASH_YIELD_DURING_ERASE
- CONFIG_SPI_FLASH_WRITE_CHUNK_SIZE
- CONFIG_SPI_FLASH_SIZE_OVERRIDE
- CONFIG_SPI_FLASH_CHECK_ERASE_TIMEOUT_DISABLED
- Auto-detect flash chips

**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.
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.

CONFIG_SPI_FLASH_WARN_SETTING_ZERO_TO_ONE
Log warning if writing zero bits to ones

_found in: Component config > SPI Flash driver > CONFIG_SPI_FLASH_VERIFY_WRITE_
If this option is enabled, any SPI flash write which tries to set zero bits in the flash to ones will log a warning. Such writes will not result in the requested data appearing identically in flash once written, as SPI NOR flash can only set bits to one when an entire sector is erased. After erasing, individual bits can only be written from one to zero.

Note that some software (such as SPIFFS) which is aware of SPI NOR flash may write one bits as an optimisation, relying on the data in flash becoming a bitwise AND of the new data and any existing data. Such software will log spurious warnings if this option is enabled.

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.

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.

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:
Chapter 2. API

- 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.

**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.

**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.

**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.

**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.

**CONFIG_SPI_FLASH_ERASE_YIELD_TICKS**

CPU release time (tick)

*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.
**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.

**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.

**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.

**Auto-detect flash chips**

Contains:

- **CONFIG_SPI_FLASH_SUPPORT_ISSI_CHIP**
- **CONFIG_SPI_FLASH_SUPPORT_MXIC_CHIP**
- **CONFIG_SPI_FLASH_SUPPORT_GD_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.

**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.

**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.
Chapter 2. API

SPIFFS Configuration Contains:

- CONFIG_SPIFFS_MAX_PARTITIONS
- SPIFFS Cache Configuration
- CONFIG_SPIFFS_PAGE_CHECK
- CONFIG_SPIFFS_GC_MAX_RUNS
- CONFIG_SPIFFS_GC_STATS
- CONFIG_SPIFFS_PAGE_SIZE
- CONFIG_SPIFFS_OBJ_NAME_LEN
- CONFIG_SPIFFS_FOLLOW_SYMLINKS
- CONFIG_SPIFFS_USE_MAGIC
- CONFIG_SPIFFS_META_LENGTH
- CONFIG_SPIFFS_USE_MTIME
- CONFIG_SPIFFS_MTIME_WIDE_64_BITS
- Debug Configuration

CONFIG_SPIFFS_MAX_PARTITIONS

Maximum Number of Partitions

Found in: Component config > SPIFFS Configuration

Define maximum number of partitions that can be mounted.

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.

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.

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.

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.
**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.

**CONFIG_SPIFFS_GC_STATS**

Enable SPIFFS GC Statistics

*Found in: Component config > SPIFFS Configuration*

Enable/disable statistics on gc. Debug/test purpose only.

**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.

**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.

**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.

**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.

**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.
**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.

**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.

**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_64_BITS).

**Debug Configuration**

Contains:

- **CONFIG_SPIFFS_DBG**
- **CONFIG_SPIFFS_API_DBG**
- **CONFIG_SPIFFS_GC_DBG**
- **CONFIG_SPIFFS_CACHE_DBG**
- **CONFIG_SPIFFS_CHECK_DBG**
- **CONFIG_SPIFFS_TEST_VISUALISATION**

**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.

**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.
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.

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.

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.

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.

TCP Transport  Contains:

- **CONFIG_WS_BUFFER_SIZE**

CONFIG_WS_BUFFER_SIZE
Websocket transport buffer size

*Found in: Component config > TCP Transport*

Size of the buffer used for constructing the HTTP Upgrade request during connect

TinyUSB

Unity unit testing library  Contains:

- **CONFIG.Unity_ENABLE_FLOAT**
- **CONFIG.Unity_ENABLE_DOUBLE**
- **CONFIG.Unity_ENABLE_COLOR**
- **CONFIG.Unity_ENABLE_IDF_TEST_RUNNER**
- **CONFIG.Unity_ENABLE_FIXTURE**
- **CONFIG.Unity_ENABLE_BACKTRACE_ON_FAIL**

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.
Chapter 2. API Reference

**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.

**CONFIG_UNITY_ENABLE_COLOR**
Colorize test output

*Found in: Component config > Unity unit testing library*

If set, Unity will colorize test results using console escape sequences.

**CONFIG_UNITY_ENABLE_IDF_TEST_RUNNER**
Include ESP-IDF test registration/running helpers

*Found in: Component config > Unity unit testing library*

If set, then the following features will be available:

- TEST_CASE macro which performs automatic registration of test functions
- Functions to run registered test functions: unity_run_all_tests, unity_run_tests_with_filter, unity_run_single_test_by_name.
- Interactive menu which lists test cases and allows choosing the tests to be run, available via unity_run_menu function.

Disable if a different test registration mechanism is used.

**CONFIG_UNITY_ENABLE_FIXTURE**
Include Unity test fixture

*Found in: Component config > Unity unit testing library*

If set, unity_fixture.h header file and associated source files are part of the build. These provide an optional set of macros and functions to implement test groups.

**CONFIG_UNITY_ENABLE_BACKTRACE_ON_FAIL**
Print a backtrace when a unit test fails

*Found in: Component config > Unity unit testing library*

If set, the unity framework will print the backtrace information before jumping back to the test menu. The jumping is usually occurs in assert functions such as TEST_ASSERT, TEST_FAIL etc.

**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.

**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.

**CONFIG_VFS_SUPPORT_SELECT**

Provide select function

*Found in: Component config > Virtual file system > CONFIG_VFS_SUPPORT_IO*

If enabled, select function is provided by the VFS component, and can be used on peripheral file descriptors (such as UART) and sockets at the same time.

If disabled, the default select implementation will be provided by LWIP for sockets only.

Disabling this option can reduce code size if support for “select” on UART file descriptors is not required.

**CONFIG_VFS_SUPPRESS_SELECT_DEBUG_OUTPUT**

Suppress select() related debug outputs

*Found in: Component config > Virtual file system > CONFIG_VFS_SUPPORT_IO > CONFIG_VFS_SUPPORT_SELECT*

Select() related functions might produce an unconveniently lot of debug outputs when one sets the default log level to DEBUG or higher. It is possible to suppress these debug outputs by enabling this option.

**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.

**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.
Chapter 2. API Reference

**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.

**Wear Levelling**  
Contains:

- **CONFIG_WL_SECTOR_SIZE**
- **CONFIG_WL_SECTOR_MODE**

**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 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_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.

**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.

**Supplicant** Contains:

- **CONFIG_WPA_MBEDTLS_CRYPTO**
- **CONFIG_WPA_DEBUG_PRINT**
- **CONFIG_WPA_TESTING_OPTIONS**
- **CONFIG_WPA_WPS_WARS**

**CONFIG_WPA_MBEDTLS_CRYPTO**

Use MbedTLS crypto API’s

*Found in: Component config > Supplicant*

Select this option to use MbedTLS crypto API’s which utilize hardware acceleration.

**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.

**CONFIG_WPA_TESTING_OPTIONS**

Add DPP testing code

*Found in: Component config > Supplicant*

Select this to enable unity test for DPP.

**CONFIG_WPA_WPS_WARS**

Add WPS Inter operatability Fixes

*Found in: Component config > Supplicant*

Select this option to enable WPS related IOT fixes with different APs. This option fixes IOT related issues with APs which do not follow some of the standards of WPS-2.0 specification. These do not include any of the security related bypassing, just simple configuration corrections.

Current fixes under this flag. 1. Allow NULL-padded WPS attributes: Some APs keep NULL-padding at the end of some variable length WPS Attributes. This is not as par the WPS2.0 specs, but to avoid
interop issues, ignore the padding by reducing the attribute length by 1. 2. Bypass WPS-Config method validation: Some APs set display/pbc button bit without setting virtual/physical display/button bit which will cause M2 validation fail, bypassing WPS-Config method validation.

Compatibility options

Contains:

- **CONFIG_LEGACY_INCLUDE_COMMON_HEADERS**

**CONFIG_LEGACY_INCLUDE_COMMON_HEADERS**

Include headers across components as before IDF v4.0

*Found in: Compatibility options*

Soc, esp32, and driver components, the most common components. Some header of these components are included implicitly by headers of other components before IDF v4.0. It’s not required for high-level components, but still included through long header chain everywhere.

This is harmful to the modularity. So it’s changed in IDF v4.0.

You can still include these headers in a legacy way until it is totally deprecated by enable this option.

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_LEVELVerbose
- **CONFIG_AVDT_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_AVDT_TRACE_LEVEL)**
  - CONFIG_AVDT_TRACE_LEVEL_NONE
  - CONFIG_AVDT_TRACE_LEVEL_ERROR
Chapter 2. API

- CONFIG_AVDT_TRACE_LEVEL_WARNING
- CONFIG_AVDT_TRACE_LEVEL_API
- CONFIG_AVDT_TRACE_LEVEL_EVENT
- CONFIG_AVDT_TRACE_LEVEL_DEBUG
- CONFIG_AVDT_TRACE_LEVEL_VERBOSE

• CONFIG_AVRC_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_AVRC_TRACE_LEVEL)
  - CONFIG_AVRC_TRACE_LEVEL_NONE
  - CONFIG_AVRC_TRACE_LEVEL_ERROR
  - CONFIG_AVRC_TRACE_LEVEL_WARNING
  - CONFIG_AVRC_TRACE_LEVEL_API
  - CONFIG_AVRC_TRACE_LEVEL_EVENT
  - CONFIG_AVRC_TRACE_LEVEL_DEBUG
  - CONFIG_AVRC_TRACE_LEVEL_VERBOSE

• CONFIG_BLE_ACTIVE_SCAN_REPORT_ADV_SCAN_RSP_INDIVIDUALLY (CONFIG_BT_BLE_ACT_SCAN_REPORT_ADV_SCAN_RSP_INDIVIDUALLY)
- CONFIG_BLE_ADV_REPORT_DISCARD_THRESHOLD (CONFIG_BT_BLE_ADV_REPORT_DISCARD_THRESHOLD)
- CONFIG_BLE_ADV_REPORT_FLOW_CONTROL_NUM (CONFIG_BT_BLE_ADV_REPORT_FLOW_CONTROL_NUM)
- CONFIG_BLE_ADV_REPORT_FLOW_CONTROL_SUPPORTED (CONFIG_BT_BLE_ADV_REPORT_FLOW_CONTROL_SUPPORTED)
- CONFIG_BLE_ESTABLISH_LINK_CONNECTION_TIMEOUT (CONFIG_BT_BLE_ESTABLISH_LINK_CONNECTION_TIMEOUT)
- CONFIG_BLE_HOST_QUEUE_CONGESTION_CHECK (CONFIG_BT_BLE_HOST_QUEUE_CONGESTION_CHECK)
- CONFIG_BLE_MESH_GATT_PROXY (CONFIG_BT_BLE_MESH_GATT_PROXY)
- CONFIG_BLE_MESH_SCAN_DUPLICATE_EN (CONFIG_BT_BLE_MESH_SCAN_DUPLICATE_EN)
- CONFIG_BLE_SCAN_DUPLICATE (CONFIG_BT_BLE_SCAN_DUPLICATE)
- CONFIG_BLE_SMP_ENABLE (CONFIG_BT_BLE_SMP_ENABLE)
- CONFIG_BLUEDROID_MEM_DEBUG (CONFIG_BT_BLUEDROID_MEM_DEBUG)
- CONFIG_BLUEDROID_PINNED_TO_CORE_CHOICE (CONFIG_BT_BLUEDROID_PINNED_TO_CORE_CHOICE)
  - CONFIG_BLUEDROID_PINNED_TO_CORE_0
  - CONFIG_BLUEDROID_PINNED_TO_CORE_1

• CONFIG_BLUFI_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_BLUFI_TRACE_LEVEL)
  - CONFIG_BLUFI_TRACE_LEVEL_NONE
  - CONFIG_BLUFI_TRACE_LEVEL_ERROR
  - CONFIG_BLUFI_TRACE_LEVEL_WARNING
  - CONFIG_BLUFI_TRACE_LEVEL_API
  - CONFIG_BLUFI_TRACE_LEVEL_EVENT
  - CONFIG_BLUFI_TRACE_LEVEL_DEBUG
  - CONFIG_BLUFI_TRACE_LEVEL_VERBOSE

• CONFIG_BNEP_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_BNEP_TRACE_LEVEL)
  - CONFIG_BNEP_TRACE_LEVEL_NONE
  - CONFIG_BNEP_TRACE_LEVEL_ERROR
  - CONFIG_BNEP_TRACE_LEVEL_WARNING
  - CONFIG_BNEP_TRACE_LEVEL_API
  - CONFIG_BNEP_TRACE_LEVEL_EVENT
  - CONFIG_BNEP_TRACE_LEVEL_DEBUG
  - CONFIG_BNEP_TRACE_LEVEL_VERBOSE

• 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
Chapter 2. API

- **CONFIG_BT_BTU_TASK_STACK_SIZE**  
- **CONFIG_BT_DM_CONTROLLER_BLE_MAX_CONN**  
- **CONFIG_BT_DM_CONTROLLER_BR_EDR_MAX_ACL_CONN**  
- **CONFIG_BT_DM_CONTROLLER_BR_EDR_MAX_SYNC_CONN**  
- **CONFIG_BT_DM_CONTROLLER_FULL_SCAN_SUPPORTED**  
- **CONFIG_BT_DM_CONTROLLER_HCI_MODE_CHOICE**  
  - **CONFIG_BT_DM_CONTROLLER_HCI_MODE_VHCI**  
  - **CONFIG_BT_DM_CONTROLLER_HCI_MODE_UART_H4**  
- **CONFIG_BT_DM_CONTROLLER_MODE**  
  - **CONFIG_BT_DM_CONTROLLER_MODE_BLE_ONLY**  
  - **CONFIG_BT_DM_CONTROLLER_MODE_BR_EDR_ONLY**  
  - **CONFIG_BT_DM_CONTROLLER_MODE_BTDM**  
- **CONFIG_BT_DM_CONTROLLER_MODEM_SLEEP**  
- **CONFIG_BT_DM_CONTROLLER_PINNED_TO_CORE_CHOICE**  
- **CONFIG_BT_HL_LOG_SDP_INITIAL_TRACE_LEVEL**  
  - **CONFIG_BT_HL_LOG_SDP_TRACE_LEVEL_NONE**  
  - **CONFIG_BT_HL_LOG_SDP_TRACE_LEVEL_ERROR**  
  - **CONFIG_BT_HL_LOG_SDP_TRACE_LEVEL_WARNING**  
  - **CONFIG_BT_HL_LOG_SDP_TRACE_LEVEL_API**  
  - **CONFIG_BT_HL_LOG_SDP_TRACE_LEVEL_EVENT**  
  - **CONFIG_BT_HL_LOG_SDP_TRACE_LEVEL_DEBUG**  
  - **CONFIG_BT_HL_LOG_SDP_TRACE_LEVEL_VERBOSE**  
- **CONFIG_BTIF_INITIAL_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_BT_INITIAL_TRACE_LEVEL**  
  - **CONFIG_BT_TRACE_LEVEL_NONE**  
  - **CONFIG_BT_TRACE_LEVEL_ERROR**  
  - **CONFIG_BT_TRACE_LEVEL_WARNING**  
  - **CONFIG_BT_TRACE_LEVEL_API**  
  - **CONFIG_BT_TRACE_LEVEL_EVENT**  
  - **CONFIG_BT_TRACE_LEVEL_DEBUG**  
  - **CONFIG_BT_TRACE_LEVEL_VERBOSE**  
- **CONFIG_BTU_TASK_STACK_SIZE**  
- **CONFIG_COMPATIBLE_PRE_V2_1_BOOTLOADERS**  
- **CONFIG_CONSOLE_UART**  
  - **CONFIG_CONSOLE_UART_DEFAULT**  
  - **CONFIG_CONSOLE_UART_CUSTOM**  
  - **CONFIG_ESP_CONSOLE_UART_NONE**  
- **CONFIG_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_CONSOLE_UART_TX_GPIO**  
- **CONFIG_CXX_EXCEPTIONS**  
  - **CONFIG_CXX_EXCEPTIONS_EMG_POOL_SIZE**  

Espressif Systems 1370 Release v4.3-dev-1561-g357a277603

Submit Document Feedback
• 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_DUPLICATE_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_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_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_DECODE_INFO
  – CONFIG_ESP32_CORE_DUMP_DECODE_DISABLE
• CONFIG_ESP32_CORE_DUMP_MAX_TASKS_NUM (CONFIG_ESP_COREDUMP_MAX_TASKS_NUM)
• CONFIG_ESP32_CORE_DUMP_STACK_SIZE (CONFIG_ESP_COREDUMP_STACK_SIZE)
• CONFIG_ESP32_CORE_DUMP_UART_DELAY (CONFIG_ESP_COREDUMP_UART_DELAY)
• CONFIG_ESP32_GCOV_ENABLE (CONFIG_APPTRACE_GCOV_ENABLE)
  – CONFIG_ESP32_DEFAULT_PTHREAD_CORE_NO_AFFINITY
  – CONFIG_ESP32_DEFAULT_PTHREAD_CORE_0
  – CONFIG_ESP32_DEFAULT_PTHREAD_CORE_1
• CONFIG_ESP32_RTC_CLOCK_SOURCE (CONFIG_ESP32_RTC_CLK_SRC)
  – CONFIG_ESP32_RTC_CLOCK_SOURCE_INTERNAL_RC
  – CONFIG_ESP32_RTC_CLOCK_SOURCE_EXTERNALCRYSTAL
  – CONFIG_ESP32_RTC_CLOCK_SOURCE_EXTERNAL_OSC
  – CONFIG_ESP32_RTC_CLOCK_SOURCE_INTERNAL_8MD256
• CONFIG_ESP32_RTC_EXTERNALCRYSTAL_ADDITIONAL_CURRENT (CONFIG_ESP32_RTC_EXTCRYST_ADDIT_CURRENT)
• CONFIG_ESP32_RTC_XTAL_BOOTSTRAP_CYCLES (CONFIG_ESP_SYSTEM_RTC_EXT_XTAL_BOOTSTRAP_CYCLES)
• CONFIG_ESP_GRAYTUITOUS_ARP (CONFIG_LWIP_ESP_GRAYTUITOUS_ARP)
• CONFIG_ESP_TCP_KEEP_CONNECTION_WHEN_IP_CHANGES (CONFIG_LWIP_TCP_KEEP_CONNECTION_WHEN_IP_CHANGES)
• 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_GAP_TMR_INTERVAL` (*CONFIG_LWIP_GARP_TMR_INTERVAL*)

• `CONFIG_GATT_CACHE_NVS_FLASH` (*CONFIG_BT_GATT_CACHE_NVS_FLASH*)

• `CONFIG_GATT_ENABLE` (*CONFIG_BT_GATT_ENABLE*)

• `CONFIG_GATTS_ENABLE` (*CONFIG_BT_GATTS_ENABLE*)

• `CONFIG_GATTS_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`
Chapter 2. 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_MAKE_WARN_UNDEFINED_VARIABLES (CONFIG_SDK_MAKE_WARN_UNDEFINED_VARIABLES)
• CONFIG_MB_CONTROLLER_NOTIFY_QUEUE_SIZE (CONFIG_FMB_CONTROLLER_NOTIFY_QUEUE_SIZE)
• CONFIG_MB_CONTROLLER_NOTIFY_TIMEOUT (CONFIG_FMB_CONTROLLER_NOTIFY_TIMEOUT)
• CONFIG_MB_CONTROLLER_SLAVE_ID (CONFIG_FMB_CONTROLLER_SLAVE_ID)
• CONFIG_MB_CONTROLLER_SLAVE_ID_SUPPORT (CONFIG_FMB_CONTROLLER_SLAVE_ID_SUPPORT)
• CONFIG_MB_CONTROLLER_STACK_SIZE (CONFIG_FMB_CONTROLLER_STACK_SIZE)
• CONFIG_MB_EVENT_QUEUE_TIMEOUT (CONFIG_FMB_EVENT_QUEUE_TIMEOUT)
• CONFIG_MB_MASTER_DELAY_MS_CONVERT (CONFIG_FMB_MASTER_DELAY_MS_CONVERT)
• CONFIG_MB_MASTER_TIMEOUT_MS_RESPOND (CONFIG_FMB_MASTER_TIMEOUT_MS_RESPOND)
• 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_GROUP (CONFIG_FMB_TIMER_GROUP)
• CONFIG_MB_TIMER_INDEX (CONFIG_FMB_TIMER_INDEX)
• 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_IEVL)
• CONFIG_NIMBLE_HS_FLOW_CTRL_THRESH (CONFIG_BT_NIMBLE_HS_FLOW_CTRL_THRESH)
Chapter 2. API

- \texttt{CONFIG_BT_NIMBLE_HS_FLOW_CTRL_TX_ON_DISCONNECT}
- \texttt{CONFIG_BT_NIMBLE_L2CAP_COC_MAX_NUM}
- \texttt{CONFIG_BT_NIMBLE_MAX_BONDS}
- \texttt{CONFIG_BT_NIMBLE_MAX_CCCDS}
- \texttt{CONFIG_BT_NIMBLE_MAX_CONNECTIONS}
- \texttt{CONFIG_BT_NIMBLE_MEM_ALLOC_MODE}
  - \texttt{CONFIG_BT_NIMBLE_MEM_ALLOC_MODE_INTERNAL}
  - \texttt{CONFIG_BT_NIMBLE_MEM_ALLOC_MODE_EXTERNAL}
  - \texttt{CONFIG_BT_NIMBLE_MEM_ALLOC_MODE_DEFAULT}
- \texttt{CONFIG_BT_NIMBLE_MESH}
- \texttt{CONFIG_BT_NIMBLE_MESH_DEVICE_NAME}
- \texttt{CONFIG_BT_NIMBLE_MESH_FRIEND}
- \texttt{CONFIG_BT_NIMBLE_MESH_GATT_PROXY}
- \texttt{CONFIG_BT_NIMBLE_MESH_LOW_POWER}
- \texttt{CONFIG_BT_NIMBLE_MESH_PB_ADV}
- \texttt{CONFIG_BT_NIMBLE_MESH_PB_GATT}
- \texttt{CONFIG_BT_NIMBLE_MESH_PROXY}
- \texttt{CONFIG_BT_NIMBLE_MESH_RELAY}
- \texttt{CONFIG_BT_NIMBLE_MESH_MSYS1_BLOCK_COUNT}
- \texttt{CONFIG_BT_NIMBLE_NVS_PERSIST}
- \texttt{CONFIG_BT_NIMBLE_PINNED_TO_CORE_CHOICE}
  - \texttt{CONFIG_BT_NIMBLE_PINNED_TO_CORE_0}
  - \texttt{CONFIG_BT_NIMBLE_PINNED_TO_CORE_1}
- \texttt{CONFIG_BT_NIMBLE_ROLE_BROADCASTER}
- \texttt{CONFIG_BT_NIMBLE_ROLE_CENTRAL}
- \texttt{CONFIG_BT_NIMBLE_ROLE_OBSERVER}
- \texttt{CONFIG_BT_NIMBLE_ROLE_PERIPHERAL}
- \texttt{CONFIG_BT_NIMBLE_RPA_TIMEOUT}
- \texttt{CONFIG_BT_NIMBLE_SM_LEGACY}
- \texttt{CONFIG_BT_NIMBLE_SM_SC}
- \texttt{CONFIG_BT_NIMBLE_SM_SC_DEBUG_KEYS}
- \texttt{CONFIG_BT_NIMBLE_SVC_GAP_APPEARANCE}
- \texttt{CONFIG_BT_NIMBLE_SVC_GAP_DEVICE_NAME}
- \texttt{CONFIG_BT_NIMBLE_TASK_STACK_SIZE}
- \texttt{CONFIG_ESP32_NO_BLOBS}
- \texttt{CONFIG_ESP32_NUMBER_OF_UNIVERSAL_MAC_ADDRESS}
- \texttt{CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL}
  - \texttt{CONFIG_COMPILER_OPTIMIZATION_ASSERTIONS_ENABLED}
  - \texttt{CONFIG_COMPILER_OPTIMIZATION_ASSERTIONS_SILENT}
  - \texttt{CONFIG_COMPILER_OPTIMIZATION_ASSERTIONS_DISABLED}
- \texttt{CONFIG_COMPILER_OPTIMIZATION}
  - \texttt{CONFIG_COMPILER_OPTIMIZATION_LEVEL_DEBUG}
  - \texttt{CONFIG_COMPILER_OPTIMIZATION_LEVEL_RELEASE}
- \texttt{CONFIG_LOG_OSI_TRACE_LEVEL}
  - \texttt{CONFIG_LOG_OSI_TRACE_LEVEL_NONE}
  - \texttt{CONFIG_LOG_OSI_TRACE_LEVEL_ERROR}
  - \texttt{CONFIG_LOG_OSI_TRACE_LEVEL_WARNING}
  - \texttt{CONFIG_LOG_OSI_TRACE_LEVEL_API}
  - \texttt{CONFIG_LOG_OSI_TRACE_LEVEL_EVENT}
  - \texttt{CONFIG_LOG_OSI_TRACE_LEVEL_DEBUG}
  - \texttt{CONFIG_LOG_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_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_SMP_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_SMP_TRACE_LEVEL)
  - CONFIG_SMP_TRACE_LEVEL_NONE
  - CONFIG_SMP_TRACE_LEVEL_ERROR
  - CONFIG_SMP_TRACE_LEVEL_WARNING
  - CONFIG_SMP_TRACE_LEVEL_API
  - CONFIG_SMP_TRACE_LEVEL_EVENT
  - CONFIG_SMP_TRACE_LEVEL_DEBUG
  - CONFIG_SMP_TRACE_LEVEL_VERBOSE

• CONFIG_SPI_FLASH_WRITING_DANGEROUS_REGIONS (CONFIG_SPI_FLASH_DANGEROUS_WRITE)
  - CONFIG_SPI_FLASH_WRITING_DANGEROUS_REGIONS_ABORTS
  - CONFIG_SPI_FLASH_WRITING_DANGEROUS_REGIONS_FAILS
  - CONFIG_SPI_FLASH_WRITING_DANGEROUS_REGIONS_ALLOWED

• CONFIG_STACK_CHECK_MODE (CONFIG_COMPILER_STACK_CHECK_MODE)
  - CONFIG_STACK_CHECK_NONE
  - CONFIG_STACK_CHECK_NORM
  - CONFIG_STACK_CHECK_STRONG
  - CONFIG_STACK_CHECK_ALL

• CONFIG_SUPPORT_STATIC_ALLOCATION (CONFIG_FREERTOS_SUPPORT_STATIC_ALLOCATION)
• 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)
2.8.7 Customisations

Because IDF builds by default with 警告未定义的变量, when the Kconfig tool generates Makefiles (the auto.
conf file) its behaviour has been customised. In normal Kconfig, a variable which is set to “no” is undefined. In
IDF’s version of Kconfig, this variable is defined in the Makefile but has an empty value.

(Note that ifdef and ifndef can still be used in Makefiles, because they test if a variable is defined and has a
non-empty value.)

When generating header files for C & C++, the behaviour is not customised - so #ifdef can be used to test if a
boolean config item is set or not.

2.9 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)
Chapter 2. API

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 (0x201)
ESP_ERR_NVS_BASE (0x1100): Starting number of error codes
ESP_ERR_NVS_NOT_INITIALIZED (0x1101): The storage driver is not initialized
ESP_ERR_NVS_NOT_FOUND (0x1102): Id namespace doesn’t exist yet and mode is NVS_READONLY
ESP_ERR_NVS_TYPE_MISMATCH (0x1103): The type of set or get operation doesn’t match the type of value stored in NVS
ESP_ERR_NVS_READ_ONLY (0x1104): Storage handle was opened as read only
ESP_ERR_NVS_NOT_ENOUGH_SPACE (0x1105): There is not enough space in the underlying storage to save the value
ESP_ERR_NVS_INVALID_NAME (0x1106): Namespace name doesn’t satisfy constraints
ESP_ERR_NVS_INVALID_HANDLE (0x1107): Handle has been closed or is NULL
ESP_ERR_NVS_REMOVE_FAILED (0x1108): The value wasn’t updated because flash write operation has failed. The value was written however, and update will be finished after re-initialization of nvs, provided that flash operation doesn’t fail again.
ESP_ERR_NVS_KEY_TOO_LONG (0x1109): Key name is too long
ESP_ERR_NVS_PAGE_FULL (0x110a): Internal error; never returned by nvs API functions
ESP_ERR_NVS_INVALID_STATE (0x110b): NVS is in an inconsistent state due to a previous error. Call nvs_flash_init and nvs_open again, then retry.
ESP_ERR_NVS_INVALID_LENGTH (0x110c): String or blob length is not sufficient to store data
ESP_ERR_NVS_NO_FREE_PAGES (0x110d): NVS partition doesn’t contain any empty pages. This may happen if NVS partition was truncated. Erase the whole partition and call nvs_flash_init again.
ESP_ERR_NVS_VALUE_TOO_LONG (0x110e): String or blob length is longer than supported by the implementation
ESP_ERR_NVS_PART_NOT_FOUND (0x110f): Partition with specified name is not found in the partition table
ESP_ERR_NVS_NEW_VERSION_FOUND (0x1110): NVS partition contains data in new format and cannot be recognized by this version of code
ESP_ERR_NVS_XTS_ENCR_FAILED (0x1111): XTS encryption failed while writing NVS entry
ESP_ERR_NVS_XTS_DECR_FAILED (0x1112): XTS decryption failed while reading NVS entry
ESP_ERR_NVS_XTS_CFG_FAILED (0x1113): XTS configuration setting failed
ESP_ERR_NVS_XTS_CFG_NOT_FOUND (0x1114): XTS configuration not found
ESP_ERR_NVS_ENCR_NOT_SUPPORTED (0x1115): NVS encryption is not supported in this version
Chapter 2. API

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_U LP_BASE (0x1200): Offset for ULP-related error codes
ESP_ERR_U LP_SIZE_TOO_BIG (0x1201): Program doesn’t fit into RTC memory reserved for the ULP
ESP_ERR_U LP_INVALID_LOAD_ADDR (0x1202): Load address is outside of RTC memory reserved for the ULP
ESP_ERR_U LP_DUPLICATE_LABEL (0x1203): More than one label with the same number was defined
ESP_ERR_U LP_UNDEFIN ED_LABEL (0x1204): Branch instructions references an undefined label
ESP_ERR_U LP_BRANCH_OUT_OF_RANGE (0x1205): Branch target is out of range of B instruction (try replacing with BX)
ESP_ERR_OTA_BASE (0x1500): Base error code for ota_ops api
ESP_ERR_OTA_PARTITION_CONFLICT (0x1501): Error if request was to write or erase the current running partition
ESP_ERR_OTA_SELECT_INFO_INVALID (0x1502): Error if OTA data partition contains invalid content
ESP_ERR_OTA_VALIDATE_FAILED (0x1503): Error if OTA app image is invalid
ESP_ERR_OTA_SMALL_SEC_VER (0x1504): Error if the firmware has a secure version less than the running firmware.
ESP_ERR_OTA_ROLLBACK_FAILED (0x1505): Error if flash does not have valid firmware in passive partition and hence rollback is not possible
ESP_ERR_OTA_ROLLBACK_INVALID_STATE (0x1506): Error if current active firmware is still marked in pending validation state (ESP_OTA_IMG_PENDING_VERIFY), essentially first boot of firmware image post upgrade and hence firmware upgrade is not possible
ESP_ERR_EFUSE (0x1600): Base error code for efuse api.
ESP_OK_EFUSE_CNT (0x1601): OK the required number of bits is set.
ESP_ERR_EFUSE_CNT_IS_FULL (0x1602): Error field is full.
ESP_ERR_EFUSE_REPEATED_PROG (0x1603): Error repeated programming of programmed bits is strictly forbidden.
ESP_ERR_CODING (0x1604): Error while a encoding operation.
ESP_ERR_IMAGE_BASE (0x2000)
ESP_ERR_IMAGE_FLASH_FAIL (0x2001)
ESP_ERR_IMAGE_INVALID (0x2002)
ESP_ERR_WIFI_BASE (0x3000): Starting number of WiFi error codes
ESP_ERR_WIFI_NOT_INIT (0x3001): WiFi driver was not installed by esp_wifi_init
ESP_ERR_WIFI_NOT_STARTED (0x3002): WiFi driver was not started by esp_wifi_start
ESP_ERR_WIFI_NOT_STOPPED (0x3003): WiFi driver was not stopped by esp_wifi_stop
ESP_ERR_WIFI_IF (0x3004): WiFi interface error
ESP_ERR_WIFI_MODE (0x3005): WiFi mode error
ESP_ERR_WIFI_STATE (0x3006): WiFi internal state error
**ESP_ERR_WIFI_CONN** (0x3007): WiFi internal control block of station or soft-AP error

**ESP_ERR_WIFI_NVS** (0x3008): WiFi internal NVS module error

**ESP_ERR_WIFI_MAC** (0x3009): MAC address is invalid

**ESP_ERR_WIFI_SSID** (0x300a): SSID is invalid

**ESP_ERR_WIFI_PASSWORD** (0x300b): Password is invalid

**ESP_ERR_WIFI_TIMEOUT** (0x300c): Timeout error

**ESP_ERR_WIFI_WAKE_FAIL** (0x300d): WiFi is in sleep state (RF closed) and wakeup fail

**ESP_ERR_WIFI_WOULD_BLOCK** (0x300e): The caller would block

**ESP_ERR_WIFI_NOT_CONNECT** (0x300f): Station still in disconnect status

**ESP_ERR_WIFI_POST** (0x3012): Failed to post the event to WiFi task

**ESP_ERR_WIFI_INIT_STATE** (0x3013): Invalid WiFi state when init/deinit is called

**ESP_ERR_WIFI_STOP_STATE** (0x3014): Returned when WiFi is stopping

**ESP_ERR_WIFI_NOT_ASSOC** (0x3015): The WiFi connection is not associated

**ESP_ERR_WIFI_TX_DISALLOW** (0x3016): The WiFi TX is disallowed

**ESP_ERR_WIFI_REGISTRAR** (0x3033): WPS registrar is not supported

**ESP_ERR_WIFI_WPS_TYPE** (0x3034): WPS type error

**ESP_ERR_WIFI_WPS_SM** (0x3035): WPS state machine is not initialized

**ESP_ERR_ESPNOW_BASE** (0x3064): ESPNOW error number base.

**ESP_ERR_ESPNOW_NOT_INIT** (0x3065): ESPNOW is not initialized.

**ESP_ERR_ESPNOW_ARG** (0x3066): Invalid argument

**ESP_ERR_ESPNOW_NO_MEM** (0x3067): Out of memory

**ESP_ERR_ESPNOW_FULL** (0x3068): ESPNOW peer list is full

**ESP_ERR_ESPNOW_NOT_FOUND** (0x3069): ESPNOW peer is not found

**ESP_ERR_ESPNOW_INTERNAL** (0x306a): Internal error

**ESP_ERR_ESPNOW_EXIST** (0x306b): ESPNOW peer has existed

**ESP_ERR_ESPNOW_IF** (0x306c): Interface error

**ESP_ERR_MESH_BASE** (0x4000): Starting number of MESH error codes

**ESP_ERR_MESH_WIFI_NOT_START** (0x4001)

**ESP_ERR_MESH_NOT_INIT** (0x4002)

**ESP_ERR_MESH_NOT_CONFIG** (0x4003)

**ESP_ERR_MESH_NOT_START** (0x4004)

**ESP_ERR_MESH_NOT_SUPPORT** (0x4005)

**ESP_ERR_MESH_NOT_ALLOWED** (0x4006)

**ESP_ERR_MESH_NO_MEMORY** (0x4007)

**ESP_ERR_MESH_ARGUMENT** (0x4008)

**ESP_ERR_MESH_EXCEED_MTU** (0x4009)

**ESP_ERR_MESH_TIMEOUT** (0x400a)

**ESP_ERR_MESH_DISCONNECTED** (0x400b)

**ESP_ERR_MESH_QUEUE_FAIL** (0x400c)
### ESP Error Codes

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ESP_ERR_MESH_QUEUE_FULL</strong> (0x400d)</td>
<td>Mesh queue is full.</td>
</tr>
<tr>
<td><strong>ESP_ERR_MESH_NO_PARENT_FOUND</strong> (0x400e)</td>
<td>Mesh parent not found.</td>
</tr>
<tr>
<td><strong>ESP_ERR_MESH_NO_ROUTE_FOUND</strong> (0x400f)</td>
<td>Mesh route not found.</td>
</tr>
<tr>
<td><strong>ESP_ERR_MESH_OPTION_NULL</strong> (0x4010)</td>
<td>Mesh option is null.</td>
</tr>
<tr>
<td><strong>ESP_ERR_MESH_OPTION_UNKNOWN</strong> (0x4011)</td>
<td>Unknown mesh option.</td>
</tr>
<tr>
<td><strong>ESP_ERR_MESH_XON_NO_WINDOW</strong> (0x4012)</td>
<td>XON command not implemented.</td>
</tr>
<tr>
<td><strong>ESP_ERR_MESH_INTERFACE</strong> (0x4013)</td>
<td>Mesh interface error.</td>
</tr>
<tr>
<td><strong>ESP_ERR_MESH_DISCARD_DUPLICATE</strong> (0x4014)</td>
<td>Discard due to duplicate packet.</td>
</tr>
<tr>
<td><strong>ESP_ERR_MESH_DISCARD</strong> (0x4015)</td>
<td>Mesh discard.</td>
</tr>
<tr>
<td><strong>ESP_ERR_MESH_VOTING</strong> (0x4016)</td>
<td>Voting error.</td>
</tr>
<tr>
<td><strong>ESP_ERR_MESH_XMIT</strong> (0x4017)</td>
<td>XMIT error.</td>
</tr>
<tr>
<td><strong>ESP_ERR_MESH_QUEUE_READ</strong> (0x4018)</td>
<td>Mesh queue read error.</td>
</tr>
<tr>
<td><strong>ESP_ERR_MESH_PS</strong> (0x4019)</td>
<td>Mesh PS error.</td>
</tr>
<tr>
<td><strong>ESP_ERR_MESH_RECV_RELEASE</strong> (0x401a)</td>
<td>Mesh recv release error.</td>
</tr>
<tr>
<td><strong>ESP_ERR_ESP_NETIF_BASE</strong> (0x5000)</td>
<td>ESP Netif base error.</td>
</tr>
<tr>
<td><strong>ESP_ERR_ESP_NETIF_INVALID_PARAMS</strong> (0x5001)</td>
<td>Invalid Netif parameters.</td>
</tr>
<tr>
<td><strong>ESP_ERR_ESP_NETIF_IF_NOT_READY</strong> (0x5002)</td>
<td>Interface not ready.</td>
</tr>
<tr>
<td><strong>ESP_ERR_ESP_NETIF_DHCPC_START_FAILED</strong> (0x5003)</td>
<td>DHCP start failed.</td>
</tr>
<tr>
<td><strong>ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED</strong> (0x5004)</td>
<td>DHCP already started.</td>
</tr>
<tr>
<td><strong>ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED</strong> (0x5005)</td>
<td>DHCP already stopped.</td>
</tr>
<tr>
<td><strong>ESP_ERR_ESP_NETIF_NO_MEM</strong> (0x5006)</td>
<td>No memory for Netif.</td>
</tr>
<tr>
<td><strong>ESP_ERR_ESP_NETIF_DHCP_NOT_STOPPED</strong> (0x5007)</td>
<td>DHCP not stopped.</td>
</tr>
<tr>
<td><strong>ESP_ERR_ESP_NETIF_DRIVER_ATTACH_FAILED</strong> (0x5008)</td>
<td>Driver attach failed.</td>
</tr>
<tr>
<td><strong>ESP_ERR_ESP_NETIF_INIT_FAILED</strong> (0x5009)</td>
<td>Netif init failed.</td>
</tr>
<tr>
<td><strong>ESP_ERR_ESP_NETIF_DNS_NOT_CONFIGURED</strong> (0x500a)</td>
<td>DNS not configured.</td>
</tr>
<tr>
<td><strong>ESP_ERR_FLASH_BASE</strong> (0x6000)</td>
<td>Starting number of flash error codes</td>
</tr>
<tr>
<td><strong>ESP_ERR_FLASH_OP_FAIL</strong> (0x6001)</td>
<td>Flash operation fail.</td>
</tr>
<tr>
<td><strong>ESP_ERR_FLASH_OP_TIMEOUT</strong> (0x6002)</td>
<td>Flash operation timeout.</td>
</tr>
<tr>
<td><strong>ESP_ERR_FLASH_NOT.Initialised</strong> (0x6003)</td>
<td>Flash not initialised.</td>
</tr>
<tr>
<td><strong>ESP_ERR_FLASH_UNSUPPORTED_HOST</strong> (0x6004)</td>
<td>Flash unsupported host.</td>
</tr>
<tr>
<td><strong>ESP_ERR_FLASH_UNSUPPORTED_CHIP</strong> (0x6005)</td>
<td>Flash unsupported chip.</td>
</tr>
<tr>
<td><strong>ESP_ERR_FLASH_PROTECTED</strong> (0x6006)</td>
<td>Flash protected.</td>
</tr>
<tr>
<td><strong>ESP_ERR_HTTP_BASE</strong> (0x7000)</td>
<td>Starting number of HTTP error codes</td>
</tr>
<tr>
<td><strong>ESP_ERR_HTTP_MAX_REDIRECT</strong> (0x7001)</td>
<td>The error exceeds the number of HTTP redirects.</td>
</tr>
<tr>
<td><strong>ESP_ERR_HTTP_CONNECT</strong> (0x7002)</td>
<td>Error open the HTTP connection.</td>
</tr>
<tr>
<td><strong>ESP_ERR_HTTP_WRITE_DATA</strong> (0x7003)</td>
<td>Error write HTTP data.</td>
</tr>
<tr>
<td><strong>ESP_ERR_HTTP_FETCH_HEADER</strong> (0x7004)</td>
<td>Error read HTTP header from server.</td>
</tr>
<tr>
<td><strong>ESP_ERR_HTTP_INVALID_TRANSPORT</strong> (0x7005)</td>
<td>There are no transport support for the input scheme.</td>
</tr>
<tr>
<td><strong>ESP_ERR_HTTP_CONNECTING</strong> (0x7006)</td>
<td>HTTP connection hasn’t been established yet.</td>
</tr>
</tbody>
</table>
**ESP_ERR_HTTP_EAGAIN** (0x7007): Mapping of errno EAGAIN to esp_err_t

**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 socket option

**ESP_ERR_MBEDTLS_CERT_PARTLY_OK** (0x8006): mbedtls parse certificates was partly successful

**ESP_ERR_MBEDTLS_CTR_DBG_SEED_FAILED** (0x8007): mbedtls api returned error

**ESP_ERR_MBEDTLS_SSL_SET_HOSTNAME_FAILED** (0x8008): mbedtls api returned error

**ESP_ERR_MBEDTLS_SSL_CONFIG_DEFAULTS_FAILED** (0x8009): mbedtls api returned error

**ESP_ERR_MBEDTLS_SSL_CONF_ALPN_PROTOCOLS_FAILED** (0x800a): mbedtls api returned error

**ESP_ERR_MBEDTLS_X509_CRT_PARSE_FAILED** (0x800b): mbedtls api returned error

**ESP_ERR_MBEDTLS_SSL_SETUP_FAILED** (0x800c): mbedtls api returned error

**ESP_ERR_MBEDTLS_SSL_CONF_OWN_CERT_FAILED** (0x800d): mbedtls api returned error

**ESP_ERR_MBEDTLS_SSL_WRITE_FAILED** (0x800e): mbedtls api returned error

**ESP_ERR_MBEDTLS_PK_PARSE_KEY_FAILED** (0x800f): mbedtls api returned failed

**ESP_ERR_MBEDTLS_SSL_CONF_PSK_FAILED** (0x8010): mbedtls api returned failed

**ESP_ERR_MBEDTLS_SSL_CONNECTION_TIMEOUT** (0x8011): mbedtls api returned failed

**ESP_ERR_WOLFSSL_SSL_HANDSHAKE_FAILED** (0x8012): mbedtls api returned failed

**ESP_ERR_WOLFSSL_CTX_SETUP_FAILED** (0x8013): mbedtls api returned failed

**ESP_ERR_WOLFSSL_SSL_SETUP_FAILED** (0x8014): mbedtls api returned failed

**ESP_ERR_WOLFSSL_SSL_WRITE_FAILED** (0x8015): mbedtls api returned failed

**ESP_ERR_WOLFSSL_SSL_CONF_PSK_FAILED** (0x8016): mbedtls api returned failed

**ESP_ERR_WOLFSSL_SSL_CONF_OWN_CERT_FAILED** (0x8017): mbedtls api returned failed

**ESP_ERR_WOLFSSL_SSL_CONF_ALPN_PROTOCOLS_FAILED** (0x8018): mbedtls api returned failed

**ESP_ERR_WOLFSSL_SSL_CONF_HOSTNAME_FAILED** (0x8019): mbedtls api returned failed

**ESP_ERR_WOLFSSL_SSL_WRITE_FAILED** (0x801a): mbedtls api returned failed

**ESP_ERR_ESP_TLS_CONNECTION_TIMEOUT** (0x801b)

**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_DS_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)
Chapter 3

ESP32 H/W 硬件参考

3.1 ESP32 系列模组和开发板

乐鑫设计并提供多种模组和开发板以供用户体验 ESP32 系列芯片的强大功能。
本文档主要介绍了当前乐鑫所提供的各种模组和开发板。

注解：如需了解较早版本或已停产的模组和开发板，请参考 ESP32 模组与开发板（历史版本）。

3.1.1 相关文档

• ESP32 模组与开发板（历史版本）

3.2 ESP32 模组与开发板（历史版本）

本节列出了旧版或已停产 ESP32 模组和开发板的概述和文档链接，便于有意购买和使用旧版模组和开发板的用户参考。

3.2.1 相关文档

• ESP32 系列模组和开发板
Chapter 4

API 指南

4.1 ESP-IDF 编程注意事项

4.1.1 应用程序的启动流程

本文将会介绍 ESP32 从上电到运行 app_main 函数中间所经历的步骤（即启动流程）。

宏观上，该启动流程可以分为如下 3 个步骤:

1. 一级引导程序被固化在了 ESP32 内部的 ROM 中，它会从 Flash 的 0x1000 偏移地址处加载二级引导程序至 RAM(I RAM & DRAM) 中。
2. 二级引导程序从 Flash 中加载分区表和主程序镜像至内存中，主程序中包含了 RAM 段和通过 Flash 高速缓存映射的只读段。
3. 主程序运行，这时第二个 CPU 和 RTOS 的调度器可以开始运行。

下面会对上述过程进行更为详细的阐述。

一级引导程序

SoC 复位后，PRO CPU 会立即开始运行，执行复位向量代码，而 APP CPU 仍然保持复位状态。在启动过程中，PRO CPU 会执行所有的初始化操作。APP CPU 的复位状态会在应用程序启动代码的 call_start_cpu0 函数中失效。复位向量代码位于 ESP32 芯片掩膜 ROM 的 0x40000400 地址处，该地址不能被修改。

复位向量调用的启动代码会根据 GPIO Strap 寄存器的值来确定 ESP32 的工作模式，该寄存器保存着复位后 bootstrap 引脚的电平状态。根据不同的复位原因，程序会执行不同的操作:

1. 从深度睡眠模式复位：如果 RTC_CNTL_STORE6_REG 寄存器的值非零，并且 RTC_CNTL_STORE7_REG 寄存器中的 RTC 内存的 CRC 校验值有效，那么程序会使用 RTC_CNTL_STORE6_REG 寄存器的值作为入口地址，并立即跳转到该地址运行。如果 RTC_CNTL_STORE6_REG 的值为零，或者 RTC_CNTL_STORE7_REG 中的 CRC 校验值无效，又或者跳转到 RTC_CNTL_STORE6_REG 地址处运行的程序返回，那么将会执行上电复位的相关操作。注意：如果想在这里运行自定义的代码，可以参考深度睡眠文档里面介绍的方法。
2. 上电复位：软件 SoC 复位、看门狗 SoC 复位：检查 GPIO Strap 寄存器，判断是否 UART 或 SDIO 请求进入下载模式。如果是，则配置好 UART 或者 SDIO，然后等待下载代码。否则程序将会执行软件 CPU 复位的相关操作。
3. 软件 CPU 复位、看门狗 CPU 复位：根据 EFUSE 中的值配置 SPI Flash，然后尝试从 Flash 中加载代码，这部分的内存将在后面一小节详细介绍。如果从 Flash 中加载代码失败，就会将 BASIC 解析器加压缩到 RAM 中启动。需要注意的是，此时 RTC 看门狗会处于睡眠状态，如果在几百毫秒内没有任何输入事件，那么看门狗会再次复位 SoC，重复整个过程。如果解析器收到了来自 UART 的输入，程序会关闭看门狗。

应用程序的二进制镜像会从 Flash 的 0x1000 地址处加载。Flash 的第一个 4kB 扇区用于存储安全引导程序和应用程序镜像的签名。有关详细信息，请查看安全启动文档。
二级引导程序

在 ESP-IDF 中，存放在 Flash 的 0x1000 偏移地址处的二进制镜像就是二级引导程序。二级引导程序的源码可以在 ESP-IDF 的 components/bootloader 目录下找到。请注意，对于 ESP32 芯片来说，这并不是唯一的安排程序镜像的方式。事实上用户完全可以把一个功能齐全的应用程序烧写到 Flash 的 0x1000 偏移地址处运行，但这超出本文档的范围。ESP-IDF 使用二级引导程序可以增加 Flash 区分的灵活性（使用分区表），并且方便实现 Flash 加密，安全引导和空中升级（OTA）等功能。

当一级引导程序校验并加载完二级引导程序后，它会从二进制镜像的头部找到二级引导程序的入口点，并跳转过去运行。

二级引导程序从 Flash 的 0x8000 偏移地址处读取分区表。详细信息请参阅分区表文档 分区表。二级引导程序会寻找出厂分区和 OTA 分区，然后根据 OTA 信息分区的数据表引导哪个分区。

对于选定的分区，二级引导程序将映射到 IRAM 和 DRAM 的数据和代码段复制到它们的加载地址处。对于一些加载地址位于 DROM 和 IROM 区域的段，会通过配置 Flash MMU 为其提供正确的映射。请注意，二级引导程序会为 PRO CPU 和 APP CPU 都配置 Flash MMU，但它只使能了 PRO CPU 的 Flash MMU。这么做的原因是二级引导程序的代码被加载到了 APP CPU 的高速缓存使用的内存区域，因此使能 APP CPU 高速缓存的任务就交给应用程序。一旦代码加载完毕并且设置好 Flash MMU，二级引导程序会从应用程序二进制镜像文件的头部寻找入口地址，然后跳转到该地址处运行。

目前还不支持添加分支函数到二级引导程序中以自定义应用程序分区选择的逻辑，但是可以通过别的途径实现这个功能，比如根据某个 GPIO 的不同状态来引导不同的应用程序镜像。此类自定义的功能将在未来添加到 ESP-IDF 中。目前，可以将 bootloader 组件复制到应用程序目录并在那里进行必要的更改来自定义引导程序。在这种情况下，ESP-IDF 的编译系统将编译应用程序目录中的组件而不是 ESP-IDF 组件目录。

应用程序启动阶段

ESP-IDF 应用程序的入口是 components/esp32/cpu_start.c 文件中的 call_start_cpu0 函数，该函数主要完成了两件事，一是启用堆分配器，二是使 APP CPU 跳转到其入口点——call_start_cpu1 函数。PRO CPU 上的代码会设置 APP CPU 设置好入口地址，解除其复位状态，然后等待 APP CPU 上运行的代码设置一个全局标志，以表明 APP CPU 已经正常启动。完成后，PRO CPU 跳转到 start_cpu0 函数，APP CPU 跳转到 start_cpu1 函数。

start_cpu0 和 start_cpu1 这两个函数都是裸函数的，这意味着如果某些特定的应用程序需要修改初始化顺序，就可以通过重写这两个函数来实现。start_cpu0 默认的实现方式是初始化用户在 menuconfig 中选择的组件，具体实现步骤可以阅读 components/esp32/cpu_start.c 文件中的源码。请注意，此阶段会调用应用程序中存在于的 C++ 全局构造函数。一旦所有必要的组件都初始化好，就会创建 main task，并启动 FreeRTOS 的调度器。

当 PRO CPU 在 start_cpu0 函数中进行初始化的时候，APP CPU 在 start_cpu1 函数中自旋，等待 PRO CPU 上的调度器启动。一旦 PRO CPU 上的调度器启动后，APP CPU 上的代码也会启动调度器。

主任务是指运行 app_main 函数的任务，主任务的堆栈大小和优先级可以在 menuconfig 中进行配置。应用程序可以用此任务来完成用户程序相关的初始化设置，比如启动其他的任务。应用程序还可以将主任务用于事件循环和其他通用活动。如果 app_main 函数返回，那么主任务将会被删除。

4.1.2 应用程序的内存布局

ESP32 芯片具有灵活的内存映射功能，本小节将介绍 ESP-IDF 默认使用这些功能的方式。

ESP-IDF 应用程序的代码可以在以下内存区域之一。

IRAM（指令 RAM）

ESP-IDF 将内部 SRAM0 区域（在技术参考手册中有定义）的一部分分配为指令 RAM。除了开始的 64KB 用作 PRO CPU 和 APP CPU 的高速缓存外，剩余内存区域（从 0x40080000 至 0x400A0000）被用来存储应用程序中部分需要在 RAM 中运行的代码。

Epressif Systems 1386 Release v4.3-dev-1561-g357a277603
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一些 ESP-IDF 的组件和 WiFi 协议栈的部分代码通过链接脚本文件被存放在了这块内存区域。
如果一些应用程序的代码需要放在 IRAM 中运行，可以使用 IRAM_ATTR 宏定义进行声明。

```c
#include "esp_attr.h"

void IRAM_ATTR gpio_isr_handler(void* arg)
{
    // ...
}
```

下面列举了应用程序中可能或者应该放入 IRAM 中运行的例子。

- 当注册中断处理程序的时候设置了 ESP_INTR_FLAG_IRAM，那么中断处理程序就必须要放在 IRAM 中运行。这种情况，ISR 只能调用存放在 IRAM 或者 ROM 中的函数。注意：目前所有的 FreeRTOS 的 API 都已经存放在了 IRAM 中，所以在中断中调用 FreeRTOS 的中断专属 API 是安全的。如果将 ISR 放在 IRAM 中运行，那么必须使用宏定义 DRAM_ATTR 将该 ISR 用到所有常量数据和调用的函数（但不包括于 const char 数组）放入 DRAM 中。
- 可以将一些时间关键的代码放在 IRAM 中，这样可以缩减从 Flash 加载代码所消耗的时间。ESP32 是通过 32kB 的高速缓存来从外部 Flash 中读取代码和数据的，将函数放在 IRAM 中运行可以减少由高速缓存未命中引起的时间延迟。

IROM（代码从 Flash 中运行）

如果一个函数没有被显式地声明放在 IRAM 或者 RTC 内存中，则将其置于 Flash 中。Flash 技术参考手册中介绍了 Flash MMU 允许代码从 Flash 执行的机制。ESP-IDF 将从 Flash 中执行的代码放在 0x400D0000 — 0x40400000 区域的开始，在启动阶段，二级引导程序会初始化 Flash MMU，将代码在 Flash 中的位置映射到这个区域的开头。对这个区域的访问会被透明地缓存到 0x40070000 — 0x40080000 范围内的两个 32kB 的块中。

请注意，使用 Window ABI CALLx 指令可能无法访问 0x40000000 — 0x40400000 区域以外的代码，所以要特别留意应用程序是否使用了 0x40400000 — 0x40800000 或者 0x40800000 — 0x40C00000 区域，ESP-IDF 默认不会使用这两个区域。

RTC 快速内存

从深度睡眠模式唤醒后必须要运行的代码要放在 RTC 内存中，更多信息请查阅文档『深度睡眠』。

DRAM（数据 RAM）

链接器将非变量静态数据和零初始化数据放于 0x3FFB0000 — 0x3FFF0000 这 256kB 的区域。注意，如果使用蓝牙堆栈，此区域会减少 64kB（通过将起始地址移至 0x3FFC0000）。如果使用了内存跟踪的功能，该区域的长度还要减少 16kB 或者 32kB。放置静态数据后，留在此区域中的剩余空间都用作运行时堆。

常量数据也可以放在 DRAM 中，例如，用在 ISR 中的常量数据（参见上面 IRAM 部分的介绍），为此需要使用 DRAM_ATTR 宏来声明。

```c
DRAM_ATTR const char[] format_string = "%p %x";
char buffer[64];
printf(buffer, format_string, ptr, val);
```

毋庸置疑，不建议在 ISR 中使用 printf 和其余输出函数。出于调试的目的，可以在 ISR 中使用 ESP_EARLY_LOGx 来输出日志，不过要确保将 TAG 和格式字符串都放在了 DRAM 中。

宏 __NOSTART_ATTR 可以用来声明将数据放在 .noinit 段中，放在此段中的数据不会在启动时被初始化，并且在软件重启后会保留原来的值。

例子：

```
```
__NOINIT_ATTR uint32_t noinit_data;

DROM（数据存储在 Flash 中）
默认情况下，链接器将常量数据放入一个 4MB 区域 (0x3F400000 — 0x3F800000)，该区域用于通过 Flash MMU 和高速缓存来访问外部 Flash。一种特例情况是，字面值会被编译器嵌入到应用程序代码中。

RTC 慢速内存
从 RTC 内存运行的代码（例如深度睡眠模块的代码）使用的全局和静态变量必须要放在 RTC 慢速内存中。更多详细说明请查看文档深度睡眠。
宏 RTC_NOINIT_ATTR 用来声明将数据放入 RTC 慢速内存中，该数据在深度睡眠唤醒后将保持不变。
例子:
RTC_NOINIT_ATTR uint32_t rtc_noinit_data;

4.1.3 DMA 能力要求
大多数的 DMA 控制器（比如 SPI, SDMMC 等）都要求发送/接收缓冲区放在 DRAM 中，并且按字对齐。我们建议将 DMA 缓冲区放在静态变量中而不是堆栈中。使用 DMA_ATTR 宏可以声明该全局/本地的静态变量具备 DMA 能力，例如:
DMA_ATTR uint8_t buffer[] = "I want to send something";
void app_main()
{
    // 初始化代码...
    spi_transaction_t temp = {
        .tx_buffer = buffer,
        .length = 8*sizeof(buffer),
    };
    spi_device_transmit( spi, &temp );
    // 其他程序
}
或者:
void app_main()
{
    DMA_ATTR static uint8_t buffer[] = "I want to send something";
    // 初始化代码...
    spi_transaction_t temp = {
        .tx_buffer = buffer,
        .length = 8*sizeof(buffer),
    };
    spi_device_transmit( spi, &temp );
    // 其他程序
}

在堆栈中放置 DMA 缓冲区仍然是允许的，但是你必须记住:
1. 如果堆栈在 pSRAM 中，切勿尝试这样做，因为堆栈在 pSRAM 中的话就要按照片外 SRAM 文档介绍的步骤来操作（至少要在 menuconfig 中使能 SPIRAM_ALLOW_STACK_EXTERNAL_MEMORY），所以请确保你的任务不在 pSRAM 中。
2. 在函数中使用 WORD_ALIGNED_ATTR 宏来修饰变量，将其放在适当的位置上，比如:

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```c
void app_main()
{
    uint8_t stuff;
    WORD_ALIGNED_ATTR uint8_t buffer[]="I want to send something";  // 否则
    // 初始化代码...
    spi_transaction_t temp = {
        .tx_buffer = buffer,
        .length = 8*sizeof(buffer),
    };
    spi_device_transmit( spi, &temp );
    // 其他程序
}
```

### 4.2 构建系统（CMake版）

如需您想了解如何使用 CMake 构建系统来组织和构建新的 ESP-IDF 项目或组件，请阅读本文档。

#### 4.2.1 概述

一个 ESP-IDF 项目可以看作是多个不同组件的集合，例如一个显示当前湿度的网页服务器会包含以下组件:

- ESP32 基础库，包括 libc，ROM bindings 等
- Wi-Fi 驱动
- TCP/IP 协议栈
- FreeRTOS 操作系统
- 网页服务器
- 湿度传感器的驱动
- 负责将上述组件整合到一起的主程序

ESP-IDF 可以显式地指定和配置每个组件。在构建项目的时候，构建系统会前往 ESP-IDF 目录、项目目录和用户自定义目录（可选）中查找所有组件，允许用户通过文本菜单系统配置 ESP-IDF 项目中用到的每个组件。在所有组件配置结束后，构建系统开始编译整个项目。

#### 概念

- 项目特指一个目录，其中包含了构建可执行应用程序所需的全部文件和配置，以及其他支持型文件，例如分区表、数据文件系统分区和引导程序。
- 项目配置保存在项目根目录下名为 adkconfig 的文件中，可以通过 idf.py menuconfig 进行修改，且一个项目只能包含一个项目配置。
- 应用程序是由 ESP-IDF 构建得到的可执行文件。一个项目通常会构建两个应用程序：程序应用程序（可执行的主文件，即用户自定义的固件）和引导程序（启动并初始化项目应用程序）。
- 组件是模块化且独立的代码，会被编译成静态库 (.a 文件) 并链接到应用程序。部分组件由 ESP-IDF 官方提供，其他组件则来源于其它开源项目。
- 目标特指运行构建后应用程序的硬件设备。ESP-IDF 当前仅支持 ESP32 这一个硬件目标。

请注意，以下内容并不属于项目的组成部分:

- ESP-IDF 并不是项目的一部分，它独立于项目。通过 IDF_PATH 环境变量保存 esp-idf 目录的路径，链接到项目，从而将 IDF 框架与项目分离。
- 交叉编译工具链并不是项目的组成部分，它应该被安装在系统 PATH 环境变量中。

#### 4.2.2 使用构建系统
idf.py

idf.py 命令行工具提供了一个前端，可以帮助您轻松管理项目的构建过程，它管理了以下工具：

- CMake，配置及构建的系统
- 命令行构建工具（Ninja 或 GNU Make）
- esptool.py，烧录 ESP32

入门指南 简要介绍了如何设置 idf.py 用于配置、构建并烧录项目。

idf.py 应运行在 ESP-IDF 的项目目录下，即包含 CMakeLists.txt 文件的目录，仅包含 Makefile 的老式项目并不支持 idf.py。

运行 idf.py --help 查看完整的命令列表。下面总结了最常用的命令：

- idf.py menuconfig 会运行 menuconfig 工具来配置项目。
- idf.py build 会构建当前目录下找到的项目，它包括以下步骤：
  - 根据需要创建 build 建构目录，它用于保存构建过程的输出文件，可以使用 -B 选项修改默认的构建目录。
  - 根据需要运行 CMake 配置程序，为主构建工具生成构建文件。
  - 运行主构建工具（Ninja 或 GNU Make）。默认情况下，构建工具会被自动检测，可以使用 -G 选项显式地指定构建工具。
构建过程是增量式的，如果自上次构建以来源文件或项目配置没有发生改变，则不会执行任何操作。

- idf.py clean 会把构建输出的文件从构建目录中删除，从而清理整个项目，下次构建时会强制“重新完整构建”这个项目。清理时，不会删除 CMake 配置输出及其他文件。
- idf.py fullclean 会将整个 build 目录下的内容全部删除，包括所有 CMake 的配置输出文件。下次构建项目时，CMake 会从头开始配置项目。请注意，该命令会递归删除构建目录下的所有文件，请谨慎使用。项目配置文件不会被删除。
- idf.py flash 会在必要时自动构建项目，并将生成的二进制程序烧录到 ESP32 设备中。-p 和 -b 选项可分别设置串行的设备名和烧录时的波特率。
- idf.py monitor 用于显示 ESP32 设备的串口输出。-p 选项可用于设置主机串口的设备名，按下 Ctrl-` 可退出监视器。更多有关监视器的详情，请参阅 IDF 监视器。

多个 idf.py 命令可合并成一个，例如，idf.py -p COM4 clean flash monitor 会依次清理源码树，构建项目，烧录进 ESP32 设备，最后运行串口监视器。

注解：环境变量 ESPPORT 和 ESPBAUD 可分别用作 -p 和 -b 选项的默认值。在命令行中，重新为这两个选项赋值，会覆盖其默认值。

高级命令

- idf.py app, idf.py bootloader, idf.py partition_table 仅可用于从适用的项目中构建应用程序、引导程序或分区表。
- idf.py app-flash 等匹配命令，仅将项目特定部分烧录到 ESP32。
- idf.py -p PORT erase_flash 会使用 esptool.py 擦除 ESP32 的整个 Flash。
- idf.py size 会打印应用程序相关的大小信息，idf.py size-components 和 idf.py size-files 这两个命令相似，分别用于打印每个组件或源文件的详细信息。
- idf.py reconfigure 命令会重新运行 CMake （即便无需重新运行）。正常使用时，并不需要运行此命令，但当源码树中添加/删除文件后或更改 CMake cache 变量时，此命令会非常有用。例如，idf.py -DNAME=’VALUE’ reconfigure 会将 CMake cache 中的变量 NAME 的值设置为 VALUE。

同时调用多个 idf.py 命令时，命令的输入顺序并不重要，它们会按照正确的顺序依次执行，并保证每一条命令都生效（即先构建后烧录，先擦除后烧录等）。

直接使用 CMake

为了方便，idf.py 已经封装了 CMake 命令，但是您愿意，也可以直接调用 CMake。
当idf.py在执行某些操作时，它会打印出其运行的每条命令以便参考。例如运行idf.py build命令与在bash shell（或者Windows Command Prompt）中运行以下命令是相同的：

```bash
mkdir -p build
cd build
cmake .. -G Ninja  # 或者 'Unix Makefiles'
ninja
```

在上面的命令列表中，cmake命令对项目进行配置，并生成用于最终构建工具的构建文件。在这个例子中，最终构建工具是Ninja：运行ninja来构建项目。

没有必要多次运行cmake。第一次构建后，往后每次只需运行ninja即可。如果项目需要重新配置，ninja会自动重新调用cmake。

若在CMake中使用ninja或make，则多数idf.py子命令也会有其对应的目标，例如在构建目录下运行make menuconfig或ninja menuconfig与运行idf.py menuconfig是相同的。

**注解：**如果您已经熟悉了CMake，那么可能会发现ESP-IDF的CMake构建系统不同寻常，为了减少样板文件，该系统封装了CMake的许多功能。请参考编写《CMake组件》以编写更多CMake风格的组件。

### 使用Ninja/Make来烧录
您可以直接使用ninja或make运行如下命令来构建项目并烧录：

```bash
ninja flash
```

或：

```bash
make app-flash
```

可用的目标还包括：flash、app-flash（仅用于app）、bootloader-flash（仅用于bootloader）。

以这种方式烧录时，可以通过设置ESPPORT和ESPBAUD环境变量来指定串口号设备和波特率。您可以在操作系统或IDE项目中设置该环境变量，或者在命令行中进行设置：

```bash
ESPPORT=/dev/ttyUSB0 ninja flash
```

**注解：**在命令的开头为环境变量赋值属于Bash shell的语法，可在Linux、macOS和Windows的类Bash shell中运行，但在Windows Command Prompt中无法运行。

或：

```bash
make -j3 app-flash ESPPORT=COM4 ESPBAUD=2000000
```

**注解：**在命令末尾为变量赋值属于make的语法，适用于所有平台的make。

### 在IDE中使用CMake
您还可以使用CMake的IDE，仅需将项目CMakeLists.txt文件的路径告诉IDE即可。集成CMake的IDE通常会有自己的构建工具（CMake称之为“生成器”），它是组成IDE的一部分，用来构建源文件。

向IDE中添加除build目标以外的自定义目标（如添加“Flash”目标到IDE）时，建议调用idf.py命令来执行这些“特殊”的操作。

有关将ESP-IDF同CMake集成到IDE中的详细信息，请参阅构建系统的元数据。
设置 Python 解释器

目前，ESP-IDF 仅适用于 Python 2.7，如果系统中默认的 python 解释器是 Python 3.x，可能会出现问题。

如果使用了 idf.py，并以 python2 $IDF_PATH/tools/idf.py ... 的方式运行 idf.py 则会解决这个问题（idf.py 会通知其他 Python 进程使用相同的 Python 解释器）。你可以通过设置 shell 别名或其他脚本来简化该命令。

如果直接使用 CMake，运行 cmake -D PYTHON=python2 ...，CMake 会使用传入的值覆盖默认的 Python 解释器。

如果使用集成 CMake 的 IDE，可以在 IDE 的图形用户界面中给定 PYTHON 的 CMake cache 变量设置新的值来覆盖默认的 Python 解释器。

如果想在命令行中更优雅地管理 Python 的各个版本，请查看 pyenv 或 virtualenv 工具，它们会帮助您更改默认的 python 版本。

### 4.2.3 示例项目

示例项目的目录树结构可能如下所示：

```
- myProject/
  - CMakeLists.txt
  - sdkconfig
  - components/
    - component1/
      - CMakeLists.txt
      - Kconfig
      - src1.c
    - component2/
      - CMakeLists.txt
      - Kconfig
      - src1.c
      - include/
        - component2.h
  - main/
    - src1.c
    - src2.c
  - build/
```

该示例项目 myproject 包含以下组成部分：

- 顶层项目 CMakeLists.txt 文件，这是 CMake 用于学习如何构建项目的主要文件。可以在这个文件中设置项目全局的 CMake 参数。顶层项目 CMakeLists.txt 文件会合并 tools/cmake/project.cmake 文件，由它负责实现构建系统的其余部分。该文件最后会设置项目的名称，并定义该项目。
- sdkconfig 项目配置文件，执行 idf.py menuconfig 时会创建或更新此文件，文件中保存了项目中所有组件（包括 ESP-IDF 本身）的配置信息。sdkconfig 文件可能会也会被添加到项目的源码管理系统中。
- 可选的 component 目录中包含了项目的部分自定义组件，并不是每个项目都需要这种自定义组件，但它组件有助于构建可复用的代码或者导入第三方（不属于 ESP-IDF）的组件。
- main 目录是一个特殊的伪组件，包含项目本身的源代码。main 是默认名称，CMake 参数 COMPONENT_DIRS 默认包含此组件，但您可以修改此参数。或者，您也可以将此文件在顶层 CMakeLists.txt 中设置 EXTRA_COMPONENT_DIRS 变量以查找其他指定位置处的组件。有关详细信息，请参阅命名 main 组件。如果项目中源文件较多，建议将其归为组件中，而不是全部放在 main 中。
- build 目录是存放构建输出的地方。如果没有此目录，idf.py 会自动创建。CMake 会配置项目，并在此目录下生成临时的构建文件。随后，在主构建过程的运行期间，该目录还会保存临时目标文件、库文件以及最终输出的二进制文件。此目录通常不会添加到项目的源码管理系统中，也不会随项目源码一同发布。

每个组件目录都包含一个 CMakeLists.txt 文件，里面会定义一些变量以控制该组件的构建过程，以及与整个项目的集成。更多详细信息请参阅组件 CMakeLists 文件。

每个组件还可以包含一个 Kconfig 文件，它用于定义 menuconfig 时展示的组件配置选项。某些组件可能还会包含 Kconfig.projbuild 和 project_include.cmake 特殊文件，它们用于覆盖部分设置。
4.2.4 项目 `CMakeLists` 文件

每个项目都有一个顶层 `CMakeLists.txt` 文件，包含整个项目的构建设置。默认情况下，项目 `CMakeLists` 文件会非常小。

最小 `CMakeLists` 文件示例

最小项目:

```makefile
cmake_minimum_required(VERSION 3.5)
include($ENV{IDF_PATH}/tools/cmake/project.cmake)
project(myProject)
```

必要部分

每个项目都要按照上面显示的顺序添加上述三行代码:

- `cmake_minimum_required(VERSION 3.5)` 必须放在 `CMakeLists.txt` 文件的第一行，它会告诉 CMake 构建该项目所需要的最小版本号。ESP-IDF 支持 CMake 3.5 或更高的版本。
- `include($ENV{IDF_PATH}/tools/cmake/project.cmake)` 会导入 CMake 的其余功能来完成配置项目，搜索组件等任务。
- `project(myProject)` 会创建项目本身，并指定项目名称。该名称会作为最终输出的二进制文件的名字，即 `myProject.elf` 和 `myProject.bin`。每个 `CMakeLists` 文件只能定义一个项目。

可选的项目变量

以下这些变量都有默认值，用户可以覆盖这些变量值以自定义构建行为。更多实现细节，请参阅 `tools/cmake/project.cmake` 文件。

- `COMPONENT_DIRS`: 组件的搜索目录，默认为 `$(IDF_PATH)/components, $(PROJECT_PATH)/components 和 EXTRA_COMPONENT_DIRS`。如果您不想在这些位置搜索组件，请覆盖此变量。
- `EXTRA_COMPONENT_DIRS`: 用于搜索组件的其它可选目录列表。路径可以是相对于项目目录的相对路径，也可以是绝对路径。
- `COMPONENTS`: 要构建进项目中的组件名称列表，默认为 `COMPONENT_DIRS` 目录下检索到的所有组件。使用此变量可以“精简”项目以缩短构建时间。请注意，如果一个组件通过 `COMPONENT_REQUIRES` 指定了它依赖的另一个组件，则会自动将其添加到 `COMPONENTS` 中，所以 `COMPONENTS` 列表可能会非常短。
- `COMPONENT_REQUIRES_COMMON`: 每个组件都需要的通用组件列表，这些通用组件会自动添加到每个组件的 `COMPONENT_PRIV.Requires` 列表中以及项目的 `COMPONENTS` 列表中。默认情况下，此变量设置为 ESP-IDF 项目所需的最小核心“系统”组件集。通常您无需在项目中更改此变量。

以上变量中的路径可以是绝对路径，或者是相对于项目目录的相对路径。

请使用 `cmake` 中的 `set` 命令来设置这些变量，即 `set(VARIABLE "VALUE")`。请注意，`set()` 命令需放在 `include(...)` 之前，`cmake_minimum(...)` 之后。

重命名 main 组件

构建系统会对 `main` 组件进行特殊处理。假如 `main` 组件位于预期的位置（即 `$(PROJECT_PATH)/main`），那么它会被自动添加到构建系统中。其他组件也会作为其依赖项被添加到构建系统中，这使用户免于处理依赖关系，并提供即时可用的构建功能。重命名 `main` 组件会减轻上述这些幕后工作量。但要求用户指定重命名后的组件名称，为添加依赖项。重命名 `main` 组件的步骤如下:

1. 重命名 `main` 目录。
2. 在项目 `CMakeLists.txt` 文件中设置 `EXTRA_COMPONENT_DIRS` 并添加重命名后的 `main` 目录。
3. 在组件的 `CMakeLists.txt` 文件中设置 `COMPONENT_REQUIRES` 或 `COMPONENT_PRIV_REQUIRES` 以指定依赖项。
4.2.5 组件 CMakeLists 文件

每个项目都包含一个或多个组件，这些组件可以是 ESP-IDF 的一部分，可以是项目自身组件目录的一部分，也可以从自定义组件目录添加（见上文）。

组件是 COMPONENT_DIRS 列表中包含 CMakeLists.txt 文件的任何目录。

搜索组件

搜索 COMPONENT_DIRS 中的目录列表以查找项目的组件，此列表中的目录可以是组件自身（即包含 CMakeLists.txt 文件的目录），也可以是子目录为组件的顶层目录。

当 CMake 运行项目配置时，它会记录本次构建包含的组件列表，它可用于调试某些组件的添加/排除。

同名组件

ESP-IDF 在搜索所有待构建的组件时，会按照 COMPONENT_DIRS 指定的顺序依次进行，这意味着在默认情况下，首先搜索 ESP-IDF 内部组件，然后是项目组件，最后是 EXTRA_COMPONENT_DIRS 中的组件。如果这些目录中的两个或者多个包含具有相同名字的组件，则使用搜索到的最后一个位置的组件。这就允许将组件复制到项目目录中再修改以覆盖 ESP-IDF 组件，如果使用这种方式，ESP-IDF 目录本身可以保持不变。

最小的组件 CMakeLists 文件

最小组件 CMakeLists.txt 文件内容如下：

```
set(COMPONENT_SRCS "foo.c")
set(COMPONENT_ADD_INCLUDEDIRS "include")
register_component()
```

- COMPONENT_SRCS 是用空格分隔的源文件列表 (*.c, *.cpp, *.cc, *.S)，里面所有的源文件都将被编译为组件库中。
- COMPONENT_ADD_INCLUDEDIRS 是用空格分隔的目录列表，里面的路径会被添加到所有需要该组件的组件（包括 main 组件）全局 include 搜索路径中。
- register_component() 使用上述设置的变量将组件添加到构建系统中，构建生成与组件同名的库，并最终被链接到应用程序中。如果因为使用了 CMake 中的 if 命令或类似命令而跳过了这一步，那么该组件将不会被添加到构建系统中。

上述目录通常设置为相对于 CMakeLists.txt 文件的相对路径，当然也可以设置为绝对路径。

有关更完整的 CMakeLists.txt 示例，请参阅组件 CMakeLists 示例。

预设的组件变量

以下专用于组件的变量可以在组件 CMakeLists 中使用，但不建议修改：

- COMPONENT_PATH：组件目录，即包含 CMakeLists.txt 文件的绝对路径，它与 CMAKE_CURRENT_SOURCE_DIR 变量一样，路径中不能包含空格。
- COMPONENT_NAME：组件名，与组件目录名相同。
- COMPONENT_TARGET：库目标名，它由构建系统在内部为组件创建。

以下变量在项目级别中被设置，但可在组件 CMakeLists 中使用：

- PROJECT_NAME：项目名，在项目 CMakeLists.txt 文件中设置。
- PROJECT_PATH：项目目录（包含项目 CMakeLists 文件）的绝对路径，与 CMAKE_SOURCE_DIR 变量相同。
- COMPONENTS：此次构建中包含的所有组件的名称，具体格式为用分号隔开的 CMake 列表。
- CONFIG_*：项目配置中的每个值在 cmake 中都对应一个以 CONFIG_ 开头的变量。更多详细信息请参阅 Kconfig。
Chapter 4. API 指南

- IDF_VER: ESP-IDF 的 git 版本号，由 git describe 命令生成。
- IDF_VERSION_MAJOR, IDF_VERSION_MINOR, IDF_VERSION_PATCH: ESP-IDF 的组件版本，可用于条件表达式。请注意这些信息的精确度不如 IDF_VER 变量，版本号 v4.0-dev-*，v4.0-beta1, v4.0-rc1 和 v4.0 对应的 IDF_VERSION_* 变量值是相同的，但是 IDF_VER 的值是不同的。
- IDF_TARGET: 项目的硬件目标名称。
- PROJECT_VER: 项目版本号。
  - 如果在项目 CMakeLists.txt 文件中设置了 PROJECT_VER 变量，则该变量值可以使用。
  - 或者，如果 $(PROJECT_PATH)/version.txt 文件存在，其内容会用作 PROJECT_VER 的值。
  - 或者, 如果项目位于某个 Git 仓库中，则使用 git describe 命令的输出作为 PROJECT_VER 的值。
  - 否则，PROJECT_VER 的值为空。

如果您在组件的 CMakeLists.txt 中修改以上变量，并不会影响其他组件的构建，但可能会使该组件变得难以构建或调试。

- COMPONENT_ADD_INCLUDE_DIRS: 相对于组件目录的相对路径，为被添加到所有需要该组件的其他组件的全局 include 搜索路径中。如果某个 include 路径仅仅在编译当前组件时需要，请将其添加到 COMPONENT_PRIV_INCLUDE_DIRS 中。
- COMPONENT_REQUIRES 是一个用空格分隔的组件列表，列出了当前组件依赖的其他组件。如果当前组件有一个头文件位于 COMPONENT_ADD_INCLUDE_DIRS 目录下，且该头文件包含了另一个组件的头文件，那么这个被依赖的组件需要在 COMPONENT_REQUIRES 中指出。这种依赖关系可以是递归的。

COMPONENT_REQUIRES 可以为空，因为所有的组件都需要一些常用的组件（如 newlib 组件提供的 libc 库、freertos 组件提供的 RTOS 功能），这些通用组件已经在项目级变量 COMPONENT_REQUIRES_COMMON 中被设置。

如果一个组件还需要额外组件的头文件来编译其源文件（而不是全局引入它们的头文件），则这些被依赖的组件需要在 COMPONENT_PRIV_REQUIRES 中指出。

请参阅 组件依赖，查看详细信息。

可选的组件特定变量

以下变量可在 CMakeLists.txt 中进行设置，用以控制该组件的构建行为：

- COMPONENT_PRIV_INCLUDE_DIRS: 相对于组件目录的相对路径，仅会被添加到该组件的 include 搜索路径中。
- COMPONENT_PRIV_REQUIRES: 以空格分隔的组件列表，用于编译或链接当前组件的源文件，这些组件的头文件路径不会传递给其余需要它的组件，仅用于编译当前组件的源代码。更多详细信息请参阅 组件依赖。
- COMPONENT_SRCS: 要编译成当前组件的源文件的路径，推荐使用此方法向构建系统中添加源文件。
- COMPONENT_SRCDIRS: 相对于组件目录的源文件目录路径，用于搜索源文件 (*.cpp, *.c, *.S)。匹配成功的源文件会替代 COMPONENT_SRCS 中指定的源文件，进而被编译进组件。即设置 COMPONENT_SRCDIRS 会导致 COMPONENT_SRCS 被忽略。此方法可以很容易地将源文件整体导入到组件中，但并不推荐使用（详情请参阅 文件配置 & 增量构建）。
- COMPONENT_SRCEXCLUDE: 需要从组件中剔除的源文件路径。当某个目录中有大量的源文件需要被导入组件中，但同时又有个别文件不需要导入时，可以配合 COMPONENT_SRCDIRS 变量一起设置。路径可以是相对于组件目录的相对路径，也可以是绝对路径。
- COMPONENT_ADD_LIBFRAGMENTS: 组件使用的链接片段文件的路径，用于自动生成链接器脚本文件。详细信息请参阅 链接脚本生成机制。

注解：如果没有设置 COMPONENT_SRCDIRS 或 COMPONENT_SRCS，组件不会被编译成库文件，但仍可以被添加到 include 路径中，以便在编译其他组件时使用。
组件编译控制

在编译特定组件的源文件时，可以使用 `target_compile_options` 命令来传递编译器选项:

```
target_compile_options(${COMPONENT_LIB} PRIVATE -Wno-unused-variable)
```

这条命令封装了 CMake 的 `target_compile_options` 命令。
如果给单个源文件指定编译器标志，可以使用 CMake 的 `set_source_files_properties` 命令:

```
set_source_files_properties(mysrc.c
   PROPERTIES COMPILE_FLAGS
   -Wno-unused-variable)
```

如果上游代码在编译的时候发出了警告，那么这么做可能会很有效。
请注意，上述两条命令只能在组件 CMakeLists 文件的 `register_component()` 命令之后调用。

### 4.2.6 组件配置

每个组件都可以包含一个 Kconfig 文件，和 CMakeLists.txt 放在同一目录下。Kconfig 文件中包含要添加到该组件配置菜单中的一些配置设置信息。
运行 `menuconfig` 时，可以在 Component Settings 菜单栏下找到这些设置。
创建一个组件的 Kconfig 文件，最简单的方法就是使用 ESP-IDF 中现有的 Kconfig 文件作为模板，在此基础上进行修改。
有关示例请参阅添加条件配置。

### 4.2.7 预处理器定义

ESP-IDF 构建系统会在命令行中添加以下 C 预处理器定义：

- `ESP_PLATFORM`：可以用来检测在 ESP-IDF 内发生了构建行为。
- `IDF_VER`：定义 git 版本字符串，例如: v2.0 用于标记已发布的版本，v1.0-275-g0efaa4f 则用于标记任意某次的提交记录。
- `PROJECT_VER`：项目版本号，详细信息请参阅预设的组件变量。
- `PROJECT_NAME`：项目名称，定义在项目 CMakeLists.txt 文件中。

### 4.2.8 组件依赖

编译各个组件时，ESP-IDF 系统会递归评估其组件。
每个组件的源文件都会使用以下路径中的头文件进行编译:

- 当前组件的 `COMPONENT_ADD_INCLUDEDIRS` 和 `COMPONENT_PRIV_INCLUDEDIRS`。
- 当前组件的 `COMPONENTQUIRES` 和 `COMPONENT_PRIVQUIRES` 变量指定的其他组件（即当前组件的所有公共和私有依赖项）所设置的 `COMPONENT_ADD_INCLUDEDIRS`。
- 所有组件的 `COMPONENTQUIRES` 做递归操作，即该组件递归运算后的所有公共依赖项。

编写组件

- `COMPONENTQUIRES` 需要包含所有被当前组件的公共头文件 `#include` 的头文件所在的组件。
- `COMPONENT_PRIVQUIRES` 需要包含被当前组件的源文件 `#include` 的头文件所在的组件（除非已经被设置在了 `COMPONENT_PRIVQUIRES` 中），或者是当前组件正常工作必须要链接的组件。
Chapter 4. API 指南

- COMPONENT_REQUIRES, COMPONENT_PRIV_REQUIRES 需要在调用 register_component() 之前设置。
- COMPONENT_REQUIRES 和 COMPONENT_PRIV_REQUIRES 的值不能依赖于任何配置选值 (CONFIG_xxx)，这是因为在配置加载之前，依赖关系就已被展开。其它组件变量（比如 COMPONENT_SRCS 和 COMPONENT_ADD_INCLUDEDIRS）可以依赖配置选择。
- 如果当前组件除了 COMPONENT_REQUIRES_COMMON 中设置的通用组件（比如 RTOS, libc 等）外，并不依赖其它组件，那么上述两个 REQUIRES 变量可以为空。

如果组件仅支持某些硬件目标 (即依赖于特定的 IDF_TARGET)，则可以调用 require_idf_targets(NAMES...) CMake 函数来声明这个需求。在这种情况下，如果构建系统导入了不支持当前硬件目标的组件时就会报错。

创建项目

- 默认情况下，每个组件都会包含在构建系统中。
  - 如果将 COMPONENTS 变量设置为项目直接使用的最小组件列表，那么构建系统会导入：
    - COMPONENTS 中明确提及的组件。
    - 这些组件的依赖项（以及递归运算后的组件）。
    - 每个组件都依赖的通用组件。
  - 将 COMPONENTS 设置为所需组件的最小列表，可以显著减少项目的构建时间。

构建系统中依赖处理的实现细节

- 在 CMake 配置进程的早期阶段会运行 expand_requirements.cmake 脚本。该脚本会对所有组件的 CMakeLists.txt 文件进行局部的运算，得到一张组件依赖关系图（此图可能包含闭环）。此图用于在构建目录中生成 componentdepends.cmake 文件。
- CMake 主进程会导人该文件，并以此来确定要包含到构建系统中的组件列表（内部使用的 BUILD_COMPONENTS 变量）。BUILD_COMPONENTS 变量已排好序，依赖组件会排在前面。由于组件依赖关系图中可能存在闭环，因此不能保证每个组件都满足该排序规则。如果给定相同的组件集和依赖关系，那么最终的排序结果应该是确定的。
- CMake 会将 BUILD_COMPONENTS 的值以 “Component names:” 的形式打印出来。
- 然后执行构建系统中包含的每个组件的配置。
- 每个组件都被正常包含在构建系统中，然后再次执行 CMakeLists.txt 文件，将组件库加入构建系统。

组件依赖顺序 BUILD_COMPONENTS 变量中组件的顺序决定了构建过程中的其它顺序，包括：
- 项目导入 project_include.cmake 文件的顺序。
- 生成用于编译 (通过 -I 参数) 的头文件路径列表的顺序。请注意，对于给定组件的源文件，仅需将该组件的依赖组件的头文件路径告知编译器。

4.2.9 构建的内部过程

关于 CMake 以及 CMake 命令的详细信息，请参阅 CMake v3.5 官方文档。

project.cmake 的内容

当项目 CMakeLists 文件导入 project.cmake 文件时，project.cmake 会定义一些实用的模块和全局变量。如果系统环境中没有设置 IDF_PATH，那么它还会自动设置 IDF_PATH 变量。

project.cmake 文件还重写了 CMake 内置的 project 函数，以添加所有 ESP-IDF 项目特有的功能。

自定义的 project() 函数会执行以下步骤：
• 确定硬件目标（由 IDF_TARGET 环境变量设置），并将其保存在 CMake cache 中。如果环境变量中设置的硬件目标与 CMake cache 中的不匹配，则会报错并退出。
• 计算组件依赖，并构造 BUILD_COMPONENTS 变量，它是包含所有需要导入到构建系统中的组件列表（详情请见上文）。
• 查找项目中所有的组件（搜索 COMPONENT_DIRS，并按 COMPONENTS 进行过滤（前提是设置了该变量）。
• 从 sdkconfig 文件中加载配置信息，生成 sdkconfig.cmake 和 sdkconfig.h 文件，分别用在 CMake 和 C/C++ 中定义配置项。如果项目配置发生了更改，CMake 会自动重新运行，重新生成上述两个文件，接着重新配置项目。
• 根据硬件目标（IDF_TARGET）的值，将 CMAKE_TOOLCHAIN_FILE 变量设置为相应的工具链文件。
• 调用 CMake 的 project 函数声明实际的 CMake-level 项目。
• 加载 git 版本号。如果在 git 中检出了新的版本，就会使用一些技巧重新运行 CMake。详情请参考文件适配符 & 增量构建。
• 从包含有 project_include.cmake 文件的组件中导入该文件。
• 将每个组件都添加到构建系统中，每个组件的 CMakeLists 文件都会调用 register_component 函数，它会调用 CMake 的 add_library 函数来添加一个库，然后添加源文件，编译选项等。
• 将最终的应用程序可执行文件添加到构建系统中。
• 返回并为组件之间指定依赖关系（将每个组件的公共头文件目录添加到其他组件中）。

更多详细信息请参阅 /tools/cmake/project.cmake 文件。

CMake 调试

调试 ESP-IDF CMake 构建系统的一些技巧：
• CMake 运行时，会打印大量诊断信息，包括组件列表和组件路径。
• 运行 cmake -DDEBUG=1, IDF 构建系统会生成更详细的诊断输出。
• 运行 cmake 时指定 --trace 或 --trace-expand 选项会提供大量有关控制流信息。详情请参考 CMake 命令行文档。

警告未定义的变量 默认情况下，idf.py 在调用 CMake 时会给它传递 --warn-uninitialized 标志。如果在构建的过程中引用了未定义的变量，CMake 会打印警告。这对查找有错误的 CMake 文件非常有用。

如果您不想启用此功能，可以给 idf.py 传递 --no-warnings 标志。

覆盖项目的部分设置

project_include.cmake 如果组件的某些构建行为需要在组件 CMakeLists 文件之前被执行，您可以在组件目录下创建名为 project_include.cmake 的文件，project.cmake 在运行过程中会导入此 CMake 文件。

project_include.cmake 文件在 ESP-IDF 内部使用，以定义项目范围内的构建功能，比如 esptool.py 的命令行参数和 bootloader 这个特殊的应用程序。

与组件 CMakeLists.txt 文件有所不同，在导入“project_include.cmake”文件的时候，当前源文件目录（即 CMAKE_CURRENT_SOURCE_DIR）和工作目录为项目目录。如果想获得当前组件的绝对路径，可以使用 COMPONENT_PATH 变量。

请注意，project_include.cmake 对于大多数常见的组件并不是必需的。例如给项目添加 include 搜索目录，给最终的链接步骤添加 LDFLAGS 选项等等都可以通过 CMakeLists.txt 文件来自定义。详细信息请参考可选的项目变量。

project_include.cmake 文件会按照 BUILD_COMPONENTS 变量中组件的顺序（由 CMake 记录）依次导入。即只有在当前组件所有依赖组件的 project_include.cmake 文件都被导入后，当前组件的 project_include.cmake 文件才会被读入，除非两个组件在同一个依赖闭环中。如果某个 project_include.cmake 文件依赖于另一组件设置的变量，则要特别注意上述情况。更多详情请参阅构建系统中依赖处理的实现细节。
在 `project_include.cmake` 文件中设置变量或目标时要格外小心，这些值被包含在项目的顶层 `CMake` 文件中，因此他们会影响或破坏所有组件的功能。

**KConfig.projectbuild** 与 `project_include.cmake` 类似，也可以为组件定义一个 KConfig 文件以实现全局的配置。如果要在 menuconfig 的顶层添加配置选项，而不是在“Component Configuration”子菜单中，则可以在 `CMakeLists.txt` 文件所在目录的 `KConfig.projectbuild` 文件中定义这些选项。

在此文件中添加配置时要小心，因为这些配置会包含在整个项目配置中。在可能的情况下，请为组件配置创建 KConfig 文件。

**配置组件** 仅配置组件是一类不包含源文件的特殊组件，仅包含 Kconfig.projectbuild、KConfig 和 `CMakeLists.txt` 文件，该 `CMakeLists.txt` 文件仅有一行代码，调用了 `register_config_only_component()` 函数。此函数会将组件导入到项目构建中，但不会构建任何库，也不会将头文件添加到任何 include 搜索路径中。

如果 `CMakeLists.txt` 文件没有调用 `register_component()` 或 `register_config_only_component()`，那么该文件将会被排除在项目构建之外。根据项目的配置，有时可能需要这么做。

### 4.2.10 组件 CMakeLists 示例

因为构建环境试图设置大多数情况都能工作的合理默认值，所以组件 `CMakeLists.txt` 文件可能非常小，甚至为空的，请参考最小的组件 `CMakeLists` 文件。但有些功能往往需要覆盖预设的组件变量才能实现。

以下是组件 `CMakeLists` 文件的更高级的示例。

#### 添加条件配置

配置系统可用于根据项目配置中选择的选项有条件地编译某些文件。

**Kconfig:**

```
config FOO_ENABLE_BAR
  bool "Enable the BAR feature."
  help
    This enables the BAR feature of the FOO component.
```

**CMakeLists.txt:**

```
set(COMPONENT_SRCS "foo.c" "more_foo.c")
if(CONFIG_FOO_ENABLE_BAR)
  list(APPEND COMPONENT_SRCS "bar.c")
endif()
```

上述示例使用了 CMake 的 if 函数和 list APPEND 函数。

也可用于选择或删除某一实现，如下所示:

**Kconfig:**

```
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"
```

(下页继续)
depends on ENABLE_LCD_OUTPUT
help
Select this to output debugging output to the LCD

cfg config ENABLE_LCD_PLOT
bool "Output temperature plots to LCD"
depends on ENABLE_LCD_OUTPUT
help
Select this to output temperature plots

CMakeLists.txt:

```cmake
if (CONFIG_ENABLE_LCD_OUTPUT)
  set (COMPONENT_SRCS lcd-real.c lcd-spi.c)
else()
  set (COMPONENT_SRCS lcd-dummy.c)
endif()

# 请使用 Kconfig 变量 CONFIG_IDF_TARGET_XYZ
cfg config CONFIG_IDF_TARGET_XYZ
if (CONFIG_ENABLE_LCD_CONSOLE OR CONFIG_ENABLE_LCD_PLOT)
  list (APPEND COMPONENT_SRCS "font.c")
endif()
```

### 硬件目标的条件判断

CMake 文件可以使用 IDF_TARGET 变量来获取当前的硬件目标。

此外，如果当前的硬件目标是 `xyz`（即 IDF_TARGET=xxyz），那么 Kconfig 变量 CONFIG_IDF_TARGET_XYZ 同样也会被设置。

请注意，组件可以依赖 IDF_TARGET 变量，但不能依赖这个 Kconfig 变量。同样也不可在 CMake 文件的 include 语句中使用 Kconfig 变量，在这种上下文中可以使用 IDF_TARGET。

### 生成源代码

有些组件的源文件可能并不是由组件本身提供，而必须从另外的文件生成。假设组件需要一个头文件，该文件由 BMP 文件转换后（使用 bmp2h 工具）的二进制数据组成，然后将头文件包含在名为 `graphics_lib.c` 的文件中:

```cmake
add_custom_command (OUTPUT logo.h
  COMMAND bmp2h -i ${COMPONENT_DIR}/logo.bmp -o log.h
  DEPENDS ${COMPONENT_DIR}/logo.bmp
  VERBATIM)

add_custom_target (logo DEPENDS logo.h)
add_dependencies (${COMPONENT_LIB} logo)

set_property (DIRECTORY "${COMPONENT_DIR}" APPEND PROPERTY
ADDITIONAL_MAKE_CLEAN_FILES logo.h)
```

这个示例改编自 CMake 的一则 FAQ，其中还包含了一些同样适用于 ESP-IDF 构建系统的示例。

这个示例会在当前目录（构建目录）中生成 `logo.h` 文件，而 `logo.bmp` 会随组件一起提供在组件目录中。因为 `logo.h` 是一个新生成的文件，一旦项目需要清理，该文件也应该被清除。因此，要将该文件添加到 ADDITIONAL_MAKE_CLEAN_FILES 属性中。

注解：如果需要生成文件作为项目 CMakeLists.txt 的一部分，而不是作为组件 CMakeLists.txt 的一部分，此时需要使用 `${PROJECT_PATH}` 替代 `${COMPONENT_DIR}`，使用 `${PROJECT_NAME}.elf` 替代
代 `${COMPONENT_LIB}`。

如果某个源文件是从其他组件中生成，且包含 `logo.h` 文件，则需要调用 `add_dependencies`，在这两个组件之间添加一个依赖项，以确保组件源文件按照正确顺序进行编译。

### 嵌入二进制数据

有时您的组件希望使用一个二进制文件或者文本文件，但是您又不希望将它们重新格式化为 C 源文件。这时，您可以在组件 `CMakeLists` 中添加 `COMPONENT_EMBED_FILES` 变量，指定要嵌入的文件名称（以空格分隔）。

```cmake
set(COMPONENT_EMBED_FILES server_root_cert.der)
```

或者，如果文件是字符串，则可以设置 `COMPONENT_EMBED_TEXTFILES` 变量，把文件的内容转成以 null 结尾的字符串嵌入。

```cmake
set(COMPONENT_EMBED_TEXTFILES server_root_cert.pem)
```

文件的内容会被添加到 Flash 的 `rodata` 段，用户可以通过符号名来访问，如下所示:

```cmake
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");
```

符号名会根据文件全名生成，如 `COMPONENT_EMBED_FILES` 中所示，字符 `/` 等都会被下划线替代。符号名称中的 `_binary` 前缀由 `objcopy` 命令添加，对文本文件和二进制文件都是如此。

如果要将文件嵌入到项目中，而非组件中，可以调用 `target_add_binary_data` 函数:

```cmake
target_add_binary_data(myproject.elf "main/data.bin" TEXT)
```

并这行代码放在项目 `CMakeLists.txt` 的 `project()` 命令之后。修改 `myproject.elf` 为你自己的项目名。如果最后一个参数是 `TEXT`，那么构建系统会嵌入以 null 结尾的字符串，如果最后一个参数被设置为 `BINARY`，则将文件内容按照原样嵌入。

有关使用此技术的示例，请参看 `protocols/https_request`，证书文件的内容会在编译时从 `.pem` 文件中加载。

### 代码和数据的存放


### 完全覆盖组件的构建过程

当然，在有些情况下，上面提到的方法不一定够用。如果组件封装了另一个第三方组件，而这个第三方组件并不能直接在 ESP-IDF 的构建系统中工作，在这种情况下，就需要放弃 ESP-IDF 的构建系统，改为使用 CMake 的 `ExternalProject` 功能。组件 `CMakeLists` 示例如下:

```cmake
# 用于 quirc 的外部构建过程，在源目录中运行并生成 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 ""
```

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## 4.2.11 自定义 sdkconfig 的默认值

对于示例工程或者其他您不想指定完整 `sdkconfig` 配置的项目，但是您确实希望覆盖 ESP-IDF 默认值中的某些键值，则可以在项目中创建 `sdkconfig.defaults` 文件。重新创建新配置时将会用到此文件，另外在 `sdkconfig` 没有设置新配置时，上述文件也会被用到。

如若需要覆盖此文件的名称，请设置 `SDKCONFIG_DEFAULTS` 环境变量。

### 依赖于硬件目标的 `sdkconfig` 默认值

除了 `sdkconfig.defaults` 之外，构建系统还将从 `sdkconfig.defaults.TARGET_NAME` 文件加载默认值，其中 IDF_TARGET 的值为 `TARGET_NAME`。例如，对于 ESP32 这个硬件目标，`sdkconfig` 的默认值会首先从 `sdkconfig.defaults` 获取，然后再从 `sdkconfig.defaults.esp32` 获取。
如果使用 SDKCONFIG_DEFAULTS 覆盖了 sdkconfig 默认文件的名称，则硬件目标的 sdkconfig 默认文件名也会从 SDKCONFIG_DEFAULTS 值中派生。

### 4.2.12 Flash 参数

有些情况下，我们希望在没有 IDF 时也能烧写目标板卡。为此，我们希望可以保存已构建的二进制文件、esptool.py 和 esptool_write_flash 命令的参数。可以通过编写一段简单的脚本来保存二进制文件和 esptool.py。

运行项目构建之后，构建目录将包含项目二进制输出文件 (.bin 文件)，同时也包含以下烧录数据文件：

- `flash_project_args` 包含烧录整个项目的参数，包括应用程序 (app)、引导程序 (bootloader)、分区表，如果设置了 PHY 数据，也会包含此数据。
- `flash_app_args` 只包含烧录应用程序的参数。
- `flash_bootloader_args` 只包含烧录引导程序的参数。

您可以参照如下命令将任意烧录参数文件传递给 esptool.py:

```bash
goto $PROJECT_DIR
python esptool.py --chip esp32 write_flash @build/flash_project_args
```

也可以手动复制参数文件中的数据到命令行中执行。

构建目录中还包含生成的 flasher_args.json 文件，此文件包含 JSON 格式的项目烧录信息，可用于 idf.py 和其它需要项目构建信息的工具。

### 4.2.13 构建 Bootloader

引导程序默认作为 idf.py build 的一部分被构建，也可以通过 idf.py bootloader 来单独构建。

引导程序是 /components/bootloader/subproject 内部独特的 “子项目”。它有自己的项目 CMakeLists.txt 文件，能够构建独立于主项目的 .ELF 和 .BIN 文件，同时它又与主项目共享配置和构建目录。

子项目通过 /components/bootloader/project_include.cmake 文件作为外部项目插入到项目的顶层，主构建进程会运行子项目的 CMake，包括查找组件（主项目使用的组件的子集），生成引导程序专用的配置文件（从主 sdkconfig 文件中派生）。

### 4.2.14 选择 “目标” 芯片

ESP-IDF 支持多款芯片，它们通过在软件中使用不同的 “目标” (target) 名进行区分。具体对应关系如下：

- esp32 — 适用于 ESP32-D0WD、ESP32-D2WD、ESP32-S0WD (ESP-SOLO)、ESP32-U4WDH、ESP32-PICO-D4
- esp32s2 — 适用于 ESP32-S2

在构建项目时，请首先根据您的芯片选择正确的软件目标。具体命令为 idf.py set-target <target>。举例

```bash
idf.py set-target esp32s2
```

**重要：** 运行 idf.py set-target 命令将清除 build 文件夹的内容，并重新生成一个 sdkconfig 文件。之前的 sdkconfig 将另存为 sdkconfig.old。

**注解：** 运行 idf.py set-target 命令相当于分别运行以下几个命令：

1. 清除 build 文件夹(idf.py fullclean)
2. 移除 sdkconfig 文件(mv sdkconfig sdkconfig.old)
3. 根据选择的 “目标” 芯片配置项目(idf.py -DIDF_TARGET=esp32 reconfigure)
您也可以将要用的 IDF_TARGET 设置为环境变量，比如：export IDF_TARGET=esp32s2；或设置为 CMake
变量，比如将 -DIDF_TARGET=esp32s2 以参数形式传递给 CMake 或 idf.py。如果您大多数时间仅使用
一款芯片，则将 IDF_TARGET 配置环境变量比较方便。

对于特定项目，您可以使用以下方式为 IDF_TARGET 配置 _default_ 值：把 CONFIG_IDF_TARGET 的值
加入 sdkconfig.defaults。举例而言，配置 CONFIG_IDF_TARGET="esp32s2"。这样一来，除非
特别设置（比如使用环境变量，CMake 变量或 idf.py set-target 命令），否则 IDF_TARGET 将默
认采用 CONFIG_IDF_TARGET。

如果您从未通过以上任何方式配置过“目标”芯片，则构建系统会默认将 esp32 设定为“目标”芯片。

4.2.15 编写纯 CMake 组件

ESP-IDF 构建系统用“组件”的概念“封装”了 CMake，并提供了很多帮助函数来自动将这些组件集成
到项目构建当中。

然而，“组件”概念的背后是一个完整的 CMake 构建系统，因此可以制作纯 CMake 组件。

下面是使用纯 CMake 语法为 json 组件编写的最小 CMakeLists 文件的示例：

```
add_library(json STATIC
  cJSON/cJSON.c
  cJSON/cJSON_Utils.c)

target_include_directories(json PUBLIC cJSON)
```

- 这实际上与 IDF 中的 json 组件是等效的。
- 因为组件中的源文件不多，所以这个 CMakeLists 文件非常简单。对于具有大量源文件的组件而言，
  ESP-IDF 支持的组件通配符，可以简化组件 CMakeLists 的样式。
- 每当组件中新增一个与组件同名的库目标时，ESP-IDF 构建系统会自动将其添加到构建中，并公开
  公共的 include 目录。如果组件想要添加一个与组件同名的库目标，就需要使用 CMake 命令手动
  添加依赖关系。

4.2.16 组件中使用第三方 CMake 项目

CMake 在许多开源的 C/C++ 项目中广泛使用，用户可以在自己的应用程序中使用开源代码。CMake 构建
系统的一大好处就是可以导入这些第三方的项目，有时候甚至不用做任何改动。这就允许用户使用当前
ESP-IDF 组件尚未提供的功能，或者使用其它库来实现相同的功能。

假设 main 组件需要导入一个假想库 foo，相应的组件 CMakeLists 文件如下所示：

```
# 注册组件
register_component()

# 设置‘foo’项目中的一些 CMake 变量，以控制 ‘foo’ 的构建过程
set(FOO_BUILD_STATIC OFF)
set(FOO_BUILD_TESTS OFF)

# 创建并导人第三方库目标
add_subdirectory(foo)

# 将 ‘foo’ 全局的编译器设置，宏定义及其它选项传递给 ‘foo’ 目标
target_include_directories(foo ${IDF_INCLUDE_DIRECTORIES})
target_compile_options(foo ${IDF_COMPILE_OPTIONS})
target_compile_definitions(foo ${IDF_COMPILE_DEFINITIONS})

# 将 ‘foo’ 目标链接至 ‘main’ 组件
target_link_libraries(main foo)
```
实际的案例请参考 build_system/cmake/import_lib，请注意，导入第三方库所需要做的工作可能会因库的不同而有所差异。建议仔细阅读第三方库的文档，了解如何将其导入到其它项目中。阅读第三方库的 CMakeLists.txt 文件以及构建结构也会有所帮助。

用这种方式还可以将第三方库封装成 ESP-IDF 的组件。例如 mbedtls 组件就是封装了 mbedtls 项目得到的。详情请参考 mbedtls 组件的 CMakeLists.txt 文件。

每当使用 ESP-IDF 构建系统时，CMake 变量 ESP_PLATFORM 都会被设置为 1。如果要在通用的 CMake 代码加入 IDF 特定的代码时，可以采用 if (ESP_PLATFORM) 的形式加以分隔。

### 4.2.17 在自定义 CMake 项目中使用 ESP-IDF

ESP-IDF 提供了一个模板 CMake 项目，可以基于此轻松创建应用程序。然而在有些情况下，用户可能已有一个现成的 CMake 项目，或者想自己创建一个 CMake 项目，此时就需要将 IDF 中的组件以库的形式链接到用户目标（库/可执行文件）。

build_system/cmake/idf_as_lib 中的示例演示了如何在自定义的 CMake 项目创建一个类似于 Hello World 的应用程序。

### 4.2.18 文件通配符 & 增量构建

在 ESP-IDF 组件中添加源文件的首选方法是在 COMPONENT_SRCS 中手动列出它们:

```cpp
set(COMPONENT_SRCS library/a.c library/b.c platform/platform.c)
```

这是在 CMake 中手动列出源文件的最佳实践。然而，当有许多源文件都需要添加到构建中时，这种方法就会很不方便。ESP-IDF 构建系统因此提供了另一种替代方法，即使用 COMPONENT_SRCDIRS 来指定源文件:

```cpp
set(COMPONENT_SRCDIRS library platform)
```

后台会使用通配符在指定的目录中查找源文件。但是请注意，在使用这种方法的时候，如果组件中添加了一个新的源文件，CMake 并不知道重新运行配置，最终该文件也没有被加入构建中。

如果是自己添加的源文件，这种折衷还是可以接受的，因为用户可以触发一次干净的构建，或者运行 idf.py reconfigure 来手动重启 CMake。但是，如果你需要与其他使用 Git 等版本控制工具的开发人员共享项目时，问题就会变得更加困难，因为开发人员有可能会拉取新的版本。

ESP-IDF 中的组件使用了第三方的 Git CMake 集成模块(/tools/cmake/third_party/GetGitRevisionDescription.cmake)，任何时候源码仓库的提交记录发生了改变，该模块就会自动重新运行 CMake，即只要拉取了新的 ESP-IDF 版本，CMake 就会重新运行。

对于不属于 ESP-IDF 的项目组件，有以下几个选项供参考:

- 如果项目文件保存在 Git 中，ESP-IDF 会自动跟踪 Git 修订版本，并在它发生变化时重新运行 CMake。
- 如果一些组件保存在第三方 Git 仓库中（不在项目仓库或 ESP-IDF 仓库），则可以在组件 CMakeLists 文件中调用 git_describe 函数，以便在 Git 修订版本发生变化时自动重启 CMake。
- 如果没有使用 Git，请记住在源文件发生变化时手动运行 idf.py reconfigure。
- 使用 COMPONENT_SRCS 在项目组件中列出所有源文件，可以完全避免这一问题。

具体选择哪一方式，就要取决于项目本身，以及项目用户。

### 4.2.19 构建系统的元数据

为了将 ESP-IDF 集成到 IDE 或者其它构建系统中，CMake 在构建的过程中会在 build/ 目录下生成大量元数据文件。运行 cmake 或 idf.py reconfigure（或任何其它 idf.py 构建命令），可以重新生成这些元数据文件。
• `compile_commands.json` 是标准格式的 JSON 文件，它描述了在项目中参与编译的每个源文件。
CMake 其中的一个功能就是生成此文件，许多 IDE 都知道如何解析此文件。
• `project_description.json` 含有关于 ESP-IDF 项目、配置路径等的一些常规信息。
• `flasher_args.json` 包含 `esptool.py` 工具用于烧录项目二进制文件的参数，此外还有 `flash_*.args` 文件，可直接与 `esptool.py` 一起使用。更多详细信息请参阅 `Flash 参数`。
• `CMacache.txt` 是 CMake 的缓存文件，包含 CMake 进程、工具链等其它信息。
• `config/sdkconfig.json` 是在 `menuconfig` 中显示菜单的 JSON 格式版本，用于外部 IDE 的 UI。

### JSON 配置服务器

`confserver.py` 工具可以帮助 IDE 轻松地与配置系统的逻辑进行集成，它运行在后台，通过使用 stdin 和 stdout 读写 JSON 文件的方式与调用进程交互。

您可以通过 `idf.py confserver` 或 `ninja confserver` 从项目中运行 `confserver.py`，也可以使用不同的构建生成器来触发类似的目标。

有关 `confserver.py` 的更多信息，请参阅 tools/kconfig_new/README.md

#### 4.2.20 从 ESP-IDF GNU Make 构建系统迁移到 CMake 构建系统

ESP-IDF CMake 构建系统与旧版的 GNU Make 构建系统在某些方面非常相似，例如将 `component.mk` 文件改写 `CMakeLists.txt`，像 `COMPONENT_ADD_INCLUDEDIRS` 和 `COMPONENT_SRCDIRS` 等变量可以保持不变，只需将语法改为 CMake 语法即可。

### 自动转换工具

`tools/cmake/convert_to_cmake.py` 中提供了一个项目自动转换工具，运行此命令时需要加上项目路径，如下所示:

```
$IDF_PATH/tools/cmake/convert_to_cmake.py /path/to/project_dir
```

项目目录必须包含 Makefile 文件，并确保主机已安装 GNU Make (make) 工具，并且被添加到了 PATH 环境变量中。

该工具会将项目 Makefile 文件和所有组件的 component.mk 文件转换为对应的 CMakeLists.txt 文件。

转换过程如下：该工具首先运行 `make` 来展开 ESP-IDF 构建系统设置的变量，然后创建相应的 CMakeLists 文件来设置相同的变量。

转换工具并不能处理复杂的 Makefile 逻辑或异常的目标，这些需要手动转换。

### CMake 中不可用的功能

有些功能已从 CMake 构建系统中移除，或者已经发生很大改变。GNU Make 构建系统中的以下变量已从 CMake 构建系统中删除：

- `COMPONENT_BUILD_DIR`：由 `CMAKE_CURRENT_BINARY_DIR` 替代。
- `COMPONENT_LIBRARY`：默认为 `$(COMPONENT_NAME).a` 但是库名可以被组件覆盖。在 CMake 构建系统中，组件库名称不可再被组件覆盖。
- CC、LD、AR、OBJCOPY 等 gcc xtensa 交叉工具链中每个工具的完整路径。CMake 使用 `CMAKE_C_COMPILER`、`CMAKE_C_LINK_EXECUTABLE` 和 `CMAKE_OBJCOPY` 进行替代。完整列表请参阅 `CMake 语言变量`。
- `HOSTCC、HOSTLD、HOSTAR`：宿主机本地工具链中每个工具的全名。CMake 系统不再提供此变量，外部项目需要手动检测所需的宿主机工具链。
- `COMPONENT_ADD_LDFLAGS`：用于覆盖链接标志。CMake 中使用 `target_link_libraries` 命令替代。
Chapter 4. API

• COMPONENT_ADD_LINKER_DEPS: 链接过程依赖的文件列表。target_link_libraries 通常会自动推断这些依赖。对于链接脚本，可以使用自定义的 CMake 函数 target_linker_scripts。
• COMPONENT_SUBMODULES: 不再使用。CMake 会自动枚举 ESP-IDF 仓库中所有的子模块。
• COMPONENT_EXTRA_INCLUDES: 曾是 COMPONENT_PRIV_INCLUDEDIRS 变量的替代版本，仅支持绝对路径。CMake 系统中统一使用 COMPONENT_PRIV_INCLUDEDIRS（可以是相对路径，也可以是绝对路径）。
• COMPONENT_OBJJS: 以前，可以以目标文件列表的方式指定组件源，现在，可以通过 COMPONENT_SRCS 以源文件列表的形式指定组件源。
• COMPONENT_OBJEXCLUDE: 已被 COMPONENT_SRCEXCLUDE 替换。用于指定源文件（绝对路径或组件目录的相对路径）。
• COMPONENT_EXTRA_CLEAN: 已被 ADDITIONAL_MAKE_CLEAN_FILES 属性取替，注意，CMake 对此项功能有部分限制。
• COMPONENT_OWNBUildeNTARGET & COMPONENT_OWNCLEANTARGET: 已被 CMake 外部项目 替代，详细内容请参阅完全覆盖组件的构建过程。
• COMPONENT_CONFIGURATIONONLY: 已被 register_config_only_component() 函数替代，请参阅组件配置控制。

无默认值的变量

以下变量不再具有默认值：
- COMPONENT_SRCDIRS
- COMPONENT_ADD_INCLUDEDIRS

不再需要的变量

如果设置了 COMPONENT_SRCS，就不需要再设置 COMPONENT_SRCDIRS。实际上，CMake 构建系统中如果设置了 COMPONENT_SRCDIRS，那么 COMPONENT_SRCS 就会被忽略。

从 Make 中烧录

仍然可以使用 make flash 或者类似的目标来构建和烧录，但是项目 sdkconfig 不能再用来指定串口和波特率。可以使用环境变量来覆盖串口和波特率的设置，详情请参阅使用 Ninja/Make 未烧录。

4.3 构建系统 (传统 GNU Make)

注解：ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能不会继续支持基于 GNU Make 的构建系统。

本文将介绍乐鑫物联网开发框架中的构建系统和组件的相关概念。
如果您想了解如何构建一个新的 ESP-IDF 项目，请阅读本文档。
我们建议您使用 ESP-IDF 模板工程 来开始您的新项目。

4.3.1 使用构建系统

ESP-IDF 的 README.md 文件对如何使用构建系统来构建项目作了简要的说明。
4.3.2 概述

一个 ESP-IDF 项目可以看作是许多不同组件的集合，例如对于一个展示当前湿度的网站服务器来说，它可能会包含如下一些组件:

- ESP32 基础库（libc，rom bindings 等）
- WiFi 驱动库
- TCP/IP 协议栈
- FreeRTOS 操作系统
- 网站服务器
- 湿度传感器的驱动
- 将上述组件组织在一起的主代码

ESP-IDF 可以显式地指定和配置每个组件。在构建项目的时候，构建系统会查找 ESP-IDF 目录、项目目录和用户自定义目录（可选）中所有的组件，然后使用基于文本的菜单系统让用户配置 ESP-IDF 项目中需要的每个组件。在配置结束后，构建系统开始编译整个项目。

概念

- 项目特指一个目录，其中包含了构建可执行文件的所有源文件和配置，还有其他的支持性输出文件，比如分区表、数据/文件系统分区和引导程序。
- 项目配置保存在项目根目录下名为 sdkconfig 的文件中，它可以通过 make menuconfig 进行修改，且一个项目只能包含一个项目配置。
- 应用程序是由 ESP-IDF 构建得到的可执行文件。一个项目通常会构建两个应用程序：项目应用程序（主可执行文件，即用户自定义的固件）和引导程序（启动并初始化项目应用程序的引导程序）。
- 组件是模块化的、独立的代码，它们被编译成静态库（.a 文件）后再链接成应用程序，有些组件是 ESP-IDF 官方提供的，有些则可能来自其它项目。

以下内容并不是项目的组成部分：

- ESP-IDF 并不是项目的一部分，相反，它是独立的，并通过 IDF_PATH 环境变量链接到项目中，这样做就可以让 IDF 框架与你的项目分离，其中 IDF_PATH 变量保存了 ESP-IDF 目录的路径。
- 交叉编译工具链并不是项目的组成部分，它应该被安装在系统 PATH 环境变量中，或者可以在项目配置中显式指定工具链的前缀为本地的安装路径。

示例项目

示例项目的目录树结构可能如下所示:

```
- myProject/
  - Makefile
  - sdkconfig
    - components/  - component1/  - component.mk
      - Kconfig
      - src1.c
    - component2/  - component.mk
      - Kconfig
      - src1.c
      - include/  - component2.h
  - main/        - src1.c
    - src2.c
    - component.mk
  - build/
```

该示例项目 myProject 包含以下组成部分:

- 项目顶层 Makefile，该 Makefile 设置了 PROJECT_NAME 变量，还可以定义作用于整个项目的其它 make 变量（可选）。顶层 Makefile 会导入核心 Makefile 文件 $(IDF_PATH)/make/project.mk，由它负责实现 ESP-IDF 构建系统的剩余部分。
项目 Makefiles

每个项目都有一个 Makefile，它包含整个项目的构建设置。默认情况下，项目 Makefile 可以非常小。

最小 Makefile 示例

```
PROJECT_NAME := myProject
include $(IDF_PATH)/make/project.mk
```

必须设置的项目变量

- `PROJECT_NAME`: 项目名称，最终输出的二进制文件也使用该名称，即 `myProject.bin`, `myProject.elf`。

可选的项目变量

- `PROJECT_PATH`: 顶层项目目录，默认是包含 Makefile 文件的目录。许多其他的项目变量都基于此变量。注意，项目路径中不能包含空格。
- `BUILD_DIR_BASE`: 所有对象、库、二进制文件的输出目录，默认为 `$(PROJECT_PATH)/build`。
- `COMPONENT_DIRS`: 组件的搜索目录，默认为 `$(IDF_PATH)/components`, `$(PROJECT_PATH)/components`, `$(PROJECT_PATH)/main` 和 `EXTRA_COMPONENT_DIRS`。如果您不希望从这些目录中搜索组件，请重写此变量。
- `EXTRA_COMPONENT_DIRS`: 组件额外的搜索路径，可选。
- `COMPONENTS`: 要构建项目中的组件列表，默认为 `COMPONENT_DIRS` 指定目录中的所有组件。
- `EXCLUDE_COMPONENTS`: 在构建的过程中需要剔除的组件列表，可选。请注意这只会减少构建的时间，并不会减少最终二进制文件的大小。
- `TEST_EXCLUDE_COMPONENTS`: 在构建单元测试的过程中需要剔除的组件列表，可选。

以上这些 Makefile 变量中的任何路径都要使用绝对路径，您可以使用 `$(PROJECT_PATH)/xxx`, `$(IDF_PATH)/xxx`，或者使用 `Make` 内置函数 `$(abspath xxx)` 将相对路径转换为绝对路径。

以上这些变量要在 Makefile 中 include `$(IDF_PATH)/make/project.mk` 的前面进行设置。

组件 Makefiles

每个项目都包含一个或者多个组件，这些组件可以是 ESP-IDF 的一部分，也可以从其他组件目录添加。组件是包含 component.mk 文件的任何目录。
搜索组件

搜索 COMPONENT_DIRS 中指定的目录以查找项目会使用的组件，目录可以是组件本身 (即它们包含 component.mk 文件)，也可以是包含组件的上层目录。

运行 make list-components 命令可以查询这些变量的值，这有助于调试组件的搜索路径是否正确。

同名组件 ESP-IDF 搜索组件时，会按照 COMPONENT_DIRS 指定的顺序依次进行，这意味着在默认情况下，首先是 ESP-IDF 组件，然后是项目组件，最后是 EXTRA_COMPONENT_DIRS 中的组件。如果这些目录中的两个或者多个包含具有相同名字的组件，则使用搜索到的最后一个位置的组件，这就允许将组件复制到项目目录中再修改来覆盖 ESP-IDF 组件，如果使用这种方式，ESP-IDF 目录本身可以保持不变。

最小组件 Makefile 最简单的 component.mk 文件可以是一个空文件，如果文件为空，则组件的默认构建行为会被设置为:

- makefile 所在目录中的所有源文件 (*.c, *.cpp, *.cc, *.s) 将会被编译进组件库中。
- 于目录 include 将被添加到其他组件的全局头文件搜索路径中。

组件库将会被链接到项目的应用程序中。

更完整的组件 makefile 可以查看组件 Makefile 示例。

请注意，空的 component.mk 文件同没有 component.mk 文件之间存在本质差异。前者会调用默认的组件构建行为，后者不会发生默认的组件构建行为。一个组件如果只包含影响项目配置或构建过程的文件，那么它没有 component.mk 文件。

预设的组件变量 以下特定于组件的变量可以在 component.mk 中使用，但不应该被修改。

- COMPONENT_PATH: 组件的目录，即包含 component.mk 文件的绝对路径，路径中不能包含空格。
- COMPONENT_NAME: 组件的名字，默认为组件目录的名称。
- COMPONENT_BUILD_DIR: 组件的构建目录，即存放组件构建输出的绝对路径，它是 $BUILD_DIR_BASE 的子目录。该变量也是构建组件时的当前工作目录，所以 make 中的相对路径都以此目录为基础。
- COMPONENT_LIBRARY: 组件构建后的静态库文件（相对于组件的构建目录）的名字，默认为 $(COMPONENT_NAME).a。

以下变量在项目顶层中设置，并被导出到组件中构建时使用:

- PROJECT_NAME: 项目名称，在项目的 Makefile 中设置。
- PROJECT_PATH: 包含项目 Makefile 的目录的绝对路径。
- COMPONENTS: 此次构建中包含的所有组件的名字。
- CONFIG_*: 项目配置中的每个值在 make 中都需要一个 (以 CONFIG_ 开头的变量)。
- CC, LD, AR, OBJCOPY: gcc xtensa 交叉编译工具链中每个工具的完整路径。
- HOSTCC, HOSTLD, HOSTAR: 主机本地工具链中每个工具的全名。
- IDF_VER: ESP-IDF 的版本号，可以通过检索 $(IDF_PATH)/version.txt 文件 (假如存在的) 或者使用 git command git describe 来获取。这里推荐的格式是在一行中指定主 IDF 的发布版本号，例如标记为 v2.0 的发布版本或者是在记事本一次提交记录的 v2.0-275-g0efaa4f。应用程序可以通过调用 esp_get_idf_version() 函数来使用该变量。
- IDF_VERSION_MAJOR, IDF_VERSION_MINOR, IDF_VERSION_PATCH: ESP-IDF 的组件版本，可用于条件表达式。请注意这些信息的精确度不如 IDF_VER 变量，版本号 v4.0-dev-, v4.0-beta1, v4.0-rc1 和 v4.0 对应的 IDF_VERSION_* 变量值是相同的，但是 IDF_VER 的值是不同的。

如果您在 component.mk 文件中修改这些变量，这并不会影响其它组件的构建，但可能会使您的组件变得难以构建或调试。

可选的项目通用组件变量 可以在 component.mk 中设置以下变量来控制整个项目的构建行为:

- COMPONENT_ADD_INCLUDEDIRS: 相对于组件目录的路径，将被添加到项目中所有组件的头文件搜索路径中。如果该变量未被覆盖，则默认为 include 目录。如果一个头文件路径仅仅为当前组件所用，那么应该将该路径添加到 COMPONENT_PRIV_INCLUDEDIRS 中。
Chapter 4. API 指南

- COMPONENT_ADD_LDFLAGS: 添加链接参数到全局 LDFLAGS 中用以指导链接最终的可执行文件，默认为 -l$(COMPONENT_NAME)。如果将预编译好的库添加到此目录，请使用它们为绝对路径，即 $(COMPONENT_PATH)/libwhatever.a。
- COMPONENT_DEPENDS: 需要在当前组件之前构建的组件列表，这对于处理链接时的依赖是必需的，因为所有组件的头文件目录始终可用。如果一个组件会生成一个头文件，然后另一个组件需要使用它，此时该变量就有必要进行设置。大多数的组件不需要设置该变量。
- COMPONENT_ADD_LINKER_DEPS: 保存一些文件的路径，当这些文件发生改变时，会触发 ELF 文件重新链接。该变量通常用于链接脚本文档和二进制文件，大多数的组件不需要设置该变量。

以下变量仅适用于属于 ESP-IDF 的组件:

- COMPONENT_SUBMODULES: 组件使用的 git 子模块的路径列表（相对于 COMPONENT_PATH），它们在构建的过程中被检查（并在必要的时候初始化）。如果组件位于 IDF_PATH 目录之外，则忽略此变量。

可选的组件特定变量 以下变量可以在 component.mk 中进行设置，用以控制该组件的构建行为:

- COMPONENT_PRIV_INCLUDEDIRS: 相对于组件目录的目录路径，该目录仅会被添加到该组件源文件的头文件搜索路径中。
- COMPONENT_EXTRA_INCLUDES: 编译组件的源文件时需要指定额外的源文件搜索路径，这些路径将被为编译器的编译器参数，这些 COMPONENT_PRIV_INCLUDEDIRS 变量的功能有些类似，但是这些路径不会相对于组件目录进行扩展。
- COMPONENT_SRCDIRS: 相对于组件目录的目录路径，这些路径用于搜索源文件 (*.cpp, *.c, *.h)。默认为 .，即组件目录本身。重写该变量可以指定包含源文件的不同目录列表。
- COMPONENT_OBJS: 要编译生成的目标文件，默认是 COMPONENT_SRCDIRS 中每个源文件的.o 文件。重写该变量将允许您删除 COMPONENT_SRCDIRS 中的某些源文件，否则它们将被编译。相关示例请参阅指定需要编译的组件源文件。
- COMPONENT_EXTRA_CLEAN: 相对于组件构建目录的路径，指向 component.mk 文件中自定义 make 规则生成的任何文件，它们也是 make clean 命令需要删除的文件。相关示例请参阅示例代码生成。
- COMPONENT_OWNBUILDTARGET & COMPONENT_OWNCLEANTARGET: 这些目标允许您完全覆盖组件的默认编译行为。有关详细信息，请参阅完全覆盖组件的 Makefile。
- COMPONENT_CONFIG_ONLY: 如果设置了此标志，则表示组件根本不会产生构建输出（即不会构建得到 COMPONENT_LIBRARY），并且会忽略大多数其它组件变量。此标志用于 IDF 内部组件，其仅包含 Kconfig, projbuild 和/或 Makefile.project 文件来配置项目，但是没有源文件。
- CFFLAGS: 传递给 C 编译器的标志。根据项目设置已经定义一组默认的 CFFLAGS，可以用通过 CFFLAGS += 来为组件添加特定的标志，也可以完全重写该变量(尽管不推荐这么做)。
- CPPFLAGS: 传递给 C 预处理器的标志 (于 .c, .cpp 和 .s 文件)。根据项目设置已经定义一组默认的 CPPFLAGS，可以通过 CPPFLAGS += 来为组件添加特定的标志，也可以完全重写该变量（尽管不推荐这么做）。
- CXXFLAGS: 传递给 C++ 编译器的标志。根据项目设置已经定义一组默认的 CXXFLAGS，可以通过 CXXFLAGS += 来为组件添加特定的标志，也可以完全重写该变量(尽管不推荐这么做)。

如果要将编译标志应用于单个源文件，您可以将该源文件的目标规则覆盖，例如。

```
apps/dhcpsserver.o: CFFLAGS += -Wno-unused-variable
```

如果上游代码在编译的时候发出了警告，那这么做可能会很有效。

配置组件

每个组件都可以包含一个 Kconfig 文件，和 component.mk 放在同一个目录下。Kconfig 中包含此组件在 make menuconfig 时要展示的配置规则的设置。

运行 menuconfig 时，可以在 Component Settings 菜单栏下找到这些设置。

创建一个组件的 Kconfig 文件，最简单的方法就是使用 ESP-IDF 中现有的 Kconfig 文件作为模板，在此基础上进行修改。

有关示例请参阅添加条件配置。

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预处理器定义

ESP-IDF 构建系统会在命令行中添加以下 C 预处理器定义:

- `ESP_PLATFORM` — 可以用来检测在 ESP-IDF 内发生的构建行为。
- `IDF_VER` — ESP-IDF 的版本，请参阅预设的组件变量。

构建的内部过程

顶层: 项目 Makefile

- `make` 始终从项目目录处运行，并且项目的 `makefile` 名字通常为 `Makefile`。
- 项目的 `makefile` 文件会设置 `PROJECT_NAME`，并且可以自定义其他可选的项目变量。
- 项目 `makefile` 文件会导入 $(IDF_PATH)/make/project.mk，该文件中会导入项目级的 `Makefile`。
- `project.mk` 文件填写默认的项目级 `make` 变量，并导入项目配置中的 `make` 变量，如果生成的包含项目配置的 `makefile` 文件已经过期，那么它将会被重新生成（通过 `project_config.mk` 中的目标规则）, 然后 `make` 进程从顶层重新开始。
- `project.mk` 根据默认组件目录或者可选项目变量中设置的自定义组件列表来编译组件。
- 每个组件都可以设置一些可选的项目配置组件变量，他们会通过 `component_project_vars.mk` 被导入 `project.mk` 文件中。如果这些文件有缺失或者过期，他们会被重新生成（通过组件 `makefile` 的递归调用），然后 `make` 进程从顶层重新开始。
- 组件中的 `Makefile.projbuild` 文件被包含在了 `make` 的进程中，以添加额外的目标或者配置。
- 默认情况下，项目 `makefile` 还为每个组件生成顶层的编译和清理目标，并设置 `app` 和 `clean` 目标来调用所有这些目标。
- 为了编译每个组件, 对组件 `makefile` 执行递归构建。

为了更好地理解项目的构建过程，请阅读 `project.mk` 文件。

第二层: 组件 Makefile 文件

- 每次调用组件 `makefile` 文件都是通过 $(IDF_PATH)/make/component_wrapper.mk 这个包...
- 此组件组件器包含了所有组件的 `Makefile.componentbuild` 文件，使这些文件中的任何配置，变量都可用于每个组件。
- 调用 `component_wrapper.mk` 时将当前目录设置为组件构建目录，并将 `COMPONENT_MAKEFILE` 变量设置为 `component.mk` 的绝对路径。
- `component_wrapper.mk` 为所有组件变量设置默认值，然后导入 `component.mk` 文件来覆盖或修改这些变量。
- 如果未定义 `COMPONENT_OWNBUILDTARGET` 和 `COMPONENT_OWNCLEANTARGET` 文件，则会为组件的源文件和必备组件 `COMPONENT_LIBRARY` 静态库文件创建默认构建和清理目标。
- `component_project_vars.mk` 文件在 `component_wrapper.mk` 中有自己的目标。如果组件的 `makefile` 或者项目配置的更改而需要重建此文件，则从 `project.mk` 文件中进行评估。

为了更好地理解组件制作过程, 请阅读 `component_wrapper.mk` 文件和 ESP-IDF 中的 `component.mk` 文件。

以非交互的方式运行 Make

如果在运行 `make` 的时候不希望出现交互式提示（例如：在 IDE 或自动构建系统中），可以将 `BATCH_BUILD=1` 添加到 `make` 的参数中（或者将其设置为环境变量）。

设置 `BATCH_BUILD` 意味着:

- 详细输出 (与 `V=1` 相同，见下文)，如果不需要详细输出，就设置 `V=0`。
- 如果项目配置缺少新配置项 (来自新组件或者 ESP-IDF 更新)，则项目使用默认值，而不是提示用户输入每个项目。
- 如果构建系统需要调用 `menuconfig`，则会打印错误并且构建失败。
构建目标的进阶用法

- make app, make bootloader, make partition table 可以根据需要为项目单独构建生成应用程序文件、启动引导文件和分区表文件。
- make erase_flash 和 make erase_ota_data 会调用 esptool.py 脚本分别擦除整块闪存芯片或者其中 OTA 分区的内容。
- make size 会打印应用程序的大小信息。make size_components 和 make size-files 两者功能相似，分别打印每个组件或者每个源文件大小的详细信息。

调试 Make 的过程

调试 ESP-IDF 构建系统的一些技巧：

- 将 V=1 添加到 make 的参数中（或将其设置为环境变量）将使 make 回显所有已经执行的命令，以及为 make 输入的每个目录。
- 运行 make -w 将导致 make 在为 make 输入时回显每个目录——与 V=1 相同但不回显所有命令。
- 运行 make --trace（可能除了上述参数之一）将打印出构建时的每个目标，以及导致它构建的依赖项。
- 运行 make -p 会打印每个 makefile 中每个生成的目标的（非常详细的）摘要。

更多调试技巧和通用的构建信息，请参阅 GNU 构建手册。

警告未定义的变量 默认情况下，如果引用了未定义的变量（如 $(DOES_NOT_EXIST)，构建过程将会打印警告，这对于查找变量名称中的错误非常有用。

如果不想要此行为，可以在 menuconfig 顶层菜单下的 SDK tool configuration 中禁用它。
请注意，如果在 Makefile 中使用 ifdef 或者 ifndef，则此选项不会发出警告。

覆盖项目的内容

Makefile.projbuild 如果一个组件含有必须要在项目构建过程的顶层进行计算的变量，则可以在组件目录下创建名为 Makefile.projbuild 的文件，项目在执行 project.mk 的时候会引入此 makefile。
例如，如果您的组件需要为整个项目添加 CFLAGS（不仅仅是为自身的源文件），那么可以在 Makefile.projbuild 中设置 CFLAGS +=。

Makefile.projbuild 文件在 ESP-IDF 中大量使用，用于定义项目范围的构建功能，例如 esptool.py 命令行参数和 bootloader 这个特殊的程序。
请注意，Makefile.projbuild 对于最常见的组件不是必需的 - 例如向项目中添加 include 目录，或者将 LDFLAGS 添加到最终链接步骤。同样可以通过 component.mk 文件来自定义这些值。有关详细信息，请参阅可选的项目通用组件变量。

警告：在此文件中设置变量或者目标时要小心，由于这些值包含在项目的顶层 makefile 中，因此他们可以影响或者破坏所有组件的功能！

KConfig.projbuild 这相当于 Makefile.projbuild 的组件配置 KConfig 文件，如果要在 menuconfig 的顶层添加配置选项，而不是在组件配置子菜单中，则可以在 component.mk 文件所在目录中的 KConfig.projbuild 文件中定义这些选项。
在此文件中添加配置时要小心，因为他们将包含在整个项目配置中，在可能的情况下，通常最好为组件创建和配置 KConfig 文件。
**Makefile.componentbuild** 对于一些特殊的组件，比如它们会使用工具从其余文件中生成源文件，这时就有必要将配置、宏或者变量的定义添加到每个组件的构建过程中。这是通过在组件目录中包含 `Makefile.componentbuild` 文件来实现的。此文件在 `component.mk` 文件之前被导人 `component_wrapper.mk` 中。同 `Makefile.projbuild` 文件一样，请留意这些文件，因为他们包含在每个组件的构建中，所有只有在编译完全不同的组件时才会出现 `Makefile.componentbuild` 错误。

**仅配置的组件** 仅配置的组件是一类不包含源文件的特殊组件，只有 `Kconfig.projbuild` 和 `Makefile.projbuild` 文件可以在 `component.mk` 文件中设置标志 `COMPONENT_CONFIG_ONLY`。如果设置了此标志，则忽略大多数其他组件变量，并且不会为组件执行构建操作。

**组件 Makefile 示例**

因为构建环境试图设置大多数情况都能工作的合理默认值，所以 `component.mk` 可能非常小，甚至是空的，请参考小组件 `Makefile`。但是某些功能通常需要覆盖组件的变量。

以下是 `component.mk` 的一些更高级的示例:

**增加源文件目录** 默认情况下，将忽略子目录。如果您的项目在子目录中而不是在组件的根目录中有源文件，那么您可以通过设置 `COMPONENT_SRCDIRS` 将其告知构建系统:

```
COMPONENT_SRCDIRS := src1 src2
```

构建系统将会编译 `src1` 和 `src2` 子目录中的所有源文件。

**指定源文件** 标准 `component.mk` 逻辑将源目录中的所有 .S 和 .c 文件添加为无条件编译的源。通过将 `COMPONENT_OBJS` 变量手动设置为需要生成的对象的名称，可以绕过该逻辑并对要编译的对象进行硬编码。

```
COMPONENT_OBJS := file1.o file2.o thing/filea.o thing/fileb.o anotherthing/main.o
COMPONENT_SRCDIRS := . thing anotherthing
```

请注意，还需要另外设置 `COMPONENT_SRCDIRS`。

**添加条件配置** 配置系统可用于有条件地编译某些文件，具体取决于 `make menuconfig` 中选择的选项。为此，ESP-IDF 具有 `compile_only_if` 和 `compile_only_if_not` 的宏:

Kconfig:

```
config FOO_ENABLE_BAR
  bool "Enable the BAR feature."
  help
    This enables the BAR feature of the FOO component.
```

```
component.mk:
$(call compile_only_if,$(CONFIG_FOO_ENABLE_BAR),bar.o)
```

从示例中可以看出，`compile_only_if` 宏将条件和目标文件列表作为参数。如果条件为真（在这种情况下，如果在 `menuconfig` 中启用了 BAR 功能），将始终编译目标文件（在本例中为 `bar.o`）。相反的情况也是如此。如果条件不成立，`bar.o` 将永远不会被编译。`compile_only_if_not` 执行相反的操作，如果条件为 `false` 则编译，如果条件为 `true` 则不编译。

这也可以用于选择或者删除实现，如下所示:

Kconfig:
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

component.mk:

```make
# If LCD is enabled, compile interface to it, otherwise compile dummy interface
$(call compile_only_if,$(CONFIG_ENABLE_LCD_OUTPUT),lcd-real.o lcd-spi.o)
$(call compile_only_if_not,$(CONFIG_ENABLE_LCD_OUTPUT),lcd-dummy.o)

# We need font if either console or plot is enabled
$(call compile_only_if,$(or $(CONFIG_ENABLE_LCD_CONSOLE),$(CONFIG_ENABLE_LCD_PLOT)), font.o)
```

请注意使用 Make 或者函数来包含字体文件。其他的替换函数，比如 and 和 if 也适用于此处。也可以使用不在 menuconfig 中定义的变量，ESP-IDF 使用默认的 Make 策略，将一个空的或者只包含空格的变量视为 false，而其中任何非空格的比脑袋都为 true。

（注意：本文档的历史版本建议将目标文件添加到 COMPONENT_OBJJS 中，虽然这仍然可行，但是只有当组件中的所有目标文件都明确命名时才会起作用，并且在 make clean 后并不会清除 make 中取消选择的目标文件）

源代码生成 某些组件会出现源文件无序组件本身提供，而必须从另外一个文件生成的情况。假设我们的组件有一个头文件，该文件由 BMP 文件转换后的二进制数据组成，假设使用 bmp2h 的工具进行转换，然后将头文件包含在名为 graphics_lib.c 的文件中：

```make
COMPONENT_EXTRA_CLEAN := logo.h
graphics_lib.o: logo.h

goals.h: $(COMPONENT_PATH)/logo.bmp
  bmp2h -i $^ -o $@
```

这个示例会在当前目录（构建目录）中生成 graphics_lib.o 和 logo.h 文件，而 logo.bmp 随组件一起提供并位于组件路径下。因为 logo.h 是一个生成的文件，所以当调用 make clean 时需要清理它，这就是为什么要将它添加到 COMPONENT_EXTRA_CLEAN 变量中。

润色与改进 将 logo.h 添加作为 graphics_lib.o 的依赖项会导致编译 graphics_lib.c 之前先生成它。

如果另一个组件中的源文件需要使用 logo.h，则必须将此组件的名称添加到另一个组件的 COMPONENT_DEPENDS 列表中，以确保组件按顺序编译。

嵌入二进制数据 有时您的组件希望使用一个二进制文件或者文本文件，但是您又不希望将它重新格式化为 C 源文件。
这时，您可以在 component.mk 文件中设置变量 COMPONENT_EMBED_FILES，以这种方式指定要嵌入的文件的名称:

```
COMPONENT_EMBED_FILES := server_root_cert.der
```

或者，如果文件是字符串，则可以使用变量 COMPONENT_EMBED_TXTFILES，这将把文本文件的内容当成以 null 结尾的字符串嵌入:

```
COMPONENT_EMBED_TXTFILES := server_root_cert.pem
```

文件的内容会被编译进 flash 中的 .rodata 段，并通过符号名称来访问，如下所示:

```
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");
```

符号名称是根据文件的全名生成的，如 COMPONENT_EMBED_FILES 中的所示。字符串 /... 等都将被下划线替代。符号名称中的 _binary 前缀由 objcopy 添加，对于文本和二进制文件都是相同的。

有关使用此技术的示例，请参考 protocols/https_request - 证书文件的内容会在编译时从 pem 文件中加载。

### 完全覆盖组件的 Makefile

显然，在某些情况下，所有这些配置都不足以满足某个组件，例如，当组件基本上是另一个第三方组件的包装器时，该第三方组件最初不打算在 ESP-IDF 构建系统下工作。在这种情况下，可以通过设置 COMPONENT_OWNBUILDTARGET 和可能的 COMPONENT_OWNCLEANTARGET，并在 component.mk 中定义名为 build 和 clean 的目标。构建目标可以执行任何操作，只要它为项目生成了 $(COMPONENT_LIBRARY)，并最终被链接到应用程序二进制文件中即可。

(实际上，这并不是必须的 - 如果 COMPONENT_ADD_LDFLAGS 变量被覆盖，那么组件可以指示链接器链接其他二进制文件。)

### 自定义 sdkconfig 的默认值

对于示例工程或者其他您不想指定完整 sdkconfig 配置的项目，但是您确实希望覆盖 ESP-IDF 默认值中的某些键值，则可以在项目中创建文件 sdkconfig.defaults，运行 make defconfig 或从头创建新配置时将会使用此文件。

要想覆盖此文件的名称，请设置 SDKCONFIG_DEFAULTS 环境变量。

### 保存 flash 参数

在某些情况下，我们希望在没有 IDF 的情况下烧写目标板卡。对于这种情况，我们需要保存构建的二进制文件、esptool.py 和 esptool write flash 命令的参数。可以简单编写一段脚本来保存二进制文件和 esptool.py，并且使用命令 make print_flash_cmd 来查看烧写 flash 时的参数。

```
--flash_mode dio --flash_freq 40m --flash_size detect 0x1000 bootloader/bootloader.bin
--bin 0x10000 example_app.bin 0x8000 partition_table_unit_test_app.bin
```

然后使用这段 flash 参数作为 esptool write flash 命令的参数:

```
python esptool.py --chip esp32 --port /dev/ttyUSB0 --baud 921600 --before default_
--reset --after hard_reset write_flash -z --flash_mode dio --flash_freq 40m --
--flash_size detect 0x1000 bootloader/bootloader.bin 0x10000 example_app.bin_
--0x8000 partition_table_unit_test_app.bin
```
Chapter 4. API 指南

4.3.3 构建 Bootloader

引导程序默认作为 make all 的一部分被构建，或者也可以通过 make bootloader-clean 来单独构建，此外还可以通过 make bootloader-list-components 来查看构建引导程序时包含的组件。

引导程序是一个特殊的组件，因为主项目中的二级引导程序拥有单独的 EFL 和 BIN 文件。但是它与主项目共享配置和构建目录。

这是通过在 components/bootloader/subproject 下添加子项目来完成的。这个子项目有自己的 Makefile，但它希望通过 components/bootloader/Makefile.projectbuild 文件中的一些配置使其自己从主项目的 Makefile 被调用。有关详细信息，请参阅这些文件。

4.4 错误处理

4.4.1 概述

在应用程序开发中，及时发现并处理在运行时期的错误，对于保证程序的健壮性非常重要。常见的运行时错误有如下几种:

- 可恢复的错误：
  - 通过函数的返回值（错误码）表示的错误
  - 使用 throw 关键字抛出的 C++ 异常
- 不可恢复（严重）的错误：
  - 断言失败（使用 assert 宏或者其它类似方法）或者直接调用 abort() 函数造成的错误
  - CPU 异常：访问受保护的内存区域、非法指令等
  - 系统级检查：看门狗超时、缓存访问错误、堆栈溢出、堆栈粉碎、堆栈损坏等

本文将介绍 ESP-IDF 中针对可恢复错误的错误处理机制，并提供一些常见错误的处理模式。

关于如何处理不可恢复的错误，请查阅 不可恢复错误。

4.4.2 错误码

ESP-IDF 中大多数函数会返回 esp_err_t 类型的错误码，esp_err_t 实质上是带符号的整型，ESP_OK 代表成功（没有错误），具体值定义为 0。

在 ESP-IDF 中，许多头文件都会使用预处理器，定义可能出现的错误代码。这些错误代码通常均以 ESP_ERR_ 前缀开头，一些常见错误（比如内存不足、超时、无效参数等）的错误代码则已经在 esp_err.h 文件中定义好了。此外，ESP-IDF 中的各种组件 (component) 也都可以针对具体情况，自行定义更多错误代码。

完整错误代码列表，请见 错误代码参考 中查看完整的错误列表。

4.4.3 错误码到错误消息

错误代码并不直观，因此 ESP-IDF 还可以使用 esp_err_to_name() 或者 esp_err_to_name_r() 函数，将错误代码转换为具体的错误消息。例如，我们可以向 esp_err_to_name() 函数传递错误代码 0x101，可以得到返回字符串 “ESP_ERR_NO_MEM”。这样一来，我们可以在日志中输出更加直观的错误消息，而不是简单的错误码，从而帮助研究人员更快速理解发生了何种错误。

此外，如果出现找不到匹配的 ESP_ERR_ 值的情况，函数 esp_err_to_name_r() 则会尝试将错误码作为一种 标准 POSIX 错误代码 进行解释。具体过程为：POSIX 错误代码（例如 ENOENT, ENOMEM）定义在 errno.h 文件中，可以通过 errno 变量获得。进而调用 strerror_r 函数函数。在 ESP-IDF 中，errno 是一个基于线程的局部变量，即每个 FreeRTOS 任务都有自己的 errno 副本，通过函数修改 errno 也只会作用于当前任务中的 errno 变量值。

该功能（即在无法匹配 ESP_ERR_ 值时，尝试用标准 POSIX 解释错误码）默认启用。用户也可以禁用该功能，从而减小应用程序的二进制文件大小。详情可见 CONFIG_ESP_ERR_TO_NAME_LOOKUP。注意，该功能对禁用并不影响 esp_err_to_name() 和 esp_err_to_name_r() 函数的定义，用户仍可调用...
这两个函数用于将错误码转换为可读的错误信息。在无法匹配到对应错误码的情况下，`esp_err_to_name()` 函数会返回 `UNKNOWN ERROR`，而 `esp_err_to_name_r()` 函数会返回 `Unknown error 0xXXXX(YYYYY)`，其中 0xXXXX 和 YYYYY 分别代表错误代码的十六进制和十进制表示。

### 4.4.4 ESP_ERROR_CHECK 宏

宏 `ESP_ERROR_CHECK()` 的功能和 `assert` 类似，不同之处在于：这个宏会检查 `esp_err_t` 的值，并非判断 `bool` 条件。如果传给 `ESP_ERROR_CHECK()` 的参数不等于 `ESP_OK`，则会在控制台上打印错误消息，然后调用 `abort()` 函数。

错误消息通常如下所示：

```c
ESP_ERROR_CHECK failed: esp_err_t 0x107 (ESP_ERR_TIMEOUT) at 0x400d1fdf
```

- 第一行打印错误代码的十六进制表示，及该错误在源代码中的标识符。这个标识符取决于 `CONFIG_ESP_ERR_TO_NAME_LOOKUP` 选项的设定。最后，第一行还会打印程序中该错误发生的具体位置。
- 下面几行显示了程序中调用 `ESP_ERROR_CHECK()` 宏的具体位置，以及传递给该宏的参数。
- 最后一行打印错误结果。对于所有不可恢复错误，这里在应急处理程序中打印的内容都是一样的。更多有关回溯结果的详细信息，请参阅相关错误。

**注释**：如果使用 `IDF monitor`，则最后一行回溯结果中的地址将会被替换为相应的文件名和行号。

### 4.4.5 错误处理模式

1. 尝试恢复。根据具体情况不同，我们具体可以：
   - 在一段时间后，重新调用该函数；
   - 尝试删除该驱动，然后重新进行“初始化”；
   - 采用其他带外机制，修改导致错误发生的条件（例如，对一直没有响应的外设进行复位等）。

   示例：
   ```c
   esp_err_t err;
   do {
       err = sdio_slave_send_queue(addr, len, arg, timeout);
       // 如果发送队列已满则不断重试
   } while (err == ESP_ERR_TIMEOUT);
   if (err != ESP_OK) {
       // 处理其他错误
   }
   ```

2. 将错误传递回调用程序。在某些中间件组件中，采用此类处理模式代表函数必须以相同的错误码退出，这样才能确保所有分配的资源都能得到释放。

   示例：
   ```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) {
   ```

(下页继续)
3. 转为不可恢复错误，比如使用 ESP_ERROR_CHECK。详情请见 ESP_ERROR_CHECK 章节。
对于中间件组件而言，通常并不希望在发生错误时中止应用程序。不过，有时在应用程序级别，这种做法是可以接受的。在 ESP-IDF 的示例代码中，很多都会使用 ESP_ERROR_CHECK 来处理各种 API 引发的错误，虽然这不是应用程序的最佳做法，但可以让示例代码看起来更加简洁。
示例：
```
ESP_ERROR_CHECK(spi_bus_initialize(host, bus_config, dma_chan));
```

4.4.6 C++ 异常
默认情况下，ESP-IDF 会禁用对 C++ 异常的支持，但是可以通过 CONFIG_COMPILER_CXX_EXCEPTIONS 选项启用。

通常情况下，启用异常处理会让应用程序的二进制文件增加几 kB。此外，启用该功能时还需为异常事故池预留一定内存。当应用程序无法从堆中分配异常对象时，就可以使用这个池中的内存。该内存池的大小可以通过CONFIG_COMPILER_CXX_EXCEPTIONS_EMG_POOL_SIZE 来设定。

如果 C++ 程序抛出了异常，但是程序中并没有 catch 代码块来捕获该异常，那么程序的运行就会被 abort 函数中止，然后打印回溯信息。有关回溯的更多信息，请参阅不可恢复错误。

4.5 严重错误
4.5.1 概述
在某些情况下，程序并不会按照我们的预期运行。在 ESP-IDF 中，这些情况包括：
- CPU 异常：非法指令，加载/存储时的内存对齐错误，加载/存储时的访问权限错误，双重异常。
- 系统级检查错误：
  - 中断看门狗 超时
  - 任务看门狗 超时（只有开启 CONFIG_ESP_TASK_WDT_PANIC 后才会触发严重错误）
  - 高速缓存访问错误
  - 掉电检测事件
  - 堆栈溢出
  - Stack 粉碎保护检查
  - Heap 完整性检查
- 使用 assert, configASSERT 等类似的宏断言失败。

本指南会介绍 ESP-IDF 中这类错误的处理流程，并给出对应的解决建议。

4.5.2 紧急处理程序
概述 中列举的所有错误都会由 紧急处理程序 (Panic Handler) 负责处理。
紧急处理程序首先会将出错原因打印到控制台。例如 CPU 异常的错误信息通常会类似于：
```
Guru Meditation Error: Core 0 panic'ed (IllegalInstruction). Exception was unhandled.
```

对于一些系统级检查错误（如中断看门狗超时，高速缓存访问错误等），错误信息会类似于：
Guru Meditation Error: Core 0 panic'ed (Cache disabled but cached memory region... accessed)

不管何种情况，错误原因都会被打印在括号中。请参阅 Guru Meditation 错误 以查看所有的出错原因。

紧急处理程序接下来的行为将取决于 CONFIG_ESP_SYSTEM_PANIC 的设置，支持的选项包括：

- 打印 CPU 寄存器，然后重启 (CONFIG_ESP_SYSTEM_PANIC_PRINT_REBOOT) - 默认选项
- 打印系统发生异常时 CPU 寄存器的值，打印回溯，最后重启芯片。
- 打印 CPU 寄存器，然后暂停 (CONFIG_ESP_SYSTEM_PANIC_PRINT_HALT)
  与上一个选项类似，但不会重启，而是选择暂停程序的运行。重启程序需要外部执行复位操作。
- 静默重启 (CONFIG_ESP_SYSTEM_PANIC_SILENT_REBOOT)
  不打印 CPU 寄存器的值，也不打印回溯，立即重启芯片。
- 使用 GDB Stub (CONFIG_ESP_SYSTEM_PANIC_GDBSTUB)
  启动 GDB 服务器，通过控制台 UART 接口与 GDB 进行通信。详细信息请参阅 GDB Stub。

紧急处理程序的行为还受到另外两个配置项的影响：

- 如果 CONFIG_ESP32_DEBUG_OCDAWARE 被使能了 (默认)，紧急处理程序会检测 ESP32 是否已经连接 JTAG 调试器。如果检测成功，程序会暂停运行，并将控制权交给调试器。在这种情况下，寄存器和回溯不会被打印到控制台，并且也不会使用 GDB Stub 和 Core Dump 的功能。
- 如果 使 用 了 Core Dump 功能 (CONFIG_ESP_COREDUMP_ENABLE_TO_FLASH 或者 CONFIG_ESP_COREDUMP_ENABLE_TO_UART 选项)，系统状态 (任务堆栈和寄存器) 会被转储到 Flash 或者 UART 以供后续分析。

下图展示了紧急处理程序的行为：

### 4.5.3 寄存器转储与回溯

除非启用了 CONFIG_ESP_SYSTEM_PANIC_SILENT_REBOOT 否则紧急处理程序会将 CPU 寄存器和回溯打印到控制台。

<table>
<thead>
<tr>
<th>Core 0 register dump:</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC : 0x400e14ed PS : 0x00060030 A0 : 0x800d0805 A1 :...</td>
</tr>
<tr>
<td>~0x3ff5030 A2 : 0x00000000 A3 : 0x00000001 A4 : 0x00000001 A5 :...</td>
</tr>
<tr>
<td>~0x3ff50dc A6 : 0x00000000 A7 : 0x00000001 A8 : 0x00000000 A9 :...</td>
</tr>
<tr>
<td>~0x3ff5000 A10 : 0x00000000 A11 : 0x3ff50bac A12 : 0x40082d1c A13 :...</td>
</tr>
<tr>
<td>~0x06ff1ff8 A14 : 0x3ff7078 A15 : 0x00000000 SAR : 0x00000014 EXCCAUSE :...</td>
</tr>
<tr>
<td>~0x00000001d EXCVADDR : 0x00000000 LBEQ : 0x4000c46c LEND : 0x4000c477 LCOUNT :...</td>
</tr>
<tr>
<td>~0x00000000f Backtrace : 0x400e14ed :0x3ff5030 0x400d0802 :0x3ff5050</td>
</tr>
</tbody>
</table>

仅会打印异常帧中 CPU 寄存器的值，即引发 CPU 异常或者其它严重错误时刻的值。

紧急处理程序如果是因为 abort() 而调用，则不会打印寄存器转储。

在某些情况下，例如中断影响到 CPUs 时，紧急处理程序会额外打印 CPU 寄存器 (EPC1-EPC4) 的值，以及另一个 CPU 的寄存器值和代码回溯。

回溯行包含了当前任务中每个堆栈帧的 PC:SP 对 (PC 是程序计数器，SP 是堆栈指针)。如果在 ISR 中发生了严重错误，回溯会同时包括被中断任务的 PC:SP 对，以及 ISR 中的 PC:SP 对。

如果使用了 IDF 监视器，该工具会将程序计数器的值转换为对应的代码位置 (函数名，文件名，行号)，并加以注释。
图 1: 紧急处理程序流程图（点击放大）
若要查找发生严重错误的代码位置，请查看 “Backtrace” 的后面几行，发生严重错误的代码显示在顶行，后续几行显示的是调用堆栈。

### 4.5.4 GDB Stub

如果启用了 CONFIG_ESP_SYSTEM_PANIC_GDBSTUB 选项，在发生严重错误时，紧急处理程序不会复位芯片。相反，它将启动 GDB 远程协议服务器，通常称为 GDB Stub。发生这种情况时，可以让主机上运行的 GDB 实例通过 UART 端口连接到 ESP32。

如果使用了 IDF 监视器，该工具会在 UART 端口检测到 GDB Stub 提示符后自动启动 GDB，输出会类似于:

```
Entering gdb stub now.
$70b#e6GNU gdb (crosstool-NG crosstool-ng-1.22.0-80-gff1f415) 7.10
Copyright (C) 2015 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law. Type "show copying"
and "show warranty" for details.
This GDB was configured as "--host=x86_64-build_apple-darwin16.3.0 --target=xtensa-
.esp32-elf".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
Find the GDB manual and other documentation resources online at:
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from /Users/user/esp/example/build/example.elf...done.
Remote debugging using /dev/cu.usbserial-13101
0x400e6b41 in app_main ()
at /Users/user/esp/example/main/main.cpp:36
36 *( (int*) 0 ) = 0;
(gdb)
```

在 GDB 会话中，我们可以检查 CPU 寄存器，本地和静态变量以及内存中任意位置的值。但是不支持设置断点，改变 PC 值或者恢复程序的运行。若要复位程序，请退出 GDB 会话，在 IDF 监视器中连续输入 Ctrl-T Ctrl-R，或者按下开发板上的复位按键也可以重新运行程序。
4.5.5 **Guru Meditation** 错误

本节将对打印在 Guru Meditation Error: Core panic'ed 后面括号中的致错原因进行逐一解释。

** IllegalInstruction **

此 CPU 异常表示当前执行的指令不是有效指令，引起此错误的常见原因包括：

- FreeRTOS 中的任务函数已返回。在 FreeRTOS 中，如果想终止任务函数，需要调用 vTaskDelete() 函数释放当前任务的资源，而不是直接返回。
- 使用 SPI Flash 中加载一条指令，这通常发生在：
  - 应用程序将 SPI Flash 的引脚重新配置为其它功能（如 GPIO、UART 等等）。有关 SPI Flash 引脚的详细信息，请参阅硬件设计指南和芯片/模块的数据手册。
  - 某些外部设备意外连接到 SPI Flash 的引脚上，干扰了 ESP32 和 SPI Flash 之间的通信。

** InstrFetchProhibited **

此 CPU 异常表示 CPU 无法加载指令，因为指令的地址不在 IRAM 或者 IROM 中的有效区域内。

通常这意味着代码中调用了并不指向有效地址块的函数指针。这种情况下，可以查看 FC（程序计数器）寄存器的值并做进一步判断：若为 0 或其它非法值（即只要不是 0x4xxxxxxxx 的情况），则证实确实是该原因。

** LoadProhibited, StoreProhibited **

当应用程序尝试读取或写入无效的内存位置时，会发生此类 CPU 异常。此类无效内存地址可以在寄存器 EXCVADDR 中找到。如果该地址为零，通常意味着应用程序正尝试从一个 NULL 指针。如果该地址接近于零，则通常意味着应用程序试图访问某个结构体的成员，但是该结构体的指针为 NULL。如果该地址是其它非法值（不在 0x3fxxxxxx - 0x6xxxxxxx 的范围内），则可能意味着用于访问数据的指针未初始化或者已经损坏。

** IntegerDivideByZero **

应用程序尝试将整数除以零。

** LoadStoreAlignment **

应用程序尝试读取/写入的内存位置不符合加载/存储指令对字节对齐大小的要求。例如，32 位加载指令只能访问 4 字节对齐的内存地址，而 16 位加载指令只能访问 2 字节对齐的内存地址。

** LoadStoreError **

应用程序尝试从未支持 32 位加载/存储的内存区域执行 8 位或 16 位加载/存储操作，例如，解引用一个指向内存区域的 char* 指针就会导致这样的错误。
Chapter 4. API 指南

Unhandled debug exception

这后面通常会再跟一条消息:

Debug exception reason: Stack canary watchpoint triggered (task_name)

此错误表示应用程序写入的位置越过了 task_name 任务堆栈的末尾，请注意，并非每次堆栈溢出都会触发此错误。任务有可能会绕过堆栈金丝雀（stack canary）的位置访问堆栈，在这种情况下，监控点就不会被触发。

Interrupt wdt timeout on CPU0 / CPU1

这表示发生了中断看门狗超时，详细信息请查阅 看门狗 文档。

Cache disabled but cached memory region accessed

在某些情况下，ESP-IDF 会暂时禁止通过高速缓存访问外部 SPI Flash 和 SPI RAM，例如在使用 spi_flash API 读取/写入/擦除/映射 SPI Flash 的时候。在这些情况下，任务会被挂起，并且未使用 ESP_INTR_FLAG_IRAM 注册的中断处理程序会被禁用。请确保任何使用此标志注册的中断处理程序所访问的代码和数据分别位于 IRAM 和 DRAM 中。更多详细信息请参阅 SPI Flash API 文档。

4.5.6 其它严重错误

欠压

ESP32 内部集成掉电检测电路，并且会默认启用。如果电源电压低于安全值，掉电检测器可以触发系统复位。掉电检测器可以使用 CONFIG_ESP32_BROWNOUT_DET 和 CONFIG_ESP32_BROWNOUT_DET_LVL_SEL 这两个选项进行设置。

当掉电检测器被触发时，会打印如下信息:

Brownout detector was triggered

芯片会在该打印信息结束后复位。

请注意，如果电源电压快速下降，则只能在控制台上看到部分打印信息。

Heap 不完整

ESP-IDF 堆的实现包含许多运行时的堆结构检查，可以在 menuconfig 中开启额外的检查（“Heap Poisoning”）。如果其中的某项检查失败，则会打印类似如下信息:

CORRUPT HEAP: Bad tail at 0x3ffe270a. Expected 0xbaad5678 got 0xbaac5678
assertion "head != NULL" failed: file "../multi_heap_poisoning.c", line 201, function: multi_heap_free
abort() was called at PC 0x400dca43 on core 0

更多详细信息，请查阅 堆内存调试 文档。

Stack 粉碎

Stack 粉碎保护（基于 GCC -fstack-protector* 标志）可以通过 ESP-IDF 中的 CONFIG_COMPILER_STACK_CHECK_MODE 选项来开启。如果检测到 Stack 粉碎，则会打印类似如下的信息:
Chapter 4. API

Stack smashing protect failure!

abort() was called at PC 0x400d2138 on core 0

Backtrace: 0x4008e6c0:0x3ffc1780 0x4008e8b7:0x3ffc17a0 0x400d2138:0x3ffc17c0
→ 0x400e79d5:0x3ffc17e0 0x400e79a7:0x3ffc1840 0x400e79df:0x3ffc18a0
→ 0x400e2235:0x3ffc18c0 0x400e1916:0x3ffc18f0 0x400e19cd:0x3ffc1910
→ 0x400e1a11:0x3ffc1930 0x400e1bb2:0x3ffc1950 0x400d2c44:0x3ffc1a80

4.6 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.

4.6.1 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 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>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>wifi_event_sta_connected_t</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_DISCONNECTED (SYSTEM_EVENT_STA_DISCONNECTED)</td>
<td>wifi_event_sta_disconnected_t</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_AUTHMODE_CHANGE (SYSTEM_EVENT_STA_AUTHMODE_CHANGE)</td>
<td>wifi_event_sta_authmode_change_t</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_WPS_ER_SUCCESS (SYSTEM_EVENT_STA_WPS_ER_SUCCESS)</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_WPS_ER_FAILED (SYSTEM_EVENT_STA_WPS_ER_FAILED)</td>
<td>wifi_event_sta_wps_fail_reason_t</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_WPS_ER_TIMEOUT (SYSTEM_EVENT_STA_WPS_ER_TIMEOUT)</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_WPS_ER_PIN (SYSTEM_EVENT_STA_WPS_ER_PIN)</td>
<td>wifi_event_sta_wps_er_pin_t</td>
</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>wifi_event_ap_staconnected_t</td>
</tr>
<tr>
<td>WIFI_EVENT_AP_STADISCONNECTED (SYSTEM_EVENT_AP_STADISCONNECTED)</td>
<td>wifi_event_ap_stadisconnected_t</td>
</tr>
<tr>
<td>WIFI_EVENT_AP_PROBEREQRECVED (SYSTEM_EVENT_AP_PROBEREQRECVED)</td>
<td>wifi_event_ap_probe_req_rx_t</td>
</tr>
<tr>
<td>ETHERNET_EVENT_START (SYSTEM_EVENT_ETH_START)</td>
<td>n/a</td>
</tr>
<tr>
<td>ETHERNET_EVENT_STOP (SYSTEM_EVENT_ETH_STOP)</td>
<td>n/a</td>
</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>
<td>n/a</td>
</tr>
<tr>
<td>IP_EVENT_STA_GOT_IP (SYSTEM_EVENT_STA_GOT_IP)</td>
<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>
<tr>
<td>IP_EVENT_GOT_IP6 (SYSTEM_EVENT_GOT_IP6)</td>
<td>ip_event_got_ip6_t</td>
</tr>
<tr>
<td>IP_EVENT_ETH_GOT_IP (SYSTEM_EVENT_ETH_GOT_IP)</td>
<td>ip_event_got_ip_t</td>
</tr>
</tbody>
</table>

**4.6.2 Mesh Events**

ESP-MESH uses a system similar to the *Legacy Event Loop* to deliver events to the application. See 系统事件 for details.
### 4.6.3 Bluetooth Events

Various modules of the Bluetooth stack deliver events to applications via dedicated callback functions. Callback functions receive the event type (enumerated value) and event data (union of structures for each event type). The following list gives the registration API name, event enumeration type, and event parameter types.

- **BLE GAP**: esp_ble_gap_register_callback(), esp_gap_ble_cb_event_t, esp_ble_gap_cb_param_t.
- **BT GAP**: esp_bt_gap_register_callback(), esp_bt_gap_cb_event_t, esp_BT_gap_cb_param_t.
- **GATT**: esp_ble_gattc_register_callback(), esp_gattc_cb_event_t, esp_ble_gattc_cb_param_t.
- **GATTS**: esp_ble_gatts_register_callback(), esp_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.

### 4.7 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.

#### 4.7.1 Rules for Wake Stubs

Wake stub code must be carefully written:

- As the SoC has freshly woken from sleep, most of the peripherals are in reset states. The SPI flash is unmapped.
- The wake stub code can only call functions implemented in ROM or loaded into RTC Fast Memory (see below.)
- The wake stub code can only access data loaded in RTC memory. All other RAM will be uninitialised and have random contents. The wake stub can use other RAM for temporary storage, but the contents will be overwritten when the SoC goes back to sleep or starts ESP-IDF.
- RTC memory must include any read-only data (.rodata) used by the stub.
- Data in RTC memory is initialised whenever the SoC restarts, except when waking from deep sleep. When waking from deep sleep, the values which were present before going to sleep are kept.
- Wake stub code is a part of the main esp-idf app. During normal running of esp-idf, functions can call the wake stub functions or access RTC memory. It is as if these were regular parts of the app.

#### 4.7.2 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.

### 4.7.3 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.

### 4.7.4 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);
}
```

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*.

### 4.8 Core Dump

#### 4.8.1 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

#### 4.8.2 Configuration

There are a number of core dump related configuration options which user can choose in project configuration menu (`idf.py menuconfig`).

1. 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)

2. 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. It also stores SHA256 of crashed application image. 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.

3. Maximum number of taskssnapshots in core dump (`Components -> Core dump -> Maximum number of tasks`).
4. Delay before core dump is printed to UART (`Components -> Core dump -> Delay before print to UART`). Value is in ms.
5. Type of data integrity check for core dump (`Components -> Core dump -> Core dump data integrity check`).
   - Use CRC32 for core dump integrity verification
   - Use SHA256 for core dump integrity verification

The SHA256 hash algorithm provides greater probability of detecting corruption than a CRC32 with multiple bit errors. The CRC32 option provides better calculation performance and consumes less memory for storage.
4.8.3 Save core dump to flash

When this option is selected core dumps are saved to special partition on flash. When using default partition table files which are provided with ESP-IDF it automatically allocates necessary space on flash. But if user wants to use its own layout file together with core dump feature it should define separate partition for core dump as it is shown below:

```
# Name, Type, SubType, Offset, Size
# Note: if you have increased the bootloader size, make sure to update the offsets...
 nvs, data, nvs, 0x9000, 0x6000
phy_init, data, phy, 0xf000, 0x1000
factory, app, factory, 0x10000, 1M
coredump, data, coredump,, 64K
```

There are no special requirements for partition name. It can be choosen 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>`

4.8.4 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 info_corefile -t b64 -c </path/to/saved/base64/text> </path/to/program/elf/file>` or `espcoredump.py 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.

4.8.5 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`.

4.8.6 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

Example

1. In Project Configuration Menu, enable COREDUMP TO FLASH, then save and exit.
2. In your project, create a global variable in DRAM area as such as:

```c
// uint8_t global_var;
COREDUMP_DRAM_ATTR uint8_t global_var;
```

3. In main application, set the variable to any value and `assert(0)` to cause a crash.

```c
global_var = 25;
assert(0);
```

4. Build, flash and run the application on a target device and wait for the dumping information.

5. Run the command below to start core dumping in GDB, where `PORT` is the device USB port:

```bash
espcoredump.py -p PORT dbg_corefile <path/to/elf>
```

6. In GDB shell, type `p global_var` to get the variable content:

```gdb
(gdb) p global_var
$1 = 25 '\031'
```

### 4.8.7 Running ‘espcoredump.py’

Generic command syntax:

```
espcoredump.py [options] command [args]
```

**Script Options**
- `-port,-p PORT`. Serial port device.
- `-baud,-b BAUD`. Serial port baud rate used when flashing/reading.

**Commands**
- `info_corefile`. Retrieve core dump and print useful info.
- `dbg_corefile`. Retrieve core dump and start GDB session with it.

**Command Arguments**
- `-debug,-d DEBUG`. Log level (0..3).
- `-gdb,-g GDB`. Path to gdb to use for data retrieval.
- `-core,-c CORE`. Path to core dump file to use (if skipped core dump will be read from flash).
- `-core-format,-t CORE_FORMAT`. Specifies that file passed with “-c” is an ELF (“elf”), dumped raw binary (“raw”) or base64-encoded (“b64”) format.
- `-off,-o OFF`. Offset of coredump partition in flash (type `idf.py partition_table` to see it).
- `-save-core,-s SAVE_CORE`. Save core to file. Otherwise temporary core file will be deleted. Ignored with “-c”.
- `-rom-elf,-r ROM_ELF`. Path to ROM ELF file to use (if skipped “esp32_rom.elf” is used).
- `-print-mem,-m Print memory dump. Used only with “info_corefile”.
- `<prog>` Path to program ELF file.

### 4.9 Flash 加密

本文档将介绍 ESP32 的 Flash 加密功能，并通过示例展示用户如何在开发及生产过程中使用此功能。本文档旨在引导用户快速入门如何测试及验证 Flash 加密的相关操作。有关 Flash 加密块的详细信息可参见 ESP32 技术参考手册。

#### 4.9.1 概述

Flash 加密功能用于加密与 ESP32 搭载使用的 SPI Flash 中的内容。启用 Flash 加密功能后，物理读取 SPI Flash 便无法恢复大部分 Flash 内容。通过明文数据烧录 ESP32 可应用加密功能。若已启用加密功能，引导加载程序会在首次启动时对数据进行加密。
启用 Flash 加密后，系统将默认加密下列类型的 Flash 数据：

- 引导加载程序
- 分区表
- 所有“app”类型的分区

其他类型的 Flash 数据将视情况进行加密：

- 安全启动引导加载程序摘要（如果已启用安全启动）
- 分区表中标有“加密”标记的分区

**重要**：启用 Flash 加密将限制后续 ESP32 更新。请务必阅读本文档（包括 Flash 加密的局限性）了解启用 Flash 加密的影响。

### 4.9.2 Flash 加密过程中使用的 eFuse

Flash 加密操作由 ESP32 上的多个 eFuse 控制。以下是这些 eFuse 列表及其描述：

<table>
<thead>
<tr>
<th>eFuse</th>
<th>描述</th>
<th>是否可锁定为</th>
<th>读取/写入</th>
</tr>
</thead>
<tbody>
<tr>
<td>故障方</td>
<td>默认</td>
<td>是</td>
<td>-</td>
</tr>
<tr>
<td>故障方</td>
<td>= 值</td>
<td>损</td>
<td>-</td>
</tr>
</tbody>
</table>

- **编码方案**
  - 该 2 位宽 eFuse 控制 BLOCK1 中使用的实际位数，从而获得最终的 256 位 AES 密钥。编码方案值解码如下：
    - 0: 256 bits
    - 1: 192 bits
    - 2: 128 bits
  - 最终的 AES 密钥根据 FLASH_CRYPT_CONFIG 的值产生。

- **BLOCK1**
  - 存储 AES 密钥的 256 位宽 eFuse 块

- **FLASH_CRYPT_CONFIG**
  - 4 位宽 eFuse，控制 AES 加密进程

- **download_dis_encrypt**
  - 设置后，在 UART 下载模式运行时关闭 Flash 加密操作

- **download_dis_decrypt**
  - 设置后，在 UART 下载模式运行时关闭 Flash 解密操作

- **FLASH_CRYPT_CNT**
  - 7 位 eFuse，在启动时启用/关闭加密功能

- 偶数位（0, 2, 4, 6）: 启动时加密 Flash
- 奇数位（1, 3, 5, 7）: 启动时不加密 Flash

对上述位的读写访问由 efuse_wr_disable 和 efuse_rd_disable 寄存器中的相应位控制。有关 ESP32 eFuse 的详细信息可参见 eFuse 管理器。
4.9.3 Flash 的加密过程

假设 eFuse 值处于默认状态，且第二阶段的引导加载程序编译为支持 Flash 加密，则 Flash 加密过程执行如下:

- 首次上电复位时，Flash 中的所有数据都是未加密形式（明文数据）。第一阶段加载器 (Rom) 将在 IRAM 中加载第二阶段加载器。
- 第二阶段引导加载程序将读取 flash_crypt_cnt (=00000000b) eFuse 值，因为该值为 0（偶数位），第二阶段引导加载程序将配置并启用 Flash 加密，同时将 FLASH_CRYPT_CFG eFuse 的值编程为 0xF。
- Flash 加密块将生成 AES-256 位密钥，并将其储存在 BLOCK1 eFuse 中。该操作在硬件中执行，软件将无法访问此密钥。
- 接着，Flash 加密块将加密 Flash 的内容（根据分区表的标记值）。原地加密可能会有耗时（取决于大分区的耗时）。
- 随后，第二阶段引导加载程序将在 flash_crypt_cnt (=00000001b) 中设置第一个可用位，从而标记加密的 Flash 内容（偶数位）。
- 在释放模式下，第二阶段引导加载程序将把 download_dis_encrypt、download_dis_decrypt 和 download_dis_cache 的 eFuse 位改写为 1，防止 UART 引导加载程序解密 Flash 的内容。同时也会写保护 FLASH_CRYPT_CNT 的 eFuse 位。
- 在开发模式下，第二阶段引导加载程序将仅改写 download_decrypt 和 download_dis_cache 的 eFuse 位，从而允许 UART 引导加载程序重新烧录加密的二进制文件。同时将不会写保护 FLASH_CRYPT_CNT 的 eFuse 位。
- 然后，第二阶段引导加载程序重启设备并开始执行加密映像，同时将透明解密 Flash 的内容并将其加载至 IRAM。

在开发阶段常需要编写不同的明文 Flash 映像，以及测试 Flash 的加密过程。这要求 UART 下载模式能够根据需求不断加载新的明文映像。但是，在量产和生产过程中，出于安全考虑，UART 下载模式不应当有权限访问 Flash 内容。因此需要有两种不同的 ESP32 配置：一种用于测试，另一种用于生产。以下章节介绍了 Flash 加密的开发模式和释放模式及其使用指南。

重要：顾名思义，开发模式仅在开发过程使用，因为该模式可以修改和回读加密的 Flash 内容。

4.9.4 设置 Flash 加密的步骤

开发模式

可使用 ESP32 内部生成的密钥或外部主机生成的密钥在开发中运行 Flash 加密。

使用 ESP32 生成的 Flash 加密密钥

正如上文所说，开发模式允许用户使用 UART 下载模式多次下载明文映像。需完成以下步骤测试 Flash 加密过程:

- 确保您的 ESP32 设备有 Flash 加密过程中使用的 eFuse 中所示的 Flash 加密 eFuse 的默认设置。
- 可在 $IDF_PATH/examples/security/flash_encryption 文件夹中找到 Flash 加密的示例应用程序。该示例应用程序中显示 Flash 加密的状态（开启或关闭）以及 FLASH_CRYPT_CNT eFuse 值。
- 在第二阶段引导加载程序中启用 Flash 加密支持。请前往 Project Configuration Menu，选择 “Security Features”。
- 选择 Enable flash encryption on boot。
- 默认设置模式为 开发模式。
- 在引导加载程序 config 下选择适当详细程度的日志。
- 保存配置并退出。

构建并烧录完整的映像包括：引导加载程序，分区表和 app。这些分区最初以未加密形式写入 Flash。
一旦烧录完成，设备将复位。在下次启动时，第二阶段引导加载程序将加密 Flash 的 app 分区，然后重置该分区。现在，示例应用程序将在运行时解密并执行命令。以下是首次启用 Flash 加密后 ESP32 启动时的样例输出。

```bash
--- idf_monitor on /dev/cu.SLAB_USBtoUART 115200 ---
--- Quit: Ctrl+] | Menu: Ctrl+T | Help: Ctrl+T followed by Ctrl+H ---

rst:0x1 (POWERON_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configspi: 0, SPIWP:0xee
clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:2
load:0x3fff0018,len:4
load:0x3fff001c,len:8452
load:0x40078000,len:13608
load:0x40080400,len:6664
entry 0x40080764
I (28) boot: ESP-IDF v4.0-dev-850-gc4447462-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 00001000
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=0x01e4 (7844) load
I (109) esp_image: segment 2: paddr=0x00029f60 vaddr=0x40080000...
→size=0x00400 (1024) load
0x40080000: _WindowOverflow4 at esp-idf/esp-idf/components/freertos/
→xtensa_vectors.S:1778
I (114) esp_image: segment 3: paddr=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:4561
I (168) boot: Loaded app from partition at offset 0x200000
I (168) boot: Checking flash encryption...
I (168) flash_encrypt: Generating new flash encryption key...
I (187) flash_encrypt: Read & write protecting new key...
I (187) flash_encrypt: Setting 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)
```

启用Flash加密后，在下次启动时输出将显示已启用Flash加密。
在此阶段，如果用户希望以加密格式将已修改的明文应用程序映像更新到Flash中，可使用以下命令：

```
idf.py encrypted-app-flash monitor
```

### 加密多重分区

如果所有分区都需以加密格式更新，则可使用以下命令：

```
idf.py encrypted-flash monitor
```
使用主机生成的 Flash 加密密钥

可在主机中自动生成 Flash 加密密钥，并将其烧录到 ESP32 的 eFuse 密钥块中。这样，无需明文 Flash 更新便可以在主机上预加密数据并将其烧录到 ESP32 中。该功能允许在开发模式和释放模式 modes 两模式下加密烧录。

- 确保您的 ESP32 设备有 Flash 加密过程中使用的 eFuse 中所示 Flash 加密 eFuse 的默认设置。
- 使用 espsecure.py 随机生成一个密钥:

```python
espsecure.py generate_flash_encryption_key my_flash_encryption_key.bin
```

- 将该密钥烧录到设备上（一次性）。该步骤须在第一次加密启动前完成，否则 ESP32 将随机生成一个软件无权限访问或修改的密钥:

```python
espefuse.py --port PORT burn_key flash_encryption my_flash_encryption_key.bin
```

- 在第二阶段引导加载程序中启用 Flash 加密支持。请前往 Project Configuration Menu，选择“Security Features”。
- 选择 Enable flash encryption on boot。
- 模式默认设置为 开发模式。
- 在引导加载程序 config 下选择适当详细程度的日志。
- 保存配置并退出。

构建并烧录完整的映像包括：引导加载程序、分区表和 app。这些分区最初以未加密形式写入 Flash

```
idf.py flash monitor
```

下次启动时，第二阶段引导加载程序将加密 Flash 的 app 分区并重置该分区。现在，示例应用程序将在运行时解密并执行命令。

在此阶段，如果用户希望将新的明文应用程序映像更新到 Flash，应调用以下命令

```
idf.py encrypted-app-flash monitor
```

如何以加密格式重新编程所有分区，可参考 加密多重分区。

释放模式

在释放模式下，UART 引导加载程序无法执行 Flash 加密操作，只能使用 OTA 方案下载新的明文映像，该方案将在写入 Flash 前加密明文映像。

- 确保您的 ESP32 设备有 Flash 加密过程中使用的 eFuse 中所示 Flash 加密 eFuse 的默认设置。
- 在第二阶段引导加载程序中启用 Flash 加密支持。请前往 Project Configuration Menu，选择“Security Features”。
- 选择 Enable flash encryption on boot。
- 选择 释放模式，模式默认设置为 开发模式。请注意，一旦选择了释放模式，download_dis_encrypt 为 download_dis_decrypt eFuse 位将被编程为禁止 UART 引导加载程序访问 Flash 的内容。
- 在引导加载程序 config 下选择适当详细程度的日志。
- 保存配置并退出。

构建并烧录完整的映像包括：引导加载程序、分区表和 app。这些分区最初以未加密形式写入 Flash

```
idf.py flash monitor
```

下次启动时，第二阶段引导加载程序将加密 Flash app 分区并重置该分区。现在，示例应用程序应正确执行命令。

一旦在释放模式下启用 Flash 加密，引导加载程序将写保护 FLASH_CRYPT_CNT eFuse。

应使用 OTA 方案对字段中的明文进行后续更新。详情可参见 OTA。
可能存在错误

启用Flash加密后，如果FLASH_CRYPT_CNT eFuse值中有奇数位，则所有（标有加密标志的）分区都应包含加密密文。以下为ESP32加载明文数据产生的三种典型错误情况:

1. 如果通过明文引导加载程序映像重新更新了引导加载程序分区，则ROM加载器将无法加载引导加载程序，并会显示以下错误类型:

   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

2. 如果引导加载程序已加密，但使用明文分区表映像更新了分区表，则引导加载程序将无法读取分区表，并会显示以下错误类型:

   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
   load:0x3fff001c, len:10464
   ho 0 tail 12 room 4
   load:0x40078000, len:19168
   load:0x40080400, len:6664
   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...
   I (67) boot: SPI Speed : 40MHz
   I (72) boot: SPI Mode : DIO
   I (76) boot: SPI Flash Size : 4MB
   E (80) flash_parts: partition 0 invalid magic number 0x94f6
   E (86) boot: Failed to verify partition table
   E (91) boot: load partition table error!

3. 如果引导加载程序和分区表已加密，但使用明文应用程序映像重新更新了应用程序，则引导加载程序将无法加载新的应用程序，并会显示以下错误类型:

   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
   (下页继续)
4.9.5 Flash 加密的优点

- 使用 AES-256 加密 Flash 的内容。Flash 加密密钥存储于 eFuse 内部的芯片中，并（默认）受保护防止软件访问。
- flash 加密算法采用的是 AES-256，其中密钥随着 Flash 的每个 32 字节块的偏移地址“调整”。这意味着，每个 32 字节块（2 个连续的 16 字节 AES 块）使用从 Flash 加密密钥中产生的一个特殊密钥进行加密。
- 通过 ESP32 的 Flash 缓存映射功能，Flash 可支持透明访问——读取任一映射到地址空间的 Flash 区域时，都将透明解密该区域。
- 为便于访问，某些数据分区最好保持未加密状态，或者也可使用对已加密数据无效的 Flash 友好型更新算法。由于 NVS 库无法与 Flash 加密直接兼容，因此无法加密非易失性存储区的 NVS 分区。详情可参见NVS 加密。
- 如果可能已启用 Flash 加密，则编写使用加密 flash 的代码时，编程人员须小心谨慎。
- 如果已启用安全启动，则重新烧录加密设备的引导加载程序则需要“可重新烧录”的安全启动摘要（可参见Flash 加密与安全启动）。

重要：在首次启动加密过程中，请勿中断 ESP32 的电源。如果电源中断，Flash 的内容将受到破坏，并需要重新烧录来加密数据。而这类重新烧录将不计入烧录限制次数。

4.9.6 使用加密的 Flash

ESP32 app 代码可通过调用函数 esp_flash_encryption_enabled() 来确认当前是否已启用 Flash 加密。同时，设备可通过调用函数 esp_get_flash_encryption_mode() 来识别使用的 Flash 加密模式。启用 Flash 加密后，使用代码访问 Flash 内容时需加注意。

Flash 加密的范围

只要 FLASH_CRYPT_CNT eFuse 设置为奇数位的值，所有通过 MMU 的 Flash 缓存访问的 Flash 内容都将被透明解密。包括：
Chapter 4. API 指南

- Flash 中可执行的应用程序代码 (IROM)。
- 所有存储于 Flash 中的只读数据 (DROM)。
- 通过函数 `spi_flash_mmap()` 访问的任意数据。
- ROM 引导加载程序读取的软件引导加载程序映像。

重要：MMU Flash 缓存将无条件解密所有数据。Flash 中未加密存储的数据将通过 Flash 缓存“被透明解密”，并在软件中存储为随机垃圾数据。

### 读取加密的 Flash

如果在不使用 Flash 缓存 MMU 映射的情况下读取数据，推荐使用分区读取函数 `esp_partition_read()`，使用该函数时，只有从加密分区读取的数据才会被解密。其他分区的数据将以未加密形式读取。这样，软件便能同样访问加密和未加密的 Flash。

通过其他 SPI 读取 API 读取的数据均未解密：
- 通过函数 `spi_flash_read()` 读取的数据均未解密。
- 通过 ROM 函数 SPIRead() 读取的数据均未解密 (esp-idf app 不支持该函数)。
- 使用非易失性存储器 (NVS) API 存储的数据始终从 Flash 加密的角度进行存储和读取解密。如有需要，则由库提供加密功能。详情可参见 NVS 加密。

### 写入加密的 Flash

在可能的情况下，推荐使用分区写入函数 `esp_partition_write`。使用该函数时，只有向加密分区写入的数据才会被加密。而写入其他分区的数据均未加密。这样，软件便可同样访问加密和未加密的 Flash。

当 `write_encrypted` 参数设置为“是”时，函数 `esp_spi_flash_write` 将写入数据。否则，数据将以未加密形式写入。

ROM 函数 `esp_rom_spiflash_write_encrypted` 将在 Flash 中写入加密数据，而 ROM 函数 SPIWrite 将在 Flash 中写入未加密数据（esp-idf app 不支持上述函数）。

由于数据均采用块加密方式，加密数据最小的写入大小为 16 字节（16 字节对齐）。

### 4.9.7 更新加密的 Flash

#### OTA 更新

只要使用了函数 `esp_partition_write`，则加密分区的 OTA 更新将自动以加密形式写入。

#### 4.9.8 关闭 Flash 加密

若因某些原因意外启用了 Flash 加密，则接下来烧录固件数据时将使 ESP32 软件 (设备不断重启，并报错 `flash read err, 1000`)。

可通过写入 `FLASH_CRYPT_CNT` eFuse 再次关闭 Flash 加密 (仅适用于开发模式下)：

- 首先，前往 Project Configuration Menu，在“安全性能”目录下关闭启用 Flash 加密启动。
- 退出 menuconfig 并保存最新配置。
- 再次运行 `idf.py menuconfig` 并复核是否确认已关闭该选项！如果该选项仍处于已启用状态，则引导加载程序会在启动后立即重新启用加密。
- 在未启用 Flash 加密的状态下，运行 `idf.py flash` 构建并烧录新的引导加载程序与 `app`。
- 运行 `espefuse.py`（components/esptool_py/esptool 中）以关闭 `FLASH_CRYPT_CNT`：

```
espefuse.py burn_efuse FLASH_CRYPT_CNT
```

重置 ESP32，Flash 加密应处于关闭状态，引导加载程序将正常启动。
4.9.9 Flash 加密的局限性

Flash 加密可防止从加密 Flash 中读取明文，从而保护固件防止未经授权的读取与修改。了解 Flash 加密系统的局限之处亦十分重要:

- Flash 加密功能与密钥同样稳固。因而，推荐您首先启动设备时在设备上生成密钥（默认行为）。如果在设备外生成密钥，请确保遵循正确的后续步骤。
- 并非所有数据都是加密存储。因而在 Flash 上存储数据时，请检查您使用的存储方式（库、API 等）是否支持 Flash 加密。
- Flash 加密无法防止攻击者获取 Flash 的高层次布局信息。这是因为同一 AES 密钥要用于每对相邻的 16 字节 AES 块。当这些相邻的 16 字节块中包含相同内容时（如空白或填充区域）。这些字节块将加密以产生匹配的加密块对。这可能使得攻击者可在加密设备中进行高层次对比（例如，确认两设备是否可能在运行相同的固件版本）。
- 出于相同原因，攻击者始终可获取一对相邻的 16 字节块（32 字节对齐）时包含相同内容。因此，在 Flash 上存储敏感数据时应牢记这点，并进行相关设置避免该情况发生（可使用计数器字节或每 16 字节设置不同的值即可）。

4.9.10 Flash 加密与安全启动

推荐搭配使用 Flash 加密与安全启动。但是，如果已启用安全启动，则重新烧录设备时会受到其他限制:

- OTA 更新不受限制（如果新的 app 已使用安全启动签名密钥进行正确签名）。

4.9.11 使用无安全启动的 Flash 加密

尽管 Flash 加密与安全启动可独立使用，但强烈建议您将这二者 搭配使用 以确保更高的安全性。

4.9.12 Flash 加密的高级功能

以下信息可帮助您使用 Flash 加密的高级功能:

加密分区标志

部分分区默认为已加密。除此之外，可将任意分区标记为需加密:

在 分区表 文档对 CSV 文件的描述中有标志字段。

该字段通常保留为空白。如果在字段中写入“encrypted”，则该分区将在分区表中标记为已加密，此处写入的数据也视为加密数据（app 分区同样适用）:

<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>

- 默认分区表都不包含任何加密数据分区。
- “app” 分区一般都视为加密分区，因此无需将其标记为已加密。
- 如果未启用 Flash 加密，则“encrypted”标记无效。
- 可将带有 phy_init 数据的可选 phy 分区标记为已加密，保护该数据防止物理访问读取或修改。
- nvs 分区无法标记为已加密。

启用 UART 引导加载程序加密/解密

默认情况下，首次启动 Flash 加密过程中将烧录 eFuse DISABLE_DL_ENCRYPT、DISABLE_DL_DECRYPT 和 DISABLE_DL_CACHE:
Chapter 4. API 指南

• DISABLE_DL_ENCRYPT 在 UART 引导加载程序启动模式下运行时，终止 Flash 加密操作。
• DISABLE_DL_DECRYPT 在 UART 引导加载程序模式下运行时，终止透明 Flash 解密。（即使 FLASH_CRYPTO_CNT 已设置为在正常操作中启用 Flash 透明解密）。
• DISABLE_DL_CACHE 在 UART 引导加载程序模式下运行时终止整个 MMU flash 缓存。

为了完整保存数据，可在首次启动前仅烧录部分 eFuse，并写保护其他部分（未设置值为 0）。例如:

```
esefuse.py --port PORT burn_efuse DISABLE_DL_ENCRYPT
esefuse.py --port PORT write_protect_efuse DISABLE_DL_ENCRYPT
```

（请注意，一个写保护位即可关闭这 3 个 eFuse，因此，写保护一个 eFuse 将写保护上述所有 eFuse。所以，在写保护前须设置任意位）。

**重要：** 由于 esptool.py 不支持读取加密的 Flash，因此目前基本无法通过写保护这些 eFuse 来将其保持为未设状态。

**重要：** 如果保留 DISABLE_DL_DECRYPT 未设置（为 0），则实际上将使 Flash 加密无效，因为此时有物理访问权限的攻击者便可使用 UART 引导加载程序模式（使用自定义存根代码）读取 Flash 的内容。

### 设置 FLASH_CRYPTO_CONFIG

FLASH_CRYPTO_CONFIG eFuse 决定 Flash 加密密钥中随机偏移“调整”的位数。详情可参见Flash 加密算法。

首次启动引导加载程序时，该值始终设置为最大 0xF。

可手动写入这些 eFuse，并在首次启动前对其写保护，以便选择不同的调整值，但不推荐该操作。

当 FLASH_CRYPTO_CONFIG 的值为 0 时，强烈建议始终不对其进行写保护。如果该 eFuse 设置为 0，则 Flash 加密密钥中无调整位，且 Flash 加密算法相当与 AES ECB 模式。

#### 4.9.13 技术细节

下节将提供 Flash 加密操作的相关信息。

**Flash 加密算法**

- AES-256 在 16 字节的数据块上运行。Flash 加密引擎在 32 字节的数据块和 2 个串行 AES 块上加密或解密数据。
- Flash 加密的主密钥存储于 eFuse (BLOCK1) 中，默认受保护防止进一步写入或软件读取。
- AES-256 密钥大小为 256 位 (32 字节)。从 eFuse block 1 中读取。硬件 AES 引擎使用反字节序密钥于 eFuse 块中存储的字节序。
  - 如果 CODING_SCHEME eFuse 设置为 0（默认“无”编码方案），则 eFuse 密钥块为 256 位，且密钥按原方式存储 (反字节序)。
  - 如果 CODING_SCHEME eFuse 设置为 1 (3/4 编码)，则 eFuse 密钥块为 192 位 (反字节序)，信息熵总量减少。硬件 Flash 加密仍在 256 字节密钥上运行，在读取后 (字节序未反向)，密钥扩展为 key = key[0:255] + key[64:127]。
- Flash 加密使用了逆向 AES 算法，因此 Flash 加密的“加密”操作相当于 AES 加密，而其“解密”操作则相当于 AES 解密，这是为了优化性能，不会影响算法的有效性。
- 每个 32 字节块 (2 个相邻的 16 字节 AES 块) 都由一个特殊的密钥进行加密。该密钥由 eFuse 中 Flash 加密的主密钥产生，并随 Flash 中该字节块的偏移进行 XOR 运算 (一次“密钥调整”)。
- 具体调整量取决于 FLASH_CRYPTO_CONFIG eFuse 的设置。该 eFuse 共 4 位，每位对特定范围的密钥位进行 XOR 运算：
  - Bit 1，对密钥的 0-66 位进行 XOR 运算。
  - Bit 2，对密钥的 67-131 位进行 XOR 运算。
Chapter 4. API

```
– Bit 3, 对密钥的 132-194 位进行 XOR 运算。
– Bit 4, 对密钥的 195-256 位进行 XOR 运算。
建议将 FLASH_CRYPT_CONFIG 的值始终保留为默认值 0xF，这样所有密钥位都随块偏移进行 XOR 运算。详情可参见设置 Flash 加密密钥的 256 位有一个特殊的选择，用于决定与哪个位置进行 XOR 运算。有关详细映射可参见 espsecure.py 源代码中的变量

```

4.10 ESP-IDF FreeRTOS SMP Changes

4.10.1 Overview

The ESP-IDF FreeRTOS is a modified version of vanilla FreeRTOS which supports symmetric multiprocessing (SMP). ESP-IDF FreeRTOS is based on the Xtena port of FreeRTOS v8.2.0. This guide outlines the major differences between vanilla FreeRTOS and ESP-IDF FreeRTOS. The API reference for vanilla FreeRTOS can be found via https://www.freertos.org/a00106.html

For information regarding features that are exclusive to ESP-IDF FreeRTOS, see ESP-IDF FreeRTOS Additions.

Thread Local Storage Pointers & Deletion Callbacks: Deletion callbacks are called automatically during task deletion and are used to free memory pointed to by TLSP. Call vTaskSetThreadLocalStoragePointerAndDelCallback() to set TLSP and Deletion Callbacks.

Configuring ESP-IDF FreeRTOS: Several aspects of ESP-IDF FreeRTOS can be set in the project configuration (idf.py menuconfig) such as running ESP-IDF in Unicore (single core) Mode, or configuring the number of Thread Local Storage Pointers each task will have.

4.10.2 Tasks and Task Creation

Tasks in ESP-IDF FreeRTOS are designed to run on a particular core, therefore two new task creation functions have been added to ESP-IDF FreeRTOS by appending PinnedToCore to the names of the task creation functions in vanilla FreeRTOS. The vanilla FreeRTOS functions of xTaskCreate() and xTaskCreateStatic() have led to the addition of xTaskCreatePinnedToCore() and xTaskCreateStaticPinnedToCore() in ESP-IDF FreeRTOS

For more details see freertos/tasks.c

The ESP-IDF FreeRTOS task creation functions are nearly identical to their vanilla counterparts with the exception of the extra parameter known as xCoreID. This parameter specifies the core on which the task should run on and can be one of the following values.

• 0 pins the task to PRO_CPU
• 1 pins the task to APP_CPU
• tskNO_AFFINITY allows the task to be run on both CPUs

For example xTaskCreatePinnedToCore(tsk_callback, “APP_CPU Task”, 1000, NULL, 10, NULL, 1) creates a task of priority 10 that is pinned to APP_CPU with a stack size of 1000 bytes. It should be noted that the uxStackDepth parameter in vanilla FreeRTOS specifies a task’s stack depth in terms of the number of words, whereas ESP-IDF FreeRTOS specifies the stack depth in terms of bytes.

Note that the vanilla FreeRTOS functions xTaskCreate() and xTaskCreateStatic() have been defined in ESP-IDF FreeRTOS as inline functions which call xTaskCreatePinnedToCore() and xTaskCreateStaticPinnedToCore() respectively with tskNO_AFFINITY as the xCoreID value.
Each Task Control Block (TCB) in ESP-IDF stores the xCoreID as a member. Hence when each core calls the scheduler to select a task to run, the xCoreID member will allow the scheduler to determine if a given task is permitted to run on the core that called it.

### 4.10.3 Scheduling

The vanilla FreeRTOS implements scheduling in the vTaskSwitchContext() function. This function is responsible for selecting the highest priority task to run from a list of tasks in the Ready state known as the Ready Tasks List (described in the next section). In ESP-IDF FreeRTOS, each core will call vTaskSwitchContext() independently to select a task to run from the Ready Tasks List which is shared between both cores. There are several differences in scheduling behavior between vanilla and ESP-IDF FreeRTOS such as differences in Round Robin scheduling, scheduler suspension, and tick interrupt synchronicity.

#### Round Robin Scheduling

Given multiple tasks in the Ready state and of the same priority, vanilla FreeRTOS implements Round Robin scheduling between each task. This will result in running those tasks in turn each time the scheduler is called (e.g. every tick interrupt). On the other hand, the ESP-IDF FreeRTOS scheduler may skip tasks when Round Robin scheduling multiple Ready state tasks of the same priority.

The issue of skipping tasks during Round Robin scheduling arises from the way the Ready Tasks List is implemented in FreeRTOS. In vanilla FreeRTOS, pxReadyTasksList is used to store a list of tasks that are in the Ready state. The list is implemented as an array of length configMAX_PRIORITIES where each element of the array is a linked list. Each linked list is of type List_t and contains TCBs of tasks of the same priority that are in the Ready state. The following diagram illustrates the pxReadyTasksList structure.

![Illustration of FreeRTOS Ready Task List Data Structure](image)

Each linked list also contains a pxIndex which points to the last TCB returned when the list was queried. This index allows the vTaskSwitchContext() to start traversing the list at the TCB immediately after pxIndex hence implementing Round Robin Scheduling between tasks of the same priority.

In ESP-IDF FreeRTOS, the Ready Tasks List is shared between cores hence pxReadyTasksList will contain tasks pinned to different cores. When a core calls the scheduler, it is able to look at the xCoreID member of each TCB in the list to determine if a task is allowed to run on calling the core. The ESP-IDF FreeRTOS pxReadyTasksList is illustrated below.

Therefore when PRO_CPU calls the scheduler, it will only consider the tasks in blue or purple. Whereas when APP_CPU calls the scheduler, it will only consider the tasks in orange or purple.

Although each TCB has an xCoreID in ESP-IDF FreeRTOS, the linked list of each priority only has a single pxIndex. Therefore when the scheduler is called from a particular core and traverses the linked list, it will skip all TCBs pinned to the other core and point the pxIndex at the selected task. If the other core then calls the scheduler,
it will traverse the linked list starting at the TCB immediately after pxIndex. Therefore, TCBs skipped on the previous scheduler call from the other core would not be considered on the current scheduler call. This issue is demonstrated in the following illustration.

![Diagram](image)

**Figure 3:** Illustration of FreeRTOS Ready Task List Data Structure in ESP-IDF

Referring to the illustration above, assume that priority 9 is the highest priority, and none of the tasks in priority 9 will block hence will always be either in the running or Ready state.

1) **PRO_CPU** calls the scheduler and selects Task A to run, hence moves pxIndex to point to Task A

2) **APP_CPU** calls the scheduler and starts traversing from the task after pxIndex which is Task B. However Task B is not selected to run as it is not pinned to APP_CPU hence it is skipped and Task C is selected instead. pxIndex now points to Task C

3) **PRO_CPU** calls the scheduler and starts traversing from Task D. It skips Task D and selects Task E to run and points pxIndex to Task E. Notice that Task B isn’t traversed because it was skipped the last time APP_CPU called the scheduler to traverse the list.

4) The same situation with Task D will occur if **APP_CPU** calls the scheduler again as pxIndex now points to Task E

One solution to the issue of task skipping is to ensure that every task will enter a blocked state so that they are removed from the Ready Task List. Another solution is to distribute tasks across multiple priorities such that a given priority will not be assigned multiple tasks that are pinned to different cores.

**Scheduler Suspension**

In vanilla FreeRTOS, suspending the scheduler via `vTaskSuspendAll()` will prevent calls of `vTaskSwitchContext` from context switching until the scheduler has been resumed with `xTaskResumeAll()`. However servicing ISRs are still permitted. Therefore any changes in task states as a result from the current running task or ISRSs will not be executed until the scheduler is resumed. Scheduler suspension in vanilla FreeRTOS is a common protection method against simultaneous access of data shared between tasks, whilst still allowing ISRs to be serviced.
In ESP-IDF FreeRTOS, `xTaskSuspendAll()` will only prevent calls of `vTaskSwitchContext()` from switching contexts on the core that called for the suspension. Hence if `PRO_CPU` calls `vTaskSuspendAll()`, `APP_CPU` will still be able to switch contexts. If data is shared between tasks that are pinned to different cores, scheduler suspension is NOT a valid method of protection against simultaneous access. Consider using critical sections (disables interrupts) or semaphores (does not disable interrupts) instead when protecting shared resources in ESP-IDF FreeRTOS.

In general, it’s better to use other RTOS primitives like mutex semaphores to protect against data shared between tasks, rather than `vTaskSuspendAll()`.

**Tick Interrupt Synchronicity**

In ESP-IDF FreeRTOS, tasks on different cores that unblock on the same tick count might not run at exactly the same time due to the scheduler calls from each core being independent, and the tick interrupts to each core being unsynchronized.

In vanilla FreeRTOS the tick interrupt triggers a call to `xTaskIncrementTick()` which is responsible for incrementing the tick counter, checking if tasks which have called `vTaskDelay()` have fulfilled their delay period, and moving those tasks from the Delayed Task List to the Ready Task List. The tick interrupt will then call the scheduler if a context switch is necessary.

In ESP-IDF FreeRTOS, delayed tasks are unblocked with reference to the tick interrupt on `PRO_CPU` as `PRO_CPU` is responsible for incrementing the shared tick count. However tick interrupts to each core might not be synchronized (same frequency but out of phase) hence when `PRO_CPU` receives a tick interrupt, `APP_CPU` might not have received it yet. Therefore if multiple tasks of the same priority are unblocked on the same tick count, the task pinned to `PRO_CPU` will run immediately whereas the task pinned to `APP_CPU` must wait until `APP_CPU` receives its out of sync tick interrupt. Upon receiving the tick interrupt, `APP_CPU` will then call for a context switch and finally switches contexts to the newly unblocked task.

Therefore, task delays should NOT be used as a method of synchronization between tasks in ESP-IDF FreeRTOS. Instead, consider using a counting semaphore to unblock multiple tasks at the same time.

**4.10.4 Critical Sections & Disabling Interrupts**

Vanilla FreeRTOS implements critical sections in `vTaskEnterCritical` which disables the scheduler and calls `portDISABLE_INTERRUPTS`. This prevents context switches and servicing of ISRs during a critical section. Therefore, critical sections are used as a valid protection method against simultaneous access in vanilla FreeRTOS.

For this reason, ESP-IDF FreeRTOS implements critical sections using special mutexes, referred by `portMUX_Type` objects on top of specific spinlock component and calls to enter or exit a critical must provide a spinlock object that is associated with a shared resource requiring access protection. When entering a critical section in ESP-IDF FreeRTOS, the calling core will disable its scheduler and interrupts similar to the vanilla FreeRTOS implementation. However, the calling core will also take the locks whilst the other core is left unaffected during the critical section. If the other core attempts to take the spinlock, it will spin until the lock is released. Therefore, the ESP-IDF FreeRTOS implementation of critical sections allows a core to have protected access to a shared resource without disabling the other core. The other core will only be affected if it tries to concurrently access the same resource.

The ESP-IDF FreeRTOS critical section functions have been modified as follows…

- `taskENTER_CRITICAL(mux)`, `taskENTER_CRITICAL_ISR(mux)`, `portENTER_CRITICAL(mux)`, `portENTER_CRITICAL_ISR(mux)` are all macro defined to call `vTaskEnterCritical()`.
- `taskEXIT_CRITICAL(mux)`, `taskEXIT_CRITICAL_ISR(mux)`, `portEXIT_CRITICAL(mux)`, `portEXIT_CRITICAL_ISR(mux)` are all macro defined to call `vTaskExitCritical()`.
- `portENTER_CRITICAL_SAFE(mux)`, `portEXIT_CRITICAL_SAFE(mux)` macro identifies the context of execution, i.e ISR or Non-ISR, and calls appropriate critical section functions (`port_*_CRITICAL` in Non-ISR and `port_*_CRITICAL_ISR` in ISR) in order to be in compliance with Vanilla FreeRTOS.

For more details see `soc/include/soc/spinlock.h` and `freertos/tasks.c`.
It should be noted that when modifying vanilla FreeRTOS code to be ESP-IDF FreeRTOS compatible, it is trivial to modify the type of critical section called as they are all defined to call the same function. As long as the same spinlock is provided upon entering and exiting, the type of call should not matter.

### 4.10.5 Floating Point Arithmetic

ESP-IDF FreeRTOS implements Lazy Context Switching for FPUs. In other words, the state of a core’s FPU registers are not immediately saved when a context switch occurs. Therefore, tasks that utilize `float` must be pinned to a particular core upon creation. If not, ESP-IDF FreeRTOS will automatically pin the task in question to whichever core the task was running on upon the task’s first use of `float`. Likewise due to Lazy Context Switching, only interrupt service routines of lowest priority (that is it the Level 1) can use `float`, higher priority interrupts do not support FPU usage.

ESP32 does not support hardware acceleration for double precision floating point arithmetic (`double`). Instead `double` is implemented via software hence the behavioral restrictions with regards to `float` do not apply to `double`. Note that due to the lack of hardware acceleration, `double` operations may consume significantly larger amount of CPU time in comparison to `float`.

### 4.10.6 Task Deletion

In FreeRTOS task deletion the freeing of task memory will occur immediately (within `vTaskDelete()`) if the task being deleted is not currently running or is not pinned to the other core (with respect to the core `vTaskDelete()` is called on). TLSP deletion callbacks will also run immediately if the same conditions are met.

However, calling `vTaskDelete()` to delete a task that is either currently running or pinned to the other core will still result in the freeing of memory being delegated to the Idle Task.

### 4.10.7 Thread Local Storage Pointers & Deletion Callbacks

Thread Local Storage Pointers (TLSP) are pointers stored directly in the TCB. TLSP allow each task to have its own unique set of pointers to data structures. However task deletion behavior in vanilla FreeRTOS does not automatically free the memory pointed to by TLSP. Therefore if the memory pointed to by TLSP is not explicitly freed by the user before task deletion, memory leak will occur.

ESP-IDF FreeRTOS provides the added feature of Deletion Callbacks. Deletion Callbacks are called automatically during task deletion to free memory pointed to by TLSP. Each TLSP can have its own Deletion Callback. Note that due to the to `Task Deletion` behavior, there can be instances where Deletion Callbacks are called in the context of the Idle Tasks. Therefore Deletion Callbacks should never attempt to block and critical sections should be kept as short as possible to minimize priority inversion.

Deletion callbacks are of type `void (*TlsDeleteCallbackFunction_t)( int, void * )` where the first parameter is the index number of the associated TLSP, and the second parameter is the TLSP itself.

Deletion callbacks are set alongside TLSP by calling `vTaskSetThreadLocalStoragePointerAndDelCallback()`. 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. If a deletion callback is `NULL`, users should manually free the memory pointed to by the associated TLSP before task deletion in order to avoid memory leak.

For more details see `FreeRTOS API reference`.

### 4.10.8 Configuring ESP-IDF FreeRTOS

The 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 `FreeRTOS`
**Chapter 4. API**

`CONFIG_FREERTOS_SUPPORT_STATIC_ALLOCATION` will enable the functionality of `xTaskCreateStaticPinnedToCore()` in ESP-IDF FreeRTOS.

`CONFIG_FREERTOS_ASSERT_ON_UNTESTED_FUNCTION` will trigger a halt in particular functions in ESP-IDF FreeRTOS which 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
```

### 4.11 Thread Local Storage

#### 4.11.1 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.

#### 4.11.2 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 `configNUM_THREAD_LOCAL_STORAGE_POINTERS` macro. Variables are kept in the task control block (TCB) and accessed by their index. Note that index 0 is reserved for ESP-IDF internal uses. Using that API user can allocate thread local variables of an arbitrary size and assign them to any number of tasks. Different tasks can have different sets of TLS variables. If size of the variable is more then 4 bytes then user is responsible for allocating/deallocating memory for it. Variable’s deallocation is initiated by FreeRTOS when task is deleted, but user must provide function (callback) to do proper cleanup.

#### 4.11.3 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 of 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.

#### 4.11.4 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.](https://gcc.gnu.org/onlinedocs/gcc-5.5.0/gcc/Thread-Local.)
**4.12 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)*

---

### 4.12.1 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.
# Chapter 4. API

## 4.1 Hardware Abstraction Header Files

<table>
<thead>
<tr>
<th>Include Directive</th>
<th>Target Specific</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>#include 'soc/xxx_caps.h'</td>
<td>Y</td>
<td>This header contains a list of C macros specifying the various capabilities of the ESP32’s peripheral xxx. Hardware capabilities of a peripheral include things such as the number of channels, DMA support, hardware FIFO/buffer lengths, etc.</td>
</tr>
<tr>
<td>#include &quot;soc/xxx_struct.h&quot; #include &quot;soc/xxx_reg.h&quot;</td>
<td>Y</td>
<td>The two headers contain a representation of a peripheral’s registers in C structure and C macro format respectively. Users can operate a peripheral at the register level via either of these two header files.</td>
</tr>
<tr>
<td>#include &quot;soc/xxx_pins.h&quot;</td>
<td>Y</td>
<td>If certain signals of a peripheral are mapped to a particular pin of the ESP32, their mappings are defined in this header as C macros.</td>
</tr>
<tr>
<td>#include &quot;soc/xxx_periph.h&quot;</td>
<td>N</td>
<td>This header is mainly used as a convenience header file to automatically include xxx_caps.h, xxx_struct.h, and xxx_reg.h.</td>
</tr>
</tbody>
</table>
| #include "hal/xxx_types.h" | N | This header contains type definitions and macros that are shared among the LL, HAL, and driver layers. Moreover, it is considered public API thus can be included by the application level. The shared types and definitions usually related to non-implementation specific concepts such as the following:  
  • Protocol related types/macros such as a frames, modes, common bus speeds, etc.  
  • Features/characteristics of an xxx peripheral that are likely to be present on any implementation (implementation-independent) such as channels, operating modes, signal amplification or attenuation intensities, etc. |
| #include "hal/xxx_ll.h" | Y | This header contains the Low Level (LL) Layer of hardware abstraction. LL Layer API are primarily used to abstract away register operations into readable functions. |
| #include "hal/xxx_hal.h" | Y | The Hardware Abstraction Layer (HAL) is used to abstract away peripheral operation steps into functions (e.g., reading a buffer, starting a transmission, handling an event, etc). The HAL is built on top of the LL Layer. |
| #include "driver/xxx.h" | N | The driver layer is the highest level of ESP-IDF’s hardware abstraction. Driver layer API are meant to be called from ESP-IDF applications, and internally utilize OS primitives. Thus, driver layer API are event-driven, and can used in a multi-threaded environment. |

## 4.12 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;
}
```

(下页转接)
The code snippet above illustrates typical LL functions for a peripheral \textit{xxx}. LL functions typically have the following characteristics:

- All LL functions are defined as \texttt{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 \texttt{xxx\_dev\_t} type. The \texttt{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, \texttt{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.

4.12.3 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.

### 4.13 High-Level Interrupts

The Xtensa architecture has support for 32 interrupts, divided over 8 levels, 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, allowing for very low interrupt latencies.

#### 4.13.1 Interrupt Levels

<table>
<thead>
<tr>
<th>Level</th>
<th>Symbol</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N/A</td>
<td>Exception and level 0 interrupts. Handled by ESP-IDF</td>
</tr>
<tr>
<td>2-3</td>
<td>N/A</td>
<td>Medium level interrupts. Handled by ESP-IDF</td>
</tr>
<tr>
<td>4</td>
<td>xt_highint4</td>
<td>Normally used by ESP-IDF debug logic</td>
</tr>
<tr>
<td>5</td>
<td>xt_highint5</td>
<td>Free to use</td>
</tr>
<tr>
<td>NMI</td>
<td>xt_nmi</td>
<td>Free to use</td>
</tr>
<tr>
<td>dbg</td>
<td>xt_debugexception</td>
<td>Debug exception. Called on e.g. a BREAK instruction.</td>
</tr>
</tbody>
</table>

Using these symbols is done by creating an assembly file (suffix `.S`) and defining the named symbols, like this:

```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/esp32/dport_panic_highint_hdl.S` file; the panic handler interrupt is implemented there.

#### 4.13.2 Notes

- Do not call C code from a high-level interrupt; because these interrupts still run in critical sections, this can cause crashes. (The panic handler interrupt does call normal C code, but this is OK because there is no intention of returning to the normal code flow afterwards.)
- Make sure your assembly code gets linked in. If the interrupt handler symbol is the only symbol the rest of the code uses from this file, the linker will take the default ISR instead and not link the assembly file into the final project. To get around this, in the assembly file, define a symbol, like this:
Chapter 4. API

4.14 JTAG 调试

本文将指导安装 ESP32 的 OpenOCD 调试环境，并介绍如何使用 GDB 来调试 ESP32 的应用程序。本文的组织结构如下：

引言 介绍本指南主旨。
工作原理 介绍 ESP32、JTAG（Joint Test Action Group）接口，OpenOCD 和 GDB 是如何相互连接从而实现 ESP32 的调试功能。
选择 JTAG 适配器 介绍有关 JTAG 硬件适配器的选择及参照标准。
安装 OpenOCD 介绍如何安装官方预编译好的 OpenOCD 软件包并验证是否安装成功。
配置 ESP32 目标板 介绍如何设置 OpenOCD 软件并安装 JTAG 硬件适配器，这两者共同组成最终的调试目标。
启动调试器 介绍如何从 Eclipse 集成开发环境 和 命令行终端 启动 GDB 调试会话。
调试范例 如果你对 GDB 不太熟悉，本小节会分别针对 Eclipse 集成开发环境 和 命令行终端 来讲解调试的范例。
从源码构建 OpenOCD 介绍如何在 Windows、Linux 和 MacOS 操作系统上从源码构建 OpenOCD。
注意事项和补充内容 介绍使用 OpenOCD 和 GDB 通过 JTAG 接口调试 ESP32 时的注意事项和补充内容。

4.14.1 引言

乐鑫已经为 ESP32 处理器和多核 FreeRTOS 架构移植好了 OpenOCD，它将成为大多数 ESP32 应用程序的基础。此外，乐鑫还提供了一些 OpenOCD 本身并不支持的工具来进一步丰富调试的功能。

本文将指导如何在 Linux、Windows 和 MacOS 环境下为 ESP32 安装 OpenOCD，并使用 GDB 进行软件调试。除了个别操作系统的安装过程有所差别以外，软件用户界面和使用流程都是一样的。

注解：本文使用的图片素材来自于 Ubuntu 16.04 LTS 上 Eclipse Neon 3 软件的截图，不同的操作系统（Windows、MacOS 或者 Linux）和 Eclipse 软件版本在用户界面上可能会有细微的差别。

4.14.2 工作原理

通过 JTAG（Joint Test Action Group）接口使用 OpenOCD 调试 ESP32 时所需要的一些关键的软件和硬件包括 xtensa-esp32-elf-gdb 调试器，OpenOCD 片上调试器和连接到 ESP32 目标的 JTAG 适配器。
在“Application Loading and Monitoring”下还有另外一组软件和硬件，它们用来编译、构建和烧写应用程序到 ESP32 上，以及监视来自 ESP32 的运行诊断信息。

Eclipse 环境集成了 JTAG 调试和应用程序加载、监视的功能，它使得软件从编写、编译、加载到调试的迭代过程变得更加简单。所有的软件均适用于 Windows, Linux 和 MacOS 平台。

如果你使用的是 ESP-WROVER-KIT 开发板，得益于板载的 FT232H 芯片，PC 和 ESP32 的连接只需要一根 USB 线即可完成。FT232H 提供了两路 USB 通道，一路连接到 JTAG，另一路连接到 UART。

根据用户的喜好，除了使用 Eclipse 集成开发环境，还可以直接在命令行终端运行 debugger 和 idf.py build。

### 4.14.3 选择 JTAG 适配器

上手 JTAG 最快速便捷的方式是使用 ESP-WROVER-KIT 开发板。因为它板载了 JTAG 调试接口，无需使用外部的 JTAG 硬件适配器和额外的线缆来连接 JTAG 与 ESP32。ESP-WROVER-KIT 采用 FT232H 提供的 JTAG 接口，可以稳定运行在 20 MHz 的时钟频率，外接的适配器很难达到这个速度。

如果你想使用单独的 JTAG 适配器，确保其与 ESP32 的电平电压和 OpenOCD 软件都兼容。ESP32 使用的是业界标准的 JTAG 接口，它省略了（实际上也并不需要）TRST 信号线。JTAG 使用的 IO 引脚由 VDD_3P3_RTC 电源引脚供电（通常连接到外部 3.3 V 的电源轨），因此 JTAG 硬件适配器的引脚需要能够在该电压范围内正常工作。

在软件方面，OpenOCD 支持相当多数量的 JTAG 适配器，可以参阅 OpenOCD 支持的适配器列表（尽管上面显示的器件不太完整）。这个页面还列出了兼容 SWD 接口的适配器。但是请注意，ESP32 目前并不支持 SWD。此外那些被硬编码为只支持特定产品线的 JTAG 适配器也不能在 ESP32 上工作，比如用于 STM32 产品家族的 ST-LINK 适配器。

JTAG 正常工作至少需要连接的信号线有：TDO、TDO、TCK、TMS 和 GND。某些 JTAG 适配器还需要 ESP32 提供一路电源到适配器的某个引脚上（比如 Vref）用以设置适配器的工作电压。SRST 信号线是可以选的，它可以连接到 ESP32 的 CH_PD 引脚上。尽管目前 OpenOCD 对该信号线的支持还非常有限。

### 4.14.4 安装 OpenOCD

如果你已经按照快速入门一文中的介绍安装好了 ESP-IDF 及其 CMake 构建系统，那么 OpenOCD 已经被默认安装到了你的开发系统中。在设置开发环境结束后，你应该能够在终端中运行如下 OpenOCD 命令：

```bash
openocd
```
openocd --version

终端会输出以下信息（实际版本号可能会比这里列出的更新）：

<table>
<thead>
<tr>
<th>Open On-Chip Debugger</th>
<th>v0.10.0-esp32-20190708 (2019-07-08-11:04)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Licensed under GNU GPL v2</td>
<td></td>
</tr>
<tr>
<td>For bug reports, read</td>
<td><a href="http://openocd.org/doc/doxygen/bugs.html">http://openocd.org/doc/doxygen/bugs.html</a></td>
</tr>
</tbody>
</table>

你还可以检查 OPENOCD_SCRIPTS 环境变量的值来确认 OpenOCD 配置文件的路径。Linux 和 macOS 用户可以在终端输入 echo $OPENOCD_SCRIPTS，Windows 用户需要输入 echo %OPENOCD_SCRIPTS%。如果终端打印了有效的路径，则表明 OpenOCD 已经被正确安装。

如果上述步骤没有成功执行，请返回快速入门手册，参考其中设置安装工具 章节的说明。

### 注解：
另外，我们还可以从源代码编译 OpenOCD 工具，相关详细信息请参阅从源码构建 OpenOCD 章节。

#### 4.14.5 配置 ESP32 目标板

安装好 OpenOCD 之后就可以配置 ESP32 目标板（即带 JTAG 接口的 ESP32 板），具体可以通过以下三个步骤进行：

- 配置并连接 JTAG 接口
- 运行 OpenOCD
- 上传待调试的应用程序

### 配置并连接 JTAG 接口

此步骤取决于您使用的 JTAG 和 ESP32 板，但参考以下两种情况。

#### 配置 ESP-WROVER-KIT 上的 JTAG 接口

所有版本的 ESP-WROVER-KIT 板子都内置了 JTAG 调试功能，要使其正常工作，还需要设置相关跳线来启用 JTAG 功能，设置 SPI 闪存电压和配置 USB 驱动程序。具体步骤请参考以下说明。

#### 配置硬件

- 根据 ESP-WROVER-KIT V4.1 入门指南 文档中设置选项 章节所描述的信息，设置 JP8 便可启用 JTAG 功能。
- 检查 ESP32 上用于 JTAG 通信的引脚是否被接到了其它硬件上，这可能会影响 JTAG 的工作。

<table>
<thead>
<tr>
<th>ESP32 引脚</th>
<th>JTAG 信号</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>

#### 配置 USB 驱动

安装和配置 USB 驱动，这样 OpenOCD 才能够与 ESP-WROVER-KIT 板上的 JTAG 接口通信，并且使用 UART 接口上传待烧写的镜像文件。请根据你的操作系统按照以下步骤进行安装配置。

### 注解：
ESP-WROVER-KIT 使用了 FT2232 芯片实现了 JTAG 适配器，所以以下说明同样适用于其他基于 FT2232 的 JTAG 适配器。
Chapter 4. API 指南

Windows

1. 使用标准 USB A / micro USB B 线将 ESP-WROVER-KIT 与计算机相连接，并打开板子的电源。
2. 等待 Windows 识别出 ESP-WROVER-KIT 并且为其安装驱动。如果驱动没有被自动安装，请前往官网下载并手动安装。
3. 从 Zadig 官网下载 Zadig 工具（Zadig_X.X.exe）并运行。
4. 在 Zadig 工具中，进入 “Options” 菜单中选中 “List All Devices”。
5. 检查设备列表，其中应该包含两条与 ESP-WROVER-KIT 相关的条目：“Dual RS232-HS (Interface 0)” 和 “Dual RS232-HS (Interface 1)”。驱动的名字应该是 “FTDIBUS (vxxxx)” 并且 USB ID 为：0403 6010。

![Zadig Tools](image)

图 6: 在 Zadig 工具中配置 JTAG USB 驱动

6. 第一个设备 “Dual RS232-HS (Interface 0)” 连接到了 ESP32 的 JTAG 端口。此设备原来的 “FTDIBUS (vxxxx)” 驱动需要替换为 “WinUSB (v6xxxxx)”。为此，请选择 “Dual RS232-HS (Interface 0)” 并将驱动重新安装为 “WinUSB (v6xxxxx)”，具体可以参考上图。

注解：请勿更改第二个设备 “Dual RS232-HS (Interface 1)” 的驱动，它被连接到 ESP32 的串口 (UART)，用于上传应用程序映像给 ESP32 进行烧写。

现在，ESP-WROVER-KIT 的 JTAG 接口应该可以被 OpenOCD 使用了，想要进一步设置调试环境，请前往运行 OpenOCD 章节。

Linux

1. 使用标准 USB A / micro USB B 线将 ESP-WROVER-KIT 与计算机相连接，并打开板子的电源。
2. 打开终端，输入 ls -l /dev/ttyUSB* 命令检查操作系统是否能够识别板子的 USB 端口。类似识别结果如下：

```bash
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. 根据 OpenOCD README 文档中 “Permissions delegation” 小节的介绍，设置这两个 USB 端口的访问权限。
4. 注销并重新登录 Linux 系统，然后重新拔插板子的电源使之前的改动生效。在终端再次输入 ls -l /dev/ttyUSB* 命令进行验证，查看这两个设备的组所有者是否已经从 dialout 更改为 plugdev:
如果看到类似的输出结果，并且你也是 plugdev 组的成员，那么设置工作就完成了。

具有较低编号的 /dev/ttyUSBn 接口用于 JTAG 通信，另一路接口被连接到 ESP32 的串口 (UART)，用于上传应用程序映像给 ESP32 进行烧写。

现在，ESP-WROVER-KIT 的 JTAG 接口应该可以被 OpenOCD 使用了，想要进一步设置调试环境，请前往 OpenOCD 章节。

**MacOS** 在 macOS 上，同时使用 FT232 的 JTAG 接口和串口还需另外进行其它操作。当操作系统加载 FTDI 串口驱动的时候，它会对 FT232 芯片的两个通道做相同的操作，但是，这两个通道中只有一个被用作串口，而另一个用于 JTAG，如果操作系统已经为用于 JTAG 的通道加载了 FTDI 串口驱动的话，OpenOCD 将无法连接到芯片。有两个方法可以解决这个问题：

1. 在启动 OpenOCD 之前手动卸载 FTDI 串口驱动程序，然后启动 OpenOCD，再加载串口驱动程序。
2. 修改 FTDI 驱动程序的配置，使其不会为 FT232 芯片的通道 B 进行自我加载，该通道用于 ESP-WROVER-KIT 板上的 JTAG 通道。

**手动卸载驱动程序**

1. 从 FTDI 官网 安装驱动。
2. 使用 USB 线连接 ESP-WROVER-KIT。
3. 卸载串口驱动

```bash
sudo kextunload -b com.FTDI.driver.FTDIUSBSerialDriver
```

有时，您可能还需要卸载苹果的 FTDI 驱动：

```bash
sudo kextunload -b com.apple.driver.AppleUSBFTDI
```

4. 运行 OpenOCD:

```bash
.. include:: esp32.inc
   :start-after: run-openocd
   :end-before: ---
```

5. 在另一个终端窗口，再一次加载 FTDI 串口驱动:

```bash
sudo kextload -b com.FTDI.driver.FTDIUSBSerialDriver
```

**注解：** 如果你需要重启 OpenOCD，则无需再次卸载 FTDI 驱动程序，只需停止 OpenOCD 并再次启动它。只有在重新连接 ESP-WROVER-KIT 或者切换了电源的情况下才需要再次卸载驱动。

你也可以根据自身需求，将此过程包装进 shell 脚本中。

**修改 FTDI 驱动** 简而言之，这种方法需要修改 FTDI 驱动程序的配置文件，这样可以防止为 FT232H 的通道 B 自动加载串口驱动。

**注解：** 其他板子可能将通道 A 用于 JTAG，因此请谨慎使用此选项。

**警告：** 此方法还需要操作系统禁止对驱动进行签名验证，因此可能无法被所有的用户所接受。

1. 使用文本编辑器打开 FTDI 驱动的配置文件（注意 sudo）:
sudo nano /Library/Extensions/FTDIUSBSerialDriver.kext/Contents/Info.plist

2. 找到并删除以下几行:

```plaintext
<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>
  <key>bInterfaceNumber</key>
  <integer>1</integer>
  <key>bcdDevice</key>
  <integer>1792</integer>
  <key>idProduct</key>
  <integer>24592</integer>
  <key>idVendor</key>
  <integer>1027</integer>
</dict>
```

3. 保存并关闭文件
4. 禁用驱动的签名认证:
   1. 点击苹果的 logo，选择 “Restart…”
   2. 重启后当听到响铃时，立即按下键盘上的 CMD+R 组合键
   3. 进入恢复模式后，打开终端
   4. 运行命令:

   ```bash
csrutil enable --without kext
   ```

5. 再一次重启系统

完成这些步骤后，可以同时使用串口和 JTAG 接口了。
想要进一步设置调试环境，请前往运行 OpenOCD 章节。

配置其它 JTAG 接口 关于适配 OpenOCD 和 ESP32 的 JTAG 接口选择问题，请参考选择 JTAG 适配器章节，确保 JTAG 适配器能够与 OpenOCD 和 ESP32 一同工作。然后按照以下三个步骤进行设置，使其正常工作。

配置硬件

1. 找到 JTAG 接口和 ESP32 板上需要相互连接并建立通信的引脚/信号。

<table>
<thead>
<tr>
<th>ESP32 引脚</th>
<th>JTAG 信号</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. 检查 ESP32 上用于 JTAG 通信的的引脚是否被连接到了其它硬件上，这可能会影响 JTAG 的工作。
3. 连接 ESP32 和 JTAG 接口上的引脚/信号。

配置驱动  你可能还需要安装软件驱动，才能使 JTAG 在计算机上正常工作，请参阅你所使用的 JTAG 适配器的有关文档，获取相关详细信息。
连接  将 JTAG 接口连接到计算机，打开 ESP32 和 JTAG 接口板上的电源，然后检查计算机是否可以识别到 JTAG 接口。
要继续设置调试环境，请前往运行 OpenOCD 章节。

运行 OpenOCD
配置完目标并将其连接到电脑后，即可启动 OpenOCD。
打开终端，按照快速入门中的指南设置好开发环境，然后运行如下命令，启动 OpenOCD（该命令在 Windows, Linux, 和 macOS 中通用）：

```
openocd -f board/esp32-wrover-kit-3.3v.cfg
```

注解：上述命令中 -f 选项后跟的配置文件专用于板载 ESP32-WROOM-32 模组的 ESP-WROVER-KIT 开发板。您可能需要根据具体使用的硬件而选择或修改不同的配置文件，相关指导请参阅 Configuration of OpenOCD for specific target。

现在应该可以看到如下输入（此日志来自板载 ESP32-WROOM-32 模组的 ESP-WROVER-KIT 开发板）：

```
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=0x0F, after clear 0x0F).
```

- 如果出现指示权限问题的错误，请参阅 ~/esp/openocd-esp32 目录下 OpenOCD README 文件中关于 “Permissions delegation” 的说明。
- 如果发现配置文件有错误，例如 Can't find board/esp32-wrover-kit-3.3v.cfg，请检查 -s 后面的路径，OpenOCD 会根据此路径来查找 -f 指定的文件。此外，还需要检查配置文件是否确实位于该路径下。
- 如果看到 JTAG 错误（输出全是 1 或者全是 0），请检查硬件连接，除了 ESP32 的引脚之外是否还有其他信号连接到了 JTAG，并查看是否所有器件都已经上电。

上传待调试的应用程序
您可以像往常一样构建并上传 ESP32 应用程序，具体请参阅第八步：编译工程 章节。
除此以外，还支持使用 OpenOCD 通过 JTAG 接口将应用程序镜像烧写到闪存中，命令如下：

```
openocd -f board/esp32-wrover-kit-3.3v.cfg -c "program esp filename.bin 0x10000
   --verify exit"
```

其中 OpenOCD 的烧写命令 program_esp 具有以下格式：
```
program_esp <image_file> <offset> [verify] [reset] [exit]
```

- image_file - 程序镜像文件存放的路径
• offset - 镜像烧写到闪存中的偏移地址
• verify - 烧写完成后校验闪存中的内容（可选）
• reset - 烧写完成后重启目标（可选）
• exit - 烧写完成后退出 OpenOCD（可选）

现在可以进行应用程序的调试了，请按照以下章节中讲解的步骤进行操作。

4.14.6 启动调试器

ESP32 的工具链中带有 GNU 调试器 (简称 GDB) xtensa-esp32-elf-gdb. 它和其它工具链软件存放
在同一 bin 目录下。除了直接在命令行终端中调用并操作 GDB 外，还可以在 IDE (例如 Eclipse、Visual Studio Code 等) 中调用它，在图形用户界面的帮助下间接操作 GDB，无需在终端中输入任何命令。

关于以上两种调试器的使用方法，详情以下链接。

- 在 Eclipse 中使用 GDB
- 在命令行中使用 GDB

建议首先检查调试器是否能在命令行终端下正常工作，然后再转到使用 Eclipse 等集成开发环境下进行调试工作。

4.14.7 调试范例

本节适用于不熟悉 GDB 的用户，将使用 get-started/blink 下简单的应用程序来演示调试会话的工作流程，
同时会介绍以下常用的调试操作：

1. 浏览代码，查看堆栈和线程
2. 设置和清除断点
3. 手动暂停调试
4. 单步执行代码
5. 查看并设置内存
6. 观察和设置程序变量
7. 设置条件断点

此外还会提供在命令行终端进行调试 的案例。

在演示之前，请设置好 ESP32 目标板并加载 get-started/blink 至 ESP32 中。

4.14.8 从源码构建 OpenOCD

请参阅以下文档，它们分别介绍了在各大操作系统平台上从源码构建 OpenOCD 的流程。

Windows 环境下从源码编译 OpenOCD

除了从 Espressif 官方直接下载 OpenOCD 可执行文件，你还可以选择从源码编译得到 OpenOCD。如果想
要快速设置 OpenOCD 而不是自行编译，请备份好当前文件，前往安装 OpenOCD 章节查阅。

下载 OpenOCD 源码 支持 ESP32 的 OpenOCD 源代码可以从乐鑫官方的 GitHub 获得，网址为 https://github.com/espressif/openocd-esp32，请使用以下命令来下载源代码：

cd ~/esp
git clone --recursive https://github.com/espressif/openocd-esp32.git

克隆后的源代码被保存在 ~/openocd-esp32 目录中。
安装依赖的软件包 安装编译 OpenOCD 所需的软件包。

注解：依次安装以下软件包，检查安装是否成功，然后继续下一个软件包的安装。在进行下一步操作之前，要先解决当前报告的问题。

```bash
pacman -S libtool
pacman -S autoconf
pacman -S automake
pacman -S texinfo
pacman -S mingw-w64-i686-libusb-compat-git
pacman -S pkg-config
```

注解：安装 pkg-config 会破坏 esp-idf 的工具链，因而在 OpenOCD 构建完成后，应将其卸载。详见文末进一步说明。如果想要再次构建 OpenOCD，你需要再次运行 pacman -S pkg-config。此步骤安装的其他软件包（在 pkg-config 之前）并不会出现这一问题。

构建 OpenOCD 配置和构建 OpenOCD 的流程如下:

```bash
cd ~/esp/openocd-esp32
./bootstrap
./configure
make
```

你可以选择最后再执行 sudo make install，如果你已经安装过别的开发平台的 OpenOCD，请跳过这个步骤。因为它可能会覆盖掉原来的 OpenOCD。

注解:

- 如果发生错误，请解决后再次尝试编译，直到 make 成功为止。
- 如果 OpenOCD 存在子模块问题，请 cd 到 openocd-esp32 目录，并输入 git submodule update --init 命令。
- 如果 ./configure 成功运行，JTAG 被使能的信息会被打印在 OpenOCD configuration summary 目录下。
- 如果您的设备信息未显示在日志中，请根据../openocd-esp32/doc/INSTALL.txt 文中的描述使用 ./configure 启用它。
- 有关编译 OpenOCD 的详细信息，请参阅 openocd-esp32/README.Windows。

一旦 make 过程成功完成，OpenOCD 的可执行文件会被保存到 ~/esp/openocd-esp32/src/openocd 目录中。

如安装依赖步骤所述，最后还需要移除 pkg-config 软件包:

```bash
pacman -Rs pkg-config
```

下一步 想要进一步配置调试环境，请前往 配置 ESP32 目标板 章节。

Linux 环境下从源码编译 OpenOCD

除了从 Espressif 官方 直接下载 OpenOCD 可执行文件，你还可以选择从源码编译得到 OpenOCD。如果想要快速设置 OpenOCD 而不是自行编译，请备份好当前文件，前往 安装 OpenOCD 章节查阅。
下 载 OpenOCD 源码  支持 ESP32 的 OpenOCD 源代码可以从乐鑫官方的 GitHub 获得，网址为 https://github.com/espressif/openocd-esp32，请使用以下命令来下载源代码：

```bash
cd ~/esp
git clone --recursive https://github.com/espressif/openocd-esp32.git
```

克隆后的源代码被保存在 ~/esp/openocd-esp32 目录中。

安装依赖的软件包  安装编译 OpenOCD 所需的软件包。

**注解**：依次安装以下软件包，检查安装是否成功，然后继续下一个软件包的安装。在进行下一步操作之前，要先解决当前报告的问题。

```bash
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
```

**注解**:
- `pkg-config` 应为 0.2.3 或以上的版本。
- `autoconf` 应为 2.6.4 或以上的版本。
- `automake` 应为 1.9 或以上的版本。
- 当使用 USB-Blaster，ASIX Presto，OpenJTAG 和 FT2232 作为适配器时，需要下载安装 libFTDI 和 FTD2XX 的驱动。
- 当使用 CMSIS-DAP 时，需要安装 HIDAPI。

构建 OpenOCD  配置和构建 OpenOCD 的流程如下：

```bash
cd ~/esp/openocd-esp32
./bootstrap
./configure
make
```

你可以选择最后再执行 `sudo make install`，如果你已经安装过别的开发平台的 OpenOCD，请跳过这个步骤，因为它可能会覆盖掉原来的 OpenOCD。

**注解**:
- 如果发生错误，请解决后再次尝试编译，直到 `make` 成功为止。
- 如果 OpenOCD 存在于模块问题，请 `cd` 到 openocd-esp32 目录，并输入 `git submodule update --init` 命令。
- 如果 `./configure` 成功运行，JTAG 被使能的信息会被打印在 `OpenOCD configuration summary` 下面。
- 如果您的设备信息未显示在日志中，请根据 `./openocd-esp32/doc/INSTALL.txt` 文中的描述使用 `./configure` 启用它。
- 有关编译 OpenOCD 的详细信息，请参阅 `openocd-esp32/README`。

一旦 `make` 过程成功结束，OpenOCD 的可执行文件会被保存到 ~/openocd-esp32/bin 目录中。

下一步  想要进一步配置调试环境，请前往配置 ESP32 目标板 章节。
MacOS 环境下从源码编译 OpenOCD

除了从 Espressif 官方直接下载 OpenOCD 可执行文件，你还可以选择从源码编译得到 OpenOCD。如果想要快速设置 OpenOCD 而不是自行编译，请备份好当前文件，前往安装 OpenOCD 章节查阅。

下载 OpenOCD 源码 支持 ESP32 的 OpenOCD 源代码可以从乐鑫官方的 GitHub 获取，网址为 https://github.com/espressif/openocd-esp32。请使用以下命令来下载源代码:

```bash
cd ~/esp
git clone --recursive https://github.com/espressif/openocd-esp32.git
```

克隆后的源代码被保存在 ~/openocd-esp32 目录中。

安装依赖的软件包 使用 Homebrew 安装编译 OpenOCD 所需的软件包:

```bash
brew install automake libtool libusb wget gcc@4.9 pkg-config
```

构建 OpenOCD 配置和构建 OpenOCD 的流程如下:

```bash
cd ~/esp/openocd-esp32
./bootstrap
./configure
make
```

你可以选择最后再执行 sudo make install，如果你已经安装过别的开发平台的 OpenOCD，请跳过这个步骤，因为它可能会覆盖掉原来的 OpenOCD。

注解:

- 如果发生错误，请解决后再次尝试编译，直到 make 成功为止。
- 如果 OpenOCD 存在子模块问题，请 cd 到 openocd-esp32 目录，并输入 git submodule update --init 命令。
- 如果 ./configure 成功运行，JTAG 被使能的信息会被打印在 OpenOCD configuration summary 下面。
- 如果您的设备信息未显示在日志中，请根据 ./openocd-esp32/doc/INSTALL.txt 文中的描述使用 ./configure 启用它。
- 有关编译 OpenOCD 的详细信息，请参阅 openocd-esp32/README.OSX。

一旦 make 过程成功结束，OpenOCD 的可执行文件会被保存到 ~/esp/openocd-esp32/src/openocd 目录中。

下一步 想要进一步配置调试环境，请前往配置 ESP32 目标板 章节。

本文档演示所使用的 OpenOCD 是安装 OpenOCD 章节中介绍的预编译好的二进制发行版。

如果要使用本地从源代码编译的 OpenOCD 程序，需要将相应可执行文件的路径修改为 src/openocd，并设置 OPENOCD_SCRIPTS 环境变量，这样 OpenOCD 才能找到配置文件。Linux 和 macOS 用户可以执行:

```bash
cd ~/esp/openocd-esp32
export OPENOCD_SCRIPTS=$PWD/tcl
```

Windows 用户可以执行:

```bash
cd %USERPROFILE%\esp\openocd-esp32
set "OPENOCD_SCRIPTS=%CD%\tcl"
```
运行本地编译的 OpenOCD 的示例如下（Linux 和 macOS 用户）：

```
src/openocd -f board/esp32-wrover-kit-3.3v.cfg
```

Windows 用户：

```
src\openocd -f board\esp32-wrover-kit-3.3v.cfg
```

4.14.9 注意事项和补充内容

本节列出了本指南中提到的所有注意事项和补充内容的链接。

注意事项和补充内容

本节提供了本指南中各部分提到的一些注意事项和补充内容。

可用的断点和观察点 ESP32 调试器支持 2 个硬件断点和 64 个软件断点。硬件断点是由 ESP32 芯片内部的逻辑电路实现的，能够设置在代码的任何位置：闪存或者 IRAM 的代码区域。除此以外，OpenOCD 实现了两种软件断点：闪存断点（最多 32 个）和 IRAM 断点（最多 32 个）。目前 GDB 无法在闪存中设置软件断点，因此除非解决此限制，否则这些断点只能由 OpenOCD 模拟为硬件断点。（详细信息可以参阅下文），ESP32 还支持 2 个观察点，所以可以观察两个变量的变化或者通过 GDB 命令 watch myVariable 来读取变量的值。请注意 menuconfig 中的 CONFIG_FREERTOS_WATCHPOINT_END_OF_STACK 选项会使用第二个观察点。如果你想在 OpenOCD 或者 GDB 中再次尝试使用这个观察点，可能不会得到预期的结果。详情请查看 menuconfig 中的帮助文档。

关于断点的补充知识 使用软件闪存模拟部分硬件断点的意思就是当使用 GDB 命令 hb myFunction 给某个函数设置硬件断点时，如果该函数位于闪存中，并且此时还有可用的硬件断点，那调试器就会使用硬件断点。否则就使用 32 个软件闪存断点中的一个来模拟。这个规则同样适用于 b myFunction 之类的命令。在这种情况下，GDB 会自己决定该使用哪种类型的断点。如果 myFunction 位于可写区域（IRAM），那就会使用软件 IRAM 断点，否则就会像处理 hb 命令一样使用硬件断点或者软件闪存断点。

闪存映射 vs 软件闪存断点 为了在闪存中设置或者清除软件断点，OpenOCD 需要知道它们在闪存中的地址。为了完成从 ESP32 的地址空间到闪存地址的转换，OpenOCD 使用闪存中程序代码区域的映射。这些映射被保存在程序映像的头部，位于二进制数据（代码段和数据段）之前，并且存储于写入闪存的每一个应用程序的映像。因此，为了支持软件闪存断点，OpenOCD 需要知道待调试的应用程序映像在闪存中的位置。默认情况下，OpenOCD 会在 0x8000 处读取分区表并使用第一个找到的应用程序映像的映射，但是也可能会存在无法工作的情况，比如分区表不在标准的闪存位置，甚至可能有多个映像：一个出厂映像和两个 OTA 映像。你可能需要调试其中的任意一个。为了涵盖所有可能的调试情况，OpenOCD 支持特殊的命令，用于指定待调试的应用程序映像在闪存中的具体位置。该命令具有以下格式：

```
esp appimage_offset <offset>
```

偏移量应为十六进制格式，如果要恢复默认行为，可以将偏移地址设置为 -1。

注解：由于 GDB 在连接 OpenOCD 时仅仅请求一次内存映射，所以可以在 TCL 配置文件中指定该命令，或者通过命令行传递给 OpenOCD。对于后者，命令行示例如下：

```
openocd -f board/esp32-wrover-kit-3.3v.cfg -c "init; halt; esp appimage_offset_-0x210000"
```

另外还可以通过 OpenOCD 的 telnet 会话执行该命令，然后再连接 GDB，不过这种方式似乎没有那么便捷。
"next" 命令无法跳过子程序的原因 当使用 next 命令单步执行代码时，GDB 会在子程序的前面设置一个断点（两个中可用的一个），这样就可以跳过进入子程序内部的细节。如果这两个断点已经被用在代码的其它位置，那么 next 命令将不起作用。在这种情况下，请删除一个断点以使其中一个变得可用。当两个断点都已经使用时，next 命令会像 step 命令一样工作，调试器就会进入子程序内部。

OpenOCD 支持的编译时选项 ESP-IDF 有一些针对 OpenOCD 调试功能的选项可以在编译时进行设置：

- `CONFIG_ESP32_DEBUG_OCDADATA` 默认会被使能。如果程序抛出了不可修复或者未处理的异常，并且此时已经连接了 JTAG 调试器（即 OpenOCD 正在运行），那么 ESP-IDF 将会进入调试器工作模式。
- `CONFIG_FREERTOS_WATCHPOINT_END_OF_STACK` 默认没有使能。在所有任务堆栈的末尾设置观察点，从 1 号开始索引。这是调试任务堆栈溢出的最准确的方式。

更多有关设置编译时选项的信息，请参阅项目配置菜单。

支持 FreeRTOS OpenOCD 完全支持 ESP-IDF 自带的 FreeRTOS 操作系统，GDB 会将 FreeRTOS 中的任务当做线程。使用 GDB 命令 `i threads` 可以查看所有的线程，使用命令 `thread n` 可以切换到某个具体任务的堆栈。其中 `n` 是进程的编号。检测 FreeRTOS 的功能可以在配置目标时被禁用。更多详细信息，请参阅 Configuration of OpenOCD for specific target。

在 OpenOCD 的配置文件中设置 SPI 闪存的工作电压 ESP32 的 MTDI 引脚是用于 JTAG 通信的四个引脚之一，同时也是 ESP32 的 bootstrapping 引脚。上电时，ESP32 会在 MTDI 引脚上采样二进制电平，据此来设置内部的稳压器，用于给外部的 SPI 闪存芯片供电。如果上电时 MTDI 引脚上的二进制电平为低电平，则稳压器会被设置为 3.3V；如果 MTDI 引脚为高电平，则稳压器会被设置为 1.8V。MTDI 引脚通常需要一个上拉电阻或者直接使内部的弱下拉电阻（详见 ESP32 系列芯片技术规格书），具体取决于所使用的 SPI 闪存芯片的类型。但是一旦连接上 JTAG 后，原来用于实现 bootstrapping 功能的上拉或者下拉电阻都会被覆盖掉。

为了解决这个问题，OpenOCD 的板级配置文件（例如 ESP-WROVER-KIT 开发板的 board\esp32-wrover-kit-3.3v.config）提供了 ESP32_FLASH_VOLTAGE 参数来设置 TDO 信号线在空闲状态下的二进制电平，这样就可以减少由于闪存电压不正确而导致的应用程序启动不良的几率。

查看 JTAG 连接的 ESP32 模组的规格书，检查其 SPI 闪存芯片的供电电压值，然后再相应的设置 ESP32_FLASH_VOLTAGE。大多数 WROOM 模块使用 3.3V 的闪存芯片，早于 ESP32-WROVER-B 的 WROVER 模块使用 1.8V 闪存芯片，而 ESP32-WROVER-B 和-E 模块使用 3.3V 闪存芯片。

优化 JTAG 的速度 为了实现更高的数据通信速率同时最小化丢包数，建议优化 JTAG 时钟频率的设置，使其达到 JTAG 能稳定运行的最低值。为此，请参考以下建议。

1. 如果 CPU 以 80 MHz 运行，则 JTAG 时钟频率的上限为 20 MHz；如果 CPU 以 160 MHz 或者 240 MHz 运行，则上限为 26 MHz。
2. 如果支持的 JTAG 适配器和连接线缆的长度，你可能需要将 JTAG 的工作频率降低至 20 / 26 MHz 以下。
3. 在某些特殊情况下，如果你看到 DSR/DIR 错误（并且它并不是由 OpenOCD 试图从一个没有物理存储器映射的地址空间读取数据而导致的），请降低 JTAG 的工作频率。
4. ESP-WROVER-KIT 能够稳定运行在 20 / 26 MHz 频率下。

调试器的自动命令的含义 在启动时，调试器发出一系列命令来复位芯片并使其在特定的代码行停止运行。这个命令序列（如下所示）支持自定义。用户可以选择在最合适的代码行开始调试工作。

- `set remote hardware-watchpoint-limit 2` — 限制 GDB 仅使用 ESP32 支持的两个硬件观察点。更多详细信息，请查阅 GDB 配置远程目标。
- `mon reset halt` — 复位芯片并使 CPU 停止运行。
- `flushregs monitor (mon)` 命令无法通知 GDB 目标状态已经更改，GDB 会假设在 mon reset halt 之前所有的任务堆栈仍然有效。实际上，复位后目标状态将发生变化。执行 flushregs 是一种强制 GDB 从目标获取最新状态的方法。
Chapter 4. API指南

- thb app_main — in app_main 处插入一个临时的硬件断点，如果有需要，可以将其替换为其他函数名。
- c — 恢复程序运行，它将会在 app_main 的断点处停止运行。

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>名字</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>board/esp32-wrover-kit-3.3v.cfg</td>
<td>板载 3.3V 模组 (ESP32-WROOM-32, ESP32-WROVER-B, ESP32-WROVER-E) 的 ESP-WROVER-KIT 开发板配置文件</td>
</tr>
<tr>
<td>board/esp32-wrover-kit-1.8v.cfg</td>
<td>板载 1.8V 模组 (ESP32-WROVER) 的 ESP-WROVER-KIT 开发板配置文件</td>
</tr>
<tr>
<td>board/esp32-ethernet-kit-3v.cfg</td>
<td>板载 3.3V 模组 (ESP32-WROVER-B / ESP32-WROVER-E) 的 ESP-Ethernet-KIT 开发板配置文件</td>
</tr>
<tr>
<td>target/esp32.cfg</td>
<td>ESP32 的目标配置文件，可以和某个 interface/ 下的配置文件一同使用</td>
</tr>
<tr>
<td>target/esp32-solo-1.cfg</td>
<td>ESP32-SOLO-1 的目标配置文件，和 esp32.cfg 的差别在于它仅配置一个 CPU</td>
</tr>
<tr>
<td>interface/ftdi/esp32_devkitj_v1.cfg</td>
<td>适用于 ESP-WROVER-KIT 和 ESP-Prog 板子的 JTAG 配置文件</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-xxxxxx-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.

### 5: Common ESP-related OpenOCD variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_RTOS</td>
<td>Set to <code>none</code> to disable RTOS support. In this case, thread list will not be available in GDB. Can be useful when debugging FreeRTOS itself, and stepping through the scheduler code.</td>
</tr>
<tr>
<td>ESP_FLASH_SIZE</td>
<td>Set to <code>0</code> to disable Flash breakpoints support.</td>
</tr>
<tr>
<td>ESP_SEMIHOST_BASEDIR</td>
<td>Set to the path (on the host) which will be the default directory for semihosting functions.</td>
</tr>
</tbody>
</table>

### 6: ESP32 相关的 OpenOCD 变量

<table>
<thead>
<tr>
<th>名字</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32_FLASH_VOLTAGE</td>
<td>如果 ESP32 模组集成的是 1.8 V 的 Flash，将该变量设置为 1.8，详情请参考 &amp; OpenOCD 的配置文件中设置 SPI 闪存的工作电压</td>
</tr>
<tr>
<td>ESP32_ONLYCPU</td>
<td>对于多核芯片，将该值设置为 1 可以启用单核调试功能</td>
</tr>
</tbody>
</table>

### 复位 ESP32

通过在 GDB 中输入 `mon reset` 或者 `mon reset halt` 来复位板子。

### 不要将 JTAG 引脚用于其他功能

如果除了 ESP32 模组和 JTAG 适配器之外的其他硬件也连接到了 JTAG 引脚，那么 JTAG 的操作可能会受到干扰。ESP32 JTAG 使用以下引脚：

如果应用程序更改了 JTAG 引脚的配置，JTAG 通信可能会失败。如果 OpenOCD 正确初始化 (检测到两个 Tensilica 核)，但在程序运行期间失去了同步并报出大量 DTR/DIR 错误，则应用程序可能将 JTAG 引脚重新配置为其他功能或者用户忘记将 Vtar 连接到 JTAG 适配器。

### 7: ESP32 引脚和 JTAG 接口信号

<table>
<thead>
<tr>
<th>ESP32 引脚</th>
<th>JTAG 信号</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>

下面是 GDB 在应用程序进入重新配置 MTDO/GPIO15 作为输入代码后报告的一系列错误摘要:

```
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. For example:

```
openocd -c 'set ESP_FLASH_SIZE 0' -f board/esp32-wrover-kit-3.3v.cfg
```

注解：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.

报告 OpenOCD / GDB 的问题 如果你遇到 OpenOCD 或者 GDB 程序本身的问题，并且在网上没有找到可用的解决方案，请前往 https://github.com/espressif/openocd-esp32/issues 新建一个议题。

1. 请在问题报告中提供你使用的配置的详细信息:
   a. JTAG 适配器类型。
   b. 用于编译和加载正在调试的应用程序的 ESP-IDF 版本号。
   c. 用于调试的操作系统的详细信息。
   d. 操作系统是在本地计算机运行还是在虚拟机上运行？
2. 创建一个能够演示问题的简单示例工程，描述复现该问题的步骤。且这个调试示例不能受到 Wi-Fi 协议栈引入的非确定性行为的影响，因而再次遇到同样问题时，更容易复现。
3. 在启动命令中添加额外的参数来输出调试日志。

OpenOCD 端：

```
openocd -l openocd_log.txt -d3 -f board/esp32-wrover-kit-3.3v.cfg
```

这种方式会将日志输出到文件，但是它会阻止调试信息打印在终端上。当有大量信息需要输出的时候（比如调试等级提高到 -d3）这是个不错的选择。如果你仍然希望在屏幕上看到调试日志，请改用以下命令：

```
openocd -d3 -f board/esp32-wrover-kit-3.3v.cfg 2>&1 | tee openocd.log
```

Debugger 端：

```
xtensa-esp32-elf-gdb -ex "set remotelogfile gdb_log.txt" <all other options>
```

也可以将命令 remotelogfile gdb_log.txt 添加到 gdbinit 文件中。

4. 请将 openocd_log.txt 和 gdb_log.txt 文件附在你的问题报告中。

4.14.10 相关文档

使用调试器

本节会在 Eclipse 和 命令行 中分别介绍配置和运行调试器的方法。我们建议你首先通过 命令行 检查调试器是否正常工作，然后再转到使用 Eclipse 平台。

在 Eclipse 中使用 GDB 标准的 Eclipse 安装流程默认安装调试功能，另外我们还可以使用插件来调试，比如 “GDB Hardware Debugging”。这个插件用起来非常方便，本指南会详细介绍该插件的使用方法。

首先，通过打开 Eclipse 并转到 “Help” > “Install New Software” 来安装 “GDB Hardware Debugging” 插件。安装完成后，按照以下步骤配置调试会话。请注意，一些配置参数是通用的，有些则针对特定项目。我们会通过配置“blink”示例项目的调试环境来进行展示，先请按照使用 Eclipse IDE 编译和烧写 文章介绍
的方法将该示例项目添加到 Eclipse 的工作空间。示例项目 get-started/blink 的源代码可以在 ESP-IDF 仓库的 examples 目录下找到。

1. 在 Eclipse 中，进入 Run > Debug Configuration，会出现一个新的窗口。在窗口的左侧窗格中，双击 “GDB Hardware Debugging”（或者选择 “GDB Hardware Debugging” 然后按下 “New” 按钮）来新建一个配置。
2. 在右边显示的表单中， “Name:” 一栏中输入配置的名称，例如：“Blink checking”。
3. 在下面的 “Main” 选项卡中，点击 “Project” 边上的 “Browse” 按钮，然后选择当前的 “blink” 项目。
4. 在下一行的 “C/C++ Application:” 中，点击 “Browse” 按钮，选择 “blink.elf” 文件。如果 “blink.elf” 文件不存在，那么很可能会出现编译错误。请参考使用 Eclipse IDE 编译和调试指南中的介绍。
5. 最后，在 “Build (if required) before launching” 下面点击 “Disable auto build”。

上述步骤 1-5 的示例输入如下图所示。

![GDB 硬件调试的配置 - Main 选项卡](image)

6. 点击 “Debugger” 选项卡，在 “GDB Command” 栏中输入 xtensa-esp32-elf-gdb 来调用调试器。
7. 更改 “Remote host” 的默认配置，在 “Port number” 下面输入 3333。

上述步骤 6-7 的示例输入如下图所示。

8. 最后一个需要更改默认配置的选项卡是 “Startup” 选项卡。在 “Initialization Commands” 下，取消选中 “Reset and Delay (seconds)” 和 “Halt”，然后在下面一栏中输入以下命令：

```
mon reset halt
flushregs
set remote hardware-watchpoint-limit 2
```

**注释:** 如果你想在启动新的调试会话之前自动更新闪存中的镜像，请在 “Initialization Commands” 文本框的开头添加以下命令行:
图 8: GDB 硬件调试的配置 - Debugger 选项卡
有关 program_esp 命令的说明请参考上传待调试的应用程序 章节。
9. 在“Load Image and Symbols”下，取消选中“Load image”选项。
10. 在同一个选项卡中继续往下浏览，建立一个初始断点用来在调试器复位后暂停 CPU。插件会根据“Set break point at:”一栏中输入的函数名，在该函数的开头设置断点。选中这一选项，并在相应的字段中输入 app_main。
11. 选中“Resume”选项，这会使执行在每次调用步 8 中的 mon reset halt 之后恢复，然后在 app_main 的断点处停止。

上述步骤 8 - 11 的示例输入如下图所示。

图 9: GDB 硬件调试的配置 - Startup 选项卡

上面的启动序列看起来有些复杂，如果你对其中的初始化命令不太熟悉，请查阅调试器的启动命令的含义 章节获取更多说明。
12. 如果你前面已经完成配置 ESP32 目标板 中介绍的步骤，那么目标正在运行并准备与调试器进行对话。按下“Debug”按钮就可以直接调试。否则请按下“Apply”按钮保存配置，返回配置 ESP32 目标板 章节进行配置，最后再回到这里开始调试。

一旦所有 1 - 12 的配置步骤都已完成，Eclipse 就会打开“Debug”视图，如下图所示。

如果你不太了解 GDB 的常用方法，请查阅使用 Eclipse 的调试示例 文章中的调试示例章节调试范例。

在命令行中使用 GDB
图 10: Eclipse 中的调试视图
1. 为了能够启动调试会话，需要先启动并运行目标，如果还没有完成，请按照配置 ESP32 目标板 中的介绍进行操作。

2. 打开一个新的终端会话并前往待调试的项目目录，比如：

```
   cd ~/esp/blink
```

3. 当启动调试器时，通常需要提供几个配置参数和命令，为了避免每次都在命令行中逐行输入这些命令，我们可以新建一个配置文件，并将其命名为 gdbinit:

```
   target remote :3333
   set remote hardware-watchpoint-limit 2
   mon reset halt
   flushregs
   thb app_main
   c
```

将此文件保存在当前目录中。有关 gdbinit 文件内部的更多信息，请参阅调试器的启动命令的含义 章节。

4. 准备好启动 GDB，请在终端中输入以下内容：

```
   xtensa-esp32-elf-gdb -x gdbinit build/blink.elf
```

5. 如果前面的步骤已经正确完成，你会看到如下的输出日志，在日志的最后会出现 (gdb) 提示符：

```
user-name@computer-name:~/esp/blink$ xtensa-esp32-elf-gdb -x gdbinit build/
   →blink.elf
GNU gdb (crosstool-NG crosstool-ng-1.22.0-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).
esp32 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=0x400D1D8
```

(下页继续)
使用 `idf.py` 进行调试

我们还可以使用 `idf.py` 更方便地执行上述提到的调试命令:

1. `idf.py openocd`

   在终端中运行 OpenOCD，其配置信息来源于环境变量或命令行。默认会使用 `OPENOCD_SCRIPTS` 环境变量中指定的脚本路径，它是由 ESP-IDF 项目仓库中的导出脚本（`export.sh` 或 `export.bat`）添加到系统环境变量中的。当然，我们可以在命令行中通过 `--openocd-scripts` 来覆盖这个变量的值。

   你可以定义 `OPENOCD_COMMANDS` 环境变量来指定当前开发板的 JTAG 配置，或者通过 `--openocd-commands` 传递该参数。如果这二者都没有被定义，那么 OpenOCD 会使用 `-f board/esp32-wrover-kit-3.3v.cfg` 参数来启动。

2. `idf.py gdb`

   根据当前项目的 elf 文件自动生成 gdb 启动脚本，然后会按照命令行中使用 GDB 中所描述的步骤启动 GDB。

3. `idf.py gdbtui`

   和步骤 2 相同，但是会在启动 GDB 的时候传递 `tui` 参数，这样可以方便在调试过程中查看源代码。

4. `idf.py gdbgui`

   在浏览器中打开调试器的前端界面。上述这些命令也可以合并到一起使用。`idf.py` 会自动将后台进程（比如 openocd）最先运行，交互式进程（比如 gdb, monitor）最后运行。

   常用的组合命令如下所示:

   ```
   idf.py openocd gdbgui monitor
   ```

   上述命令会将 OpenOCD 运行至后台，然后启动 gdbgui 打开一个浏览器窗口，显示调试器的前端界面，最后在活动终端打开串口监视器。

调试示例

本节将介绍如何在 Eclipse 和命令行中使用 GDB 进行调试的示例。

使用 Eclipse 的调试示例

请检查目标板是否已经准备就绪，并加载了 `get-started/blink` 示例代码。然后按照在 Eclipse 中使用 GDB 中介绍的步骤配置和启动调试器。最后选择让应用程序在 `app_main()` 建立的断点处停止。

本小节的示例

1. 浏览代码，查看堆栈和线程
图 11: Eclipse 中的 Debug 视图
2. 设置和清除断点
3. 手动暂停目标
4. 单步执行代码
5. 查看并设置内存
6. 观察和设置程序变量
7. 设置条件断点

浏览代码、查看堆栈和线程 当目标暂停时，调试器会在“Debug”窗口中显示线程的列表，程序暂停的代码行在下面的另一个窗口中被高亮显示，如下图所示。此时板子上的 LED 停止了闪烁。

图 12: 调试时目标停止

暂停的程序所在线程也会被展开，显示函数调用的堆栈。它表示直到目标暂停所在代码行（下图高亮处）为止的相关函数的调用关系。1 号线程下函数调用堆栈的第一行包含了最后一个被调用的函数 app_main()，根据下一行显示，它又是在函数 main_task() 中被调用的。堆栈的每一行还包含调用函数的文件名和行号。通过单击每个堆栈的条目，在下面的窗口中，你将看到此文件的内容。

通过展开线程，你可以浏览整个应用程序。展开 5 号线程，它包含了更长的函数调用堆栈，你可以看到函数调用旁边的数字，比如 0x4000000C，它们代表未以源码形式提供的二进制代码所在的内存地址。

无论项目是以源代码还是仅以二进制形式提供，在右边一个窗口中，都可以看到反汇编后的机器代码。

回到 1 号线程中的 app_main() 函数所在的 blink.c 源码文件，下面的示例将会以该文件为模介绍调试的常用功能。调试器可以轻松浏览整个应用程序的代码，这给单步调试代码和设置断点带来了很大的便利，下面将——展开讨论。

设置和清除断点 在调试时，我们希望能够直接的代码行停止应用程序，然后检查特定的变量、内存、寄存器和外设的状态。为此我们需要使用断点，以便在特定某行代码处快速访问和停止应用程序。

我们在控制 LED 状态发生变化的两处代码行分别设置一个断点。基于以上代码列表，这两处分别为第 33 和 36 代码行。按住键盘上的“Control”键，双击 blink.c 文件中的行号 33，并在弹出的对话框中点击
图 13: 浏览函数调用堆栈
“OK”按钮进行确定。如果你不想看到此对话框，双击行号即可。执行同样操作，在第 36 行设置另外一个断点。

图 14: 设置断点

断点的数量和位置信息会显示在右上角的“断点”窗口中。单击“Show Breakpoints Supported by Selected Target”图标可以刷新此列表。除了刚才设置的两个断点外，列表中可能还包含在调试器启动时设置在 app_main() 函数处的临时断点。由于最多只允许设置两个断点（详细信息请参阅可用的断点和观察点），你需要将其删除，否则调试会失败。

单击“Resume”（如果“Resume”按钮是灰色的，请先单击 8 号线程的 blink_task() 函数）后处理器将开始继续运行，并在断点处停止。再一次单击“Resume”按钮，使程序再次运行，然后停在第二个断点处，依次类推。

每次单击“Resume”按钮恢复程序运行后，都会看到 LED 切换状态。

更多关于断点的信息，请参阅可用的断点和观察点和关于断点的补充知识。

手动暂停目标  在调试时，你可以恢复程序运行并输入代码等待某个事件发生或者保持无限循环而不设置任何断点。后者，如果想要返回调试模式，可以通过单击“Suspend”按钮来手动中断程序的运行。

在此之前，请删除所有的断点，然后单击“Resume”按钮。接着单击“Suspend”按钮，应用程序会停止在某个随机的位置，此时 LED 也将停止闪烁。调试器将展开断点并高亮显示停止的代码行。

在上图所示的情况下，应用程序已经在 freertos_hooks.c 文件的第 52 行暂停运行，现在你可以通过单击“Resume”按钮再次将其恢复运行或者进行下面要介绍的调试工作。

单步执行代码 我们还可以使用“Step Into (F5)”和“Step Over (F6)”命令单步执行代码。这两者之间的区别是执行“Step Into (F5)”命令会进入调用的子程序，而执行“Step Over (F6)”命令则会直接将子程序看作单个源码行，单步就能将其运行结束。
图 15: 设置了三个断点 / 最多允许两个断点
图 16: 手动暂停目标
在继续演示此功能之前，请参照上文所述确保目前只在`blink.c`文件的第36行设置了一个断点。
按下F8键让程序继续运行然后在断点处停止运行，多次按下“Step Over (F6)”按钮，观察调试器是如何单步执行一行代码的。

![Step Over (F6)](image)

图17: 使用“Step Over (F6)”单步执行代码

如果你改用“Step Into (F5)”，那么调试器将会进入调用的子程序内部。
在上述例子中，调试器进入`gpio_set_level(BLINK_GPIO, 0)`代码内部，同时代码窗口快速切换到`gpio.c`驱动文件。
请参阅“next”命令无法跳过子程序的原因 文档以了解 next 命令的潜在局限。

### 查看并设置内存
要显示或者设置内存的内容，请使用“调试”视图中位于底部的“Memory”选项卡。
在“Memory”选项卡下，我们将在内存地址0x3FF44004处读取和写入内容，该地址也是GPIO_OUT_REG寄存器的地址，可以用来控制（设置或者清除）某个GPIO的电平。
关于该寄存器的更多详细信息，请参阅 ESP32技术参考手册中的 IO_MUX 和 GPIO Matrix 章节。
同样在`blink.c`项目文件中，在两个`gpio_set_level`语句的后面各设置一个断点，单击“Memory”选项卡，然后单击“Add Memory Monitor”按钮，在弹出的对话框中输入0x3FF44004。
按下F8按键恢复程序运行，并观察“Monitor”选项卡。
每按一次F8，你就会看到在内存0x3FF44004地址处的一个比特被翻转（并且LED会改变状态）。
要修改内存的数值，请在“Monitor”选项卡中找到待修改的内存地址，如前面观察的结果一样，输入特定比特翻转后的值。当按下回车键后，将立即看到LED的状态发生了改变。
图 18: 使用 “Step Into (F5)” 单步执行代码

图 19: 观察内存地址 0x3FF44004 处的某个比特被置高
观察和设置程序变量 常见的调试任务是在程序执行期间检查程序中某个变量的值，为了演示这个功能，更新 blink.c 文件，在 blink_task 函数的上面添加一个全局变量声明 int i，然后在 while(1) 里添加 i++，这样每次 LED 改变状态的时候，变量 i 都会增加 1。

退出调试器，这样就不会与新代码混淆，然后重新构建并烧写代码到 ESP32 中，接着重启调试器，注意，这里不需要我们重启 OpenOCD。

一旦程序停止运行，在代码 i++ 处添加一个断点。

下一步，在 “Breakpoints” 所在的窗口中，选择 “Expressions” 选项卡。如果该选项卡不存在，请在顶部菜单栏的 Window > Show View > Expressions 中添加这一选项卡。然后在该选项卡中单击“Add new expression”，并输入 i。

按下 F8 继续运行程序，每次程序停止时，都会看到变量 i 的值在递增。

如想更改 i 的值，可以在“Value”一栏中输入新的数值。按下 “Resume (F8)” 后，程序将从新输入的数字开始递增 i。

设置条件断点 接下来的内容更为有趣，你可能想在一定条件满足的情况下设置断点，然后让程序停止运行。右击断点打开上下文菜单，选择 “Breakpoint Properties”，将 “Type:” 改选为 “Hardware” 然后在 “Condition:” 一栏中输入条件表达式，例如 i == 2。

如果当前 i 的值小于 2（如果有需要也可以更改这个阈值）并且程序被恢复运行，那么 LED 就会循环闪烁，直到 i == 2 条件成立，最后程序停止在该处。

使用命令行的调试示例 请检查您的目标板是否已经准备好，并加载了 get-started/blink 示例代码，然后按照命令行中使用 GDB 中介的步骤配置和启动调试器，最后选择让应用程序在 app_main() 建立的断点处停止运行。

```
Temporary breakpoint 1, app_main() at /home/user-name/esp/blink/main/.blink.c:43
43 xTaskCreate(&blink_task, "blink_task", configMINIMAL_STACK_SIZE, NULL, _
-5, NULL);
(gdb)
```

本小节的示例
1. 浏览代码，查看堆栈和线程
2. 设置和清除断点
3. 暂停和恢复应用程序的运行
4. 单步执行代码
5. 查看并设置内存
图 21: 观察程序变量 “i”
图 22: 设置条件断点
6. 观察和设置程序变量
7. 设置条件断点

浏览代码，查看堆栈和线程 当看到 (gdb) 提示符时，应用程序已停止运行，LED 也停止闪烁。
要找到代码暂停的位置，输入 l 或者 list 命令，调试器会打印出停止点 (blink.c 代码文件的第 43 行) 附近的几行代码。

```c
(gdb) l
37
38 }
39 }
40
41 void app_main()
42 {
43 xTaskCreate(&blink_task, "blink_task", configMINIMAL_STACK_SIZE, NULL,
44 )
45 return;
46 }
(gdb)
```

也可以通过输入 l 30, 40 等命令来查看特定行号范围内的代码。
使用 bt 或者 backtrace 来查看哪些函数最终导致了此代码被调用。

```c
(gdb) bt
#0 app_main () at /home/user-name/esp/blink/main/./blink.c:43
#1 0x400d057e in main_task (args=0x0) at /home/user-name/esp/esp-idf/components/
    esp32/./cpu_start.c:339
(gdb)
```

输出的第 0 行表示应用程序暂停之前调用的最后一个函数，即我们之前列出的 app_main ()。app_main () 又被位于 cpu_start.c 文件第 339 行的 main_task 函数调用。

想查看 cpu_start.c 文件中 main_task 函数的上下文，需要输入 frame N，其中 N = 1，因为根据前面的输出，main_task 位于 #1 下。

```c
(gdb) frame 1
#1 0x400d057e in main_task (args=0x0) at /home/user-name/esp/esp-idf/components/
    esp32/./cpu_start.c:339
339 app_main();
(gdb)
```

输入 1 将显示一段名为 app_main() 的代码 (在第 339 行)。

```c
(gdb) l
334
335 #endif
336 //Enable allocation in region where the startup stacks were located.
337 heap_caps_enable_nonos_stack_heaps();
338 app_main();
339 vTaskDelete(NULL);
340 }
341 }
342 }
(gdb)
```

通过打印前面的一些行，你会看到我们一直在寻找的 main_task 函数。
如果要查看其他代码，可以输入 `i threads` 命令，则会输出目标板上运行的线程列表:

```
(gdb) i threads
   Id   Target Id   Frame
  8    Thread 1073411336 (dport) 0x400d0848 in dport_access_init_core (arg=...
       at /home/user-name/esp/esp-idf/components/esp32/.dport_access.c:170
  7    Thread 1073408744 (ipc0) xQueueGenericReceive (xQueue=0x3ffae694,...
       pvBuffer=0x0, xTicksToWait=1644638200, xJustPeeking=0) at /home/user-name/esp/esp-idf/components/freertos/.queue.
       c:1452
  6    Thread 1073431096 (Tmr Svc) prvTimerTask (pvParameters=0x0)
       at /home/user-name/esp/esp-idf/components/freertos/.timers.c:445
  5    Thread 1073410208 (ipc1 : Running) 0x4000bfea in ?? ()
  4    Thread 1073432224 (dport) dport_access_init_core (arg=0x0)
       at /home/user-name/esp/esp-idf/components/freertos/.dport_access.c:150
  3    Thread 1073413156 (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
(gdb)
```

线程列表显示了每个线程最后一个被调用的函数以及所在的 C 源文件名（如果存在的话）。

您可以通过输入 `thread N` 进入特定的线程，其中 N 是线程 ID。我们进入 5 号线程来看一下它是如何工作的:

```
(gdb) thread 5
[Switching to thread 5 (Thread 1073410208)]
#0 0x4000bfea in ?? ()
(gdb)
```

然后查看回溯:

```
(gdb) bt
#0 0x4000bfea in ?? ()
#1 0x40083a85 in vPortCPUReleaseMutex (mux=<optimized out>) at /home/user-name/esp-idf/components/freertos/.port.c:415
#2 0x40083fc8 in vTaskSwitchContext () at /home/user-name/esp-idf/components/freertos/.tasks.c:2846
#3 0x4008532b in _frxtDispatch ()
#4 0x40089395c in xPortStartScheduler () at /home/user-name/esp-idf/components/freertos/.port.c:222
#5 0x40000000c in ?? ()
```
#6 0x4000000c in ?? ()
#7 0x4000000c in ?? ()
#8 0x4000000c in ?? ()

(gdb)

如上所示，函数可能会包含多个条目，方便查看直至目标停止运行的函数调用顺序。如果找不到某个函数的源码文件，将会使用问号 ?? 替代，这表示该函数是以二进制格式提供的，像 0x4000bfea 这样的值是被调用函数所在的内存地址。

使用诸如 bt, i threads, thread N 和 list 命令可以浏览整个应用程序的代码。这给单步调试代码和设置断点带来很大的便利，下面将——展开来讨论。

设置和清除断点 在调试时，我们希望能够关键的代码行停止应用程序，然后检查特定的变量，内存、寄存器和外设的状态。为此我们需要使用断点，以便在特定某行代码处快速访问和停止应用程序。

我们在控制 LED 状态发生变化的两处代码行分别设置一个断点。基于以上代码列表，这两处分别为第 33 和 36 代码行。使用命令 break M 设置断点，其中 M 是具体的代码行:

```
(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.
```

输入命令 c，处理器将运行并在断点处停止。再次输入 c 将使其再次运行，并在第二个断点处停止。以此类推:

```
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB6F6 (active)   APP_CPU: PC=0x400D10D8
Breakpoint 2, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/./
  → blink.c:33
  33  gpio_set_level(BLINK_GPIO, 0);
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB6F8 (active)   APP_CPU: PC=0x400D10D8
Target halted. PRO_CPU: PC=0x400DB704 (active)   APP_CPU: PC=0x400D10D8
Breakpoint 3, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/./
  → blink.c:36
  36  gpio_set_level(BLINK_GPIO, 1);
(gdb)
```

只有在输入命令 c 恢复程序运行后才能看到 LED 改变状态。

查看已设置断点的数量和位置，请使用命令 info break:

```
(gdb) info break
Num Type Disp Enb Address What
2   breakpoint keep y  0x400db6f6 in blink_task at /home/user-name/esp/
  → blink/main/./blink.c:33
  breakpoint already hit 1 time
3   breakpoint keep y  0x400db704 in blink_task at /home/user-name/esp/
  → blink/main/./blink.c:36
  breakpoint already hit 1 time
(gdb)
```

请注意，断点序号（在 Num 栏列出）从 2 开始，这是因为在调试器启动时执行 thb app_main 命令已经在 app_main() 函数处建立了第一个断点。由于它是一个临时断点，已经被自动删除，所以没有被列出。

要删除一个断点，请输入 delete N 命令 (或者简写成 d N)，其中 N 代表断点序号:

```
(gdb) delete 2
Breakpoint 2 disabled
(gdb) delete 3
Breakpoint 3 disabled
```
更多关于断点的信息，请参阅可用的断点和观察点 相关断点的补充知识。

### 停止和恢复应用程序的运行
在调试时，可以恢复程序运行并输入代码等待某个事件发生或者保持无限循环而不设置任何断点。对于后者，想要返回调试模式，可以通过输入 Ctrl+C 手动中断程序的运行。

在此之前，请删除所有的断点，然后输入 c 恢复程序运行。接着输入 Ctrl+C，应用程序会停止在某个随机的位置。此时 LED 也将停止闪烁。调试器会打印如下信息:

```plaintext
(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)
```

在上图所示的情况下，应用程序已经在 freertos_hooks.c 文件的第 52 行暂停运行，现在您可以通过输入 c 再次将其恢复运行或者进行如下所述的一些调试工作。

**注释：** 在 MSYS2 的 shell 中输入 Ctrl+C 并不会暂停目标的运行，而是会退出调试器。解决这个问题的方法可以通过使用 Eclipse 来调试 或者参考 http://www.mingw.org/wiki/Workaround_for_GDB_Ctrl_C_Interrupt 里的解决方案。

### 单步执行代码
我们还可以使用 step 和 next 命令（可以简写成 s 和 n）单步执行代码。这二者之间的区别是执行“step”命令会进入调用的子程序内部，而执行“next”命令则会直接将子程序看成单个源码行，单步就能将其运行结束。

在继续演示此功能之前，请使用前面介绍的 break 和 delete 命令，确保目前只在 blink.c 文件的第 36 行设置了一个断点:

```plaintext
(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)
```

输入 c 恢复程序运行然后等它在断点处停止运行:

```plaintext
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB754 (active) APP_CPU: PC=0x400D1128
Breakpoint 3, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/./→
    blink.c:36
36    gpio_set_level(BLINK_GPIO, 1);
(gdb)
```

然后输入 n 多次，观察调试器是如何单步执行一行代码的:
如果你输入 `s`，那么调试器将进入子程序:

```
(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=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
   → GPIO_CHECK(GPIO_IS_VALID_OUTPUT_GPIO(gpio_num), "GPIO output gpio_num error", ESP_ERR_INVALID_ARG);
```

上述例子中，调试器进入 `gpio_set_level(BLINK_GPIO, 0)` 代码内部，同时代码窗口快速切换到 `gpio.c` 驱动文件。

请参阅 "next" 命令无法跳过子程序的原因 文档以了解 `next` 命令的潜在局限。

查看并设置内存 使用命令 `x` 可以显示内存的内容，配合其余参数还可以调整所显示内存位置的格式和数量。运行 `help x` 可以查看更多相关细节。与 `x` 命令配合使用的命令是 `set`，它允许你将值写入内存。

为了演示 `x` 和 `set` 的使用，我们将在内存地址 0x3FF44004 处读取和写入内容。该地址也是 `GPIO_OUT_REG` 寄存器的地址，可以用来控制（设置或者清除）某个 `GPIO` 的电平。关于该寄存器的更多详细信息，请参阅 `ESP32 技术参考手册` 中的 IO_MUX 和 GPIO Matrix 章节。

同样在 `blink.c` 项目文件中，在两个 `gpio_set_level` 语句的后面各设置一个断点。输入两次 `c` 命令后停止在断点处，然后输入 `x /1wx 0x3FF44004` 来显示 `GPIO_OUT_REG` 寄存器的值:

```
(gdb) x /1wx 0x3FF44004
0x3FF44004: 0x00000000
(gdb) c
Continuing.
```

```
34 vTaskDelay(1000 / portTICK_PERIOD_MS);
```

```
(gdb) x /1wx 0x3FF44004
0x3FF44004: 0x00000000
```

```
(gdb) c
Continuing.
```
如果闪烁的 LED 连接到了 GPIO4，那么每次 LED 改变状态时你会看到第 4 比特被翻转:

```
0x3ff44004: 0x00000010
```

现在，当 LED 熄灭时，与之对应地会显示 0x3ff44004: 0x00000000，尝试使用 set 命令向相同的内存地址写入 0x00000000 来将该比特置高:

```
(gdb) x /1wx 0x3FF44004
0x3ff44004: 0x00000000
(gdb) set {unsigned int}0x3FF44004=0x000010
```

在输入 set {unsigned int}0x3FF44004=0x000010 命令后，你会立即看到 LED 亮起。

**观察和设置程序变量** 常见的调试任务是在程序运行期间检查程序中某个变量的值，为了能够演示这个功能，更新 blink.c 文件，在 blink_task 函数的上面添加一个全局变量的声明 int i，然后在 while(1) 里添加 i++，这样每次 LED 改变状态的时候，变量 i 都会增加 1。

退出调试器。这样就不会与新代码混淆，然后重新构建并烧写代码到 ESP32 中，接着重启调试器。注意，这里不需要我们重启 OpenOCD。

一旦程序停止运行，输入命令 watch i:

```
(gdb) watch i
Hardware watchpoint 2: i
(gdb)
```

这会在所有变量 i 发生改变的代码处插入所谓的“观察点”。现在输入 continue 命令来恢复应用程序的运行并观察它停止:

```
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB751 (active) APP_CPU: PC=0x400D0811
[New Thread 1073432196]
```

```
Program received signal SIGTRAP, Trace/breakpoint trap.
[Switching to Thread 1073432196]
0x400db751 in blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/.
-blink.c:33
33 i++;
(gdb)
```

多次恢复程序运行后，变量 i 的值会增加。现在你可以输入 print i（简写 p i）来查看当前 i 的值:

```
(gdb) p i
$1 = 3
```

要修改 i 的值，请使用 set 命令，如下所示（可以将其打印输出来查看是否已修改）:

```
(gdb) set var i = 0
(gdb) p i
$3 = 0
```

最多可以使用两个观察点，详细信息请参阅可用的断点和观察点。
你可能想在一定条件满足的情况下设置断点。请先删除已有的断点，然后尝试如下命令:

```
(gdb) break blink.c:34 if (i == 2)
Breakpoint 3 at 0x400db753: file /home/user-name/esp/blink/main/./blink.c, line 34.
(gdb)
```

以上命令在 blink.c 文件的 34 处设置了一个条件断点。当 i==2 条件满足时，程序会停止运行。

如果当前 i 的值小于 2 并且程序被恢复运行，那么 LED 就会循环闪烁，直到 i == 2 条件成立，最后程序停止在该处:

```
(gdb) set var i = 0
(gdb) c
Continuing.
```

```
(blink.c) 34 gpio_set_level(BLINK_GPIO, 0);
```

```
(gdb)
```

获得命令的帮助信息 目前所介绍的都是些非常基础的命令，目的在于让您快速上手 JTAG 调试。如果想获得特定命令的语法和功能相关的信息，请在 (gdb) 提示符下输入 help 和命令名:

```
(gdb) help next
Step program, proceeding through subroutine calls.
Usage: next [N]
Unlike "step", if the current source line calls a subroutine, this command does not enter the subroutine, but instead steps over the call, in effect treating it as a single source line.
(gdb)
```

只需输入 help 命令，即可获得高级命令列表。帮助你了解更多详细信息。此外，还可以参考一些 GDB 命令速查表，比如 https://darkdust.net/files/GDB%20Cheat%20Sheet.pdf。虽然不是所有命令都适用于嵌入式环境，但还是会有所裨益。

结束调试会话 输入命令 q 可以退出调试器:

```
(gdb) q
A debugging session is active.

   Inferior 1 [Remote target] will be detached.

Quit anyway? (y or n) y
Detaching from program: /home/user-name/esp/blink/build/blink.elf, Remote target
Ending remote debugging.
user-name@computer-name:~/esp/blink$
```

应用层跟踪库

概述 为了分析应用程序的行为，IDF 提供了一个有用的功能：应用层跟踪。这个功能以库的形式提供，可以通过 menuconfig 开启。此功能使得用户可以在程序运行开销很小的前提下，通过 JTAG 接口在主机和 ESP32 之间传输任意数据。

开发人员可以使用这个功能将应用程序的运行状态发送给主机，运行时接收来自主机的命令或其他类型的信息。该库的主要使用场景有:

**Chapter 4. API 指南**
1. 收集应用程序特定的数据，具体请参阅特定应用程序的跟踪
2. 轻量级的日志记录，具体请参阅记录日志到主机
3. 系统行为分析，具体请参阅基于 SEGGER SystemView 的系统行为分析

使用 JTAG 接口的跟踪组件工作示意图：

图 23: 使用 JTAG 接口的跟踪组件

运行模式：该库支持两种操作模式：

后验模式：这是默认的模式。该模式不需要和主机进行交互。在这种模式下，跟踪模块不会检查主机是否已经从 HW UP BUFFER 缓冲区读取所有数据，而是直接使用新数据覆盖旧数据。该模式在用户仅对最新的跟踪数据感兴趣时会很有用，例如分析程序在崩溃之前的行为。主机可以稍后根据用户的请求来读取数据，例如通过特殊的 OpenOCD 命令（假如使用了 JTAG 接口）。

流模式：当主机连接到 ESP32 时，跟踪模块会进入此模式。在这种模式下，跟踪模块在新数据写入 HW UP BUFFER 之前会检查其中是否有足够的空间，并在必要的时候等待主机读取数据并释放足够的内存。用户会将最长的等待时间作为超时时间参数传递给相应的 API 函数。如果超时时间是个有限值，那么应用程序有可能会因为超时而将待写的的数据丢弃。尤其需要注意，如果在讲究时效的代码中（如中断处理函数，操作系统调度等）指定了无限的超时时间，那么系统会产生故障。为了避免丢失此类关键数据，开发人员可以使用 menuconfig 中开启 CONFIG_APPTRACE_PEND_DATA_SIZE_MAX 选项来启用额外的数据缓冲区。此宏还指定了在上述条件下可以缓冲的数据大小，它有助于缓解由于 USB 总线拥塞等导致的向主机传输数据间歇性减缓的状况。但是，当跟踪数据流的平均比特率超过硬件接口的能力时，它也无能为力。

配置选项与依赖项

使用此功能需要在主机端和目标端做相应的配置：

1. 主机端：应用程序跟踪是通过 JTAG 来完成的，因此需要在主机上安装并运行 OpenOCD。相关详细信息请参阅 JTAG Debugging。
2. 目标端：在 menuconfig 中开启应用程序跟踪功能。Component config > Application Level Tracing 菜单允许选择跟踪数据的传输目标（具体用于传输的硬件接口），选择任一非 None 的目标都会自动开启 CONFIG_APPTRACE_ENABLE 这个选项。
Chapter 4. API 指南

注解：为了实现更高的数据速率并降低丢包率，建议优化 JTAG 的时钟频率，使其达到能够稳定运行的
最大值。详细信息请参阅优化 JTAG 的速度。

以下为前述未提及的另外两个 menuconfig 选项:

1. Threshold for flushing last trace data to host on panic (CONFIG_APPTRACE_POSTMORTEM_FLUSH_THRESH).
   由于在 JTAG 上工作的性质，此选项是必选项。在该模式下，跟踪数据以 16 KB 数据块的形式曝露
   给主机。在后验模式中，当一个块被填充时，它会曝露给主机，而之前的块会变得不可用。换句话说，
   跟踪数据以 16 KB 的粒度进行覆盖。在发生 panic 的时候，当前输入块的最新数据将会被曝露
   给主机，主机可以读取它们以进行后续分析。如果系统发生 panic 的时候仍有少量数据还没来得及
   曝光给主机，那么之前收集的 16 KB 的数据将丢失，主机可能看到非常少的最新的跟踪部分，它可
   能不足以用来诊断问题所在。此 menuconfig 选项允许避免此类情况。它可以控制在发生 panic 时刷
   新数据的阈值。例如用户可以确定它需要不少于 512 字节的最新跟踪数据，所以如果在发生 panic
   时待处理的数据少于 512 字节，它们不会被刷新，也不会覆盖之前的 16 KB。该选项仅在后验模式
   和 JTAG 工作时有意义。

2. Timeout for flushing last trace data to host on panic (CONFIG_APPTRACE_ONPANIC_HOST_FLUSH_TMO).
   该选项仅在流模式下才起作用，它控制跟踪模块在发生 panic 时等待主机读取最新数据的最长时间。

如何使用这个库：该库提供了用于在主机和 ESP32 之间传输任意数据的 API。当在 menuconfig 中启用时，
目标应用程序的跟踪模块会在系统启动时自动初始化，因此用户需要做的就是调用相应的 API 来发送、
接收或者刷新数据。

特定应用程序的跟踪：通常，用户需要决定在每个方向上待传输数据的类型以及如何解析（处理）这些
数据。要想在目标和主机之间传输数据，用户必须要执行以下几个步骤。

1. 在目标端，用户需要实现将跟踪数据写入主机的算法，下面的代码片段展示了如何执行此操作。

```c
#include "esp_app_trace.h"
...
char buf[] = "Hello World!", number;

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);

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;
}
    char *ptr = (char *)esp_apptrace_buffer_get(ESP_APPTRACE_DEST_TRAX, 32, 100/*tmo in us*/);
```

2. 在主机端， esp_apptrace_buffer_get() 函数使用 memcpy 把用户数据复制到内部缓存中。在某些情况下，使用
esp_apptrace_buffer_get() 和 esp_apptrace_buffer_put() 函数会更加理想，它们允
许开发人员自行分配缓冲区并填充。下面的代码片段展示了如何执行此操作。

```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;
}
    char *ptr = (char *)esp_apptrace_buffer_get(ESP_APPTRACE_DEST_TRAX, 32, 100/*tmo in us*/);
```
另外，根据实际项目的需要，用户可能希望从主机接收数据。下面的代码片段展示了如何执行此操作。

```c
#include "esp_app_trace.h"
...
char buf[32];
char down_buf[32];
size_t sz = sizeof(buf);

/* config down buffer */
esp_apptrace_down_buffer_config(down_buf, sizeof(down_buf));
/* check for incoming data and read them if any */
esp_err_t res = esp_apptrace_read(ESP_APPTRACE_DEST_TRAX, buf, &sz, 0/*do not wait*/);
if (res != ESP_OK) {
    ESP_LOGE(TAG, "Failed to read data from host!");
    return res;
}
if (sz > 0) {
    /* we have data, process them */
    ...
}
```

`esp_apptrace_read()` 函数使用 `memcpy` 来把主机端的数据复制到用户缓存区。在某些情况下，使用 `esp_apptrace_down_buffer_get()` 和 `esp_apptrace_down_buffer_put()` 函数可能更为理想。它们允许开发人员占用一块读缓冲区并就地进行有关处理操作。下面的代码片段展示了如何执行此操作。

```c
#include "esp_app_trace.h"
...
char down_buf[32];
uint32_t *number;
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, /*tmo in us*/);
if (ptr == NULL) {
    ESP_LOGE(TAG, "Failed to get buffer!");
    return ESP_FAIL;
}
if (sz > 0) {
    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. 下一步是编译应用程序的镜像并将其下载到目标板上。这一步可以参考文档构建并烧写。
3. 运行 OpenOCD（参见 `JTAG 调试`）。
4. 连接到 OpenOCD 的 telnet 服务器，在终端执行如下命令 `telnet <oocd_host> 4444`。如果在运行 OpenOCD 的同一台机器上打开 telnet 会话，您可以使用 localhost 替换上面命令中的 `<oocd_host>`。
5. 使用特殊的 OpenOCD 命令开始收集待跟踪的数据，此命令将传输跟踪数据并将其重定向到指定的

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6. 最后一步是处理接收到的数据。由于数据格式由用户定义，因此处理阶段超出了文档的范围。数据处理的范例可参考位于 $IDF_PATH/tools/esp_app_trace 下的 Python 脚本 aptrace_proc.py（用于功能测试）和 logtrace_proc.py（请参阅记录日志到主机 章节中的详细信息）。

OpenOCD 应用程序跟踪命令 HW UP BUFFER 在用户数据块之间共享，并且会替 API 的调用者（在任务或者中断上下文中）填充分配到的内存。在多线程环境下，正在填充缓冲区的任务/中断可能会被另一个高优先级的任务/中断抢占，有可能发生主机会读取还未准备好的用户数据的情况。为了处理这样的情况，跟踪模块在所有用户数据块之前添加一个数据头，其中包含有分配的用户缓冲区的大小（2 字节）和实际字符串的长度（2 字节），也就是说数据头总共长 4 字节。负责读取跟踪数据的 OpenOCD 命令在读取不完整的用户数据块时会报错，但是无论如何它都会将整个用户数据块（包括未填充的区域）的内容放到输出文件中。

下面是 OpenOCD 应用程序跟踪命令的使用说明。

注解: 目前, OpenOCD 还不支持将任意用户数据发送到目标的命令。

命令用法:

```
esp32 aptrace [start <options>] | [stop]  | [status] | [dump <cores_num> <outfile>]
```

子命令:

- **start** 开始跟踪（连续流模式）。
- **stop** 停止跟踪。
- **status** 获取跟踪状态。
- **dump** 转储存所有后验模式的数据。

Start 子命令的语法:

```
start <outfile> [poll_period [trace_size [stop_tmo [wait4halt [skip_size]]]]]
```

**outfile** 用于保存来自两个 CPU 的数据文件的路径。该参数需要具有以下格式：file://path/to/file。

- **poll_period** 轮询跟踪数据的周期（单位：毫秒），如果大于 0 则以非阻塞模式运行。默认为 1 毫秒。
- **trace_size** 最多要收集的数据量（单位：字节），接收到指示数值的数据后将会停止跟踪。默认情况下是 -1（禁用跟踪大小停止触发器）。
- **stop_tmo** 空闲超时（单位：秒），如果指定的时间段内没有数据就会停止跟踪。默认为 -1（禁用跟踪超时触发器）。还可以将其设置为比目标跟踪命令之间的最长暂停值更长的值（可选）。
- **wait4halt** 如果设置为 0 则立即开始跟踪，否则命令等待目标停止（复位，打断点等），然后自动恢复并开始跟踪。默认值为 0。
- **skip_size** 开始时要跳过的字节数，默认为 0。

注解：如果 poll_period 为 0，则在跟踪停止之前，OpenOCD 的 telnet 命令将不可用。必须通过复位电路板或者在 OpenOCD 的窗口中（不是 telnet 会话窗口）按下 Ctrl+C。另一种选择是设置 trace_size 并等待，当收集到指定数据量时，跟踪会自动停止。

命令使用示例:

1. 将 2048 个字节的跟踪数据收集到 “trace.log” 文件中。该文件将保存在“openocd-esp32”目录中。

   ```
   esp32 aptrace start file://trace.log 1 2048 5 0 0
   ```

   跟踪数据会被检查并以非阻塞的模式保存到文件中，如果收集满 2048 字节的数据或者在 5 秒内都没有新的数据，那么该过程就会停止。
2. 在非阻塞模式下无限地检索跟踪数据。

```c
esp32_aptrace_start file://trace.log 1 -1 -1 0 0
```

对收集数据的大小没有限制，并且没有设置任何超时时间。可以通过在 OpenOCD 的 telnet 会话窗口中发送 esp32_aptrace_stop 命令，或者在 OpenOCD 窗口中使用快捷键 Ctrl+C 来停止此过程。

3. 检索跟踪数据并无限期保存。

```c
esp32_aptrace_start file://trace.log 0 -1 -1 0 0
```

在跟踪停止之前，OpenOCD 的 telnet 会话窗口将不可用。要停止跟踪，请在 OpenOCD 的窗口中使用快捷键 Ctrl+C。

4. 等待目标停止，然后恢复目标的操作并开始检索数据。当收集满 2048 字节的数据后就停止：

```c
esp32_aptrace_start file://trace.log 0 2048 -1 1 0
```

想要复位后立即开始跟踪，请使用 OpenOCD 的 reset halt 命令。

### 记录日志到主机

记录日志到主机是 IDF 的一个非常实用的功能：通过应用层跟踪库将日志保存到主机端。某种程度上这也算是一种半主机 (semihosting) 机制，相较于调用 ESP_LOGx 将待打印的字符串发送到 UART 的日志记录方式，这个功能的优势在于它减少了本地的工作量，而将大部分工作转移到了主机端。

IDF 的日志库会默认使用类 vprintf 的函数将格式化的字符串输出到专用的 UART。一般来说，它涉及到以下几个步骤：

1. 解析格式字符串以获取每个参数的类型。
2. 根据其类型，将每个参数都转换为字符串。
3. 格式字符串与转换后的参数一起发送到 UART。

虽然可以将类 vprintf 函数优化到一定程度，但是上述步骤在任何情况下都是必须要执行的，并且每个步骤都会消耗一定的时间（尤其是步骤 3）。所以经常会发生以下这种情况：向程序中添加额外的打印信息以诊断问题，却改变了应用程序的行为，使得问题无法复现。在最差的情况下，程序会无法正常工作，最终导致报错甚至挂起。

解决此类问题的可能方法是使用更高的波特率或者其他更快的接口，并将字符串格式化的工作转移到主机端。

通过应用层跟踪库的 esp_aptrace_vprintf 函数，可以将日志信息发送到主机。该函数不执行格式字符串和参数的完全解析。而仅仅计算传递的参数的数量，并将它们与格式字符串地址一起发送给主机。主机端会通过一个特殊的 Python 脚本来处理并打印接收到的日志数据。

### 局限

目前通过 JTAG 实现记录日志还存在以下几点局限：

1. 不支持使用 ESP_EARLY_LOGx 宏进行跟踪。
2. 不支持大小超过 4 字节的 printf 参数（例如 double 和 uint64_t）。
3. 仅支持 rodata 段中的格式字符串和参数。
4. printf 参数最多 256 个。

### 如何使用

为了使用跟踪模块来记录日志，用户需要执行以下步骤：

1. 在目标端，需要安装特殊的类 vprintf 函数。正如前面提到的，这个函数是 esp_aptrace_vprintf，它会负责将日志数据发送给主机。示例代码参见 system/app_trace_to_host。
2. 按照特定应用程序的跟踪章节中第 2-5 步骤中的说明进行操作。
3. 打印接收到的日志记录，请在终端运行以下命令：
$IDF_PATH/tools/esp_app_trace/logtrace_proc.py /path/to/trace/file /path/to/program/elf/file。

**Log Trace Processor 命令选项**
命令用法：

```
logtrace_proc.py [-h] [--no-errors] <trace_file> <elf_file>
```

- **trace_file** 日志跟踪文件的路径
- **elf_file** 程序 ELF 文件的路径

可选参数：
- `-h, --help` 显示此帮助信息并退出
- `--no-errors, -n` 不打印错误信息

**基于 SEGGER SystemView 的系统行为分析**
IDF 中另一个基于应用层跟踪库的实用功能是系统级跟踪。它会生成与 SEGGER SystemView 工具相兼容的跟踪信息。SEGGER SystemView 是一种实时记录和可视化工具，用来分析应用程序运行时的行为。

**如何使用**
若需使用这个功能，需要在 menuconfig 中开启 `CONFIG_SYSVIEW_ENABLE` 选项，具体路径为：

```
Component config > Application Level Tracing > FreeRTOS SystemView Tracing
```

在同一个菜单栏下还开启了其他几个选项：

1. **ESP32 timer to use as SystemView timestamp source** (`CONFIG_SYSVIEW_TS_SOURCE`) 选择 SystemView 事件使用的时间戳来源。在单核模式下，使用 ESP32 内部的循环计数器生成时间戳，其最大的工作频率是 240 MHz（时间戳粒度大约为 4 ns）。在双核模式下，使用工作在 40 MHz 的外部定时器，因此时间戳粒度为 25 ns。
2. 可以单独启用或禁用的 SystemView 事件集 (CONFIG_SYSVIEW_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
   - Task Scheduling Event
   - System Idle Event
   - Timer Enter Event
   - Timer Exit Event

IDF 中已经包含了所有用于生成兼容 SystemView 跟踪信息的代码，用户只需配置必要的项目选项（如上所示），然后构建、烧写映像到目标板，接着参照前面的介绍，使用 OpenOCD 收集数据。

**OpenOCD SystemView 跟踪命令选项**
命令用法：

```
esp32 sysview [start <options>] | [stop] | [status]
```

自命令：
- `start` 开始跟踪（连续流模式）。
- `stop` 停止跟踪。
- `status` 获取跟踪状态。
Chapter 4. API 指南

Start 命令语法:

```
start <outfile1> [outfile2] [poll_period [trace_size [stop_tmo]]]
```

- `outfile1` 保存 PRO CPU 数据的文件路径，此参数需要具有如下格式：file://path/to/file。
- `outfile2` 保存 APP CPU 数据的文件路径，此参数需要具有如下格式：file://path/to/file。
- `poll_period` 跟踪数据的轮询周期（单位：毫秒）。如果该值大于 0，则命令以非阻塞的模式运行。默认为 1 毫秒。
- `trace_size` 最多要收集的数据量（单位：字节）。当收到指定数量的数据后，将停止跟踪。默认值是 -1（禁用跟踪大小停止触发器）。
- `stop_tmo` 空闲超时（单位：秒）。如果指定的时间内没有数据，将停止跟踪。默认值是 -1（禁用跟踪超时停止触发器）。

**注解**：如果 `poll_period` 为 0，则在跟踪停止之前，OpenOCD 的 telnet 命令行将不可用。你需要通过复位板卡或者在 OpenOCD 的窗口（不是 telnet 会话窗口）输入 Ctrl+C 命令来手动停止它。另一个办法是设置 `trace_size` 然后等到收集满指定数量的数据后自动停止跟踪。

命令使用示例:

1. 将 SystemView 跟踪数据收集到文件“pro-cpu.SVDat”和“pro-cpu.SVDat”中。这些文件会被保存在“openocp-esp32”目录中。

   ```
   esp32 sysview start file://pro-cpu.SVDat file://app-cpu.SVDat
   ```

   跟踪数据被检索并以非阻塞的方式保存，要停止此过程，需要在 OpenOCD 的 telnet 会话窗口输入 esp32 aptrace stop 命令，或者也可以在 OpenOCD 窗口中按下 Ctrl+C。

2. 检索跟踪数据并无限保存。

   ```
   esp32 sysview start file://pro-cpu.SVDat file://app-cpu.SVDat 0 -1 -1
   ```

   OpenOCD 的 telnet 命令行在跟踪停止前会无法使用，要停止跟踪，请在 OpenOCD 窗口按下 Ctrl+C。

**数据可视化** 收集到跟踪数据后，用户可以使用特殊的工具来可视化结果并分析程序的行为。遗憾的是，SystemView 不支持从多个核心进行跟踪。所以当追踪双核模式下的 ESP32 时会生成两个文件：一个用于 PRO CPU，另一个用于 APP CPU。用户可以将每个文件加载到工具中单独分析。

在工具中单独分析每个核的跟踪数据是比较棘手的。幸运的是，Eclipse 中有一款 Impulse 的插件可以加载多个跟踪文件，并且可以在同一个视图中检查来自两个内核的事件。此外，与免费版的 SystemView 相比，此插件没有 1,000,000 个事件的限制。

关于如何安装、配置 Impulse 并使用它可视化来自单个核心的跟踪数据，请参阅 官方教程。

**注释**：IDF 使用自己的 SystemView FreeRTOS 事件 ID 映射，因此用户需要将 $SYSVIEW_INSTALL_DIR/Description/SYSVIEW_FreeRTOS.txt 替换为 $IDF_PATH/docs/api-guides/SYSVIEW_FreeRTOS.txt。在使用上述链接配置 SystemView 序列化程序时，也应该使用该 IDF 特定文件的内容。

**配置 Impulse 实现双核跟踪** 在安装好 Impulse 插件后，先确保它能够在单独的选项卡中成功加载每个核心的跟踪文件，然后用户可以添加特殊的 Multi Adapter 端口并将这两个文件加载到一个视图中。为此，用户需要在 Eclipse 中执行以下操作：

1. 打开“Signal Ports”视图，前往 Windows->Show View->Other 菜单，在 Impulse 文件夹中找到“Signal Ports”视图，然后双击它。
2. 在“Signal Ports”视图中，右键单击“Ports”并选择“Add ...”，然后选择 New Multi Adapter Port。
3. 在打开的对话框中按下“Add”按钮，选择“New Pipe/Files”。
4. 在打开的对话框中设置“SystemView Serializer”并设置 PRO CPU 跟踪文件的路径，按下确定保存设置。
5. 对 APP CPU 的跟踪文件重复步骤 3 和 4。
6. 双击创建的端口，会打开此端口的视图。
7. 单击 Start/Stop Streaming 按钮，数据将会被加载。
8. 使用“Zoom Out”，“Zoom In”和“Zoom Fit”按钮来查看数据。
9. 有关设置测量光标和其他的功能，请参阅 Impulse 官方文档。

注解：如果您在可视化方面遇到了问题（未显示数据或者缩放操作很奇怪），您可以尝试删除当前信号的层次结构，再双击必要的文件或端口。Eclipse 会要求您创建新的信号层次结构。

4.15 引导加载程序（Bootloader）

引导加载程序（Bootloader）主要执行以下任务：

1. 内部模块的最小化初始化配置；
2. 根据分区表和 ota_data（如果存在）选择需要引导的应用程序（app）分区；
3. 将此应用程序映像加载到 RAM（IRAM 和 DRAM）中，最后把控制权转交给应用程序。

引导加载程序位于 Flash 的 0x1000 偏移地址处。

4.15.1 恢复出厂设置

用户可以编写一个基本的工作固件，然后将其加载到工厂分区（factory）中。

接下来，通过 OTA（空中升级）更新固件。更新后的固件会被保存到某一个 OTA app 分区中，OTA 数据分区也会做相应更新以指示从该分区引导应用程序。

如果你希望回滚到出厂固件并清除设置，则需要设置 CONFIG_BOOTLOADER_FACTORY_RESET。

出厂设置机制允许将设备重置为出厂模式：

- 清除一个或多个数据分区。
- 从工厂分区启动。

CONFIG_BOOTLOADER_DATA_FACTORY_RESET - 允许用户选择在恢复出厂设置时需要删除的数据分区。可以通过逗号来分隔多个分区的名字，并适当增加空格以便阅读（例如 “nvs, phy_init, nvs_custom, …”）。请确保此处指定的名称和分区表中的名称相同，且不含有“app”类型的分区。

CONFIG_BOOTLOADER_OOTA_DATA_ERASE - 恢复出厂模式后，设备会从工厂分区启动，OTA 数据分区会被清除。

CONFIG_BOOTLOADER_NUM_PIN_FACTORY_RESET - 设置用于触发出厂重置的 GPIO 编号，必须在芯片复位时将此 GPIO 拉低才能触发出厂重置事件。

CONFIG_BOOTLOADER_HOLD_TIME_GPIO - 设置进入重置或测试模式所需要的保持时间（默认为 5 秒）。设备复位后，GPIO 必须在这段时间内持续保持低电平，然后才会执行出厂重置或引导测试分区。

示例分区表如下：

<table>
<thead>
<tr>
<th># Name, Type, SubType, Offset, Size, Flags</th>
</tr>
</thead>
<tbody>
<tr>
<td># 注意：如果您增大了引导加载程序的大小，请确保更新偏移量，避免和其它分区发生重叠</td>
</tr>
<tr>
<td>nvs, data, nvs, 0x9000, 0x4000</td>
</tr>
<tr>
<td>ota_data, data, ota, 0xd000, 0x2000</td>
</tr>
<tr>
<td>phy_init, data, phy, 0xf000, 0x1000</td>
</tr>
<tr>
<td>factory, 0, 0, 0x10000, 1M</td>
</tr>
<tr>
<td>test, 0, test, , 512K</td>
</tr>
<tr>
<td>ota_0, 0, ota_0, , 512K</td>
</tr>
<tr>
<td>ota_1, 0, ota_1, , 512K</td>
</tr>
</tbody>
</table>
4.15.2 从测试固件启动

用户可以编写在生产环境中测试用的特殊固件，然后在需要的时候运行。此时需要在分区表中专门申请一块分区用于保存该测试固件（详情请参阅分区表）。如果想要触发测试固件，还需要设置 `CONFIG_BOOTLOADER_APP_TEST`。

`CONFIG_BOOTLOADER_NUM_PIN_APP_TEST` - 设置引导测试分区的 GPIO 管脚编号，该 GPIO 会被配置为输入模式，并且会使能内部上拉电阻。若想触发测试固件，该 GPIO 必须在芯片复位时拉低。设备重启时如果该 GPIO 没有被激活（即处于高电平状态），那么会加载常规配置的应用程序（可能位于工厂分区或 OTA 分区）。

`CONFIG_BOOTLOADER_HOLD_TIME_GPIO` - 设置进入重置或测试模式所需要的保持时间（默认为 5 秒）。设备复位后，GPIO 必须在这段时间内持续保持低电平，然后才会执行出厂重置或引导测试分区。

4.15.3 自定义引导程序

用户可以重写当前的引导加载程序，具体做法是：复制 `/esp-idf/components/bootloader` 文件夹到项目目录中，然后编辑 `/your_project/components/bootloader/subproject/ain/bootloader_main.c` 文件。在引导加载程序的代码中，用户不可以使用驱动和其他组件提供的函数，如果确实需要，请将该功能的实现部分放在 bootloader 目录中（注意，这会增加引导程序的大小）。监视生成的引导程序的大小是必要的，因为它可能会与内存中的分区表发生重叠而损坏固件。目前，引导程序被限制在了分区表之前的一小块区域（分区表位于 `0x8000` 地址处）。

4.16 分区表

4.16.1 概述

每片 ESP32 的 flash 可以包含多个应用程序，以及多种不同类型的数据（例如校准数据、文件系统数据、参数存储器数据等）。因此，我们需要引入分区表的概念。

分区表中的每个条目都包括以下几个部分：Name（标签）、Type（app、data 等）、SubType 以及在 flash 中的偏移量（分区的加载地址）。

在使用分区表时，最简单的方法就是打开项目配置菜单（`idf.py menuconfig`），并在 `CONFIG_PARTITION_TABLE_TYPE` 下选择一个预定义的分区表:

- “Single factory app, no OTA”
- “Factory app, two OTA definitions”

在以上两种选项中，出厂应用程序均将被烧录至 flash 的 `0x10000` 偏移地址处。这时，运行 `idf.py partition_table`，即可以打印当前使用分区表的信息摘要。

4.16.2 内置分区表

以下是“Single factory app, no OTA”选项的分区表信息摘要:

```bash
# 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,
```

以上是“Factory app, two OTA definitions”选项的分区表信息摘要:

```bash
# ESP-IDF Partition Table # Name, Type, SubType, Offset, Size, Flags nvs, data, nvs, 0x9000, 0x4000,
otadata, data, ota, 0x0000, 0x2000, phy_init, data, phy, 0xf000, 0x1000, factory, app, factory, 0x10000,
1M, ota_0, app, ota_0, 0x10000, 1M, ota_1, app, ota_1, 0x210000, 1M,
```
4.16.3 创建自定义分区表

如果在 menuconfig 中选择了 “Custom partition table CSV”，则还需要输入该分区表的 CSV 文件在项目中的路径。CSV 文件可以根据需要，描述任意数量的分区信息。

CSV 文件的格式与上面摘要中打印的格式相同，但是在 CSV 文件中并非所有字段都是必需的。例如下面是一个自定义的 OTA 分区表的 CSV 文件：

```csv
# Name, Type, SubType, Offset, Size, Flags
nvs, data, nvs, 0x9000, 0x4000, otadata, data, ota, 0x0000, 0x2000 phy_init, data, phy, 0x0000, 0x1000 factory, app, factory, 0x10000, 1M ota_0, app, ota_0, , 1M ota_1, app, ota_1, , 1M nvs_key, data, nvs_keys, , 0x1000
```

- 字段之间的空格会被忽略，任何以 `#` 开头的行（注释）也会被忽略。
- CSV 文件中的每个非注释行均为一个分区定义。
- 每个分区的 Offset 字段可以为空，gen_esp32part.py 工具会从分区表位置的后面开始自动计算并填充该分区的偏移地址，同时确保每个分区的偏移地址正确对齐。

**Name 字段**

Name 字段可以是任何有意义的名称，但不能超过 16 个字符（之后的内容将被截断）。该字段对 ESP32 并不是特别重要。

**Type 字段**

Type 字段可以指定为 app (0) 或者 data (1)，也可以直接使用数字 0-254（或者十六进制 0x00-0xFE）。注意，0x00-0x3F 不得使用（预留给 esp-idf 的核心功能）。

如果您的应用程序需要保存数据，请在 0x40-0x4F 内添加一个自定义分区类型。

注意，启动加载器将忽略 app (0) 和 data (1) 以外的其他分区类型。

**SubType 字段**

SubType 字段长度为 8 bit，内容与具体 Type 有关。目前，esp-idf 仅仅规定了 “app” 和 “data” 两种子类型。

- 当 Type 定义为 app 时，SubType 字段可以指定为 factory (0), 0x10) … ota_15 (0x1F) 或者 test (0x20)。
  - factory (0) 是默认的 app 分区。启动加载器将默认加载该应用程序。但如果存在类型为 data/ota 分区，则启动加载器将加载 data/ota 分区中的数据，进而判断启动哪个 OTA 镜像文件。OTA 升级永远都不会更新 factory 分区中的内容。- 如果您希望在 OTA 项目中预留更多 flash，可以删除 factory 分区，转而使用 ota_0 分区。
  - ota_0 (0x10) … ota_15 (0x1F) 为 OTA 应用程序分区，启动加载器将根据 OTA 分区中的数据来决定加载哪个 OTA 应用程序分区中的程序。在使用 OTA 功能时，应用程序应至少拥有 2 个 OTA 应用程序分区 (ota_0 和 ota_1)，更多信息请参看 OTA 文档。
- test (0x2) 为预留 app 子类型，用于工厂测试流程。如果没有其他有效 app 分区，test 将作为备选启动分区使用，也可以在每次启动时启动加载器读取 GPIO，如果 GPIO 被拉低则启动该分区。详细信息请查阅从测试固件启动。
- 当 Type 定义为 data 时，SubType 字段可以指定为 ota (0), phy (1), nvs (2) 或者 nvs_keys (4)。
  - ota (0) 即 OTA 数据分区，用于存储当前所选的 OTA 应用程序的信息。这个分区的大小需要设定为 0x2000。更多信息，请参考 OTA 文档。
- phy (1) 分区用于存放 PHY 初始化数据，从而保证可以为每个设备单独配置 PHY，而非必须采用固件中的统一 PHY 初始化数据。
  * 默认配置下，phy 分区并不启用，而是直接将 phy 初始化数据编译至应用程序中，从而节省分区表空间（直接将此分区删除）。
  * 如果需要从此分区加载 phy 初始化数据，请打开项目配置菜单 (idf.py menuconfig)，并且使用 CONFIG_ESP32_PHY_INIT_DATA_IN_PARTITION 选项。此时，您还需要手动将 phy 初始化数据烧录至设备 flash (esp-idf 编译系统并不会自动完成该操作)。
- nvs (2) 是专为非易失性存储 (NVS) API 使用的分区。
  * 用于存储每台设备的 PHY 校准数据 (注意，并非 PHY 初始化数据)。
  * 用于存储 Wi-Fi 数据 (如果使用了 esp_wifi_set_storage (WIFI_STORAGE_FLASH) 初始化函数)。
  * NVS API 还可以用于其他应用程序数据。
  * 强烈建议您应为 NVS 分区分配至少 0x3000 字节空间。
  * 如果使用 NVS API 存储大量数据，请增加 NVS 分区的大小 (默认是 0x6000 字节)。
- nvs_keys (4) 是 NVS 秘钥分区。详细信息，请参考非易失性存储 (NVS) API 文档。
  * 用于存储加密密钥 (如果启用了 NVS 加密功能)。
  * 此分区应至少设定为 4096 字节。

其它数据子类型已预留给 esp-idf 未来使用。

**Offset 和 Size 字段**

分区若偏移地址为空，则会紧跟着前一个分区之后开始；若为首个分区，则将紧跟着分区表开始。

app 分区的偏移地址必须要与 0x10000 (64K) 对齐，如果将偏移字节留空，gen_esp32part.py 工具会自动计算得到一个满足对齐要求的偏移地址。如果 app 分区的偏移地址没有与 0x10000 (64K) 对齐，则该工具会报错。

app 分区的大小和偏移地址可以采用十进制数，以 0x 为前缀的十六进制数，且支持 K 或 M 的倍数单位 (分别代表 1024 和 1024*1024 字节)。

如果您希望允许分区表中的分区采用任意起始偏移量 (CONFIG_PARTITION_TABLE_OFFSET)，请将分区表 (CSV 文件) 中所有分区的偏移字段都留空。注意，此时，如果您更改了分区表中任意分区的偏移地址，则其他分区的偏移地址也会跟着改变。这种情况下，如果您之前还曾设定某个分区采用固定偏移地址，则可能造成分区表冲突，从而导致报错。

**Flags 字段**

当前仅支持 encrypted 标记。如果 Flags 字段设置为 encrypted，且已启用 Flash Encryption 功能，则该分区将会被加密。

注解：app 分区始终会被加密，不管 Flags 字段是否设置。

### 4.16.4 生成二进制分区表

烧写到 ESP32 中的分区表采用二进制格式，而不是 CSV 文件本身。此时，partition_table/gen_esp32part.py 工具可以实现 CSV 和二进制文件之间的转换。

如果您在项目配置菜单 (idf.py menuconfig) 中设置了分区表 CSV 文件的名称，然后构建项目或执行 idf.py partition_table。这时，转换将在编译过程中自动完成。

手动将 CSV 文件转换为二进制文件:

```
python gen_esp32part.py input_partitions.csv binary_partitions.bin
```

手动将二进制文件转换为 CSV 文件:

```
python gen_esp32part.py binary_partitions.bin input_partitions.csv
```
在标准输出（stdout）上，打印二进制分区表的内容（在运行 idf.py partition_table 时，我们正是这样打印上文展示的信息摘要的）：

```python
python gen_esp32part.py binary_partitions.bin
```

### 4.16.5 烧写分区表

- `idf.py partition_table-flash`：使用 `esptool.py` 工具烧写分区表。
- `idf.py flash`：会烧写所有内容，包括分区表。

在执行 `idf.py partition_table` 命令时，手动烧写分区表的命令也将打印在终端上。

**注释**：分区表的更新并不会擦除根据之前分区表存储的数据。此时，您可以使用 `idf.py erase_flash` 命令或者 `esptool.py erase_flash` 命令来擦除 flash 中的所有内容。

### 4.16.6 分区工具 (parttool.py)

`partition_table` 组件中有分区工具 `parttool.py`，可以在目标设备上完成分区相关操作。该工具有如下用途：

- 读取分区，将内容存储到文件中 (read_partition)
- 将文件中的内容写入分区 (write_partition)
- 擦除分区 (erase_partition)
- 检索特定分区的偏移和大小等信息 (get_partition_info)

用户若想通过编程方式完成相关操作，可从另一个 Python 脚本导入并使用分区工具，或者从 Shell 脚本调用分区工具。前者可使用工具的 Python API，后者可使用命令行界面。

### Python API

首先请确保已导入 `parttool` 模块。

```python
import sys
import os

idf_path = os.environ["IDF_PATH"]  # 从环境中获取 IDF_PATH 的值
parttool_dir = os.path.join(idf_path, "components", "partition_table")  # parttool.py 位于 $IDF_PATH/components/partition_table 下
sys.path.append(parttool_dir)  # 使能 Python 寻找 parttool 模块
from parttool import *  # 导入 parttool 模块内的所有名称
```

要使用分区工具的 Python API，第一步是创建 `ParttoolTarget`：

```bash
# 创建 `parttool.py` 的目标设备，并将目标设备连接到串行端口 /dev/ttyUSB1
target = ParttoolTarget("/dev/ttyUSB1")
```

现在，可使用创建的 `ParttoolTarget` 在目标设备上完成操作：

```bash
Espressif Systems Release v4.3-dev-1561-g357a277603
Submit Document Feedback
```
# 撤除名为 'storage' 的分区
target.erase_partition(PartitionName("storage"))

# 读取类型为 'data'、子类型为 'spiffs' 的分区，保存至文件 'spiffs.bin'
target.read_partition(PartitionType("data", "spiffs"), "spiffs.bin")

# 将 'factory.bin' 文件的内容写至 'factory' 分区
target.write_partition(PartitionName("factory"), "factory.bin")

# 打印默认启动分区的大小
storage = target.get_partition_info(PARTITION_BOOT_DEFAULT)
print(storage.size)

使用 PartitionName、PartitionType 或 PARTITION_BOOT_DEFAULT 指定要操作的分区。顾名思义，这三个参数可以指向拥有特定名称的分区、特定类型和子类型的分区或默认启动分区。

更多关于 Python API 的信息，请查看分区工具的代码注释。

命令行界面

`parttool.py` 的命令行界面具有如下结构：

```
parttool.py [command-args] [subcommand] [subcommand-args]
```

- command-args - 执行主命令（parttool.py）所需的实际参数，多与目标设备有关
- subcommand - 要执行的操作
- subcommand-args - 所选操作的实际参数

# 撤除名为 'storage' 的分区
parttool.py --port "/dev/ttyUSB1" erase_partition --partition-name=storage

# 读取类型为 'data'、子类型为 'spiffs' 的分区，保存至 'spiffs.bin' 文件
parttool.py --port "/dev/ttyUSB1" read_partition --partition-type=data --partition=subtype=spiffs "spiffs.bin"

# 将 'factory.bin' 文件中的内容写入到 'factory' 分区
parttool.py --port "/dev/ttyUSB1" write_partition --partition-name=factory "factory.bin"

# 打印默认启动分区的大小
parttool.py --port "/dev/ttyUSB1" get_partition_info --partition-boot-default --.info size

更多信息可用 `-help` 指令查看：

# 显示可用的子命令和子命令描述
parttool.py --help

# 显示子命令的描述
parttool.py [subcommand] --help

### 4.17 Secure Boot

**重要：** All references in this document are related to Secure Boot V1 (The AES based Secure Boot Scheme). ESP32 Revision 3 onwards, the preferred secure boot scheme is Secure Boot V2. Please refer to Secure Boot V2 document for ESP32 Revision 3 or ESP32-S2.
Secure Boot is a feature for ensuring only your code can run on the chip. Data loaded from flash is verified on each reset.

Secure Boot is separate from the Flash Encryption feature, and you can use secure boot without encrypting the flash contents. However, for a secure environment both should be used simultaneously. See Secure Boot & Flash Encryption for more details.

Important: Enabling secure boot limits your options for further updates of your ESP32. Make sure to read this document thoroughly and understand the implications of enabling secure boot.

4.17.1 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 about efuse, see Chapter 11 “eFuse Controller” in the Technical Reference Manual.
- 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.

4.17.2 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.

4.17.3 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.

The algorithm operates on a 256 bit key in all cases, 192 bit keys are extended by repeating some bits (details).

• “secure boot signing key” is a standard ECDSA public/private key pair (see Image Signing Algorithm) in PEM format.
  - The public key from this key pair (for signature verification but not signature creation) is compiled into the software bootloader and used to verify the second stage of booting (partition table, app image) before booting continues. The public key can be freely distributed, it does not need to be kept secret.
  - The private key from this key pair must be securely kept private, as anyone who has this key can authenticate to any bootloader that is configured with secure boot and the matching public key.

### 4.17.4 Bootloader Size

When secure boot is enabled the bootloader app binary bootloader.bin may exceed the default bootloader size limit. This is especially likely if flash encryption is enabled as well. The default size limit is 0x7000 (28672) bytes (partition table offset 0x8000 - bootloader offset 0x1000).

If the bootloader becomes too large, 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:

- 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 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.)

### 4.17.5 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 generateSigningKey.

重要：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.

重要：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).

### 4.17.6 Re-Flashable Software Bootloader

Configuration “Secure Boot: One-Time Flash” is the recommended configuration for production devices. In this mode, each device gets a unique key that is never stored outside the device.

However, an alternative mode **Secure Boot: Reflashable** is also available. This mode allows you to supply a binary key file that is used for the secure bootloader key. As you have the key file, you can generate new bootloader images and secure boot digests for them.

In the esp-idf build process, this 256-bit key file is derived from the ECDSA app signing key generated by the user (see the **Generating Secure Boot Signing Key** step below). This private key’s SHA-256 digest is used as the secure bootloader key in efuse (as-is for Coding Scheme None, or truncate to 192 bytes for 3/4 Encoding). This is a convenience so you only need to generate/protect a single private key.

**Note:** Although it’s possible, we strongly recommend not generating one secure boot key and flashing it to every device in a production environment. The “One-Time Flash” option is recommended for production environments.

To enable a reflashable bootloader:

1. In the **Project Configuration Menu**, select “Bootloader Config” -> **CONFIG_SECURE_BOOT** -> **CONFIG_SECURE_BOOT_V1_ENABLED** -> **CONFIG_SECURE_BOOTLOADER_MODE** -> Reflashable.

2. If necessary, set the **CONFIG_SECURE_BOOTLOADER_KEY_ENCODING** based on the coding scheme used by the device. The coding scheme is shown in the **Features** line when `esptool.py` connects to the chip, or in the `espefuse.py` summary output.

2. Follow the steps shown above to choose a signing key file, and generate the key file.

3. Run `idf.py bootloader`. A binary key file will be created, derived from the private key that is used for signing. Two sets of flashing steps will be printed - the first set of steps includes an `espefuse.py burn_key` 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).

4. 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.
4.17.7 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.

4.17.8 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 BINARY_FILE
```

4.17.9 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.

4.17.10 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算法.
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
```

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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
```

### 4.17.11 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.

### 4.17.12 Signed App Verification Without Hardware Secure Boot

The integrity of apps can be checked even without enabling the hardware secure boot option. This option uses the same app signature scheme as hardware secure boot, but unlike hardware secure boot it does not prevent the bootloader from being physically updated. This means that the device can be secured against remote network access, but not physical access. Compared to using hardware Secure Boot this option is much simpler to implement. See How To Enable Signed App Verification for step by step instructions.

An app can be verified on update and, optionally, be verified on boot.

- **Verification on update:** When enabled, the signature is automatically checked whenever the esp_ota_ops.h APIs are used for OTA updates. If hardware secure boot is enabled, this option is always enabled and cannot be disabled. If hardware secure boot is not enabled, this option still adds significant security against network-based attackers by preventing spoofing of OTA updates.
- **Verification on boot:** When enabled, the bootloader will be compiled with code to verify that an app is signed before booting it. If hardware secure boot is enabled, this option is always enabled and cannot be disabled. If hardware secure boot is not enabled, this option doesn’t add significant security by itself so most users will want to leave it disabled.

### How To Enable Signed App Verification

1. Open Project Configuration Menu -> Security features -> Enable `CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT`
2. “Bootloader verifies app signatures” can be enabled, which verifies app on boot.
3. By default, “Sign binaries during build” will be enabled on selecting “Require signed app images” option, which will sign binary files as a part of build process. The file named in “Secure boot private signing key” will be used to sign the image.
4. If you disable “Sign binaries during build” option then you’ll have to enter path of a public key file used to verify signed images in “Secure boot public signature verification key” . In this case, private signing key should be generated by following instructions in Generating Secure Boot Signing Key; public verification key and signed image should be generated by following instructions in Remote Signing of Images.

### 4.17.13 Advanced Features
Chapter 4. API

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.

4.18 Secure Boot V2

The references in this document are related to Secure Boot V2, the preferred scheme from ESP32-ECO3 onwards and in ESP32-S2.

Secure Boot V2 uses RSA based app and bootloader verification. This document can also be referred for signing apps with the RSA scheme without signing the bootloader.

4.18.1 Background

Secure Boot protects a device from running unsigned code (verification at time of load). A new RSA based secure boot verification scheme (Secure Boot V2) has been introduced for ESP32-S2 and ESP32 ECO3 onwards.

• The software bootloader’s RSA-PSS signature is verified by the Mask ROM and it is executed post successful verification.
• The verified software bootloader verifies the RSA-PSS signature of the application image before it is executed.

4.18.2 Advantages

• The RSA public key is stored on the device. The corresponding RSA private key is kept secret on a server and is never accessed by the device.
• Up to three public keys can be generated and stored in ESP32-S2 during manufacturing. (ESP32 ECO3: only one key)
• Same image format & signature verification is applied for applications & software bootloader.
• No secrets are stored on the device. Therefore immune to passive side-channel attacks (timing or power analysis, etc.)

4.18.3 Secure Boot V2 Process

This is an overview of the Secure Boot V2 Process, Step by step instructions are supplied under How To Enable Secure Boot V2.

1. Secure Boot V2 verifies the signature blocks appended to the bootloader and application binaries. The signature block contains the image binary signed by a RSA-3072 private key and its corresponding public key. More details on the Signature Block Format.
2. On startup, ROM code checks the Secure Boot V2 bit in eFuse.
3. If secure boot is enabled, ROM checks the SHA-256 of the public key in the signature block in the eFuse.
4. The ROM code validates the public key embedded in the software bootloader’s signature block by matching the SHA-256 of its public key to the SHA-256 in eFuse as per the earlier step. Boot process will be aborted if a valid hash of the public key isn’t found in the eFuse.
5. The ROM code verifies the signature of the bootloader with the pre-validated public key with the RSA-PSS Scheme. In depth information on Verifying the signature Block.
6. Software bootloader, reads the app partition and performs similar verification on the application. The application is verified on every boot up and OTA update. If selected OTA app partition fails verification, bootloader will fall back and look for another correctly signed partition.
Chapter 4. API

4.18.4 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.

Each signature block contains the following:

- **Offset 0 (1 byte):** Magic byte (0xe7)
- **Offset 1 (1 byte):** Version number byte (currently 0x02), 0x01 is for Secure Boot V1.
- **Offset 2 (2 bytes):** Padding bytes, Reserved. Should be zero.
- **Offset 4 (32 bytes):** SHA-256 hash of only the image content, not including the signature block.
- **Offset 36 (384 bytes):** RSA Public Modulus used for signature verification. (value \( m \) in RFC8017).
- **Offset 420 (4 bytes):** RSA Public Exponent used for signature verification (value \( e \) in RFC8017).
- **Offset 424 (384 bytes):** Precalculated R, derived from \( m \).
- **Offset 808 (4 bytes):** Precalculated M', derived from \( m \).
- **Offset 812 (384 bytes):** RSA-PSS Signature result (section 8.1.1 of RFC8017) of image content, computed using following PSS parameters: SHA256 hash, MFG1 function, 0 length salt, default trailer field (0xBC).
- **Offset 1196:** CRC32 of the preceding 1095 bytes.
- **Offset 1200 (16 bytes):** Zero padding to length 1216 bytes.

It is recommended to use hardware-assisted Montgomery Multiplication.

The remainder of the signature sector is erased flash (0xFF) which allows writing other signature blocks after previous signature block.

4.18.5 Verifying the signature Block

A signature block is “valid” if the first byte is 0xe7 and a valid CRC32 is stored at offset 1196. Upto 3 signature blocks can be appended to the bootloader or application image in ESP32-S2. (ESP32 ECO3: only one key)

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. The magic byte, signature block CRC is validated.
2. Public key digests are generated per signature block and compared with the digests from eFuse. If none of the digests match, the verification process is aborted.
3. The application image digest is generated and matched with the image digest in the signature blocks. The verification process is aborted if the digests don’t match.
4. The public key is used to verify the signature of the bootloader image, using RSA-PSS (section 8.1.2 of RFC8017) with the image digest calculated in step (3) for comparison.

The application signing scheme is set to RSA for Secure Boot V2 and to ECDSA for Secure Boot V1.

Important: It is recommended to use Secure Boot V2 on the chip versions supporting them.

4.18.6 Bootloader Size

When secure boot is enabled the bootloader app binary \texttt{bootloader.bin} may exceed the default bootloader size limit. This is especially likely if flash encryption is enabled as well. The default size limit is 0x7000 (28672) bytes (partition table offset 0x8000 - bootloader offset 0x1000).

If the bootloader becomes too large, the ESP32 will fail to boot - errors will be logged about either invalid partition table or invalid bootloader checksum.

When Secure Boot V2 is enabled, there is also an absolute binary size limit of 48KB (0xC000 bytes) (excluding the 4KB signature), because the bootloader is first loaded into a fixed size buffer for verification.

Options to work around this are:
4.18.7 eFuse usage

4.18.8 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.

4. 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.

5. The first time you run `make` or `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`.

6. 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`.

7. 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.

8. 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.

注解：`idf.py flash` doesn’t flash the bootloader if secure boot is enabled.

9. 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.

注解：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.

注解：If the ESP32 is reset or powered down during the first boot, it will start the process again on the next boot.

10. 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).
4.18.9 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 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 behaviour can be disabled, but this is not recommended.

4.18.10 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.

4.18.11 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:

```
espsecure.py sign_data --version 2 --keyfile PRIVATE_SIGNING_KEY --output SIGNED_BINARY_FILE BINARY_FILE
```

4.18.12 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.

4.18.13 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 `make` or `idf.py build` will sign an app image and `idf.py bootloader` will produce a signed bootloader if secure signed binaries on build is enabled.

However, it is possible to use the `espsecure.py` tool to make standalone signatures and digests.

To sign a binary image:

```
espsecure.py sign_data --version 2 --keyfile ./my_signing_key.pem --output ./image_--signed.bin image(unsigned.bin)
```

Keyfile is the PEM file containing an RSA-3072 private signing key.

### 4.18.14 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.

### 4.18.15 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.

### 4.19 ULP 协处理器编程

#### 4.19.1 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:
Chapter 4. API

entry:
   NOP
   NOP
   NOP
   NOP

loop:
   MOVE R1, loop
   JUMP R1

When this program is assembled and linked, address of label loop will be equal to 16 (expressed in bytes). However JUMP instruction expects the address stored in register 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:

```
0000 NOP
0004 NOP
0008 NOP
000c NOP
0010 MOVE R1, 4
0014 JUMP R1
```

The other case is when the argument of MOVE instruction is not a label but a constant. In this case assembler will use the value as is, without any conversion:

```
.set   val, 0x10
MOVE   R1, val
```

In this case, value loaded into R1 will be 0x10.

Similar considerations apply to LD and ST instructions. Consider the following code:

```
.global array
array: .long 0
       .long 0
       .long 0
       .long 0

MOVE R1, array
MOVE R2, 0x1234
ST R2, R1, 0     // write value of R2 into the first array element,
                 // i.e. array[0]
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:

```
#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 cycle to fetch next instruction

**Description** No operation is performed. Only the PC is incremented.

**Example:**

```
1:   NOP
```

**ADD - Add to register**

**Syntax** ADD Rsdt, Rsrc1, Rsrc2

**ADD Rsdt, Rsrc1, imm**

**Operands**
- Rsdt - Register R[0..3]
- Rsrc1 - Register R[0..3]
- Rsrc2 - Register R[0..3]
- Imm - 16-bit signed value

**Cycles** 2 cycles to execute, 4 cycles to fetch next instruction

**Description** The instruction adds source register to another source register or to a 16-bit signed value and stores 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 Rsdt, Rsrc1, Rsrc2

**SUB Rsdt, Rsrc1, imm**

**Operands**
- Rsdt - 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 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:
```assembly
SUB R1, R2, R3
```
```
// R1 = R2 - R3
```

2:
```assembly
sub R1, R2, 0x1234
```
```
// R1 = R2 - 0x1234
```

3:
```assembly
.set value1, 0x03
SUB R1, R2, value1
```
```
// constant value1 = 0x03
// R1 = R2 - value1
```

4:
```assembly
.global label
SUB R1, R2, label
```
```
// declaration of variable label
// R1 = R2 - label
```
```
label: nop
```
```
// definition of variable label
```

---

**AND - Logical AND of two operands**

**Syntax**

```assembly
AND Rdst, Rsrl, Rsrc2
```
```
AND Rdst, Rsrl, imm
```

**Operands**

- **Rdst** - Register R[0..3]
- **Rsrl** - 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:
```assembly
AND R1, R2, R3
```
```
// R1 = R2 \& R3
```

2:
```assembly
AND R1, R2, 0x1234
```
```
// R1 = R2 \& 0x1234
```

3:
```assembly
.set value1, 0x03
AND R1, R2, value1
```
```
// constant value1 = 0x03
// R1 = R2 \& value1
```

4:
```assembly
.global label
AND R1, R2, label
```
```
// declaration of variable label
// R1 = R2 \& label
```
```
label: nop
```
```
// definition of variable label
```

---

**OR - Logical OR of two operands**

**Syntax**

```assembly
OR Rdst, Rsrl, Rsrc2
```
```
OR Rdst, Rsrl, imm
```

**Operands**

- **Rdst** - Register R[0..3]
- **Rsrl** - 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:
```assembly
OR R1, R2, R3
```
```
// R1 = R2 | R3
```

2:
```assembly
OR R1, R2, 0x1234
```
```
// R1 = R2 | 0x1234
```

3:
```assembly
.set value1, 0x03
AND R1, R2, value1
```
```
// constant value1 = 0x03
// R1 = R2 \& value1
```

4:
```assembly
.global label
AND R1, R2, label
```
```
// declaration of variable label
// R1 = R2 \& label
```
```
label: nop
```
```
// definition of variable label
```
Chapter 4. API

1: OR R1, R2, R3  //R1 = R2 \| R3
2: OR R1, R2, 0x1234  //R1 = R2 \| 0x1234
3: .set value1, 0x03  //constant value1=0x03
   OR R1, R2, value1  //R1 = R2 \| value1
4: .global label  //declaration of variable label
   OR R1, R2, label  //R1 = R2 \| label
   ...  //definition of variable label

LSH - Logical Shift Left

Syntax  LSH Rdst, Rsrl, Rsrcl
        LSH Rdst, Rsrl, imm

Operands
• Rdst - Register R[0..3]
• Rsrl - Register R[0..3]
• Rsrcl - 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
   ...  //definition of variable label

RSH - Logical Shift Right

Syntax  RSH Rdst, Rsrl, Rsrcl
        RSH Rdst, Rsrl, imm

Operands  Rdst - Register R[0..3]  Rsrl - Register R[0..3]  Rsrcl - 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
Chapter 4. API 指南

MOVE – Move to register

Syntax MOVE Rdst, Rsrс

MOVE Rdst, imm

Operands
• Rdst – Register R[0..3]
• Rsrс – Register R[0..3]
• 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: MOVE R1, R2 //R1 = R2
2: MOVE R1, 0x03 //R1 = 0x03
3: .set value1, 0x03 //constant value1=0x03
   MOVE R1, value1 //R1 = value1
4: .global label //declaration of label
   MOVE R1, label //R1 = address_of(label) / 4
   ...
   label: nop //definition of label

ST – Store data to the memory

Syntax ST Rsrс, Rdst, offset

Operands
• Rsrс – Register R[0..3], holds the 16-bit value to store
• Rdst – Register R[0..3], address of the destination, in 32-bit words
• Offset – 13-bit signed value, offset in bytes

Cycles 4 cycles to execute, 4 cycles to fetch next instruction

Description The instruction stores the 16-bit value of Rsrс to the lower half-word of memory with address
Rdst+offset. The upper half-word is written with the current program counter (PC), expressed in words, shifted
left by 5 bits:

\[ \text{Mem}[\text{Rdst} + \text{offset} / 4\{31:0\}] = (\text{PC}[10:0], 5'b0, \text{Rsrc}[15:0]) \]

The application can use higher 16 bits to determine which instruction in the ULP program has written any
particular word into memory.

Examples:

1: ST R1, R2, 0x12 //MEM[R2+0x12] = R1
2: .data //Data section definition
   Addr1: .word 123 // Define label Addr1 16 bit
   .set offs, 0x00 // Define constant offs
   .text //Text section definition
   MOVE R1, 1 // R1 = 1
### LD – Load data from the memory

**Syntax** \( \text{LD} \ Rdst, \ Rsrc, \ offset \)

**Operands**
- \( Rdst \) – Register \( R[0..3] \), destination
- \( Rsrc \) – Register \( R[0..3] \), holds address of destination, in 32-bit words
- \( Offset \) – 13-bit signed value, offset in bytes

**Cycles** 4 cycles to execute, 4 cycles to fetch next instruction

**Description** The instruction loads lower 16-bit half-word from memory with address \( Rsrc + \) offset into the destination register \( Rdst \):

\[
Rdst[15:0] = \text{Mem}[Rsrc + \text{offset} / 4][15:0]
\]

**Examples:**

1: \[\text{LD} \ R1, \ R2, 0x12 \] \hspace{1em} \( \text{R1} = \text{MEM}[R2 + 0x12] \)

2: \[.data\]

\[\text{Addr1: \ .word} \ 123\] \hspace{1em} \( \text{Define label Addr1 16 bit} \)

\[\text{.set \ offs, \ 0x00}\] \hspace{1em} \( \text{Define constant offs} \)

\[\text{.text}\]

\[\text{MOVE} \ R1, \ 1\] \hspace{1em} \( \text{R1} = 1 \)

\[\text{MOVE} \ R2, \ \text{Addr1}\] \hspace{1em} \( \text{R2} = \text{Addr1} / 4 \) (address of label is...)

\[\text{LD} \ R1, \ R2, \ \text{offs} \] \hspace{1em} \( \text{R1} = \text{MEM}[R2 + \text{0}] \)

\[\text{R1 will be 123} \]

### JUMP – Jump to an absolute address

**Syntax** \( \text{JUMP} \ Rdst \)

\( \text{JUMP} \ \text{ImmAddr} \)

\( \text{JUMP} \ Rdst, \ Condition \)

\( \text{JUMP} \ \text{ImmAddr}, \ Condition \)

**Operands**
- \( Rdst \) – Register \( R[0..3] \) containing address to jump to (expressed in 32-bit words)
- \( \text{ImmAddr} \) – 13 bits address (expressed in bytes), aligned to 4 bytes
- \( \text{Condition} \):
  - \( \text{EQ} \) – jump if last ALU operation result was zero
  - \( \text{OV} \) – 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: \[\text{JUMP} \ R1 \] \hspace{1em} \( \text{Jump to address in R1 (address in R1 is in...} \)

2: \[\text{JUMP} \ 0x120, \ \text{EQ} \] \hspace{1em} \( \text{Jump to address 0x120 (in bytes) if ALU...} \)

3: \[\text{JUMP} \ \text{label} \] \hspace{1em} \( \text{Jump to label} \)

\[\text{... label: \ nop} \] \hspace{1em} \( \text{Definition of label} \)
### 4. API

#### Chapter 4. API

| 4: | .global label | // Declaration of global label |
|  | MOVE R1, label | // R1 - label (value loaded into R1 is in words) |
|  | JUMP R1 | // Jump to label |
| ... |  |  |
| label: | nop | // Definition of label |

### JUMPR – Jump to a relative offset (condition based on R0)

**Syntax** JUMPR Step, Threshold, Condition

**Operands**
- **Step** – relative shift from current position, in bytes
- **Threshold** – threshold value for branch condition
- **Condition**:
  - `EQ` (equal) – jump if value in R0 == threshold
  - `LT` (less than) – jump if value in R0 < threshold
  - `LE` (less or equal) – jump if value in R0 <= threshold
  - `GT` (greater than) – jump if value in R0 > threshold
  - `GE` (greater or equal) – jump if value in R0 >= threshold

**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:

```plaintext
// JUMPR target, threshold, GT is implemented as:
JUMPR target, threshold+1, GE

// JUMPR target, threshold, LE is implemented as:
JUMPR target, threshold + 1, LT
```

Conditions `EQ` is implemented in the assembler using two JUMPR instructions:

```plaintext
// JUMPR target, threshold, EQ is implemented as:

JUMPR next, threshold + 1, GE
JUMPR 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 R0 register value and the threshold value.

**Examples**:

```plaintext
1: pos: JUMPR 16, 20, GE // Jump to address (position + 16 bytes) if value in R0 >= 20

2: // Down counting loop using R0 register
MOVE R0, 16 // load 16 into R0
label: SUB R0, R0, 1 // R0--
NOP // do something
JUMPR label, 1, GE // jump to label if R0 >= 1
```

### JUMPS – Jump to a relative address (condition based on stage count)

**Syntax** JUMPS Step, Threshold, Condition

**Operands**
• **Step** – relative shift from current position, in bytes
• **Threshold** – threshold value for branch condition
• **Condition:**
  - **EQ** (equal) – jump if value in stage_cnt == threshold
  - **LT** (less than) – jump if value in stage_cnt < threshold
  - **LE** (less or equal) – jump if value in stage_cnt <= threshold
  - **GT** (greater than) – jump if value in stage_cnt > threshold
  - **GE** (greater or equal) – jump if value in stage_cnt >= threshold

**Cycles**  Conditions **LE, LT, GE**: 2 cycles to execute, 2 cycles to fetch next instruction
Conditions **EQ, GT** are implemented in the assembler using two **JUMPS** instructions:

```c
// JUMPS target, threshold, EQ is implemented as:
JUMPS next, threshold, LT
JUMPS target, threshold, LE

// JUMPS target, threshold, GT is implemented as:
JUMPS next, threshold, LE
JUMPS 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 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:**
**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:**

1: `STAGE_DEC 10 // stage_cnt -= 10`

2: `STAGE_RST // set stage_cnt to 0`  
   STAGE_INC 1 // stage_cnt++  
   NOP // do something  
   JUMPS label, 16, LT // jump to label if stage_cnt < 16

---

**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:**

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_ULP_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:**

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
Chapter 4. API

(Jump is_rdy_for_wakeup, eq) // Retry until the bit is set
WAKE // Trigger wake up
REG_WR 0x006, 24, 24, 0 // Stop ULP timer (clear RTC_CNTL_ULP_CP_—SLP_TIMER_EN)
HALT // Stop the ULP program
// After these instructions, SoC will wake up,
// and ULP will not run again until started by the main program.

SLEEP – set ULP wake up 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 wake up timer as wake up 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 - selected PAD, SARADC Pad[Mux-1] is enabled. If the user passes Mux value 1, then ADC pad 0 gets used.

Cycles  23 + max(1, SAR_AMP_WAIT1) + max(1, SAR_AMP_WAIT2) + max(1, SAR_AMP_WAIT3) + SARx_SAMPLE_CYCLE + SARx_SAMPLE_BIT cycles to execute, 4 cycles to fetch next instruction

Description The instruction makes measurements from ADC.

Examples:

1: ADC R1, 0, 1 // Measure value using ADC1 pad 2 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: 
\[ R0 = \text{REG}[\text{Addr}[\text{High:Low}]]. \]

This instruction can access registers in RTC_CNTL, RTC_IO, SENS, and RTC_I2C peripherals. Address of the register, as seen from the ULP, can be calculated from the address of the same register on the DPORT bus as follows:

\[ \text{addr}_\text{ulp} = (\text{addr}_\text{dport} - \text{DR_REG_RTCCNTL_BASE}) / 4 \]

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:
\[ \text{REG}[\text{Addr}][\text{High:Low}] = \text{data}. \]

This instruction can access registers in RTC_CNTL, RTC_IO, SENS, and RTC_I2C peripherals. Address of the register, as seen from the ULP, can be calculated from the address of the same register on the DPORT bus as follows:

\[ \text{addr}_\text{ulp} = (\text{addr}_\text{dport} - \text{DR_REG_RTCCNTL_BASE}) / 4 \]

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:

```cpp
#include "soc/soc_ulp.h"
#include "soc/rtc_cntl_reg.h"
```
4.19.2 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:

```c
const ulp_insn_t program[] = {
    I_MOVI(R3, 16),          // R3 <- 16
    I_LD(R0, R3, 0),        // R0 <- RTC_SLOW_MEM[R3 + 0]
    I_LD(R1, R3, 1),        // R1 <- RTC_SLOW_MEM[R3 + 1]
    I_ADDR(R2, R0, R1),     // R2 <- R0 + R1
    I_ST(R2, R3, 2),        // R2 -> RTC_SLOW_MEM[R2 + 2]
    I_HALT()                
};
```

The `program` array is an array of `ulp_insn_t`, i.e. ULP coprocessor instructions. Each `I_XXX` preprocessor define translates into a single 32-bit instruction. Arguments of these preprocessor defines can be register numbers (`R0`, `R3`) and literal constants. See `ULP coprocessor instruction defines` section for descriptions of instructions and arguments they take.

注解：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).
Chapter 4. API

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_Baaa_ 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:

```c
const ulp_insn_t program[] = {
    I_MOVI(R0, 34),  // R0 <- 34
    M_LABEL(1),      // label_1
    I_MOVI(R1, 32),  // R1 <- 32
    I_LD(R1, R1, 0), // R1 <- RTC_SLOW_MEM[R1]
    I_MOVI(R2, 33),  // R2 <- 33
    I_LD(R2, R2, 0), // R2 <- RTC_SLOW_MEM[R2]
    I_SUBR(R3, R1, R2),  // R3 <- R1 - R2
    I_ST(R3, R0, 0),   // R3 -> RTC_SLOW_MEM[R0 + 0]
    I_ADDI(R0, R0, 1), // R0++
    M_BL(1, 64),      // if (R0 < 64) goto label_1
    I_HALT(),
};
RTC_SLOW_MEM[32] = 42;
RTC_SLOW_MEM[33] = 18;
size_t load_addr = 0;
size_t size = sizeof(program)/sizeof(ulp_insn_t);
ulp_process_macros_and_load(load_addr, program, &size);
ulp_run(load_addr);
```

Application Example

Demonstration of entering into deep sleep mode and waking up using several wake up sources: _system/deep_sleep_.

API Reference

Header File

- `ulp/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 *size)
```

Resolve all macro references in a program and load it into RTC memory.

Return

- ESP_OK on success
- ESP_ERR_NO_MEM if auxiliary temporary structure cannot be allocated
- one of ESP_ERR_ulp_xxx if program is not valid or can not be loaded

Parameters

- `load_addr`: address where the program should be loaded, expressed in 32-bit words
- `program`: ulp_insn_t array with the program
- `size`: 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

ESP_ERR_ULP_DUPLICATE_LABEL
More than one label with the same number was defined

ESP_ERR_ULP_UNDEFINED_LABEL
Branch instructions references an undefined label

ESP_ERR_ULP_BRANCH_OUT_OF_RANGE
Branch target is out of range of B instruction (try replacing with BX)

ULP coprocessor registers  ULP co-processor has 4 16-bit general purpose registers. All registers have same functionality, with one exception. R0 register is used by some of the compare-and-branch instructions as a source register.

These definitions can be used for all instructions which require a register.

R0
general purpose register 0

R1
general purpose register 1

R2
general purpose register 2

R3
general purpose register 3

ULP coprocessor instruction defines

I_DELAY (cycles_)
Delay (nop) for a given number of cycles

I_HALT ()
Halt the coprocessor.
This instruction halts the coprocessor, but keeps ULP timer active. As such, ULP program will be restarted again by timer. To stop the program and prevent the timer from restarting the program, use I_END(0) instruction.

I_END ()
Stop ULP program timer.
This is a convenience macro which disables the ULP program timer. Once this instruction is used, ULP program will not be restarted anymore until ulp_run function is called.

ULP program will continue running after this instruction. To stop the currently running program, use I_HALT().

I_ST (reg_val, reg_addr, offset_)
Store value from register reg_val into RTC memory.
The value is written to an offset calculated by adding value of reg_addr register and offset_field (this offset is expressed in 32-bit words). 32 bits written to RTC memory are built as follows:

• bits [31:21] hold the PC of current instruction, expressed in 32-bit words
• bits [20:16] = 5’b1
• bits [15:0] are assigned the contents of reg_val
RTC_SLOW_MEM[addr + offset_] = \{ 5’b0, insn_PC[10:0], val[15:0] \}

**I_LD** (reg_dest, reg_addr, offset_)
Load value from RTC memory into reg_dest register.
Loads 16 LSBs from RTC memory word given by the sum of value in reg_addr and value of offset_.

**I_WR_REG** (reg, low_bit, high_bit, val)
Write literal value to a peripheral register
reg[high_bit : low_bit] = val This instruction can access RTC_CNTL_, RTC_IO_, SENS_, and RTC_I2C peripheral registers.

**I_RD_REG** (reg, low_bit, high_bit)
Read from peripheral register into R0
R0 = reg[high_bit : low_bit] This instruction can access RTC_CNTL_, RTC_IO_, SENS_, and RTC_I2C peripheral registers.

**I_BL** (pc_offset, imm_value)
Branch relative if R0 less than immediate value.
pc_offset is expressed in words, and can be from -127 to 127 imm_value is a 16-bit value to compare R0 against

**I_BGE** (pc_offset, imm_value)
Branch relative if R0 greater or equal than immediate value.
pc_offset is expressed in words, and can be from -127 to 127 imm_value is a 16-bit value to compare R0 against

**I_BXR** (reg_pc)
Unconditional branch to absolute PC, address in register.
reg_pc is the register which contains address to jump to. Address is expressed in 32-bit words.

**I_BXI** (imm_pc)
Unconditional branch to absolute PC, immediate address.
Address imm_pc is expressed in 32-bit words.

**I_BXZR** (reg_pc)
Branch to absolute PC if ALU result is zero, address in register.
reg_pc is the register which contains address to jump to. Address is expressed in 32-bit words.

**I_BXZI** (imm_pc)
Branch to absolute PC if ALU result is zero, immediate address.
Address imm_pc is expressed in 32-bit words.

**I_BXFR** (reg_pc)
Branch to absolute PC if ALU overflow, address in register
reg_pc is the register which contains address to jump to. Address is expressed in 32-bit words.

**I_BXFI** (imm_pc)
Branch to absolute PC if ALU overflow, immediate address
Address imm_pc is expressed in 32-bit words.

**I_ADDR** (reg_dest, reg_src1, reg_src2)
Addition: dest = src1 + src2

**I_SUBR** (reg_dest, reg_src1, reg_src2)
Subtraction: dest = src1 - src2

**I_ANDR** (reg_dest, reg_src1, reg_src2)
Logical AND: dest = src1 & src2
**Chapter 4. API**

**I_ORR** (reg_dest, reg_src1, reg_src2)
Logical OR: dest = src1 | src2

**I_MOVDR** (reg_dest, reg_src)
Copy: dest = src

**I_LSHR** (reg_dest, reg_src, reg_shift)
Logical shift left: dest = src << shift

**I_RSHR** (reg_dest, reg_src, reg_shift)
Logical shift right: dest = src >> shift

**I_ADDI** (reg_dest, reg_src, imm_)
Add register and an immediate value: dest = src1 + imm

**I_SUBI** (reg_dest, reg_src, imm_)
Subtract register and an immediate value: dest = src - imm

**I_ANDI** (reg_dest, reg_src, imm_)
Logical AND register and an immediate value: dest = src & imm

**I_ori** (reg_dest, reg_src, imm_)
Logical OR register and an immediate value: dest = src | imm

**I_MOVI** (reg_dest, imm_)
Copy an immediate value into register: dest = imm

**I_LSHI** (reg_dest, reg_src, imm_)
Logical shift left register value by an immediate: dest = src << imm

**I_RSHI** (reg_dest, reg_src, imm_)
Logical shift right register value by an immediate: dest = src >> 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

ULP （Ultra Low Power 超低功耗）协处理器是一种简单的有限状态机 (FSM)，可以在主处理器处于深度睡眠模式时，使用 ADC、温度传感器和外部 12C 传感器执行测量操作。ULP 协处理器可以访问 RTC_SLOW_MEM 内存区域及 RTC_CNTL、RTC_IO、SARADC 等外设寄存器。ULP 协处理器使用 32 位固定宽度的指令，32 位内存寻址，配备 4 个 16 位通用寄存器。

4.19.3 安装工具链

ULP 协处理器代码是用汇编语言编写的，并使用 binutils-esp32ulp 工具链进行编译。

如果你已经按照 快速入门指南 中的介绍安装好了 ESP-IDF 及其 CMake 构建系统，那么 ULP 工具链已被默认安装到了你的开发环境中。

4.19.4 编译 ULP 代码

若需要将 ULP 代码编译为某组件的一部分，则必须执行以下步骤：

1. 用汇编语言编写的 ULP 代码必须导入到一个或多个 .S 扩展文件中，并且这些文件必须放在组件目录中一个独立的目录中，例如 ulp/。

2. 注册后从组件 CMakeLists.txt 中调用 ulp_embed_binary 示例如下：

   ```
   ...
   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}")
   ```

上述第一个参数到 ulp_embed_binary 为 ULP 二进制文件命名，此名称也用于生成的其他文件，如：ELF 文件、.map 文件、.o 文件和链接器生成文件。第二个参数设置 ULP 程序集源文件。最后，第三个参数设置组件源文件列表，其中包括被生成的头文件。此列表用以建立正确的依赖项，并确保在构建过程中生成所有包含头文件的源文件。请参考下文，查看 ULP 程序生成的头文件等相关概念。

3. 使用常规方法（例如 idf.py app）编译应用程序

   在内部，构建系统将按照以下步骤编译 ULP 程序：

   1. 通过 C 预处理器执行所有程序集文件 (foo.S)。此步骤在组件编译目录中生成预处理的程序集文件 (foo.ulp.S)，同时生成依赖文件 (foo.ulp.d)。

   2. 通过汇编器执行预处理过的汇编源码。此步骤会生成目标文件 (foo.ulp.o) 和清单 (foo.ulp.lst)。清单文件仅用于调试，不用于编译过程的后续步骤。

   3. 通过 C 预处理器执行链接器脚本模板。模板位于 components/ulp/ld 目录中。

   4. 将目标文件链接到 ELF 输出文件 (ulp_app_name.elf)。此步骤生成的.map 文件 (ulp_app_name.map) 默认用于调试。

   5. 将 ELF 文件中的内容转换为二进制文件 (ulp_app_name.bin)，以便嵌入到应用程序中。

   6. 使用 esp32ulp-elf-nm 在 ELF 文件中生成全局符号列表 (ulp_app_name.sym)。
Chapter 4. API

7. 创建 LD 导出脚本和头文件 (ulp_app_name.ld 和 ulp_app_name.h)，包含来自 ulp_app_name.sym 的符号。此步骤可借 esp32ulp_mapgen.py 工具来完成。
8. 将生成的二进制文件添加到要嵌入应用程序的二进制文件列表中。

4.19.5 访问 ULP 程序变量

在 ULP 程序中定义的全局符号也可以在主程序中使用。

例如，ULP 程序可以定义 measurement_count 变量，此变量可以定义程序从深度睡眠中唤醒芯片之前需要进行的 ADC 测量的次数：

```c
.global measurement_count
measurement_count: .long 0

/* later, use measurement_count */
move r3, measurement_count
ld r3, r3, 0
```

主程序需要在启动 ULP 程序之前初始化 measurement_count 变量，构建系统生成定义 ULP 编程中全局符号的 $(ULP_APP_NAME).h 和 $(ULP_APP_NAME).ld 文件，可以实现上述操作，这些文件包含在 ULP 程序中定义的所有全局符号，文件以 ulp_ 开头。

头文件包含对此类符号的声明：

```c
extern uint32_t ulp_measurement_count;
```

注意，所有符号（包括变量、数组、函数）均被声明为 uint32_t，对于函数和数组，先获取符号地址，然后转换为适当的类型。

生成的链接器脚本文本定义了 RTC_SLOW_MEM 中的符号位置：

```c
PROVIDE ( ulp_measurement_count = 0x50000060 );
```

如果要从主程序访问 ULP 程序变量，应先使用 include 语句包含生成的头文件，这样，就可以像访问常规变量一样访问 ulp 程序变量。操作如下：

```c
#include "ulp_app_name.h"

// later
void init_ulp_vars() {
    ulp_measurement_count = 64;
}
```

注意，ULP 程序在 RTC 内存中只能使用 32 位字的低 16 位，因为寄存器是 16 位的，并且不具备从字的高位加载的指令。

同样，ULP 储存指令将寄存器值写入 32 位字的低 16 位中。高 16 位写入的值取决于储存指令的地址，因此在读取 ULP 写的变量时，主应用程序需要屏蔽高 16 位，例如：

```c
printf("Last measurement value: \033[0;30;37m%d\033[0m", ulp_last_measurement & UINT16_MAX);
```

4.19.6 启动 ULP 程序

要运行 ULP 程序，主应用程序需要调用 ulp_load_binary 函数将 ULP 程序加载到 RTC 内存中，然后调用 ulp_run 函数，启动 ULP 程序。

注意，在 menuconfig 中必须启用 “Enable Ultra Low Power (ULP) Coprocessor” 选项，以便为 ULP 预留内存。“RTC slow memory reserved for coprocessor” 选项设置的值必须足够储存 ULP 代码和数据。如果应用程序组件包含多个 ULP 程序，则 RTC 内存必须足以容纳最大的程序。
每个 ULP 程序均以二进制 BLOB 的形式嵌入到 ESP-IDF 应用程序中。应用程序可以引用此 BLOB，并以下面的方式加载此 BLOB（假设 ULP_APP_NAME 已被定义为 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)) );
}
```

```c
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

一旦上述程序加载到 RTC 内存后，应用程序即可启动此程序，并将入口点的地址传递给 ulp_run 函数：

```c
ESP_ERROR_CHECK( ulp_run(&ulp_entry - RTC_SLOW_MEM) );
```

```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

上述生成的头文件 $(ULP_APP_NAME).h 声明了入口点符号。在 ULP 应用程序的汇编源代码中，此符号必须标记为 .global：

```asm
.global entry
entry:
/* code starts here */
```
4.19.7 ULP 程序流

ULP 协处理器由定时器启动，而调用 ulp_run 则可启动此定时器。定时器为 RTC_SLOW_CLK 的 Tick 事件计数（默认情况下，Tick 由内部 150 KHz 晶振器生成）。使用 SENS_ULP_CP_SLEEP_CYCx_REG 寄存器 (x = 0..4) 设置 Tick 数值。第一次启动 ULP 时，使用 SENS_ULP_CP_SLEEP_CYC0_REG 设置定时器 Tick 数值，之后，ULP 程序可以使用 sleep 指令来另外选择 SENS_ULP_CP_SLEEP_CYC_REG 寄存器。

此应用程序可以调用 ulp_set_wakeup_period 函数来设置 ULP 定时器周期值 (SENS_ULP_CP_SLEEP_CYC_REG, x = 0..4)。

```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 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

一旦定时器为所选的 SENS_ULP_CP_SLEEP_CYCx_REG 寄存器的 Tick 事件计数，ULP 协处理器就会启动，并调用 ulp_run 的入口点开始运行程序。

程序保持运行，直到遇到 halt 指令或非法指令。一旦程序停止，ULP 协处理器电源关闭，定时器再次启动。

如果想禁用定时器（有效防止 ULP 程序再次运行），请清除 RTC_CNTL_STATE0_REG 寄存器中的 RTC_CNTL_ULP_CP_SLP_TIMER_EN 位，可在 ULP 代码或主程序中进行以上操作。

4.20 ULP 协处理器 (传统的 GNU Make)

注解：ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统构建系统。请注意，未来，我们可能不会继续支持基于 GNU Make 的构建系统。

ULP（Ultra Low Power 超低功耗）协处理器是一种简单的有限状态机 (FSM)，可以在主处理器处于深度睡眠模式时，使用 ADC、温度传感器和外部 I2C 传感器执行测量操作。ULP 协处理器可以访问 RTC_SLOW_MEM 内存区域及 RTC_CNTL、RTC_IO、SARADC 等外设寄存器。ULP 协处理器使用 32 位固定宽度的指令，32 位内存寻址，配备 4 个 16 位通用寄存器。
4.20.1 安装工具链

ULP 协处理器代码是用汇编语言编写的，并使用 binutils-esp32ulp toolchain 进行编译。
1. 从 https://github.com/espressif/binutils-esp32ulp/releases 网站下载预编译的最新版本工具链二进制文件。
2. 将工具链提取至目录中，向工具链的 bin/ 目录中添加路径至 PATH 环境变量中。

4.20.2 编译 ULP 代码

若需要将 ULP 代码编译为某组件的一部分，则必须执行以下步骤：
1. 用汇编语言编写的 ULP 代码必须导入到一个或多个 .S 扩展文件中，且这些文件必须放在组件目录中一个独立的目录中，例如 ulp/。
2. 修改组件 makefile，添加下列参数:

   ```
   ULP_APP_NAME := ulp_${COMPONENT_NAME}
   ULP_S_SOURCES = $(COMPONENT_PATH)/ulp/ulp_source_file.S
   ULP_EXP_DEP_OBJECTS := main.o
   include $(IDF_PATH)/components/ulp/component_ulp_common.mk
   ```

代码解释如下：
ULP_APP_NAME 为生成的 ULP 应用程序命名，不带扩展名。此名称用于 ULP 应用程序的构建输出：ELF 文件、map 文件、二进制文件、生成的头文件和链接器导出文件。
ULP_S_SOURCES 设置要传递给 ULP 汇编器的程序集文件列表。列表中的路径是绝对路径，即以 $(COMPONENT_PATH) 开头的路径。如果列表中需列出多个文件，可使用函数 $(addprefix)。因为路径与组件构建目录相关，因而需前缀。
ULP_EXP_DEP_OBJECTS 设置组件中目标文件名称的列表，其中包含生成的头文件。此列表用于生成正确的依赖项，并确保在此类文件被编译前生成头文件。ULP 应用程序头文件的定义请见下文。
include $(IDF_PATH)/components/ulp/component_ulp_common.mk 包含常见的 ULP 编译步骤。为 ULP 目标文件、ELF 文件、二进制文件等定义编译目标。
3. 使用常规方法（例如 idf.py build 或 idf.py app）编译应用程序

在编译过程中，构建系统将按照以下步骤编译 ULP 程序：
1. 通过 C 预处理器运行每个程序集文件 （foo.S）。此步骤在组件编译目录中生成预处理的程序集文件 （foo.ulp.pS）。同时生成依赖文件 （foo.ulp.d）。
2. 通过汇编器运行预处理过的汇编源码。此步骤会生成目标文件 （foo.ulp.o）和清单文件 （foo.ulp.lst）。生成的清单文件用于调试，不用于构建过程的后续步骤。
3. 通过 C 预处理器运行链接器脚本模板。模板位于 components/ulp/ld 目录中。
4. 将目标文件链接到 ELF 输出文件 （ulp_app_name.elf）。此步骤生成的.map 文件 （ulp_app_name.map）可能会用于调试。
5. 将 ELF 文件中内容转储为二进制文件 （ulp_app_name.bin），以便嵌入到应用程序中。
6. 使用 esp32ulp-elf-nm 在 ELF 文件中生成全局符号列表 （ulp_app_name.sym）。
7. 创建 LD 导出脚本和头文件 （ulp_app_name.ld 和 ulp_app_name.h），包含来自 ulp_app_name.sym 的符号。此步骤通过 esp32ulp_mapgen.py 工具来完成。
8. 将生成的二进制文件添加到要嵌入应用程序的二进制文件列表中。

4.20.3 访问 ULP 程序变量

在 ULP 程序中定义的全局符号也可以在主程序中使用。
例如，ULP 程序可以定义 measurement_count 变量，此变量规定了芯片从深度睡眠模式唤醒之前，程序需要进行 ADC 测量的次数：

```
.globl measurement_count
measurement_count: .long 0
```

(下页继续)
主程序需要在启动 ULP 程序之前初始化 measurement_count 变量，构建系统通过生成定义 ULP 程序中全局符号的 $(ULP_APP_NAME).h$ 和 $(ULP_APP_NAME).ld$ 文件，可以实现上述操作：这些文件包含了 ULP 程序中所有全局符号，文件名以 ulp_ 开头。

头文件包含对此类符号的声明:

```c
extern uint32_t ulp_measurement_count;
```

注意，所有符号（包括变量、数组、函数）均被声明为 uint32_t。对于函数和数组，先获取符号地址，然后转换为适当的类型。

生成的链接器脚本文件定义了符号在 RTC_SLOW_MEM 中的位置:

```c
PROVIDE ( ulp_measurement_count = 0x50000060 );
```

如果要从主程序访问 ULP 程序变量，应先使用 include 语句包含生成的头文件，这样，就可以像访问常规变量一样访问 ulp 程序变量。操作如下:

```c
#include "ulp_app_name.h"

// later
void init_ulp_vars() {
    ulp_measurement_count = 64;
}
```

注意，ULP 程序只能使用 RTC 内存中 32 位字的低 16 位，因为寄存器是 16 位的，并且不存在从字的高位加载的指令。

同样，ULP 储存指令将寄存器值写入 32 位字的低 16 位中，写入高 16 位的值取决于存储指令的地址，因此在读取 ULP 写的变量时，主应用程序需要屏蔽高 16 位，例如:

```c
printf("Last measurement value: %d\n", ulp_last_measurement & UINT16_MAX);
```

### 4.20.4 启动 ULP 程序

要运行 ULP 程序，主应用程序需要调用 ulp_load_binary 函数将 ULP 程序加载到 RTC 内存中，然后调用 ulp_run 函数，启动 ULP 程序。

注意，在 menuconfig 中必须启用“Enable Ultra Low Power (ULP) Coprocessor”选项，以便为 ULP 预留内存。“RTC slow memory reserved for coprocessor”选项设置的值必须足够储存 ULP 代码和数据。如果应用程序组件包含多个 ULP 程序，则 RTC 内存必须足以容纳最大的程序。

每个 ULP 程序均以二进制 BLOB 的形式嵌入到 ESP-IDF 应用程序中。应用程序可以引用此 BLOB，并以下面的方式加载此 BLOB（假设 ULP_APP_NAME 已被定义为 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

一旦上述程序加载到 RTC 内存后，应用程序即可启动此程序，并将入口点的地址传递给 `ulp_run` 函数:

```
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

上述生成的头文件 $(ULP_APP_NAME).h$ 声明了入口点符号。在 ULP 应用程序的汇编源代码中，此符号必须标记为 `.global`:

```
.global entry
entry:
    /* code starts here */
```

### 4.20.5 ULP 程序流

ULP 协处理器由定时器启动，而调用 `ulp_run` 则可启动此定时器。定时器为 RTC_SLOW_CLK 的 Tick 事件计数 (默认情况下，Tick 由内部 150 kH 脉冲振荡器生成)。使用 SENS_ULP_CP_SLEEP_CYC_REG 寄存器 (x = 0..4) 设置 Tick 数值。第一次启动 ULP 时，使用 SENS_ULP_CP_SLEEP_CYC0_REG 设置定时器 Tick 数值，之后，ULP 程序可以使用 sleep 指令来另外选择 SENS_ULP_CP_SLEEP_CYC_REG 寄存器。

此应用程序可以调用 `ulp_set_wakeup_period` 函数来设置 ULP 定时器周期值 (SENS_ULP_CP_SLEEP_CYCx_REG, x = 0..4).

`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,
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 does 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

一旦定时器数值达到在所选的 SENS_ulp_cp_sleep_cycx_REG 寄存器中设置的数值，ULP 协处理器
就会启动，并调用 ulp_run 的入口点，开始运行程序。

程序保持运行，直到遇到 halt 指令或非法指令才停止。一旦程序停止，ULP 协处理器电源关闭，定时
器再次启动。

如果想禁用定时器（禁用定时器可有效防止 ULP 程序再次运行），请清除 RTC_CNTL_state0_REG 寄
存器中的 RTC_CNTL_ulp_cp_slp_timer_en 位，可在 ULP 代码或主程序中进行以上操作。

4.21 ESP32 中的单元测试

ESP-IDF 中附带了一个基于 Unity 的单元测试应用程序框架，且所有的单元测试用例分别保存在
ESP-IDF 仓库中每个组件的 test 子目录中。

4.21.1 添加常规测试用例

单元测试被添加在相应组件的 test 子目录中，测试用例写在 C 文件中，一个 C 文件可以包含多个测试
用例。测试文件的名字要以“test”开头。

测试文件需要包含 unity.h 头文件，此外还需要包含待测试 C 模块需要的头文件。

测试用例需要通过 C 文件中特定的函数来添加，如下所示:

```c
TEST_CASE("test name", "[module name]"
{
    // 在这里添加测试用例
}
```

• 第一个参数是字符串，用来描述当前测试。
• 第二个参数是字符串，用方括号中的标识符来表示，标识符用来对相关测试或具有特定属性的测试
进行分组。

注解： 没有必要在每个测试用例中使用 UNITY_BEGIN() 和 UNITY_END() 来声明主函数的区域，
unity_platform.c 会自动调用 UNITY_BEGIN(), 然后运行测试用例，最后调用 UNITY_END()。

test 子目录应包含：ref: 组件 CMakeLists.txt <component-directories>，因为他们本身就是一种组件。ESP-
IDF 使用了 unity 测试框架，需要将其指定为组件的依赖项。通常，组件：ref: 需要手动指定待编译的
源文件<make-file-globbing>，但是，对于测试组件来说，这个要求被放宽为仅建议将参数 SRC_DIRS 用于 idf_component_register。
总的来说，test 子目录下最小的 CMakeLists.txt 文件可能如下所示:

```cmake
idf_component_register(
    SRC_DIRS ".
    INCLUDE_DIRS ".
    REQUIRES unity)
```

更多关于如何在 Unity 下编写测试用例的信息，请查阅 http://www.throwtheswitch.org/unity。

### 4.21.2 添加多设备测试用例

常规测试用例会在一个 DUT（Device Under Test，在试设备）上执行，但是，那些需要互相应通的组件（比如 GPIO、SPI）需要与其通信的其他设备，因此不能使用常规测试用例进行测试。多设备测试用例包括写入多个测试函数，并在多个 DUT 进行运行测试。

以下是一个多设备测试用例:

```c
void gpio_master_test()
{
    gpio_config_t slave_config = {
        .pin_bit_mask = 1 << MASTER_GPIO_PIN,
        .mode = GPIO_MODE_INPUT,
    };
    gpio_config(&slave_config);
    unity_wait_for_signal("output high level");
    TEST_ASSERT(gpio_get_level(MASTER_GPIO_PIN) == 1);
}

void gpio_slave_test()
{
    gpio_config_t master_config = {
        .pin_bit_mask = 1 << SLAVE_GPIO_PIN,
        .mode = GPIO_MODE_OUTPUT,
    };
    gpio_config(&master_config);
    gpio_set_level(SLAVE_GPIO_PIN, 1);
    unity_send_signal("output high level");
}

TEST_CASE_MULTIPLE_DEVICES("gpio multiple devices test example", "[driver]", gpio_master_test, gpio_slave_test);
```

宏 TEST_CASE_MULTIPLE_DEVICES 用来声明多设备测试用例，
- 第一个参数指定测试用例的名字。
- 第二个参数是测试用例的描述。
- 从第三个参数开始，可以指定最多 5 个测试函数，每个函数都是单独运行在一个 DUT 上的测试入口点。

在不同的 DUT 上运行的测试用例，通常会要求它们之间进行同步。我们提供 unity_wait_for_signal 和 unity_send_signal 这两个函数来使用 UART 去支持同步操作。如上例中的场景， slave 应该在在 master 设置好 GPIO 电平后去读取 GPIO 电平，DUT 的 UART 终端会打印提示信息，并要求用户进行交互。

DUT1（master）终端:

Waiting for signal: [output high level]!
Please press "Enter" key once any board send this signal.

DUT2（slave）终端:
一 旦 DUT2 发送了信号，您需要在 DUT1 的终端按键回车键，然后 DUT1 会从
unity_wait_for_signal 函数中解除阻塞，并开始更改 GPIO 的电平。

4.21.3 添加多阶段测试用例

常规的测试用例无需重启就会结束（或者仅需要检查是否发生了重启）。有些时候我们想在某些特定类型
的重启事件后运行指定的测试代码。例如，我们想在深度睡眠唤醒后检查复位的原因是否正确。首先
我们需要出发深度睡眠复位事件，然后检查复位的原因。为了实现这一点，我们可以定义多阶段测试用
例来将这些测试函数组合在一起。

```c
static void trigger_deepsleep(void)
{
    esp_sleep_enable_timer_wakeup(2000);
    esp_deep_sleep_start();
}
void check_deepsleep_reset_reason()
{
    RESET_REASON reason = rtc_get_reset_reason(0);
    TEST_ASSERT(reason == DEEPSLEEP_RESET);
}
TEST_CASE_MULTIPLE_STAGES("reset reason check for deepsleep", "/esp32", trigger_-
→deepsleep, check_deepsleep_reset_reason);
```

多阶段测试用例向用户呈现了一组测试函数，它需要用户进行交互（选择用例并选择不同的阶段）来运
行。

4.21.4 应用于不同芯片的单元测试

某些测试（尤其与硬件相关的）无法在所有的芯片上执行。请参照本节让你的单元测试只在其中一部分
芯片上执行。

1. 使用宏！(TEMPORARY_)DISABLED_FOR_TARGETS() 保护你的测试代码，并将其放
在原来的位置，或者放在另外准备以功能区分的文件。但请确保所有这些文件都会被编译器处理到。例：

```c
#if !TEMPORARY_DISABLED_FOR_TARGETS(ESP32, ESP8266) TEST_CASE("a test that is
→not ready for esp32 and esp8266 yet", ")
{
}
#endif
```

一旦您需要其中一个测试在某个芯片上被编译，只需要修改禁止的芯片列表。我们更鼓励使用一些
通用的概念（能在 soc_caps.h 中被清楚描述）来禁止某些单元测试。如果你已经这样做，但有
一些测试还没有在新的芯片版本中被调试通过，请同时使用上述两种方法，当调试完成后移除
(TEMPORARY_)DISABLED_FOR_TARGETS()。例：

```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
#endif
```
2. 对于某些你绝对不可能被支持的测试（例如，芯片根本没该外设），使用 `DISABLED_FOR_TARGETS` 来禁止该测试；对于其他只是临时性需要关闭的（例如，没有 `runner` 资源等），使用 `TEMPORARY_DISABLED_FOR_TARGETS` 来暂时关闭该测试。

请勿继续使用一些旧的禁止单元测试在一些芯片上执行的做法，因为他们具有明显的坏处:

- 请勿将测试代码放在 test/芯片版本目录下，然后用 CMakeLists.txt 来选择其中一个进行编译。这是因为测试代码比实现代码更容易被复用。如果你将一些代码放在 test/esp32 目录下避免 esp32S 芯片执行它，一旦你需要在新的芯片（比如 esp32S3）中启用该测试，你会发现这种结构非常难以保持代码的整洁。
- 请勿继续使用 `CONFIG_IDF_TARGET_xxx` 宏来禁止某些测试在一些芯片上编译。这种方法会让被禁止的测试项目难以追踪和重新打开，并且，相比于白名单式的 `if CONFIG_IDF_TARGET_xxx` ，黑名单式的 `if !disabled` 能避免新芯片引入时，这些测试被自动关闭。
  但对于用于测试的一些实现，`if CONFIG_IDF_TARGET_xxx` 仍可用于给不同芯片版本选择实现代码。测试项目和测试实现区分如下:
  - 测试项目：某些你会在一些芯片上执行，而另外一些上跳过的项目，例如：
    - 有三个测试项目 `SD 1-bit`、`SD 4-bit` 和 `SDSPI`，对于不支持 SD Host 外设的 ESP32-S2 芯片，只有 SD SPI 一个项目需要被执行。
  - 测试实现：某些代码永远会发生，但采取不同的做法。例如：
    - ESP32C6 芯片没有 `SDIO_PKT_LEN` 寄存器。如果在测试过程中需要获取从机准备好的数据长度，你可以用 `if CONFIG_IDF_TARGET_xxx` 宏来选取读取该长度的不同方法实现。
    但请注意避免使用 `else` 宏。这样当新芯片被引入时，测试就会在编译阶段失败，提示维护者去显示选择一个正确的测试实现。

### 4.2.15 编辑单元测试程序

按照 esp-idf 顶层目录的 README 文件中的说明进行操作，请确保 IDF_PATH 环境变量已经被设指向了 esp-idf 的顶层目录。

切换到 tools/unit-test-app 目录下进行配置和编译:

```
  * idf.py menuconfig - 配置单元测试程序。
  * idf.py -T all build - 编译单元测试程序，测试每个组件 test 子目录下的用例。
  * idf.py -T "xxx yyyy" build - 编译单元测试程序，测试指定的组件。
  * idf.py -T all -E "xxx yyyy" build - 编译单元测试程序，测试所有（除开指定）的组件。
    (例如 idf.py -T all -E "ulp mbedtls" build - 编译所有的单元测试，不包括 ulp 和 mbedtls 组件。)
```

当编译完成时，它会打印出烧写芯片的指令。您只需要运行 idf.py flash 即可烧写所有编译输出的文件。

您还可以运行 idf.py -T all flash 或者 idf.py -T xxx flash 来编译并烧写，所有需要的文件都会在烧写之前自动重新编译。

使用 menuconfig 可以设置烧写测试程序所使用的串口。

### 4.2.16 运行单元测试

烧写完成后重启 ESP32，它会启动单元测试程序。

当单元测试应用程序空闲时，输入回车键，它会打印出测试菜单，其中包含所有的测试项目。

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]

(下页继续)
4.22 单元测试（传统的 GNU Make）

注解：ESP-IDF V4.0 及之后版本的默认构建系统为 CMake。本文档主要针对之前基于 GNU Make 的传统
构建系统。请注意，未来，我们可能不会继续支持基于 GNU Make 的构建系统。

ESP-IDF 中附带了一个基于 Unity 的单元测试应用程序框架，且所有的单元测试用例分别保存在
ESP-IDF 仓库中每个组件的 test 子目录中。
4.22.1 添加常规测试用例

单元测试被添加在相应组件的 test 子目录中。测试用例写在 C 文件中，一个 C 文件可以包含多个测试用例。测试文件的名字要以 "test" 开头。

测试文件需要包含 unity.h 头文件。此外还需要包含待测试 C 模块需要的头文件。

测试用例需要通过 C 文件中特定的函数来添加。如下所示:

```c
TEST_CASE("test name", "[module name]
{
  // 在这里添加测试用例
}
```

第一个参数是字符串，用来描述当前测试。第二个参数是字符串，用于括号中的标识符来表示，标识符用来对相关测试或具有特定属性的测试进行分组。

注解：没有必要在每个测试用例中使用 UNITY_BEGIN() 和 UNITY_END() 来声明主函数的区域，unity_platform.c 会自动调用 UNITY_BEGIN()，然后运行测试用例，最后调用 UNITY_END()。

每一个测试子目录下都需包含 component.mk 文件，并且其中至少要包含下述的一行代码:

```c
COMPONENT_ADD_LDFLAGS = -Wl,--whole-archive -l$(COMPONENT_NAME) -Wl,--no-whole-archive
```

更多关于如何在 Unity 下编写测试用例的信息，请查阅 http://www.throwtheswitch.org/unity。

4.22.2 添加多设备测试用例

常规测试用例会在一个 DUT（Device Under Test，在试设备）上执行。但是，那些需要互相通信的组件（比如 GPIO、SPI）需要与其通信的其他设备，因此不能使用常规测试用例进行测试。多设备测试用例包括写入多个测试函数，并在多个 DUT 进行运行测试。

以下是一个多设备测试用例:

```c
void gpio_master_test()
{
  gpio_config_t slave_config = {
    .pin_bit_mask = 1 << MASTER_GPIO_PIN,
    .mode = GPIO_MODE_INPUT,
  }
  gpio_config(&slave_config);
  unity_wait_for_signal("output high level");
  TEST_ASSERT(gpio_get_level(MASTER_GPIO_PIN) == 1);
}
void gpio_slave_test()
{
  gpio_config_t master_config = {
    .pin_bit_mask = 1 << SLAVE_GPIO_PIN,
    .mode = GPIO_MODE_OUTPUT,
  }
  gpio_config(&master_config);
  gpio_set_level(SLAVE_GPIO_PIN, 1);
  unity_send_signal("output high level");
}
TEST_CASE_MULTIPLE_DEVICES("gpio multiple devices test example", "[driver]", gpio_--master_test, gpio_slave_test);
```

宏 TEST_CASE_MULTIPLE_DEVICES 用来声明多设备测试用例。

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Chapter 4. API

• 第一个参数指定测试用例的名字。
• 第二个参数是测试用例的描述。
• 从第三个参数开始，可以指定最多 5 个测试函数，每个函数都是单独运行在一个 DUT 上的测试入口点。

在不同的 DUT 上运行的测试用例，通常会要求它们之间进行同步。我们提供 unity_wait_for_signal 和 unity_send_signal 这两个函数来使用 UART 去支持同步操作。如上例中的场景，slave 应该在在 master 设置好 GPIO 电平后再去读取 GPIO 电平，DUT 的 UART 终端会打印提示信息，并要求用户进行交互。

DUT1（master）终端:

Waiting for signal: [output high level]!
Please press "Enter" key once any board send this signal.

DUT2（slave）终端:

Send signal: [output high level]!

一旦 DUT2 发送了该信号，您需要在 DUT1 按回车键，然后 DUT1 会从 unity_wait_for_signal 函数中解除阻塞，并开始更改 GPIO 的电平。

信号也可以用来在不同设备之间传递参数。例如，DUT1 希望得到 DUT2 的 MAC 地址来进行蓝牙连接，这时，可使用 unity_wait_for_signal_param 以及 unity_send_signal_param。

DUT1 终端:

Waiting for signal: [dut2 mac address]!
Please input parameter value from any board send this signal and press "Enter" key.

DUT2 终端:

Send signal: [dut2 mac address][10:20:30:40:50:60]!

一旦 DUT2 发送信号，您需要在 DUT1 输入 10:20:30:40:50:60 并按回车键，然后 DUT1 会获取 DUT2 的 MAC 地址字符串，并从 unity_wait_for_signal_param 函数中解除阻塞，然后蓝牙连接 DUT2。

4.22.3 添加多阶段测试用例

常规的测试用例无需重启就会结束（或者仅需要检查是否发生了重启），可有些时候我们想在某些特定类型的重启事件后运行指定的测试代码。例如，我们想在深度睡眠唤醒后检查复位的原因是否正确。首先我们需要发出深度睡眠复位事件，然后检查复位的原因。为了实现这一点，我们可以定义多阶段测试用例来将这些测试函数组合在一起。

```c
static void trigger_deepsleep(void)
{
    esp_sleep_enable_timer_wakeup(2000);
    esp_deep_sleep_start();
}

void check_deepsleep_reset_reason()
{
    RESET_REASON reason = rtc_get_reset_reason(0);
    TEST_ASSERT(reason == DEEPSLEEP_RESET);
}

TEST_CASE_MULTIPLE_STAGES("reset reason check for deepsleep", "{esp32}", trigger_deepsleep, check_deepsleep_reset_reason);
```

多阶段测试用例向用户呈现了一组测试函数，它需要用户进行交互（选择用例并选择不同的阶段）来运行。
4.22.4 编译单元测试程序

按照 esp-idf 顶层目录的 README 文件中的说明进行操作，请确保 IDF_PATH 环境变量已经被设置指向了 esp-idf 的顶层目录。

切换到 tools/unit-test-app 目录下进行配置和编译

- make menuconfig - 配置单元测试程序。
- make TESTS_ALL=1 - 编译单元测试程序，测试每个组件 test 子目录下的用例。
- make TEST_COMPONENTS='xxx' - 编译单元测试程序，测试指定的组件。
- make TESTS_ALL=1 TEST_EXCLUDE_COMPONENTS='xxx' - 编译所有的单元测试，不包括 ulp 和 mbedtls 组件。

当编译完成时，它会打印出烧写芯片的指令。您只需要运行 make flash 即可烧写所有编译输出的文件。

您还可以运行 make flash TESTS_ALL=1 或者 make TEST_COMPONENTS='xxx' 来编译并烧写，所有需要的文件都会在烧写之前自动重新编译。

使用 menuconfig 可以设置烧写测试程序所使用的串口。

4.22.5 运行单元测试

烧写完成后重启 ESP32，它将启动单元测试程序。

当单元测试应用程序空闲时，输入回车键，它会打印出测试菜单，其中包含所有的测试项目。

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 (HSPI) to host2 (VSPI)"  [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"

常规测试用例会打印用例名字和描述，主从测试用例还会打印子菜单（已注册的测试函数的名字）。

可以输入以下任意一项来运行测试用例：

- 引号中的测试用例的名字（例如 "esp_ota_begin() verifies arguments"），运行单个测试用例。
- 测试用例的序号（例如 1），运行单个测试用例。
- 方括号中的模组名称（例如 [cxx]），运行指定模组的所有的测试用例。
4.23 ESP32 ROM console

When an ESP32 is unable to boot from flash ROM (and the fuse disabling it hasn’t been blown), it boots into a rom console. The console is based on TinyBasic, and statements entered should be in the form of BASIC statements. As is common in the BASIC language, without a preceding line number, commands entered are executed immediately; lines with a prefixed line number are stored as part of a program.

4.23.1 Full list of supported statements and functions

System

- **BYE** - exits Basic, reboots and retries booting from flash
- **END** - stops execution from the program, also “STOP”
- **MEM** - displays memory usage statistics
- **NEW** - clears the current program
- **RUN** - executes the current program

IO, Documentation

- **PEEK** (address) - get a 32-bit value from a memory address
- **POKE** - write a 32-bit value to memory
- **USR** (addr, arg1,..) - Execute a machine language function
- **PRINT** expression - print out the expression, also “?”
- **PHEX** expression - print expression as a hex number
- **REM** stuff - remark/comment, also “;”

Expressions, Math

- **A=V, LET A=V** - assign value to a variable
- **+,-,*,/** - Math
- **<,<=,=,>,!=,>=** - Comparisons
• ABS(expression) - returns the absolute value of the expression
• RSEED(v) - sets the random seed to v
• RND(m) - returns a random number from 0 to m
• A=1234 - * Assign a decimal value*
• A=&h1A2 - * Assign a hex value*
• A=&b1001 - * Assign a binary value*

Control

• IF expression statement - perform statement if expression is true
• FOR variable = start TO end - start for block
• FOR variable = start TO end STEP value - start for block with step
• NEXT - end of for block
• GOTO linenum - continue execution at this line number
• GOSUB linenum - call a subroutine at this line number
• RETURN - return from a subroutine
• DELAY - Delay a given number of milliseconds

Pin IO

• IODIR - Set a GPIO-pin as an output (1) or input (0)
• IOSET - Set a GPIO-pin, configured as output, to high (1) or low (0)
• IOGET - Get the value of a GPIO-pin

4.23.2 Example programs

Here are a few example commands and programs to get you started…

Read UART_DATE register of uart0

```
> PHEX PEEK(&h3FF40078)  
15122500
```

Set GPIO2 using memory writes to GPIO_OUT_REG

Note: you can do this easier with the IOSET command

```
> POKE &h3FF44004,PEEK(&h3FF44004) OR &h100
```

Get value of GPIO0

```
> IODIR 0,0  
> PRINT IOGET(0)  
0
```

Blink LED

Hook up an LED between GPIO2 and ground. When running the program, the LED should blink 10 times.
Chapter 4. API

4.23.3 Credits

The ROM console is based on “TinyBasicPlus” by Mike Field and Scott Lawrence, which is based on “68000 TinyBasic” by Gordon Brandly

4.24 RF calibration

ESP32 supports three RF calibration methods during RF initialization:

1. Partial calibration
2. Full calibration
3. No calibration

4.24.1 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_ESP32_PHY_CALIBRATION_AND_DATA_STORAGE`.

4.24.2 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_ESP32_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.

4.24.3 No calibration

No calibration method is only used when the device wakes up from deep sleep.
4.24.4 PHY initialization data

The PHY initialization data is used for RF calibration. There are two ways to get the PHY initialization data.

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_ESP32_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_ESP32_PHY_INIT_DATA_IN_PARTITION`.

4.25 Wi-Fi Driver

4.25.1 ESP32 Wi-Fi Feature List

- Support Station-only mode, AP-only mode, Station/AP-coexistence mode
- Support IEEE-802.11B, IEEE-802.11G, IEEE802.11N and APIs to configure the protocol mode
- Support WPA/WPA2/WPA2-Enterprise and WPS
- Support AMPDU, HT40, QoS and other key features
- Support Modem-sleep
- Support an Espressif-specific protocol which, in turn, supports up to 1 km of data traffic
- Up to 20 MBit/sec TCP throughput and 30 MBit/sec UDP throughput over the air
- Support Sniffer
- Support both fast scan and all-channel scan
- Support multiple antennas
- Support channel state information

4.25.2 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 that you become familiar at least with the following sections: `<ESP32 Wi-Fi API Error Code>`, `<ESP32 Wi-Fi Programming Model>`, and `<ESP32 Wi-Fi Event Description>`.

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>`

4.25.3 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.

4.25.4 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 or - 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.

4.25.5 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
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).

### 4.25.6 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 AP+Station, 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 AP+Station, 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(), or esp_wifi_deinit(), or esp_wifi_restart() 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. Its 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".

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 scenario, 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.
Chapter 4. API

**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 WiFi 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 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.

### 4.25.7 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.
图 25: 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.

4.25.8 ESP32 Wi-Fi AP General Scenario

Below is a “big scenario” which describes some small scenarios in AP mode:
Chapter 4. API 指南

图 26: Sample Wi-Fi Event Scenarios in AP Mode

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### 4.25.9 ESP32 Wi-Fi Scan

Currently, the `esp_wifi_scan_start()` API is supported only in Station or Station+AP mode.

#### Scan Type

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Scan</td>
<td>Scan by sending a probe request. The default scan is an active scan.</td>
</tr>
<tr>
<td>Passive Scan</td>
<td>No probe request is sent out. Just switch to the specific channel and wait for a beacon. Application can enable it via the <code>scan_type</code> field of <code>wifi_scan_config_t</code>.</td>
</tr>
<tr>
<td>Foreground Scan</td>
<td>This scan is applicable when there is no Wi-Fi connection in Station mode. Foreground or background scanning is controlled by the Wi-Fi driver and cannot be configured by the application.</td>
</tr>
<tr>
<td>Background Scan</td>
<td>This scan is applicable when there is a Wi-Fi connection in Station mode or in Station+AP mode. Whether it is a foreground scan or background scan depends on the Wi-Fi driver and cannot be configured by the application.</td>
</tr>
<tr>
<td>All-Channel Scan</td>
<td>It scans all of the channels. If the channel field of <code>wifi_scan_config_t</code> is set to 0, it is an all-channel scan.</td>
</tr>
<tr>
<td>Specific Channel</td>
<td>It scans specific channels only. If the channel field of <code>wifi_scan_config_t</code> set to 1, 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
--- | ---
ssid | If the SSID is not NULL, it is only the AP with the same SSID that can be scanned.
bssid | If the BSSID is not NULL, it is only the AP with the same BSSID that can be scanned.
channel | If “channel” is 0, there will be an all-channel scan; otherwise, there will be a specific-channel scan.
show_hidden | If “show_hidden” is 0, the scan ignores the AP with a hidden SSID; otherwise, the scan considers the hidden AP a normal one.
scan_type | If “scan_type” is WIFI_SCAN_TYPE_ACTIVE, the scan is “active”; otherwise, it is a “passive” one.
scan_time | This field is used to control how long the scan dwells on each channel. For passive scans, scan_time.passive designates the dwell time for each channel. For active scans, dwell times for each channel are listed in the table below. Here, min is short for scan_time.active.min and max is short for scan_time.active.max.
  - min=0, max=0: scan dwells on each channel for 120 ms.
  - min>0, max=0: scan dwells on each channel for 120 ms.
  - min=0, max>0: scan dwells on each channel for max ms.
  - min>0, max>0: the minimum time the scan dwells on each channel is min ms. If no AP is found during this time frame, the scan switches to the next channel. Otherwise, the scan dwells on the channel for max ms.

If you want to improve the performance of the the scan, you can try to modify these two parameters.

There are also some global scan attributes which are configured by API esp_wifi_set_config(), refer to Station Basic Configuration.

### Scan All APs on All Channels (Foreground)

**Scenario:**
The scenario above describes an all-channel, foreground scan. The foreground scan can only occur in Station mode where the station does not connect to any AP. Whether it is a foreground or background scan is totally determined by the Wi-Fi driver, and cannot be configured by the application.

**Detailed scenario description:**

**Scan Configuration Phase**
- s1.1: Call esp_wifi_set_country() to set the country info if the default country info is not what you want, refer to <Wi-Fi Country Code>.
- s1.2: Call esp_wifi_scan_start() to configure the scan. To do so, you can refer to <Scan Configuration>. Since this is an all-channel scan, just set the SSID/BSSID/channel to 0.

**Wi-Fi Driver’s Internal Scan Phase**
图 27: Foreground Scan of all Wi-Fi Channels
Chapter 4. API

- s2.1: The Wi-Fi driver switches to channel 1, in case the scan type is WIFI_SCAN_TYPE_ACTIVE, and broadcasts a probe request. Otherwise, the Wi-Fi will wait for a beacon from the APs. The Wi-Fi driver will stay in channel 1 for some time. The dwell time is configured in min/max time, with default value being 120 ms.
- s2.2: The Wi-Fi driver switches to channel 2 and performs the same operation as in step 2.1.
- s2.3: The Wi-Fi driver scans the last channel N, where N is determined by the country code which is configured in step 1.1.

Scan-Done Event Handling Phase

- s3.1: When all channels are scanned, <WIFI_EVENT_SCAN_DONE> will arise.
- s3.2: The application’s event callback function notifies the application task that <WIFI_EVENT_SCAN_DONE> is received. esp_wifi_scan_get_ap_num() is called to get the number of APs that have been found in this scan. Then, it allocates enough entries and calls esp_wifi_scan_get_ap_records() to get the AP records. Please note that the AP records in the Wi-Fi driver will be freed, once esp_wifi_scan_get_ap_records() is called. Do not call esp_wifi_scan_get_ap_records() twice for a single scan-done event. If esp_wifi_scan_get_ap_records() is not called when the scan-done event occurs, the AP records allocated by the Wi-Fi driver will not be freed. So, make sure you call esp_wifi_scan_get_ap_records(), yet only once.

Scan All APs on All Channels (Background)

Scenario:
The scenario above is an all-channel background scan. Compared to Scan All APs on All Channels (Foreground), the difference in the all-channel background scan is that the Wi-Fi driver will scan the back-to-home channel for 30 ms before it switches to the next channel to give the Wi-Fi connection a chance to transmit/receive data.

Scan for Specific AP on All Channels

Scenario:
This scan is similar to Scan All APs on All Channels (Foreground). The differences are:
- s1.1: In step 1.2, the target AP will be configured to SSID/BSSID.
- s2.1~s2.N: Each time the Wi-Fi driver scans an AP, it will check whether it is a target AP or not. If the scan is WIFI_FAST_SCAN scan and the target AP is found, then the scan-done event will arise and scanning will end; otherwise, the scan will continue. Please note that the first scanned channel may not be channel 1, because the Wi-Fi driver optimizes the scanning sequence.

If there are multiple APs which match the target AP info, for example, if we happen to scan two APs whose SSID is “ap”. If the scan is WIFI_FAST_SCAN, then only the first scanned “ap” will be found, if the scan is WIFI_ALL_CHANNEL_SCAN, both “ap” will be found and the station will connect the “ap” according to the configured strategy, refer to Station Basic Configuration.

You can scan a specific AP, or all of them, in any given channel. These two scenarios are very similar.

Scan in Wi-Fi Connect

When esp_wifi_connect() is called, the Wi-Fi driver will try to scan the configured AP first. The scan in “Wi-Fi Connect” is the same as Scan for Specific AP On All Channels, except that no scan-done event will be generated 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.
Chapter 4. API 指南

图 28: Background Scan of all Wi-Fi Channels
图 29: Scan of specific Wi-Fi Channels
Chapter 4. API

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.

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-existed 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>`.

4.25.10 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.
Chapter 4. API

Event task  Wi-Fi task  AP

1. Scan Phase
   1.1 > Scan
   1.2 > WIFI_EVENT_STA_DISCONNECTED

2. Auth Phase
   2.1 > Auth request
   2.2 > WIFI_EVENT_STA_DISCONNECTED
   2.3 > Auth response
   2.4 > WIFI_EVENT_STA_DISCONNECTED

3. Assoc Phase
   3.1 > Assoc request
   3.2 > WIFI_EVENT_STA_DISCONNECTED
   3.3 > Assoc response
   3.4 > WIFI_EVENT_STA_DISCONNECTED

4. 4-way Handshake Phase
   4.1 > WIFI_EVENT_STA_DISCONNECTED
   4.2 > 1/4 EAPOL
   4.3 > 2/4 EAPOL
   4.4 > WIFI_EVENT_STA_DISCONNECTED
   4.5 > 3/4 EAPOL
   4.6 > 4/4 EAPOL
   4.7 > WIFI_EVENT_STA_CONNECTED
Chapter 4. API

• s2.2. If the authentication response packet is not received before the authentication timer times out, `<WIFI_EVENT_STA_DISCONNECTED>` will arise and the reason-code will be WIFI_REASON_AUTH_EXPIRE. Refer to <Wi-Fi Reason Code>.
• s2.3. The auth-response packet is received and the auth-timer is stopped.
• s2.4. The AP rejects authentication in the response and `<WIFI_EVENT_STA_DISCONNECTED>` arises, while the reason-code is WIFI_REASON_AUTH_FAIL or the reasons specified by the AP. Refer to <Wi-Fi Reason Code>.

Association Phase

• s3.1. The association request is sent and the association timer is enabled.
• s3.2. If the association response is not received before the association timer times out, `<WIFI_EVENT_STA_DISCONNECTED>` will arise and the reason-code will be WIFI_REASON_ASSOC_EXPIRE. Refer to <Wi-Fi Reason Code>.
• s3.3. The association response is received and the association timer is stopped.
• s3.4. The AP rejects the association in the response and `<WIFI_EVENT_STA_DISCONNECTED>` arises, while the reason-code is the one specified in the association response. Refer to <Wi-Fi Reason Code>.

Four-way Handshake Phase

• s4.1. The handshake timer is enabled, the 1/4 EAPOL is not received before the handshake timer expires, `<WIFI_EVENT_STA_DISCONNECTED>` will arise and the reason-code will be WIFI_REASON_HANDSHAKE_TIMEOUT. Refer to <Wi-Fi Reason Code>.
• s4.2. The 1/4 EAPOL is received.
• s4.3. The STA 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 STA replies 4/4 EAPOL.
• s4.7. The STA 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 ieee802.11-2012. (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>1</td>
<td>Generally, it means an internal failure, e.g., the memory runs out, the internal TX fails, or the reason is received from the remote side, etc.</td>
</tr>
<tr>
<td>AUTH_EXPIRE</td>
<td>2</td>
<td>2</td>
<td>The previous authentication is no longer valid. For the ESP Station, this reason is reported when: • the auth is timed out • the reason is received from the AP. For the ESP AP, this reason is reported when: • the AP has not received any packets from the station in the past five minutes. • the AP is stopped by calling esp_wifi_stop(). • the station is deauthorized by calling esp_wifi_deauth_sta()</td>
</tr>
<tr>
<td>AUTH_LEAVE</td>
<td>3</td>
<td>3</td>
<td>De-authenticated, because the sending STA is leaving (or has left). 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 STA is connected, yet not authenticated</td>
</tr>
<tr>
<td>ASSOC_EXPIRE</td>
<td>4</td>
<td>4</td>
<td>Disassociated due to inactivity. For the ESP Station, this reason is reported when: • it is received from the AP. For the ESP AP, this reason is reported when: • the AP has not received any packets from the station in the past five minutes. • the AP is stopped by calling esp_wifi_stop(). • the station is deauthorized by calling esp_wifi_deauth_sta()</td>
</tr>
<tr>
<td>ASSOC_TOOMANY</td>
<td>5</td>
<td>5</td>
<td>Disassociated, because the AP is unable to handle all currently associated STAs at the same time. 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 STA is disconnected by sending a packet with esp_wifi_disconnect().</td>
</tr>
</tbody>
</table>

Chapter 4. API 指南

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4.25.11 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.

4.25.12 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.

4.25.13 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.

4.25.14 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>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 STA and the AP without calling esp_wifi_deinit() to unload the whole Wi-Fi driver.</td>
</tr>
<tr>
<td>WIFI_MODE_STA</td>
<td>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() is called, the STA will connect to the target AP.</td>
</tr>
<tr>
<td>WIFI_MODE_AP</td>
<td>in this mode, esp_wifi_start() will init the internal AP data, while the AP’s interface is ready for RX/TX Wi-Fi data. Then, the Wi-Fi driver starts broad-casting beacons, and the AP is ready to get connected to other stations.</td>
</tr>
<tr>
<td>WIFI_MODE_APSTA</td>
<td>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.
### Field Description

<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>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,</td>
</tr>
<tr>
<td></td>
<td>the station connects to the AP whose SSID is the same as the “ssid” field,</td>
</tr>
<tr>
<td></td>
<td>while its BSSID is the same the “bssid” field.</td>
</tr>
<tr>
<td>bssid</td>
<td>This is valid only when bssid_set is 1; see field “bssid_set”.</td>
</tr>
<tr>
<td>channel</td>
<td>If the channel is 0, the station scans the channel 1~N to search for the</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 sorted</td>
</tr>
<tr>
<td></td>
<td>by signal, for AP with best signal will be connected firstly. E.g. if the</td>
</tr>
<tr>
<td></td>
<td>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 -90dBm, the second AP’</td>
</tr>
<tr>
<td></td>
<td>s signal is -30dBm, the station connects the second AP firstly, it doesn’t</td>
</tr>
<tr>
<td></td>
<td>connect the first one unless it fails to connect the second one.</td>
</tr>
<tr>
<td></td>
<td>If the sort_method is WIFI_CONNECT_AP_BY_SECURITY, all matched APs are</td>
</tr>
<tr>
<td></td>
<td>sorted by security. E.g. if the station wants to connect AP whose ssid is</td>
</tr>
<tr>
<td></td>
<td>“apxx”, the scan finds two AP whose ssid is “apxx”, the security of the</td>
</tr>
<tr>
<td></td>
<td>first found AP is open while the second one is WPA2, the stations connects</td>
</tr>
<tr>
<td></td>
<td>to the second AP firstly, it doesn’t connect the second one unless it fails</td>
</tr>
<tr>
<td></td>
<td>to connect the first one.</td>
</tr>
<tr>
<td>threshold</td>
<td>The threshold is used to filter the found AP, if the RSSI or security mode</td>
</tr>
<tr>
<td></td>
<td>is less than the configured threshold, the AP will be discarded.</td>
</tr>
<tr>
<td></td>
<td>If the RSSI set to 0, it means default threshold, the default RSSI threshold</td>
</tr>
<tr>
<td></td>
<td>is -127dBm. If the authmode threshold is set to 0, it means default threshold,</td>
</tr>
<tr>
<td></td>
<td>the default authmode threshold is open.</td>
</tr>
</tbody>
</table>

注意: 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.

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ssid</td>
<td>SSID of AP; if the ssid[0] is 0xFF and ssid[1] is 0xFF, the AP defaults the</td>
</tr>
<tr>
<td></td>
<td>SSID to ESP_aabbcc, where “aabbcc” is the last three bytes of the AP MAC.</td>
</tr>
<tr>
<td>password</td>
<td>Password of AP; if the auth mode is WIFI_AUTH_OPEN, this field will be ignored.</td>
</tr>
<tr>
<td>ssid_len</td>
<td>Length of SSID; if ssid_len is 0, check the SSID until there is a termination</td>
</tr>
<tr>
<td></td>
<td>character. If ssid_len &gt; 32, change it to 32; otherwise, set the SSID length</td>
</tr>
<tr>
<td></td>
<td>according to ssid_len.</td>
</tr>
<tr>
<td>channel</td>
<td>Channel of AP; if the channel is out of range, the Wi-Fi driver defaults the</td>
</tr>
<tr>
<td></td>
<td>channel to channel 1. So, please make sure the channel is within the required</td>
</tr>
<tr>
<td></td>
<td>range. For more details, refer to [Wi-Fi Country Code].</td>
</tr>
<tr>
<td>authmode</td>
<td>Auth mode of ESP AP; currently, ESP Wi-Fi does not support AUTH_WEP. If the</td>
</tr>
<tr>
<td></td>
<td>authmode is an invalid value, AP defaults the value to WIFI_AUTH_OPEN.</td>
</tr>
<tr>
<td>ssid_hidden</td>
<td>If ssid_hidden is 1, AP does not broadcast the SSID; otherwise, it does</td>
</tr>
<tr>
<td></td>
<td>broadcast the SSID.</td>
</tr>
<tr>
<td>max_connection</td>
<td>Currently, ESP Wi-Fi supports up to 10 Wi-Fi connections. If max_connection</td>
</tr>
<tr>
<td></td>
<td>&gt; 10, AP defaults the value to 10.</td>
</tr>
<tr>
<td>beacon_interval</td>
<td>Beacon interval; the value is 100 ~ 60000 ms, with default value being</td>
</tr>
<tr>
<td></td>
<td>100 ms. If the value is out of range, AP defaults it to 100 ms.</td>
</tr>
</tbody>
</table>
Wi-Fi Protocol Mode

Currently, the IDF supports the following protocol modes:

<table>
<thead>
<tr>
<th>Protocol Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11 B</td>
<td>Call <code>esp_wifi_set_protocol(ifx, WIFI_PROTOCOL_11B)</code> to set the station/AP to 802.11B-only mode.</td>
</tr>
<tr>
<td>802.11 BG</td>
<td>Call `esp_wifi_set_protocol(ifx, WIFI_PROTOCOL_11B</td>
</tr>
<tr>
<td>802.11 BGN</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 <code>esp_wifi_set_protocol(ifx, WIFI_PROTOCOL_LR)</code> to set the station/AP only to the Espressif-specific mode.</td>
</tr>
</tbody>
</table>

This mode is an Espressif-patented mode which can achieve a one-kilometer line of sight range. Please, make sure both the station and the AP are connected to an ESP device.

Long Range (LR)

Long Range (LR) mode is an Espressif-patented Wi-Fi mode which can achieve a one-kilometer line of sight range. It has better reception sensitivity, stronger anti-interference ability and longer transmission distance than the traditional 802.11B mode.

LR Compatibility Since LR is Espressif unique Wi-Fi mode, only ESP32 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:

<table>
<thead>
<tr>
<th>AP</th>
<th>STA</th>
<th>BGN</th>
<th>BG</th>
<th>B</th>
<th>BGNLR</th>
<th>BGLR</th>
<th>BLR</th>
<th>LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>BGN</td>
<td>BGN</td>
<td>BG</td>
<td>B</td>
<td>BGN</td>
<td>BGLR</td>
<td>B</td>
<td>LR</td>
<td></td>
</tr>
<tr>
<td>BG</td>
<td>BG</td>
<td>BG</td>
<td>B</td>
<td>BG</td>
<td>BG</td>
<td>B</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>BGNLR</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>BGNLR</td>
<td>BGLR</td>
<td>BLR</td>
<td>LR</td>
<td></td>
</tr>
<tr>
<td>BGLR</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>BGLR</td>
<td>BGLR</td>
<td>BLR</td>
<td>LR</td>
<td></td>
</tr>
<tr>
<td>BLR</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>BLR</td>
<td>BLR</td>
<td>BLR</td>
<td>LR</td>
<td></td>
</tr>
<tr>
<td>LR</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td></td>
</tr>
</tbody>
</table>

In above table, the row is the Wi-Fi mode of AP and the column is the Wi-Fi mode of station. The “-” indicates Wi-Fi mode of the AP and station are not compatible.

According to the table, we can conclude that:
• For LR enabled in ESP32 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 WiFi 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 802.11 B 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 WiFi 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 2.4GHz 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 attribute identifies the country or noncountry entity in which the station/AP is operating. If it’s a country, the first two octets of this string is the two-character country info as described in document ISO/IEC3166-1. The third octect is one of the following:  
- an ASCII space character, if the regulations under which the station/AP is operating encompass all environments for the current frequency band in the country  
- an ASCII ‘O’ character if the regulations under which the station/AP is operating are for an outdoor environment only, or  
- 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 WiFi 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 WiFi Mode and different country policy, also describe the impact to active scan.
<table>
<thead>
<tr>
<th>WiFi Mode</th>
<th>Policy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station</td>
<td>WIFI_COUNTRY_POLICY_AUTO</td>
<td>If the connected AP has country IE in its beacon, the country info equals to the country info in beacon, otherwise, use default country info.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>For scan:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>If schan+nchan-1 &gt;11:</strong> Use active scan from schan to 11 and use passive scan from 12 to schan+nchan-1.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>If schan+nchan-1 &lt;= 11:</strong> Use active scan from schan to schan+nchan-1.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Always keep in mind that if an AP with hidden SSID is set to a passive scan channel, the passive scan will not find it. In other words, if the application hopes to find the AP with hidden SSID in every channel, the policy of country info should be configured to WIFI_COUNTRY_POLICY_MANUAL.</td>
</tr>
<tr>
<td>Station</td>
<td>WIFI_COUNTRY_POLICY_MANUAL</td>
<td>Always use the configured country info.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For scan, scans channel “schan” to “schan+nchan-1” with active scan</td>
</tr>
<tr>
<td>AP</td>
<td>WIFI_COUNTRY_POLICY_AUTO</td>
<td>Always use the configured country info.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AP</td>
<td>WIFI_COUNTRY_POLICY_MANUAL</td>
<td>Always use the configured country info.</td>
</tr>
<tr>
<td>Station/AP-coexistence</td>
<td>WIFI_COUNTRY_POLICY_AUTO</td>
<td>If the station doesn’t connects to any AP, the AP use the configured country info. If the station connects to an AP, the AP has the same country info as the station. Same as station mode with policy WIFI_COUNTRY_POLICY_AUTO</td>
</tr>
</tbody>
</table>

**Home Channel**  In AP mode, the home channel is defined as the AP channel. In Station mode, home channel is defined as the channel of AP which the station is connected to. In Station/AP-coexistence mode, the home channel of AP and station must be the same, 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 SoftAP 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 SoftAP.

**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.

### 4.25.15 Wi-Fi Security

In addition to traditional security methods (WEP/WPA-TKIP/WPA2-CCMP), ESP32 Wi-Fi now 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 in traditional modes.

**Protected Management Frames (PMF)**

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 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.

ESP32 supports the following three modes of operation with respect to PMF.

- **PMF not supported:** In this mode, ESP32 indicates to AP that it is not capable of supporting management protection during association. In effect, security in this mode will be equivalent to that in traditional mode.
- **PMF capable, but not required:** In this mode, ESP32 indicates to AP that it is capable of supporting PMF. The management protection will be used if AP mandates PMF or is at least capable of supporting PMF.
- **PMF capable and required:** In this mode, ESP32 will only connect to AP, if AP supports PMF. If not, ESP32 will refuse to connect to the AP.

*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.

**WPA3-Personal**

Wi-Fi Protected Access-3 (WPA3) is a set of enhancements to Wi-Fi access security intended to replace the current WPA2 standard. In order to provide more robust authentication, 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. WPA3 also 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.

In order to enable WPA3-Personal, “Enable WPA3-Personal” should be selected in menuconfig. If enabled, ESP32 uses SAE for authentication if supported by the AP. Since PMF is a mandatory requirement for WPA3, PMF capability should be at least set to “PMF capable, but not required” for ESP32 to use WPA3 mode. Application developers need not worry about the underlying security mode as highest available is chosen from security standpoint. Note that Wi-Fi stack size requirement will increase approximately by 3k when WPA3 is used. Currently, WPA3 is supported only in Station mode.


4.25.16 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).

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 future, all power save features will be supported on ESP32 AP.

4.25.17 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/sec</td>
<td>Internal tool</td>
<td>NA</td>
</tr>
<tr>
<td>Raw 802.11 Packet TX</td>
<td>N/A</td>
<td>130 MBit/sec</td>
<td>Internal tool</td>
<td>NA</td>
</tr>
<tr>
<td>UDP RX</td>
<td>30 MBit/sec</td>
<td>90 MBit/sec</td>
<td>iperf example</td>
<td>05838641</td>
</tr>
<tr>
<td>UDP TX</td>
<td>30 MBit/sec</td>
<td>60 MBit/sec</td>
<td>iperf example</td>
<td>05838641</td>
</tr>
<tr>
<td>TCP RX</td>
<td>20 MBit/sec</td>
<td>50 MBit/sec</td>
<td>iperf example</td>
<td>05838641</td>
</tr>
<tr>
<td>TCP TX</td>
<td>20 MBit/sec</td>
<td>50 MBit/sec</td>
<td>iperf example</td>
<td>05838641</td>
</tr>
</tbody>
</table>

When the throughput is tested by iperf example, the sdkconfig is examples/wifi/iperf/sdkconfig.ci.99

4.25.18 Wi-Fi 80211 Packet Send

Important notes: The API esp_wifi_80211_tx is not available in IDF 2.1, but will be so in the upcoming release.
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 WiFi connection, the data rate is 1Mbps.
- If there is WiFi connection and the packet is from station to AP or from AP to station, the data rate is same as the WiFi connection. Otherwise the data rate is 1Mbps.

Side-Effects to Avoid in Different Scenarios

Theoretically, if we do not consider the side-effects the API imposes on the Wi-Fi driver or other stations/APs, we can send a raw 802.11 packet over the air, with any destination MAC, any source MAC, any BSSID, or any other type of packet. However, robust/useful applications should avoid such side-effects. The table below provides some tips/recommendations on how to avoid the side-effects of esp_wifi_80211_tx in different scenarios.
**Scenario** | **Description**  
--- | ---  
No WiFi 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 WiFi 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 WiFi connection” scenario also apply to this scenario. 
If the WiFi 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 WiFi 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 WiFi connections, the following checks are applied: 
• If the packet type is data and is from the station to AP, the ToDS bit in ieee80211 frame control should be 1, the FromDS bit should be 0, otherwise the packet will be discarded by WiFi driver. 
• If the packet type is data and is from the AP to station, the ToDS bit in ieee80211 frame control should be 0, the FromDS bit should be 1, otherwise the packet will be discarded by WiFi driver. 
• If the packet is from station to AP or from AP to station, the Power Management, More Data, Re-Transmission bit should be 0, otherwise the packet will be discarded by WiFi driver. 
ESP_ERR_WIFI_ARG is returned if any check fails.
4.25.19 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

The following packets will NOT be dumped to the application:

- 802.11 error frame, such as the frame with a CRC error, etc.

For frames that the sniffer can dump, the application can additionally decide which specific type of packets can be filtered to the application by using esp_wifi_set_promiscuous_filter() and esp_wifi_set_promiscuous_ctrl_filter(). By default, it will filter all 802.11 data and management frames to the application.

The Wi-Fi sniffer mode can be enabled in the Wi-Fi mode of WIFI_MODE_NULL, or WIFI_MODE_STA, or WIFI_MODE_AP, or WIFI_MODE_APSTA. In other words, the sniffer mode is active when the station is connected to the AP, or when the AP has a Wi-Fi connection. Please note that the sniffer has a great impact on the throughput of the station or AP Wi-Fi connection. Generally, we should NOT enable the sniffer, when the station/AP Wi-Fi connection experiences heavy traffic unless we have special reasons.

Another noteworthy issue about the sniffer is the callback wifi_promiscuous_cb_t. The callback will be called directly in the Wi-Fi driver task, so if the application has a lot of work to do for each filtered packet, the recommendation is to post an event to the application task in the callback and defer the real work to the application task.

4.25.20 Wi-Fi Multiple Antennas

The Wi-Fi multiple antennas selecting can be depicted as following picture:

```
+-------------------+-------------------+-------------------+-------------------+
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
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|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
|       |       |       |       |
+-------------------+-------------------+-------------------+-------------------+
```

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, WiFi 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 -65dBm 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 BT 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 WiFi 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
};
```

4.25.21 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.
### 4.25.22 Wi-Fi Channel State Information Configure

To use Wi-Fi CSI, the following steps need to be done.

- Select Wi-Fi CSI in menuconfig. It is “Menuconfig -> Components config -> Wi-Fi -> WiFi CSI(Channel State Information)”.
- Set CSI receiving callback function by calling API `esp_wifi_set_csi_rx_cb()`.

---

<table>
<thead>
<tr>
<th>secondary channel</th>
<th>below</th>
<th>above</th>
</tr>
</thead>
<tbody>
<tr>
<td>channel band-width</td>
<td>20MHz, 20MHz</td>
<td>20MHz, 40MHz</td>
</tr>
<tr>
<td>packet information</td>
<td>HT, non-HT</td>
<td>HT, non-HT</td>
</tr>
<tr>
<td>STBC</td>
<td>non, STBC</td>
<td>non, STBC</td>
</tr>
<tr>
<td>sub-carrier index</td>
<td>LLTF</td>
<td>HT-LTF</td>
</tr>
<tr>
<td>LLTF</td>
<td>0<del>31, -32</del>1</td>
<td>0<del>31, -32</del>1</td>
</tr>
<tr>
<td>HT-LTF</td>
<td></td>
<td>0<del>63, -64</del>1</td>
</tr>
<tr>
<td>STBC-HT-LTF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total bytes</td>
<td>128</td>
<td>256</td>
</tr>
</tbody>
</table>

All of the information in the table can be found in the structure `wifi_csi_info_t`.

- Secondary channel refers to secondary_channel field of `rx_ctrl` field.
- Signal mode of packet refers to sig_mode field of `rx_ctrl` field.
- Channel bandwidth refers to cbw field of `rx_ctrl` field.
- STBC refers to stbc field of `rx_ctrl` field.
- Total bytes refers to len field.
- The CSI data corresponding to each Long Training Field (LTF) type is stored in a buffer starting from the buf field. Each item is stored as two bytes: imaginary part followed by real part. The order of each item is the same as the sub-carrier in the table. The order of LTFs 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.

### 注解:

- 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 -200ns, 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).

---

All information in the table can be found in the structure `wifi_csi_info_t`.

- Secondary channel refers to `secondary_channel` field of `rx_ctrl` field.
- Signal mode of packet refers to `sig_mode` field of `rx_ctrl` field.
- Channel bandwidth refers to `cbw` field of `rx_ctrl` field.
- STBC refers to `stbc` field of `rx_ctrl` field.
- Total bytes refers to `len` field.
- The CSI data corresponding to each Long Training Field (LTF) type is stored in a buffer starting from the buf field. Each item is stored as two bytes: imaginary part followed by real part. The order of each item is the same as the sub-carrier in the table. The order of LTFs 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.

### 注解:

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- 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).
Chapter 4. API

• 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()`.

4.25.23 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.

4.25.24 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:

```c
const int ip_precedence_vi = 4;
const int ip_precedence_offset = 5;
int priority = (ip_precedence_vi << ip_precedence_offset);
setsockopt(socket_id, IPPROTO_IP, IP_TOS, &priority, sizeof(priority));
```

Theoretically the higher priority AC has better performance than the low priority AC, however, it’s not always be true, here...
• 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.

4.25.25  Wi-Fi AMSDU

ESP32 supports receiving AMSDU but doesn’t support transmitting AMSDU. The transmitting AMSDU is not necessary since ESP32 has transmitting AMPDU.

4.25.26  Wi-Fi Fragment

ESP32 supports Wi-Fi receiving fragment, but doesn’t support Wi-Fi transmitting fragment. The Wi-Fi transmitting fragment will be supported in future release.

4.25.27  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.

4.25.28  Wi-Fi Buffer Usage

This section is only about the dynamic buffer configuration.

Why Buffer Configuration Is Important

In order to get a robust, 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.

**4.25.29 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**

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 RX buffer size of the LWIP layer for each TCP stream. Its value should be configured to the value of WIFI_DYNAMIC_RX_BUFFER_NUM(KB) to reach a high and stable performance. Meanwhile, in case of multiple streams, this value needs to be reduced proportionally.

TX direction:

• `CONFIG_ESP32_WIFI_STATIC_TX_BUFFER_NUM` 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.

注解：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.
Using PSRAM

PSRAM is generally used when the application takes up a lot of memory. In this mode, the `CONFIG_ESP32_WIFI_TX_BUFFER` is forced to be static. `CONFIG_ESP32_WIFI_STATIC_TX_BUFFER_NUM` indicates the number of DMA buffers at the hardware layer, increase this parameter can improve performance. The following are the recommended ranks for using PSRAM:

4.25.30 Wi-Fi Menuconfig

Wi-Fi Buffer Configure

If you are going to modify the default number or type of buffer, it would be helpful to also have an overview of how the buffer is allocated/freed in the data path. The following diagram shows this process in the TX direction:

![TX Buffer Allocation Diagram](image)

**Description:**
- The application allocates the data which needs to be sent out.
- The application calls TCP/IP-/Socket-related APIs to send the user data. These APIs will allocate a PBUF used in LwIP, and make a copy of the user data.
- When LwIP calls a Wi-Fi API to send the PBUF, the Wi-Fi API will allocate a “Dynamic Tx Buffer” or “Static Tx Buffer”, make a copy of the LwIP PBUF, and finally send the data.

The following diagram shows how buffer is allocated/freed in the RX direction:

![RX Buffer Allocation Diagram](image)

**Description:**
- The Wi-Fi hardware receives a packet over the air and puts the packet content to the “Static Rx Buffer”, which is also called “RX DMA Buffer”.

注解：The result is tested 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.
• 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.
## Buffer Type

<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 esp_wifi_init() and freed in esp_wifi_deinit(). 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 menuconfig, 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 upper-layer (LwIP) sends packets to the Wi-Fi driver, it firstly allocates a Dynamic TX Buffer and makes a copy of the upper-layer buffer. The Dynamic and Static TX Buffers are mutually exclusive.</td>
</tr>
<tr>
<td>Static TX Buffer</td>
<td>Static</td>
<td>16 * 1600 Bytes</td>
<td>Yes</td>
<td>This is a kind of DMA memory. It is initialized in esp_wifi_init() and freed in esp_wifi_deinit(). When the upper-layer (LwIP) sends packets to the Wi-Fi driver, it firstly allocates a Static TX Buffer and makes a copy of the upper-layer buffer. The Dynamic and Static TX Buffers are mutually exclusive.</td>
</tr>
</tbody>
</table>

---

**Note:**

- **Buffer Types:**
  - Static RX Buffer (Hardware RX Buffer)
  - Dynamic RX Buffer
  - Dynamic TX Buffer
  - Static TX Buffer

- **Alloc Types:**
  - Static
  - Dynamic

- **Default Values:**
  - Static RX Buffer: 10 * 1600 Bytes
  - Dynamic RX Buffer: 32
  - Dynamic TX Buffer: 32
  - Static TX Buffer: 16 * 1600 Bytes

- **Configurability:**
  - Static: Yes
  - Dynamic: Yes
  - Static RX Buffer: Yes

- **Description:**
  - Static RX Buffer: DMA memory initialized in esp_wifi_init() and freed in esp_wifi_deinit(). Forms the hardware receiving list.
  - Dynamic RX Buffer: Variable buffer length allocated from the heap.
  - Dynamic TX Buffer: DMA memory allocated to the upper-layer (LwIP).
  - Static TX Buffer: DMA memory initialized in esp_wifi_init() and freed in esp_wifi_deinit().
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.

4.25.31 Troubleshooting

Please refer to a separate document with Wireshark 使用指南.

乐鑫 Wireshark 使用指南

1. 概述

1.1 什么是 Wireshark？ Wireshark（原称 Ethereal）是一个网络封包分析软件。网络封包分析软件的功能是撷取网络封包，并尽可能显示出最为详细的网络封包资料。Wireshark 使用 WinPCAP 作为接口，直接与网卡进行数据报文交换。

网络封包分析软件的功能可想像成“电工技师使用电表来量测电流、电压、电阻”的工作，只是将场景移植到网络上，并将电线替换成网线。

在过去，网络封包分析软件是非常昂贵，或是专门属于营利用的软件。Wireshark 的出现改变了这一切。在 GNU GPL 通用许可证的保障范围内，使用者可以以免费的代价取得软件与其源代码，并拥有针对其源代码修改及客制化权利。

Wireshark 是目前全世界最广泛的网络封包分析软件之一。

1.2 Wireshark 的主要应用 下面是 Wireshark 一些应用的举例:

- 网络管理员用来解决网络问题
- 网络安全工程师用来检测安全隐患
- 开发人员用来测试协议执行情况
- 用来学习网络协议

除了上面提到的，Wireshark 还可以用在其它许多场合。

1.3 Wireshark 的特性

- 支持 UNIX 和 Windows 平台
- 在接口实时捕提包
- 能详细显示包的详细协议信息
- 可以打开/保存捕提的包
- 可以导入导出其他捕捉程序支持的包数据格式
- 可以通过多种方式过滤包
- 多种方式查找包
- 通过过滤以多种色彩显示包
- 创建多种统计分析
- 等等
1.4 Wireshark 的“能”与“不能”？

- 捕捉多种网络接口
  Wireshark 可以捕捉多种网络接口类型的包，哪怕是无线局域网接口。
- 支持多种其它程序捕捉的文件
  Wireshark 可以打开多种网络分析软件捕捉的包。
- 支持多格式输出
  Wireshark 可以将捕捉文件输出为多种其他捕捉软件支持的格式。
- 对多种协议解码提供支持
  Wireshark 可以支持许多协议的解码。
- Wireshark 不是入侵检测系统
  如果您的网络中存在任何可疑活动，Wireshark 并不会主动发出警告。不过，当您希望对这些可疑活动一探究竟时，Wireshark 可以发挥作用。
- Wireshark 不会处理网络事务，它仅仅是在“测量”（监视）网络
  Wireshark 不会发送网络包或做其它交互性的事情（名称解析例外，但您也可以禁止解析）。

2. 如何获取 Wireshark 官网链接：https://www.wireshark.org/download.html

Wireshark 支持多种操作系统，请在下载安装文件时，注意选择与您所用操作系统匹配的安装文件。

3. 使用步骤 本文档仅以 Linux 系统下的 Wireshark（版本号：2.2.6）为例。

1) 启动 Wireshark

Linux 下，可编写一个 Shell 脚本，运行该文件即可启动 Wireshark 配置抓包网卡和信道。Shell 脚本如下：

```bash
ifconfig $1 down
iwconfig $1 mode monitor
iwconfig $1 channel $2
ifconfig $1 up
Wireshark
```

脚本中有两个参数：$1 和 $2，分别表示网卡和信道，例如，./xxx.sh wlan0 6（此处，wlan0 即为抓包使用的网卡，后面的数字 6 即为 AP 或 soft-AP 所在的 channel）。

2) 运行 Shell 脚本打开 Wireshark，会出现 Wireshark 抓包开始界面

![Wireshark界面](image)

图 34: Wireshark 抓包界面

3) 选择接口，开始抓包

从上图红色框中可以看到有多个接口，第一个为本地网卡，第二个为无线网络。
可根据自己的需求选取相应的网卡，本文是以利用无线网卡抓取空中包为例进行简单说明。
双击 wlan0 即可开始抓包。

4) 设置过滤条件

抓包过程中会抓取到同信道所有的包，但其实很多都是我们不需要的，因此很多时候我们会设置抓包的过滤条件从而得到我们想要的包。

下图中红色框内即为设置 filter 的位置。

![图 35: 设置 Wireshark 过滤条件](image)

点击 Filter 按钮（下图的左上角蓝色按钮）会弹出 display filter 对话框。

![图 36: Display Filter 对话框](image)

点击 Expression 按钮，会出现 Filter Expression 对话框，在此你可以根据需求进行 filter 的设置。

最直接的方法：直接在工具栏上输入过滤条件。

点击在此区域输入或修改显示的过滤字符，在输入过程中会进行语法检查。如果您输入的格式不正确，或者未输入完成，则背景显示为红色。直到您输入合法的表达式，背景才变为绿色。你可以点击下拉列表选择您当前键入的过滤字符。列表会一直保留，即使您重新启动程序。

例如：下图所示，直接输入 2 个 MAC 作为过滤条件，点击 Apply（即图中的蓝色箭头），则表示只抓取 2 个此 MAC 地址之间的交互的包。

5) 封包列表

若想查看包的具体的信息只需要选中要查看的包，界面的下方会显示出包的具体的格式和包的内容。

如上图所示，我们要查看第 1 个包，选中此包，图中红色框中即为包的具体内容。

6) 停止/开始包的捕捉

若要停止当前抓包，点击下图的红色按钮即可。
图 37: Filter Expression 对话框

图 38: 过滤条件工具栏

图 39: 在过滤条件工具栏中运用 MAC 地址过滤示例
图 40: 封包列表具体信息示例

图 41: 停止包的捕捉

图 42: 开始或继续包的捕捉
若要重新开始抓包，点击下图左上角的蓝色按钮即可。

7) 保存当前捕包

Linux 下，可以通过依次点击“File”->“Export Packet Dissections”->“As Plain Text File”进行保存。

![Wireshark Export Packet Dissections](image)

图 43: 保存捕包

上图中，需要注意的是，选择 All packets、Displayed 以及 All expanded 三项。

Wireshark 捕捉的包可以保存为其原生格式文件 (libpcap)，也可以保存为其他格式（如.txt 文件）供其他工具进行读取分析。

### 4.26 ESP-BLE-MESH

#### 4.26.1 概述

蓝牙 mesh 网络实现了无线设备的“多对多”通讯，其可用于建立包含大量设备的网络。

设备能将数据中继至不在初始设备无线电覆盖范围内的其他设备。这样，mesh 网络就能够覆盖非常大的物理区域，并且囊括大量设备。Mesh 网络非常适用于楼宇自动化、传感器网络和其他物联网解决方案，这些环境下数以十计、百计、千计的设备需要与其他设备进行安全可靠的通信。

蓝牙 mesh 并非无线通信技术，而是一种网络技术。该技术基于一种无线通讯协议栈，即低功耗蓝牙。

ESP-BLE-MESH 基于 Zephyr 蓝牙 mesh 协议栈的顶端，其实现支持设备配网和节点控制，同时也实现了代理、中继、低功耗和朋友等节点功能。

有关 ESP-BLE-MESH 架构实现的信息，请参见 ESP-BLE-MESH 架构；有关各自 API 的信息，请参见 ESP-BLE-MESH API Reference。

ESP-BLE-MESH 的实现和认证基于最新的 Mesh Profile v1.0.1。有关 ESP-BLE-MESH 认证的细节，请参考此处。

**注解：** 如果您在寻找 ESP32 基于 Wi-Fi 的 mesh 方案，请查阅乐鑫的另一款产品 ESP-MESH。更多相关信息及文档，请参见 ESP-MESH。
4.26.2 ESP-BLE-MESH 快速入门

该章节旨在帮助您基于乐鑫的 ESP32 开发板搭建 ESP-BLE-MESH 网络。

我们将展示如何搭建并运行一个包含 3 个节点的小型 ESP-BLE-MESH 网络，其中包含设备配网、节点配置，以及向特定节点上的 Generic OnOff Server Model 发送开关灯命令。

如果您是第一次接触 ESP-IDF，请参见 esp-idf 快速入门来设置开发环境，编译、烧写和运行示例应用程序。

硬件及软件准备

硬件：

- 3 块 ESP32 开发板，请参见 options。
- 连接开发板的 USB 线。
- ESP-IDF 开发环境。
- 运行 Android 或 iOS 的手机或平板。

软件：

- 下载至 ESP32 开发板的示例应用 bluetooth/esp_ble_mesh/ble_mesh_node。
- 手机 App: nRF Mesh Android 或 iOS 版本。除 nRF Mesh 的 App，以下 App 也支持 ESP-BLE-MESH：
  - EspBleMesh Android App
  - Silicon Labs Android 或 iOS App

安装

以下详细步骤可指导您完成安装过程。

步骤 1. 检查硬件 ESP32-DevKitC 和 ESP-WROVER-KIT 开发板均支持 ESP-BLE-MESH。您可以通过 menuconfig: idf.py menuconfig > Example Configuration > Board selection for ESP-BLE-MESH 选择特定的开发板。

注解：如果您打算使用 ESP32-DevKitC 开发板，请将 RGB 灯焊接至 GPIO 管脚 25、26 和 27。

步骤 2. 配置软件进入 bluetooth/esp_ble_mesh/ble_mesh_node 示例文件夹，运行 idf.py menuconfig 选择所使用的开发板，然后运行 idf.py build 编译示例。

步骤 3. 下载应用

bluetooth/esp_ble_mesh/ble_mesh_node 示例编译成功后，用户可以运行 idf.py flash 将编译生成的二进制文件下载至 3 块开发板中。

当开发板上电后，RGB 灯会变为 绿色。

步骤 4. 设备配网 在该章节中，我们将使用 nRF Mesh Android App 演示如何配网设备。用户也可以从 App Store 下载其 iOS 版本。

4.1 扫描 (scanner) 扫描 (Scanner) 是 nRF Mesh App 搜索蓝牙通信范围内未配网设备的功能。打开 App，点击底部的扫描按钮 Scanner。App 便会开始扫描设备，很快，便可在屏幕上看到 3 个未配网设备。
图 44: ESP-BLE-MESH 设备上电

图 45: nRF Mesh - 扫描
4.2 识别 用户可以选择任何一个未配网设备，此时 App 会尝试和该设备建立连接。连接成功（有时可能需要尝试多次），且发现相应的 ESP-BLE-MESH GATT 服务后，用户可以在屏幕上看到识别按钮 IDENTIFY。IDENTIFY 操作告诉用户该设备将被配网。

注解：IDENTIFY 需要设备侧的支持，然后才能用来识别当前正在配网的设备。当前如果点击识别按钮 IDENTIFY，除了串口输出的 log，当前的 example 中设备侧不会有其他现象。

点击识别按钮 IDENTIFY 后，用户可以看到配网按钮 PROVISION。

![图 46: nRF Mesh - 识别 - 配网](image)

4.3 配网 点击配网按钮 PROVISION，App 会开始配网设备。当设备配网成功后，开发板上的 RGB 灯会熄灭，此时 App 会执行以下几个步骤：

1. 和该节点（设备配网后成为节点）断开连接
2. 尝试和该节点重新建立连接
3. 连接成功并且发现了相应的 ESP-BLE-MESH GATT 服务
4. 获取节点的 Composition Data 并且给该节点添加 AppKey

当以上所有的步骤完成后，节点初始化完成。此时点击 OK，用户可以看见节点的单播地址分配成功，并且其 Composition Data 也被成功解析。

有时在上述步骤 2 中，App 可能与节点连接失败。这种情况下，用户点击 OK 后可以看到，节点只有单播地址被成功分配，Composition data 并没有被成功获取。此时用户需要点击右上角的连接按钮 CONNECT，屏幕上会显示原先配网的节点，用户需要选择该节点并与其建立连接。

连接成功后，App 会显示获取 Composition Data 以及添加 AppKey 的按钮。

如果该设备是 App 配网的第二个或第三个节点，此时点击连接按钮 CONNECT 后，用户可以在屏幕中看到 2 个或 3 个节点。这种情况下，用户可以选择其中的任何一个节点建立连接，连接成功后可以返回至主界面选择需要配置的节点。

这里给出一个 3 个节点的示例。

- 左侧图片表示第三个设备成功配网，但是 App 没有和其成功建立连接。当 App 尝试去重新连接第二个节点时，界面上会出现 3 个节点。
图 47: nRF Mesh - 配置完成

图 48: nRF Mesh - 初始配置失败
图 49: nRF Mesh - 重连 - 初始配置

- 右侧图片表示和节点成功建立连接后，App 显示这 3 个节点的信息。用户可以看到 App 已经获取了第一个和第二个节点的 Composition Data，但是对于第三个节点，只有单播地址被成功分配而节点的 Composition Data 未知。

4.4 配置 当成功配网和初始化配置完成后，用户可以配置节点的其余信息，例如将 AppKey 绑定至每个元素 (element) 的每个模型 (model) 中，设置模型的发布信息等。

下图展示了如何将 AppKey 绑定至 Primary Element 中的 Generic OnOff Server Model 上。

注解：用户不需要将 AppKey 绑定至 Configuration Server Model，因为该模型使用 DevKey 在 Upper Transport Layer 中对消息进行加密。

Step 5. 运行网络 当 3 个元素中的 Generic OnOff Server Models 均成功绑定 AppKey 后，用户可以使用 App 开关 RBG 灯。

在 bluetooth/esp_ble_mesh/ble_mesh_node 示例中，第一个 Generic OnOff Server Model 用来控制 红色，第二个用来控制 绿色，同时第三个用来控制 蓝色。

下图展示了打开了不同色灯的开发板。

注解：对于 nRF Mesh iOS App [version 1.0.4]，当节点包含超过一个元素时，App 表现不正确。如果用户尝试打开或者关闭第 2 个或第 3 个 Generic OnOff Server Model，App 会将相应的消息发送至第 1 个 Generic OnOff Server Model。

4.26.3 ESP-BLE-MESH 示例

- ESP-BLE-MESH 节点 - 展示了将 ESP-BLE-MESH 作为拥有 Configuration Server model 和 Generic
图 50: nRF Mesh - 重连 - 3 个节点

图 51: nRF Mesh - Model Bind AppKey
图 52: nRF Mesh - 通用开关控制

图 53: 3 个上电的 ESP-BLE-MESH 节点
OnOff Server model 的节点设备的用法。然后，ESP-BLE-MESH Provisioner 可以配网设备，控制表示开/关状态的 RGB 灯，示例请见 example code。

- **ESP-BLE-MESH 客户端模型** - 展示了 Generic OnOff Client model 如何在节点内工作。节点拥有 Configuration Server model、Generic OnOff Server model 和 Generic OnOff Client model，示例请见 example code。
- **ESP-BLE-MESH Provisioner** - 展示了设备如何充当 ESP-BLE-MESH Provisioner 以配网设备。Provisioner 拥有 Configuration Server model、Configuration Client model 和 Generic OnOff Client model，示例请见 example code。
- **ESP-BLE-MESH 快速配网 - Client 和 Server - 该示例用于演示快速配网。配网 100 个设备费时不超过 60 秒，示例请见：example client code 和 example server code。
- **Wi-Fi 和 ESP-BLE-MESH 共存 - 该示例用于演示 Wi-Fi 和 ESP-BLE-MESH 共存的功能。简而言之，用户可在运行 ESP-BLE-MESH 时使用 Wi-Fi，示例请见 example code。
- **ESP-BLE-MESH 节点控制台 - 该演示实现 ESP-BLE-MESH 节点的基本功能。在演示中，Provisioner and Node 可以扫描、验证节点。节点可以回复 Provisioner 的获取/设置消息，示例请见：example code。

### 4.26.4 ESP-BLE-MESH 演示视频

- 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

### 4.26.5 ESP-BLE-MESH 常见问题手册

- 1. **Provisioner 开发**
- 2. 节点开发
- 3. **ESP-BLE-MESH 和 Wi-Fi 共存**
- 4. 快速配网
- 5. **Log 帮助**
- 6. 示例帮助
- 7. 其他

### 4.26.6 相关文档

ESP-BLE-MESH Feature List

**Supported Features**

**Mesh Core**

- **Provisioning: Node Role**
  - PB-ADV and PB-GATT
  - OOB Authentication
- **Provisioning: Provisioner Role**
  - PB-ADV and PB-GATT
  - OOB Authentication

**Networking**

- Relay
- Segmentation and Reassembly
- Key Refresh Procedure
- IV Update Procedure
- Friend
- Low Power
- Proxy Server
- Proxy Client
• **Multiple Client Models Run Simultaneously**
  – Support multiple client models send packets to different nodes simultaneously
  – No blocking between client model and server model

• **NVS Storing**
  – Store provisioning and configuration information of ESP-BLE-MESH Node

**Mesh Models**

• **Foundation models**
  – Configuration Server model
  – Configuration Client model
  – Health Server model
  – Health Client model

• **Generic client models**
  – Generic OnOff Client
  – Generic Level Client
  – Generic Default Transition Time Client
  – Generic Power OnOff Client
  – Generic Power Level Client
  – Generic Battery Client
  – Generic Location Client
  – Generic Property Client

• **Sensor client models**
  – Sensor Client

• **Time and Scenes client models**
  – Time Client
  – Scene Client
  – Scheduler Client

• **Lighting client models**
  – Light Lightness Client
  – Light CTL Client
  – Light HSL Client
  – Light xyl Client
  – Light LC Client

• **Generic server models**
  – Generic OnOff Server
  – Generic Level Server
  – Generic Default Transition Time Server
  – Generic Power OnOff Server
  – Generic Power OnOff Setup Server
  – Generic Power Level Server
  – Generic Power Level Setup Server
  – Generic Battery Server
  – Generic Location Server
  – Generic Location Setup Server
  – Generic User Property Server
  – Generic Admin Property Server
  – Generic Manufacturer Property Server
  – Generic Client Property Server

• **Sensor server models**
  – Sensor Server
  – Sensor Setup Server

• **Time and Scenes server models**
  – Time Server
  – Time Setup Server
  – Scene Server
  – Scene Setup Server
  – Scheduler Server
Chapter 4. API

- 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 架构**

本文档将介绍 ESP-BLE-MESH 的架构概览、架构实现和辅助程序。

- **ESP-BLE-MESH 架构概览**
  - 描述了 ESP-BLE-MESH 架构的 5 大部分及每个部分的功能。

- **ESP-BLE-MESH 架构实现**
  - 描述了 ESP-BLE-MESH 文件的基本功能、文件与 ESP-BLE-MESH 架构的对应关系及文件间调用的接口。
Chapter 4. API 指南

- ESP-BLE-MESH 辅助程序
  - 描述了 ESP-BLE-MESH 的辅助程序，比如 Mesh 网络管理，Mesh 特性等。

1. ESP-BLE-MESH 架构概览 目前，ESP-BLE-MESH 已经实现了 Mesh Profile 的大多数功能及 Mesh Model 规范中定义的所有 Client Model。未支持的功能/模型尚在开发中，会尽快提供。ESP-BLE-MESH 已通过 Bluetooth SIG 蓝牙技术联盟的 认证。

图 54: 图 1.1 ESP-BLE-MESH 架构图

ESP-BLE-MESH 架构主要由以下 5 大部分组成：
- Mesh 协议栈
  - Mesh Networking 负责 BLE Mesh 设备的网络消息处理等。
- 网络管理
  - 网络管理的实现，包括节点删除程序、网络索引 (IV Index) 恢复程序等。
- 特性
  - 网络管理的特性，如低功耗特性、好友特性、中继特性等。

### 1.1 Mesh Provisioning

#### 1.1.1 Mesh Networking

协议栈架构中的 Mesh Networking 实现了如下功能:

- Mesh 网络中节点间的通讯。
- Mesh 网络中消息的加密和解密。
- Mesh 网络中的管理，如网路密钥 (NetKey)、网络索引等。
- Mesh 网络消息的分包与重组。
- 网络在不同模型间的模型映射。
- 更多功能，请参见 ESP-BLE-MESH Feature List。

Mesh Networking 功能的实现是基于层级结构的。每一层的功能如表 1.1 所示:

<table>
<thead>
<tr>
<th>层级</th>
<th>功能</th>
</tr>
</thead>
<tbody>
<tr>
<td>接入层</td>
<td>接入层定义应用程序数据的格式，还对上层传输层对数据包的加密和解密进行定义和控制。</td>
</tr>
<tr>
<td>上层传输层</td>
<td>上层传输层对接入层进来的应用数据进行加密、解密和认证，也叫“传输控制消息”的特殊消息，这种消息包括了与“友谊”和心跳相关的消息。</td>
</tr>
<tr>
<td>底层传输层</td>
<td>底层传输层处理 PDU 的分包和重组。</td>
</tr>
<tr>
<td>网络层</td>
<td>网络层定义网络消息的地址类型和格式，实现设备的中继功能。</td>
</tr>
</tbody>
</table>

#### 1.1.2 Mesh Provisioning

协议栈架构中的 Mesh Provisioning 实现了如下功能:

- 对未配网设备的配网。
- Mesh 网络资源的分配 (单播地址、网络索引和网络密钥)。
- 配网期间对 4 种验证方法的支持。
- 更多功能，请参见 ESP-BLE-MESH Feature List。

Mesh Provisioning 功能的实现是基于层级结构的。每一层的功能如表 1.2 所示:

<table>
<thead>
<tr>
<th>层级</th>
<th>功能</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provisioning PDUs</td>
<td>通过配网协议处理不同层级的 Provisioning PDUs。</td>
</tr>
<tr>
<td>Generic Provisioning PDU/Proxy PDU</td>
<td>使用 Generic Provisioning 层或代理协议层将 Provisioning PDU 传输到未配网的设备。</td>
</tr>
<tr>
<td>PB-ADV/PB-GATT</td>
<td>这些层级定义了 Provisioning PDUs 作为可分包和重组的消息进行传输的方式。</td>
</tr>
<tr>
<td>Advertising/Provisioning Service</td>
<td>Provisioning bearer 定义了会话建立的方式，该方式用来将 Generic Provisioning 层的传输包传送到设备。</td>
</tr>
</tbody>
</table>
1.1.3 Mesh Models 协议栈架构中的 Mesh Models 实现了如下功能：

- 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

每一层的功能如表 1.3 所示：

表 10: 表 1.3 Mesh Models 框架描述

<table>
<thead>
<tr>
<th>层级</th>
<th>功能</th>
</tr>
</thead>
<tbody>
<tr>
<td>模型层</td>
<td>模型层实现用于标准化典型用户场景操作的模型，包括 Generic Client/Server Models, Sensor Client/Server Models, Time and Scenes Client/Server Models, Lighting Client/Server Models 和若干自定义模型。</td>
</tr>
<tr>
<td>基础模型层</td>
<td>基础模型层实现与 ESP-BLE-MESH 网络配置、管理和自我诊断等相关的模型。</td>
</tr>
</tbody>
</table>

1.2 Mesh 网络管理 网络管理实现了如下功能：

- 节点移除程序：用于将节点从网络中移除。
- 网络索引恢复程序：用于恢复节点的网络索引。
- 网络索引更新程序：用于更新节点的网络索引。
- 秘钥更新程序：用于更新节点的网络秘钥，应用秘钥 (AppKey) 等。
- 网络创建程序：用于创建 mesh 网络。
- NVS 存储器：用于存储节点的网络信息。

1.3 Mesh 特性 特性包括以下几项：

- 低功耗特性：用于降低节点的能耗。
- 好友特性：用于为低功耗节点存储消息。
- 中继特性：用于中继/转发节点通过广播承载层收到的网络 PDU。
- Proxy Server/Client 是代理协议中的两个节点角色，其使节点可以通过面向连接的承载层收发 Network PDUs, mesh beacons, 代理配置消息和 Provisioning PDU。

1.4 Mesh 承载层 协议栈框架中的 承载层负责 ESP-BLE-MESH 协议栈和低功耗蓝牙核心协议间的数据传输。

承载层可视为是基于蓝牙低功耗核心协议的载体层，其实现了 ESP-BLE-MESH 协议栈数据的接收和传输。

表 11: 表 1.3 Mesh 承载层描述

<table>
<thead>
<tr>
<th>层级</th>
<th>功能</th>
</tr>
</thead>
<tbody>
<tr>
<td>GATT 承载层</td>
<td>GATT 承载层使用代理协议通过 GATT 连接在两个设备之间发送和接收 Proxy PDUs。</td>
</tr>
<tr>
<td>广播承载层</td>
<td>使用广播承载层时，必须使用低功耗蓝牙广播通道来发送 mesh 数据包, 数据包中的 AD Type 需要设置为 mesh 数据包的类型。</td>
</tr>
</tbody>
</table>

1.5 Mesh 应用层 协议栈框架图中的 应用层通过调用 ESP-BLE-MESH 协议栈提供的 API 并处理协议栈上报的事件来实现相应的功能，有一些常用应用，比如网关、照明等。

应用层和 API / 事件之间的交互

- 应用层调用 API
  - 调用配网相关的 API 进行配网。
  - 调用模型相关的 API 发送消息。
  - 调用设备属性相关的 API 获取设备的本地信息。
• 应用层处理事件
  应用层的设计基于事件设计，事件将参数传输给应用层。事件主要分为两大类。
  - 调用 API 完成的事件。
    - 比如接收消息的节点。
  - 协议栈主动上报给应用层的事件。
    - 协议栈主动上报的事件。
    - 模型主动上报的事件。
• 事件通过应用层注册的回调函数进行上报，同时回调函数中也会包含对事件的相应处理。

API / 事件与 ESP-BLE-MESH 协议栈的交互
• 用户使用的 API 主要调用 “Mesh Networking”、Mesh Provisioning 和 Mesh Models 提供的函数。
• API / 事件和协议栈的交互不会跨越协议栈的层级进行操作。比如 API 不会调用 Network Layer 相关的函数。

2. ESP-BLE-MESH 架构实现  ESP-BLE-MESH 架构的设计和实现是基于层级和模块的。具体而言，第 2.1 节（Mesh 网络的实现）、第 2.2 节（Mesh 配网实现）和第 2.3 节（Mesh 层级实现）基于层级思想，第 2.4 节（网络模型的实现）基于模块思想。
• 层级思想：基于层级思想，网络架构根据 Mesh Profile Specification 中指定的层级设计而成。每层都有独特的文件，文件包括该层的 API 等。具体设计如图 2.1 所示。
• 模块思想：每个文件实现一个独立的功能，供其它程序调用。

ESP-BLE-MESH 架构采用分层的方式进行设计，数据包的处理所经过的层级顺序是固定的，也就是数据包的处理过程会形成一个消息流。因此，我们可以从图 2.1 的协议栈接口图中看到消息流。

2.1 Mesh 协议栈的实现

2.1.1 Mesh Networking 实现  Mesh Networking 中的文件列表和每个文件实现的功能如表 2.1 所示：

<table>
<thead>
<tr>
<th>文件</th>
<th>功能</th>
</tr>
</thead>
<tbody>
<tr>
<td>access.c</td>
<td>BLE Mesh 接入层</td>
</tr>
<tr>
<td>transport.c</td>
<td>BLE Mesh 底层/上层传输层</td>
</tr>
<tr>
<td>net.c</td>
<td>BLE Mesh 网络层</td>
</tr>
<tr>
<td>adv.c</td>
<td>用于发送 BLE Mesh 广播包的任务，一个用于处理收到的广播包的回调以及用于分配 adv 缓冲区的 API</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>文件</th>
<th>功能</th>
</tr>
</thead>
<tbody>
<tr>
<td>prov.c</td>
<td>BLE Mesh 节点配网 (PB-ADV &amp; PB-GATT)</td>
</tr>
<tr>
<td>proxy_server.c</td>
<td>BLE Mesh 节点代理服务器相关功能</td>
</tr>
<tr>
<td>beacon.c</td>
<td>用于处理 BLE Mesh Beacon 的 API</td>
</tr>
</tbody>
</table>

2.1.2 Mesh Provisioning 实现  由于 Node/Provisioner 共存的限制，Mesh Provisioning 的实现分为两大模块。实现 Node 启动配置的特定文件如表 2.2 所示：

<table>
<thead>
<tr>
<th>文件</th>
<th>功能</th>
</tr>
</thead>
<tbody>
<tr>
<td>provisioner_prov.c</td>
<td>BLE Mesh Provisioner 配置入网 (PB-ADV &amp; PB-GATT)</td>
</tr>
<tr>
<td>proxy_client.c</td>
<td>BLE Mesh 代理客户端相关功能</td>
</tr>
<tr>
<td>provisioner_main.c</td>
<td>BLE Mesh Provisioner 网络相关功能</td>
</tr>
</tbody>
</table>

实现 Provisioner 配置功能的特定文件如表 2.3 所示：
2.1.3 Mesh Models 实现 Mesh Models 用于实现节点中所包含的模型的具体功能。服务器模型主要用于维护节点状态。客户端模型主要用于获取和修改节点状态。

<table>
<thead>
<tr>
<th>文件</th>
<th>功能</th>
</tr>
</thead>
<tbody>
<tr>
<td>cfg_cli.c</td>
<td>发送 Configuration Client 消息。接收相应应答消息</td>
</tr>
<tr>
<td>cfg_srv.c</td>
<td>接收 Configuration Client 消息。发送适当应答消息</td>
</tr>
<tr>
<td>health_cli.c</td>
<td>发送 Health Client 消息。接收相应应答消息</td>
</tr>
<tr>
<td>health_srv.c</td>
<td>接收 Health Client 消息。发送适当应答消息</td>
</tr>
<tr>
<td>client_common.c</td>
<td>BLE Mesh 模型相关操作</td>
</tr>
<tr>
<td>generic_client.c</td>
<td>发送 BLE Mesh Generic Client 消息。接收相应应答消息</td>
</tr>
<tr>
<td>lighting_client.c</td>
<td>发送 BLE Mesh Lighting Client 消息。接收相应应答消息</td>
</tr>
<tr>
<td>sensor_client.c</td>
<td>发送 BLE Mesh Sensor Client 消息。接收相应应答消息</td>
</tr>
<tr>
<td>time_scene_client.c</td>
<td>发送 BLE Mesh Time Scene Client 消息。接收相应应答消息</td>
</tr>
</tbody>
</table>

表 15: Table 2.4 Mesh Models 文件描述

2.2 Mesh Bearers 实现 Mesh Bearers 在实现时充分考虑了可移植性。当 ESP-BLE-MESH 协议栈需要移植到其它平台时，用户只需要修改 mesh_bearer_adapt.c 就能移植成功。

<table>
<thead>
<tr>
<th>文件</th>
<th>功能</th>
</tr>
</thead>
<tbody>
<tr>
<td>mesh_bearer_adapt.c</td>
<td>BLE Mesh 承载层适配文件。此文件提供用于接收和发送 BLE Mesh ADV 和 GATT 相关数据包的接口。</td>
</tr>
</tbody>
</table>

表 16: 表 2.5 Mesh Bearers 文件描述

注解：mesh_bearer_adapt.c 是对 Mesh 网络框架中 Advertising Bearer 和 GATT Bearer 的实现。

2.3 Mesh Applications 实现 我们提供了一系列用于客户开发的应用示例，用户可以基于 ESP-BLE-MESH 示例 开发产品。

3. ESP-BLE-MESH 辅助程序 辅助程序指的是 ESP-BLE-MESH 协议栈中可选的功能。辅助程序的设计通常通过 CONFIG_BLE_MESH 来实现代码的裁剪。

3.1 特性
- 低功耗
- 好用
- 中继
- 代理客户端/代理服务器

3.2 网络管理
- 节点移除程序
- 网络索引恢复程序
- 网络索引更新程序
- 秘钥更新程序
- 网络创建程序
- NVS 存储器

3.3 辅助程序实现 采用独立模块的设计主要考虑到两个因素：
- 该模块不具备分层实现的条件，其实现可以完全独立，不需要依赖其它模块。
- 模块中的函数会被反复使用到，因此最好设计成独立模块。独立模块如表 3.1 所示：
表 17: 表 3.1 模块文件描述

<table>
<thead>
<tr>
<th>文件</th>
<th>功能</th>
</tr>
</thead>
<tbody>
<tr>
<td>lpn.c</td>
<td>BLE Mesh 低功耗功能</td>
</tr>
<tr>
<td>friend.c</td>
<td>BLE Mesh 好友功能</td>
</tr>
<tr>
<td>net.c</td>
<td>BLE Mesh 中继功能、网络创建、网络索引更新程序、网络索引恢复程序、秘钥更新程序相关功能</td>
</tr>
<tr>
<td>proxy_server.c</td>
<td>BLE Mesh 代理服务器相关功能</td>
</tr>
<tr>
<td>proxy_client.c</td>
<td>BLE Mesh 代理客户端相关功能</td>
</tr>
<tr>
<td>settings.c</td>
<td>BLE Mesh NVS 存储器功能</td>
</tr>
<tr>
<td>main.c</td>
<td>BLE Mesh 协议栈初始化、协议栈使能、节点移除相关功能</td>
</tr>
</tbody>
</table>

ESP-BLE-MESH 常见问题手册

本文汇总了 ESP-BLE-MESH 协议栈开发的常见问题及解答，全文分为 7 个章节。

- 1. Provisioner 开发
- 2. 节点开发
- 3. ESP-BLE-MESH 和 Wi-Fi 共存
- 4. 快速配网
- 5. Log 帮助
- 6. 示例帮助
- 7. 其他

用户可以参考这些章节，快速找到问题的答案。该文档会根据各种渠道收集的反馈进行更新。

1. Provisioner 开发

通常而言，Provisioner 用于配网未配网设备并形成 mesh 网络。组网后，设备的角色变成节点。

1.1 未配网设备加入 ESP-BLE-MESH 网络的流程是什么？

设备通过 Provisioner 加入 ESP-BLE-MESH 网络分为两个阶段，配网阶段和配置阶段。
- 配网阶段：为设备分配单播地址、添加网络密钥 (NetKey) 等。通过配网，设备加入 ESP-BLE-MESH 网络，身份从未配网设备变为节点。
- 配置阶段：为节点添加应用密钥 (AppKey)，并将应用密钥绑定到相应模型。配置期间，有些选项是可选的，比如为节点添加订阅地址、设置发布地址等。通过配置，该节点实际上可以向 Provisioner 发送消息，也可以接收来自 Provisioner 的消息。

1.2 如果 Provisioner 想要改变节点状态，其需满足什么条件？

- 需要有和节点的服务器模型相对应的客户端模型。
- 需要和节点有相同的，可用于加密消息的网络密钥和应用密钥。
- 需要知道节点的地址，可以是单播地址，也可以是订阅地址。

1.3 如何使用网络密钥和应用密钥？

- 网络密钥用于加密网络层的消息。具有相同网络密钥的节点视作在同一网络中。具有不同网络密钥的节点相互之间不能进行通信。
- 应用密钥用于加密上层传输层中的消息。如果服务器模型和客户端模型绑定的应用密钥不同，则无法实现相互通信。

1.4 如何生成网络密钥或应用密钥？是否可以采用固定的网络密钥或应用密钥？

- API esp_ble_mesh_provisioner_add_local_net_key() 可以用来添加包含固定值或随机值的网络密钥。
API `esp_ble_mesh_provisioner_add_local_app_key()` 可以用来添加包含固定值或随机值的应用密钥。

### 1.5 Provisioner 的单播地址是不是固定的？

`esp_ble_mesh_prov_t` 中 `provunicast_addr` 的值用于设置 Provisioner 的单播地址，只能在初始化期间设置一次，此后不能更改。

### 1.6 Provisioner 的地址是否可以作为节点上报状态消息的目的地址？

Provisioner 的单播地址只能在初始化期间设置一次，此后不能更改。理论而言，只要节点知道 Provisioner 的单播地址，此地址便可用作节点上报状态消息的目的地址。节点在网络配置的过程中可以知道 Provisioner 的单播地址，因为 Provisioner 限节点发送消息时，消息的源地址就是 Provisioner 的单播地址。

订阅地址也可使用。Provisioner 订阅组地址或者虚拟地址，节点向该订阅地址发送消息。

### 1.7 被 Provisioner 配网到 ESP-BLE-MESH 网络中的第一个节点的单播地址是否是固定的？

`esp_ble_mesh_prov_t` 中 `prov_start_address` 的值用于设置 Provisioner 配网未配网设备的起始地址，即其首先配网的节点的单播地址。单播地址只能在初始化期间设置一次，此后不能修改。

### 1.8 手机 App 首先配置的节点的单播地址是不是固定的？

该 App 将确定单播地址，目前大多数单播地址是固定的。

### 1.9 如何知道当前 Provisioner 正在配网哪个未配网设备？

`esp_ble_mesh_prov_t` 中 `provattention` 的值由 Provisioner 在配网过程中设置给未配网设备。该值只能在初始化期间设置一次，此后不能修改。未配网设备加入 mesh 网络后可以用特定的方式来显示自己正在配网，比如灯光闪烁，以告知 Provisioner 其正在配网。

### 1.10 配网过程中，认证设备共有多少种方法？提供的范例中 provided examples 使用了什么方法？

共有四种设备认证方法，即 No OOB、Static OOB、Output OOB 和 Input OOB。提供的范例使用了 No OOB 的方式。

### 1.11 配置入网前，未配网设备的广播包可以携带哪些信息？

- Device UUID
- OOB Info
- URL Hash (可选的)

### 1.12 这些信息可以用于设备识别吗？

是的。每个设备都有独一无二的 Device UUID，用户可以通过 Device UUID 识别设备。

### 1.13 当 Provisioner 配网的节点包含多个元素时，单播地址是如何分配的？

- Provisioner 会给设备的主元素分配一个单播地址，其余元素的单播地址在此基础上递增。
- 比如：如果一个未配网设备有三个元素，即主要元素，第二元素和第三元素。配网完成后，节点主元素的单播地址为 0x0002，节点第二元素的单播地址为 0x0003，节点第三元素的单播地址为 0x0004。
1.14 Provisioner 如何通过 Configuration Client Model 获取并且解析节点的构成数据？

- Provisioner 可以调用 Configuration Client Model API `esp_ble_mesh_config_client_set_state()` 设置参数，调用 `esp_ble_meshCfg_client_get_state_t` 中的 `comp_data_get` 获取节点的构成数据。
- 用户可以参考以下代码解析 Composition Data:

```c
#include <stdio.h>
#include <string.h>
#include <stdint.h>

// test date: 0C001A0001000800000010501000000080010001003103F002A00
// 0C00 IA00 0100 0800 0300 0001 05 01 0000 0080 0100 0010 0310 3F002A00

// CID is 0x000C
// PID is 0x001A
// VID is 0x0001
// CRPL is 0x0008
// Features is 0x0003 — Relay and Friend features.
// Loc is "front" — 0x0100
// NumS is 5
// NumV is 1
// The Bluetooth SIG Models supported are: 0x0000, 0x8000, 0x0001, 0x1000, ...
// 0x1003
// 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) {
    // 处理错误
  }
  // 解码过程
}
```
```c
return -1;
}

pos_sig_base = sizeof(*head) - 1;

for(i = 1; i < head->sig_models * 2; i = i + 2) {
    data->SIG_models[i/2] = mystr[i + pos_sig_base] | (mystr[i + pos_
    sig_base + 1] << 8);
    printf("%d: %4.4x\n", i/2, data->SIG_models[i/2]);
}

pos_vnd_base = head->sig_models * 2 + pos_sig_base;

for(i = 1; i < head->vnd_models * 2; i = i + 2) {
    data->Vendor_models[i/2].model_id = mystr[i + pos_vnd_base] | (mystr[i + pos_vnd_base + 1] << 8);
    printf("%d: %4.4x\n", i/2, data->Vendor_models[i/2].model_id);
    data->Vendor_models[i/2].vendor_id = mystr[i + pos_vnd_base + 2] | (mystr[i + pos_vnd_base + 3] << 8);
    printf("%d: %4.4x\n", i/2, data->Vendor_models[i/2].vendor_id);
}

return 0;
}

void app_main(void)
{
    esp_ble_mesh_composition_head head = {0};
    esp_ble_mesh_composition_decode data = {0};
    uint8_t mystr[] = { 0x0C, 0x00, 0x1A, 0x00,
        0x01, 0x00, 0x08, 0x00,
        0x03, 0x00, 0x00, 0x01,
        0x05, 0x01, 0x00, 0x00,
        0x00, 0x80, 0x01, 0x00,
        0x00, 0x10, 0x03, 0x10,
        0x3F, 0x00, 0x2A, 0x00};

    int ret;

    ret = decode_comp_data(&head, &data, mystr, sizeof(mystr));
    if (ret == -1) {
        printf("decode_comp_data error\n");
    }
}
```

1.15 Provisioner 如何通过获取的 Composition Data 进一步配置节点？

Provisioner 通过调用 Configuration Client Model API `esp_ble_mesh_config_client_set_state()` 来进行如下配置。

- 正确设置参数 `esp_ble_mesh_cfg_client_set_state_t` 中的 `app_key_add`，将应用密钥添加到节点中。
- 正确设置参数 `esp_ble_mesh_cfg_client_set_state_t` 中的 `model_sub_add`，将订阅地址添加到节点的模型中。
- 正确设置参数 `esp_ble_mesh_cfg_client_set_state_t` 中的 `model_pub_set`，将发布地址添加到节点的模型中。

1.16 节点可以自己添加相应的配置吗？

本法可用于特殊情况，如测试阶段。
此示例展示了节点如何为自己的模型添加新的组地址。

```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;
}
```

注释：使能了节点的 NVS 存储器后，通过该方式添加的组地址以及绑定的应用密钥在设备掉电的情况下不能保存。这些配置信息只有通过 Configuration Client Model 配置时才会保存。

1.17 Provisioner 如何通过分组方式控制节点？

通常而言，在 ESP-BLE-MESH 网络中实现组控制有两种方法，即组地址方法和虚拟地址方法。假设在 ESP-BLE-MESH 网络中有 10 个设备，即 5 个带蓝灯的设备和 5 个带红灯的设备。

- 方案一：5 个蓝灯设备订阅一个组地址，5 个红灯设备订阅另一个组地址。Provisioner 往不同的组地址发送消息，即可实现分组控制设备。
1.18 Provisioner 如何将节点添加至子网？

节点配置期间，Provisioner 可以为节点添加多个网络密钥，拥有相同网络密钥的节点属于同一子网。Provisioner 可以通过不同的网络密钥与不同子网内的节点进行通信。

1.19 Provisioner 如何知道网络中的某个设备是否离线？

节点离线通常定义为：电源故障或其他原因导致的节点无法与 mesh 网络中的其他节点正常通信的情况。

ESP-BLE-MESH 网络中的节点间彼此不连接，它们通过广播通道进行通信。

此示例展示了如何通过 Provisioner 检测节点是否离线。

- 节点定期给 Provisioner 发送心跳包。如果 Provisioner 超过一定的时间未接收到心跳包，则视该节点离线。

注解：心跳包的设计应该采用单包（字节数小于 11 个字节）的方式，这样收发效率会更高。

1.20 Provisioner 删除网络中的节点时，需要进行哪些操作？

通常而言，Provisioner 从网络中移除节点主要涉及三个步骤：

- 首先，Provisioner 将需要移除的节点添加至“黑名单”。
- 其次，Provisioner 启动密钥更新程序。
- 最后，节点执行节点重置程序，切换自身身份为未配网设备。

1.21 在密钥更新的过程中，Provisioner 如何更新节点的网络密钥？

- 通过正确设置参数 esp_ble_mesh_cfg_client_set_state_t 中的 net_key_update，使用 Configuration Client Model API esp_ble_mesh_config_client_set_state()，Provisioner 更新节点的网络密钥。
- 通过正确设置参数 esp_ble_mesh_cfg_client_set_state_t 中的 app_key_update，使用 Configuration Client Model API esp_ble_mesh_config_client_set_state()，Provisioner 更新节点的应用密钥。

1.22 Provisioner 如何管理 mesh 网络中的节点？

ESP-BLE-MESH 在示例中实现了一些基本的节点管理功能，比如 esp_ble_mesh_store_node_info()。ESP-BLE-MESH 还提供了用于设置节点本地名称的 API esp_ble_mesh_provisioner_set_node_name() 和可用于获取节点本地名称的 API esp_ble_mesh_provisioner_get_node_name()。

1.23 Provisioner 想要控制节点的服务器模型时需要什么？

Provisioner 在控制节点的服务器模型前，必须包括相应的客户端模型。

Provisioner 应当添加本地的网络密钥和应用密钥。

- Provisioner 调用 API esp_ble_mesh_provisioner_add_local_net_key() 以添加网络密钥。
- Provisioner 调用 API esp_ble_mesh_provisioner_add_local_app_key() 以添加应用密钥。

Provisioner 应当配置自己的客户端模型。
• Provisioner 调用 API esp_ble_mesh_provisioner_bind_app_key_to_local_model() 以绑定应用密钥至自己的客户端模型。

1.24 Provisioner 如何控制节点的服务器模型？

ESP-BLE-MESH 支持所有 SIG 定义的客户端模型。Provisioner 可以使用这些客户端模型控制节点的服务器模型。客户端模型分为 6 类，每类有相应的功能。

• Configuration Client Model
  - API esp_ble_mesh_config_client_get_state() 可用于获取 Configuration Server Model 的 esp_ble_mesh_cfg_client_get_state_t 值。
  - API esp_ble_mesh_config_client_set_state() 可用于获取 Configuration Server Model 的 esp_ble_mesh_cfg_client_set_state_t 值。

• Health Client Model
  - API esp_ble_mesh_health_client_get_state() 可用于获取 Health Server Model 的 esp_ble_mesh_health_client_get_state_t 值。
  - API esp_ble_mesh_health_client_set_state() 可用于获取 Health Server Model 的 esp_ble_mesh_health_client_set_state_t 值。

• Generic Client Models
  - API esp_ble_mesh_generic_client_get_state() 可用于获取 Generic Server Model 的 esp_ble_mesh_generic_client_get_state_t 值。
  - API esp_ble_mesh_generic_client_set_state() 可用于获取 Generic Server Model 的 esp_ble_mesh_generic_client_set_state_t 值。

• Lighting Client Models
  - API esp_ble_mesh_light_client_get_state() 可用于获取 Lighting Server Model 的 esp_ble_mesh_light_client_get_state_t 值。
  - API esp_ble_mesh_light_client_set_state() 可用于获取 Lighting Server Model 的 esp_ble_mesh_light_client_set_state_t 值。

• Sensor Client Models
  - API esp_ble_mesh_sensor_client_get_state() 可用于获取 Sensor Server Model 的 esp_ble_mesh_sensor_client_get_state_t 值。
  - API esp_ble_mesh_sensor_client_set_state() 可用于获取 Sensor Server Model 的 esp_ble_mesh_sensor_client_set_state_t 值。

• Time and Scenes Client Models
  - API esp_ble_mesh_time_scene_client_get_state() 可用于获取 Time and Scenes Server Model 的 esp_ble_mesh_time_scene_client_get_state_t 值。
  - API esp_ble_mesh_time_scene_client_set_state() 可用于获取 Time and Scenes Server Model 的 esp_ble_mesh_time_scene_client_set_state_t 值。

2. 节点开发

2.1 节点包含什么样的模型？

• ESP-BLE-MESH 中，节点由一系列的模型组成，每个模型实现节点的某些功能。
  • 模型分为两种，客户端模型和服务器模型。客户端模型可以获取并设置服务器模型的状态。
  • 模型也可以分为 SIG 模型和自定义模型。SIG 模型的所有行为都由官方定义，而自定义模型的行为均由用户定义。

2.2 每个模型对应的消息格式是不是固定的？

• 消息由 opcode 和 payload 组成，通过 opcode 进行区分。
  • 与模型对应的消息的类型和格式都是固定的，这意味着模型之间传输的消息是固定的。
2.3 节点的模型可以使用哪些函数发送消息？

- 对于客户端模型，用户可以调用 API `esp_ble_mesh_client_model_send_msg()` 发送消息。
- 对于服务器模型，用户可以调用 API `esp_ble_mesh_server_model_send_msg()` 发送消息。
- 对于发布，用户可以调用 API `esp_ble_mesh_model_publish()` 发布消息。

2.4 如何实现消息传输不丢包？

如果用户要实现消息传输不丢包，则需有应答的消息。等待应答的默认时间在 `CONFIG_BLE_MESH_CLIENT_MSG_TIMEOUT` 中设置。如果发送端等待应答超时，就会触发对应的超时事件。

注解：API `esp_ble_mesh_client_model_send_msg()` 中可以设置应答的超时时间。如果参数 `msg_timeout` 设为 0，那么超时时间便会采用默认值 (4 秒)。

2.5 如何发送无应答的消息？

对于客户端模型，用户可以调用 API `esp_ble_mesh_client_model_send_msg()` with the parameter `need_rsp` set to false 发送无应答消息。

对于服务器模型，调用 API `esp_ble_mesh_server_model_send_msg()` 发送的消息总是无应答的消息。

2.6 如何为模型添加订阅地址？

通过 Configuration Client Model 添加订阅地址。

2.7 模型发送的消息和发布的消息有何不同？

调用 API `esp_ble_mesh_client_model_send_msg()` 或 `esp_ble_mesh_server_model_send_msg()` 发送的消息会在 Network Transmit 状态规定的期限内发送。

调用 API `esp_ble_mesh_model_publish()` 发布的消息将由模型发布状态决定是否发布。消息的发布一般是周期性的，或者有固定次数。发布周期和发布次数由模型发布状态控制，并且可以通过 Configuration Client Model 进行配置。

2.8 发送不分包消息时，最多可携带多少有效字节？

不分包消息的总有效载荷长度（可由用户设置）为 11 个八位位组，因此，如果消息的 `opcode` 为 2 个八位位组，则该消息可以携带 9 个八位位组的有效信息。对于 `vendor` 消息，由于 `opcode` 是 3 个八位位组，剩余的有效负载长度为 8 个八位位组。

2.9 什么时候应该使用节点的 Relay 功能？

如果 `mesh` 网络中检测到的节点很稀疏，用户可以使能节点的 Relay 功能。

如果 `mesh` 网络中检测到的节点很密集，用户可以选择仅使能一些节点的 Relay 功能。

如果 `mesh` 网络大小未知，用户可以默认使能 Relay 功能。

2.10 什么时候应该使用节点的 Proxy 功能？

如果未配网设备将由电话配网，则未配网设备应该使能 Proxy 功能，因为当前几乎所有电话都不支持通过广播承载层发送 ESP-BLE-MESH 数据包。并且，未配网设备成功配网成为 Proxy 节点后，其会通过 GATT 承载层和广播承载层与 mesh 网络中的其他节点通信。
2.11 如何使用代理过滤器？
代理过滤器用于减少 Proxy Client（如手机）和 Proxy Server（如节点）之间交换的 Network PDU 的数量。另外，通过代理过滤器，Proxy Client 可以明确请求仅接收来自 Proxy Server 的某些目标地址的 mesh 消息。

2.12 Relay 节点什么时候可以中继消息？
如果要中继消息，消息需满足以下要求。
• 消息存在于 mesh 网络中。
• 消息的目的地址不是节点的单播地址。
• 消息的 TTL 值需大于 1。

2.13 如果一条消息分成几段，那么其他 Relay 节点是接收到一段消息就中继还是等接收到完整的数据包才中继？
 Relay 节点收到其中一段消息时就中继，而非一直等到接收所有的消息。

2.14 使用 Low Power 功能降低功耗的原理是什么？
• 开启无线电进行收听时，设备消耗能量。使能节点的低功耗功能后，它将在大多数时间内关闭无线电功能。
• 低功耗节点和好友节点需要合作，因此低功耗节点可以以适当或较低的频率接收消息，而无需一直收听。
• 当低功耗节点有一些新消息时，好友节点将为其存储消息。低功耗节点可以间隔固定时间轮询好友节点，以查看是否有新的消息。

2.15 设备断电后上电，如何能继续在网络中进行通讯？
在 menuconfig 中启用配置 Store BLE Mesh Node configuration persistently。

2.16 如何实现节点自检的信息发送出来？
推荐节点通过 Health Server Model 定期发布其自检结果。

2.17 节点间如何传输消息？
节点间传输信息的可能应用场景是，一旦烟雾警报检测到高浓度的烟雾，就会触发喷淋设备。有两种实现方法。
• 方法 1：喷淋设备订阅组地址。当烟雾警报器检测到高浓度的烟雾时，它会发布一条消息，该消息的目标地址是喷淋设备已订阅的组地址。
• 方法 2：Provisioner 可以配置喷洒设备的单播地址为烟雾报警器的地址。当检测到高浓度的烟雾时，烟雾报警器以喷淋设备的单播地址为目标地址，将消息发送到喷淋设备。

2.18 设备通信必须要网关吗？
• 情况 1：节点仅在 mesh 网络内通信。这种情况下，不需要网关。ESP-BLE-MESH 网络是一个泛洪的网络，网络中的消息没有固定的路径，节点与节点之间可以随意通信。
• 情况 2：如果用户想要远程控制网络，比如在到家之前打开某些节点，则需要网关。

2.19 何时使用 IV Update 更新程序？
一旦节点的底层检测到发送的消息的序列号达到临界值，IV Update 更新程序便会启用。
2.20 如何启用 IV Update 更新程序？

节点可以使用带有 Secure Network Beacon 的 IV Update 更新程序。

3. ESP-BLE-MESH 和 Wi-Fi 共存

3.1 Wi-Fi 和 ESP-BLE-MESH 共存时，支持哪些模式？

目前，只有 Wi-Fi STA 模式支持共存。

3.2 Wi-Fi 和 ESP-BLE-MESH 共存时，为什么 Wi-Fi 吞吐量很低？

未搭载 PSRAM 的 ESP32-DevKitC 开发板，Wi-Fi 和 ESP-BLE-MESH 共存可以正常运行，但是吞吐率较低。当 Wi-Fi 和 ESP-BLE-MESH 共存时，搭载 PSRAM 的 ESP32-DevKitC 速率可以稳定在 1 Mbps 以上。

应使能 menuconfig 中的一些配置来支持 PSRAM。

• ESP32-specific --> Support for external, SPI-connected RAM -->
  Try to allocate memories of Wi-Fi and LWIP...
• Bluetooth --> Bluedriod Enable --> BT/BLE will first malloc the
  memory from the PSRAM
• Bluetooth --> Bluedriod Enable --> Use dynamic memory
  allocation in BT/BLE stack.
• Bluetooth --> Blutooth controller --> BLE full scan feature
  supported.
• Wi-Fi --> Software controls Wi-Fi/Bluetooth coexistence -->
  Wi-Fi

4. 快速配网

4.1 为什么需要快速配网？

通常而言，存在少量未配网设备时，用户可以逐个配置。但是如果有大量未配网设备（比如 100 个）时，逐个配置会耗费大量时间。通过快速配网，用户可以在约 50 秒内配网 100 个未配网设备。

4.2 为什么会出现 EspBleMesh App 在快速配网期间长时间等待的情况？

快速配网期间，代理节点在配置完一个节点后会断开与 APP 的连接，待所有节点配网完成后
再与 APP 重新建立连接。

4.3 为什么 APP 中显示的节点地址的数量比现有的节点地址更多？

每完成一次快速配网后，开始新一次快速配网前，APP 会存有上次配网的数据，因此 APP 中显示的节点地址的数量比现有的节点地址更多。

4.4 在 EspBleMesh App 中输入的 ** count ** 值有什么用途？

此 count 值提供给 App 配置的代理节点，以决定何时提前开始 Proxy 广播信息。

4.5 运行以下示例 fast_prov_server 的节点的 Configuration Client Model 何时开始工作？

使能了 Temporary Provisioner 功能后，Configuration Client Model 会开始工作。
4.6 Temporary Provisioner 功能会一直处于使能的状态吗？
节点收到打开/关闭电信的消息后，所有节点会禁用其 Temporary Provisioner 功能并且转化为一般节点。

5. Log 帮助 当 ESP-BLE-MESH 协议栈底层出现错误或者警告时，您可以在这儿找到这些错误和警告的含义。

5.1 ran out of retransmit attempts 代表什么？
节点发送分段消息时，由于某些原因，接收端未收到完整的消息，节点会重传消息。当重传次数达到最大重传次数时，会出现该警告，当前最大重传次数为 4。

5.2 Duplicate found in Network Message Cache 代表什么？
当节点收到一条消息时，它会把该消息与网络缓存中存储的消息进行比较。如果在缓存中找到相同的消息，这意味着之前已接收过该消息，则该消息会被丢弃。

5.3 Incomplete timer expired 代表什么？
当节点在一定时间段（比如 10 秒）内未收到分段消息的所有段时，则 Incomplete 计时器到时，并且出现该警告。

5.4 No matching TX context for ack 代表什么？
当节点收到一个分段 ack 且不能找到任何自己发送的与该 ack 相关的消息时，会出现该警告。

5.5 No free slots for new incoming segmented messages 代表什么？
当节点没有空间来接收新的分段消息时，会出现该警告。用户可以通过配置 CONFIG_BLE_MESH_RX_SEG_MSG_COUNT 扩大空间。

5.6 Model not bound to AppKey 0x0000 代表什么？
当节点发送带有消息的信号且该模型尚未绑定到索引为 0x0000 的应用密钥时，会出现该错误。

5.7 Busy sending message to DST xxxx 代表什么？
该错误表示节点的客户端模型将消息发送给目标节点，并且正在等待响应，用户无法将消息发送到单播地址相同的同一节点。接收到相应的响应或计时器到时后，可以发送另一条消息。

6. 示例帮助

6.1 ESP-BLE-MESH 回调函数如何分类？
- API esp_ble_mesh_register_prov_callback() 用于注册处理配网和入网相关事件的回调函数。
- API esp_ble_mesh_register_config_client_callback() 用于注册处理 Configuration Client Model 相关事件的回调函数。
- API esp_ble_mesh_register_config_server_callback() 用于注册处理 Configuration Server Model 相关事件的回调函数。
- API esp_ble_mesh_register_health_client_callback() 用于注册处理 Health Client Model 相关事件的回调函数。
- API esp_ble_mesh_register_health_server_callback() 用于注册处理 Health Server Model 相关事件的回调函数。
• API esp_ble_mesh_register_generic_client_callback() 用于注册处理 Generic Client Models 相关事件的回调函数。
• API esp_ble_mesh_register_light_client_callback() 用于注册处理 Lighting Client Models 相关事件的回调函数。
• API esp_ble_mesh_register_sensor_client_callback() 用于注册处理 Sensor Client Model 相关事件的回调函数。
• API esp_ble_mesh_register_time_scene_client_callback() 用于注册处理 Time and Scenes Client Models 相关事件的回调函数。
• API esp_ble_mesh_register_custom_model_callback() 用于注册处理自定义模型和未实现服务器模型的相关事件的回调函数。

7. 其他

7.1 如何打印数据包？
示例使用如下函数 ESP_LOG_BUFFER_HEX() 打印信息语境，而 ESP-BLE-MESH 协议栈使用 bt_hex() 打印。

7.2 重启 ESP32 应使用哪个 API？
API esp_restart()。

7.3 如何监控任务栈的剩余空间？
API vTaskList() 可用于定期打印任务栈的剩余空间。

7.4 如何在不更改 menuconfig 输出级别的情况下改变 log 级别？
无需使用 menuconfig，可以通过 API esp_log_level_set() 修改 log 的输出级别。
## ESP-BLE-MESH Terminology

<table>
<thead>
<tr>
<th>术语</th>
<th>官方定义</th>
<th>详细说明</th>
</tr>
</thead>
<tbody>
<tr>
<td>未配网设备</td>
<td>“A device that is not a member of a mesh network is known as an unprovisioned device.”</td>
<td>示例：照明装置、温控设备、制造设备和电动门等。</td>
</tr>
<tr>
<td>节点</td>
<td>“A node is a provisioned device.”</td>
<td>经配网加入 ESP-BLE-MESH 网络后，未配网设备的身份将变成交互点。节点（如照明装置、温控设备、制造设备和电动门）是指能在蓝牙 ESP-BLE-MESH 网络中发送、接收或中继消息的设备，且节点可以选择性地支持一个或多个子网。</td>
</tr>
<tr>
<td>中继节点</td>
<td>“A node that supports the Relay feature and has the Relay feature enabled is known as a Relay node.”</td>
<td>中继节点接收并中继 ESP-BLE-MESH 消息，因此消息可以传输得更远。用户可以根据节点的状态来决定是否使能节点的中继功能。消息可以中继多次，每次中继为“一跳”。消息最多可有 126 跳，足以让消息在广阔的区域内传输。</td>
</tr>
<tr>
<td>代理节点</td>
<td>“A node that supports the Proxy feature and has the Proxy feature enabled is known as a Proxy node.”</td>
<td>代理节点从一个承载层（通常包括广播承载层和 GATT 承载层）接收消息，并通过另一个承载层重新发送消息。其目的是将只支持 GATT 承载层的通讯设备接入到 ESP-BLE-MESH 网络中。通常而言，手机 App 需要一个代理节点才能接入 Mesh 网络。没有代理节点，手机 App 无法与 Mesh 网络中成员通信。</td>
</tr>
<tr>
<td>好友节点</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>好友节点相当于低功耗节点 (LPN) 的备份，可存储发送低功耗节点的消息及安全更新信息；当低功耗节点需要这些存储的信息时，这些消息便会被传输至低功耗节点。低功耗节点必须与支持好友特性的另一节点建立“友谊”，以减少其接收器的空口。从而降低低功耗节点的功耗。低功耗节点需要找到好友节点，与其友好关系，其中涉及的过程称为“友谊建立”。低功耗节点与好友节点的搭配可让低功耗节点规划对无线电的使用，从而以适当或较低的频率接收消息，无需保持收听状态。低功耗节点会轮询好友节点以查看是否有新的消息。</td>
</tr>
<tr>
<td>低功耗节点</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>低功耗节点通过轮询好友节点获取信息，比如消息、安全更新等。</td>
</tr>
<tr>
<td>启动配置设备 (以下为 Provisioner)</td>
<td>“A node that is capable of adding a device to a mesh network.”</td>
<td>能够配网未配网设备的设备称为启动配置设备。这一流程通常需要通过产品制造商的提供的 App 来实现，并可在网关、智能手机、平板电脑和其他载体上使用。</td>
</tr>
</tbody>
</table>
表 19: 表 2 ESP-BLE-MESH 术语 - 节点构成

<table>
<thead>
<tr>
<th>术语</th>
<th>官方定义</th>
<th>详细说明</th>
</tr>
</thead>
<tbody>
<tr>
<td>状态</td>
<td>“A value representing a condition of an element that is exposed by an element of a node.”</td>
<td>ESP-BLE-MESH 网络中的每台设备都有一组独立的状态值，表示设备的某些状态，比如照明设备的亮度、颜色等状态。更改状态值会修改设备本身的物理状态，比如更改设备的开关状态值实际是在打开或关闭设备。</td>
</tr>
<tr>
<td>模型</td>
<td>“A model defines the basic functionality of a node.”</td>
<td>一个节点可能包含多个模型，而每个模型定义了节点的基本功能，比如节点所需要的状态、控制状态的消息以及处理消息所产生的动作等。节点功能的实现是基于模型的，模型可为 SIG 模型和自定义模型，前者由 SIG 定义，而后者由用户定义。</td>
</tr>
<tr>
<td>元素</td>
<td>“An addressable entity within a device.”</td>
<td>一个节点可以包含一个或多个元素，每个元素都有一个单播地址和一个或多个模型，并且同一元素所包含的模型不可以出现重复。</td>
</tr>
<tr>
<td>节点构成状态</td>
<td>“The Composition Data state contains information about a node, the elements it includes, and the supported models.”</td>
<td>通过读取节点构成状态的值，用户可以了解节点的基本信息，比如元素的数量及每个元素中的模型。Provisioner 通过获取这个消息对设备进一步配置，比如配置节点的订阅地址与发布地址。</td>
</tr>
</tbody>
</table>

表 20: 表 3 ESP-BLE-MESH 术语 - 特性

<table>
<thead>
<tr>
<th>术语</th>
<th>官方定义</th>
<th>详细说明</th>
</tr>
</thead>
<tbody>
<tr>
<td>低功耗特性</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>低功耗功能可降低节点的功耗。当低功耗节点寻找好友节点、且附近有多个好友节点时，它会通过算法选择最适合的好友节点。</td>
</tr>
<tr>
<td>好友特性</td>
<td>“The ability to help a node supporting the Low Power feature to operate by storing messages destined for those nodes.”</td>
<td>通过使低功耗特性，节点可以使用存储低功耗节点的信息。使能好友特性的节点可能会产生更大的功耗和内存消耗。</td>
</tr>
<tr>
<td>中继特性</td>
<td>“The ability to receive and retransmit mesh messages over the advertising bearer to enable larger networks.”</td>
<td>中继特性能让 ESP-BLE-MESH 的消息在节点之间实现多次跳跃，传输距离可超过两个节点之间直接进行无线电传输的范围，从而覆盖整个网络。实现了中继特性后，中继在节点中继消息时，只中继其所在子网的消息，不中继其它子网的消息。使能了中继特性的节点中继分段消息时不考虑数据的完整性。节点每收到一条分段消息便直接中继，不会等待收到完整的消息。</td>
</tr>
<tr>
<td>代理特性</td>
<td>“The ability to receive and retransmit mesh messages between GATT and advertising bearers.”</td>
<td>代理特性的目的是允许不具备广播承载层的节点访问 ESP-BLE-MESH 网络。代理特性通常为需要和手机 App 连接的节点所用。</td>
</tr>
</tbody>
</table>
### 表 21: 表 4 ESP-BLE-MESH 术语 - 配置入网

<table>
<thead>
<tr>
<th>术语</th>
<th>官方定义</th>
<th>详细说明</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB-ADV</td>
<td>“PB-ADV is a provisioning bearer used to provision a device using Generic Provisioning PDUs over the advertising channels.”</td>
<td>PB-ADV 通过广播通道传输数据包，只有 Provisioner 和未配网设备都支持 PB-ADV 时才可使用这种方法进行配网。</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 通过连接通道传输数据包。如果未配网设备想使用此方式进行配网，其需要实现相关的 Mesh Provisioning Service。未实现此服务的未配网设备不能通过 PB-GATT 承载层配网接入 mesh 网络。</td>
</tr>
<tr>
<td>配置入网</td>
<td>“Provisioning is a process of adding an unprovisioned device to a mesh network, managed by a Provisioner.”</td>
<td>经过配网，“未配网设备”的身份转变为“节点”，成为 ESP-BLE-MESH 网络中的一员。</td>
</tr>
<tr>
<td>认证方式</td>
<td>“Authentication is a step during the provisioning of nodes.”</td>
<td>未配网设备有四种认证方法：输入带外 (Input OOB)、输出带外 (Output OOB)、静态带外 (Static OOB) 和无带外 (No OOB)。</td>
</tr>
<tr>
<td>输入带外 (Input OOB)</td>
<td><strong>Input Out-of-Band</strong></td>
<td>输入带外 (Input OOB)：输入 OOB。如 Provisioner 生成并显示随机数，然后提示用户获取适当操作将随机数输入未配网的设备中。以照明开关为例子，用户可以在一定时间内数次按下按钮，以这种形式输入 Provisioner 端显示的随机数。输入带外认证方法与输出带外的认证方法类似，但设备的角色相反。</td>
</tr>
<tr>
<td>输出带外 (Output OOB)</td>
<td><strong>Output Out-of-Band</strong></td>
<td>输出带外 (Output OOB)：输出 OOB。如果未配网设备是一个灯泡，则其能够闪烁指定的次数。如果未配网设备有 LCD 屏幕，则可以将随机数显示为多位数字。启动 Provisioner 的用户需要输入观察到的数字，来认证未配网的设备。</td>
</tr>
<tr>
<td>静态带外 (Static OOB)</td>
<td><strong>Static Out-of-Band</strong></td>
<td>静态 OOB 的认证方法：使用静态 OOB 信息。如果需要使用无 OOB 信息，请将静态 OOB 字段赋值为 0。如果需要使用 OOB 信息，请使用静态 OOB 信息认证正在配网的设备。</td>
</tr>
<tr>
<td>无带外 (No OOB)</td>
<td><strong>No Out-of-Band</strong></td>
<td>无 OOB 的认证方法：将“静态 OOB”字段赋值为 0。采用这种方式相当于不认证未配网的设备。</td>
</tr>
</tbody>
</table>
### 表 22: 表 5 ESP-BLE-MESH 术语 - 地址

<table>
<thead>
<tr>
<th>术语</th>
<th>官方定义</th>
<th>详细说明</th>
</tr>
</thead>
<tbody>
<tr>
<td>未分配地址</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>本配置的元素地址或未分配的元素地址都称为未分配地址。鉴于这些元素没有固定的地址，它们不会用于消息的传输。建议在设置用户代码的地址之前，将该地址的值设为未分配地址。</td>
</tr>
<tr>
<td>单播地址</td>
<td>“A unicast address is a unique address allocated to each element.”</td>
<td>在单播期间，Provisioner 会给网络中处于生命周期内节点的每个元素分配一个单播地址。单播地址可能会出现在消息的源/目标地址字段中。发送到单播地址的消息只能由拥有该单播地址的元素进行处理。</td>
</tr>
<tr>
<td>虚拟地址</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>虚拟地址与特定的 UUID 标签相关联，可以用作模型的发布地址或订阅地址。UUID 标签与一个或多个节点的元素相关联的 128 位值。虚拟地址的第 15 位和第 14 位分别设置为 1 和 0。从第 13 位到第 0 位置为散列值（提供 16384 个散列值）。散列是 UUID 标签的派生。使用订阅元组检查完整的 128 位 UUID 十分低效，而散列值提供了一种更有效的方法来确定最终将哪些消息发送到哪些元素。</td>
</tr>
<tr>
<td>群组地址</td>
<td>“A group address is an address that is programmed into zero or more elements.”</td>
<td>群组地址是 ESP-BLE-MESH 网络中的另一种多播地址。通常用于将节点进行分组。发送到 all-proxies 地址的信息应由开启了代理功能的所有节点的主要元素处理。发送到 all-friends 地址的消息应由启用了好友功能的所有节点的主要元素处理。发送到 all-configuration 客户端和 all-nodes 地址的消息应由所有节点的主要元素处理。</td>
</tr>
</tbody>
</table>

### 表 23: 表 6 ESP-BLE-MESH 术语 - 安全

<table>
<thead>
<tr>
<th>术语</th>
<th>官方定义</th>
<th>详细说明</th>
</tr>
</thead>
<tbody>
<tr>
<td>设备密钥 (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>设备密钥让您能够配网未配网设备、配置节点。设备密钥用来加密配置信息，即配置设备时 Provisioner 和节点之间传输的消息。</td>
</tr>
<tr>
<td>应用密钥 (AppKey)</td>
<td>“Application keys are used to secure communications at the upper transport layer.”</td>
<td>应用密钥用于应用数据传递至应用层过程中对应用数据的解密，和应用层层过程中对数据的加密。网络中的一些节点有特定的用途，并且可以根据应用程序的需求对一些潜在敏感数据的访问进行限制。通过特定的应用密钥，这些节点与特定应用程序相关联。通常而言，使用不同应用密钥的领域有安全（楼宇门禁、机房门禁和 CEO 办公室门禁）、照明（工厂、外部楼宇和人行道）和 HVAC 系统。应用密钥绑定在网络密钥上，这意味着应用密钥仅在绑定网络密钥的情况下使用。每个应用密钥仅可绑定到一个网络密钥。</td>
</tr>
<tr>
<td>主安全料</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>使用好友安全材料加密的相应友谊消息有：1. 好友查询 (Friend Poll), 2. 好友更新 (Friend Update), 3. 好友订阅列表 (Friend Subscription List), 添加/删除/确认, 4. 好友节点发送到低功耗节点的“已存储消息”，使用主安全材料加密的相应友谊消息有：1. 好友清除 (Friend Clear), 2. 好友清除确认 (Friend Clear Confirm)。根据应用程序的设置，从低功耗节点发送到好友节点的消息会使用友谊安全材料或主安全材料进行加密，前者用于低功耗节点与好友节点之间的消息传输，而后者用于其他网络消息。</td>
</tr>
</tbody>
</table>
### Table 24: ESP-BLE-MESH Terminology - Messages

<table>
<thead>
<tr>
<th>术语</th>
<th>官方定义</th>
<th>详细说明</th>
</tr>
</thead>
<tbody>
<tr>
<td>重组 / 分包</td>
<td>“Segmentation and reassembly (SAR) is a method of communication network, which is divided into small units before transmitting packets and re-assembled in a proper order at the communication receiving end.”</td>
<td>底层传输层会自动分包过大的消息。接收端会回复一条应答消息，根据应答消息，发送端会重新向接收端发送其未接收到的数据包。这些是由底层传输层自动完成的。未分包的消息最多携带 15 个字节，其中 4 个字节是 transMIC，所以剩余 11 个字节；在分包的情况下，前面的包中每包有 12 个有效字节，最后一个包中有 8 个有效字节。特殊情况下，一个较长的包需要底层传输端强制分包，这种情况下有 8 个有效字节。</td>
</tr>
<tr>
<td>无应答 / 有应答</td>
<td>“There are two types of messages: UnAcknowledged or Acknowledged.”</td>
<td>根据接收端是否需要发送应答消息，发送的消息可分为两种。发送端需要设置最大重传次数。</td>
</tr>
</tbody>
</table>

### Table 25: ESP-BLE-MESH Terminology - Advanced Model

<table>
<thead>
<tr>
<th>术语</th>
<th>官方定义</th>
<th>详细说明</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>节点必须包含 Configuration Server Model，其负责维护配置相关的状态。Configuration Server Model 维护的状态包括：网络密钥名单 (NetKey List)、应用密钥名单 (AppKey List)、模型绑定的应用密钥名单 (Model to AppKey List)、节点身份 (Node Identity)、密钥更新阶段 (Key Refresh Phase)、心跳消息发布 (Heartbeat Publish)、心跳消息订阅 (Heartbeat Subscription)、网络传输 (Network Transmit) 和中继重传 (Relay Retransmit) 等。</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>Configuration Client Model 通过消息控制 Configuration Server Model 维护的状态。Provisioner 必须包含 Configuration Client Model，有了该模型就可以发送“Configuration Composition Data Get”等配置消息。</td>
</tr>
<tr>
<td>Health Server Model</td>
<td>“This model is used to represent a mesh network diagnostics of a device.”</td>
<td>Health Server Model 主要用于设备检查自身状态，查看自身是否发生错误。Health Server model 维护的状态包含：当前故障 (Current Fault)、已登记故障 (Registered Fault)、健康周期 (Health Period) 和关注计时器 (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>Health Client Model 通过消息控制 Health Server Model 维护的状态。该模型可通过对消息“Health Fault Get”获取其他节点的自检信息。</td>
</tr>
</tbody>
</table>
表 26: 表 9 ESP-BLE-MESH 术语 - 网络管理

<table>
<thead>
<tr>
<th>术语</th>
<th>官方定义</th>
<th>详细说明</th>
</tr>
</thead>
<tbody>
<tr>
<td>密钥更新程序</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>密钥更新程序用于更新 ESP-BLE-MESH 网络的网络密钥和应用密钥。当一个或多个网络密钥和/或一个或多个应用密钥的安全受到威胁或可能受到威胁时，会启动密钥更新程序。通常而言，在网络中某些节点移除后可以进行密钥更新。</td>
</tr>
<tr>
<td>IV 更新程序</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>IV 更新程序用于更新 ESP-BLE-MESH 网络的 IV Index 的值。这个值和消息加密时所需的随机数相关。为了保证随机数的值不重复，所以将这个值定期增加。IV Index 是一个 32 位的值，是一种共享网络资源。比如一个 mesh 网中的所有节点共享一个 IV Index 值。IV Index 从 0x00000000 开始，在 IV 更新过程中递增，并由特定的进程维护，以保证整个 Mesh 网内共享一个 IV Index。当节点认为它有耗尽其序列号的风险，或它确定另一个节点即将耗尽其序列号时，可以启动该程序。注意：每次的更新时间不得低于 96 小时。节点接收到 secure network beacon 或者确定自己的序列号大于特定值时，会触发 IV 更新程序。</td>
</tr>
</tbody>
</table>

官方定义摘自 ESP-BLE-MESH Glossary of Terms。查看更多术语，也请参照上述网址。

蓝牙 SIG 文档

- BLE Mesh Profile Specification
- BLE Mesh Model Specification
- An Intro to Bluetooth Mesh Part 1 / Part 2
- The Fundamental Concepts of Bluetooth Mesh Networking, Part 1 / Part 2
- Bluetooth Mesh Networking: Friendship
- Management of Devices in a Bluetooth Mesh Network
- Bluetooth Mesh Security Overview
- Provisioning a Bluetooth Mesh Network Part 1 / Part 2

4.27 ESP-MESH

本指南提供有关 ESP-MESH 协议的介绍。更多有关 API 使用的信息，请见 MESH API 参考。

4.27.1 概述

ESP-MESH 是一套建立在 Wi-Fi 协议之上的网络协议。ESP-MESH 允许分布在大范围区域内（室内和室外）的大量设备（下文称节点）在同一个 WLAN（无线局域网）中相互连接。ESP-MESH 具有自组网和自修复的特性，也就是说 mesh 网络可以自主地构建和维护。

本 ESP-MESH 指南分为以下几个部分：

1. 简介
2. ESP-MESH 概念
3. 建立网络
4. 管理网络
5. 数据传输
6. 信道切换
7. 性能
8. 更多注意事项
4.27.2 简介

图 56: 传统 Wi-Fi 网络架构

传统基础设施 Wi-Fi 网络是一个“单点对多点”的网络。这种网络架构的中心节点为接入点 (AP)，其他节点 (station) 均与 AP 直接相连。其中，AP 负责各个 station 之间的仲裁和转发，一些 AP 还会通过路由器与外部 IP 网络交换数据。在传统 Wi-Fi 网络架构中，1) 由于所有 station 均需与 AP 直接相连，不能距离 AP 太远，因此覆盖区域相对有限；2) 受到 AP 容量的限制，因此网络中允许的 station 数量相对有限，很容易超载。

图 57: ESP-MESH 网络架构示意图

ESP-MESH 与传统 Wi-Fi 网络的不同之处在于：网络中的节点不需要连接到中心节点，而是可以与相邻节点连接，各节点均负责相连节点的数据中继。由于无需受限于距离中心节点的位置，所有节点仍可互联，因此 ESP-MESH 网络的覆盖区域更广。类似地，由于不再受限于中心节点的容量限制，ESP-MESH 允许更多节点接入，也不易超载。
4.27.3 ESP-MESH 概念

术语

<table>
<thead>
<tr>
<th>术语</th>
<th>描述</th>
</tr>
</thead>
<tbody>
<tr>
<td>节点</td>
<td>任何属于 ESP-MESH 网络一部分的设备</td>
</tr>
<tr>
<td>根节点</td>
<td>网络顶部的节点</td>
</tr>
<tr>
<td>子节点</td>
<td>如节点 X 连接至节点 Y，且 X 相较 Y 与根节点的距离更远（跨越的连接数量更多），则称 X 为 Y 的子节点。</td>
</tr>
<tr>
<td>交节点</td>
<td>与子节点对应的概念</td>
</tr>
<tr>
<td>后裔节点</td>
<td>任何可以从根节点追踪到的节点</td>
</tr>
<tr>
<td>兄弟节点</td>
<td>连接至同一个父节点的所有节点</td>
</tr>
<tr>
<td>连接</td>
<td>AP 和 station 之间的传统 Wi-Fi 关联。ESP-MESH 中的节点使用 station 接口与另一个节点的 SoftAP 接口产生关联，进而形成连接。连接包括 Wi-Fi 网络中的身份验证和关联过程。</td>
</tr>
<tr>
<td>上行连接</td>
<td>从节点到其父节点的连接</td>
</tr>
<tr>
<td>下行连接</td>
<td>从父节点到其子节点的连接</td>
</tr>
<tr>
<td>无线跳</td>
<td>源节点和目标节点间无线连接路径中的一部分。单跳指遍历单个节点的数据包，多跳指遍历多个节点的数据包。</td>
</tr>
<tr>
<td>子网</td>
<td>子网指 ESP-MESH 网络的一部分，包括一个节点及其所有后裔节点。因此，根节点的子网包括 ESP-MESH 网络中的所有节点。</td>
</tr>
<tr>
<td>MAC 地址</td>
<td>在 ESP-MESH 网络中用于区别每个节点或路由器的唯一地址</td>
</tr>
<tr>
<td>DS</td>
<td>分布式系统（外部 IP 网络）</td>
</tr>
</tbody>
</table>

树型拓扑

ESP-MESH 建立在传统 Wi-Fi 协议之上，可被视为一种将多个独立 Wi-Fi 网络组合为一个单一 WLAN 网络的组网协议。在 Wi-Fi 网络中，station 在任何时候都仅限于与 AP 建立单个连接（上行连接），而 AP 则可以同时连接到多个 station（下行连接）。然而，ESP-MESH 网络则允许节点同时充当 station 和 AP。因此，ESP-MESH 中的节点可以使用其 SoftAP 接口建立多个下行连接，同时使用其 station 接口建立一个上行连接。这将自然产生一个由多层父子结构组成的树型网络拓扑结构。

图 58: ESP-MESH 树型拓扑

ESP-MESH 是一个多跳网络，也就是说网络中的节点可以通过单跳或多跳向网络中的其他节点传送数据包。因此，ESP-MESH 中的节点不仅传输自己的数据包，而且同时充当其他节点的中继。假设 ESP-MESH
网络中的任意两个节点存在物理层上连接（通过单跳或多跳），则这两个节点可以进行通信。

**注解：** ESP-MESH 网络中的大小（节点总数）取决于网络中允许的最大层级，以及每个节点可以具有的最大下行连接数。因此，这两个变量可用于配置 ESP-MESH 网络的大小。

### 节点类型

![ESP-MESH 节点类型图](image)

**根节点：** 指网络顶部的节点，是 ESP-MESH 网络和外部 IP 网络之间的唯一接口。根节点直接连接至传统的 Wi-Fi 路由器，并在 ESP-MESH 网络的节点和外部 IP 网络之间中继数据包。ESP-MESH 网络中只能有一个根节点，且根节点的上行连接只能是路由器。如上图所示，节点 A 即为该 ESP-MESH 网络的根节点。

**叶子节点：** 指不允许拥有任何子节点（即无下行连接）的节点。因此，叶子节点只能传输或接收自己的数据包，但不能转发其他节点的数据包。如果节点处于 ESP-MESH 网络的最大允许层级，则该节点将成为叶子节点。叶子节点不回再产生下行连接，这可以防止节点继续生成下行连接，从而确保网络层级不会超出限制。由于建立下行连接必须使用 SoftAP 接口，因此一些没有 SoftAP 接口的节点（仅有 station 接口）也将被分配为叶子节点。如上图所示，位于网络最外层的 L/M/N 节点即为叶子节点。

**中间父节点：** 既不是根节点也不属于叶子节点的节点即为中间父节点。中间父节点必须且仅有一个上行连接（即一个父节点），但可以具有 0 个或多个下行连接（即 0 个或多个子节点）。因此，中间父节点可以发送和接收自己的数据包，也可以转发其上行和下行连接的数据包。如上图所示，节点 B 到 J 即为中间父节点。注意，E/F/G/L/J 等没有下行连接的中间父节点并不等同于叶子节点，原因在于这些节点仍允许形成下行连接。

**空闲节点：** 尚未加入网络的节点即为空闲节点。空闲节点将尝试与中间父节点形成上行连接，或者在有条件的情况下（参见自动根节点选择）成为一个根节点。如上图所示，K 和 O 节点即为空闲节点。
信标帧和 RSSI 阈值

ESP-MESH 中能够形成下行连接的每个节点（即具有 SoftAP 接口）都会定期传输 Wi-Fi 信标帧。节点可以通过信标帧让其他节点检测自己的存在和状态。空闲节点将侦听信标帧以生成一个潜在父节点列表，并与其中一个潜在父节点形成上行连接。ESP-MESH 使用“供应商信息元素”来存储元数据，例如:

- 节点类型（根节点、中间节点、叶子节点、空闲节点）
- 节点当前所处的层级
- 网络中允许的最大层级
- 当前子节点数量
- 可接受的最大下行连接数量

潜在上行连接的信号强度可由潜在父节点信标帧的 RSSI 表示。为了防止节点形成弱上行连接，ESP-MESH 采用了针对信标帧的 RSSI 阈值控制机制。如果节点检测到某节点的信标帧 RSSI 过低（即低于预设阈值），则会在尝试形成上行连接时忽略该节点。

图像 60: RSSI 阈值的影响

上图（A 面）展示了 RSSI 阈值将如何影响空闲节点的候选父节点数量。

上图（B 面）展示了 RF 屏蔽物如何降低潜在父节点的 RSSI。由于存在 RF 屏蔽物，节点 X 的 RSSI 高于阈值的区域显著减小。这会导致空闲节点忽略节点 X，即使从地理位置上看 X 就在空闲节点附近。相反，该空闲节点将从更远的地方找到一个 RSSI 更强的节点 Y 形成上行连接。

注解：事实上，ESP-MESH 网络中的节点在 MAC 层仍可以接收所有的信标帧，但 RSSI 阈值控制功能可以过滤掉所有 RSSI 低于预设阈值的信标帧。

首选父节点

当一个空闲节点有多个候选父节点（潜在父节点）时，空闲节点将与其中的首选父节点形成上行连接。首选父节点基于以下条件确定:

- 候选父节点所处的层级
- 候选父节点当前具有的下行连接（子节点）数量

在网络中所处层级较低的候选父节点（包括根节点）将优先成为首选父节点。这有助于在形成上行连接时控制 ESP-MESH 网络中的总层级数使之最小。例如，在位于第二层和第三层的候选父节点中选择时，位于第二层的候选父节点将始终优先成为首选父节点。
如果同一层上存在多个候选父节点，则子节点最少的候选父节点将优先成为首选父节点。这有助于平衡同一层节点的下行连接数量。

图 61: 首选父节点选择

上图（A 侧）展示了空闲节点 G 如何在 B/C/D/E/F 五个候选父节点中选择首选父节点：首先，B/C 节点优于 D/E/F 节点，因为这两个节点所处的层级更浅。其次，C 节点优于 B 节点，因为 C 节点的下行连接数量（子节点数量）更少。

上图（B 侧）展示了空闲节点 G 如何在根节点 A 和其他候选父节点中选择首选父节点。此时根节点 A 处于空闲节点 G 范围之内（即空闲节点 G 接收到的根节点 A 信标帧 RSSI 强度高于预设阈值）: 由于根节点 A 处于网络中最浅的层，因此将成为首选父节点。

注解：用户还可以自行定义首选父节点的选择规则，也可以直接指定某个节点为首选父节点（见 Mesh 手动配网示例）。

路由表

ESP-MESH 网络中的每个节点都将维护自己的路由表，并按路由表记录数据包（请见 ESP-MESH 数据包）沿正确的路线发送至正确的目标节点。每个特定节点的路由表将包含该节点的子网中所有节点的 MAC 地址，也包括该节点自己的 MAC 地址。每个路由表会划分为多个子路由表，与每个子节点的子网对应。

以上图为例，节点 B 的路由表中将包含节点 B 到节点 I 的 MAC 地址（即相当于节点 B 的子网）。节点 B 的路由表可划分为节点 C 和 G 的子路由表，分别包含节点 C 到节点 F 的 MAC 地址、节点 G 到节点 I 的 MAC 地址。

ESP-MESH 利用路由表来使用以下规则进行转发，确定 ESP-MESH 数据包应根据向上行转发还是向下行转发。

1. 如果数据包的目标 MAC 地址处于当前节点的路由表中且不是当前节点本身，则选择包含目标 MAC 地址的子路由表，并将数据包向下转发给子路由表对应的子节点。

2. 如果数据包的目标 MAC 地址不在当前节点的路由表内，则将数据包上转发给当前节点的父节点，并重复执行该操作直至数据包达到目标地址。此步骤可重复至根节点（根节点包含整个网络的全部节点）。

注解：用户可以通过调用 esp_mesh_get_routing_table() 获取一个节点的路由表，调用 esp_mesh_get_routing_table_size() 获取一个路由表的大小，也可
通过调用 `esp_mesh_get_subnet_nodes_list()` 获取某个子节点的子路由表，调用 `esp_mesh_get_subnet_nodes_num()` 获取子路由表的大小。

### 4.27.4 建立网络

一般过程

警告：ESP-MESH 正式开始构建网络前，必须确保网络中所有节点具有相同的配置（见 `mesh_cfg_t`）。每个节点必须配置相同的 MESH 网络 ID，路由器配置和 SoftAP 配置。

ESP-MESH 网络将首先选择根节点，然后逐层形成下行连接，直到所有节点均加入网络。网络的布局可能取决于子根节点选择、父节点选择和步进上电复位等因素。但简单来说，一个 ESP-MESH 网络的构建过程可以概括为以下步骤：

1. **根节点选择** 根节点直接进行指定（见用户指定根节点）或通过选举信号强度最强的节点担任（见自动根节点选择）。一旦选定，根节点与路由器连接，并开始允许下行连接形成。如上图所示，节点 A 被选为根节点，因此节点 A 上行连接到路由器。

2. **第二层形成** 一旦根节点连接到路由器，根节点范围内的空闲节点将开始与根节点连接，从而形成第二层网络。一旦连接，第二层节点成为中间父节点（假设最大允许层级大于 2 层），并进而形成下一层。如上图所示，节点 B 到节点 D 都在根节点的连接范围内。因此，节点 B 到节点 D 将与根节点形成上行连接，并成为中间父节点。

3. **其余层形成** 剩余的空闲节点将与所处范围内的中间父节点连接，并形成新的层。一旦连接，根据网络的最大允许层级，空闲节点成为中间父节点或叶子节点。此后重复该步骤，直到网络中的所有空闲节点均加入网络或达到网络最大允许层级。如上图所示，节点 E/F/G 分别与节点 B/C/D 连接，并成为中间父节点。
为了防止网络超过最大允许层级，最大允许层级上的节点将在完成连接后成为叶子节点。这样一来，其他空闲节点将无法与这些最大允许层级上的叶子节点形成连接，因此不会超过最大允许层级。然而，如果空闲节点无法找到其他潜在父节点，则将无限期地保持空闲状态。如上图所示，网络的最大允许层级为四。因此，节点 H 在完成连接后将成为叶子节点，以防止任何下行连接的形成。

自动根节点选择

在自动模式下，根节点的选择取决于相对于路由器的信号强度。每个空闲节点将通过 Wi-Fi 信标帧发送自己的 MAC 地址和路由器 RSSI 值。MAC 地址可以表示网络中的唯一节点，而路由器 RSSI 值代表相对于路由器的信号强度。

此后，每个节点将同时扫描来自其他空闲节点的信标帧。如果节点检测到具有更弱的路由器 RSSI 的信标帧，则节点将开始传输该信标帧的内容（相当于为这个节点投票）。经过最小迭代次数（可预先设置，默认为 10 次）将选举出路由器 RSSI 值最强的信标帧。

在达到预设迭代次数后，每个节点将单独检查其得票百分比（得票数/总票数）以确定它是否应该成为根节点。如果节点的得票百分比大于预设的阈值（默认为 90%），则该节点将成为根节点。

下图展示了在 ESP-MESH 网络中，根节点的自动选择过程。

1. 上电复位时，每个节点开始传输自己的信标帧（包括 MAC 地址和路由器 RSSI 值）。

2. 在多次传输和扫描迭代中，路由器 RSSI 最强的信标帧将在整个网络中传播。节点 C 具有最强的路由器 RSSI 值（-10 dB），因此它的信标帧在整个网络中传播。所有参与选举的节点均给节点 C 投票，因此节点 C 的得票百分比为 100%。因此，节点 C 成为根节点，并与路由器连接。

3. 一旦节点 C 与路由器连接，节点 C 将成为节点 A/B/D/E 的首选父节点（即最浅的节点），并与这些节点连接。节点 A/B/D/E 将形成网络的第二层。

4. 节点 F 和节点 G 分别连接节点 D 和节点 E，并完成网络构建过程。

注释：用户可以通过 esp_mesh_set_attempts() 配置选举的最小迭代次数。用户应根据网络内的节点数量配置迭代次数（即 mesh 网络越大，所需的迭代次数越高）。
Chapter 4. API 指南

警告：得票百分比阈值也可以使用 `esp_mesh_set_vote_percentage()` 进行配置。得票百分比阈值过低可能导致同一 mesh 网络中两个或多个节点成为根节点，进而分化为多个 mesh 网络。如果发生这种情况，ESP-MESH 具有内部机制，可自主解决 根节点冲突。这些具有多个根节点的网络将围绕一个根节点形成一个网络。然而，两个或多个路由器 SSID 相同但路由器 BSSID 不同的根节点冲突尚无法解决。

用户指定根节点

根节点也可以由用户指定，即直接让指定的根节点与路由器连接，并放弃选举过程。当根节点指定后，网络内的所有其他节点也必须放弃选举过程，以防止根节点冲突的发生。下图展示了在 ESP-MESH 网络中，根节点的自动选择过程。

1. 节点 A 是由用户指定的根节点，因此直接与路由器连接。此时，所有其他节点放弃选举过程。
2. 节点 C 和节点 D 将节点 A 选为自己的首选父节点，并与之形成连接。这两个节点将形成网络的第二层。
3. 类似地，节点 B 和节点 E 将与节点 C 连接，节点 F 将与节点 D 连接。这三个节点将形成网络的第三层。
4. 节点 G 将与节点 E 连接，形成网络的第四层。然而，由于该网络的最大允许层级已配置为 4，因此节点 G 将成为叶子节点，以防止形成任何新层。

注解：一旦指定根节点，该根节点应调用 `esp_mesh_set_parent()` 使其直接与路由器连接。类似地，所有其他节点都应该调用 `esp_mesh_fix_root()` 放弃选举过程。

选择父节点

默认情况下，ESP-MESH 具有可以自组网的特点，也就是每个节点都可以自主选择与其形成上行连接的潜在父节点。自主选择出的父节点被成为首选父节点。用于选择首选父节点的标准旨在减少 ESP-MESH 网络的层级，并平衡各个潜在父节点的下行连接数。（参见首选父节点）
不过，ESP-MESH 也允许用户禁用自组网功能，即允许用户自己定义父节点选择标准，或直接指定某个节点为父节点（见：Mesh 手动组网示例）。

**异步上电复位**

ESP-MESH 网络构建可能会受到节点上电顺序的影响。如果网络中的某些节点为异步上电（即相隔几分钟上电），网络的最终结构可能与所有节点同步上电时的理想情况不同。延迟上电的节点将遵循以下规则：

**规则 1**：如果网络中已存在根节点，则延迟节点不会尝试选举成为新的根节点，即使自身的路由器 RSSI 更强。相反，延迟节点与任何其他空闲节点无异，将通过与首选父节点连接来加入网络。如果该延迟节点为用户指定的根节点，则网络中的所有其他节点将保持空闲状态，直到延迟节点完成上电。

**规则 2**：如果延迟节点形成上行连接，并成为中间父节点，则后续也可能成为其他节点（即其他更浅的节点）的新首选父节点。此时，其他节点切换上行连接至该延迟节点（见父节点切换）。

**规则 3**：如果空闲节点的指定父节点上电延迟了，则该空闲节点在没有找到指定父节点前不会尝试形成任何上行连接。空闲节点将无限期地保持空闲，直到其指定的父节点上电完成。

下方示例展示了异步上电对网络构建的影响。

1. 节点 A/C/D/F/G/H 同步上电，并通过广播其 MAC 地址和路由器 RSSI 开始选举根节点。节点 A 的 RSSI 最强，因此当选为根节点。

2. 一旦节点 A 成为根节点，其余的节点就开始与其首选父节点逐层形成上行连接，并最终形成一个具有五层的网络。

3. 节点 B/E 由于存在上电延迟，因此即使路由器 RSSI 比节点 A 更强（-20 dB 和 -10 dB）也不会尝试成为根节点。相反，这两个上电延迟节点均将与对应的第一级父节点 D 和 C 形成上行连接。加入网络后，节点 B/E 均将成为中继父节点。

4. 节点 B 由于所处层级变化（现为第二层）而成为新的首选父节点，因此节点 D/G 将切换其上行连接从而选择新的首选父节点。由于切换的次数，最终的网络层级从原来的五层减少至三层。

**同步上电**：如果所有节点均同步上电，节点 E (-10 dB) 由于路由器 RSSI 最强而成为根节点。此时形成的网络结构将与异步上电的情况截然不同。但是，如果用户手动切换根节点，则仍可以达到同步上电的网络结构（请见esp_mesh_waive_root())。
图 66: 网络构建（异步电源）示例
Chapter 4. API 指南

注解：从某种程度上，ESP-MESH 可以自动修复部分因异步上电引起的父节点选择的偏差（请见父节点切换）

环路避免、检测和处理

环路是指特定节点与其后代节点（特定节点子网中的节点）形成上行连接的情况。因此产生的循环连接路径将打破 mesh 网络的树型拓扑结构。ESP-MESH 的节点在选择父节点时将主动排除路由表（见路由表）中的节点，从而避免与其子网中的节点建立上行连接并形成环路。

在存在环路的情况下，ESP-MESH 可利用路径验证机制和能量传递机制来检测环路的产生。因与子节点建立上行连接而导致环形形成的父节点将通知子节点环路的存在，并主动断开连接。

4.27.5 管理网络

作为一个自修复网络，ESP-MESH 可以检测并修正网络路由中的故障。当具有一个或多个子节点的父节点断开或父节点与其子节点之间的连接不稳定时，会发生故障。ESP-MESH 中的子节点将自动选择一个新的父节点，并与其形成上行连接，以维持网络互联。ESP-MESH 可以处理根节点故障和中间父节点故障。

根节点故障

如果根节点断开，则与其连接的节点（第二层节点）将及时检测到该根节点故障。第二层节点将主动尝试与根节点重建，但是在多次尝试失败后，第二层节点将启动新轮的根节点选举。第二层中 RSSI 最强的节点当选为新的根节点，而剩余的第二层节点将与新的根节点（如果不在范围内的话，也可与相邻父节点连接）形成上行连接。

如果根节点和下面多层的节点（例如根节点、第二层节点和第三层节点）同时断开，则位处于最底层的仍在正常工作的节点将发起根节点选举。下方示例展示了网络从根节点断开故障中进行自修复。

图 67: 根节点故障的自修复示意

1. 节点 C 是网络的根节点。节点 A/B/D/E 是连接到节点 C 的第二层节点。
2. 节点 C 断开。在多次重连尝试失败后，第二层节点开始通过广播其路由器 RSSI 开始新一轮的选举。此时，节点 B 的路由器 RSSI 最强。
3. 节点 B 被选为根节点，并开始接受下行连接。剩余的第二层节点 A/D/E 形成与节点 B 的上行连接，因此网络已经恢复，并且可以继续正常运行。
注解：如果是手动指定的根节点断开，则无法进行自动修复。任何节点不会在存在指定根节点的情况下开始选举过程。

中间父节点故障

如果中间父节点断开，则与之断开的子节点将主动尝试与该父节点重新连接。在多次重连尝试失败后，每个子节点开始扫描潜在父节点（请见节点和 RSSI 通知）。

如果存在其他可用的潜在父节点，每个子节点将分别给自己选择一个新的首选父节点（请见反选父节点），并与它形成上行连接。如果特定子节点没有其他潜在的父节点，则将无限期地保持空闲状态。

下方示例展示了网络从中间父节点断开故障中进行自修复。

1. 网络中存在节点 A 至 G。
2. 节点 C 断开。节点 F/G 检测到节点 C 的断开故障，并尝试与节点 C 重新连接。在多次重连尝试失败后，节点 F/G 将开始选择新的首选父节点。
3. 节点 G 因其范围内不存在任何父节点而暂时保持空闲。节点 F 的范围内有 B 和 E 两个节点，但节点 B 因为所处层级更低而当选新的父节点。节点 F 将与节点 B 连接后，并成为一个中间父节点，节点 G 将于节点 F 相连。这样一来，网络已经恢复了，但结构发生了变化（网络层级增加了 1 层）。

注解：如果子节点的父节点已被指定，则子节点不会尝试与其他潜在父节点连接。此时，该子节点将无限期地保持空闲状态。

根节点切换

除非根节点断开，否则 ESP-MESH 不会自动切换根节点。即使根节点的路由器 RSSI 降低至必须断开的情况，根节点也将保持不变。根节点切换是指明确启动新选举过程的行为，即具有更强路由器 RSSI 的节点选为新的根节点。这可以用于应对根节点性能降低的情况。

要触发根节点切换，当前根节点必须明确调用 esp_mesh_waive_root() 以触发新的选举。当下根节点将指示网络中的所有节点开始发送并扫描信标帧（见自动根节点选择），但与此同时一直保持联网（即不会变为空闲节点）。如果另一个节点收到的票数超过当前根节点，则将启动根节点切换过程，否则根节点将保持不变。

新选出的根节点向当前的根节点发送 切换请求，而原先的根节点将返回一个应答通知，表示已经准备好切换。一旦接收到应答，新选出的根节点将与其父节点断开连接，并迅速与路由器形成上行连接，进而
成为网络的新根节点。原先的根节点将断开与路由器的连接，并与原同时保持其所有下行连接并进入空闲状态。之后的根节点将开始扫描潜在的父节点并选择首选父节点。

下图说明了根节点切换的示例。

切换根节点示例

1. 节点 C 是当前的根节点，但路由器 RSSI 值 (-85 dB) 降低至较低水平。此时，新的选举过程被触发了。所有节点开始传输和扫描信标帧（此时仍保持连接）。

2. 经过多轮传输和扫描后，节点 B 被选为新的根节点。节点 B 向节点 C 发送了一个切换请求，节点 C 回复一个应答。

3. 节点 B 与其父节点断开连接，并与路由器连接，成为网络中的新根节点。节点 C 与路由器断开连接，进入空闲状态，并开始扫描并选择新的首选父节点。节点 C 在整个过程中仍保持其所有的下行连接。

4. 节点 C 选择节点 B 作为其的首选父节点，与之形成上行连接，并成为一个第二层节点。由于节点 C 仍保持相同的子网，因此根节点切换后的网络结构没有变化。然后，由于切换的发生，节点 C 子网中每个节点的所处层次均增加了一层。如果根节点切换过程中产生了新的根节点，则父节点切换 可以随后调整网络结构。

注解：根节点切换必须要求选举，因此只有在使用自组网 ESP-MESH 网络时才支持。换句话说，如果使用指定的根节点，则不能进行根节点切换。

父节点切换

父节点切换是指一个子节点将其上行连接切换到更浅一层的另一个父节点。父节点切换是自动的，这意味着如果较浅层出现了可用的潜在父节点（因“异步上电复位”产生），子节点将自动更改其上行连接。

所有潜在的父节点将定期发送信标帧（参见信标帧和 RSSI 阈值），从而允许子节点扫描较浅层的父节点的可用性。由于父节点切换，自组网 ESP-MESH 网络可以动态调整其网络结构，以确保每个连接均具有良好的 RSSI 值，并且网络中的层次最小。

4.27.6 数据传输
ESP-MESH 数据包

ESP-MESH 网络使用 ESP-MESH 数据包传输数据。ESP-MESH 数据包完全包含在 Wi-Fi 数据帧中。ESP-MESH 网络中的多数据传输将通过不同 Wi-Fi 数据帧在每个无线跳上传输的单个 ESP-MESH 数据包。

下图显示了 ESP-MESH 数据包的结构及其与 Wi-Fi 数据帧的关系。

ESP-MESH 数据包的报头包含源节点和目标节点的 MAC 地址。选项 (option) 字段包含有关特殊类型 ESP-MESH 数据包的信息，例如组传输或来自外部 IP 网络的数据包（请参阅 MESH_OPT_SEND_GROUP 和 MESH_OPT_RECV_DS_ADDR）。

ESP-MESH 数据包的有效载荷包含实际的应用数据。该数据可以为原始二进制数据，也可以是使用 HTTP、MQTT 和 JSON 等应用层协议的编码数据（请见 mesh_proto_t）。

注解：当向外部 IP 网络发送 ESP-MESH 数据包时，报头的目标地址字段将包含目标服务器的 IP 地址和端口号，而不是节点的 MAC 地址（请见 mesh_addr_t）。此外，根节点将处理外发 TCP/IP 数据包的形成。

组控制和组播

组播功能允许将单个 ESP-MESH 数据包同时发送给网络中的多个节点。ESP-MESH 中的组播可以通过“指定一个目标节点列表”或“预配置一个节点组”来实现。这两种组播方式均需调用 esp_mesh_send() 实现。

如果通过“指定目标节点列表”实现组播，用户必须首先将 ESP-MESH 数据包的目标地址设置为组播组地址（例如 01:00:5e:xx:xx:xx）。这表明 ESP-MESH 数据包是一个拥有一个地址的组播数据包，且该地址应该从报头选项中获得。然后，用户必须将目标节点的 MAC 地址列为选项（请见 mesh_opt_t 和 MESH_OPT_SEND_GROUP）。这种组播方法不需要进行提前设置，但由于每个目标节点的 MAC 地址均需列为报头的选项字段，因此会产生大量开销数据。

分组组播允许 ESP-MESH 数据包被发送到一个预先配置的节点组。每个分组都有一个具有唯一性的 ID 标识。用户可通过 esp_mesh_set_group_id() 将节点加入一个组。分组组播需要将 ESP-MESH 数据包的目标地址设置为目标组的 ID，还必须设置 MESH_DATA_GROUP 标志位。分组组播产生的开销更小，但必须提前将节点加入分组中。

注解：在组播期间，网络中的所有节点在 MAC 层都会收到 ESP-MESH 数据包。然而，不包括在 MAC 地址列表或目标组中的节点将简单地过滤掉这些数据包。

广播

广播功能允许将单个 ESP-MESH 数据包同时发送给网络中的所有节点。每个节点可以将一个广播包转发至其所有上行和下行连接，使得数据包尽可能快地在整个网络中传播。但是，ESP-MESH 利用以下方法...
Chapter 4. API

来避免在广播期间浪费带宽。
1. 当中间父节点收到来自其父节点的广播包时，它会将该数据包转发给自己的各个子节点，同时为自己保存一份数据包的副本。
2. 当中间父节点是广播的源节点时，它会将该数据包向上发送至其父节点，并向下发送给自己的各个子节点。
3. 当中间父节点接收到一个来自其子节点的广播包时，它会将该数据包转发给其父节点和其余子节点，同时为自己保存一份数据包的副本。
4. 当叶子节点是广播的源节点时，它会直接将该数据包发送至其父节点。
5. 当根节点是广播的源节点时，它会将该数据包发送至自己的所有子节点。
6. 当根节点接收到来自其子节点的广播包时，它会将该数据包转发给其余子节点，同时为自己保存一份数据包的副本。
7. 当节点接收到一个源地址与自身 MAC 地址匹配的广播包时，它会将该广播包丢弃。
8. 当中间父节点接收到一个来自其父节点的广播包时（该数据包最初来自该父节点的一个子节点），它会将该广播包丢弃。

**上行流量控制**

ESP-MESH 依赖父节点来控制其直接子节点的上行数据流。为了防止父节点的消息缓冲区上行传输过载而溢出，父节点将为每个子节点分配一个称为接收窗口的上行传输配额。每个子节点均必须申请接收窗口才允许进行上行传输。接收窗口的大小可以动态调整。完成从子节点到父节点的上行传输包括以下步骤：
1. 在每次传输之前，子节点向其父节点发送窗口请求。窗口请求中包括一个序号，与子节点的待传输数据包相对应。
2. 父节点接收窗口请求，并将序号与子节点发送的前一个数据包的序号进行比较，用于计算返回给子节点的接收窗口大小。
3. 子节点根据父节点指定的窗口大小发送数据包。如果子节点的接收窗口耗尽，它必须通过发送请求获得另一个接收窗口，然后才允许继续发送。

**注解：**ESP-MESH 不支持任何下行流量控制。

**警告：**由于父节点切换，数据包可能会在上行传输期间丢失。

由于根节点是通向外部 IP 网络的唯一接口，因此下行节点必须了解根节点与外部 IP 网络的连接状态。否则，节点可能会尝试向一个已经与 IP 网络断开连接的根节点发送数据，从而造成不必要的传输和数据包丢失。ESP-MESH 可以基于检测根节点和外部 IP 网络的连接状态，提供一种稳定外发数据吞吐量的机制。根节点可以通过调用 esp_mesh_post_toDS_state() 将自身与外部 IP 网络的连接状态广播给所有其他节点。

**双向数据流**

下图展示了 ESP-MESH 双向数据流涉及的各种网络层。

由于使用路由表，ESP-MESH 能够在 mesh 层中完全处理数据包的转发。TCP/IP 层仅与 mesh 网络的根节点有关，可帮助根节点与外部 IP 网络的数据包传送。
4.27.7 信道切换

背景

在传统的 Wi-Fi 网络中，信道代表预设的频率范围。在基础设置基本服务集 (BSS) 中，工作 AP 及与之相连的 station 必须处于传输信号的工作信道（1 到 14）中。物理上相邻的 BSS 使用相同的工作信道会导致干扰产生和性能下降。

为了允许 BSS 适应不断变化的物理层条件并保持性能，Wi-Fi 网络中增加了网络信道切换的机制。网络信道切换是将 BSS 移至新的工作信道，并同时最大限度地减少期间对 BSS 的影响。然而，我们应该认识到，网络信道切换可能不会成功，无法将原信道中的所有 station 均移动至新的信道。

在基础设置 Wi-Fi 网络中，网络信道切换由 AP 触发，目的是将该 AP 及与之相连的所有 station 同步切换到新的信道。网络信道切换是通过在 AP 的周期性发送信标帧中嵌入一个信道切换公告 (CSA) 元素来实现的。在网络信道切换前，该 CSA 元素用于向所有连接的 station 广播有关即将发生的网络信道切换，并且将包含在多个信标帧中。

一个 CSA 元素包含有关 新信道号 和 信道切换计数 的信息。其中，信道切换计数指示在网络信道切换之前的剩余的信标帧间隔 (TBTT) 数量。因此，信道切换计数依每个信标帧递减，并且允许与之连接的 station 与 AP 同步进行信道切换。

ESP-MESH 网络信道切换

ESP-MESH 网络信道切换还利用包含 CSA 元素的信标帧。然而，ESP-MESH 作为一个多跳网络，其信标帧可能无法到达网络中的所有节点（这点与单跳网络不同），因此信道切换过程更加复杂。因此，ESP-MESH 网络依赖于通过节点转发 CSA 元素，从而实现整个网络中的传播。

当具有一个或多个子节点的中间父节点接收到包含 CSA 元素的信标帧时，该节点会将该元素包含在其下一个发送的信标帧（即具有相同的 新信道号 和 信道切换计数）中，从而实现该 CSA 元素的转发。鉴于 ESP-MESH 网络中的所有节点都接收到相同的 CSA 元素，这些节点可以使用 信道切换计数 来同步其信道切换，但也会经历因 CSA 元素转发造成的延迟。

ESP-MESH 网络信道切换可以由路由器或根节点触发。

根节点触发 由根节点触发的信道切换只能在 ESP-MESH 网络未连接到路由器时才会发生。通过调用 esp_mesh_switch_channel()，根节点将设置一个初始 信道切换计数值，并开始在其信标帧中包含 CSA 元素。接着，每个 CSA 元素将抵达第二层节点，并通过第二层节点自己的信标帧继续进行向下转发。
Chapter 4. API 指南

路由器触发  当 ESP-MESH 网络连接到路由器时，整个网络必须与路由器采用同一个信道。因此，根节点在连接到路由器时无法触发信道切换。

当根节点从路由器接收包含 CSA 元素的信标帧时，根节点将 CSA 元素中的信道切换计数值设置为自定义值，然后再次通过信标帧继续向下转发。此后，该信道切换计数将逐渐变化，自定义值将随之递减。该自定义值可以基于诸如网络层级、当前节点数等因素。

ESP-MESH 网络及其路由器可能具有不同且变化的信标间隔，因此需要将信道切换计数值设置为自定义值。也就是说，路由器提供的信道切换计数值与 ESP-MESH 网络无关。通过使用自定义值，ESP-MESH 网络中的节点能够同时适用于 ESP-MESH 网络的信标间隔同步切换信道。正因如此，ESP-MESH 网络也会出现信道与路由器及其连接 station 的信道切换不同步的情况。

网络信道切换的影响

- 由于 ESP-MESH 网络信道切换与路由器的信道切换不同步，ESP-MESH 网络和路由器之间会出现临时信道差异。
  - ESP-MESH 网络的信道切换时间取决于 ESP-MESH 网络的信标间隔和根节点的自定义信道切换计数。
  - 在 ESP-MESH 网络切换期间，信道差异将阻止根节点和路由器之间的任何数据交换。
  - 在 ESP-MESH 网络中，根节点和中间节点将允许与其连接的子节点停止传输，直至信道切换发生（通过将 CSA 元素的信道切换模式字段值设为 1）。频宽的路由器触发网络信道切换可能会降低 ESP-MESH 网络的性能。请注意，这可能是由 ESP-MESH 网络本身造成的（例如由于 ESP-MESH 网络的无线介质争用等原因）。此时，用户应该禁用路由器触发的自主信道切换，并直接指定一个信道。
  - 当存在临时信道差异时，根节点从技术上来说仍保持连接至路由器。
    - 如果根节点经过一定信标间隔后无法接收到信标帧或探测来自路由器的响应，则会断开连接。
    - 断开连接后，根节点将自动重新扫描所有信道以确认是否存在路由器。
  - 如果根节点无法接收到任何路由器的 CSA 信标帧（例如短暂的路由器切换时间），则路由器将在没有 ESP-MESH 网络的情况下。
    - 在路由器切换信道后，根节点将不再能够接收路由器的信标帧和探测响应，并导致在一定数量的信标间隔后断开连接。
    - 在断开连接后，根节点将重新扫描信道，寻找路由器。
    - 根节点将在整个过程中维护与之相连的下行连接。

注解：虽然 ESP-MESH 网络信道切换的目的是将网络内的所有节点移动到新的工作信道，但也应该认识到，信道切换可能无法成功移动所有节点（比如由于节点故障等原因）。

信道和路由器切换配置

ESP-MESH 允许通过配置启用或禁用自主信道切换。同样，也可以通过配置启用或禁用自主路由器切换（即当前节点自主切换到另一个路由器时）。自主信道切换和自主路由器切换取决于以下配置参数和运行条件。

允许信道切换：本参数决定是否允许 ESP-MESH 网络进行自主信道切换，具体可通过 mesh_cfg_t 结构体中的 allow_channel_switch 字段进行配置。

预设信道：ESP-MESH 网络可以将 mesh_cfg_t 结构体中的 channel 字段设置为相应的信道号，而具体一个预设信道。如果未设置此字段，则 allow_channel_switch 的设置将被覆盖，即始终允许信道切换。

允许路由器切换：本参数决定是否允许 ESP-MESH 网络进行自主路由器切换，具体可通过 mesh_router_t 结构体中的 allow_router_switch 字段进行配置。

预设路由器 BSSID：ESP-MESH 网络可以将 mesh_router_t 结构体的 bssid 字段设置为目标路由器的 BSSID。预设一个路由器。如果未设置此字段，则 allow_router_switch 的设置将被覆盖，即始终允许路由器切换。

存在根节点：根节点的存在也会影响是否允许信道或路由器切换。
下表说明了在不同参数/条件组合下是否允许信道切换和路由器切换。请注意，X 代表参数“不关心”。

<table>
<thead>
<tr>
<th>预设信道</th>
<th>允许信道切换</th>
<th>预设路由器</th>
<th>允许路由器切换</th>
<th>存在根节点</th>
<th>允许切换？</th>
</tr>
</thead>
<tbody>
<tr>
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<td>X</td>
<td>N</td>
<td>X</td>
<td>X</td>
<td>信道与路由器</td>
</tr>
<tr>
<td>N</td>
<td>X</td>
<td>Y</td>
<td>N</td>
<td>X</td>
<td>仅信道</td>
</tr>
<tr>
<td>N</td>
<td>X</td>
<td>Y</td>
<td>Y</td>
<td>X</td>
<td>信道与路由器</td>
</tr>
<tr>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>X</td>
<td>X</td>
<td>信道与路由器</td>
</tr>
<tr>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>X</td>
<td>N</td>
<td>仅路由器</td>
</tr>
<tr>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>X</td>
<td>仅信道</td>
</tr>
<tr>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>仅路由器</td>
</tr>
<tr>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>信道与路由器</td>
</tr>
<tr>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>信道与路由器</td>
</tr>
</tbody>
</table>

### 4.27.8 性能

ESP-MESH 网络的性能可以基于以下多个指标进行评估：

**组网时长**：从头开始构建 ESP-MESH 网络所需的总时长。

**修复时间**：从网络检测到节点断开执行适当操作（例如生成新的根节点或形成新的连接等）以修复网络所需的时间。

**每跳延迟**：数据每经过一次无线 hop 而经历的延迟。即从父节点向子节点（或从子节点向父节点）发送一个数据包所需的时间。

**网络节点容量**：ESP-MESH 网络可以同时支持的节点总数。该指标取决于节点可以接受到的最大下行连接数和网络中允许的最大层级。

ESP-MESH 网络的常见性能指标如下表所示：

- 组网时长：< 60 秒
- 修复时间
  - 根节点断开：< 10 秒
  - 子节点断开：< 5 秒
- 每条延迟：10 到 30 毫秒

**注解**：上述性能指标的测试条件见下。

- 测试设备数量：100
- 最大允许下行连接数量：6
- 最大允许层级：6

**注解**：吞吐量取决于数据包错误率和 hop 数量。

**注解**：根节点访问外部 IP 网络的吞吐量直接受到 ESP-MESH 网络中节点数量和路由器带宽的影响。

**注解**：用户应注意，ESP-MESH 网络的性能与网络配置和工作环境密切相关。
4.27.9 更多注意事项

- 数据传输使用 Wi-Fi WPA2-PSK 加密
- Mesh 网络 IE 使用 AES 加密

本文图片中使用的路由器与互联网图标来自 www.flaticon.com 的 Smashicons。

4.28 BluFi

4.28.1 概览

BluFi 是一款基于蓝牙通道的 Wi-Fi 网络配置功能，适用于 ESP32。它通过安全协议将 Wi-Fi 配置和证书传输到 ESP32，然后 ESP32 可基于这些信息连接到 AP 或建立 SoftAP。

BluFi 流程的关键部分包括数据的分片、加密、校验和验证。

用户可按需自定义用于对称加密、非对称加密和校验的算法。这里我们采用 DH 算法进行密钥协商、128-AES 算法用于数据加密、CRC16 算法用于校验和验证。

4.28.2 BluFi 流程

BluFi 配网功能包含配置 SoftAP 和 Station 两部分。

下面以配置 Station 为例说明配置步骤。BluFi 配网的配置 Station 包含广播、连接、服务发现、协商共享密钥、传输数据、回传连接状态等步骤。

4.28.3 ESP32 配网流程

1. ESP32 开启 GATT Server 功能，发送带有特定 adv data 的广播。你可以自定义该广播，该广播不属于 BluFi Profile。
2. 使用手机 APP 搜索到该特定广播，手机作为 GATT Client 连接 ESP32。你可以决定使用哪款手机 APP。
3. GATT 连接建立成功后，手机向 ESP32 发送“协商过程”数据帧（详情见 BluFi 传输格式）。
4. ESP32 收到“协商过程”数据帧后，会按照使用者自定义的协商过程来解析。
5. 手机与 ESP32 进行密钥协商。协商过程可使用 DH/RSA/ECC 等加密算法进行。
6. 协商结束后，手机端向 ESP32 发送“设置安全模式”控制帧。
7. ESP32 收到“设置安全模式”控制帧后，使用经过协商的共享密钥以及配置的安全策略对通信数据进行加密和解密。
8. 手机向 ESP32 发送“BluFi 传输格式”定义的 SSID、Password 等用于 Wi-Fi 连接的必要信息。
9. 手机向 ESP32 发送“Wi-Fi 连接请求”控制帧，ESP32 收到之后，识别为手机已将必要的信息传输完毕，准备连接 Wi-Fi。
10. ESP32 连接到 Wi-Fi 后，发送“Wi-Fi 连接状态报告”控制帧到手机，以报告连接状态。至此配网结束。

注解:

1. 安全模式设置可在任何时候进行，ESP32 收到安全模式的配置后，会根据安全模式指定的模式进行安全相关的操作。
2. 进行对称加密和解密时，加密和解密前后的数据长度必须一致，支持原地加密和解密。

4.28.4 配网流程图

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图 71: BluFi Flow Chart
4.28.5 BluFi 传输格式

手机 APP 与 ESP32 之间的 BluFi 通信格式定义如下：

帧不分片情况下的标准格式 (8 bit):

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSB - Type</td>
<td>1</td>
</tr>
<tr>
<td>Frame Control</td>
<td>1</td>
</tr>
<tr>
<td>Sequence Number</td>
<td>1</td>
</tr>
<tr>
<td>Data Length</td>
<td>1</td>
</tr>
<tr>
<td>Data</td>
<td>${\text{Data Length}}$</td>
</tr>
<tr>
<td>MSB - CheckSum</td>
<td>2</td>
</tr>
</tbody>
</table>

如果 Frame Control 帧中的 More Frag 使能，则 Total Content Length 为数据帧中剩余部分的总长度，用于报告终端需要分配多少内存。

帧分片格式 (8 bit):

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSB - Type</td>
<td>1</td>
</tr>
<tr>
<td>Frame Control(Frag)</td>
<td>1</td>
</tr>
<tr>
<td>SequenceNumber</td>
<td>1</td>
</tr>
<tr>
<td>DataLength</td>
<td>1</td>
</tr>
<tr>
<td>Data</td>
<td>Total Content Length 2</td>
</tr>
<tr>
<td></td>
<td>Content ${\text{Data Length}} - 2$</td>
</tr>
<tr>
<td>MSB - CheckSum</td>
<td>2</td>
</tr>
</tbody>
</table>

通常情况下，控制帧不包含数据位，Ack 帧类型除外。

Ack 帧格式 (8 bit):

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSB - Type (Ack)</td>
<td>1</td>
</tr>
<tr>
<td>Frame Control</td>
<td>1</td>
</tr>
<tr>
<td>SequenceNumber</td>
<td>1</td>
</tr>
<tr>
<td>DataLength</td>
<td>1</td>
</tr>
<tr>
<td>Data</td>
<td>Acked Sequence Number 2</td>
</tr>
<tr>
<td>MSB - CheckSum</td>
<td>2</td>
</tr>
</tbody>
</table>

1. Type

类型域，占 1 byte。分为 Type 和 Subtype（子类型域）两部分, Type 占低 2 bit，Subtype 占高 6 bit。

- 控制帧：暂不进行加密，可校验；
- 数据帧，可加密，可校验。

1.1 控制帧 (0x0 b’00)
<table>
<thead>
<tr>
<th>控制帧 (二进制)</th>
<th>含义</th>
<th>解释</th>
<th>备注</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00 (b'0000)</td>
<td>Ack</td>
<td>用来回复对方发的帧，Ack 帧的 Data 域使用回复对象帧的 Sequence 值。</td>
<td>Data 域使用 1 byte Sequence 值，与回复对象帧的 Sequence 值相同。</td>
</tr>
<tr>
<td>0x10 (b'0001)</td>
<td>Set ESP32 to the security mode.</td>
<td>通知 ESP32 发送数据时使用的安全模式，在该过程中可设置多次，每次设置后影响后续安全模式。在不设置的情况下，ESP32 默认控制帧和数据帧均为无校验、无加密。手机到 ESP32 方向依赖于帧 Control 域。</td>
<td>Data 域占用 1 byte，高 4 bit 为控制帧的安全模式，低 4bit 为数据帧的安全模式。</td>
</tr>
<tr>
<td>0x20 (b'0010)</td>
<td>Set the Wi-Fi mode of ESP32.</td>
<td>设置 ESP32 的 Wi-Fi 模式，帧包含 opmode 信息。</td>
<td>data[0] 用于表示 opmode 类型，包括：</td>
</tr>
<tr>
<td>0x30 (b'0011)</td>
<td>Connect ESP32 to the AP.</td>
<td>通知 ESP32，必要的信息已经发送完毕，可以连接 AP。</td>
<td>不包含 Data 域。</td>
</tr>
<tr>
<td>0x40 (b'0100)</td>
<td>Disconnect ESP32 from the AP.</td>
<td>通知 ESP32 断开与 AP 的连接</td>
<td>不包含 Data 域。</td>
</tr>
<tr>
<td>0x50 (b'0101)</td>
<td>Get the status of Wi-Fi.</td>
<td>获取 ESP32 的 Wi-Fi 模式和状态等信息。</td>
<td>不包含 Data 域。ESP32 收到此控制帧后，后续会通过 Wi-Fi 连接状态报告 (Wi-Fi Connection State Report) 数据帧来回复手机端当前所处的 opmode、连接状态、SSID 等信息，提供给手机端的信息由应用决定。</td>
</tr>
<tr>
<td>0x60 (b'0110)</td>
<td>Disconnect the STA device from the SoftAP in SoftAP mode.</td>
<td>处于 SoftAP 模式时，踢掉某个 STA 设备。</td>
<td>data[0~5] 为 STA 设备的 MAC 地址，如有多个 STA，则 [6-11] 为第二个，依次类推。</td>
</tr>
<tr>
<td>0x70 (b'0111)</td>
<td>Get the version.</td>
<td>通知 ESP32 获取版本。</td>
<td></td>
</tr>
<tr>
<td>0x80 (b'1000)</td>
<td>Tell ESP32 to disconnect the BLE GATT link.</td>
<td>通知 ESP32 断开蓝牙连接。</td>
<td>ESP32 收到该指令后主动断开蓝牙连接。</td>
</tr>
</tbody>
</table>

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### 1.2 数据帧 (0x1 b’ 01)

<table>
<thead>
<tr>
<th>数据帧 (二进制)</th>
<th>含义</th>
<th>解释</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0 (b’ 000000)</td>
<td>Negotiation data.</td>
<td>用来发送协商数据，传输到应用层注册的回调函数。</td>
</tr>
<tr>
<td>0x1 (b’ 000001)</td>
<td>BSSID for STA mode.</td>
<td>STA 将要连接的 AP 的 BSSID（用于隐藏 SSID）。</td>
</tr>
<tr>
<td>0x2 (b’ 000010)</td>
<td>SSID for STA mode.</td>
<td>STA 将要连接的 AP 的 SSID。</td>
</tr>
<tr>
<td>0x3 (b’ 000011)</td>
<td>Password for STA mode.</td>
<td>STA 将要连接的 AP 的密码。</td>
</tr>
<tr>
<td>0x4 (b’ 000100)</td>
<td>SSID for SoftAP mode.</td>
<td>SoftAP 模式使用的 SSID。</td>
</tr>
<tr>
<td>0x5 (b’ 000101)</td>
<td>Password for SoftAP mode.</td>
<td>SoftAP 模式使用的密码。</td>
</tr>
<tr>
<td>0x6 (b’ 000110)</td>
<td>Max connection number for SoftAP mode.</td>
<td>AP 模式的最大连接数。</td>
</tr>
<tr>
<td>0x7 (b’ 000111)</td>
<td>Authentication mode for SoftAP mode.</td>
<td>AP 模式的认证模式。</td>
</tr>
<tr>
<td>0x8 (b’ 001000)</td>
<td>Channel for SoftAP mode.</td>
<td>SoftAP 模式的通道数量。</td>
</tr>
<tr>
<td>0x9 (b’ 001001)</td>
<td>Username.</td>
<td>使用企业级加密时，Client 端的用户名。</td>
</tr>
<tr>
<td>0xa (b’ 001010)</td>
<td>CA certification.</td>
<td>进行企业级加密时使用的 CA 证书。</td>
</tr>
<tr>
<td>0xb (b’ 001011)</td>
<td>Client certification.</td>
<td>进行企业级加密时，Client 端的证书。可包含或不包含私钥，由证书内容决定。</td>
</tr>
<tr>
<td>0xc (b’ 001100)</td>
<td>Server certification.</td>
<td>进行企业级加密时，Server 端的证书。可包含或不包含私钥，由证书内容决定。</td>
</tr>
<tr>
<td>0xd (b’ 001101)</td>
<td>Client private key.</td>
<td>进行企业级加密时，Client 端的私钥。</td>
</tr>
<tr>
<td>0xe (b’ 001110)</td>
<td>Server private key.</td>
<td>进行企业级加密时，Server 端的私钥。</td>
</tr>
<tr>
<td>0xf (b’ 001111)</td>
<td>Wi-Fi connection state report.</td>
<td>通知手机 ESP32 的 Wi-Fi 状态，包括 STA 状态和 SoftAP 状态。用于手机配置界面。但收到手机询问 Wi-Fi 状态时，除了回复此帧外，还可回复其他数据帧。</td>
</tr>
<tr>
<td>0x10 b’ 010000</td>
<td>Version.</td>
<td></td>
</tr>
<tr>
<td>0x11 (b’ 010001)</td>
<td>Wi-Fi list.</td>
<td>通知手机 ESP32 周围的 Wi-Fi 热点列表。</td>
</tr>
<tr>
<td>0x12 (b’ 010010)</td>
<td>Report error.</td>
<td>通知手机 BluFi 过程出现异常错误。</td>
</tr>
</tbody>
</table>
数据帧 (二进制) | 含义 | 解释
---|---|---
0x13 (010011) | Custom data. | 用户发送或者接收自定义数据。

2. Frame Control
帧控制域，占 1 byte，每个 bit 表示不同含义。

<table>
<thead>
<tr>
<th>位</th>
<th>含义</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x01</td>
<td>表示帧是否加密。 1 表示加密，0 表示未加密。加密部分帧括完整的 DATA 域加密之前的明文（不帧含末尾的校验）。控制帧暂不加密，故控制帧此位为 0。</td>
</tr>
<tr>
<td>0x02</td>
<td>表示帧 Data 域结尾是否帧含校验（例如 SHA1, MD5, CRC 等）需要校验的数据域括 sequence + data length + 明文 data，控制帧和数据帧都可以包含校验位或不包含。</td>
</tr>
<tr>
<td>0x04</td>
<td>表示数据方向。 0 表示手机发向 ESP32，1 表示 ESP32 发向手机。</td>
</tr>
<tr>
<td>0x08</td>
<td>表示是否要求对方回复 ack。 0 表示不要求，1 表示要求回复 ack。</td>
</tr>
<tr>
<td>0x10</td>
<td>表示是否有后数据分片。 0 表示此帧没有后数据分片：1 表示有后数据分片，用来传输较长的数据。如果是 Frag 帧，则告知当前 content 部分 + 后续 content 部分的总长度，位于 Data 域的前 2 字节（即最大支持 64K 的 content 数据）。</td>
</tr>
<tr>
<td>0x10~0x80</td>
<td>保留</td>
</tr>
</tbody>
</table>

3. Sequence Control
序列控制域。帧发送时，无论帧的类型是什么，序列 (Sequence) 都会自动加 1。用来防止重放攻击 (Replay Attack)。每次重建连接后，序列清零。

4. Length
Data 域的长度，不包含 CheckSum。

5. Data
不同的 Type 或 Subtype，Data 域的含义均不同。请参考上方表格。

6. CheckSum
此域为 2 byte 的校验，用来校验『序列 + 数据长度 + 明文数据』。

### 4.2.8.6 ESP32 端的安全实现

1. 保证数据安全
为了保证 Wi-Fi SSID 和密码的传输过程是安全的。需要使用对称加密算法（例如 AES, DES 等）对报文进行加密；在使用对称加密算法之前，需要使用非对称加密算法 (DH, RSA, ECC 等) 协商出 (或生成出) 一个共享密钥。

2. 保证数据完整性
保证数据完整性；需要加入校验算法（例如 SHA1, MD5, CRC 等）。

3. 身份安全（签名）
某些算法如 RSA 可以保证身份安全。有些算法如 DH，本身不能保证身份安全，需要添加其他算法来签名。

4. 防止重放攻击 (Replay Attack)
加入帧发送序列 (Sequence)，并且序列参与数据校验。
在 ESP32 端的代码中，你可以决定和开发密钥协商等安全处理的流程参考上述流程图。手机应用向 ESP32 发送协商数据，将传送给应用层处理。如果应用层不处理，可使用 BluFi 提供的 DH 加密算法来协商密钥。应用层需向 BluFi 注册以下几个与安全相关的函数:

```c
typedef void (*esp_blufi_negotiate_data_handler_t)(uint8_t *data, int len, uint8_t *output_data, int *output_len, bool *need_free);
```

该函数用来接收协商期间的正常数据 (normal data)，处理完成后，需要将待发送的数据使用 output_data 和 output_len 传出。

BluFi 会在调用完 negotiate_data_handler 后，发送 negotiate_data_handler 传出的 output_data。

这里的两个『*』，因为需要发出去的数据长度未知，所以需要函数自行分配 (malloc) 或者指向全局变量，通过 need_free 通知是否需要释放内存。

```c
typedef int (*esp_blufi_encrypt_func_t)(uint8_t iv8, uint8_t *crypt_data, int _crypt_len);
```

加密和解密的数据长度必须一致。其中 iv8 为帧的 8 bit 序列 (sequence)，可作为 iv 的某 8 bit 来使用。

```c
typedef int (*esp_blufi_decrypt_func_t)(uint8_t iv8, uint8_t *crypt_data, int _crypt_len);
```

加密和解密的数据长度必须一致。其中 iv8 为帧的 8 bit 序列 (sequence)，可作为 iv 的某 8 bit 来使用。

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

该函数用来计算 CheckSum，返回值为 CheckSum 的值。BluFi 会使用该函数返回值与包末尾的 CheckSum 做比较。

### 4.28.7 GATT 相关说明

**UUID**

BluFi Service UUID: 0xFFFF, 16 bit

BluFi（手机 -> ESP32）特性: 0xFF01, 主要权限: 可写

BluFi（ESP32 -> 手机）特性: 0xFF02, 主要权限: 可读可通知

### 4.29 片外 RAM

#### 4.29.1 简介

ESP32 提供了 520 KB 的片上 SRAM，可以满足大部分需求。但有些场景可能需要更多 RAM，因此 ESP32 另外提供了高达 4 MB 的片外 SPI RAM 存储器以供用户使用。片外 RAM 被添加到内存映射中，在某些范围内与片上 RAM 使用方式相同。

#### 4.29.2 硬件

ESP32 支持与 SPI Flash 芯片并联的 SPI PSRAM。ESP32 支持多种类型的 RAM 芯片，但 ESP32 SDK 当前仅支持 ESP-PSRAM32 芯片。

ESP-PSRAM32 芯片的工作电压为 1.8 V，只能与 1.8 V flash 并联使用。请确保在启动时将 MTDI 管脚设置为高电平，或者将 ESP32 中的熔丝设置为始终使用 1.8 V 的 VDD_SIO 电平，否则有可能会损坏 PSRAM 和/或 flash 芯片。

要将 ESP-PSRAM 芯片连接到 ESP32D0W*，请连接以下信号:

- PSRAM /CE (pin 1) > ESP32 GPIO 16
Chapter 4. API

- PSRAM SO (pin 2) > flash DO
- PSRAM SIO[2] (pin 3) > flash WP
- PSRAM SI (pin 5) > flash DI
- PSRAM SCLK (pin 6) > ESP32 GPIO17
- PSRAM SIO[3] (pin 7) > flash HOLD
- PSRAM Vcc (pin 8) > ESP32 VCC_SDIO

ESP32D2W* 芯片的连接方式有待确认。

注解：乐鑫同时提供 ESP32-WROVER 模组，内部搭载 ESP32 芯片，集成 1.8 V flash 和 ESP-PSRAM32，可直接用于终端产品 PCB 中。

4.29.3 配置片外 RAM

ESP-IDF 完全支持将外部存储器集成到您的应用程序中。您可以将 ESP-IDF 配置成启动并完成初始化后以多种方式处理片外 RAM:

- 集成片外 RAM 到 ESP32 内存映射
- 添加片外 RAM 到内存分配程序
- 调用 malloc() 分配片外 RAM （默认）
- 允许.bss 段放入片外存储器

集成片外 RAM 到 ESP32 内存映射

在 CONFIG_SPIRAM_USE 中选择 “Integrate RAM into ESP32 memory map (集成片外 RAM 到 ESP32 内存映射)” 选项。

这是集成片外 RAM 最基础的设置选项，大多数用户需要用到其他更高级的选项。

ESP-IDF 启动过程中，片外 RAM 被映射到以 0x3F800000 起始的数据地址空间（字节可寻址），空间大小正好为 RAM 的大小(4 MB)。

应用程序可以通过创建指向该区域的指针手动将数据放入片外存储器，同时应用程序全权负责管理片外 RAM，包括协调 Buffer 的使用，防止发生损坏等。

添加片外 RAM 到内存分配程序

在 CONFIG_SPIRAM_USE 中选择 “Make RAM allocatable using heap_caps_malloc(…, MALLOC_CAP_SPIRAM)” 选项。

启用上述选项后，片外 RAM 被映射到地址 0x3F800000，并将这个区域添加到内存分配程序里携带 MALLOC_CAP_SPIRAM 标志的程序如果想从片外存储器分配存储空间，则需要调用 heap_caps_malloc(size, MALLOC_CAP_SPIRAM)，之后可以调用 free() 函数释放这部分存储空间。

调用 malloc() 分配片外 RAM

在 CONFIG_SPIRAM_USE 中选择 “Make RAM allocatable using malloc() as well” 选项，该选项为默认选项。

启用此选项后，片外存储器将被添加到内存分配程序（与上一选项相同），同时也将被添加到由标准 malloc() 返回的 RAM 中。

这允许应用程序使用片外 RAM 而无需重写代码以使用 heap_caps_malloc(..., MALLOC_CAP_SPIRAM)。

如果某次内存分配偏向于片外存储器，您也可以使用 CONFIG_SPIRAM_MALLOC_ALWAYSINTERNAL 设置分配空间的大小阈值，控制分配结果：
• 如果分配的空间小于阈值，分配程序将首先选择内部存储器。
• 如果分配的空间等于或大于阈值，分配程序将首先选择外部存储器。

如果优先考虑的内部或外部存储器中没有可用的存储块，分配程序则会选择其他类型存储。

由于有些 Buffer 仅可在内部存储器中分配，因此需要使用第二个配置项 `CONF_SPIRAM_MALLOC_RESERVE_INTERNAL` 定义一个内部存储池，仅限显式的内部存储器分配使用（例如用于 DMA 的存储器）。常规 `malloc()` 将不会从该池中分配，但可以使用 `MALLOCAP_DMA` 和 `MALLOC_CAP_INTERNAL` 旗帜从该池中分配存储器。

允许 bss 段放入片外存储器

设置 `CONF_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY` 启用该选项，此选项配置与上面三个选项互不影响。

启用该选项后，从 0x3F800000 起始的地址空间将用于存储来自 lwip, net80211, libpp 和 bluedroid ESP-IDF 库中零初始化的数据（BSS 段）。

`EXT_RAM_ATTR` 宏应用于任何静态声明（未初始化为非零值）之后，可以将附加数据从内部 BSS 段移到片外 RAM。

启用此选项可以减少 BSS 段占用的内部静态存储。

剩余的片外 RAM 也可以通过上述方法添加到内存分配程序中。

### 4.29.4 片外 RAM 使用限制

使用片外 RAM 有以下一些限制：

• Flash cache 禁用时（比如，正在写入 flash），片外 RAM 将无法访问；同样，对片外 RAM 的读写操作也将导致 cache 访问异常。出于这个原因，ESP-IDF 不会在片外 RAM 中分配任务堆栈（详情见下文）。

• 片外 RAM 不能用于储存 DMA 描述符，也不能用作 DMA 读写操作的缓冲区（Buffer）。与 DMA 搭配使用的 Buffer 必须仅使用 heap_caps_malloc(size, MALLOC_CAP_DMA) 进行分配，之后可以调用标准 free() 回调释放 Buffer。

• 片外 RAM 与片外 flash 使用相同的 cache 区域。即频繁在片外 RAM 访问的变量可以像在片上 RAM 中一样快速读取和修改。但访问大块数据时（大于 32 KB），cache 区域可能会不足，访问速度将回落到片外 RAM 访问速度。此外，访问大块数据可以“挤出” flash cache，可能会降低代码执行速度。

• 片外 RAM 不可用于任务堆栈存储器。因此 `xTaskCreate()` 及类似函数将始终为堆栈和任务 TCB 分配片上存储器，而 `xTaskCreateStatic()` 类型的函数将检查传递的 Buffer 是否属于片上存储器。

• 默认情况下，片外 RAM 初始化失败将终止 ESP-IDF 启动。如果想禁用此功能，可启用 `CONF_SPIRAM_IGNORE_NOTFOUND` 配置选项。如果启用 `CONF_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY` 和 `CONF_SPIRAM_IGNORE_NOTFOUND` 选项将不能使用，这是因为在链接时，链接器已经向片外 RAM 分配符号。

• Regarding stacks in PSRAM: For tasks not calling on code in ROM in any way, directly or indirectly, the menuconfig option `CONF_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 SPI1 or SPI2 bus. Select which SPI host will be used by `CONF_SPIRAM_OCCUPY_SPI_HOST`.

### 4.29.5 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:

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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.

4.30 链接脚本生成机制

4.30.1 概述

用于存放代码和数据的：内存区域 <memory-layout> 有多个。代码和只读数据默认存放在 flash 中，可写数据存放在 RAM 中。不过有时，我们必须更改默认存放区域，例如为了提高性能，将关键代码存放在 RAM 中，或者将代码存放在 RTC 存储器中以便在唤醒或和 ULP 处理器中使用。

链接脚本生成机制可以让用户指定代码和数据在 ESP-IDF 组件中的存储区域。组件包含如何存放符号、目标或完整库的信息。在构建应用程序时，组件中的这些信息会被收集、解析并处理：生成的存放规则用于链接应用程序。

4.30.2 快速上手

本段将指导如何使用 ESP-IDF 的即用方案，快速将代码和数据放入 RAM 和 RTC 存储器中。

假设我们有:

```
- components/
  - my_component/
    - CMakeLists.txt
    - component.mk
    - Kconfig
    - src/
      - my_src1.c
      - my_src2.c
      - my_src3.c
      - my_linker_fragment_file.lf
```

- 名为 my_component 的组件，在构建过程中存储为 libmy_component.a 块文件
- 库文件包含的三个源文件: my_src1.c, my_src2.c 和 my_src3.c, 编译后分别为 my_src1.o, my_src2.o 和 my_src3.o。
- 在 my_src1.o 定义的 my_function1 功能; 在 my_src2.o 定义的 my_function2 功能
• 存储在 my_component 下 Kconfig 中的布尔类型配置 PERFORMANCE_MODE (y/n) 和整数类型配置 PERFORMANCE_LEVEL（范围是 0-3）

创建和指定链接片段文件

首先，我们需要创建链接片段文件。链接片段文件是一个拓展名为 .lf 的文本文件，文件内写有想要存放的位置。文件创建成功后，需要将其呈现在构建系统中。ESP-IDF 支持的构建系统指南如下：

Make 在组件目录的 component.mk 文件中设置 COMPONENT_ADD_LDFRAGMENTS 变量的值，使其指向已创建的链接片段文件。路径可以为绝对路径，也可以为组件目录的相对路径。

CMake 在组件目录的 CMakeLists.txt 文件中，指定 idf_component_register 调用引数 LDFRAGMENTS 的值。LDFRAGMENTS 可以为绝对路径，也可为组件目录的相对路径，指向刚才创建的链接片段文件。

```
# 相对于组件的 CMakeLists.txt 的文件路径
cidf_component_register(...
  LDFRAGMENTS "path/to/linker_fragment_file.lf" "path/to/another_linker_fragment_file.lf"
  ...)
```

指定存放区域

可以按照下列粒度指定存放区域：
• 目标文件 (.obj 或 .o 文件)
• 符号 (函数/变量)
• 库 (.a 文件)

存放目标文件 假设整个 my_src1.o 目标文件对性能至关重要，所以最好把该文件放在 RAM 中。另外，my_src2.o 目标文件包含从深度睡眠唤醒所需的符号，因此需要将其存放到 RTC 存储器中。在链接片段文件中可以写入以下内容：

```
[mapping:my_component]
archive: libmy_component.a
entries:
  my_src1 (noflash) # 将所有 my_src1 代码和只读数据存放在 IRAM 和 DRAM 中
  my_src2 (rtc) # 将所有 my_src2 代码、数据和只读数据存放在 RTC 快速 RAM 和 RTC...
```

那么 my_src3.o 放在哪里呢？由于未指定存放区域，my_src3.o 会存放到默认区域。更多关于默认存放区域的信息，请查看这里。

存放符号 继上文的例子，假设 object1.o 目标文件定义的函数中，只有 function1 影响到性能；object2.o 目标文件中只有 function2 需要在芯片从深度睡眠中唤醒后运行。可以在链接片段文件中写入以下内容实现：

```
[mapping:my_component]
archive: libmy_component.a
entries:
  my_src1:my_function1 (noflash)
  my_src2:my_function2 (rtc)
```
Chapter 4. API 指南

my_src1.o 和 my_src2.o 中的其他函数以及整个 object3.o 目标文件会存放到默认区域。要指定数据的存放区域，仅需将上文的函数名替换为变量名即可，如:

my_src1:my_variable (noflash)

注意：按照符号粒度存放代码和数据有一定的要求。为确保存放区域合适，您也可以将相关代码和数据集中在源文件中，参考使用目标文件的存放规则。

存放整个库 在这个例子中，假设整个组件都需存放到 RAM 中，可以写入以下内容实现：

```
[mapping:my_component]
archive: libmy_component.a
entries:
  * (noflash)
```

类似的，写入以下内容可以将整个组件存放到 RTC 存储器中：

```
[mapping:my_component]
archive: libmy_component.a
entries:
  * (rtc)
```

根据具体配置存放 假设只有在某个条件为真时，比如 CONFIG_PERFORMANCE_MODE == y 时，整个组件库才存特定存放区域，可以写入以下内容实现：

```
[mapping:my_component]
archive: libmy_component.a
entries:
  if PERFORMANCE_MODE == y:
    * (noflash)
  else:
    * (default)
```

来看一种更复杂的情况。假设 "CONFIG_PERFORMANCE_LEVEL == 1" 时，只有 object1.o 存放到 RAM 中; CONFIG_PERFORMANCE_LEVEL == 2 时，object1.o 和 object2.o 会存放到 RAM 中; CONFIG_PERFORMANCE_LEVEL == 3 时，库中的所有目标文件都会存放到 RAM 中。以上三个条件为假时，整个库会存放到 RTC 存储器中。虽然这种使用场景很罕见，不过，还是可以通过以下方式实现：

```
[mapping:my_component]
archive: libmy_component.a
entries:
  if PERFORMANCE_LEVEL == 1:
    my_src1 (noflash)
  elif PERFORMANCE_LEVEL == 2:
    my_src1 (noflash)
    my_src2 (noflash)
  elif PERFORMANCE_LEVEL == 3:
    my_src1 (noflash)
    my_src2 (noflash)
    my_src3 (noflash)
  else:
    * (rtc)
```

也可以嵌套条件检查。以下内容与上述片段等效：

```
[mapping:my_component]
archive: libmy_component.a
```

(下页继续)
默认存放区域

到目前为止，“默认存放区域”在未指定 rtc 和 noflash 存放规则时才会使用，作为备选方案。需要注意的是，noflash 或者 rtc 标记不仅仅是关键字，实际上还是被称作片段的实体，确切地说是协议。

与 rtc 和 noflash 类似，还有一个默认协议，定义了默认存放规则。顾名思义，该协议规定了代码和数据通常存放的区域，即代码和恒量存放在 flash 中，变量存放在 RAM 中。更多关于默认协议的信息，请见这里。

### 注解：
使用链接脚本生成机制的 IDF 组件示例，请参阅 freertos/CMakeLists.txt。为了提高性能，freertos 使用链接脚本生成机制，将其目标文件存放到 RAM 中。

快速入门指南到此结束，下文将详述这个机制的内核，有助于创建自定义存放区域或修改默认方式。

### 4.30.3 链接脚本生成机制内核

链接是将 C/C++ 源文件转换成可执行文件的最后一步。链接由工具链的链接器完成，接受指定代码和数据存放区域等信息的链接脚本。链接脚本生成机制的转换过程类似，区别在于传输给链接器的链接脚本根据 (1) 收集的链接片段文件和 (2) 链接脚本模板动态生成。

### 注解：
执行链接脚本生成机制的工具存放在 tools/ldgen 之下。

### 链接片段文件

如快速入门指南所述，片段文件是拓展名为 .lf 的简单文本文件，内含想要存放区域的信息。不过，这是对片段文件所包含内容的简化版描述。实际上，片段文件内包含的是“片段”。片段是实体，包含多条信息，这些信息放在一起组成了存放规则，说明目标文件各个段在二进制输出文件中的存放位置。片段一共有三种，分别是段、协议和映射。

### 语法  三种片段类型使用同一种语法：

```
[type:name]
  key: value
  key:
    value
    value
    value
...
```

- 类型：片段类型，可以为 段、协议或 映射。
- 名称：片段名称，指定片段类型的片段名称应唯一。
- 键值：片段内容。每个片段类型可支持不同的键值和不同的键值语法。
注解：多个片段的类型和名称相同时会引发异常。

注解：片段名称和键值只能使用字母、数字和下划线。

条件检查
条件检查使得链接脚本生成机制可以感知配置。含有配置值的表达式是否为真，决定了使用哪些特定键值。检查使用的是 kconfiglib 脚本的 eval_string，遵循该脚本要求的语法和局限性，支持：

- 比较
  - 小于 <
  - 小于等于 <=
  - 大于 >
  - 大于等于 >=
  - 等于 ==
  - 不等于 !=

- 逻辑
  - 或 ||
  - 和 &&
  - 否定？取反？!

- 分组
  - 圆括号 ()

条件检查和其他语言中的 if...elseif/elif...else 块作用一样。键值和完整片段都可以进行条件检查。以下两个示例效果相同:

```python
# 键值取决于配置
[type: name]
key_1:
  if CONDITION = y:
    value_1
  else:
    value_2
key_2:
  if CONDITION = y:
    value_a
  else:
    value_b

# 完整片段的定义取决于配置
if CONDITION = y:
  [type: name]
  key_1:
    value_1
  key_2:
    value_a
else:
  [type: name]
  key_1:
    value_2
  key_2:
    value_b
```

注释
链接片段文件中的注释以 # 开头。和其他语言中一样，注释提供了有用的描述和资料，在处理过程中会被忽略。

与 ESP-IDF v3.x 链接脚本片段兼容 ESP-IDF v4.0 更新了链接脚本片段文件使用的一些语法。

Espressif Systems  1662  Release v4.3-dev-1561-g357a277603
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• 必须缩进，缩进不当的文件会产生解析异常；旧版本不强制缩进，但之前的文档和示例均遵循了正确的缩进语法
• 条件改用 if...elif...else 结构，可以嵌套检查，将完整片段置于条件内
• 映射片段和其他片段类型一样，需有名称

链接脚本生成器可解析 ESP-IDF v3.x 版本中缩进正确的链接片段文件（如 ESP-IDF v3.x 版本中的本文件所示），依然可以向后兼容此前的映射片段语法（可选名称和条件的旧语法），但是会有弃用警告。用户应换成本文档介绍的新语法，因为旧语法将在未来停用。

请注意，ESP-IDF v3.x 不支持使用 ESP-IDF v4.0 新语法的链接片段文件。

### 类型 段
段定义了 GCC 编译器输出的一系列目标文件段，可以是默认段（如 .text、.data），也可以是用户通过 __attribute__ 关键字定义的段。
‘+’表示段列表开始，且当前段为列表中的第一个段。这种表达方式更加推荐。

```markdown
[sections:name]
entries:
  .section+
  .section
...
```

示例：

```markdown
# 不推荐的方式
[sections:text]
entries:
  .text
  .text.*
  .literal
  .literal.*

# 推荐的方式，效果与上面等同
[sections:text]
entries:
  .text+       # 即 .text 和 .text.*
  .literal+    # 即 .literal 和 .literal.*
```

### 协议
协议定义了每个段对应的目目标。

```markdown
[scheme:name]
entries:
  sections -> target
  sections -> target
  ...
```

示例：

```markdown
[scheme:noflash]
entries:
  text -> iram0_text  # text 段下的所有条目均归入 iram0_text
  rodata -> dram0_data # rodata 段下的所有条目均归入 dram0_data
```

默认协议

注意，有一个默认的协议很特殊，特殊在于包罗存放规则都是根据这个协议中的条目生成的。这意味着，如果该协议有一条条目是 text -> flash_text，则将为目标 flash_text 生成如下的存放规则：

```
*(.literal .literal.* .text .text.*)
```
这些生成的包罗规则将用于未指定映射规则的情况。
默认情况下在 esp32/ld/esp32_fragments.1f 文件中定义。快速上手指南中提到的内置 noflash 协议和 rtc 协议也在该文件中定义。

映射
映射定义了可映射实体（即目标文件、函数名、变量名和库）对应的协议。

<table>
<thead>
<tr>
<th>[mapping]</th>
<th>archive: archive # 构建后输出的库文件名称（即 libxxx.a）entries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>object:symbol (scheme) # 符号</td>
<td>object (scheme) # 目标</td>
</tr>
<tr>
<td>* (scheme) # 库</td>
<td></td>
</tr>
</tbody>
</table>

有三种存放粒度：
- 符号：指定了目标文件名称和符号名称。符号名称可以是函数名或变量名。
- 目标：只指定目标文件名称。
- 库：指定 *，即某个库下面所有目标文件的简化表达法。

为了更好地理解条目的含义，我们看一个按目标存放的例子。

根据条目定义，将这个协议展开：

```object (scheme)
object (sections -> target,  
sections -> target,  
...)
```

再根据条目定义，将这个段展开：

```object (.section,  
 .section,  
 ... -> target, # 根据目标文件将这里所列出的所有段存放在该目标位置  
 .section,  
 .section,  
 ... -> target, # 同样的方法指定其他段  
 ...)        # 直至所有段均已展开```

示例：

```[mapping:map]  
archive: libfreertos.a  
entries:  
* (noflash)`
链接脚本模板

链接脚本模板是指定存放规则的存放位置的框架，与其他链接脚本没有本质区别，但带有特定的标记语法，可以指示存放生成的存放规则的位置。

如需引用一个目标标记下的所有存放规则，请使用以下语法：

```
mapping[target]
```

示例：

以下示例是某个链接脚本模板的摘录，定义了输出段 .iram0.text，该输出段包含一个引用目标 iram0_text 的标记。

```
.iram0.text :
{
    /* 标记 IRAM 空间不足 */
    _iram_text_start = ABSOLUTE(.);

    /* 引用 iram0_text */
    mapping[iram0_text]

    _iram_text_end = ABSOLUTE(.);
}
```

假设链接脚本生成器收集到了以下片段定义：

```
[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)
```

则该脚本生成器生成的链接脚本文件，其摘录应如下所示：

```
.iram0.text :
{
    /* 标记 IRAM 空间不足 */
    _iram_text_start = ABSOLUTE(.);

    /* 处理片段生成的存放规则，存放自模板标记的位置处 */
    *(.iram1 .iram1.*)
    *libfreertos.a:(.literal .text .literal.* .text.*)

    _iram_text_end = ABSOLUTE(.);
}
```

*libfreertos.a:(.literal .text .literal.* .text.*)
Chapter 4. API

4.31 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.

4.31.1 Supported APIs

ESP-IDF supports the following lwIP TCP/IP stack functions:

- BSD Sockets API
- Netconn API is enabled but not officially supported for ESP-IDF applications

Adapted APIs

Some common lwIP “app” APIs are supported indirectly by ESP-IDF:

- DHCP Server & Client are supported indirectly via the ESP-NETIF functionality
- Simple Network Time Protocol (SNTP) is supported via the lwip/include/apps/snntp/snntp.h lwip/lwip/src/include/lwip/apps/snntp.h functions (see also SNTP Time Synchronization)
- ICMP Ping is supported using a variation on the lwIP ping API. See ICMP Echo.
- NetBIOS lookup is available using the standard lwIP API. protocols/http_server/restful_server has an option to demonstrate using NetBIOS to look up a host on the LAN.
- mDNS uses a different implementation to the lwIP default mDNS (see mDNS service), but lwIP can look up mDNS hosts using standard APIs such as gethostbyname() and the convention hostname.local, provided the CONFIG_LWIP_DNS_SUPPORT_MDNS_QUERIES setting is enabled.

4.31.2 BSD Sockets API

The BSD Sockets API is a common cross-platform TCP/IP sockets API that originated in the Berkeley Standard Distribution of UNIX but is now standardized in a section of the POSIX specification. BSD Sockets are sometimes called POSIX Sockets or Berkeley Sockets.

As implemented in ESP-IDF, lwIP supports all of the common usages of the BSD Sockets API.

References

A wide range of BSD Sockets reference material is available, including:

- Single UNIX Specification BSD Sockets page
- Berkeley Sockets Wikipedia page
Examples

A number of ESP-IDF examples show how to use the BSD Sockets APIs:

- protocols/sockets/tcp_server
- protocols/sockets/tcp_client
- protocols/sockets/udp_server
- protocols/sockets/udp_client
- protocols/sockets/udp_multicast
- protocols/http_request (Note: this is a simplified example of using a TCP socket to send an HTTP request. The ESP HTTP Client is a much better option for sending HTTP requests.)

Supported functions

The following BSD socket API functions are supported. For full details see lwip/lwip/src/include/lwip/sockets.h.

- socket()
- bind()
- accept()
- shutdown()
- getpeername()
- getssockopt() & setsockopt() (see Socket Options)
- close() (via 虚拟文件系统组件)
- read(), readv(), write(), writev() (via 虚拟文件系统组件)
- recv(), recvmsg(), recvfrom()
- send(), sendmsg(), sendto()
- select() (via 虚拟文件系统组件)
- poll() (Note: on ESP-IDF, poll() is implemented by calling select internally, so using select() directly is recommended if a choice of methods is available.)
- fcntl() (see fcntl)

Non-standard functions:

- ioctl() (see ioctls)

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.

注解: getsockopt function prototype int getsockopt(int s, int level, int optname, void *optval, socklen_t *optlen). Its function is to get the current value of the option of any type, any state socket, and store the result in optval. For example, when you get the error code on a socket, you can get it by getsockopt(sockfd, SOL_SOCKET, SO_ERROR, &err, &optlen).

Example:

```c
int err;

if (select(sockfd + 1, NULL, NULL, &exfds, &tval) <= 0) {
    err = errno;
    return err;
} else {
    if (FD_ISSET(sockfd, &exfds)) {
        // select() exception set using getsockopt()
        int optlen = sizeof(int);
        getsockopt(sockfd, SOL_SOCKET, SO_ERROR, &err, &optlen);
        return err;
    }
}
```

Socket Error Reason Code Below is a list of common error codes. For more detailed list of standard POSIX/C error codes, please see newlib errno.h <https://github.com/espressif/newlib-esp32/blob/master/newlib/libc/include/sys/errno.h> and the platform-specific extensions newlib/platform_include/errno.h
### Error Codes

<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_SNDTIMEO` / `SO_RCVTIMEO`
- `SO_ERROR` (this option is only used with `select()`, see Socket Error Handling)
- `SO_TYPE`
- `SO_NO_CHECK` (for UDP sockets only)

#### IP options

Used with level argument `IPPROTO_IP`.

- `IP_TOS`
- `IP_TTL`
- `IP_PKTINFO` (available if `CONFIG_LWIP_NETBUF_RECVINFO` is set)

For multicast UDP sockets:

- `IP_MULTICAST_IF`
- `IP_MULTICAST_LOOP`
- `IP_MULTICAST_TTL`
- `IP_ADD_MEMBERSHIP`
- `IP_DROP_MEMBERSHIP`

#### TCP options

TCP sockets only. Used with level argument `IPPROTO_TCP`.

- `TCP_NODELAY`

Options relating to TCP keepalive probes:

- `TCP_KEEPALIVE` (int value, TCP keepalive period in milliseconds)
- `TCP_KEEPIDLE` (same as `TCP_KEEPALIVE`, but the value is in seconds)
- `TCP_KEEPINTVL` (int value, interval between keepalive probes in seconds)
- `TCP_KEEPCNT` (int value, number of keepalive probes before timing out)
IPv6 options IPv6 sockets only. Used with level argument IPPROTO_IPV6

• IPv6_CHECKSUM
• IPv6_V6ONLY

For multicast IPv6 UDP sockets:

• IPv6_JOIN_GROUP / IPV6_ADD_MEMBERSHIP
• IPv6_LEAVE_GROUP / IPV6_DROP_MEMBERSHIP
• IPv6_MULTICAST_IF
• IPv6_MULTICAST_HOPS
• IPv6_MULTICAST_LOOP

fcntl

The fcntl() function is a standard API for manipulating options related to a file descriptor. In ESP-IDF, the virtual file system 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 file system 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, ...).

4.31.3 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.

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.

4.31.4 lwIP FreeRTOS Task

lwIP creates a dedicated TCP/IP FreeRTOS task to handle socket API requests from other tasks.

A number of configuration items are available to modify the task and the queues ("mailboxes") used to send data to/from the TCP/IP task:
• `CONFIG_LWIP_TCPIP_RECVMBX_SIZE`
• `CONFIG_LWIP_TCPIP_TASK_STACK_SIZE`
• `CONFIG_LWIP_TCPIP_TASK_AFFINITY`

4.31.5 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.

**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`.

**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.

4.31.6 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.
Chapter 4. API

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.

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_TCPIP_RECVMBOX_SIZE, CONFIG_LWIP_TCP_RECVMBOX_SIZE and CONFIG_LWIP_UDP_RECVMBOX_SIZE reduce memory usage at the expense of throughput, depending on usage.

If using a Wi-Fi network interface, 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:

\[
\text{lwp\_dynamic\_peek\_memory} = (\text{lwp\_udp\_con\_num} \times \text{lwp\_udp\_conn}) + (\text{lwp\_tcp\_con\_num} \times (\text{lwp\_tcp\_tx\_win\_size} + \text{lwp\_tcp\_rx\_win\_size} + \text{lwp\_ tcp\_conn}))
\]

Some TCP-based applications need only one TCP connection. However, they may choose to close this TCP connection and create a new one when an error (such as a sending failure) occurs. This may result in multiple TCP connections existing in the system simultaneously, because it may take a long time for a TCP connection to close, according to the TCP state machine (refer to RFC793).
4.32 工具

4.32.1 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.

注解： 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 %USERPROFILE%\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.

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.
Chapter 4. API

• **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
    ```
    set "PATH=C:\Users\user\.espressif\tools\v1.0.0\bin;%PATH%"
    ```
    on Windows.

  - **key-value** produces output suitable for parsing by other scripts:
    ```
    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`.
- **Eclipse plugin for ESP-IDF** includes a menu item to set up the tools. Internally the plugin calls `idf_tools.py`.
- **Visual Studio Code extension for ESP-IDF** includes an onboarding flow. This flow helps setting up the tools. Although the extension does not rely on `idf_tools.py`, the same installation method is used.

Custom installation

Although the methods above are recommended for ESP-IDF users, they are not a must for building ESP-IDF applications. ESP-IDF build system expects that all the necessary tools are installed somewhere, and made available in the `PATH`.

List of IDF Tools

**xtensa-esp32-elf** Toolchain for Xtensa (ESP32) based on GCC

License: GPL-3.0-with-GCC-exception

More info: [https://github.com/espressif/crosstool-NG](https://github.com/espressif/crosstool-NG)

<table>
<thead>
<tr>
<th>Platform</th>
<th>Required</th>
<th>Download</th>
</tr>
</thead>
<tbody>
<tr>
<td>linux-amd64</td>
<td>required</td>
<td><a href="https://dl.espressif.com/dl/xtensa-esp32-elf-gcc8_4_0-esp-2020r3-linux-amd64.tar.gz">https://dl.espressif.com/dl/xtensa-esp32-elf-gcc8_4_0-esp-2020r3-linux-amd64.tar.gz</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SHA256: 674080a12f9c5eb6a5a3a5ce51c6deaf6e6dfb56d0416233df86f25b574e9279</td>
</tr>
<tr>
<td></td>
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<td>SHA256: 58419852fe4b711fdec056ac2fd7c4bd09ce4ce17610a761a977b88413527cf</td>
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</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](https://github.com/espressif/crosstool-NG)
### Chapter 4. API 指南

#### Platform | Required | Download | SHA256
---|---|---|---
linux-amd64 | required | [https://dl.espressif.com/dl/xtensa-esp32s2-elf-gcc8_4_0-esp-2020r3-linux-amd64.tar.gz](https://dl.espressif.com/dl/xtensa-esp32s2-elf-gcc8_4_0-esp-2020r3-linux-amd64.tar.gz) | 40fafa47045167fed0cd07827db5207efbe4a3b6b24475957a921bc92805ed
linux-armel | required | [https://dl.espressif.com/dl/xtensa-esp32s2-elf-gcc8_4_0-esp-2020r3-linux-armel.tar.gz](https://dl.espressif.com/dl/xtensa-esp32s2-elf-gcc8_4_0-esp-2020r3-linux-armel.tar.gz) | 6c1efec4c7829202273988cccb3888e8a17a34464bc351d677cf0f4d95e4a4b4ce0
linux-i686 | required | [https://dl.espressif.com/dl/xtensa-esp32s2-elf-gcc8_4_0-esp-2020r3-linux-i686.tar.gz](https://dl.espressif.com/dl/xtensa-esp32s2-elf-gcc8_4_0-esp-2020r3-linux-i686.tar.gz) | bd3a91166206a1a77ff7c572e15389e1938c3dce588032a5e915be677a945638
macos | required | [https://dl.espressif.com/dl/xtensa-esp32s2-elf-gcc8_4_0-esp-2020r3-macos.tar.gz](https://dl.espressif.com/dl/xtensa-esp32s2-elf-gcc8_4_0-esp-2020r3-macos.tar.gz) | fe19b0c873879d889ec0404f04d04a3ab277d93f5ff5fe59a28866111d09c
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win64 | required | [https://dl.espressif.com/dl/xtensa-esp32s2-elf-gcc8_4_0-esp-2020r3-win64.zip](https://dl.espressif.com/dl/xtensa-esp32s2-elf-gcc8_4_0-esp-2020r3-win64.zip) | 6ea78b72ec52330b69af91dbec6c77c22bdc827817f044aa30306270453032bb4

---

**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)

---

**riscv-none-embed-gcc**  Toolchain for RISC-V

License: MIT

## Platform | Required | Download |
|------------|----------|----------|
SHA256: 3d40fab50ebad8424f8574f825d2eae50f86a5d5222abd7a45a2e490f1e4f5 |
SHA256: e8b5ee33ef54aa2405183366cdef299da2ca697e8cc57627dfaad8ab4460a99 |
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SHA256: 78bcd52f7b404133de3b2f956e87101c1de74ef98db3a7b0d6b251b75a1754867 |
SHA256: 98b60720607f1400081806d6d70796b30399f8b426c2c790a4abb0f9b9e5ec |

### esp32ulp-elf Toolchain for ESP32 ULP coprocessor

License: GPL-2.0-or-later

More info: [https://github.com/espressif/binutils-esp32ulp](https://github.com/espressif/binutils-esp32ulp)

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<th>Required</th>
<th>Download</th>
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</table>
| 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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SHA256: bade30935a9f0a4e5cc30bfe84845e332050f55024b1991953871ded271ab5 |

### esp32s2ulp-elf Toolchain for ESP32-S2 ULP coprocessor

License: GPL-2.0-or-later

More info: [https://github.com/espressif/binutils-esp32ulp](https://github.com/espressif/binutils-esp32ulp)
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<td><a href="https://github.com/Kitware/CMake/releases/download/v3.16.4/cmake-3.16.4-Linux-x86_64.tar.gz">https://github.com/Kitware/CMake/releases/download/v3.16.4/cmake-3.16.4-Linux-x86_64.tar.gz</a></td>
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</table>

**cmake**  
CMake build system

On Linux and macOS, it is recommended to install CMake using the OS package manager. 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

<table>
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<th>Required</th>
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<td>f37963bcfcebdf5e5864926a3623f6c21220c35790c39cd65e644bd521cbb39c55</td>
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</table>

**openocd-esp32**  
OpenOCD for ESP32

License: GPL-2.0-only

More info: https://github.com/espressif/openocd-esp32
Chapter 4. API

Platform | Required | Download |
---|---|---|
linux-amd64 | required | https://github.com/espressif/openocd-esp32/releases/download/v0.10.0-esp32-20200709/openocd-esp32-linux64-0.10.0-esp32-20200709.tar.gz
SHA256: 77a232510625c23489d9bf1b17bdadf56e95acfe8f50ef8ebb51477f23c21ef0

linux-armel | required | https://github.com/espressif/openocd-esp32/releases/download/v0.10.0-esp32-20200709/openocd-esp32-armel-0.10.0-esp32-20200709.tar.gz
SHA256: b2cc6b7837f3cac23a752a8c43c6e0b19701ee0ec1eca4896833f0e82746062e

macos | required | https://github.com/espressif/openocd-esp32/releases/download/v0.10.0-esp32-20200709/openocd-esp32-macos-0.10.0-esp32-20200709.tar.gz
SHA256: 97cf84dd3dfb129a7d4842599870a3b0db40b2713d3c5153738c44907e85d6e

win32 | required | https://github.com/espressif/openocd-esp32/releases/download/v0.10.0-esp32-20200709/openocd-esp32-win32-0.10.0-esp32-20200709.zip
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win64 | required | https://github.com/espressif/openocd-esp32/releases/download/v0.10.0-esp32-20200709/openocd-esp32-win32-0.10.0-esp32-20200709.zip
SHA256: b96b95607ca0c5899427f5b88ca7389da11f53ac857d3d2fe467e571af5137e

**ninja**  
Ninja build system

On Linux and macOS, it is recommended to install ninja using the OS package manager. 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

Platform | Required | Download |
---|---|---|
linux-amd64 | optional | https://dl.espressif.com/dl/ninja-1.10.0-linux64.tar.gz
SHA256: 4b2ad65db438595813b981db921f675f5c775c302b34dc85710fddf07ec9033

macos | optional | https://dl.espressif.com/dl/ninja-1.10.0-osx.tar.gz
SHA256: 6cd22e2c5fe654282d26b485d9b3d68e242b09a22c2e73a253f2a4a7cf6d774c

win64 | required | https://dl.espressif.com/dl/ninja-1.10.0-win64.zip
SHA256: 919fd158c16bf135e8a505bb4046ec1ce28a7439ee08b977cd0b7f6b34e63d178

**idf-exe**  
IDF wrapper tool for Windows

License: Apache-2.0

More info: tools/windows/idf_exe

Platform | Required | Download |
---|---|---|
win32 | required | https://dl.espressif.com/dl/idf-exe-v1.0.1.zip
SHA256: 53eb6aaaf034cc7ed1a97d5c577afa0f99815b7779305e9408e74012d357d0a

win64 | required | https://dl.espressif.com/dl/idf-exe-v1.0.1.zip
SHA256: 53eb6aaaf034cc7ed1a97d5c577afa0f99815b7779305e9408e74012d357d0a

**ccache**  
Ccach (compiler cache)

License: GPL-3.0-or-later

More info: https://github.com/ccache/ccache
**dfu-util**  
dfu-util (Device Firmware Upgrade Utilities)

License: GPL-2.0-only


<table>
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</table>

### 4.32.2 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, make, ninja, cross-compiler toolchains, etc.
- All Python packages required by ESP-IDF are installed in a virtual environment.

The image entrypoint sets up `PATH` environment variable to point to the correct version of tools, and activates the Python virtual environment. As a result, the environment is ready to use the ESP-IDF build system.

The image can also be used as a base for custom images, if additional utilities are required.

**Tags**

Multiple tags of this image are maintained:

- `latest`: tracks `master` branch of ESP-IDF
- `vX.Y`: corresponds to ESP-IDF release `vX.Y`
- `release-vX.Y`: tracks release `vX.Y` branch of ESP-IDF

**注解:** Versions of ESP-IDF released before this feature was introduced do not have corresponding Docker image versions. You can check the up-to-date list of available tags at [https://hub.docker.com/r/espressif/idf/tags](https://hub.docker.com/r/espressif/idf/tags).

### Usage

**Setting up Docker**  
Before using the `espressif/idf` Docker image locally, make sure you have Docker installed. Follow the instructions at [https://docs.docker.com/install/](https://docs.docker.com/install/), if it is not installed yet.

If using the image in CI environment, consult the documentation of your CI service on how to specify the image used for the build process.

**Building a project with CMake**  
In the project directory, run:

```bash
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 --build
```

You can check the up-to-date list of available tags at https://hub.docker.com/r/espressif/idf/tags.

**Building a project with GNU Make**  
Same as for CMake, except that the build command is different:

```
docker run --rm -v $PWD:/project -w /project espressif/idf make defconfig all -j4
```

**注解:** If the `sdkconfig` file does not exist, the default behavior of GNU Make build system is to open the menuconfig UI. This may be not desired in automated build environments. To ensure that the `sdkconfig` file exists, `defconfig` target is added before `all`.

If you intend to build the same project repeatedly, you may bind the `tools/kconfig` directory of ESP-IDF to a named volume. This will prevent Kconfig tools, located in ESP-IDF directory, from being rebuilt, causing a rebuild of the rest of the project:

```
docker run --rm -v $PWD:/project -v kconfig:/opt/esp/idf/tools/kconfig -w /project... --espressif/idf make defconfig all -j4
```

If you need to clean up the `kconfig` volume, run `docker volume rm kconfig`.

**Binding the tools/kconfig directory to a volume is not necessary when using the CMake build system.**

**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
```

**注解:** Commands which communicate with the development board, such as `idf.py flash` and `idf.py monitor` will not work in the container unless the serial port is passed through into the container. However currently this is not possible with Docker for Windows (https://github.com/docker/for-win/issues/1018) and Docker for Mac (https://github.com/docker/for-mac/issues/900).
Chapter 5

Libraries and Frameworks

5.1 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:

5.1.1 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.

5.1.2 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.

5.1.3 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.

5.1.4 Aliyun IoT

https://github.com/espressif/esp-aliyun is an open source repository for ESP32 based on Aliyun’s iotkit-embedded SDK.

5.1.5 Joylink IoT

https://github.com/espressif/esp-joylink is an open source repository for ESP32 based on Joylink’s joylink_dev_sdk SDK.

5.1.6 Tencent IoT

https://github.com/espressif/esp-welink is an open source repository for ESP32 based on Tencent’s welink SDK.
5.1.7 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.

5.1.8 Baidu IoT

https://github.com/espressif/esp-baidu-iot is an open source repository for ESP32 based on Baidu’s iot-sdk-c SDK.
Chapter 6

Contributions Guide

We welcome contributions to the esp-idf project!

6.1 How to Contribute

Contributions to esp-idf - fixing bugs, adding features, adding documentation - are welcome. We accept contributions via Github Pull Requests.

6.2 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.
- Does any new code conform to the esp-idf Style Guide?
- Does the code documentation follow requirements in 编写代码文档?
- 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 创建示例项目 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.

6.3 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.

6.4 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.
6.5 Related Documents

6.5.1 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 named spaced 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
}
// place empty line here

void function2()
{
    int var = 0;
    // INCORRECT, don’t use an empty line here
    while (var < SOME_CONSTANT) {
        do_stuff(&var);
    }
}
```

The maximum line length is 120 characters as long as it doesn’t seriously affect the readability.
**Horizontal Space** Always add single space after conditional and loop keywords:

```c
if (condition) {  // correct
    // ...
}
switch (n) {  // 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)
{
}

// NOT like this:
void function(int arg) {
}
```

- Within a function, place opening brace on the same line with conditional and loop statements:
Chapter 6. Contributions Guide

```c
if (condition) {
    do_one();
} else if (other_condition) {
    do_two();
}
```

Comments  Use // for single line comments. For multi-line comments it is okay to use either // on each line or a /* */ block.

Although not directly related to formatting, here are a few notes about using comments effectively.

- Don’t use single comments to disable some functionality:

  ```c
  void init_something()
  {
      setup_dma();
      // load_resources(); // WHY is this thing commented, asks...
      --the reader?
      start_timer();
  }
  ```

- If some code is no longer required, remove it completely. If you need it you can always look it up in git history of this file. If you disable some call because of temporary reasons, with an intention to restore it in the future, add explanation on the adjacent line:

  ```c
  void init_something()
  {
      setup_dma();
      // TODO: we should load resources here, but loader is not fully integrated...
      --yet.
      // load_resources();
      start_timer();
  }
  ```

- Same goes for #if 0 ... #endif blocks. Remove code block completely if it is not used. Otherwise, add comment explaining why the block is disabled. Don’t use #if 0 ... #endif or comments to store code snippets which you may need in the future.

- Don’t add trivial comments about authorship and change date. You can always look up who modified any given line using git. E.g. this comment adds clutter to the code without adding any useful information:

  ```c
  void init_something()
  {
      setup_dma();
      // XXX add 2016-09-01
      init_dma_list();
      fill_dma_item(0);
      // end XXX add
      start_timer();
  }
  ```

Line Endings  Commits should only contain files with LF (Unix style) endings.

Windows users can configure git to check out CRLF (Windows style) endings locally and commit LF endings by setting the `core.autocrlf` setting. Github has a document about setting this option <github-line-endings>. However because MSYS2 uses Unix-style line endings, it is often easier to configure your text editor to use LF (Unix style) endings when editing ESP-IDF source files.

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):
Chapter 6. Contributions Guide

```
git rebase --exec 'git diff-tree --no-commit-id --name-only -r HEAD | xargs... dos2unix && git commit -a --amend --no-edit --allow-empty' master
```

(Note that this line rebases on master, change the branch name at the end to rebase on another branch.)

For updating a single commit, it’s possible to run `dos2unix FILENAME` and then run `git commit --amend`

**Formatting Your Code** You can use `astyle` program to format your code according to the above recommendations.

If you are writing a file from scratch, or doing a complete rewrite, feel free to re-format the entire file. If you are changing a small portion of file, don’t re-format the code you didn’t change. This will help others when they review your changes.

To re-format a file, run:

```
tools/format.sh components/my_component/file.c
```

**Type Definitions** Should be `snake_case`, ending with `_t` suffix:

```
typedef int signed_32_bit_t;
```

**Enum** Enums should be defined through the `typedef` and be Namespaced:

```
typedef enum
{
   MODULE_FOO_ONE,
   MODULE_FOO_TWO,
   MODULE_FOO_THREE
} module_foo_t;
```

**C++ Code Formatting**

The same rules as for C apply. Where they are not enough, apply the following rules.

**File Naming** C++ Header files have the extension `.hpp`. C++ source files have the extension `.cpp`. The latter is important for the compiler to distinguish them from normal C source files.

**Naming**

- **Class and struct** names shall be written in *CamelCase* with a capital letter as beginning. Member variables and methods shall be in *snake_case*.
- **Namespaces** shall be in lower *snake_case*.
- **Templates** are specified in the line above the function declaration.
- **Interfaces in terms of Object-Oriented Programming** shall be named without the suffix ...Interface. Later, this makes it easier to extract interfaces from normal classes and vice versa without making a breaking change.

**Member Order in Classes** In order of precedence:

- First put the public members, then the protected, then private ones. Omit public, protected or private sections without any members.
- First put constructors/destructors, then member functions, then member variables.

For example:
class ForExample {
public:
    // first constructors, then default constructor, then destructor
    ForExample(double example_factor_arg);
    ForExample();
    ~ForExample();
    // then remaining pubic 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

// 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) {
    // 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: 编写代码文档.

Structure

To be written.

Language Features

To be written.

6.5.2 编写代码文档

本文简要介绍了 espessif/esp-idf 项目库采用的文件风格以及如何在项目库中添加新文件。

概述

在项目库内编写代码文档时，请遵循 Doxygen 代码注释风格。要采用这一风格，您可以将 @param 特殊命令插入到标准注释块中，比如:

```
/**
 * @param ratio this is oxygen to air ratio
 */
```

Doxygen 会解析代码，提取命令和后续文本，生成代码文档。

注释块通常包含对功能的记述，如下所示。

![Doxygen code documentation example](image)

Doxygen 支持多种排版风格，对于文档中可以包含的细节非常灵活。请参考数据丰富、条理清晰的 Doxygen 手册 熟悉 Doxygen 特性。

为什么需要 Doxygen?

使用 Doxygen 的最终目的是确保所有代码编译风格一致，以便在代码变更时使用 Sphinx 和 Breathe 等工具协助编著、自动更新 API 文档。

使用这类工具时，上文代码渲染后呈现效果如下：

![Rendered Doxygen code example](image)
尝试一下！

在本项目库编写代码文档时，请遵守下列准则。

1. 写明代码的基本内容：函数、结构、类型定义、枚举、宏等。请详细说明代码的用途、功能和限制，因为在阅读他人的文档时你也想看到这些信息。
2. 函数文档需简述该函数的功能，并解释输入参数和返回值的含义。
3. 请不要在参数或除空格外的其他字符前面添加数据类型。所有空格和换行符都会压缩为一个空格。如需换行，请执行换行操作两次。

4. 如果函数没有输入参数或返回值，请跳过@param或@return。
5. 为 `define`, `struct` 和 `enum` 的成员编写文档时，请在每一项后添加注释，如下所示。

```
typedef enum {
    NVS_READONLY, /* <= read only */
    NVS_READWRITE, /* <= read and write */
} nvs_open_mode;
```

6. 请在命令后换行（如下文中的 `@return`），呈现排版精美的列表。

```
* @return
  * - ESP_OK if erase operation was successful
  * - ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL
  * - ESP_ERR_NVS_READ_ONLY if handle was opened as read only
  * - ESP_ERR_NVS_NOT_FOUND if the requested key doesn’t exist
  * - other error codes from the underlying storage driver
```

7. 头文件的功能概览和库文件应当存在同一个项目库之下，放入单独的 README.rst 文件。如果目录下包含不同 API 的头文件，应将文件命名为 apiname-readme.rst。

## 进阶

以下小贴士可以帮助你进一步提高文档质量，增强可读性。

1. 添加代码片段举例说明。请在片段前后添加 `@code(c)` 和 `@endcode` 命令。

```
* @code(c)
* // Example of using nvs_get_i32:
* int32_t max_buffer_size = 4096; // default value
* esp_err_t err = nvs_get_i32(my_handle, "max_buffer_size", &max_buffer_size);
* assert(err == ESP_OK || err == ESP_ERR_NVS_NOT_FOUND);
* // if ESP_ERR_NVS_NOT_FOUND was returned, max_buffer_size will still
* // have its default value.
* @endcode
```

代码片段应放入所介绍功能的注释块中。

2. 使用 `@attention` 或 `@note` 命令高亮显示重要信息。
Chapter 6. Contributions Guide

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. 给相似的函数编写文档时，可在前后使用 /** @/ 和 /** @} */ 标记命令。

```c
/** @} */
/** *
 * @brief common description of similar functions
 *
*/
void first_similar_function (void);
void second_similar_function (void);
/** @} */
```

示例请参照 nvs_flash/include/nvs.h。

4. 如果想跳过重复的宏定义、枚举项等代码，不添加描述，请在代码前后添加 /** @cond */ 和 /** @endcond */ 命令。示例请参照 driver/include/driver/gpio.h。

5. 使用 markdown 增强文档可读性，添加页眉、链接、表格及更多内容。

```markdown
* [ESP32 技术参考手册](https://www.espressif.com/sites/default/files/documentation/esp32_technical_reference_manual_cn.pdf)
```

### 注解：
代码片段、注释、链接等内容如没有附在所述对象对应的注释块中，将不会添加到文档中。

6. 准备一个或更多完整的代码示例和描述，将描述放入单独的 README.md 文件中，置于 examples 目录的特定文件夹中。

### 链接到示例

链接到 GitHub 上的示例时，请不要使用绝对 URLS 或硬编码 URLS。请使用 Docutils 自定义角色生成链接。自动生成的链接指向项目库中 git commit 标号 (或标记) 的 tree 或 blob。这种做法可以确保 master 分支上的文件移动或删除时，链接不会失效。Docutils 自定义角色将由透明的方式处理子模块中的文件，并使用正确的 commit ID 链接到子模块目录中。

有如下角色可以选择：

- `:idf:` - 指向 ESP-IDF 内的目录
- `:idf_file:` - 指向 ESP-IDF 内的文件
- `:idf_raw:` - 指向 ESP-IDF 内的原始格式文件
- `:component:` - 指向 ESP-IDF components 内的文件夹
- `:component_file:` - 指向 ESP-IDF components 内的原始格式文件
- `:example:` - 指向 ESP-IDF examples 内的文件夹
- `:example_file:` - 指向 ESP-IDF examples 内的原始格式文件
- `:example_raw:` - 指向 inside ESP-IDF examples 内的原始格式文件

示例：

```markdown
* :example:`get-started/hello_world`
* :example:`Hello World! <get-started/hello_world>`
```

渲染效果：

- get-started/hello_world
<p>• Hello World!</p>

CI build 脚本中添加了检查功能，查找 RST 文件中的硬编码链接（通过 URL 的 tree/master，blob/master 或 raw/master 部分识别）。该功能可通过 cd docs 和 make gh-linkcheck 命令手动运行。

### 链接到其他语言文档

要切换不同语言的文档，可使用 :link_to_translation: 自定义角色。文档页面中的角色提供其他语言版本的链接。下文的例子说明了如何在文档中添加中英文版本的链接:

```reST
:link_to_translation:`zh_CN: 中文版`
:link_to_translation:`en:English`
```

语言用 en 或 zh_CN 等标准简写表示。最后一个分号后的文本非标准化内容，可根据链接的位置自行输入，如:

```reST
:link_to_translation:`en:see description in English`
```

### 添加图例

请考虑使用图表和图片解释表达的概念。

相比于长篇的表述，图例有时可以更好地描述复杂的理念、数据结构或算法。本项目库使用 blockdiag 工具自简单文本文件生成图表。

工具包支持下列图表类型:

- 框图
- 时序图
- 活动图
- 逻辑网络图

使用该工具包，可以将简单的文本（与 graphviz 的 DOT 格式类似）转换成美观的图片。图中内容自动排版。图示代码之后会转换为 “.png” 图片，在后台添加进 Sphinx 文档中。

要查看图表的渲染效果，可使用线上的 interactive shell 即时显示生成的图片。

下面是一些图示示例:

- 简单的 框图 / blockdiag - Wi-Fi Buffer 配置
- 稍复杂 框图 - Wi-Fi 编程模型
- 时序图 / seqdiag - 在所有信道中扫描特定 AP
- 包图 / packetdiag - NVS 页面结构

尝试修改源代码，看看图表会发生什么变化。

### 注解：interactive shell 使用的字体和 esp-idf 文档使用的字体略有不同。

### 添加注释

写文档时，您可能需要:

- 留下建议，说明之后需添加会修改哪些内容。
- 提醒自己或其他人跟进。

这时，您可以使用 ".. todo::" 命令在 reST 文件中添加待做事项。如:

```reST
.. todo::
   Add a package diagram.
```

Submit Document Feedback
如果在 reST 文件中添加 .. todolist:: 命令，整篇文档中的所有待做事项将会罗列成表。
默认情况下，文档生成器会忽视 .. todo:: 和 .. todolist:: 命令。如果您想在本地生成的文档中显示注释和注释列表，请执行下列步骤：
1. 打开本地的 conf_common.py 文件。
2. 找到 todo_include_todos 参数。
3. 将该参数的值由 False 改为 True。
将改动推送到远端分支之前，请把 todo_include_todos 的值重置为 False。
更多关于扩展的信息，请参阅 sphinx.ext.todo 的相关文档。

为不同芯片书写通用文档

乐鑫各芯片的文档是基于现有文档完成的。为提高文档写作效率，使所写文档可重复用于其它芯片（以下称 “目标”）文档中，我们为您提供以下功能：

依据目标类型排除内容
有时会出现某一内容只适用于一个目标的情况。这种情况下，你可以使用 .. only:: TAG’ 指令将这部分内容设为某个目标的专属内容，’TAG’ 处替换为以下名称：
芯片名称：
• esp32
• esp32s2
从 ‘sdkconfig.h’ 中定义标识符，标识符由目标的默认 menuconfig 设置生成，例如：
• CONFIG_FREERTOS_UNICORE
从 soc ‘*_caps’ 头文件中定义标识符，例如：
• SOC_BT_SUPPORTED
• SOC_CAN_SUPPORTED
示例：
```
.. only:: esp32
   ESP32 specific content.
```
该指令也支持布尔逻辑操作符 ‘and’, ‘or’ 和 ‘not’。
示例：
```
.. only:: SOC_BT_SUPPORTED and CONFIG_FREERTOS_UNICORE
   BT specific content only relevant for single-core targets.
```
该功能由 Sphinx selective exclude 的扩展提供。
这个扩展有一个缺点，当你想要排除某个章节时，而这个章节后直接跟着一个加了标签的新章节，此时该功能无法成功操作。这种情况下，章节的标签将无法正确链接到下一节，但其它内容都可正确渲染。如遇这一情况，可暂时使用以下应急方法：
```
.. only:: esp32
   .. _section_1_label:
   Section 1
   ~~~~~~~~~~
   Section one content
```

Section 2 content

生成文档时，Sphinx 会使用上述提到的指令和角色，根据其被调用的目标标签来添加或排除某些内容。

**注释：** 如希望根据目标的标签从 toctree 中排除一个文档，则需同时更新 docs/conf_common.py 中的 exclude_patterns 列表，为其它目标排除该文档。否则，Sphinx 将发出一条错误警报：WARNING: document isn’t included in any toctree。

**对此推荐的解决方案是：** 将这个文档添加到 docs/conf_common.py conditional_include_dict 中的一个列表里，例如，一个仅供支持蓝牙的目标可见的文档应被添加至 BT_DOCS。此后，如果该文档未设置对应的标签，则 docs/idf_extensions.exclude_docs.py 会将其添加至 exclude_patterns。

如果你需要从一个列表或项目符号条目中排除某一项内容，应通过在 ‘.. list:: ’ 指令中使用 ‘:TAG:’ 角色来完成。

```rst
.. list::
   :esp32: - ESP32 specific content
   :SOC_BT_SUPPORTED: - BT specific content
   - Common bullet point
   - Also common bullet point
```

**替代宏** 如果你需要指向根据目标类型定义的芯片名称、工具链名称、路径名称或其它通用名称，可以选择使用 docs/idf_extensions/format_idf_target.py 提供的替代宏。

例如，以下 reStructuredText 内容：

```rst
This is a {IDF_TARGET_NAME}, with /{IDF_TARGET_PATH_NAME}/soc.c, compiled with xtensa-{IDF_TARGET_TOOLCHAIN_NAME}-elf-gcc with CONFIG_{IDF_TARGET_CFG_PREFIX}_MULTI_DOC
```

将在文档中渲染为：

```rst
This is a ESP32, with /esp32/soc.c, compiled with xtensa-esp32-elf-gcc with CONFIG_ESP32_MULTI_DOC
```

这一扩展也支持定义本地（在单个源文件中）替代名称的标记。请在 RST 文件的一行中插入下示定义语言:

```rst
{IDF_TARGET_SUFFIX:default="DEFAULT_VALUE",esp32="ESP32_VALUE",esp32s2="ESP32S2_VALUE"}
```

这样将在当前的 RST 文件中根据目标类型为 {IDF_TARGET_SUFFIX} 标签定义一个替代名称。例如:

```rst
{IDF_TARGET_TX_PIN:default="IO3",esp32="IO4",esp32s2="IO5"}
上例将为 `{IDF_TARGET_TX_PIN}` 标签定义一个替代名称，当使用 esp32s2 标签调用 sphinx 时，`{IDF_TARGET_TX_PIN}` 将被替代为“IOS”。

**注解**：这样的单个文档定义指令可置于.rst 文档中的任意位置（单独一行），指令名须以 IDF_TARGET_ 为开头。

**汇总文档**

文档准备好后，请参照 API Documentation Template 的要求创建一个文件，汇总所有准备好的文档。最后，
在文件中添加链接指向 /docs 文件夹或子文件夹下 index.rst 文件的 .. toctree::。

**Sphinx 手新怎么办**

1. 不要担心。所有需要的软件均有详细文档，并且开源、免费。您可以先查看 Sphinx 文档。如果您不清楚如何用 rst markup 语言写作，请查看 reStructuredText Primer。您也可以使用 markdown (.md) 文件，查找更多在 Recommonmark parser’ 文档页面 使用的特定 markdown 句法信息。
2. 查看本文档的源文件，了解文档使用的代码。源文件存储于 GitHub espressif/esp-idf 项目库的 docs 文件夹下。您可以滑动到页面上方，点击右上角的链接，直接查看本页面的源文件。您也可以通过点击 Raw 按键打开源文件，在 GitHub 上查看文件的代码。
3. 想要查看在上传至 GitHub 前文档如何生成、呈现，有两种方式：
   - 安装 ‘Sphinx’、Breathe、Blockdiag 和 Doxygen 本地生成文档，具体可查看下文。
   - 在 Read the Docs 建立账号，可云端生成文档。Read the Docs 免费提供文档生成和存储，且速度快、质量高。
4. 在生成文档前预览，可使用 Sublime Text 编辑器和 OmniMarkupPreviewer 插件。

**搭建环境本地生成文档**

**安装依赖项** 您可以安装下列包，通过搭建环境在电脑上本地生成文档：

1. Doxygen - http://doxygen.nl/

添加“sphinx_idf_theme”包之后，文档将与 ESP- IDF 编程指南 的风格保持一致。

不用担心需要安装太多包。除 Doxygen 之外，其他包均使用纯 Python 语言，可一键安装。

**重要**：目前仅支持 Python 3 版本生成文档，无法使用 Python 2。

**Doxygen** Doxygen 的安装取决于操作系统：

**Linux**

```bash
sudo apt-get install doxygen
```

**Windows - 在 MSYS2 控制台中安装**

```bash
pacman -S doxygen
```

**MacOS**
### 注解：
如果您是在 Windows MSYS2 系统上安装（Linux 和 MacOS 用户可以跳过此说明，不使用 MSYS2 的 Windows 用户需找到其它可替代系统），在安装之前，请完成以下步骤。这是安装 [添加图例](#) 提到的 “blockdiag” 依赖项的必须步骤。
1. 更新所有系统包：
   ```bash
   $ pacman -Syu
   ```
   
   该过程可能需要重启 MSYS2 MINGW32 控制台并重复上述命令，直至更新完成。
2. 安装 blockdiag 的依赖项之 pillow：
   ```bash
   $ pacman -S mingw32/mingw-w64-i686-python-pillow
   ```
   
   查看屏幕上的记录，确定 mingw-w64-i686-python-pillow-4.3.0-1 或更新的版本已安装。

Windows 安装 Doxygen 的缺点是 blockdiag pictures 字体不能正确加载，可能会存在乱码。在此问题解决之前，您可以使用 interactive shell 查看完整图片。

### 其它应用:
其他所有应用都是 Python 包。可以按照下列步骤一键安装：
```bash
cd ~/esp/esp-idf/docs
pip install --user -r requirements.txt
```

### 注解：
安装步骤设定将 ESP-IDF 放在 ~/esp/esp-idf 目录下，这是文档中使用的 ESP-IDF 默认地址。

#### 生成文档
```bash
cd ~/esp/esp-idf/docs
./build_docs.py build
```

运行该命令后，系统将为 ESP-IDF 中所有可支持的语言和目标生成文档。这一过程将需要一些时间。但各文档会并行进行，速度取决于系统中 CPU 内核的个数（可通过 --sphinx-parallel-builds 选项修改该进程，详情可见 ./build_docs.py --help）。

如需生成某一语言的单个文档，运行：
```bash
./build_docs.py -l en -t esp32 build
```

其中，语言(-l) 可选择 en 和 zh_CN；目标(-t) 可选 ESP-IDF 中任意可支持的构建目标（如 esp32 和 esp32s2）。

生成后的文档将位于 _build/<language>/<target>/html 文件夹中。如需查阅，请在网页浏览器中打开该目录里的 index.html。

#### 生成文档子集
生成整个文档可能速度较慢。因此，也可以选择只生成你所需的某个子集。
在指令中列出你需要生成的文档名称即可：
```bash
./build_docs.py -l en -t esp32 -i api-reference/peripherals/can.rst build
```

也可以同时生成多个文档：

---

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**1700**  
**Release v4.3-dev-1561-g357a277603**

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Chapter 6. Contributions Guide

```bash
./build_docs.py -l en -t esp32 -i api-reference/peripherals/can.rst api-reference/peripherals/adc.rst build
```

还可以生成通用文档:

```bash
./build_docs.py -l en -t esp32 -i api-reference/peripherals/* build
```

请注意，这一功能仅用于生成文档过程中检查和测试。其生成的 HTML 页面并非渲染完成后的格式，比如，运行这一指令并不会生成一个列有所有文档的索引，而且如果其中涉及到任何尚未生成的文档参考都将导致错误警告出现。

生成 PDF 可以使用 `build_docs.py` 生成文档的 latex 和 PDF 格式，需安装以下 latex 工具包:

- latex
- texlive-latex-recommended
- texlive-fonts-recommended
- texlive-xetex

同时，也需要安装以下字体:

- Freefont Serif、Sans 和 Mono OpenType fonts，类似于 Ubuntu 上的 fonts-freefont-otf 包
- Lmodern，类似于 Ubuntu 上的 fonts-lmodern 包
- Fandol，可从这里下载

现在，可通过以下指令生成文档的 PDF 格式:

```bash
./build_docs.py -bs latex -l en -t esp32 build
```

或者，也可以同时生成 html 和 PDF 格式:

```bash
./build_docs.py -bs html latex -l en -t esp32 build
```

Latex 和 PDF 文件将位于 `_build/<language>/<target>/latex` 文件夹中。

大功告成

我们喜欢可以做酷炫事情的好代码。但我们更喜欢有清晰文档的好代码，可以让读者快速上手，做酷炫的事情。

尝试一下，贡献你的代码和文档！

相关文档

- API Documentation Template
- 文档的附加工具和扩展功能指南

6.5.3 文档的附加工具和扩展功能指南

ESP-IDF 文档由 Sphinx 应用程序生成。使用 Sphinx 对 `docs` 目录中的 reStructuredText (.rst) 格式文档进行渲染。有关渲染过程的详细信息，请参阅编写代码文档。

除 Sphinx 外，我们也使用了其它几种可为用户提供格式精美、便于查找的文档的应用程序。搭建环境本地生成文档中列出了这些应用程序，`docs/requirements.txt` 中列出了其相应的版本号。

ESP-IDF 中包含多种芯片的双语文档（英文，简体中文）。如运行 Sphinx，不需直接使用 sphinx，可运行 Python 程序包 `build_docs.py`。

在此基础上，我们也开发了一些自定义的附加工具和扩展功能，旨在帮助整合 ESP-IDF 目录下的各个文档以及更好地查找和维护文档内容。
文件夹结构

- ESP-IDF 根目录下包含一个专门放置文档的文件夹 docs。
- docs 目录下的 docs/en（英文）和 docs/zh_CN（简体中文）子文件夹中包含本地化文档。
- 图像文件和本地化文档通用的字体包位于 docs/_static 子文件夹中。
- docs 根目录下以及 docs/en 和 docs/zh_CN 中的其它文件则提供了自动生成文档过程中所使用的配置和脚本，其中就包括本章节提到的附加工具和扩展功能。
- extensions 和 idf_extensions 两目录中提供了 Sphinx 的扩展功能。
- 使用 build_docs.py，docs 文件夹中将自动创建一个 _build 目录。这个目录不会被添加到 ESP-IDF 项目库中。

附加工具和扩展功能指南

配置文件

docs/conf_common.py 该文件中包含每个本地化文档（包括英文文档、中文文档）所通用的配置信息。在文档每一次的构建过程中，该文件中的内容都将被导入至相应语言文件夹（包括，docs/en, docs/zh_CN）下的标准 Sphinx 配置文件 conf.py 中。

docs/sphinx-known-warnings.txt Sphinx 中存在一些伪错误警报，这些警报只能通过更新 Sphinx 源代码本身来解决。针对这一情况，我们将这些伪错误警报列在了 sphinx-known-warnings.txt 文件中，每一次生成文档时系统都将检测该文件并忽略这些伪错误警报。

脚本

docs/build_docs.py 最高级可执行程序，负责运行 Sphinx 为单个或多个语言/目标生成文档。运行 build_docs.py --help 可查阅所有命令选项。

当使用 build_docs.py 运行 Sphinx 时，系统将为 idf_target 配置变量，并设置一个与该配置变量相同名称的 Sphinx 标签，然后使用一些环境变量将路径发送至 IDF 专属扩展。

docs/check_lang_folder_sync.sh 同时更新双语文档时，语言文件夹 docs/en 和 docs/zh_CN 下的文档结构和文件名应保持一致，以减少两文档间的不一致。每一次生成文档时都将运行 check_lang_folder_sync.sh 脚本，检测是否出现上述不一致的情况。

注解：若一个新的章节为英语版本，且暂时还没有中文翻译，那么 zh_CN 文件夹中相应的中文文件内应写入 .. include:: 指令，路径指向英文源文件。这样，中文读者将也可以看到英文版本源文件。例如，如果 docs/zh_CN/contribute/documenting-code.rst 这一文件还没有中文翻译，则该文件中应写入 .. include:: ../en/contribute/documenting-code.rst。

非文档脚本  以下脚本除了生成文档之外，也可以用于其它用途：

tools/genEspErrToName.py 该脚本将检测整个 ESP-IDF 库，在源代码文件中查找是否有错误代码和信息，然后在 Error Codes Reference 内生成一个 .inc 文件记录这些信息。

tools/kconfig_new/confgen.py ESP-IDF components 的配置选项包含在每个部件目录下的 Kconfig 文件中，如 components/bit/Kconfig。该脚本将检测所有 component 目录并记录检测到的配置选项，然后在 Configuration Options Reference 内生成一个 .inc 文件记录这些信息。

泛型扩展  以下是专为 IDF 开发的 Sphinx 扩展。这些扩展不依赖于任何特定的 IDF 文档操作或配置：

docs/extensions/toctree_filter.py Sphinx 扩展功能，优先于 :toctree: 指令，允许系统根据是否有标签（如 :tagname: toctree_entry）来过滤条目。完整描述请参考 Python 文件。

docs/extensions/list_filter.py Sphinx 扩展功能，提供一个 .. list:: 指令，允许系统根据是否有标签（如 :tagname: - list content）来过滤条目列表。完整描述请参考 Python 文件。
docs/extensions/html_redirects.py 在文档的维护过程中，一些源文件可能会转移位置或被重命名。这个 Sphinx 扩展功能便添加了一个重新指向机制，通过在 Sphinx 输出中生成静态 HTML 重新指向页面来为 URL 地址已改变的文档重新指向。该脚本与重新指向列表 html_redirect_pages 一起使用。conf_common.py 将负责从 docs/page_redirects.txt 中生成这个重新指向列表。

### 第三方扩展
- sphinxcontrib 为 blockdiag, seqdiag, actdiag, nwdiag, rackdiag & packetdiag 等图表的扩展
- Sphinx selective exclude 为 eager_only 的扩展

### IDF 专属扩展

#### 构建系统集成
docs/idf_extensions/build_system/
Python 包实现了一个 Sphinx 扩展功能，即将 IDF 构建系统信息拉入文档构建中
- 创建一个 CMake IDF 项目模板，并运行 CMake 生成元数据。
- 注册一些新的配置变量并生成一个 Sphinx 新事件，这些信息都用于其它扩展功能中。

#### 配置变量
- docs_root - SIDF_PATH/docs 目录的绝对路径
- idf_path - IDF_PATH 变量的值，未设置环境下为 IDF_PATH 的绝对路径
- build_dir - 运行 build_docs.py 时自动创建的文档目录，默认为 _build/<lang>/
- <target>
- idf_target - IDF_TARGET 的值。build_docs.py 应负责在 Sphinx 命令行中设置该值。

#### 新事件
CMake 项目模型运行完成后，系统将在构建初期发出 idf-info 事件。

参数为 (app, project_description)，其中 project_description 是一个字典，其中包含从 CMake 构建目录中的 project_description.json 内解析出的值。

其它 IDF 专属的扩展功能均订阅该事件，并使用该事件根据系统构建信息来设置一些文档参数。

#### 其它扩展
docs/extensions/include_build_file.py include-build-file 指令相当于是内置的 include-file 指令，只是文件路径是相对于 build_dir 来评估的。
docs/extensions/kconfig_reference.py 订阅 idf-info 事件，并使用 config 从默认构建项目所使用的部件中生成 kconfig.inc 文件，之后，这个文件将被存储至 Project Configuration 中。
docs/extensions/link_roles.py 一个自定义的 Sphinx 角色 的实现功能，帮助从文档链接到 ESP-IDF 项目中具体的文件和文件夹处。有关具体实现了哪些角色，请参阅链接到示例 和链接到其他语言文档。
docs/extensions/esp_err_definitions.py 小扩展包，调用 gen_esp_err_to_name.py 并更新修改后的 rst 文件。
docs/extensions/gen_toolchain_links.py 文档内许多地方提供了下载工具链的链接。为了整合这些链接，减少需要分别手动更新这些链接的时间，该脚本会根据 tools/toolchain_versions.mk 内的信息生成工具链下载链接和工具链解压代码片段。
docs/extensions/gen_version_specific_includes.py 也是一个自动生成 reStructuredText 文本 .inc 的扩展功能，其中内容是基于当前 ESP-IDF 版本所写。
docs/extensions/util.py 提供一系列实用功能，主要提高本地化生成文档（请参见搭建环境本地生成文档）的效率，节省后续再次生成文档所需时间。
docs/extensions/format_idf_target.py 通过将 idf_target 发送至 Sphinx 命令行替换 target 相关名称的扩展功能。例如:

```
This is a [IDF_TARGET_NAME], with /{IDF_TARGET_PATH_NAME}/soc.c, 
compiled with xtensa-{IDF_TARGET_TOOLCHAIN_NAME}-elf-gcc with CON
FIG_{IDF_TARGET_CFG_PREFIX}_MULTI_DOC
```
Chapter 6. Contributions Guide

删除退格键后, 将被渲染为

This is a ESP32, with /esp32/soc.c, compiled with xtensa-esp32-elf-gcc with CON-
FIG_ESP32_MULTI_DOC.

同时，也支持使用以下语法标记本地（单个 rst 文件）替代文件的定义:
{ IDF_TARGET_TX_PIN:default=" IO3" , esp32=" IO4" , esp32s=" IO5" }

这样将在当前的 rst 文件中定义的标签 (IDF_TARGET_TX_PIN) 的替换名称。

为了使用相同的格式规则规范文档内容，该扩展功能优先于默认的 .. include:: 指令。

在依赖于字符排版的格式内无法使用这一替换方式，例如，表格内。

docs/idf_extensions/latex_builder.py 一个在 latex 生成器内添加 ESP-IDF 专有的功能的扩展，优先于默认的 Sphinx latex 生成器。

在输出目录内创建并添加 espidf.sty latex 包，其中包含一些运行时所需变量的宏包，如 IDF-Target。

docs/idf_extensions/gen_defines.py Sphinx 扩展，将 IDF 中的定义整合入 Sphinx 构建过程中，在 IDF 项目模型创建完成后开始运行。

解析这些定义值，并将其添加为 Sphinx 标签。

发出新的 ‘idf-define-generated’ 事件，其中有一个包含所有原始定义值的字典，其它扩展功能可以使用这些原始值生成相关数据。

docs/idf_extensions/exclude_docs.py Sphinx 扩展，根据 conditional_include_dict [tag/documents] 标签更新已被排除的文档。如果文档设置有这个标签，则其将被添加至文档列表内。

同时也负责在使用 config 值 docs_to_build 生成文档时，排除不相关文档。此时，未在 docs_to_build 列表内的文档都将被排除。

订阅 idf-define-generated 事件，因为该扩展功能需要根据 Sphinx 标签来决定需排除哪些文档。

docs/idf_extensions/run_doxygen.py 订阅 idf-define-generated 事件，运行 Doxygen (docs/Doxyfile) 生成描述密钥头文件的 XML 文件，然后运行 Breathe 将这些文件转换为可直接被添加至 API 参考页面的 .inc 文件。

将一些特定目标的自定义环境变量推入 Doxygen 中，包括项目的默认 sdkconfig.h 文件内定义的包含包以及 soc 部件 xxx_caps.h 头文件中定义的所有宏包。这意味着，公共 API 头文件可以依赖于特定目标的配置选项或者 soc 功能头文件选项。如头文件中 #ifdef & #if 预处理器选项。

也就是说，我们可以根据生成文档的目标来生成不同的 Doxygen 文件。

有关这一流程的更多信息，请参考编写代码文档和 API Documentation Template 中的 API 参考章节。

相关文档

- 编写代码文档

6.5.4 创建示例项目

每个 ESP-IDF 的示例都是一个完整的项目，其他人可以将示例复制到本地，并根据实际情况进行一定修改。请注意，示例项目主要是为了展示 ESP-IDF 的功能。

示例项目结构

- main 目录需要包含一个名为 (something)_example_main.c 的源文件，里面包含示例项目的主功能。
- 如果示例项目的目标任务比较多，请根据逻辑将其拆分为 main 目录下的多个 C 或者 C++ 源文件，并将对应的头文件也放在同一目录下。
- 如果示例项目具有多种功能，可以考虑在项目中增加一个 components 子目录，通过库功能，将示例项目的不同功能划分为不同的组件。注意，如果该组件提供的功能相对完整，且具有一定的通用性，则应该将它们添加到 ESP-IDF 的 components 目录中，使其成为 ESP-IDF 的一部分。
- 示例项目需要包含一个 README.md 文件，建议使用 示例项目 README 模板，并根据项目实际情况进行修改。
- 示例项目需要包含一个 example_test.py 文件，用于进行自动化测试。如果在 GitHub 上初次提交 Pull Request 时，可以先不包含这个脚本文件。具体细节，请见有关 Pull Request 的相关内容。
一般准则
示例代码需要遵循《乐鑫物联网开发框架风格指南》。

检查清单
提交一个新的示例项目之前，需要检查以下内容：
- 示例项目的名字（包括 Makefile 和 README.md 中）应使用 example，而不要写“demo”，“test”等词汇。
- 每个示例项目只能有一个主要功能。如果某个示例项目有多个主要功能，请将其拆分为两个或更多示例项目。
- 每个示例项目应包含一个 README.md 文件。建议使用示例项目 README 模板。
- 示例项目中的函数和变量的命名要遵循命名规范中的要求。对于仅在示例项目源文件中使用的非静态变量/函数，请使用 example 或其他类似的前缀。
- 示例项目中的所有代码结构良好，关键代码要有详细注释。
- 示例项目中所有不必要的代码（如调试日志，注释掉的代码等）都必须清除掉。
- 示例项目中使用的选项（如网络名称，地址等）不得直接硬编码，应尽可能地使用配置项，或者定义为宏或常量。
- 配置项可见 KConfig.projbuild 文件。该文件中包含一个名为“Example Configuration”的菜单。具体情况下，请查看现有示例项目。
- 所有的源代码都需要在文件开头指定许可信息（表示该代码是 in the public domain CC0）和免责声明。或者，源代码也可以应用 Apache License 2.0 许可条款。请查看现有示例项目的许可信息和免责声明，并根据实际情况进行修改。
- 任何第三方代码（无论是直接使用，还是进行了一些改进）均应保留原始代码中的许可信息，这些代码的许可必须兼容 Apache License 2.0 协议。

6.5.5 API Documentation Template

注解：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

注解：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

**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

**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 docs/idf_extensions/run_doxygen.py for all header files listed in the INPUT statement of docs/Doxyfile.
3. Each line of the INPUT statement (other than a comment that begins with ##) contains a path to header file *.h that will be used to generate corresponding *.inc files:

```
## Wi-Fi - API Reference
../components/esp32/include/esp_wifi.h \
../components/esp32/include/esp_smartconfig.h \
```

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.
1. 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.
1. To show contents of *.inc file in documentation, include it as follows:

```
.. include-build-file:: inc/esp_wifi.inc
```

For example see docs/en/api-reference/network/esp_wifi.rst

1. Optionally, rather that using *.inc files, you may want to describe API in you 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 .. doxygenuion:: name_of_union
   • Structures .. doxygenstruct:: name_of_structure together with :members:
   • Macros .. doxygendefine:: name_of_define
   • Type Definitions .. doxygentypedef:: name_of_type
   • Enumerations .. doxygenerenum:: name_of_enumeration
   See Breathe documentation for additional information.
   To provide a link to header file, use the link custom role as follows:
1. In any case, to generate API reference, the file `docs/Doxyfile` should be updated with paths to *.h headers that are being documented.

1. When changes are committed and documentation is built, check how this section has been rendered. Correct annotations in respective header files, if required.

### 6.5.6 Contributor Agreement

**Individual Contributor Non-Exclusive License Agreement**

including the Traditional Patent License OPTION

Thank you for your interest in contributing to Espressif IoT Development Framework (esp-idf) ( “We” or “Us” ). The purpose of this contributor agreement ( “Agreement” ) is to clarify and document the rights granted by contributors to Us. To make this document effective, please follow the instructions at `CONTRIBUTING.rst`

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   “Submission Date” means the date You Submit a Contribution to Us.

   “Documentation” means any non-software portion of a Contribution.

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7. Term  7.1 This Agreement shall come into effect upon Your acceptance of the terms and conditions.

7.2 In the event of a termination of this Agreement Sections 4, 5, 6, 7 and 8 shall survive such termination and shall remain in full force thereafter. For the avoidance of doubt, Contributions that are already licensed under a free and open source license at the date of the termination shall remain in full force after the termination of this Agreement.

8. Miscellaneous  8.1 This Agreement and all disputes, claims, actions, suits or other proceedings arising out of this agreement or relating in any way to it shall be governed by the laws of People’s Republic of China excluding its private international law provisions.

8.2 This Agreement sets out the entire agreement between You and Us for Your Contributions to Us and overrides all other agreements or understandings.

8.3 If any provision of this Agreement is found void and unenforceable, such provision will be replaced to the extent possible with a provision that comes closest to the meaning of the original provision and that is enforceable. The terms and conditions set forth in this Agreement shall apply notwithstanding any failure of essential purpose of this Agreement or any limited remedy to the maximum extent possible under law.

8.4 You agree to notify Us of any facts or circumstances of which you become aware that would make this Agreement inaccurate in any respect.
Chapter 6. Contributions Guide

You

<table>
<thead>
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<th>Date:</th>
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<tbody>
<tr>
<td>Name:</td>
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</tbody>
</table>
Chapter 7

ESP-IDF 版本简介

ESP-IDF 的 GitHub 仓库时常更新，特别是用于开发新特性的 master 分支。如有量产需求，请使用稳定版本。

7.1 发布版本

您可以通过以下链接访问各个版本的配套文档:


ESP-IDF 在 GitHub 平台上的完整发布历史请见 发布说明页面。您可以在该页面查看各个版本的发布说明、配套文档及相应获取方式。

此外，您还可以直接前往文档页面，查看部分 ESP-IDF 版本的配套文档。具体可通过点击页面左下角的小三角标志，在不同版本间切换。
7.2 我该选择哪个版本？

- 如有量产需求，请使用 最新稳定版本。稳定版本已通过人工测试，后续更新仅修复 bug，主要特性不受影响（更多详情，请见 版本管理）。请访问 发布说明页面 界面查看每一个稳定发布版本。
- 如需尝试/测试 ESP-IDF 的最新特性，请使用 最新版本 (在 master 分支上)。最新版本包含 ESP-IDF 的所有最新特性，已通过自动化测试，但尚未全部完成人工测试（因此存在一定风险）。
- 如需使用稳定版本中没有的新特性，但同时又不希望受到 master 分支更新的影响，您可以将一个最适合您的稳定版本 更新至一个预发布版本 或更新至一个发布分支。

有关如何更新 ESP-IDF 本地副本的内容，请参考 更新 ESP-IDF 章节。

7.3 版本管理

ESP-IDF 采用了 语义版本管理方法，即您可以从字面含义理解每个版本的差异。其中

- 主要版本（例 v3.0）代表有重大更新，包括增加新特性、改变现有特性及移除已弃用的特性。
- 升级至一个新的主要版本（例 v2.1 升级至 v3.0）意味着您可能需要更新您的工程代码，并重新测试您的工程，具体可参考 发布说明页面 的重大变更 (Breaking Change) 部分。
- 次要版本（例 v3.1）代表有新增特性和 bug 修复，但现有特性不受影响，公开 API 的使用也不受影响。
升级至一个新的次要版本（例 v3.0 升级至 v3.1）意味着您可能不需要更新您的工程代码，但需重新测试您的工程，特别是发布说明页面中专门提到的部分。

- **Bugfix** 版本（例 v3.0.1）仅修复 bug，并不增加任何新特性。
  升级至一个新的 Bugfix 版本（例 v3.0 升级至 v3.0.1）意味着您不需要更新您的工程代码，仅需测试与本次发布修复 bug（列表见发布说明页面）直接相关的特性。

### 7.4 支持期限

ESP-IDF 的每个主要版本和次要版本都有相应的支持期限。支持期限满后，版本停止更新维护，将不再支持。

**支持期限政策** 对此有具体描述，并介绍了每个版本的支持期限是如何界定的。

**发布说明页面** 界面上的每一个发布版本都提供了该版本的支持期限信息。

一般而言：

- 如您刚开始一个新项目，建议使用最新稳定版本。
- 如您有 GitHub 账号，请点击发布说明页面界面右上角的“Watch”按钮，并选中“Releases only”选项。GitHub 将会在新版本发布的时候通知您。当您所使用的版本有 bugfix 版本发布时，请做好升级至该 bugfix 版本的规划。
- 如可能，请定期（如每年一次）将项目的 IDF 版本升级至一个新的主要版本或次要版本。对于小版本更新，更新过程应该比较简单，但对于主要版本更新，可能需要细致查看发布说明并做对应的更新规则。
- 请确保您所使用的版本停止更新维护前，已做好升级至新版本的规划。

### 7.5 查看当前版本

查看 ESP-IDF 本地副本的版本，请使用 idf.py 命令:

```
idf.py --version
```

此外，由于 ESP-IDF 的版本也已编译至固件中，因此您也可以使用宏 IDF_VER 查看 ESP-IDF 的版本（以字符串的格式）。ESP-IDF 默认引导程序会在设备启动时打印 ESP-IDF 的版本。请注意，在 GitHub 仓库中的代码更新时，代码中的版本信息仅会在源代码重新编译或在清除编译时才会更新，因此打印出来的版本可能并不是最新的。

几个 ESP-IDF 版本的例子:
### 版本字符串

<table>
<thead>
<tr>
<th>版本字符串</th>
<th>含义</th>
</tr>
</thead>
</table>
| v3.2-dev-306-gbeb3611ca | master 分支上的预发布版本。  
- `v3.2-dev`: 为 v3.2 进行的开发。  
- `306`: v3.2 开发启动后的 commit 数量。  
- `gbeb3611ca`: commit 标识符。 |
| v3.0.2 | 稳定版本，标签为 v3.0.2。 |
| v3.1-beta1-75-g346d6b0ea | v3.1 的 beta 测试版本（可参考更新至一个发布分支）。  
- `v3.1-beta1`: 预发布标签。  
- `75`: 添加预发布 beta 标签后的 commit 数量。  
- `g346d6b0ea`: commit 标识符。 |
| v3.0.1-dirty | 稳定版本，标签为 v3.0.1。  
- `dirty` 代表 ESP-IDF 的本地副本有修改。 |

### 7.6 Git 工作流

乐鑫 ESP-IDF 团队的 (Git) 开发工作流程如下：

- 新的改动总是在 master 分支（最新版本）上进行。master 分支上的 ESP-IDF 版本总带有 -dev 标签，表示“正在开发中”。例 v3.1-dev。
- 这些改动将首先在乐鑫的内部 Git 仓库进行代码审阅与测试，而后在自动化测试完成后推至 GitHub。
- 新版本一旦完成特性开发（在 master 分支上进行）并达到进入 beta 测试的标准，则将该版本签出至一个新分支（例 release/v3.1）。此外，该分支还打上预发布标签（例 v3.1-beta1）。您可以在 GitHub 平台上查看 ESP-IDF 的完整 分支列表 和 标签列表。Beta 预发布版本可能仍存在大量“已知问题”(Known Issue)。
- 随着对 beta 版本的不断测试，bug 修复将同时增加至该发布分支和 master 分支。而且，master 分支可能也已经开始为下个版本开发新特性了。
- 当测试快结束时，该发布分支上将增加一个 re 标签，代表候选发布 (Release Candidate)，例 v3.1-rc1。此时，该分支仍属于预发布版本。
- 如果一直未发现或报告重大 bug，则该预发布版本将最终增加“主要版本”(例 v4.0) 或“次要版本”标记 (例 v3.1.1)，成为正式发布版本，并体现在 发布说明页面。
- 后续，该版本中发现的 bug 都将在该发布分支上进行修复。人工测试完成后，该分支将增加一个 bugfix 版本标签 (例 v3.1.1.1)，并体现在 发布说明页面。

### 7.7 更新 ESP-IDF

请根据您的实际情况，对 ESP-IDF 进行更新。

- 如有量产用途，建议参考更新至一个稳定发布版本。
- 如需测试/研发/尝试最新特性，建议参考更新至 master 分支。
- 两者折衷建议参考更新至一个发布分支。

**注解:** 在参考本指南时，请首先获得 ESP-IDF 的本地副本，具体步骤请参考入门指南中的介绍。
Chapter 7. ESP-IDF 版本简介

7.7.1 更新至一个稳定发布版本

（推荐量产用户）如需更新至一个新的 ESP-IDF 发布版本，请参考以下步骤：

- 请定期查看 发布说明页面，了解最新发布情况。
- 如有新发布的 bugfix 版本（例如 v3.0.1 或 v3.0.2）时，请将新的 bugfix 版本更新至您的 ESP-IDF 目录：

```bash
cd $IDF_PATH
git fetch
git checkout vX.Y.Z
git submodule update --init --recursive
```

- 如有主要版本或次要版本新发布时，请查看发布说明中的具体描述，并决定是否升级您的版本。具体命令与上方描述一致。

**注解：**如果您之前在安装 ESP-IDF 时使用了 zip 文件包，而非通过 Git 命令，则您将无法使用 Git 命令进行版本升级，此属正常情况。这种情况下，请重新下载最新 zip 文件包，并替换掉之前 IDF_PATH 下的全部内容。

7.7.2 更新至一个预发布版本

您也可以将您的本地副本签出（命令 git checkout）至一个预发布版本或 rc 版本，具体方法请参考更新至一个稳定发布版本 的描述。

预发布版本通常不体现在 发布说明页面。更多详情，请查看完整 标签列表。使用预发布版本的注意事项，请参考更新至一个发布分支 中的描述。

7.7.3 更新至 master 分支

**注解：**ESP-IDF 中 master 分支上的代码会时时更新，因此使用 master 分支相当在 “流血的边缘试探”，存在一定风险。

如需使用 ESP-IDF 的 master 分支，请参考以下步骤：

- 本地签出至 master 分支：

```bash
cd $IDF_PATH
git checkout master
git pull
git submodule update --init --recursive
```

- 此外，您还应在后续工作中不定时使用 git pull 命令，将远端 master 上的更新同步到本地。注意，在更新 master 分支后，您可能需要更改旧代码，也可能遇到新的 bug。

- 如需从 master 分支切换至一个发布分支或稳定版本，请使用 git checkout 命令。

**重要：**强烈建议您定期使用 git pull 和 git submodule update --init --recursive 命令，确保本地副本的及时更新。旧的 master 分支相当于一个“快照”，可能存在未记录的问题，且无法获得支持。对于半稳定版本，请参考更新至一个发布分支。

7.7.4 更新至一个发布分支

从稳定性来说，使用“发布分支”相当于在使用 master 分支和稳定版本之间进行折衷，包含一些 master 分支上的新特性，但也同时保证可通过 beta 测试且基本完成了 bug 修复。
更多详情，请前往 GitHub 查看完整 标签列表。

举例，您可以关注 ESP-IDF v3.1 分支，随时关注该分支上的 bugfix 版本发布（例 v3.1.1 等）:

```bash
cd $IDF_PATH
git fetch
git checkout release/v3.1
 git pull
git submodule update --init --recursive
```

您每次在该分支上使用 git pull 时都相当于把最新的 bugfix 版本发布更新至您的本地副本中。

**注解：** 发布分支并不会有关专门的配套文档，建议您使用与本分支最接近的版本。
Chapter 8

资源

8.1 PlatformIO

• What is PlatformIO?
• Installation
• Configuration
• Tutorials
• Project Examples
• Next Steps

8.1.1 What is PlatformIO?

PlatformIO is a cross-platform embedded development environment with out-of-the-box support for ESP-IDF.

Since ESP-IDF support within PlatformIO is not maintained by the Espressif team, please report any issues with PlatformIO directly to its developers in the official PlatformIO repositories.

A detailed overview of the PlatformIO ecosystem and its philosophy can be found in the official PlatformIO documentation.

8.1.2 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
8.1.3 Configuration
Please go through the official PlatformIO configuration guide for ESP-IDF.

8.1.4 Tutorials
- ESP-IDF and ESP32-DevKitC: debugging, unit testing, project analysis

8.1.5 Project Examples
Please check ESP-IDF page in the official PlatformIO documentation

8.1.6 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

8.2 有用的链接
- 您可以在 ESP32 论坛 中提出您的问题，访问社区资源。
- 您可以通过 GitHub 的 Issues 版块提交 bug 或功能请求。在提交新 Issue 之前，请先查看现有的 Issues。
- 您可以在 ESP32 IoT Solution 库中找到基于 ESP-IDF 的解决方案、应用实例、组件和驱动等内容。
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Chapter 9

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Chapter 10

关于本指南

本指南为 乐鑫 公司 ESP32 系列芯片 官方应用开发框架 ESP-IDF 的配套文档。

ESP32 芯片是一款 2.4 GHz Wi-Fi 和蓝牙双模芯片，内置 1 或 2 个 32 位处理器，运算能力最高可达 600 DMIPS。

图 1: 乐鑫物联网综合开发框架

ESP-IDF 即乐鑫物联网开发框架，可为在 Windows、Linux 和 macOS 系统平台上开发 ESP32 应用程序提供工具链、API、组件和工作流的支持。
Chapter 11

Switch Between Languages/切换语言

The ESP-IDF Programming Manual is now available in two languages. Please refer to the English version if there is any discrepancy.

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索引

符号
_ESP_NETIF_SUPPRESS_LEGACY_WARNING_(C 夏), 521
[anonymous] (C++ enum), 58, 266

A
ADC1_CHANNEL_0 (C++ enumerator), 538
ADC1_CHANNEL_0_GPIO_NUM (C 夏), 542
ADC1_CHANNEL_1 (C++ enumerator), 538
ADC1_CHANNEL_1_GPIO_NUM (C 夏), 542
ADC1_CHANNEL_2 (C++ enumerator), 538
ADC1_CHANNEL_2_GPIO_NUM (C 夏), 542
ADC1_CHANNEL_3 (C++ enumerator), 538
ADC1_CHANNEL_3_GPIO_NUM (C 夏), 542
ADC1_CHANNEL_4 (C++ enumerator), 538
ADC1_CHANNEL_4_GPIO_NUM (C 夏), 542
ADC1_CHANNEL_5 (C++ enumerator), 538
ADC1_CHANNEL_5_GPIO_NUM (C 夏), 542
ADC1_CHANNEL_6 (C++ enumerator), 538
ADC1_CHANNEL_6_GPIO_NUM (C 夏), 542
ADC1_CHANNEL_7 (C++ enumerator), 539
ADC1_CHANNEL_7_GPIO_NUM (C 夏), 542
ADC1_CHANNEL_MAX (C++ enumerator), 539
adc1_channel_t (C++ enum), 538
adc1_config_channel_atten (C++ function), 534
adc1_config_width (C++ function), 535
adc1_get_raw (C++ function), 535
ADC1_GPIO32_CHANNEL (C 夏), 542
ADC1_GPIO33_CHANNEL (C 夏), 542
ADC1_GPIO34_CHANNEL (C 夏), 542
ADC1_GPIO35_CHANNEL (C 夏), 542
ADC1_GPIO36_CHANNEL (C 夏), 542
ADC1_GPIO37_CHANNEL (C 夏), 542
ADC1_GPIO38_CHANNEL (C 夏), 542
ADC1_GPIO39_CHANNEL (C 夏), 542
adc1_pad_get_io_num (C++ function), 534
adc1_ulp_enable (C++ function), 536
ADC2_CHANNEL_0 (C++ enumerator), 539
ADC2_CHANNEL_0_GPIO_NUM (C 夏), 542
ADC2_CHANNEL_1 (C++ enumerator), 539
ADC2_CHANNEL_1_GPIO_NUM (C 夏), 542
ADC2_CHANNEL_2 (C++ enumerator), 539
ADC2_CHANNEL_2_GPIO_NUM (C 夏), 542
ADC2_CHANNEL_3 (C++ enumerator), 539
ADC2_CHANNEL_3_GPIO_NUM (C 夏), 542
ADC2_CHANNEL_4 (C++ enumerator), 539
ADC2_CHANNEL_4_GPIO_NUM (C 夏), 542
ADC2_CHANNEL_5 (C++ enumerator), 539
ADC2_CHANNEL_5_GPIO_NUM (C 夏), 542
ADC2_CHANNEL_6 (C++ enumerator), 539
ADC2_CHANNEL_6_GPIO_NUM (C 夏), 542
ADC2_CHANNEL_7 (C++ enumerator), 539
ADC2_CHANNEL_7_GPIO_NUM (C 夏), 542
ADC2_CHANNEL_8 (C++ enumerator), 539
ADC2_CHANNEL_8_GPIO_NUM (C 夏), 542
ADC2_CHANNEL_9 (C++ enumerator), 539
ADC2_CHANNEL_9_GPIO_NUM (C 夏), 542
ADC2_CHANNEL_MAX (C++ enumerator), 539
adc2_channel_t (C++ enum), 539
adc2_config_channel_atten (C++ function), 536
adc2_get_raw (C++ function), 537
ADC2_GPIO0_CHANNEL (C 夏), 542
ADC2_GPIO12_CHANNEL (C 夏), 542
ADC2_GPIO13_CHANNEL (C 夏), 542
ADC2_GPIO14_CHANNEL (C 夏), 542
ADC2_GPIO15_CHANNEL (C 夏), 542
ADC2_GPIO25_CHANNEL (C 夏), 542
ADC2_GPIO26_CHANNEL (C 夏), 542
ADC2_GPIO27_CHANNEL (C 夏), 542
ADC2_GPIO2_CHANNEL (C 夏), 542
ADC2_GPIO4_CHANNEL (C 夏), 542
adc2_pad_get_io_num (C++ function), 536
adc2_vref_to_gpio (C++ function), 537
ADC_ATTEN_0db (C 夏), 538
ADC_ATTEN_11db (C 夏), 538
ADC_ATTEN_2_5db (C 夏), 538
ADC_ATTEN_6db (C 夏), 538
ADC_ATTEN_DB_0 (C++ enumerator), 532
ADC_ATTEN_DB_11 (C++ enumerator), 533
ADC_ATTEN_DB_2_5 (C++ enumerator), 532
ADC_ATTEN_DB_6 (C++ enumerator), 533
ADC_ATTEN_MAX (C++ enumerator), 533
adc_atten_t (C++ enum), 532
adc_bits_width_t (C++ enum), 533
ADC_CHANNEL_0 (C++ enumerator), 532
ADC_CHANNEL_1 (C++ enumerator), 532
ADC_CHANNEL_2 (C++ enumerator), 532
ADC_CHANNEL_3 (C++ enumerator), 532
ADC_CHANNEL_4 (C++ enumerator), 532
ADC_CHANNEL_5 (C++ enumerator), 532
ADC_CHANNEL_6 (C++ enumerator), 532
ADC_CHANNEL_7 (C++ enumerator), 532

1727
ADCS_CHANNEL_8 (C++ enumerator), 532
ADCS_CHANNEL_9 (C++ enumerator), 532
ADCS_CHANNEL_MAX (C++ enumerator), 532
adc_channel_t (C++ enum), 532
ADCS_CONV_ALTER_UNIT (C++ enumerator), 533
ADCS_CONV_BOTH_UNIT (C++ enumerator), 533
ADCS_CONV_SINGLE_UNIT_1 (C++ enumerator), 533
ADCS_CONV_SINGLE_UNIT_2 (C++ enumerator), 533
ADCS_CONV_UNIT_MAX (C++ enumerator), 533
adc_digi_config_t::adc1_pattern_len (C++ member), 531
adc_digi_config_t::adc1_pattern (C++ member), 531
adc_digi_config_t::adc1_pattern_len (C++ member), 531
adc_digi_config_t::adc2_pattern_len (C++ member), 531
adc_digi_config_t::adc2_pattern (C++ member), 531
adc_digi_config_t::conv_limit_en (C++ member), 531
adc_digi_config_t::conv_limit_num (C++ member), 531
adc_digi_config_t::conv_mode (C++ member), 531
adc_digi_config_t::format (C++ member), 531
adc_digi_controller_config (C++ function), 538
adc_digi_convert_mode_t (C++ enum), 533
adc_digi_deinit (C++ function), 538
ADCS_DIGI_FORMAT_11BIT (C++ enumerator), 534
ADCS_DIGI_FORMAT_12BIT (C++ enumerator), 534
ADCS_DIGI_FORMAT_MAX (C++ enumerator), 534
adc_digi_init (C++ function), 538
adc_digi_output_data_t::data (C++ member), 530
adc_digi_output_data_t::data (C++ member), 530
adc_digi_output_data_t::type1 (C++ member), 530
adc_digi_output_data_t::type2 (C++ member), 530
adc_digi_output_data_t::unit (C++ member), 530
adc_digi_output_data_t::val (C++ member), 530
adc_digi_output_format_t (C++ enum), 534
adc_digi_pattern_table_t::adc1_pattern (C++ class), 530
adc_digi_pattern_table_t::adc1_pattern_len (C++ member), 530
adc_digi_pattern_table_t::bit_width (C++ member), 530
adc_digi_pattern_table_t::channel (C++ member), 530
ADCS_ENCODE_11BIT (C++ enumerator), 539
ADCS_ENCODE_12BIT (C++ enumerator), 539
ADCS_ENCODE_MAX (C++ enumerator), 539
adc_gpio_init (C++ function), 534
ADCS_I2S_DATA_SRC_ADC (C++ enumerator), 533
ADCS_I2S_DATA_SRC_IO_SIG (C++ enumerator), 533
ADCS_I2S_DATA_SRC_MAX (C++ enumerator), 533
adc_i2s_encode_t (C++ enum), 539
adc_i2s_mode_init (C++ function), 529
adc_i2s_source_t (C++ enum), 533
adc_power_off (C++ function), 534
adc_power_on (C++ function), 534
adc_set_clk_div (C++ function), 536
adc_set_data_inv (C++ function), 536
adc_set_data_width (C++ function), 536
adc_set_i2s_data_source (C++ function), 529
ADCS_UNIT_1 (C++ enumerator), 532
ADCS_UNIT_2 (C++ enumerator), 532
ADCS_UNIT_ALTER (C++ enumerator), 532
ADCS_UNIT_BOTH (C++ enumerator), 532
ADCS_UNIT_MAX (C++ enumerator), 532
adc_unit_t (C++ enum), 532
adc_vref_to_gpio (C++ function), 537
ADC_WIDTH_10Bit (C\x00e2), 538
ADC_WIDTH_11Bit (C\x00e2), 538
ADC_WIDTH_12Bit (C\x00e2), 538
ADC_WIDTH_9Bit (C\x00e2), 538
ADC_WIDTH_BIT_10 (C++ enumerator), 533
ADC_WIDTH_BIT_11 (C++ enumerator), 533
ADC_WIDTH_BIT_12 (C++ enumerator), 533
ADC_WIDTH_BIT_9 (C++ enumerator), 533
ADC_WIDTH_MAX (C++ enumerator), 533
ADD_DEV_FLUSHABLE_DEV_FLAG (C\x00e2), 248
ADD_DEV_RM_AFTER_PROV_FLAG (C\x00e2), 248
ADV_CNLL_37 (C++ enumerator), 89
ADV_CNLL_38 (C++ enumerator), 89
ADV_CNLL_39 (C++ enumerator), 89
ADV_CNLL_ALL (C++ enumerator), 89
ADV_FILTER_ALLOW_SCAN_ANY_CON_ANY (C++ enumerator), 89
ADV_FILTER_ALLOW_SCAN_ANY_CON_WLST (C++ enumerator), 89
ADV_FILTER_ALLOW_SCAN_WLST_CON_ANY (C++ enumerator), 89
ADV_FILTER_ALLOW_SCAN_WLST_CON_WLST (C++ enumerator), 89
ADV_TYPE_DIRECT_IND_HIGH (C++ enumerator), 88
ADV_TYPE_DIRECT_IND_LOW (C++ enumerator), 88
ADV_TYPE_IND (C++ enumerator), 88
ADV_TYPE_NONCONN_IND (C++ enumerator), 88
ADV_TYPE_SCAN_IND (C++ enumerator), 88
B
BD_ADDR (C++ type), 260
BD_ADDR_LEN (C\x00e2), 248
BLE_ADDR_TYPE_PUBLIC (C++ enumerator), 63
BLE_ADDR_TYPE_RANDOM (C++ enumerator), 63
BLE_ADDR_TYPE_RPA_PUBLIC (C++ enumerator), 63
BLE_ADDR_TYPE_RPA_RANDOM (C++ enumerator), 63
BLE_BIT (C 宏), 86
BLE_HCI_UART_H4_ACL (C 宏), 215
BLE_HCI_UART_H4_CMD (C 宏), 215
BLE_HCI_UART_H4_EVT (C 宏), 215
BLE_HCI_UART_H4_NONE (C 宏), 215
BLE_HCI_UART_H4_SCO (C 宏), 215
BLE_SCAN_DUPLICATE_DISABLE (C++ enumerator), 90
BLE_SCAN_DUPLICATE_ENABLE (C++ enumerator), 90
BLE_SCAN_DUPLICATE_MAX (C++ enumerator), 90
BLE_SCAN_FILTER_ALLOW_ALL (C++ enumerator), 90
BLE_SCAN_FILTER_ALLOW_ONLY_WLST (C++ enumerator), 90
BLE_SCAN_FILTER_ALLOW_UND_RPA_DIR (C++ enumerator), 90
BLE_SCAN_FILTER_ALLOW_WLIST_PRA_DIR (C++ enumerator), 90
BLE_SCAN_TYPE_ACTIVE (C++ enumerator), 89
BLE_SCAN_TYPE_PASSIVE (C++ enumerator), 89
BLE_UUID128_VAL_LENGTH (C 宏), 865
BLE_WL_ADDR_TYPE_PUBLIC (C++ enumerator), 63
BLE_WL_ADDR_TYPE_RANDOM (C++ enumerator), 63
BT_CONTROLLER_INIT_CONFIG_DEFAULT (C 宏), 58
BT_OCCET32 (C++ type), 260
BT_OCCET32_LEN (C 宏), 248
BTC_HF_CALL_END_TIMEOUT (C 宏), 184
BTC_HF_INVALID_IDX (C 宏), 184
BTC_HF_SECURITY (C 宏), 184
BTC_HF_SERVICE_NAMES (C 宏), 184
BTC_HF_SERVICES (C 宏), 184
BTC_HFAG_SERVICE_NAME (C 宏), 184
BTC_HSA S_SERVICE_NAME (C 宏), 184
CHIP_ESP32 (C++ enumerator), 1163
CHIP_ESP32S2 (C++ enumerator), 1163
CHIP_ESP32S3 (C++ enumerator), 1163
CHIP_FEATURE_BLE (C 宏), 1162
CHIP_FEATURE_BT (C 宏), 1162
CHIP_FEATURE_EMB_FLASH (C 宏), 1162
CHIP_FEATURE_WIFI_BGN (C 宏), 1162
CONFIG_EFUSE Custom Table, 974
CONFIG_EFUSE_MAX_BLK_LEN, 975
CONFIG_EFUSE_VIRTUAL, 978
CONFIG_ESPTOOLPY_FLASHSIZE, 881
CONFIG_FEATURE_CACHE_FLASHSIZE, 881
CONFIG_FEATURE_WPA3_SAE_BIT (C 宏), 437
CONFIG_HEAP_TRACING_STACK_DEPTH (C 宏), 1137
CONFIG_LOG_DEFAULT_LEVEL, 1152
CONFIG_LWIP_SNTP_UPDATE_DELAY, 1194
CONFIG_LWIP_USB_ONLY_LWIP_SELECT, 932
CONFIG_SPIRAM_BANKSWITCH_ENABLE, 1141
CONFIG_SPIRAM_BANKSWITCH_RESERVE, 1141
D
DAC_CHANNEL_1 (C++ enumerator), 545
DAC_CHANNEL_1_GPIO_NUM (C 宏), 544
DAC_CHANNEL_2 (C++ enumerator), 545
DAC_CHANNEL_2_GPIO_NUM (C 宏), 545
DAC_CHANNEL_MAX (C++ enumerator), 545
dac_channel_t (C++ enum), 545
dac_channel_t::enonym (C++ member), 545
dac_channel_t::freq (C++ member), 545
dac_channel_t::freq (C++ member), 545
dac_channel_t::offset (C++ member), 545
dac_channel_t::phase (C++ member), 545
dac_channel_t::scale (C++ member), 544
dac_channel_t::scale (C++ member), 544
dac_generator_disable (C++ function), 544
dac_generator_disable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
dac_generator_enable (C++ function), 544
eRunning (C++ enumerator), 1029
eSetBits (C++ enumerator), 1029
eSetValueWithoutOverwrite (C++ enumerator), 1029
eSetValueWithOverwrite (C++ enumerator), 1029
eSleepModeStatus (C++ enum), 1029
ESP_A2D_AUDIO_CFG_EVT (C++ enumerator), 161
ESP_A2D_AUDIO_STATE_EVT (C++ enumerator), 160
ESP_A2D_AUDIO_STATE_REMOTE_SUSPEND (C++ enumerator), 160
ESP_A2D_AUDIO_STATE_STARTED (C++ enumerator), 160
ESP_A2D_AUDIO_STATE_STOPPED (C++ enumerator), 160
esp_a2d_audio_state_t (C++ enum), 160
esp_a2d_cb_event_t (C++ enum), 157
esp_a2d_cb_param_t (C++ union), 157
esp_a2d_cb_param_t::a2d_audio_cfg_param (C++ class), 157
esp_a2d_cb_param_t::a2d_audio_stat_param (C++ class), 157
esp_a2d_cb_param_t::a2d_conn_stat_param (C++ class), 157
esp_a2d_cb_param_t::esp_a2d_connection_state_t (C++ class), 157
esp_a2d_disc_rsn_t (C++ class), 157
esp_a2d_media_ctl (C++ function), 156
esp_a2d_mediactl (C++ function), 156
esp_a2d_sink_disconnect (C++ function), 156
esp_a2d_sink_init (C++ function), 156
ESP_A2D_CONNECTION_STATE_CONNECTED (C++ enumerator), 159
ESP_A2D_CONNECTION_STATE_CONNECTING (C++ enumerator), 159
ESP_A2D_CONNECTION_STATE_DISCONNECTED (C++ enumerator), 159
ESP_A2D_CONNECTION_STATE_DISCONNECTING (C++ enumerator), 159
ESP_A2D_CONNECTION_STATE_EVT (C++ enumerator), 160
esp_a2d_connection_state_t (C++ enum), 159
ESP_A2D_DISC_RSN_ABNORMAL (C++ enum), 160
ESP_A2D_DISC_RSN_NORMAL (C++ enum), 160
esp_a2d_disc_rsn_t (C++ enum), 160
esp_a2d_mcc_t (C++ class), 158
esp_a2d_mcc_t::atrac (C++ member), 158
esp_a2d_mcc_t::atrac (C++ member), 158
esp_a2d_mcc_t::cie (C++ member), 158
esp_a2d_mcc_t::cie (C++ member), 158
esp_a2d_mcc_t::m24 (C++ member), 158
esp_a2d_mcc_t::m24 (C++ member), 158
esp_a2d_mcc_t::m12 (C++ member), 158
esp_a2d_mcc_t::m12 (C++ member), 158
esp_a2d_mct_t (C++ class), 158
esp_a2d_mct_t (C++ class), 158
esp_a2d_mct_t::atrac (C++ member), 158
esp_a2d_mct_t::atrac (C++ member), 158
esp_a2d_mct_t::m24 (C++ member), 158
esp_a2d_mct_t::m24 (C++ member), 158
esp_a2d_mct_t::m12 (C++ member), 158
esp_a2d_mct_t::m12 (C++ member), 158
ESP_A2D_MCT_ATRAC (C++ member), 159
ESP_A2D_MCT_M24 (C++ member), 159
ESP_A2D_MCT_M12 (C++ member), 159
ESP_A2D_MCT_SBC (C++ member), 159
ESP_A2D_MCT_A2DP (C++ member), 159
ESP_A2D_MCT_NON_A2DP (C++ member), 159
ESP_A2D_MEDIA_CTRL_ACK_BUSY (C++ enum), 156
ESP_A2D_MEDIA_CTRL_ACK_EVT (C++ enum), 161
ESP_A2D_MEDIA_CTRL_ACK_FAILURE (C++ enum), 160
ESP_A2D_MEDIA_CTRL_ACK_SUCCESS (C++ enum), 160
ESP_A2D_MEDIA_CTRL_CHECK_SRC_RDY (C++ enum), 160
ESP_A2D_MEDIA_CTRL_NONE (C++ enum), 160
ESP_A2D_MEDIA_CTRL_START (C++ enum), 160
ESP_A2D_MEDIA_CTRL_STOP (C++ enum), 160
ESP_A2D_MEDIA_CTRL_SUSPEND (C++ enum), 160
ESP_A2D_MEDIA_CTRL_REGISTER_CALLBACK (C++ function), 155
ESP_A2D_MEDIA_CTRL_REGISTER_CALLBACK (C++ function), 155
ESP_A2D_MEDIA_CTRL_UNREGISTER_CALLBACK (C++ function), 155
ESP_A2D_MEDIA_CTRL_UNREGISTER_CALLBACK (C++ function), 155
ESP_A2D_CIE_LEN_ATRAC (C++ type), 159
ESP_A2D_CIE_LEN_M12 (C++ type), 159
ESP_A2D_CIE_LEN_M24 (C++ type), 159
ESP_A2D_CIE_LEN_SBC (C++ type), 159
ESP_A2D_CIE_LEN_M24 (C++ type), 159
ESP_A2D_CIE_LEN_M12 (C++ type), 159
ESP_A2D_CIE_LEN_ATRAC (C++ type), 159
ESP_A2D_CIE_LEN_SBC (C++ type), 159
ESP_A2D_CIE_LEN_M24 (C++ type), 159
ESP_A2D_CIE_LEN_M12 (C++ type), 159
ESP_A2D_CIE_LEN_ATRAC (C++ type), 159
ESP_A2D_CIE_LEN_SBC (C++ type), 159

Espressif Systems

1730

Submit Document Feedback
ESP_AVRC_FEAT_FLAG_CAT4 (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_ps_rpt_value_ids_t (C++ enum), (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PS_REPEAT_MODE (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PS_SCAN_ALL (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PS_SCAN_GROUP (C++ enumerator),
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PS_SCAN_MODE (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PS_SCAN_OFF (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_ps_scn_value_ids_t (C++ enum), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_ps_shf_value_ids_t (C++ enum), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PS_SHUFFLE_ALL (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PS_SHUFFLE_GROUP (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PS_SHUFFLE_MODE (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PS_SHUFFLE_OFF (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_ps_hst_bit_mask_operation (C++ function), 164
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_ps_hst_bit_mask_t (C++ class), 168
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_ps_hst_bit_mask_t::bits (C++ member), 169
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PSTH_FILTER_ALLOWED_CMD (C++ enumerator), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PSTH_FILTER_SUPPORTED_CMD (C++ enumerator), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_ps_hst_filter_t (C++ enum), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_0 (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_1 (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_2 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_3 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_4 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_5 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_6 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_7 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_8 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_9 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD.Angle (C++ enumerator), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_BACKWARD (C++ enumerator), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_CHAN_DOWN (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_CHAN_UP (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_CLEAR (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_CONT_MENU (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_DISP_INFO (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_DOT (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_DOWN (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_EJECT (C++ enumerator), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_FWD (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_FWD_SEEK (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_FWD_STOPPED (C++ enum), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_FWD_STOPPED (C++ enum), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_REV_SEEK (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_psth_bit_mask_t (C++ enum), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_psth_bit_mask_t::bits (C++ member), 169
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_psth_bit_mask_operation (C++ function), 164
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_psth_bit_mask_t (C++ class), 168
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_psth_bit_mask_t::bits (C++ member), 169
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PSTH_FILTER_ALLOWED_CMD (C++ enumerator), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PSTH_FILTER_SUPPORTED_CMD (C++ enumerator), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_ps_hst_filter_t (C++ enum), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_0 (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_1 (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_2 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_3 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_4 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_5 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_6 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_7 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_8 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_9 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD.Angle (C++ enumerator), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_BACKWARD (C++ enumerator), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_CHAN_DOWN (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_CHAN_UP (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_CLEAR (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_CONT_MENU (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_DISP_INFO (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_DOT (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_DOWN (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_EJECT (C++ enumerator), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD FWD (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_FWD_SEEK (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_FWD_STOPPED (C++ enum), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_FWD_STOPPED (C++ enum), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_REV_SEEK (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_psth_bit_mask_t (C++ enum), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_psth_bit_mask_t::bits (C++ member), 169
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_psth_bit_mask_operation (C++ function), 164
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_psth_bit_mask_t (C++ class), 168
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_psth_bit_mask_t::bits (C++ member), 169
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PSTH_FILTER_ALLOWED_CMD (C++ enumerator), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PSTH_FILTER_SUPPORTED_CMD (C++ enumerator), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE esp_avrc_ps_hst_filter_t (C++ enum), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_0 (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_1 (C++ enumerator), 170
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_2 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_3 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_4 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_5 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_6 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_7 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_8 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_9 (C++ enumerator), 171
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD.Angle (C++ enumerator), 172
ESP_AVRC_FEAT_FLAG_FLAG_ART_GET_IMAGE ESP_AVRC_PT_CMD_BACKWARD (C++ enumerator), 172
ESP_AVRC_PT_CMD_ENTER (C++ enumerator), 171
ESP_AVRC_PT_CMD_EXIT (C++ enumerator), 170
ESP_AVRC_PT_CMD_F1 (C++ enumerator), 172
ESP_AVRC_PT_CMD_F2 (C++ enumerator), 172
ESP_AVRC_PT_CMD_F3 (C++ enumerator), 172
ESP_AVRC_PT_CMD_F4 (C++ enumerator), 172
ESP_AVRC_PT_CMD_F5 (C++ enumerator), 172
ESP_AVRC_PT_CMD_FAST_FORWARD (C++ enumerator), 172
ESP_AVRC_PT_CMD_FAV_MENU (C++ enumerator), 170
ESP_AVRC_PT_CMD_FORWARD (C++ enumerator), 172
ESP_AVRC_PT_CMD_HELP (C++ enumerator), 171
ESP_AVRC_PT_CMD_INPUT_SEL (C++ enumerator), 171
ESP_AVRC_PT_CMD_LEFT (C++ enumerator), 170
ESP_AVRC_PT_CMD_LEFT_DOWN (C++ enumerator), 170
ESP_AVRC_PT_CMD_LEFT_UP (C++ enumerator), 170
ESP_AVRC_PT_CMD_MUTE (C++ enumerator), 172
ESP_AVRC_PT_CMD_PAGE_DOWN (C++ enumerator), 171
ESP_AVRC_PT_CMD_PAGE_UP (C++ enumerator), 171
ESP_AVRC_PT_CMD_PAUSE (C++ enumerator), 172
ESP_AVRC_PT_CMD_PLAY (C++ enumerator), 172
ESP_AVRC_PT_CMD_POWER (C++ enumerator), 171
ESP_AVRC_PT_CMD_PREV_CHAN (C++ enumerator), 171
ESP_AVRC_PT_CMD_RECORD (C++ enumerator), 172
ESP_AVRC_PT_CMD_ROOT_MENU (C++ enumerator), 170
ESP_AVRC_PT_CMD_SELECT (C++ enumerator), 170
ESP_AVRC_PT_CMD_SETUP_MENU (C++ enumerator), 170
ESP_AVRC_PT_CMD_SOUND_SEL (C++ enumerator), 171
ESP_AVRC_PT_CMD_STATE_PRESSED (C++ enumerator), 173
ESP_AVRC_PT_CMD_STATE_RELEASED (C++ enumerator), 173
esp_avrc_pt_cmd_state_t (C++ enum), 173
ESP_AVRC_PT_CMD_STOP (C++ enumerator), 172
ESP_AVRC_PT_CMD_SUBPICT (C++ enumerator), 172
esp_avrc_pt_cmd_t (C++ enum), 170
ESP_AVRC_PT_CMD_UP (C++ enumerator), 170
ESP_AVRC_PT_CMD_VENDOR (C++ enumerator), 174
ESP_AVRC_PT_CMD_VENDOR (C++ enumerator), 174
ESP_AVRC_PT_CMD_VOL_DOWN (C++ enumerator), 172
ESP_AVRC_PT_CMD_VOL_UP (C++ enumerator), 171
ESP_AVRC_RN_ADDRESSED_PLAYER_CHANGE (C++ enumerator), 174
ESP_AVRC_RN_APP_SETTING_CHANGE (C++ enumerator), 174
ESP_AVRC_RN_AVAILABLE_PLAYERS_CHANGE (C++ enumerator), 174
ESP_AVRC_RN_BATTERY_STATUS_CHANGE (C++ enumerator), 174
ESP_AVRC_RN_CAP_ALLOWED_EVT (C++ enumerator), 174
ESP_AVRC_RN_CAP_MAX (C++ enumerator), 175
ESP_AVRC_RN_CAP_SUPPORTED_EVT (C++ enumerator), 175
ESP_AVRC_RN_CHANGED (C++ enumerator), 174
esp_avrc_rn_event_ids_t (C++ enum), 174
esp_avrc_rn_evt_bit_mask_operation (C++ function), 164
esp_avrc_rn_evt_cap_mask_t (C++ class), 169
esp_avrc_rn_evt_cap_mask_t::bits (C++ member), 169
esp_avrc_rn_evt_cap_prt::bits (C++ member), 169
ESP_AVRC_RN_EVENT_IDS (C++ enum), 175
ESP_AVRC_RN_MAX_EVT (C++ enum), 175
ESP_AVRC_RN_MAX_PLAYING_CHANGE (C++ enumerator), 174
esp_avrc_rn_param_t (C++ union), 165
esp_avrc_rn_param_t::batt (C++ member), 165
esp_avrc_rn_param_t::elm_id (C++ member), 165
esp_avrc_rn_param_t::play_pos (C++ member), 165
esp_avrc_rn_param_t::playback (C++ member), 165
esp_avrc_rn_param_t::volume (C++ member), 165
ESP_AVRC_RN_PLAY_POS_CHANGED (C++ enumerator), 174
ESP_AVRC_RN_PLAY_STATUS_CHANGE (C++ enumerator), 174
ESP_AVRC_RN_RSP_CHANGED (C++ enumerator), 175
ESP_AVRC_RN_RSP_INTERIM (C++ enumerator), 175
esp_avrc_rn_rsp_t (C++ enum), 175
ESP_AVRC_RN_SYSTEM_STATUS_CHANGE (C++ enum), 174
ESP_AVRC_RN_TRACK_CHANGE (C++ enumerator), 174
ESP_AVRC_RN_TRACK_REACHED_END (C++ enumerator), 174
ESP_AVRC_RN_TRACK_REACHED_START (C++ enumerator), 174
<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_ble_gap_cb_param_t::ble_read_rssi_cmpl</td>
<td>C++ member</td>
</tr>
<tr>
<td>esp_ble_gap_cb_param_t::ble_set_channels</td>
<td>C++ member</td>
</tr>
<tr>
<td>esp_ble_gap_cb_param_t::ble_remove_bond_dev_cmpl</td>
<td>C++ member</td>
</tr>
<tr>
<td>esp_ble_gap_cb_param_t::ble_scan_param_cmpl</td>
<td>C++ member</td>
</tr>
<tr>
<td>esp_ble_gap_cb_param_t::ble_scan_rsp_data_cmpl</td>
<td>C++ member</td>
</tr>
<tr>
<td>esp_ble_gap_cb_param_t::ble_security_cmpl</td>
<td>C++ member</td>
</tr>
</tbody>
</table>

**Notes:**
- C++ member indicates the function is a C++ member function.
- C++ class indicates the function is a C++ class function.

**Additional Information:**
- Release v4.3-dev-1561-g357a277603
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Release v4.3-dev-1561-g357a277603

Submit Document Feedback
esp_ble_mesh_comp_t::vid (C++ member), 240
ESP_BLE_MESH_CONDENSATION_ERROR (C 宏), 341
ESP_BLE_MESH_CONDENSATION_WARNING (C 宏), 341
esp_ble_mesh_config_client_get_state (C++ function), 281
esp_ble_mesh_config_client_set_state (C++ function), 281
ESP_BLE_MESH_CONFIGURATION_ERROR (C 宏), 341
ESP_BLE_MESH_CONFIGURATION_WARNING (C 宏), 341
esp_ble_mesh_deinit (C++ function), 267
ESP_BLE_MESH_DEINIT_MESH_COMP_EVT (C++ enumerator), 265
esp_ble_mesh_deinit_param_t (C++ class), 236
esp_ble_mesh_deinit_param_t::erase_flash (C++ member), 237
esp_ble_mesh_dev_add_flag_t (C++ type), 260
esp_ble_mesh_dev_role_t (C++ enum), 262
esp_ble_mesh_device_delete_t (C++ class), 240
esp_ble_mesh_device_delete_t::addr (C++ member), 240
esp_ble_mesh_device_delete_t::addr_type (C++ member), 240
esp_ble_mesh_device_delete_t::flag (C++ member), 241
esp_ble_mesh_device_delete_t::uuid (C++ member), 240
ESP_BLE_MESH_DEVICE_DROPPED_ERROR (C 宏), 342
ESP_BLE_MESH_DEVICE_DROPPED_WARNING (C 宏), 342
ESP_BLE_MESH_DEVICE_MOVED_ERROR (C 宏), 342
ESP_BLE_MESH_DEVICE_MOVED_WARNING (C 宏), 342
ESP_BLE_MESH_DEVICE_NAME_MAX_LEN (C 宏), 345
ESP_BLE_MESH_DISPLAY_NUMBER (C++ enumerator), 261
ESP_BLE_MESH_DISPLAY_STRING (C++ enumerator), 261
esp_ble_mesh_elem_t (C++ class), 237
esp_ble_mesh_elem_t::element_addr (C++ member), 237
esp_ble_mesh_elem_t::location (C++ member), 237
esp_ble_mesh_elem_t::sig_model_count (C++ member), 237
esp_ble_mesh_elem_t::vnd_model_count (C++ member), 237
esp_ble_mesh_elem_t::vnd_models (C++ member), 237
ESP_BLE_MESH_ELEMENT (C 宏), 247
ESP_BLE_MESH_ELEMENT_NOT_CALIBRATED_ERROR (C 宏), 341
ESP_BLE_MESH_ELEMENT_NOT_CALIBRATED_WARNING (C 宏), 341
ESP_BLE_MESH_EMPTY_ERROR (C 宏), 342
ESP_BLE_MESH_EMPTY_WARNING (C 宏), 342
ESP_BLE_MESH_ENTER_NUMBER (C++ enumerator), 261
ESP_BLE_MESH_ENTER_STRING (C++ enumerator), 261
esp_ble_mesh_fast_prov_action_t (C++ enum), 262
esp_ble_mesh_fast_prov_info_t (C++ class), 242
esp_ble_mesh_fast_prov_info_t::flags (C++ member), 242
esp_ble_mesh_fast_prov_info_t::iv_index (C++ member), 242
esp_ble_mesh_fast_prov_info_t::match_index (C++ member), 242
esp_ble_mesh_fast_prov_info_t::match_len (C++ member), 242
esp_ble_mesh_fast_prov_info_t::match_val (C++ member), 242
esp_ble_mesh_fast_prov_info_t::net_idx (C++ member), 242
esp_ble_mesh_fast_prov_info_t::unicast_max (C++ member), 242
esp_ble_mesh_fastProvInfo_t::unicast_min (C++ member), 242
ESP_BLE_MESH_FEATURE_ALL_SUPPORTED (C 宏), 246
ESP_BLE_MESH_FEATURE_FRIEND (C 宏), 246
ESP_BLE_MESH_FEATURE_LOW_POWER (C 宏), 246
ESP_BLE_MESH_FEATURE_PROXY (C 宏), 246
ESP_BLE_MESH_FEATURE_RELAY (C 宏), 246
esp_ble_mesh_find_element (C++ function), 268
esp_ble_mesh_find_sig_model (C++ function), 268
esp_ble_mesh_find_vendor_model (C++ function), 268
ESP_BLE_MESH_FRIEND_DISABLED (C 宏), 246
ESP_BLE_MESH_FRIEND_ENABLED (C 宏), 246
ESP_BLE_MESH_FRIEND_FRIENDSHIP_ESTABLISH_EVT (C++ enumerator), 265
ESP_BLE_MESH_FRIEND_FRIENDSHIP_TERMINATE_EVT (C++ enumerator), 265
ESP_BLE_MESH_FRIEND_NOT_SUPPORTED (C 宏), 246
ESP_BLE_MESH_GATT_PROXY_DISABLED (C 宏), 246
<table>
<thead>
<tr>
<th>C++ member</th>
<th>C++ class</th>
<th>C++ enumerator</th>
<th>C++ union</th>
</tr>
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esp_ble_mesh_gen_level_set_t::trans_time (C++ class), 306
esp_ble_mesh_gen_level_set_t::trans_time (C++ member), 306
esp_ble_mesh_gen_level_set_t::tid (C++ member), 307
esp_ble_mesh_gen_level_set_t::delay (C++ member), 306
esp_ble_mesh_gen_client_status_cb_t::manufacturer_property_status (C++ member), 309
esp_ble_mesh_gen_loc_global_set_t::global_latitude (C++ class), 309
esp_ble_mesh_gen_loc_global_set_t::global_longitude (C++ class), 309
esp_ble_mesh_gen_loc_global_set_t::global_altitude (C++ class), 309
esp_ble_mesh_gen_loc_global_set_t::global_latitude (C++ member), 309
esp_ble_mesh_gen_loc_global_set_t::global_longitude (C++ member), 309
esp_ble_mesh_gen_loc_global_set_t::global_altitude (C++ member), 309
esp_ble_mesh_gen_def_trans_time_srv_t::tt_delta_level (C++ class), 317
esp_ble_mesh_gen_def_trans_time_srv_t::transition (C++ member), 317
esp_ble_mesh_gen_def_trans_time_srv_t::last (C++ member), 317
esp_ble_mesh_gen_def_trans_time_srv_t::move_start (C++ member), 317
esp_ble_mesh_gen_def_trans_time_srv_t::positive (C++ member), 317
esp_ble_mesh_gen_def_trans_time_state_t::target_level (C++ class), 317
esp_ble_mesh_gen_def_trans_time_state_t::target_level (C++ member), 317
esp_ble_mesh_gen_def_trans_time_state_t::positive (C++ member), 317
esp_ble_mesh_gen_def_trans_time_state_t::move_start (C++ member), 317
esp_ble_mesh_gen_def_trans_time_state_t::last (C++ member), 317
esp_ble_mesh_gen_def_trans_time_state_t::transition (C++ member), 317
esp_ble_mesh_gen_def_trans_time_state_t::target_level (C++ member), 317
esp_ble_mesh_gen_def_trans_time_status_cb_t::tt_delta_level (C++ class), 313
esp_ble_mesh_gen_def_trans_time_status_cb_t::transition (C++ class), 313
esp_ble_mesh_gen_def_trans_time_status_cb_t::op_en (C++ class), 313
esp_ble_mesh_gen_def_trans_time_status_cb_t::present_level (C++ member), 313
esp_ble_mesh_gen_client_status_cb_t::power_level_status (C++ class), 309
esp_ble_mesh_gen_client_status_cb_t::power_last_status (C++ class), 309
esp_ble_mesh_gen_client_status_cb_t::power_default_status (C++ class), 309
esp_ble_mesh_gen_client_status_cb_t::onpowerup_status (C++ class), 309
esp_ble_mesh_gen_client_status_cb_t::power_range_status (C++ class), 309
esp_ble_mesh_gen_client_status_cb_t::power_properties_status (C++ class), 309
esp_ble_mesh_gen_client_status_cb_t::user_property_status (C++ class), 309
esp_ble_mesh_gen_client_status_cb_t::user_properties_status (C++ class), 309
esp_ble_mesh_gen_client_status_cb_t::power_range_status (C++ member), 309
esp_ble_mesh_gen_client_status_cb_t::power_properties_status (C++ member), 309
esp_ble_mesh_gen_client_status_cb_t::user_property_status (C++ member), 309
esp_ble_mesh_gen_client_status_cb_t::user_properties_status (C++ member), 309
esp_ble_mesh_gen_client_status_cb_t::power_range_status (C++ member), 309
esp_ble_mesh_gen_client_status_cb_t::power_properties_status (C++ member), 309
esp_ble_mesh_gen_client_status_cb_t::user_property_status (C++ member), 309
esp_ble_mesh_gen_client_status_cb_t::user_properties_status (C++ member), 309

Espresif Systems  1755  Release v4.3-dev-1561-g357a277603
Submit Document Feedback
esp_ble_mesh_generic_client_set_state_t::user_property_set
(esp_ble_mesh_generic_property_t)
esp_ble_mesh_generic_client_set_state_t::power_set
(esp_ble_mesh_generic_property_t)
esp_ble_mesh_generic_client_set_state_t::power_range_set
(esp_ble_mesh_generic_property_t)
esp_ble_mesh_generic_client_set_state_t::power_level_set
(esp_ble_mesh_generic_property_t)
esp_ble_mesh_generic_client_set_state_t::power_default_set
(esp_ble_mesh_generic_property_t)
esp_ble_mesh_generic_client_set_state_t::onoff_set
(esp_ble_mesh_generic_property_t)
esp_ble_mesh_generic_client_set_state_t::move_set
(esp_ble_mesh_generic_property_t)
esp_ble_mesh_generic_client_set_state_t::manufacturer_property_set
(esp_ble_mesh_generic_property_t)
esp_ble_mesh_generic_client_set_state_t::loc_local_set
(esp_ble_mesh_generic_property_t)
esp_ble_mesh_generic_client_set_state_t::loc_global_set
(esp_ble_mesh_generic_property_t)
esp_ble_mesh_generic_client_set_state_t::level_set
(esp_ble_mesh_generic_property_t)
esp_ble_mesh_generic_client_set_state_t::delta_set
(esp_ble_mesh_generic_property_t)
esp_ble_mesh_health_client_set_state_t::fault_clear
esp_ble_mesh_health_client_set_state_t::attention_set
esp_ble_mesh_health_client_set_state
esp_ble_mesh_health_client_get_state_t::fault_get
esp_ble_mesh_health_client_get_state_t
esp_ble_mesh_client_common_cb_param_t::period_status
esp_ble_mesh_client_common_cb_param_t::current_status
esp_ble_mesh_client_common_cb_param_t::attention_status
esp_ble_mesh_client_common_cb_param_t
esp_ble_mesh_client_common_cb_event_t
esp_ble_mesh_health_attention_status_cb_t::attention
esp_ble_mesh_health_attention_set_t
esp_ble_mesh_health_attention_on_cb_t::model
esp_ble_mesh_health_client_set_state
esp_ble_mesh_health_client_get_state
ESP_BLE_MESH_HEALTH_CLIENT_EVT_MAX
ESP_BLE_MESH_HEALTH_CLIENT_EVT_MAX
ESP_BLE_MESH_PUBLISH_TRANSMIT_COUNT
ESP_BLE_MESH_PUBLISH_TRANSMIT_INTERVAL
esp_ble_mesh_health_client_set_state_t::fault_clear
esp_ble_mesh_health_client_set_state_t::attention_set
esp_ble_mesh_health_client_set_state_t esp_ble_mesh_health_model_status_t
(C++ member), 336
esp_ble_mesh_health_client_set_state_t esp_ble_mesh_health_period_set_t (C++
(C++ member), 336
(C++ type), 260
ESP_BLE_MESH_HEALTH_CLIENT_TIMEOUT_EVT esp_ble_mesh_health_period_set_t::fast_period_div
(\texttt{C++ enumerator}), 343
esp_ble_mesh_health_current_status_cb_t esp_ble_mesh_health_period_status_cb_t
(\texttt{C++ class}, 338
(\texttt{C++ member}, 339
ESP_BLE_MESH_HEALTH_FAULT_ARRAY_SIZE esp_ble_mesh_health_period_status_cb_t::fast_peri
(\texttt{C++ member}, 339
esp_ble_mesh_health_current_status_cb_t esp_BLE_MESH_HEALTH_PUB_DEFINE (C $\wedge$),
(\texttt{C++ enumerator}), 341
ESP_BLE_MESH_HEALTH_FAULT_ARRAY_SIZE ESP_BLE_MESH_HEALTH_SERVER_ATTENTION_OFF_EVT
(C $\wedge$), 342
esp_ble_mesh_health_fault_clear_cb_t esp_ble_mesh_health_server_cb_event_t
(\texttt{C++ class}, 340
(\texttt{C++ member}, 340
esp_ble_mesh_health_fault_clear_cb_t::company_mesh_health_server_cb_param_t::attention_  
(C++ member), 336
esp_ble_mesh_health_fault_clear_t esp_ble_mesh_health_server_cb_param_t::attention_  
(C++ member), 337
esp_ble_mesh_health_fault_clear_t::company_mesh_health_server_cb_param_t::fault_clear
(C++ member), 337
esp_ble_mesh_health_fault_get_t (C++ esp_ble_mesh_health_server_cb_param_t::fault_test
(C++ member), 336
esp_ble_mesh_health_fault_get_t::company_mesh_health_server_cb_param_t::fault_update
(C++ member), 336
esp_ble_mesh_health_fault_status_cb_t esp_ble_mesh_health_server_cb_t
(C++ type), 342
esp_ble_mesh_health_fault_status_cb_t: ESP_BLE_MESH_HEALTH_SERVER_EVT_MAX
(C++ member), 336
esp_ble_mesh_health_fault_status_cb_t: ESP_BLE_MESH_HEALTH_SERVER_FAULT_CLEAR_EVT
(C++ member), 336
esp_ble_mesh_health_fault_status_cb_t: ESP_BLE_MESH_HEALTH_SERVER_FAULT_TEST_EVT
(C++ member), 336
esp_ble_mesh_health_fault_test_cb_t esp_BLE_MESH_HEALTH_SERVER_FAULT_UPDATE_COMP_EVT
(C++ function), 335
esp_ble_mesh_health_fault_test_cb_t::company_mesh_health_srv_cb_t (C++ class),
(\texttt{C++ member}, 337
esp_ble_mesh_health_fault_test_cb_t::test_company_mesh_health_srv_cb_t::attention_off
(C++ member), 337
esp_ble_mesh_health_fault_test_t (C++ esp_ble_mesh_health_srv_cb_t::attention_on
(C++ member), 337
esp_ble_mesh_health_fault_test_t::company_mesh_health_srv_cb_t::fault_clear
(C++ member), 337
esp_ble_mesh_health_fault_test_t::test_company_mesh_health_srv_cb_t::fault_test
(C++ member), 337
esp_ble_mesh_health_fault_update_comp esp_ble_mesh_health_srv_t
(C++ member), 337
esp_ble_mesh_health_fault_update_comp_cb_t::company_mesh_health_srv_t::attention_timer
(C++ member), 337
esp_ble_mesh_health_fault_update_comp_cb_t::esp_ble_mesh_health_srv_t::attention_timer
(C++ member), 337
esp_ble_mesh_health_fault_update_comp_cb_t::esp_ble_mesh_health_srv_t::health_cb
(C++ member), 337
esp_ble_mesh_health_srv_t::health_test
(C++ member), 338
esp_ble_mesh_health_srv_t::model (C++ member), 337
ESP_BLE_MESH_HEALTH_STANDARD_TEST (C
宏), 341
esp_ble_mesh_health_test_t (C++ class), 337
esp_ble_mesh_health_test_t::company_id
(C++ member), 337
esp_ble_mesh_health_test_t::current_faults
(C++ member), 337
esp_ble_mesh_health_test_t::id_count
(C++ member), 337
esp_ble_mesh_health_test_t::prev_test
ESP_BLE_MESH_HC_FAULT (C++ enumerator), 384
(ESP_BLE_MESH_HC_FAULT (C++ enumerator), 384)
esp_ble_mesh_health_test_t::registered
ESP_BLE_MESH_HC_FAULT_STANDBY_AUTO
(C++ enumerator), 384
esp_ble_mesh_health_test_t::test_ids
(ESP_BLE_MESH_HC_FAULT_STANDBY_MANUAL
(C++ enumerator), 384)
(ESP_BLE_MESH_HC_FAULT_STANDBY_MANUAL
(C++ enumerator), 384)
ESP_BLE_MESH_HEARTBEAT_MESSAGE_RECV_EVT
ESP_BLE_MESH_HC_FAULT_OFF (C++ enumerator), 384
ESP_BLE_MESH_HC_FAULT_RUN (C++ enumerator), 384
ESP_BLE_MESH_HC_FAULT_STANDBY (C++ enumerator), 384
esp_ble_mesh_init (C++ function), 267
esp_ble_mesh_input_action_t (C++ enum),
261
ESP_BLE_MESH_INPUT_NO_CHANGE_ERROR (C
宏), 342
esp_ble_mesh_input_action_t (C++ enum), 261
ESP_BLE_MESH_INPUT_NO_CHANGE_WARNING
(C宏), 342
ESP_BLE_MESH_INPUT_OOB (C++ enumerator),
261
ESP_BLE_MESH_INPUT_TOO_HIGH_ERROR (C
宏), 342
esp_ble_mesh_input_action_t (C++ enum),
261
ESP_BLE_MESH_INPUT_TOO_HIGH_WARNING
(C宏), 342
ESP_BLE_MESH_INPUT_TOO_LOW_ERROR (C宏),
342
ESP_BLE_MESH_INPUT_TOO_LOW_WARNING
(C宏), 342
ESP_BLE_MESH_INTERNAL_BUS_ERROR (C宏),
342
ESP_BLE_MESH_INTERNAL_BUS_WARNING
(C宏), 342
ESP_BLE_MESH_INVALID_NODE_INDEX (C宏),
264
ESP_BLE_MESH_INVALID_SCENE_NUMBER (C宏)
宏), 419
ESP_BLE_MESH_INVALID_SENSOR_PROPERTY_ID
(C宏), 397
ESP_BLE_MESH_INVALID_SENSOR_SETTING_PROPERTY_ID
(C宏), 397
esp_ble_mesh_is_model_subscribed_to_group
ESP_BLE_MESH_KEY_ANY (C宏), 246
ESP_BLE_MESH_KEY_DEV (C宏), 246
ESP_BLE_MESH_KEY_PRIMARY (C宏), 246
ESP_BLE_MESH_KEY_UNUSED (C宏), 246
esp_ble_mesh_last_msg_info_t (C++ class),
244
esp_ble_mesh_last_msg_info_t::dst
(C++ member), 244
esp_ble_mesh_last_msg_info_t::src
(C++ member), 244
esp_ble_mesh_last_msg_info_t::tid
(C++ member), 244
esp_ble_mesh_last_msg_info_t::timestamp
(C++ member), 244
ESP_BLE_MESH_HC_FAULT (C++ enumerator), 384
C++ function, 267
ESP_BLE_MESH_KEY_UNUSED
C++ class
ESP_BLE_MESH_KEY_DEV
C++ function
ESP_BLE_MESH_KEY_PRIMARY
C++ union
esp_ble_mesh_light_client_set_state
esp_ble_mesh_light_client_get_state
esp_ble_mesh_light_client_get_state
ESP_BLE_MESH_HC_FAULT_OFF
ESP_BLE_MESH_HC_FAULT_RUN
ESP_BLE_MESH_HC_FAULT_STANDBY
esp_ble_mesh_light_client_set_state_t
ESP_BLE_MESH_HC_FAULT_STANDBY_MANUAL
esp_ble_mesh_light_client_get_state_t::lc_property_get
esp_ble_mesh_light_client_get_state
ESP_BLE_MESH_HC_FAULT_STANDBY_AUTO
ESP_BLE_MESH_HC_FAULT_OFF
ESP_BLE_MESH_HC_FAULT_RUN
ESP_BLE_MESH_HC_FAULT_STANDBY
esp_ble_mesh_light_client_set_state
esp_ble_mesh_light_client_get_state
esp_ble_mesh_light_client_set_state
ESP_BLE_MESH_HC_FAULT_OFF
ESP_BLE_MESH_HC_FAULT_RUN
ESP_BLE_MESH_HC_FAULT_STANDBY
esp_ble_mesh_light_client_set_state
esp_ble_mesh_light_client_get_state
esp_ble_mesh_light_client_set_state
ESP_BLE_MESH_HC_FAULT_OFF
ESP_BLE_MESH_HC_FAULT_RUN
ESP_BLE_MESH_HC_FAULT_STANDBY
esp_ble_mesh_light_ctl_set_t (C++ class), esp_ble_mesh_light_ctl_state_t::target_temperature

esp_ble_mesh_light_ctl_set_t::ctl_delta_temperature

esp_ble_mesh_light_ctl_set_t::ctl_lightness

esp_ble_mesh_light_ctl_set_t::ctl_temperature

esp_ble_mesh_light_ctl_temperature_range_set_t

esp_ble_mesh_light_ctl_temperature_range_status_cb_t::status_code

esp_ble_mesh_light_ctl_temperature_range_status_cb_t::range_min

esp_ble_mesh_light_ctl_temperature_range_status_cb_t::range_max

esp_ble_mesh_light_ctl_temperature_range_set_t::range_min

esp_ble_mesh_light_ctl_temperature_range_set_t::range_max

esp_ble_mesh_light_ctl_temp_srv_t::tt_delta_delta_uv

esp_ble_mesh_light_ctl_temp_srv_t::transition

esp_ble_mesh_light_ctl_temp_srv_t::state

esp_ble_mesh_light_ctl_temp_srv_t::transition

esp_ble_mesh_light_ctl_temp_srv_t::tt_delta_lightness

esp_ble_mesh_light_ctl_temp_srv_t::last

esp_ble_mesh_light_ctl_temp_srv_t::model

esp_ble_mesh_light_ctl_temp_srv_t::last

esp_ble_mesh_light_ctl_temp_srv_t::model

esp_ble_mesh_light_ctl_temp_srv_t::last

esp_ble_mesh_light_ctl_temp_srv_t::model

esp_ble_mesh_light_ctl_temp_srv_t::last

esp_ble_mesh_light_ctl_temp_srv_t::model

esp_ble_mesh_light_ctl_temp_srv_t::last

esp_ble_mesh_light_ctl_temp_srv_t::model

esp_ble_mesh_light_ctl_temp_srv_t::last

esp_ble_mesh_light_ctl_temp_srv_t::model

esp_ble_mesh_light_ctl_temp_set_t (C++ class), ESP_BLE_MESH_LIGHT_CTL_TEMP_DELTA_UV_STATE

esp_ble_mesh_lightCtlStatusCB::targetCtlTemperature

esp_ble_mesh_lightCtlStatusCB::targetCtlLightness

esp_ble_mesh_lightCtlStatusCB::remainTime

esp_ble_mesh_lightCtlStatusCB::presentCtlTemperature

esp_ble_mesh_lightCtlStatusCB::presentCtlLightness

esp_ble_mesh_lightCtlState_t::temperature_range_min

esp_ble_mesh_lightCtlState_t::temperature_range_max

esp_ble_mesh_lightCtlState_t::temperature_default

esp_ble_mesh_lightCtlState_t::temperature

esp_ble_mesh_lightCtlState_t::target_temperature

esp_ble_mesh_lightCtlState_t::delta_temperature

esp_ble_mesh_lightCtlState_t::delta_lightness

esp_ble_mesh_lightCtlState_t::delta_delta_uv

esp_ble_mesh_lightCtlState_t::temperature

esp_ble_mesh_lightCtlState_t::temperature

esp_ble_mesh_lightCtlState_t::temperature

Espressif Systems

Submit Document Feedback

Release v4.3-dev-1561-g357a277603
```cpp
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::model (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::rsp_ctrl (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::state (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::transition (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::transition (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::state (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::tt_delta_hue (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::model (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::rsp_ctrl (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::state (C++ member), 350
esp_ble_mesh_light_ctl_temperature_status_cb_t::target_ctl_temperature (C++ member), 365
esp_ble_mesh_light_ctl_temperature_status_cb_t::target_ctl_delta_uv (C++ member), 365
esp_ble_mesh_light_ctl_temperature_status_cb_t::remain_time (C++ member), 365
esp_ble_mesh_light_ctl_temperature_status_cb_t::present_ctl_temperature (C++ member), 365
esp_ble_mesh_light_ctl_temperature_status_cb_t::present_ctl_delta_uv (C++ member), 365
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::tt_delta_hue (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::model (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::rsp_ctrl (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::state (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::transition (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::transition (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::state (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::tt_delta_hue (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::model (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::rsp_ctrl (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::state (C++ member), 350
esp_ble_mesh_light_ctl_temperature_status_cb_t::targetCtlTemperature (C++ member), 365
esp_ble_mesh_light_ctl_temperature_status_cb_t::targetCtlDeltaUv (C++ member), 365
esp_ble_mesh_light_ctl_temperature_status_cb_t::remainTime (C++ member), 365
esp_ble_mesh_light_ctl_temperature_status_cb_t::presentCtlTemperature (C++ member), 365
esp_ble_mesh_light_ctl_temperature_status_cb_t::presentCtlDeltaUv (C++ member), 365
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::transition (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::state (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::tt_delta_hue (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::model (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::rsp_ctrl (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_hue_srv_t::state (C++ member), 350
esp BLE_MESH_LIGHT_HSL_HUE_STATE (C++ enumerator), 266
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::transition (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::state (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::tt_delta_hue (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::model (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::rsp_ctrl (C++ member), 350
esp_ble_mesh_light_ctl_temperature_set(esp_ble_mesh_light_hsl_sat_srv_t::state (C++ member), 350
esp_ble_mesh_light_ctl_temperature_status_cb_t::targetHue (C++ member), 357
esp_ble_mesh_light_ctl_temperature_status_cb_t::remainTime (C++ member), 357
esp_ble_mesh_light_ctl_temperature_status_cb_t::presentHue (C++ member), 357
esp_ble_mesh_light_ctl_temperature_status_cb_t::statusCode (C++ member), 357
esp BLE_MESH_LIGHT_HSL_LIGHTNESS_STATE (C++ enumerator), 266
esp_BLE_MESH_LIGHT_HSL_HUE_STATE (C++ class), 356
Esp pressif Systems
Release v4.3-dev-1561-g357a277603
Submit Document Feedback
```
esp_ble_mesh_light_hsl_srv_t::tt_delta_saturation
(C++ member), 363

esp_ble_mesh_light_hsl_saturation_set_t::esp_ble_mesh_light_hsl_srv_t::state
(C++ member), 364

esp_ble_mesh_light_hsl_saturation_set_t::esp_ble_mesh_light_hsl_srv_t::transition
(C++ class), 352

esp_ble_mesh_light_hsl_saturation_set_t::esp_ble_mesh_light_hsl_srv_t::tt_delta_hover
(C++ member), 352

esp_ble_mesh_light_hsl_saturation_set_t::esp_ble_mesh_light_hsl_srv_t::tt_delta_lightness
(C++ member), 355

esp_ble_mesh_light_hsl_saturation_set_t::esp_ble_mesh_light_hsl_srv_t::tt_delta_saturation
(C++ member), 355

esp_ble_mesh_light_hsl_saturation_set_t::esp_ble_mesh_light_hsl_srv_t::state
(C++ member), 352

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_srv_t::tt_delta_saturation
(C++ member), 366

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_srv_t::state
(C++ member), 366

ESP_BLE_MESH_LIGHT_HSL_SATURATION_STATE
(C++ enumerator), 358

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_state_t::hue
(C++ member), 366

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_state_t::lightness
(C++ member), 366

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_state_t::saturation
(C++ member), 366

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_set_t(C++ class), 351

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_set_t::delay
(C++ member), 351

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_set_t::hsl_hue
(C++ member), 351

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_set_t::hsl_lightness
(C++ member), 351

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_set_t::hsl_saturation
(C++ member), 351

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_set_t::op_en
(C++ member), 351

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_set_t::tid
(C++ member), 351

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_set_t::trans_time
(C++ member), 351

esp_ble_mesh_light_hsl_setup_srv_t::esp_ble_mesh_light_hsl_status_cb_t
(C++ class), 357

esp_ble_mesh_light_hsl_status_cb_t::esp_ble_mesh_light_hsl_status_cb_t::hsl_lightness
(C++ member), 357

esp_ble_mesh_light_hsl_status_cb_t::esp_ble_mesh_light_hsl_status_cb_t::hsl_saturation
(C++ member), 357

esp_ble_mesh_light_hsl_status_cb_t::esp_ble_mesh_light_hsl_status_cb_t::op_en
(C++ member), 357

esp_ble_mesh_light_hsl_status_cb_t::esp_ble_mesh_light_hsl_status_cb_t::remain_time
(C++ member), 357

esp_ble_mesh_light_hsl_status_cb_t::esp_ble_mesh_light_hsl_status_cb_t::last
(C++ member), 357

esp_ble_mesh_light_hsl_status_cb_t::esp_ble_mesh_light_hsl_status_cb_t::model
(C++ member), 357

esp_ble_mesh_light_hsl_status_cb_t::esp_ble_mesh_light_hsl_status_cb_t::hsl_lightness
(C++ member), 357

esp_ble_mesh_light_hsl_status_cb_t::esp_ble_mesh_light_hsl_status_cb_t::hsl_saturation
(C++ member), 357
Espresif Systems

1769

Release v4.3-dev-1561-g357a277603

Submit Document Feedback
esp_ble_mesh_lighting_server_state_change_t::lc_property_set
(\texttt{C++ member}), 346
esp_ble_mesh_lighting_server_state_change_t::lc_mode_set
(\texttt{C++ member}), 346
esp_ble_mesh_lighting_server_state_change_t::hsl_saturation_set
(\texttt{C++ member}), 346
esp_ble_mesh_lighting_server_state_change_t::hsl_range_set
(\texttt{C++ member}), 346
esp_ble_mesh_lighting_server_state_change_t::hsl_hue_set
(\texttt{C++ member}), 346
esp_ble_mesh_lighting_server_state_change_t::hsl_default_set
(\texttt{C++ member}), 346
esp_ble_mesh_lighting_server_state_change_t::ctl_temp_set
(\texttt{C++ member}), 346
esp_ble_mesh_lighting_server_state_change_t::ctl_set
(\texttt{C++ member}), 346
esp_ble_mesh_lighting_server_state_change_t
(\texttt{C++ class}), 346
ESP_BLE_MESH_LIGHTING_SERVER_STATE_CHANGE_EVT
(\texttt{C++ function}), 269
esp_ble_mesh_lighting_server_recv_status_msg_t::sensor_status
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_status_msg_t
(\texttt{C++ class}), 347
ESP_BLE_MESH_LIGHTING_SERVER_RECV_STATUS_MSG_EVT
(\texttt{C++ function}), 269
esp_ble_mesh_lighting_server_recv_set_msg_t::xyl_range
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t::xyl_default
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t::xyl
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t::lightness_range
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t::lightness_linear
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t::lightness
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t::lc_property
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t::lc_om
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t::lc_mode
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t::lc_light_onoff
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t::xyl
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t::ctl_set
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t::ctl
(\texttt{C++ member}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t
(\texttt{C++ class}), 347
esp_ble_mesh_lighting_server_recv_set_msg_t::ctl
(\texttt{C++ member}), 347
ESP_BLE_MESH_LIGHTING_SERVER_RECV_SET_EVT
(\texttt{C++ function}), 269
esp_ble_mesh_model::op
(\texttt{C++ member}), 239
esp_ble_mesh_model::model_id
(\texttt{C++ member}), 239
esp_ble_mesh_model::keys
(\texttt{C++ member}), 239
esp_ble_mesh_model::groups
(\texttt{C++ member}), 239
esp_ble_mesh_model::element_idx
(\texttt{C++ member}), 239
esp_ble_mesh_model::element
(\texttt{C++ member}), 239
esp_ble_mesh_model::company_id
(\texttt{C++ member}), 239
esp_ble_mesh_model::cb
(\texttt{C++ member}), 239
esp_ble_mesh_model::ext
(\texttt{C++ member}), 239
esp_ble_mesh_model::ext::company_id
(\texttt{C++ member}), 239
esp_ble_mesh_model::ext::element
(\texttt{C++ member}), 239
esp_ble_mesh_model::ext::element_idx
(\texttt{C++ member}), 239
esp_ble_mesh_model::ext::model_id
(\texttt{C++ member}), 239
esp_ble_mesh_model::model_id
(\texttt{C++ member}), 239
ESP_BLE_MESH_MECHANISM_JAMMED_WARNING
(\texttt{C++ function}), 342
ESP_BLE_MESH_MECHANISM_JAMMED_ERROR
(\texttt{C++ function}), 342
ESP_BLE_MESH_MEMORY_ERROR
(\texttt{C++ function}), 341
ESP_BLE_MESH_MEMORY_WARNING
(\texttt{C++ function}), 341
ESP_BLE_MESH_MIC_SHORT
(\texttt{C++ function}), 245
ESP_BLE_MESH_LIGHTING_SERVER_RECV_SET_EVT
(\texttt{C++ function}), 269
ESP_BLE_MESH_LIGHTING_SERVER_RECV_STATUS_MSG_EVT
(\texttt{C++ function}), 269
ESP_BLE_MESH_LIGHTING_SERVER_RECV_STATUS_MSG_EVT
(\texttt{C++ function}), 269
ESP_BLE_MESH_LIGHTING_SERVER_RECV_SET_EVT
(\texttt{C++ function}), 269
ESP_BLE_MESH_LIGHTING_SERVER_RECV_SET_EVT
(\texttt{C++ function}), 269
ESP_BLE_MESH_LIGHTING_SERVER_RECV_SET_EVT
(\texttt{C++ function}), 269
ESP_BLE_MESH_LIGHTING_SERVER_RECV_SET_EVT
(\texttt{C++ function}), 269
ESP_BLE_MESH_LIGHTING_SERVER_RECV_SET_EVT
(\texttt{C++ function}), 269
ESP_BLE_MESH_LIGHTING_SERVER_RECV_SET_EVT
(\texttt{C++ function}), 269
| C++ type                  | C++ member                          | C++ class                               | C++ class        | C++ class        | C++ class        | C++ class        | C++ class        | C++ class        | C++ class        |
|---------------------------|-------------------------------------|-----------------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| esp_ble_mesh_model::user_data   | (C++ member), 239                        | esp_ble_mesh_model::vnd (C++ member), 239 | esp_ble_mesh_model::{anonymous} (C++ member), 266 | esp_ble_mesh_model::cb_event_t (C++ union), 234 | esp_ble_mesh_model::cb_param_t::ble_mesh_model_send_comp_param::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_model_send_comp_param::err_code (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_model_send_comp_param::ctx (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_model_publish_update_evt_param::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_model_publish_comp_param::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_model_publish_comp_param::err_code (C++ member), 236 |
| esp_ble_mesh_model::cb_event_t (C++ union), 234 | esp_ble_mesh_model::cb_param_t::ble_mesh_model_send_comp::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_model_send_comp::err_code (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_model_send_comp::ctx (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_model_operation_evt_param::opcode (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_model_operation_evt_param::msg (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_model_operation_evt_param::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_model_operation_evt_param::length (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_mod_recv_publish_msg_param::opcode (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_mod_recv_publish_msg_param::msg (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_mod_recv_publish_msg_param::length (C++ member), 236 |
| esp_ble_mesh_model::cb_param_t::ble_mesh_mod_recv_publish_msg_param::ctx (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_mod_recv_publish_msg_param::length (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_mod_recv_publish_msg_param::ctx (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_client_model_send_timeout_param::ctx (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_client_model_send_timeout_param::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_client_model_send_timeout_param::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_client_model_send_timeout_param::err_code (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_client_model_send_timeout_param::ctx (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_client_model_send_timeout_param::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_client_model_send_timeout_param::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_client_model_send_timeout_param::ctx (C++ member), 236 |
| esp_ble_mesh_model::cb_event_t (C++ union), 234 | esp_ble_mesh_model::cb_param_t::ble_mesh_server_model_update_state_comp_param::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_server_model_update_state_comp_param::err_code (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_server_model_update_state_comp_param::ctx (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_server_model_update_state_comp_param::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_server_model_update_state_comp_param::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_server_model_update_state_comp_param::err_code (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_server_model_update_state_comp_param::ctx (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_server_model_update_state_comp_param::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_server_model_update_state_comp_param::model (C++ member), 236 | esp_ble_mesh_model::cb_param_t::ble_mesh_server_model_update_state_comp_param::ctx (C++ member), 236 |
ESP_BLE_MESH_MODEL_ID_SCHEDULER_CLI (C 宏), 250
ESP_BLE_MESH_MODEL_ID_SCHEDULER_SETUP_SRV (C 宏), 249
ESP_BLE_MESH_MODEL_ID_SCHEDULER_SRV (C 宏), 249
ESP_BLE_MESH_MODEL_ID_SENSOR_CLI (C 宏), 249
ESP_BLE_MESH_MODEL_ID_SENSOR_SETUP_SRV (C 宏), 249
ESP_BLE_MESH_MODEL_ID_SENSOR_SRV (C 宏), 249
ESP_BLE_MESH_MODEL_ID_TIME_CLI (C 宏), 249
ESP_BLE_MESH_MODEL_ID_TIME_SETUP_SRV (C 宏), 249
ESP_BLE_MESH_MODEL_ID_TIME_SRV (C 宏), 249
ESP_BLE_MESH_MODEL_LIGHT_CTL_CLI (C 宏), 381
ESP_BLE_MESH_MODEL_LIGHT_CTL_SETUP_SRV (C 宏), 382
ESP_BLE_MESH_MODEL_LIGHT_CTL_SRV (C 宏), 381
ESP_BLE_MESH_MODEL_LIGHT_CTL_TEMP_SRV (C 宏), 382
ESP_BLE_MESH_MODEL_LIGHT_HSL_CLI (C 宏), 381
ESP_BLE_MESH_MODEL_LIGHT_HSL_HUE_SRV (C 宏), 383
ESP_BLE_MESH_MODEL_LIGHT_HSL_HUE_SRV (C 宏), 383
ESP_BLE_MESH_MODEL_LIGHT_HSL_SET_UP_SRV (C 宏), 382
ESP_BLE_MESH_MODEL_LIGHT_HSL_SRV (C 宏), 382
ESP_BLE_MESH_MODEL_LIGHT_LC_CLI (C 宏), 381
ESP_BLE_MESH_MODEL_LIGHT_LC_SETUP_SRV (C 宏), 383
ESP_BLE_MESH_MODEL_LIGHT_LC_SRV (C 宏), 383
ESP_BLE_MESH_MODEL_LIGHT_LIGHTNESS_CLI (C 宏), 380
ESP_BLE_MESH_MODEL_LIGHT_LIGHTNESS_SRV (C 宏), 381
ESP_BLE_MESH_MODEL_LIGHT_XYL_CLI (C 宏), 381
ESP_BLE_MESH_MODEL_LIGHT_XYL_SETUP_SRV (C 宏), 383
eesp_ble_msg_opcode_init (C++ function), 270
ESP_BLE_MESH_MODEL_NONE (C 宏), 248
ESP_BLE_MESH_MODEL_OP (C 宏), 248
ESP_BLE_MESH_MODEL_OP_1 (C 宏), 247
ESP_BLE_MESH_MODEL_OP_2 (C 宏), 247
ESP_BLE_MESH_MODEL_OP_3 (C 宏), 247
ESP_BLE_MESH_MODEL_OP_APP_KEY_ADD (C 宏), 251
ESP_BLE_MESH_MODEL_OP_APP_KEY_DELETE (C 宏), 252
ESP_BLE_MESH_MODEL_OP_APP_KEY_GET (C 宏), 250
ESP_BLE_MESH_MODEL_OP_APP_KEY_LIST (C 宏), 252
ESP_BLE_MESH_MODEL_OP_APP_KEY_STATUS (C 宏), 252
ESP_BLE_MESH_MODEL_OP_APP_KEY_UPDATE (C 宏), 252
ESP_BLE_MESH_MODEL_OP_ATTENTION_GET (C 宏), 253
ESP_BLE_MESH_MODEL_OP_ATTENTION_SET (C 宏), 253
ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_UNACK (C 宏), 254
ESP_BLE_MESH_MODEL_OP_ATTENTION_STATUS (C 宏), 254
ESP_BLE_MESH_MODEL_OP_BEACON_GET (C 宏), 250
ESP_BLE_MESH_MODEL_OP_BEACON_SET (C 宏), 251
ESP_BLE_MESH_MODEL_OP_BEACON_STATUS (C 宏), 252
ESP_BLE_MESH_MODEL_OP_COMPOSITION_DATA_GET (C 宏), 250
ESP_BLE_MESH_MODEL_OP_COMPOSITION_DATA_STATUS (C 宏), 252
ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_GET (C 宏), 250
ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_SET (C 宏), 251
ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_STATUS (C 宏), 252
ESP_BLE_MESH_MODEL_OP_END (C 宏), 248
ESP_BLE_MESH_MODEL_OP_FRIEND_GET (C 宏), 250
ESP_BLE_MESH_MODEL_OP_FRIEND_SET (C 宏), 251
ESP_BLE_MESH_MODEL_OP_FRIEND_STATUS (C 宏), 252
ESP_BLE_MESH_MODEL_OP_GATT_PROXY_GET (C 宏), 250
ESP_BLE_MESH_MODEL_OP_GATT_PROXY_SET (C 宏), 251
ESP_BLE_MESH_MODEL_OP_GATT_PROXY_STATUS (C 宏), 252
ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTIES_GET (C 宏), 255
ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTIES_STATUS (C 宏), 255
ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_GET (C 宏), 255
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Release v4.3-dev-1561-g357a277603

Submit Document Feedback
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Espressif Systems 1777 Release v4.3-dev-1561-g357a277603
Submit Document Feedback
ESP_BLE_MESH_MODEL_OP_SCENE_DELETE
ESP_BLE_MESH_MODEL_OP_SCENE_DELETE_UNACK
ESP_BLE_MESH_MODEL_OP_SCENE_RECALL
ESP_BLE_MESH_MODEL_OP_SCENE_RECALL_UNACK
ESP_BLE_MESH_MODEL_OP_SCENE_REGISTER_GET
ESP_BLE_MESH_MODEL_OP_SCENE_REGISTER_STATUS
ESP_BLE_MESH_MODEL_OP_SCENE_STORE
ESP_BLE_MESH_MODEL_OP_SCENE_STORE_UNACK
ESP_BLE_MESH_MODEL_OP_SCENE_RECALL
ESP_BLE_MESH_MODEL_OP_SCENE_GET
ESP_BLE_MESH_MODEL_OP_SCENE_STATUS
ESP_BLE_MESH_MODEL_OP_SCENE_REGISTER_GET
ESP_BLE_MESH_MODEL_OP_SCENE_REGISTER_STATUS
ESP_BLE_MESH_MODEL_OP_SCENE_STORE
ESP_BLE_MESH_MODEL_OP_SCENE_STORE_UNACK
ESP_BLE_MESH_MODEL_OP_SCENE_RECALL
ESP_BLE_MESH_MODEL_OP_SCENE_GET
ESP_BLE_MESH_MODEL_OP_SCENE_STATUS

ESP_BLE_MESH_MODEL_OP_NET_KEY_ADD
ESP_BLE_MESH_MODEL_OP_NET_KEY_DELETE
ESP_BLE_MESH_MODEL_OP_NET_KEY_GET
ESP_BLE_MESH_MODEL_OP_NET_KEY_LIST
ESP_BLE_MESH_MODEL_OP_NET_KEY_STATUS
ESP_BLE_MESH_MODEL_OP_NET_KEY_UPDATE
ESP_BLE_MESH_MODEL_OP_NETWORK_TRANSMIT
ESP_BLE_MESH_MODEL_OP_NETWORK_TRANSMIT_SET
ESP_BLE_MESH_MODEL_OP_NETWORK_TRANSMIT_GET
ESP_BLE_MESH_MODEL_OP_NET_KEY_UPDATE
ESP_BLE_MESH_MODEL_OP_NET_KEY_STATUS
ESP_BLE_MESH_MODEL_OP_NET_KEY_LIST
ESP_BLE_MESH_MODEL_OP_NET_KEY_GET
ESP_BLE_MESH_MODEL_OP_NET_KEY_DELETE
ESP_BLE_MESH_MODEL_OP_NET_KEY_ADD
ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_OVERWRITE
ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_DELETE
ESP_BLE_MESH_MODEL_OP_MODEL_SUB_STATUS
ESP_BLE_MESH_MODEL_OP_MODEL_SUB_OVERWRITE
ESP_BLE_MESH_MODEL_OP_MODEL_SUB_DELETE_ALL
ESP_BLE_MESH_MODEL_OP_MODEL_SUB_DELETE
ESP_BLE_MESH_MODEL_OP_MODEL_SUB_ADD
ESP_BLE_MESH_MODEL_OP_MODEL_PUB_VIRTUAL_ADDR_SET
ESP_BLE_MESH_MODEL_OP_MODEL_PUB_STATUS
ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_STATUS
ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_SET
ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_GET
ESP_BLE_MESH_MODEL_OP_SENSOR_SERIES_STATUS
ESP_BLE_MESH_MODEL_OP_SENSOR_SERIES_GET
ESP_BLE_MESH_MODEL_OP_SENSOR_GET
ESP_BLE_MESH_MODEL_OP_SENSOR_DESCRIPTOR_STATUS
ESP_BLE_MESH_MODEL_OP_SENSOR_DESCRIPTOR_GET
ESP_BLE_MESH_MODEL_OP_SENSOR_COLUMN_STATUS
ESP_BLE_MESH_MODEL_OP_SENSOR_COLUMN_GET
ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_STATUS
ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_SET
ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_SET_UNACK
ESP_BLE_MESH_MODEL_OP_SCHEDULER_STATUS
ESP_BLE_MESH_MODEL_OP_SCHEDULER_GET
ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_SET
ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_SET_UNACK
ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_GET
ESP_BLE_MESH_MODEL_OP_SCENE_STORE
ESP_BLE_MESH_MODEL_OP_SCENE_STORE_UNACK
ESP_BLE_MESH_MODEL_OP_SCENE_RECALL
ESP_BLE_MESH_MODEL_OP_SCENE_GET
ESP_BLE_MESH_MODEL_OP_SCENE_STATUS
ESP_BLE_MESH_MODEL_OP_SCENE_REGISTER_STATUS
ESP_BLE_MESH_MODEL_OP_SCENE_REGISTER_GET
ESP_BLE_MESH_MODEL_OP_SCENE_DELETE
ESP_BLE_MESH_MODEL_OP_SCENE_DELETE_UNACK
ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_STATUS
ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_SET
ESP_BLE_MESH_MODEL.OP_SENSOR_SETTING_GET
ESP_BLE_MESH_MODEL.OP_SENSOR_SERIES_STATUS
ESP_BLE_MESH_MODEL.OP_SENSOR_SERIES_GET
ESP_BLE_MESH_MODEL.OP_SENSOR_GET
ESP_BLE_MESH_MODEL.OP_SENSOR_DESCRIPTOR_STATUS
ESP_BLE_MESH_MODEL.OP_SENSOR_DESCRIPTOR_GET
ESP_BLE_MESH_MODEL.OP_SENSOR_COLUMN_STATUS
ESP_BLE_MESH_MODEL.OP_SENSOR_COLUMN_GET
ESP_BLE_MESH_MODEL.OP_SENSOR_CADENCE_STATUS
ESP_BLE_MESH_MODEL.OP_SENSOR_CADENCE_SET
ESP_BLE_MESH_MODEL.OP_SENSOR_CADENCE_SET_UNACK
ESP_BLE_MESH_MODEL.OP_SCHEDULER_STATUS
ESP_BLE_MESH_MODEL.OP_SCHEDULER_GET
ESP_BLE_MESH_MODEL.OP_SCHEDULER.ACT_SET
ESP_BLE_MESH_MODEL.OP_SCHEDULER.ACT_SET_UNACK
ESP_BLE_MESH_MODEL.OP_SCHEDULER.ACT_GET

Espressif Systems 1778 Release v4.3-dev-1561-g357a277603
Submit Document Feedback
ESP_BLE_MESH_MODEL_OP_SENSOR_SETTINGS_GET
ESP_BLE_MESH_MODEL_OP_SENSOR_SETTINGS_STATUS
ESP_BLE_MESH_MODEL_OP_SENSOR_STATUS
ESP_BLE_MESH_MODEL_OP_SIG_MODEL_APP_GET
ESP_BLE_MESH_MODEL_OP_SIG_MODEL_APP_LIST
ESP_BLE_MESH_MODEL_OP_SIG_MODEL_SUB_GET
ESP_BLE_MESH_MODEL_OP_SIG_MODEL_SUB_LIST
esp_ble_mesh_model_op_t (C++ class)
esp_ble_mesh_model_op_t::min_len (C++ member)

esp_ble_mesh_model_op_t::opcode (C++ member)

esp_ble_mesh_model_op_t::param_cb (C++ member)

esp_ble_mesh_model_op_t::period (C++ member)

esp_ble_mesh_model_op_t::period_div (C++ member)

esp_ble_mesh_model_op_t::period_start (C++ member)

esp_ble_mesh_model_op_t::publish_addr (C++ member)

esp_ble_mesh_model_op_t::retransmit (C++ member)

esp_ble_mesh_model_op_t::send_rel (C++ member)

esp_ble_mesh_model_op_t::timer (C++ member)

esp_ble_mesh_model_pub_t::app_idx
esp_ble_mesh_model_pub_t::count (C++ member)
esp_ble_mesh_model_pub_t::cred (C++ member)
esp_ble_mesh_model_pub_t::dev_role
esp_ble_mesh_model_pub_t::fast_period (C++ member)
esp_ble_mesh_model_pub_t::model (C++ member)
esp_ble_mesh_model_pub_t::msg (C++ member)

ESP_BLE_MESH_MODEL_STATUS_CANNOT_SET_RANGE_MIN
ESP_BLE_MESH_MODEL_SENSOR_SRV
ESP_BLE_MESH_MODEL_SENSOR_CLI
ESP_BLE_MESH_MODEL_SENSOR_SETUP_SRV
ESP_BLE_MESH_MODEL_SENSOR_CLI
ESP_BLE_MESH_MODEL_SCENE_SETUP_SRV
ESP_BLE_MESH_MODEL_SCENE_CLI
ESP_BLE_MESH_MODEL_SCHEDULER_CLI
ESP_BLE_MESH_MODEL_SCHEDULER_SRV
ESP_BLE_MESH_MODEL_PUBLISH_UPDATE_EVT
ESP_BLE_MESH_MODEL_PUBLISH_COMP_EVT
ESP_BLE_MESH_MODEL_PUBLISH_COMP_EVT
ESP_BLE_MESH_MODEL_SCHEDULER_SRV
ESP_BLE_MESH_MODEL_SCHEDULER_SRV
ESP_BLE_MESH_MODEL_STATUS_SUCCESS (C) esp_ble_mesh_node_is_provisioned (C++ function), 274
esp_ble_mesh_model_status_t (C++ type), esp_ble_mesh_node_local_reset (C++ function), 271
esp_ble_mesh_model_subscribe_group_add (C++)
ESP_BLE_MESH_NODE_NAME_MAX_LEN (C), 245
ESP_BLE_MESH_NODE_PROVCOMPLETE_EVT (C++ enumerator), 265
esp_ble_mesh_model_t (C++ type), 260
ESP_BLE_MESH_NODE_PROXY_GATT_ENABLE_COMP_EVT (C)
ESP_BLE_MESH_NODE_PROXY_GATT_DISABLE_COMP_EVT (C)
esp_ble_mesh_node_set_oob_pub_key (C++)
ESP_BLE_MESH_NODE_PROV_DISABLECOMP_EVT (C++ enumerator), 263
esp_ble_mesh_node_prov_enable (C++ function), 274
ESP_BLE_MESH_NODE_PROV_ENABLECOMP_EVT (C++)
ESP_BLE_MESH_NODE_PROV_INPUT_EVT (C++)
ESP_BLE_MESH_NODE_PROV_OUTPUT_STRING_EVT (C++)
ESP_BLE_MESH_NODE_PROV_OUTPUT_NUMBER_EVT (C++)
esp_ble_mesh_node_prov_output_evt (C++)
ESP_BLE_MESH_NODE_PROVOUTPUTSTRING_EVT (C++)
ESP_BLE_MESH_NODE_PROVOUTPUTNUMBER_EVT (C++)
ESP_BLE_MESH_NODE_PROXY_DISABLECOMP_EVT (C++)
ESP_BLE_MESH_NODE_PROXY_ENABLECOMP_EVT (C++)
ESP_BLE_MESH_NODE_PROXYIDENTITYENABLECOMP_EVT (C++)
esp_ble_mesh_node_set_oob_pub_key (C++)
ESP_BLE_MESH_NODE_SETUNPROVDEV_NAMECOMP_EVT (C++ enumerator), 263
esp_ble_mesh_node_set_unprov_dev_name (C++)
ESP_BLE_MESH_NODE_NOT_SUPPORTED (C), 246
ESP_BLE_MESH_NODE_RUNNING (C), 246
ESP_BLE_MESH_NODE_STOPPED (C), 246
esp_ble_mesh_node_input_number (C++ function), 275
esp_ble_mesh_node_input_string (C++)
esp_ble_mesh_node_input_string (C++ function), 275
esp_ble_mesh_node_input_string (C++)
esp_ble_mesh_node_name_max_len (C), 245
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_link_open_evt_param::bearer (C++ class, 222)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_link_open_evt_param (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_link_close_evt_param::reason (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_link_close_evt_param::bearer (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_uuid_comp_param::uuid (C++ class, 223)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_uuid_comp_param::err_code (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_addr_comp_param::unicast_addr (C++ class, 223)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_addr_comp_param::err_code (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_dev_comp_param::err_code (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_dev_comp_param (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_bind_local_mod_app_comp_param::model_id (C++ class, 223)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_bind_local_mod_app_comp_param::element_addr (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_unprov_dev_comp_param::err_code (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_local_net_key_comp_param::net_idx (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_local_app_key_comp_param::net_idx (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_local_app_key_comp_param::app_idx (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_model_unsub_group_addr_comp_param::model_id (C++ class, 222)
esp_ble_mesh_prov_cb_param_t::ble_mesh_model_unsub_group_addr_comp_param::group_addr (C++ class, 222)
esp_ble_mesh_prov_cb_param_t::ble_mesh_model_unsub_group_addr_comp_param::err_code (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_model_unsub_group_addr_comp_param::company_id (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_model_sub_group_addr_comp_param::group_addr (C++ class, 222)
esp_ble_mesh_prov_cb_param_t::ble_mesh_model_sub_group_addr_comp_param::element_addr (C++ class, 224)
esp_ble_mesh_prov_cb_param_t::ble_mesh_prov_input_str_comp_param::err_code
(C++ member)
<table>
<thead>
<tr>
<th>Function Name</th>
<th>Description</th>
</tr>
</thead>
</table>
| esp_ble_mesh_prov_cb_param_t::ble_mesh_prov_input_str_comp | Input string completion for the provisioner.
| esp_ble_mesh_prov_cb_param_t::ble_mesh_prov_input_num_comp | Input number completion for the provisioner.
| esp_ble_mesh_prov_cb_param_t::node_prov_link_open | Link open function for node provisioner.
| esp_ble_mesh_prov_cb_param_t::node_prov_link_close | Link close function for node provisioner.
| esp_ble_mesh_prov_cb_param_t::node_prov_input_str_comp | Input string completion for the node provisioner.
| esp_ble_mesh_prov_cb_param_t::node_prov_input_num_comp | Input number completion for the node provisioner.
| esp_ble_mesh_prov_cb_param_t::node_prov_output_str | Output string function for the node provisioner.
| esp_ble_mesh_prov_cb_param_t::node_prov_output_num | Output number function for the node provisioner.
| esp_ble_mesh_prov_cb_param_t::node_prov_output_str_comp | Output string completion function for the node provisioner.
| esp_ble_mesh_prov_cb_param_t::node_prov_output_num_comp | Output number completion function for the node provisioner.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_identity_enable_comp | Identity enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_identity_disable_comp | Identity disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_disable_comp | GATT disable function for node proxy.
| esp_ble_mesh_prov_cb_param_t::node_proxy_gatt_enable_comp | GATT enable function for node proxy.
EspresifSystems 1786

Submit Document Feedback

esp_ble_mesh_prov_cb_param_t::provisioner_prov_data_info_t (C++ member), 241
essp_ble_mesh_prov_data_info_t::flag (C++ member), 241
essp_ble_mesh_prov_data_info_t::flags (C++ member), 241
esp_ble_mesh_prov_data_info_t::iv_index (C++ member), 241
esp_ble_mesh_prov_data_info_t::net_idx (C++ member), 241
esp_ble_mesh_prov_data_info_t::key (C++ member), 241
esp_ble_mesh_prov_data_info_t::key_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::start_ble_advertising_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::stop_ble_advertising_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::set_fast_prov_info_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::set_fast_prov_action_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::proxy_client_set_filter_type_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::proxy_client_remove_filter_addr_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::proxy_client_recv_filter_status (C++ member), 241
esp_ble_mesh_prov_data_info_t::proxy_client_recv_adv_pkt (C++ member), 241
esp_ble_mesh_prov_data_info_t::proxy_client_disconnected (C++ member), 241
esp_ble_mesh_prov_data_info_t::proxy_client_disconnect_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::proxy_client_connected (C++ member), 241
esp_ble_meshProvDataInfo_t::proxy_client_connect_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::proxy_client_add_filter_addr_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::provisioner_update_net_key_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::provisioner_update_app_key_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::provisioner_store_node_comp_data_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::provisioner_set_static_oob_val_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::provisioner_set_primary_elem_addr_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::provisioner_set_node_name_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::provisioner_set_dev_uuid_match_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::provisioner_recv_unprov_adv_pkt (C++ member), 241
esp_ble_mesh_prov_data_info_t::provisioner_prov_read_oob_pub_key_comp (C++ member), 241
esp_ble_mesh_prov_data_info_t::provisioner_prov_read_oob_pub_key (C++ member), 241
esp_ble_mesh_prov_data_info_t::provisioner_prov_output (C++ member), 241
esp_ble_mesh_prov_data_info_t::provisioner_prov_link_open (C++ member), 241
esp_ble_mesh_prov_data_info_t::provisioner_prov_link_close (C++ member), 241

C++ enum
C++ member
C++ function
C++ enumerator
Espresif Systems

1788  Release v4.3-dev-1561-g357a277603

Submit Document Feedback

esp_ble_mesh_proxy_client_disconnect (C++ function), 279
ESP_BLE_MESH_RELAY_NOT_SUPPORTED (C 宏), 246
ESP_BLE_MESH_PROXY_CLIENT_DISCONNECT_CONNREF.Mesh Sample Func Accumulated (C++ enumerator), 265
ESP_BLE_MESH_PROXY_CLIENT_DISCONNECTED.Mesh Sample Func Arithmetic Mean (C++ enumerator), 265
ESP_BLE_MESH_PROXY_CLIENT_RECV_ADV_PKT.Mesh Sample Func Count (C++ enumerator), 400
ESP_BLE_MESH_PROXY_CLIENT_RECV_FILTER.Mesh Sample Func Instantaneous (C++ enumerator), 265
esp_ble_mesh_proxy_client_remove_filter.Mesh Sample Func Maximum (C++ function), 280
ESP_BLE_MESH_PROXY_CLIENT_REMOVE_FILTER.Mesh Sample Func Minimum (C++ enumerator), 265
esp_ble_mesh_proxy_client_set_filter_type.Mesh Sample Func Unspecified (C++ enumerator), 279
esp_ble_mesh_proxy_filter_type_t (C++ enum), 262
esp_ble_mesh_proxy_gatt_disable (C++ function), 279
esp_ble_mesh_proxy_gatt_enable (C++ function), 279
esp_ble_mesh_proxy_gatt_disabled (C++ function), 279
ESP_BLE_MESH_PUBLISH_TRANSMIT (C 宏), 247
ESP_BLE_MESH_PUSH (C++ enumerator), 261
esp_ble_mesh_register_config_client_callback.Mesh Scene Recall Callback (C++ function), 280
esp_ble_mesh_register_config_server_callback.Mesh Scene Recall Callback (C++ function), 280
esp_ble_mesh_register_custom_model_callback.Mesh Scene Recall Callback (C++ function), 269
(es) Scene Delete Callback (C++ function), 304
(es) Scene Delete Callback (C++ function), 304
esp_ble_mesh_register_health_client_callback (C++ class), 407
(es) Scene Delete Callback (C++ function), 335
(es) Scene Delete Callback (C++ function), 335
(es) Scene Delete Callback (C++ function), 343
(es) Scene Delete Callback (C++ function), 344
(es) Scene Delete Callback (C++ function), 274
(es) Scene Delete Callback (C++ function), 385
(es) Scene Delete Callback (C++ function), 386
(es) Scene Delete Callback (C++ function), 400
(es) Scene Delete Callback (C++ function), 401
ESP_BLE_MESH_RELAYDISABLED (C 宏), 246
ESP_BLE_MESH_RELAY_ENABLED (C 宏), 246
(C++ member), 411
esp_ble_mesh_scene_setup_srv_t::state
(C++ member), 411
esp_ble_mesh_scene_srv_t (C++ class), 411
esp_ble_mesh_scene_srv_t::last
(C++ member), 411
esp_ble_mesh_scene_srv_t::model
(C++ member), 411
esp_ble_mesh_scene_srv_t::rsp_ctrl
(C++ member), 411
epb_ble_mesh_scene Tribe
(C++ member), 411
esp_ble_mesh_scenes_status_cb_t::target_scene
esp_ble_mesh_scenes_status_cb_t::status_code
esp_ble_mesh_scenes_status_cb_t::sequences
esp_ble_mesh_scenes_status_cb_t::scene_count
esp_ble_mesh_scenes_status_cb_t::current_scene
(esp_ble_mesh_scenes_status_cb_t)
ESP_BLE_MESH_SCENE_SUCCESS
(C=宏), 420
esp_ble_mesh_scenes_state_t (C++ class), 410
esp_ble_mesh_scenes_state_t::current_scene
(C++ member), 410
esp_ble_mesh_scenes_state_t::input
(C++ member), 410
esp_ble_mesh_scenes_state_t::more
(C++ member), 410
esp_ble_mesh_scenes_state_t::sequences
(C++ member), 410
ESP_BLE_MESH_SCHEDULE_SEC_ANY_OF_MIN
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SEC_EVERY_15_MIN
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SEC_EVERY_20_MIN
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SEC_EVERY_15_SEC
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SEC_EVERY_20_SEC
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SCENE_NO_SCENE
(C=宏), 420
ESP_BLE_MESH_SCENE_SUCCESS
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SEC_EVERY_20_MIN
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SEC_EVERY_15_SEC
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SEC_EVERY_15_MIN
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SCENE_NO_SCENE
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SEC_EVERY_20_MIN
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SEC_EVERY_15_SEC
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SEC_EVERY_15_MIN
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SCENE_NO_SCENE
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SEC_EVERY_20_MIN
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SEC_EVERY_15_SEC
(C=宏), 420
ESP_BLE_MESH_SCHEDULE_SEC_EVERY_15_MIN
(C=宏), 420
esp_ble_mesh_server_recv_scheduler_act

esp_ble_mesh_server_recv_sensor_setting_get_t::property_id

esp_ble_mesh_server_recv_sensor_setting_set_t::setting_property_id

esp_ble_mesh_server_recv_sensor_cadence_set_t::property_id

esp_ble_mesh_server_recv_time_status_t::time_zone_offset

esp_ble_mesh_server_recv_sensor_status_t::data

esp_ble_mesh_server_recv_sensor_settings_get_t::property_id

esp_ble_mesh_server_recv_sensor_role_set_t::time_role

esp_ble_mesh_server_recv_tai_utc_delta_set_t::tai_utc_delta_new

esp_ble_mesh_server_recv_tai_utc_delta_set_t::tai_utc_time_change

esp_ble_mesh_server_recv_tai_utc_delta_set_t::padding
nullptr

*esp_ble_mesh_server_recv_time_status_t::uncertainty*

*esp_ble_mesh_server_recv_time_timezone_set_t::time_zone_offset_new*

*esp_ble_mesh_server_recv_time_timezone_set_t::tai_zone_change*

*esp_ble_mesh_server_state_change_cfg_mod_pub_set_t::company_id*

*esp_ble_mesh_server_state_change_cfg_mod_pub_set_t::app_idx*

*esp_ble_mesh_server_state_change_cfg_mod_pub_set_t::app_identifier*

*esp_ble_mesh_server_state_change_cfg_mod_pub_set_t::app_prefix_len*

*esp_ble_mesh_server_state_change_cfg_mod_pub_set_t::app_key_prefix_len*

*esp_ble_mesh_server_state_change_cfg_kr_phase_set_t::net_idx*

*esp_ble_mesh_server_state_change_cfg_kr_phase_set_t::kr_phase*

*esp_ble_mesh_server_state_change_cfg_appkey_update_t::net_idx*

*esp_ble_mesh_server_state_change_cfg_appkey_update_t::app_idx*

*esp_ble_mesh_server_state_change_cfg_appkey_delete_t::net_idx*

*esp_ble_mesh_server_state_change_cfg_appkey_delete_t::app_idx*

*esp_ble_mesh_server_state_change_cfg_appkey_add_t::net_idx*

*esp_ble_mesh_server_state_change_cfg_appkey_add_t::app_key*

*esp_ble_mesh_server_state_change_cfg_appkey_add_t::app_idx*

ESP_BLE_MESH_START_BLE_ADVERTISING_COMP_EVT

ESP_BLE_MESH_SIG_MODEL

esp_ble_mesh_set_unprovisioned_device_name

*esp_ble_mesh_set_unprovisioned_device_name:: ESP_BLE_MESH_SET_FAST_PROV_INFO_COMP_EVT*

*esp_ble_mesh_set_unprovisioned_device_name:: ESP_BLE_MESH_SET_FAST_PROV_ACTION_COMP_EVT*

*esp_ble_mesh_set_fast_prov_action:: ESP_BLE_MESH_SET_FAST_PROV_ACTION_COMP_EVT*

*esp_ble_mesh_set_fast_prov_info:: ESP_BLE_MESH_SET_FAST_PROV_INFO_COMP_EVT*

*esp_ble_mesh_set_fast_prov_info:: ESP_BLE_MESH_SET_FAST_PROV_ACTION_COMP_EVT*

 ESP_BLE_MESH_RSP_BY_APP

ESP_BLE_MESH_SERVER_TRANS_TIMER_START

*esp_ble_mesh_server_state_value_t::temperature*

*esp_ble_mesh_server_state_value_t::saturation*

*esp_ble_mesh_server_state_value_t::power*

*esp_ble_mesh_server_state_value_t::onpowerup*

*esp_ble_mesh_server_state_value_t::onoff*

*esp_ble_mesh_server_state_value_t::lightness*

*esp_ble_mesh_server_state_value_t::light_xyl_lightness*

*esp_ble_mesh_server_state_value_t::light_lightness_linear*

*esp_ble_mesh_server_state_value_t::light_lightness_actual*

*esp_ble_mesh_server_state_value_t::light_lc_light_onoff*

*esp_ble_mesh_server_state_value_t::light_hsl_saturation*

*esp_ble_mesh_server_state_value_t::light_hsl_lightness*

*esp_ble_mesh_server_state_value_t::light_hsl_hue*

*esp_ble_mesh_server_state_value_t::light_ctl_lightness*

*esp_ble_mesh_server_state_value_t::level*

*esp_ble_mesh_server_state_value_t::hue*

*esp_ble_mesh_server_state_value_t::gen_power_actual*

*esp_ble_mesh_server_state_value_t::gen_onpowerup*

*esp_ble_mesh_server_state_value_t::gen_level*

*esp_ble_mesh_server_state_value_t::delta_uv*

*esp_ble_mesh_server_state_value_t::gen_onoff*

*esp_ble_mesh_server_state_value_t::gen_power*

*esp_ble_mesh_server_state_value_t::hue*

*esp_ble_mesh_server_state_value_t::level*

*esp_ble_mesh_server_state_value_t::light_ctl1*

*esp_ble_mesh_server_state_value_t::light_ctl2*

*esp_ble_mesh_server_state_value_t::light_hsl1*

*esp_ble_mesh_server_state_value_t::light_hsl2*

*esp_ble_mesh_server_state_value_t::light_3c_lightness*

*esp_ble_mesh_server_state_value_t::light_3c_saturation*

*esp_ble_mesh_server_state_value_t::light_3c_temperature*

*esp_ble_mesh_server_state_value_t::light_xyl_lightness*

*esp_ble_mesh_server_state_value_t::light_xyl_saturation*

*esp_ble_mesh_server_state_value_t::light_xyl_temperature*

*esp_ble_mesh_server_state_value_t::light_xyl_name*

*esp_ble_mesh_server_state_value_t::onoff*

*esp_ble_mesh_server_state_value_t::cred*

*esp_ble_mesh_server_rsp_ctrl_t::status_auto_rsp*

*esp_ble_mesh_server_rsp_ctrl_t::set_auto_rsp*

*esp_ble_mesh_server_rsp_ctrl_t::ESP_BLE_MESH_SERVER_RSP_BY_APP*

*esp_ble_mesh_server_rsp_ctrl_t::ESP_BLE_MESH_SERVER_RSP_BY_APP::*
<table>
<thead>
<tr>
<th>C++ class</th>
<th>370</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_ble_mesh_state_change_light_lightness_set_t::lightness</td>
<td>373</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_lightness_set_t::x</td>
<td>373</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_lightness_set_t::y</td>
<td>373</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_def_t::y_range_min</td>
<td>414</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_def_t::y_range_max</td>
<td>414</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_def_t::x_range_max</td>
<td>414</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_def_t::x</td>
<td>414</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_def_t::lightness</td>
<td>414</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_range_set_t::x_range_min</td>
<td>374</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_range_set_t::x_range_max</td>
<td>374</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_range_set_t::y_range_min</td>
<td>374</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_range_set_t::y_range_max</td>
<td>374</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_range_set_t::lightness</td>
<td>374</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_range_set_t::x</td>
<td>374</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_range_set_t::y</td>
<td>374</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_cadence_set_t::trigger_type</td>
<td>394</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_cadence_set_t::trigger_delta_up</td>
<td>394</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_cadence_set_t::trigger_delta_down</td>
<td>394</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_cadence_set_t::period_divisor</td>
<td>394</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_cadence_set_t::min_interval</td>
<td>394</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_cadence_set_t::fast_cadence_low</td>
<td>394</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_cadence_set_t::fast_cadence_high</td>
<td>394</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_cadence_set_t::property_id</td>
<td>394</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_xyl_cadence_set_t::property_id</td>
<td>394</td>
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<td>esp_ble_mesh_state_change_light_xyl_cadence_set_t::property_id</td>
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<td>394</td>
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<tr>
<td>esp_ble_mesh_state_change_light_xyl_cadence_set_t::property_id</td>
<td>394</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_scheduler_act_set_t::day_of_week</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_scheduler_act_set_t::day</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_scheduler_act_set_t::year</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_scheduler_act_set_t::trans_time</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_scheduler_act_set_t::second</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_scheduler_act_set_t::minute</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_scheduler_act_set_t::index</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_scheduler_act_set_t::hour</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_scheduler_act_set_t::scene_number</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_scheduler_act_set_t::set_occupancy_to_1_delay</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_scheduler_act_set_t::property_id</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_scheduler_act_set_t::occupancy</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_sensor_setting_set_t::setting_value</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_sensor_setting_set_t::setting_property_id</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_sensor_cadence_set_t::trigger_type</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_sensor_cadence_set_t::trigger_delta_up</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_sensor_cadence_set_t::trigger_delta_down</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_sensor_cadence_set_t::property_id</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_sensor_cadence_set_t::period_divisor</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_sensor_cadence_set_t::min_interval</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_sensor_cadence_set_t::fast_cadence_low</td>
<td>414</td>
</tr>
<tr>
<td>esp_BLE.Mesh.StateChange_sensor_cadence_set_t::fast_cadence_high</td>
<td>414</td>
</tr>
</tbody>
</table>
Espressif Systems

1802

Release v4.3-dev-1561-g357a277603

Submit Document Feedback
esp_ble_mesh_time_scene_server_recv_set_msg_t::time_zone
esp_ble_mesh_time_scene_server_recv_set_msg_t::time_status
esp_ble_mesh_time_scene_server_recv_set_msg_t::tai_utc_delta
esp_ble_mesh_time_scene_server_recv_set_msg_t::scheduler_act_set
esp_ble_mesh_time_scene_server_recv_set_msg_t::scene_store
esp_ble_mesh_time_scene_server_recv_set_msg_t::scene_recall
esp_ble_mesh_time_scene_server_recv_set_msg_t::scene_delete

esp_ble_mesh_time_scene_server_state_change_t::time_zone_set
esp_ble_mesh_time_scene_server_state_change_t::time_status
esp_ble_mesh_time_scene_server_state_change_t::tai_utc_delta_set
esp_ble_mesh_time_scene_server_state_change_t::scheduler_act_set
esp_ble_mesh_time_scene_server_state_change_t::scene_store
esp_ble_mesh_time_scene_server_state_change_t::scene_recall
esp_ble_mesh_time_scene_server_state_change_t::scene_delete

esp_ble_mesh_time_set_t::uncertainty
esp_ble_mesh_time_set_t::time_authority
esp_ble_mesh_time_set_t::tai_utc_delta
esp_ble_mesh_time_set_t::tai_seconds
esp_ble_mesh_time_set_t::sub_second

esp_ble_mesh_time_scene_server_state_t::time_zone_offset_new
esp_ble_mesh_time_scene_server_state_t::time_zone_offset_curr
esp_ble_mesh_time_scene_server_state_t::time_role
esp_ble_mesh_time_scene_server_state_t::tai_utc_delta_new
esp_ble_mesh_time_scene_server_state_t::tai_utc_delta_curr
esp_ble_mesh_time_scene_server_state_t::time_authority
esp_ble_mesh_time_scene_server_state_t::time
esp_ble_mesh_time_scene_server_state_t::tai_seconds
esp_ble_mesh_time_scene_server_state_t::tai_delta_change
esp_ble_mesh_time_scene_server_state_t::subsecond

esp_ble_mesh_time_status_cb_t::uncertainty
esp_ble_mesh_time_status_cb_t::time_zone_offset
esp_ble_mesh_time_status_cb_t::time_authority
esp_ble_mesh_time_status_cb_t::tai_utc_delta
esp_ble_mesh_time_status_cb_t::tai_seconds
esp_ble_mesh_time_status_cb_t::sub_second

esp_ble_mesh_time_state_t::uncertainty
esp_ble_mesh_time_state_t::time_zone_offset_new
esp_ble_mesh_time_state_t::time_zone_offset_curr
esp_ble_mesh_time_state_t::time_role
esp_ble_mesh_time_state_t::tai_utc_delta_new
esp_ble_mesh_time_state_t::tai_utc_delta_curr
esp_ble_mesh_time_state_t::time_authority
esp_ble_mesh_time_state_t::time
esp_ble_mesh_time_state_t::tai_seconds

merator), 261
ESP_BLE_MESH_TYPE_INPUT_CB (C++ enumerator), 261
ESP_BLE_MESH_TYPE_LINK_CLOSE_CB (C++ enumerator), 261
ESP_BLE_MESH_TYPE_LINK_OPEN_CB (C++ enumerator), 261
ESP_BLE_MESH_TYPE_OUTPUT_NUM_CB (C++ enumerator), 261
ESP_BLE_MESH_TYPE_OUTPUT_STR_CB (C++ enumerator), 261
ESP_BLE_MESH_TYPE_PROV_CB (C++ enumerator), 261
ESP_BLE_MESH_TYPE_RESET_CB (C++ enumerator), 261
ESP_BLE_MESH_UNKNOWN_TAI_DELTA_CHANGE (C 宏), 419
ESP_BLE_MESH_UNKNOWN_TAI_SECONDS (C 宏), 419
ESP_BLE_MESH_UNKNOWN_TAI_ZONE_CHANGE (C 宏), 419
esp_ble_mesh_unprov_dev_add_t::class (C++ member), 80
esp_ble_mesh_unprov_dev_add_t::addr (C++ member), 240
esp_ble_mesh_unprov_dev_add_t::addr_type (C++ member), 240
esp_ble_mesh_unprov_dev_add_t::bearer (C++ member), 240
esp_ble_mesh_unprov_dev_add_t::oob_info (C++ member), 240
esp_ble_mesh_unprov_dev_add_t::uuid (C++ member), 240
ESP_BLE_MESH_VENDOR_MODEL (C 宏), 247
ESP_BLE_MESH_VIBRATE (C++ enumerator), 261
ESP_BLE_MESH_VIBRATION_ERROR (C 宏), 341
ESP_BLE_MESH_VIBRATION_WARNING (C 宏), 341
ESP_BLE_ONLY_ACCEPT_SPECIFIED_AUTH_DISABLE (C 宏), 84
ESP_BLE_ONLY_ACCEPT_SPECIFIED_AUTH_ENABLE (C 宏), 84
esp_ble_oob_disable (C 宏), 84
esp_ble_oob_enable (C 宏), 84
esp_ble_oob_req_reply (C++ function), 71
esp_ble_passkey_reply (C++ function), 70
esp_ble_pcsrk_keys_t (C++ class), 80
esp_ble_pcsrk_keys_t::counter (C++ member), 80
esp_ble_pcsrk_keys_t::csrk (C++ member), 80
esp_ble_pcsrk_keys_t::sec_level (C++ member), 80
esp_ble_penc_keys_t (C++ class), 80
esp_ble_penc_keys_t::rand (C++ member), 80
esp_ble_penc_keys_t::ltk (C++ member), 80
esp_ble_penc_keys_t::sec_level (C++ member), 80
esp_ble_pid_keys_t (C++ class), 80
esp_ble_pid_keys_t::addr_type (C++ member), 81
esp_ble_pid_keys_t::irk (C++ member), 81
esp_ble_pid_keys_t::static_addr (C++ member), 81
esp_blepkt_data_length_params_t (C++ class), 80
esp_ble_pkt_data_length_params_t::rx_len (C++ member), 80
esp_ble_pkt_data_length_params_t::tx_len (C++ member), 80
esp_ble_power_type_t (C++ enum), 59
ESP_BLE_PWR_TYPE_ADV (C++ enumerator), 59
ESP_BLE_PWR_TYPE_CONN_HDL0 (C++ enumerator), 59
ESP_BLE_PWR_TYPE_CONN_HDL1 (C++ enumerator), 59
ESP_BLE_PWR_TYPE_CONN_HDL2 (C++ enumerator), 59
ESP_BLE_PWR_TYPE_CONN_HDL3 (C++ enumerator), 59
ESP_BLE_PWR_TYPE_CONN_HDL4 (C++ enumerator), 59
ESP_BLE_PWR_TYPE_CONN_HDL5 (C++ enumerator), 59
ESP_BLE_PWR_TYPE_CONN_HDL6 (C++ enumerator), 59
ESP_BLE_PWR_TYPE_CONN_HDL7 (C++ enumerator), 59
ESP_BLE_PWR_TYPE_CONN_HDL8 (C++ enumerator), 59
ESP_BLE_PWR_TYPE_DEFAULT (C++ enumerator), 80
ESP_BLE_PWR_TYPE_NUM (C++ enumerator), 60
ESP_BLE_PWR_TYPE_SCAN (C++ function), 60
esp_ble_remove_bond_device (C++ function), 70
esp_ble_resolve_adv_data (C++ function), 68
ESP_BLE_SCA_100PPM (C++ enumerator), 59
ESP_BLE_SCA_150PPM (C++ enumerator), 59
ESP_BLE_SCA_20PPM (C++ enumerator), 59
ESP_BLE_SCA_250PPM (C++ enumerator), 59
ESP_BLE_SCA_30PPM (C++ enumerator), 59
ESP_BLE_SCA_500PPM (C++ enumerator), 59
ESP_BLE_SCA_50PPM (C++ enumerator), 59
ESP_BLE_SCA_75PPM (C++ enumerator), 59
esp_ble_scan_duplicate_list_flush (C++ function), 57
esp_ble_scan_duplicate_t (C++ enum), 90
esp_ble_scan_filter_t (C++ enum), 89
ESP_BLE_SCAN_PARAM_UNDEF (C 宏), 62
esp_ble_scan_params_t (C++ class), 79
Espressif Systems

1806

Release v4.3-dev-1561-g357a277603

Submit Document Feedback

esp_ble_tx_power_set

ESP_BLE_TX_POWER_GET

ESP_BLE_SM_SET_STATIC_PASSKEY

ESP_BLE_SM_SET_RSP_KEY

ESP_BLE_SM_PASSKEY

esp_ble_sm_param_t::scan_type (C++ member), 79

esp_ble_sm_param_t::scan_window (C++ member), 79

ESP_BLE_SCAN_RSP_DATA_LEN_MAX (C XXX), 85

esp_ble_scan_type_t (C++ enum), 89

esp_ble_sec_act_t (C++ enum), 89

ESP_BLE_SEC_ENCRYPT (C++ enumerator), 89

ESP_BLE_SEC_ENCRYPT_MITM (C++ enumerator), 89

ESP_BLE_SEC_ENCRYPT_NO_MITM (C++ enumerator), 89

esp_ble_sec_key_notif_t::passkey (C++ member), 81

esp_ble_sec_key_notif_t::passkey (C++ member), 81

esp_ble_sec_req_t (C++ class), 81

esp_ble_sec_req_t::bd_addr (C++ member), 82

esp_ble_sec_t (C++ union), 72

esp_ble_sec_t::auth_cmpl (C++ member), 72

esp_ble_sec_t::ble_id_keys (C++ member), 72

esp_ble_sec_t::ble_key (C++ member), 72

esp_ble_sec_t::ble_req (C++ member), 72

esp_ble_sec_t::key_notif (C++ member), 72

esp_ble_set_encryption (C++ function), 70

ESP_BLE_SM_AUTHEN_REQ_MODE (C++ enumerator), 89

ESP_BLE_SM_CLEAR_STATIC_PASSKEY (C++ enumerator), 89

ESP_BLE_SM_IOCAP_MODE (C++ enumerator), 89

ESP_BLE_SM_OOB_SUPPORT (C++ enumerator), 89

ESP_BLE_SM_MAX_KEY_SIZE (C++ enumerator), 89

ESP_BLE_SM_MAX_PARAM (C++ enumerator), 89

ESP_BLE_SM_MIN_KEY_SIZE (C++ enumerator), 89

ESP_BLE_SM_ONLY_ACCEPT_SPECIFIED_SECURITY (C++ enumerator), 89

ESP_BLE_SM_SET_INIT_KEY (C++ enumerator), 89

ESP_BLE_SM_SET_RSP_KEY (C++ enumerator), 89

ESP_BLE_SM_SET_STATIC_PASSKEY (C++ enumerator), 89

esp_ble_tx_power_get (C++ function), 53

esp_ble_tx_power_set (C++ function), 53

ESP_BLE酎ELEDERLIST_ADD (C++ enumerator), 91

ESP_BLE酎ELEDERLIST_REMOVE (C++ enumerator), 91

esp_ble_wl_addr_type_t (C++ enum), 63

esp_ble_wl_operation_t (C++ enum), 91

esp_bluedroid_deinit (C++ function), 64

esp_bluedroid_disable (C++ function), 64

esp_bluedroid_enable (C++ function), 64

esp_bluedroid_get_status (C++ function), 64

esp_bluedroid_init (C++ function), 64

ESP_BLUEDROID_STATUS_CHECK (C XXX), 61

ESP_BLUEDROID_STATUS_ENABLED (C++ enumerator), 64

ESP_BLUEDROID_STATUS_INITIALIZED (C++ enumerator), 64

esp_bluedroid_status_t (C++ enum), 64

ESP_BLUEDROID_STATUS_UNINITIALIZED (C++ enumerator), 64

esp_blufi_ap_record_t (C++ class), 137

esp_blufi_ap_record_t::rssi (C++ member), 137

esp_blufi_ap_record_t::ssid (C++ member), 137

esp_blufi_callbacks_t (C++ class), 137

esp_blufi_callbacks_t::checksum_func (C++ member), 137

esp_blufi_callbacks_t::decrypt_func (C++ member), 137

esp_blufi_callbacks_t::encrypt_func (C++ member), 137

esp_blufi_callbacks_t::event_cb (C++ member), 137

esp_blufi_callbacks_t::negotiate_data_handler (C++ member), 137

esp_blufi_cb_event_t (C++ enum), 138

esp_blufi_cb_param_t (C++ union), 131

esp_blufi_cb_param_t::blufi_connect_evt_param (C++ class), 132

esp_blufi_cb_param_t::blufi_connect_evt_param::cof

ESP_BLUEDROID_STATUS_UNINITIALIZED (C++ enumerator), 64

ESP_BLUEDROID_STATUS_COMPLETED (C++ enumerator), 64

esp_bluedroid_status_t (C++ enum), 64

ESP_BLUEDROID_STATUS_UNINITIALIZED (C++ enumerator), 64

esp_blufi_ap_record_t (C++ class), 137

esp_blufi_ap_record_t::rssi (C++ member), 137

esp_blufi_ap_record_t::ssid (C++ member), 137

esp_blufi_callbacks_t (C++ class), 137

esp_blufi_callbacks_t::checksum_func (C++ member), 137

esp_blufi_callbacks_t::decrypt_func (C++ member), 137

esp_blufi_callbacks_t::encrypt_func (C++ member), 137

esp_blufi_callbacks_t::event_cb (C++ member), 137

esp_blufi_callbacks_t::negotiate_data_handler (C++ member), 137

esp_blufi_cb_event_t (C++ enum), 138

esp_blufi_cb_param_t (C++ union), 131

esp_blufi_cb_param_t::blufi_connect_evt_param (C++ class), 132

esp_blufi_cb_param_t::blufi_connect_evt_param::cof

ESP_BLUEDROID_STATUS_COMPLETED (C++ enumerator), 64

esp_blufi_cb_param_t (C++ class), 133

esp_blufi_cb_param_t::blufi_connect_evt_param::re

ESP_BLUEDROID_STATUS_COMPLETED (C++ enumerator), 64

esp_blufi_cb_param_t (C++ class), 133

esp_blufi_cb_param_t::blufi_connect_evt_param::se

ESP_BLUEDROID_STATUS_COMPLETED (C++ enumerator), 64

esp_blufi_cb_param_t (C++ class), 133

esp_blufi_cb_param_t::blufi_connect_evt_param::cof

ESP_BLUEDROID_STATUS_COMPLETED (C++ enumerator), 64

esp_blufi_cb_param_t (C++ class), 133

esp_blufi_cb_param_t::blufi_connect_evt_param::re

ESP_BLUEDROID_STATUS_COMPLETED (C++ enumerator), 64

esp_blufi_cb_param_t (C++ class), 133

esp_blufi_cb_param_t::blufi_connect_evt_param::se

ESP_BLUEDROID_STATUS_COMPLETED (C++ enumerator), 64

esp_blufi_cb_param_t (C++ class), 133

esp_blufi_cb_param_t::blufi_connect_evt_param::cof

ESP_BLUEDROID_STATUS_COMPLETED (C++ enumerator), 64

esp_blufi_cb_param_t (C++ class), 133

esp_blufi_cb_param_t::blufi_connect_evt_param::re

ESP_BLUEDROID_STATUS_COMPLETED (C++ enumerator), 64

esp_blufi_cb_param_t (C++ class), 133

esp_blufi_cb_param_t::blufi_connect_evt_param::se

ESP_BLUEDROID_STATUS_COMPLETED (C++ enumerator), 64

esp_blufi_cb_param_t (C++ class), 133
esp_blufi_cb_param_t::blufi_init_finish
[C++ member], 133
esp_blufi_cb_param_t::blufi_recv_softap_ssid_evt_param
[C++ member], 135
esp_blufi_cb_param_t::blufi_recv_ca_evt_param::blufi_recv_sta_ssid_evt_param
[C++ class], 133
esp_blufi_cb_param_t::blufi_recv_ca_evt_param
[C++ class], 133
esp_blufi_cb_param_t::blufi_recv_softap_ssid_evt_param::blufi_recv_sta_bssid_evt_param
[C++ class], 135
esp_blufi_cb_param_t::blufi_recv_softap_ssid_evt_param
[C++ class], 135
esp_blufi_cb_param_t::blufi_recv_softap_passwd_evt_param::passwd_len
[C++ member], 133
esp_blufi_cb_param_t::blufi_recv_softap_passwd_evt_param::passwd
[C++ member], 135
esp_blufi_cb_param_t::blufi_recv_softap_max_conn_num_evt_param::max_conn_num
[C++ member], 135
esp_blufi_cb_param_t::blufi_recv_softap_max_conn_num_evt_param
[C++ class], 135
esp_blufi_cb_param_t::blufi_recv_softap_channel_evt_param::channel
[C++ member], 135
esp_blufi_cb_param_t::blufi_recv_softap_channel_evt_param
[C++ class], 135
esp_blufi_cb_param_t::blufi_recv_softap_auth_mode_evt_param::auth_mode
[C++ member], 135
esp_blufi_cb_param_t::blufi_recv_softap_auth_mode_evt_param
[C++ class], 135
esp_blufi_cb_param_t::blufi_recv_server_pkey_evt_param::pkey_len
[C++ member], 135
esp_blufi_cb_param_t::blufi_recv_server_pkey_evt_param::pkey
[C++ member], 136
esp_blufi_cb_param_t::blufi_recv_server_cert_evt_param::cert_len
[C++ member], 135
esp_blufi_cb_param_t::blufi_recv_server_cert_evt_param::cert
[C++ member], 136
esp_blufi_cb_param_t::blufi_recv_custom_data_evt_param::data_len
[C++ member], 135
esp_blufi_cb_param_t::blufi_recv_custom_data_evt_param
[C++ class], 135
esp_blufi_cb_param_t::blufi_recv_client_pkey_evt_param::pkey
[C++ member], 135
esp_blufi_cb_param_t::blufi_recv_client_pkey_evt_param
[C++ class], 135
esp_blufi_cb_param_t::blufi_recv_client_cert_evt_param::cert_len
[C++ member], 135
esp_blufi_cb_param_t::blufi_recv_client_cert_evt_param::cert
[C++ member], 136
esp_blufi_cb_param_t::blufi_recv_ca_evt_param::cert_len
[C++ member], 135
esp_blufi_cb_param_t::blufi_recv_ca_evt_param::cert
[C++ member], 136
esp_blufi_cb_param_t::blufi_init_finish_evt_param::state
[C++ member], 135
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1808

Submit Document Feedback
(C++ member), 136
esp_blufi_extra_info_t::sta_passwd_len
(C++ member), 136
esp_blufi_extra_info_t::sta_ssid
(C++ member), 136
esp_blufi_extra_info_t::sta_ssid_len
(C++ member), 136
esp_blufi_get_version
(C++ function), 131
ESP_BLUFI_INIT_FAILED
(C++ enumerator), 139
ESP_BLUFI_INIT_OK
(C++ enumerator), 139
ESP_BLUFI_INIT_SECURITY_ERROR
(C++ enumerator), 139
esp_blufi_init_state_t
(C++ enum), 139
ESP_BLUFI_MAKE_PUBLIC_ERROR
(C++ enumerator), 140
esp_blufi_negotiate_data_handler_t
(C++ type), 138
esp_blufi_profile_deinit
(C++ function), 131
esp_blufi_profile_init
(C++ function), 130
ESP_BLUFI_READ_PARAM_ERROR
(C++ enumerator), 140
esp_blufi_register_callbacks
(C++ function), 131
esp_blufi_send_custom_data
(C++ function), 131
esp_blufi_send_error_info
(C++ function), 131
esp_blufi_send_wifi_conn_report
(C++ function), 131
esp_blufi_send_wifi_list
(C++ function), 131
ESP_BLUFI_SEQUENCE_ERROR
(C++ enumerator), 139
ESP_BLUFI_STA_CONN_FAIL
(C++ enumerator), 139
esp_blufi_sta_conn_state_t
(C++ enum), 139
ESP_BLUFI_STA_CONN_SUCCESS
(C++ enumerator), 139
esp_bredr_sco_datapath_set
(C++ function), 54
esp_bredr_tx_power_get
(C++ function), 54
esp_bredr_tx_power_set
(C++ function), 53
ESP_BT_CLR_COD_SERVICE_CLASS
(C++ enumer-
ator), 152
ESP_BT_COD_FORMAT_TYPE_1
(C enum), 151
ESP_BT_COD_FORMAT_TYPE_BIT_MASK
(C enum), 151
ESP_BT_COD_FORMAT_TYPE_BIT_OFFSET
(C enum), 151
ESP_BT_COD_MAJOR_DEV_AV
(C++ enumerator), 153
ESP_BT_COD_MAJOR_DEV_BIT_MASK
(C enum), 151
ESP_BT_COD_MAJOR_DEV_BIT_OFFSET
(C enum), 151
ESP_BT_COD_MAJOR_DEV_COMPUTER
(C++ enumerator), 153
ESP_BT_COD_MAJOR_DEV_HEALTH
(C++ enumerator), 154
ESP_BT_COD_MAJOR_DEV.Imaging
(C++ enumer-
orator), 153
ESP_BT_COD_MAJOR_DEV_LAN_NAP
(C++ enumer-
orator), 153
ESP_BT_COD_MAJOR_DEV_MISC
(C++ enumerator), 153
ESP_BT_COD_MAJOR_DEV_PERIPHERAL
(C++ enumer-
orator), 153
ESP_BT_COD_MAJOR_DEV_PHONE
(C++ enumerator), 153
esp_bt_cod_major_dev_t
(C++ enum), 153
ESP_BT_COD_MAJOR_DEV_uncategorized
(C++ enumerator), 154
ESP_BT_COD_MINOR_DEV_BIT_MASK
(C enum), 151
ESP_BT_COD_MINOR_DEV_BIT_OFFSET
(C enum), 151
esp_bt_cod_mode_t
(C++ enum), 151
ESP_BT_COD_SRVC_AUDIO
(C++ enumerator), 153
ESP_BT_COD_SRVC_BIT_MASK
(C enum), 151
ESP_BT_COD_SRVC_BIT_OFFSET
(C enum), 151
ESP_BT_COD_SRVC_CAPTURING
(C++ enumerator), 153
ESP_BT_COD_SRVC_INFORMATION
(C++ enumerator), 153
ESP_BT_COD_SRVC_LMTD_DISCOVER
(C++ enumer-
orator), 153
ESP_BT_COD_SRVC_NETWORKING
(C++ enumer-
orator), 153
ESP_BT_COD_SRVC_NONE
(C++ enumerator), 152
ESP_BT_COD_SRVC_OBJ_TRANSFER
(C++ enumer-
orator), 153
ESP_BT_COD_SRVC_POSITIONING
(C++ enumerator), 152
ESP_BT_COD_SRVC_RENDERING
(C++ enumerator), 153
esp_bt_cod_srvc_t
(C++ enum), 153
ESP_BT_COD_SRVC_TELEPHONY
(C++ enumer-
orator), 153
esp_bt_cod_t::major
(C++ member), 148
esp_bt_cod_t::minor
(C++ member), 148
esp_bt_cod_t::reserved_2
(C++ member), 148
esp_bt_cod_t::reserved_8
(C++ member), 148
esp_bt_cod_t::service
(C++ member), 148
ESP_BT_CONNECTABLE
(C++ enumerator), 152
esp_connection_mode_t
(C++ enum), 152
ESP_BT_CONTROLLER_CONFIG_MAGIC_VAL
(C enum), 58
esp_bt_controller_config_t::auto_latency
esp_bt_eir_type_t (C++ type), 151
ESP_BT_EIR_TYPE_TX_POWER_LEVEL (C type), 150
ESP_BT_EIR_TYPE_URL (C type), 150
esp_bt_gap_afh_channels (C++ type), 151
ESP_BT_GAP_AFH_CHANNELS_LEN (C type), 149
ESP_BT_GAP_AUTH_CMPL_EVT (C++ enumerator), 154
esp_bt_gap_cancel_discovery (C++ function), 141
esp_bt_gap_cbc_event_t (C++ enum), 154
esp_bt_gap_cbc_param_t (C++ union), 144
esp_bt_gap_cbc_param_t::auth_cmpl (C++ member), 145
esp_bt_gap_cbc_param_t::auth_cmpl_param esp_bt_gap_cbc_param_t::key_req_param (C++ member), 145
esp_bt_gap_cbc_param_t::auth_cmpl_param esp_bt_gap_cbc_param_t::key_req_param::bda (C++ member), 147
esp_bt_gap_cbc_param_t::auth_cmpl_param esp_bt_gap_cbc_param_t::key_req_param::mode_chg (C++ member), 145
esp_bt_gap_cbc_param_t::auth_cmpl_param esp_bt_gap_cbc_param_t::mode_chg_param (C++ member), 145
esp_bt_gap_cbc_param_t::bt_remove_bond_dev_cmpl_evt_param esp_bt_gap_cbc_param_t::mode_chg_param (C++ member), 145
esp_bt_gap_cbc_param_t::bt_remove_bond_dev_cmpl_evt_param esp_bt_gap_cbc_param_t::mode_chg_param::bda (C++ member), 147
esp_bt_gap_cbc_param_t::bt_remove_bond_dev_cmpl_evt_param esp_bt_gap_cbc_param_t::mode_chg_param::mode (C++ member), 147
esp_bt_gap_cbc_param_t::bt_remove_bond_dev_cmpl_evt_param esp_bt_gap_cbc_param_t::pin_req_param (C++ member), 145
esp_bt_gap_cbc_param_t::bt_remove_bond_dev_cmpl_evt_param esp_bt_gap_cbc_param_t::pin_req_param::bda (C++ member), 147
esp_bt_gap_cbc_param_t::bt_remove_bond_dev_cmpl_evt_param esp_bt_gap_cbc_param_t::pin_req_param::min_16_digit (C++ member), 147
esp_bt_gap_cbc_param_t::bt_remove_bond_dev_cmpl_evt_param esp_bt_gap_cbc_param_t::pin_req_param::stat (C++ member), 147
esp_bt_gap_cbc_param_t::bt_remove_bond_dev_cmpl_evt_param esp_bt_gap_cbc_param_t::rmt_rmr_name (C++ member), 145
esp_bt_gap_cbc_param_t::cfm_req_param esp_bt_gap_cbc_param_t::rmt_rmr_name (C++ member), 145
esp_bt_gap_cbc_param_t::read_rmt_name_param esp_bt_gap_cbc_param_t::rmt_rmr_name_param (C++ class), 147
esp_bt_gap_cbc_param_t::read_rmt_rmr_name_param esp_bt_gap_cbc_param_t::read_rmt_rmr_name_param::rmt_name (C++ member), 147
esp_bt_gap_cbc_param_t::read_rmt_rmr_name_param esp_bt_gap_cbc_param_t::read_rmt_rmr_name_param::stat (C++ member), 147
esp_bt_gap_cbc_param_t::read_rssi_delta esp_bt_gap_cbc_param_t::read_rssi_delta_param (C++ class), 147
esp_bt_gap_cbc_param_t::read_rssi_delta esp_bt_gap_cbc_param_t::read_rssi_delta_param::bdaddr (C++ member), 147
esp_bt_gap_cbc_param_t::read_rssi_delta esp_bt_gap_cbc_param_t::read_rssi_delta_param::rssi_delta (C++ member), 147
esp_bt_gap_cbc_param_t::read_rssi_delta esp_bt_gap_cbc_param_t::read_rssi_delta_param::stat (C++ member), 147
esp_bt_gap_cbc_param_t::read_rssi_delta esp_bt_gap_cbc_param_t::remove_bond_dev_cmpl_evt_param (C++ member), 145
esp_bt_gap_cbc_param_t::read_rssi_delta esp_bt_gap_cbc_param_t::rmt_srvc_rec (C++ member), 145
esp_bt_gap_cbc_param_t::disc_st_chg esp_bt_gap_cbc_param_t::rmt_srvc_rec_param (C++ member), 144
esp_bt_gap_cbc_param_t::disc_state_changed_event esp_bt_gap_cbc_param_t::disc_state_changed_param (C++ class), 146
esp_bt_gap_cbc_param_t::disc_state_changed_param esp_bt_gap_cbc_param_t::disc_state_changed_param::bda (C++ member), 146
esp_bt_gap_cbc_param_t::disc_state_changed_param esp_bt_gap_cbc_param_t::disc_state_changed_param::num_prop (C++ member), 146
esp_bt_gap_cbc_param_t::disc_state_changed_param esp_bt_gap_cbc_param_t::disc_state_changed_param::prop (C++ member), 146
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::key_notif_param (C++ class), 146
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::key_notif_param::bda (C++ member), 146
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::key_notif_param::passkey (C++ member), 146
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::key_req (C++ member), 145
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::key_req_param (C++ class), 147
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::key_req_param::bda (C++ member), 147
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::key_req_param::mode_chg (C++ member), 145
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::key_req_param::mode_chg_param (C++ member), 145
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::key_req_param::mode_chg_param::bda (C++ member), 147
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::key_req_param::mode_chg_param::mode (C++ member), 147
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::pin_req_param (C++ member), 145
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::pin_req_param::bda (C++ member), 147
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::pin_req_param::min_16_digit (C++ member), 147
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::pin_req_param::stat (C++ member), 147
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::rmt_rmr_name (C++ member), 145
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::rmt_rmr_name_param (C++ class), 147
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::rmt_rmr_name_param::rmt_name (C++ member), 147
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::rmt_rmr_name_param::stat (C++ member), 147
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::rmt_rmr_name_param::rmt_rmr_name (C++ member), 147
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::rmt_rmr_name_param::stat (C++ member), 147
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::remove_bond_dev_cmpl_evt_param (C++ member), 145
esp_bt_gap_cbc_param_t::key_notif esp_bt_gap_cbc_param_t::rmt_srvc_rec (C++ member), 145
esp_bt_gap_cbc_param_t::read_rssi_delta esp_bt_gap_cbc_param_t::rmt_srvc_rec_param (C++ member), 144
esp_bt_gap_set_scan_mode (C++ function), 141
esp_bt_gap_set_security_param (C++ function), 143
esp_bt_gap_ssp_confirm_reply (C++ function), 144
esp bt_gap_ssp_passkey_reply (C++ function), 144
esp bt_gap_start_discovery (C++ function), 141
ESP_BT_GENERAL_DISCOVERABLE (C++ enumerator), 152
esp bt hf answer call (C++ function), 206
esp bt hf bsir (C++ function), 206
esp bt hf cind_response (C++ function), 205
esp bt hf clcc_response (C++ function), 206
ESP_BT_HF_CLIENT_NUMBER_LEN (C #), 200
ESP_BT_HF_CLIENT_OPERATOR_NAME_LEN (C #), 200
esp bt hf cme_response (C++ function), 205
esp bt hf emsponse (C++ function), 206
esp bt hf connect (C++ function), 203
esp bt hf connect_audio (C++ function), 204
esp bt hf cops_response (C++ function), 205
esp bt hf delinit (C++ function), 203
esp bt hf disconnect (C++ function), 204
esp bt hf disconnect_audio (C++ function), 204
esp bt hf end call (C++ function), 207
esp bt hf indchange_notification (C++ function), 205
esp bt hf init (C++ function), 203
ESP_BT_HF_NUMBER_LEN (C #), 184
ESP_BT_HF_OPERATOR_NAME_LEN (C #), 184
esp bt hf out call (C++ function), 207
esp bt hf register callback (C++ function), 203
esp bt hf_register_data callback (C++ function), 208
esp bt hf reject call (C++ function), 207
esp bt hf volume control (C++ function), 204
esp bt hf vra (C++ function), 204
ESP_BT_INIT_COD (C++ enumerator), 152
ESP_BT_INQ_MODE_GENERAL_INQUIRY (C++ enumerator), 155
ESP_BT_INQ_MODE_LIMITED_INQUIRY (C++ enumerator), 155
esp bt mode t (C++ enum), 154
ESP_BT_IO_CAP_IN (C #), 150
ESP_BT_IO_CAP_IO (C #), 150
ESP_BT_IO_CAP_NONE (C #), 150
esp bt io cap out (C #), 150
esp bt io cap t (C++ type), 151
ESP_BT_LIMTED_DISCOVERABLE (C++ enumerator), 152
esp bt_mem release (C++ function), 55
ESP_BT_MODE_BLE (C++ enumerator), 58
ESP_BT_MODE_BTDM (C++ enumerator), 58
ESP_BT_MODE_CLASSIC_BT (C++ enumerator), 58
ESP_BT_MODE_IDLE (C++ enumerator), 58
esp bmode t (C++ enum), 58
ESP_BT_NON_CONNECTABLE (C++ enumerator), 152
ESP_BT_NON_DISCOVERABLE (C++ enumerator), 152
ESP_BT_OCTET16_LEN (C #), 61
esp octet16 t (C++ type), 62
ESP_BT_OCTET8_LEN (C #), 61
esp octet8 t (C++ type), 62
ESP_BT_PIN_CODE_LEN (C #), 150
esp pin code t (C++ type), 151
ESP_BT_PIN_TYPE_FIXED (C++ enumerator), 153
esp pin type t (C++ enum), 153
ESP_BT_PIN_TYPE_VARIABLE (C++ enumerator), 153
ESP_BT_PM_MD_ACTIVE (C++ enumerator), 150
ESP_BT_PM_MD_HOLD (C++ enumerator), 150
ESP_BT_PM_MD_PARK (C++ enumerator), 150
ESP_BT_PM_MD_SNIF (C++ enumerator), 150
esp pm mode t (C++ type), 151
ESP_BT_SET_COD_ALL (C++ enumerator), 152
ESP_BT_SET_COD_MAJOR_MINOR (C++ enumerator), 152
ESP_BT_SET_COD_SERVICE_CLASS (C++ enumerator), 152
esp sleep disable (C++ function), 56
esp sleep enable (C++ function), 56
ESP_BT_SP_IOCAP_MODE (C++ enumerator), 153
esp sp_param t (C++ enum), 153
ESP_BT_STATUS_AUTH_FAILURE (C++ enumerator), 63
ESP_BT_STATUS_AUTH_REJECTED (C++ enumerator), 63
ESP_BT_STATUS_BUSY (C++ enumerator), 62
ESP_BT_STATUS_CONTROL_LE_DATA_LEN_UNSUPPORTED (C++ enumerator), 63
ESP_BT_STATUS_DONE (C++ enumerator), 62
ESP_BT_STATUS_EIR_TOO_LARGE (C++ enumerator), 63
ESP_BT_STATUS_ERR_ILLEGAL_PARAMETER_FMT (C++ enumerator), 63
ESP_BT_STATUS_FAIL (C++ enumerator), 62
ESP_BT_STATUS_INVALID_STATIC_ADDR (C++ enumerator), 63
ESP_BT_STATUS_MEMORY_FULL (C++ enumerator), 63
ESP_BT_STATUS_NOMEM (C++ enumerator), 62
ESP_BT_STATUS_NOT_READY (C++ enumerator), 62
ESP_BT_STATUS_PARAM_OUT_OF_RANGE (C++ enumerator), 63
ESP_BT_STATUS_PARM_INVALID (C++ enumerator), 63
ESP_BT_STATUS_PEER_LE_DATA_LEN_UNSUPPORTED (C++ enumerator), 63
ESP_DRAM_LOGI (C 宏), 1156
ESP_DRAM_LOGV (C 宏), 1156
esp_duplicate_info_t (C++ type), 86
esp_duplicate_scan_exceptional_list_type (C++ enum), 91
ESP_EARLY_LOGD (C 宏), 1155
ESP_EARLY_LOGE (C 宏), 1155
ESP_EARLY_LOGI (C 宏), 1155
ESP_EARLY_LOGV (C 宏), 1155
ESP_EARLY_LOGW (C 宏), 1155
esp_efuse_batch_write_begin (C++ function), 983
esp_efuse_batch_write_cancel (C++ function), 983
esp_efuse_batch_write_commit (C++ function), 983
esp_efuse_burn_new_values (C++ function), 983
esp_efuse_check_secure_version (C++ function), 983
esp_efuse_desc_s (C++ class), 983
esp_efuse_desc_s::bit_count (C++ member), 983
esp_efuse_desc_s::bit_start (C++ member), 983
esp_efuse_desc_t::efuse_block (C++ member), 983
esp_efuse_disable_basic_rom_console (C++ function), 983
esp_efuse_disable_rom_download_mode (C++ function), 983
esp_efuse_get_chip_ver (C++ function), 983
esp_efuse_get_coding_scheme (C++ function), 982
esp_efuse_get_field_size (C++ function), 982
esp_efuse_get_pkg_ver (C++ function), 983
esp_efuse_init (C++ function), 983
esp_efuse_mac_get_custom (C++ function), 1161
esp_efuse_mac_get_default (C++ function), 1161
esp_efuse_read_block (C++ function), 982
esp_efuse_read_field_bit (C++ function), 980
esp_efuse_read_field_blob (C++ function), 980
esp_efuse_read_field_cnt (C++ function), 980
esp_efuse_read_reg (C++ function), 982
esp_efuse_read_secure_version (C++ function), 983
esp_efuse_reset (C++ function), 983
esp_efuse_set_read_protect (C++ function), 981
esp_efuse_set_write_protect (C++ function), 981
esp_efuse_update_secure_version (C++ function), 983
esp_efuse_write_block (C++ function), 982
esp_efuse_write_field_bit (C++ function), 981
esp_efuse_write_field_blob (C++ function), 980
esp_efuse_write_field_cnt (C++ function), 981
esp_efuse_write_random_key (C++ function), 983
esp_efuse_write_reg (C++ function), 982
ESP_ERR_CODING (C 宏), 984
ESP_ERR_EFUSE (C 宏), 984
ESP_ERR_EFUSE_CNT_IS_FULL (C 宏), 984
ESP_ERR_EFUSE_REPEATED_PROG (C 宏), 984
ESP_ERR_ESPNOW_BASE (C 宏), 765
ESP_ERR_ESPNOW_CANNOT_CREATE_SOCKET (C 宏), 765
ESP_ERR_ESPNOW_CANNOT_RESOLVE_HOSTNAME (C 宏), 765
ESP_ERR_ESPNOW_CONNECTION_TIMEOUT (C 宏), 765
ESP_ERR_ESPNOW_FAILED_CONNECT_TO_HOST (C 宏), 765
ESP_ERR_ESPNOW_FAILED_TO_CONNECT (C 宏), 765
ESP_ERR_ESPNOW_IOCTL_FAILED (C 宏), 766
ESP_ERR_ESPNOW_SOCKET_IN_USE (C 宏), 766
ESP_ERR_ESPNOW_UNSUPPORTED_PROTOCOL_FAMILY (C 宏), 765
ESP_ERR_ESPNOW_ARG (C 宏), 462
ESP_ERR_ESPNOW_BASE (C 宏), 462
ESP_ERR_ESPNOW_EXIST (C 宏), 462
ESP_ERR_ESPNOW_FULL (C 宏), 462
ESP_ERR_ESPNOW_IF (C 宏), 462
ESP_ERR_ESPNOW_INTERNAL (C 宏), 462
ESP_ERR_ESPNOW_NO_MEM (C 宏), 462
ESP_ERR_ESPNOW_NOT_FOUND (C 宏), 462
ESP_ERR_ESPNOW_NOT_INIT (C 宏), 462
ESP_ERR_FLASH_BASE (C 宏), 985
ESP_ERR_HTTP_BASE (C 宏), 777
ESP_ERR_HTTP_CONNECT (C 宏), 777
ESP_ERR_HTTP_CONNECTING (C 宏), 777
ESP_ERR_HTTP_EAGAIN (C 宏), 777
ESP_ERR_HTTP_FETCH_HEADER (C 宏), 777
ESP_ERR_HTTP_INVALID_TRANSPORT (C 宏), 777
ESP_ERR_HTTP_MAX_REDIRECT (C 宏), 777
ESP_ERR_HTTP_WRITE_DATA (C 宏), 777
ESP_ERR_HTTPD_ALLOC_MEM (C 宏), 804
ESP_ERR_HTTPD_BASE (C 宏), 804
ESP_ERR_HTTPD_HANDLER_EXISTS (C 宏), 804
ESP_ERR_HTTPD_HANDLERS_FULL (C 宏), 804
ESP_ERR_HTTPD_INVALID_REQ (C 宏), 804
ESP_ERR_HTTPD_RESP_HDR (C 宏), 804
ESP_ERR_HTTPD_RESP_SEND (C 宏), 804
ESP_ERR_HTTPD_RESULT_TRUNC (C 宏), 804

 Espresif Systems 1815 Release v4.3-dev-1561-g357a277603
Submit Document Feedback
ESP_ERR_HTTPD_TASK (C 室), 804
ESP_ERR_HTTPS_OTA_BASE (C 室), 988
ESP_ERR_HTTPS_OTA_IN_PROGRESS (C 室), 988
ESP_ERR_INVALID_ARG (C 室), 985
ESP_ERR_INVALID_CRC (C 室), 985
ESP_ERR_INVALID_MAC (C 室), 985
ESP_ERR_INVALID_RESPONSE (C 室), 985
ESP_ERR_INVALID_SIZE (C 室), 985
ESP_ERR_INVALID_STATE (C 室), 985
ESP_ERR_INVALID_VERSION (C 室), 985
ESP_ERR_MESH_CERT_PARTLY_OK (C 室), 765
ESP_ERR_MBEDTLS_CERT_PARTLY_OK (C 室), 765
ESP_ERR_MBEDTLS_CTR_DRBG_SEED_FAILED (C 室), 765
ESP_ERR_MBEDTLS_PK_PARSE_KEY_FAILED (C 室), 765
ESP_ERR_MBEDTLS_SSL_CONF_ALPN_PROTOCOL (C 室), 765
ESP_ERR_MBEDTLS_SSL_CONF_OWNER_CERT_FAILED (C 室), 765
ESP_ERR_MBEDTLS_SSL_CONF_PSK_FAILED (C 室), 765
ESP_ERR_MBEDTLS_SSL_CONFIG_DEFAULTS_FAILED (C 室), 765
ESP_ERR_MBEDTLS_SSL_HANDSHAKE_FAILED (C 室), 765
ESP_ERR_MBEDTLS_SSL_SET_HOSTNAME_FAILED (C 室), 765
ESP_ERR_MBEDTLS_SSL_SETUP_FAILED (C 室), 765
ESP_ERR_MBEDTLS_SSL_WRITE_FAILED (C 室), 765
ESP_ERR_X509_CRT_PARSE_FAILED (C 室), 765
ESP_ERR_MESH_ARGUMENT (C 室), 489
ESP_ERR_MESH_BASE (C 室), 985
ESP_ERR_MESH_DISCARD (C 室), 490
ESP_ERR_MESH_DISCARD_DUP (C 室), 490
ESP_ERR_MESH_DISCONNECTED (C 室), 489
ESP_ERR_MESH_EXCEED_MTU (C 室), 489
ESP_ERR_MESH_INTERFACE (C 室), 490
ESP_ERR_MESH_NO_MEMORY (C 室), 489
ESP_ERR_MESH_NO_PARENT_FOUND (C 室), 489
ESP_ERR_MESH_NO_ROUTE_FOUND (C 室), 489
ESP_ERR_MESH_NOT_ALLOWED (C 室), 489
ESP_ERR_MESH_NOT_CONFIG (C 室), 489
ESP_ERR_MESH_NOT_INIT (C 室), 489
ESP_ERR_MESH_NOT_START (C 室), 489
ESP_ERR_MESH_NOT_SUPPORTED (C 室), 489
ESP_ERR_MESH_OPTION_NULL (C 室), 490
ESP_ERR_MESH_OPTION_UNKNOWN (C 室), 490
ESP_ERR_MESH_P (C 室), 490
ESP_ERR_MESH_QUEUE_FAIL (C 室), 489
ESP_ERR_MESH_QUEUE_FULL (C 室), 489
ESP_ERR_MESH_QUEUE_READ (C 室), 490
ESP_ERR_MESH_RECV_RELEASE (C 室), 490
ESP_ERR_MESH_TIMEOUT (C 室), 489
ESP_ERR_MESH_VOTING (C 室), 490
ESP_ERR_MESH_WIFI_NOT_START (C 室), 489
ESP_ERR_MESH_XMIT (C 室), 490
ESP_ERR_MESH_XON_NO_WINDOW (C 室), 490
ESP_ERR_NO_MEM (C 室), 489
ESP_ERR_NOT_FINISHED (C 室), 846
ESP_ERR_NOT_FOUND (C 室), 489
ESP_ERR_NOT_SUPPORTED (C 室), 985
ESP_ERR_NVS_BASE (C 室), 924
ESP_ERR_NVS_CONTENT_DIFFERS (C 室), 925
ESP_ERR_NVS_CORRUPT_KEY_PART (C 室), 925
ESP_ERR_NVS_ENCRYPTION (C 室), 925
ESP_ERR_NVS_KEY_TOO_LONG (C 室), 924
ESP_ERR_NVS_PAGE_FULL (C 室), 924
ESP_ERR_NVS_PART_NOT_FOUND (C 室), 924
ESP_ERR_NVS_READ_ONLY (C 室), 924
ESP_ERR_NVS_REMOVE_FAILED (C 室), 924
ESP_ERR_NVS_TYPE_MISMATCH (C 室), 924
ESP_ERR_NVS_VALUE_TOO_LONG (C 室), 924
ESP_ERR_NVS_WRONG_ENCRYPTION (C 室), 925
ESP_ERR_NVS_XTS_CFG_FAILED (C 室), 925
ESP_ERR_NVS_XTS_CFG_NOT_FOUND (C 室), 925
ESP_ERR_NVS_XTS_DEC_FAILED (C 室), 925
ESP_ERR_NVS_XTS_ENCRYPT_FAILED (C 室), 925
ESP_ERR_OTA_BASE (C 室), 1172
ESP_ERR_OTA_PARTITION_CONFLICT (C 室), 1172
ESP_ERR_OTA_ROLLBACK_FAILED (C 室), 1173
ESP_ERR_OTA_ROLLBACK_INVALID_STATE (C 室), 1173
ESP_ERR_OTA_SELECT_INFO_INVALID (C 室), 1172
ESP_ERR_OTA_SMALL_SEC_VER (C 室), 1173
ESP_ERR_OTA_VALIDATE_FAILED (C 室), 1172
esp_err_t (C++ type), 985
ESP_INF_TIMEOUT (C 室), 985
esp_err_t_to_name (C++ function), 984
esp_err_t_to_name (C++ function), 984
ESP_INF_ULD_BASE (C 室), 1531
ESP_INF_ULD_BRANCH_OUT_OF_RANGE (C 室), 1531
ESP_INF_ULD_DUPLICATE_LABEL (C 室), 1531
ESP_INF_ULD_INVALID_LOAD_ADDR (C 室), 1531
ESP_INF_ULD_SIZE_TOO_BIG (C 室), 1531
ESP_INF_ULD_UNASSIGNED_LABEL (C 室), 1531
ESP_ERR_WIFI_BASE (C 宏), 985
ESP_ERR_WIFI_CONN (C 宏), 436
ESP_ERR_WIFI_IF (C 宏), 435
ESP_ERR_WIFI_INIT_STATE (C 宏), 436
ESP_ERR_WIFI_MAC (C 宏), 436
ESP_ERR_WIFI_MODE (C 宏), 435
ESP_ERR_WIFI_NOT_ASSOC (C 宏), 436
ESP_ERR_WIFI_NOT_CONNECT (C 宏), 436
ESP_ERR_WIFI_NOT_INIT (C 宏), 435
ESP_ERR_WIFI_NOT_STARTED (C 宏), 435
ESP_ERR_WIFI_NOT_STOPPED (C 宏), 435
ESP_ERR_WIFI_NVSS (C 宏), 436
ESP_ERR_WIFI_PASSWORD (C 宏), 436
ESP_ERR_WIFI_POST (C 宏), 436
ESP_ERR_WIFI_SSID (C 宏), 436
ESP_ERR_WIFI_STOP_STATE (C 宏), 436
ESP_ERR_WIFI_TIMEOUT (C 宏), 436
ESP_ERR_WIFI_TX_DISALLOW (C 宏), 436
ESP_ERR_WIFI_WAKE_FAIL (C 宏), 436
ESP_ERR_WIFI_WOULD_BLOCK (C 宏), 436
ESP_ERR_WOLFSSSL_CERT_VERIFY_SETUP_FAILED (C 宏), 765
ESP_ERR_WOLFSSSL_CTX_SETUP_FAILED (C 宏), 766
ESP_ERR_WOLFSSSL_KEY_VERIFY_SETUP_FAILED (C 宏), 765
ESP_ERR_WOLFSSSL_SSL_CONF_ALPN_PROTOCOLS_FAILED (C 宏), 765
ESP_ERR_WOLFSSSL_SSL_HANDSHAKE_FAILED (C 宏), 765
ESP_ERR_WOLFSSSL_SSL_SET_HOSTNAME_FAILED (C 宏), 766
ESP_ERR_WOLFSSSL_SSL_WRITE_FAILED (C 宏), 766
ESP_ERROR_CHECK (C 宏), 985
ESP_ERROR_CHECK_WITHOUT_ABORT (C 宏), 985
esp_esptouch_set_timeout (C++ function), 495
esp_eth_clear_default_handlers (C++ function), 495
esp_eth_config_t (C++ class), 495
esp_eth_config_t::check_link_period_ms (C++ member), 495
esp_eth_config_t::mac (C++ member), 497
esp_eth_config_t::on_lowlevel_deinit_done (C++ member), 498
esp_eth_config_t::on_lowlevel_init_done (C++ member), 498
esp_eth_config_t::phy (C++ member), 497
esp_eth_config_t::stack_input (C++ member), 497
esp_eth_decrease_reference (C++ function), 497
esp_eth_del_netif_glue (C++ function), 509
esp_eth_detect_phy_addr (C++ function), 498
esp_eth_driver_install (C++ function), 495
esp_eth_driver_uninstall (C++ function), 495
esp_eth_handle_t (C++ type), 498
esp_eth_increase_reference (C++ function), 497
esp_eth_ioctl (C++ function), 497
esp_eth_mac_new esp32 (C++ function), 502
esp_eth_mac_s (C++ class), 502
esp_eth_mac_s::deinit (C++ member), 502
esp_eth_mac_s::del (C++ member), 505
esp_eth_mac_s::enable_flow_ctrl (C++ member), 505
esp_eth_mac_s::get_addr (C++ member), 504
esp_eth_mac_s::init (C++ member), 502
esp_eth_mac_s::read_phy_reg (C++ member), 503
esp_eth_mac_s::receive (C++ member), 503
esp_eth_mac_s::set_addr (C++ member), 504
esp_eth_mac_s::set_duplex (C++ member), 504
esp_eth_mac_s::set_link (C++ member), 504
esp_eth_mac_s::setmediator (C++ member), 502
esp_eth_mac_s::set_peer_pause_ability (C++ member), 505
esp_eth_mac_s::set_promiscuous (C++ member), 504
esp_eth_mac_s::set_speed (C++ member), 504
esp_eth_mac_t (C++ type), 506
esp_ethmediator_s (C++ class), 499
esp_ethmediator_s::on_state_changed (C++ member), 499
esp_ethmediator_s::phy_reg_read (C++ member), 499
esp_ethmediator_s::phy_reg_write (C++ member), 499
esp_ethmediator_t (C++ type), 500
coredump (C++ function), 495
ESP_ETH_PHY_ADDR_AUTO (C 宏), 509
ESP_ETH_PHY_ADDR_AUTO (C 宏), 509
esp_phy_new_dp83848 (C++ function), 506
esp_phy_new_dp83848 (C++ function), 506
esp_phy_new_ip101 (C++ function), 506
esp_phy_new_ip101 (C++ function), 506
esp_phy_new_kx8041 (C++ function), 506
esp_phy_new_kx8041 (C++ function), 506
esp_phy_new_lan8720 (C++ function), 506
esp_phy_new_t18201 (C++ function), 506
esp_phy_s (C++ class), 506
esp_phy_s::advertise_pause_ability (C++ member), 508
esp_phy_s::deinit (C++ member), 507
Espresif Systems

Submit Document Feedback
function), 886
esp flash get protectable regions
(C++ function), 887
esp flash get protected region
(C++ function), 887
esp flash get size (C++ function), 886
esp flash init (C++ function), 885
esp flash io mode_t (C++ enum), 893
esp flash is quad mode (C++ function), 888
esp flash os functions_t (C++ class), 889
esp flash os functions_t::delay_us
(C++ member), 889
esp flash os functions_t::get_temp_buffer
(C++ member), 889
esp flash read (C++ function), 887
esp flash read encrypted (C++ function), 888
esp flash read id (C++ function), 886
esp flash region_t (C++ class), 889
esp flash region_t::offset (C++ member), 889
esp flash region_t::size (C++ member), 889
esp flash set chip write protect
(C++ function), 886
esp flash set protected region
(C++ function), 887
ESP_FLASH_SPEED_MAX (C++ enumerator), 892
ESP_FLASH_SPEED_MIN (C++ enumerator), 892
esp flash speed_t (C++ enum), 892
esp flash spi device config_t
(C++ class), 885
esp flash spi device config_t::cs_id
(C++ member), 885
esp flash spi device config_t::cs io_num
(C++ member), 885
esp flash spi device config_t::host_id
(C++ member), 885
esp flash spi device config_t::input_delay
(C++ member), 885
esp flash spi device config_t::io_mode
(C++ member), 885
esp flash spi device config_t::speed
(C++ member), 885
esp flash_t (C++ class), 889
esp flash_t (C++ type), 890
esp flash_t::chip drv (C++ member), 890
esp flash_t::chip_id (C++ member), 890
esp flash_t::host (C++ member), 890
esp flash_t::os func (C++ member), 890
esp flash_t::os func data (C++ member), 890
esp flash_t::read mode (C++ member), 890
esp flash_t::size (C++ member), 890
esp flash write (C++ function), 888
esp flash write encrypted (C++ function), 888
esp flash write protect crypt_cnt
(C++ function), 900
esp freertos_idle_cb_t (C++ type), 1116
esp freertos_tick_cb_t (C++ type), 1116
ESP_GAP_BLE_ADD_WHITELIST_COMPLETE_EVT
(C++ enumerator), 85
ESP_GAP_BLE_ADD_DATA_RAW_SET_COMPLETE_EVT
(C++ enumerator), 86
ESP_GAP_BLE_ADD_DATA_SET_COMPLETE_EVT
(C++ enumerator), 86
ESP_GAP_BLE_ADV_PARAM_SET_COMPLETE_EVT
(C++ enumerator), 86
ESP_GAP_BLE_ADV_STOP_COMPLETE_EVT
(C++ enumerator), 86
ESP_GAP_BLE_ADV_SET_COMPLETE_EVT
(C++ enumerator), 87
ESP_GAP_BLE_AUTH_CMPL_EVT
(C++ enumerator), 86
esp gap_ble cb event t (C++ enum), 86
esp gap_ble cb t (C++ type), 86
esp gap_ble_channels (C++ type), 86
ESP_GAP_BLE_CHANNELS_LEN (C++ enumerator), 85
ESP_GAP_BLE_CLEAR_BOND_DEV_COMPLETE_EVT
(C++ enumerator), 87
ESP_GAP_BLE_EVT_MAX (C++ enumerator), 87
ESP_GAP_BLE_GET_BOND_DEV_COMPLETE_EVT
(C++ enumerator), 87
ESP_GAP_BLE_KEYBOARD_EVT (C++ enumerator), 86
ESP_GAP_BLE_LOCAL_ER_EVT (C++ enumerator), 87
ESP_GAP_BLE_LOCAL_IR_EVT (C++ enumerator), 87
ESP_GAP_BLE_NC_REQ_EVT (C++ enumerator), 87
ESP_GAP_BLE_OOB_REQ_EVT (C++ enumerator), 87
ESP_GAP_BLE_PASSKEY_NOTIFY_EVT
(C++ enumerator), 86
ESP_GAP_BLE_PASSKEY_REQ_EVT
(C++ enumerator), 86
ESP_GAP_BLE_READ_RSSI_COMPLETE_EVT
(C++ enumerator), 87
ESP_GAP_BLE_REMOVE_BOND_DEV_COMPLETE_EVT
(C++ enumerator), 87
ESP_GAP_BLE_SCAN_PARAM_SET_COMPLETE_EVT
(C++ enumerator), 86
ESP_GAP_BLE_SCAN_RESULT_EVT
(C++ enumerator), 86
ESP_GAP_BLE_SCAN_RSP_DATA_RAW_SET_COMPLETE_EVT
(C++ enumerator), 86
ESP_GAP_BLE_SCAN_RSP_DATA_SET_COMPLETE_EVT
(C++ enumerator), 86
<table>
<thead>
<tr>
<th>Documentation Reference</th>
<th>C++ enumerator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_GAP_BLE_SCAN_START_COMPLETE_EVT</td>
<td>(C++ enumerator), 86</td>
<td>esp_gatt_auth_req_t (C++ enum), 101</td>
</tr>
<tr>
<td>ESP_GAP_BLE_SCAN_STOP_COMPLETE_EVT</td>
<td>(C++ enumerator), 87</td>
<td>ESP_GATT_AUTH_REQ_SIGNED_NO_MITM</td>
</tr>
<tr>
<td>ESP_GAP_BLE_SEC_REQ_EVT</td>
<td>(C++ enumerator), 86</td>
<td>ESP_GATT_AUTH_REQ_SIGNED_MITM</td>
</tr>
<tr>
<td>esp_gap_ble_set_channels</td>
<td>(C++ function), 71</td>
<td>ESP_GATT_AUTH_REQ_NONE</td>
</tr>
<tr>
<td>ESP_GAP_BLE_SET_CHANNELS_EVT</td>
<td>(C++ enumerator), 87</td>
<td>ESP_GATT_AUTH_REQ_NO_MITM</td>
</tr>
<tr>
<td>ESP_GAP_BLE_SET_LOCAL_PRIVACY_COMPLETE_EVT</td>
<td>(C++ enumerator), 87</td>
<td>ESP_GATT_AUTH_REQ_MITM</td>
</tr>
<tr>
<td>ESP_GAP_BLE_SET_PKT_LENGTH_COMPLETE_EVT</td>
<td>(C++ enumerator), 87</td>
<td>ESP_GATT_APP_RSP</td>
</tr>
<tr>
<td>ESP_GAP_BLE_SET_STATIC_RAND_ADDR_EVT</td>
<td>(C++ enumerator), 87</td>
<td>ESP_GATT_ALREADY_OPEN</td>
</tr>
<tr>
<td>ESP_GAP_BLE_UPDATE_CONN_PARAMS_EVT</td>
<td>(C++ enumerator), 87</td>
<td>ESP_GAP_SEARCH_INQ_RES_EVT</td>
</tr>
<tr>
<td>ESP_GAP_BLE_UPDATE_DUPLICATE_EXCEPTION_EVT</td>
<td>(C++ enumerator), 87</td>
<td>ESP_GAP_SEARCH_INQ_DISCARD_NUM_EVT</td>
</tr>
<tr>
<td>ESP_GAP_BLE_UPDATE_WHITELIST_COMPLETE_EVT</td>
<td>(C++ enumerator), 87</td>
<td>esp_gap_search_evt_t</td>
</tr>
<tr>
<td>esp_gap_search_evt_t::timeout</td>
<td>(C++ class), 79</td>
<td>ESP_GAP_SEARCH_DISC_BLE_RES_EVT</td>
</tr>
<tr>
<td>esp_gap_search_evt_t::latency</td>
<td>(C++ class), 79</td>
<td>ESP_GAP_SEARCH_DISC_CMPL_EVT</td>
</tr>
<tr>
<td>esp_gap_search_evt_t::timeout</td>
<td>(C++ class), 79</td>
<td>ESP_GAP_SEARCH_DISC_BLE_EVT</td>
</tr>
<tr>
<td>ESP_GAP_SEARCH_DI_DISC_CMPL_EVT</td>
<td>(C++ enumerator), 90</td>
<td>ESP_GAP_SEARCH_BLE_EVT</td>
</tr>
<tr>
<td>ESP_GAP_SEARCH_DISC_BLE_EVT</td>
<td>(C++ enumerator), 90</td>
<td>ESP_GAP_SEARCH_BLE_CMPL_EVT</td>
</tr>
<tr>
<td>ESP_GAP_SEARCH_DISC_CMPL_EVT</td>
<td>(C++ enumerator), 90</td>
<td>ESP_GAP_SECURITY_EVT</td>
</tr>
<tr>
<td>ESP_GAP_SEARCH_DISC_EVT</td>
<td>(C++ enumerator), 90</td>
<td>esp_gap_conn_params_t::timeout</td>
</tr>
<tr>
<td>esp_gap_search_discover_t</td>
<td>(C++ enum), 90</td>
<td>esp_gap_conn_params_t::interval</td>
</tr>
<tr>
<td>ESP_GAP_SEARCH_INQ_CMPL_EVT</td>
<td>(C++ enumerator), 90</td>
<td>esp_gap_search_discover_t::type</td>
</tr>
<tr>
<td>ESP_GAP_SEARCH_INQ_CMPL_EVT</td>
<td>(C++ enumerator), 90</td>
<td>esp_gap_search_discover_t::class</td>
</tr>
<tr>
<td>ESP_GAP_SEARCH_INQ_DISCARD_NUM_EVT</td>
<td>(C++ enumerator), 90</td>
<td>esp_gap_search_discover_t::class</td>
</tr>
<tr>
<td>ESP_GAP_SEARCH_INQ_RSP_EVT</td>
<td>(C++ enumerator), 90</td>
<td>esp_gap_search_discover_t::interval</td>
</tr>
<tr>
<td>ESP_GAP_SEARCH_SEARCH_CANCEL_CMPL_EVT</td>
<td>(C++ enumerator), 90</td>
<td>esp_gap_search_discover_t::class</td>
</tr>
<tr>
<td>ESP_GATT_ALREADY_OPEN</td>
<td>(C++ enumerator), 101</td>
<td>esp_gap_search_discover_t::class</td>
</tr>
<tr>
<td>ESP_GATT_APP_RSP</td>
<td>(C++ enumerator), 101</td>
<td>esp_gap_search_discover_t::class</td>
</tr>
<tr>
<td>ESP_GATT_ATTR_HANDLE_MAX</td>
<td>(C++ enum), 99</td>
<td>esp_gap_search_discover_t::class</td>
</tr>
<tr>
<td>ESP_GATT_AUTH_FAIL</td>
<td>(C++ enumerator), 100</td>
<td>ESP_GAP_BLE_SEC_REQ_EVT</td>
</tr>
<tr>
<td>ESP_GATT_AUTH_REQ_MITM</td>
<td>(C++ enumerator), 101</td>
<td>ESP_GAP_BLE_SCAN_STOP_COMPLETE_EVT</td>
</tr>
<tr>
<td>ESP_GATT_AUTH_REQ_NO_MITM</td>
<td>(C++ enumerator), 101</td>
<td>ESP_GAP_BLE_SEND_CONN_RECONFIG_EVT</td>
</tr>
<tr>
<td>ESP_GATT_AUTH_REQ_NONE</td>
<td>(C++ enumera- tor), 101</td>
<td>ESP_GAP_BLE_SCAN_START_COMPLETE_EVT</td>
</tr>
<tr>
<td>ESP_GATT_AUTH_REQ_MITM</td>
<td>(C++ enumerator), 101</td>
<td>ESP_GAP_BLE_SET_CONN_PARAMS_EVT</td>
</tr>
<tr>
<td>ESP_GATT_AUTH_REQ_SIGNED_MITM</td>
<td>(C++ enumerator), 101</td>
<td>ESP_GAP_BLE_SET_CHANNEL_RES_EVT</td>
</tr>
<tr>
<td>ESP_GATT_AUTH_REQ_SIGNED_NO_MITM</td>
<td>(C++ enumera- tor), 101</td>
<td>ESP_GAP_BLE_SET_ADVERTISEMENT_EVT</td>
</tr>
<tr>
<td>ESP_GATT_BODY_SENSOR_LOCATION</td>
<td>(C++ enumera- tor), 99</td>
<td>ESP_GAP_BLE_SET_CONN_PARAMS_EVT</td>
</tr>
<tr>
<td>ESP_GATT_BUSY</td>
<td>(C++ enumera- tor), 100</td>
<td>ESP_GAP_BLE_SCAN_STOP_EVT</td>
</tr>
<tr>
<td>ESP_GATTCANCEL</td>
<td>(C++ enumera- tor), 101</td>
<td>ESP_GAP_BLE_SCAN_RES_EVT</td>
</tr>
<tr>
<td>ESP_GATT_CMD_STARTED</td>
<td>(C++ enumera- tor), 100</td>
<td>ESP_GAP_BLE_SET.Distance</td>
</tr>
</tbody>
</table>
ESP_GATT_DUP_REG (C++ enumerator), 101
ESP_GATT_ENCRYPTED_MITM (C++ enumerator), 101
ESP_GATT_ENCRYPTED_NO_MITM (C++ enumerator), 101
ESP_GATT_ERR_UNLIKELY (C++ enumerator), 100
ESP_GATT_ERROR (C++ enumerator), 100
ESP_GATT_HEART_RATE_CNTL_POINT (C 宏), 98
ESP_GATT_HEART_RATE_MEAS (C 宏), 98
esp_gatt_id_t::inst_id (C++ class), 92
esp_gatt_id_t::inst_id (C++ member), 92
ESP_GATT_IF_NONE (C 宏), 99
esp_gatt_if_t (C++ type), 99
ESP_GATT_ILLEGAL_HANDLE (C 宏), 99
ESP_GATT_ILLEGAL_PARAMETER (C++ enumerator), 100
ESP_GATT_ILLEGAL_UUID (C 宏), 99
ESP_GATT_INSUFFICIENT_AUTHENTICATION (C++ enumerator), 100
ESP_GATT_INSUFFICIENT.Authorization (C++ enumerator), 100
ESP_GATT_INSUFFICIENT_ENCRYPTION (C++ enumerator), 100
ESP_GATT_INSUFFICIENT_KEY_SIZE (C++ enumerator), 100
ESP_GATT_INSUFFICIENT_Resource (C++ enumerator), 100
ESP_GATT_INTERNAL_ERROR (C++ enumerator), 100
ESP_GATT_INVALID_ATTR_LEN (C++ enumerator), 100
ESP_GATT_INVALID_CFG (C++ enumerator), 100
ESP_GATT_INVALID_HANDLE (C++ enumerator), 100
ESP_GATT_INVALID_OFFSET (C++ enumerator), 100
ESP_GATT_INVALID_PDU (C++ enumerator), 100
ESP_GATT_MAX_ATTR_LEN (C 宏), 99
ESP_GATT_MAX_READ_MULTI_HANDLES (C 宏), 99
ESP_GATT_MORE (C++ enumerator), 100
ESP_GATT_NO_RESOURCES (C++ enumerator), 100
ESP_GATT_NOT_ENCRYPTED (C++ enumerator), 101
ESP_GATT_NOT_FOUND (C++ enumerator), 100
ESP_GATT_NOT_LONG (C++ enumerator), 100
ESP_GATT_OK (C++ enumerator), 100
ESP_GATT_PENDING (C++ enumerator), 100
ESP_GATT_PERM_READ (C 宏), 99
ESP_GATT_PERM_READ_ENC_MITM (C 宏), 99
ESP_GATT_PERM_READ_ENCRYPTED (C 宏), 99
esp_gatt_perm_t (C++ type), 99
ESP_GATT_PERM_WRITE (C 宏), 99
ESP_GATT_PERM_WRITE_ENC_MITM (C 宏), 99
ESP_GATT_PERM_WRITE_ENCRYPTED (C 宏), 99
ESP_GATT_PERM_WRITE_SIGNED (C 宏), 99
ESP_GATT_PERM_WRITE_SIGNED_MITM (C 宏), 99
ESP_GATT_PERM_WRITE_TLS_MITM (C 宏), 99
ESP_GATT_PRC_IN_PROGRESS (C++ enumerator), 101
ESP_GATT_PREP_WRITE_CANCEL (C 宏), 113
ESP_GATT_PREP_WRITECancelar (C++ enumerator), 100
ESP_GATT_PREP_WRITE_EXEC (C 宏), 113
ESP_GATT_PREP_WRITE_EXEC (C++ enumerator), 100
esp_gatt_prep_write_type (C++ enumerator), 100
ESP_GATT_PREPARE_Q_FULL (C++ enumerator), 100
ESP_GATT_READ_NOT_PERMIT (C++ enumerator), 100
ESP_GATT_REQ_NOT_SUPPORTED (C++ enumerator), 100
ESP_GATT_RSP_BY_APP (C 宏), 99
esp_gatt_rsp_t (C++ union), 92
esp_gatt_rsp_t::attr_value (C++ member), 92
esp_gatt_rsp_t::handle (C++ member), 92
ESP_GATT_SERVICE_FROM_NV flash (C++ enumerator), 102
ESP_GATT_SERVICE_FROM_REMOTE_DEVICE (C++ enumerator), 102
ESP_GATT_SERVICE_FROM_UNKNOWN (C++ enumerator), 102
ESP_GATT_SERVICE_STARTED (C++ enumerator), 100
esp_gatt_srvc_id_t (C++ class), 92
esp_gatt_srvc_id_t::id (C++ member), 93
esp_gatt_srvc_id_t::is_primary (C++ member), 93
ESP_GATT_STACK_RSP (C++ enumerator), 101
esp_gatt_status_t (C++ enum), 100
ESP_GATT_UNKNOWN_ERROR (C++ enumerator), 101
ESP_GATT_UNSUPPORT_GRP_TYPE (C++ enumerator), 100
ESP_GATT_UUID_ALERT_LEVEL (C 宏), 97
ESP_GATT_UUID_ALERT_NTF_SVC (C 宏), 96
ESP_GATT_UUID_ALERT_STATUS (C 宏), 98
ESP_GATT_UUID_Automation_IO_SVC (C 宏), 97
ESP_GATT_UUID_BOND_MANAGEMENT_SVC (C 宏), 98
ESP_GATT_UUID_BOND_MANAGEMENT_SVC (C 宏), 98
ESP_GATT_UUID_BATTERY_LEVEL (C 宏), 98
ESP_GATT_UUID_BATTERY_SERVICE_SVC (C 宏), 96
ESP_GATT_UUID_BLOOD_PRESSURE_SVC (C 宏), 96
ESP_GATT_UUID_BODY_COMPOSITION (C 宏), 97
ESP_GATT_UUID_BOND_MANAGEMENT_SVC (C 宏), 97
ESP_GATT_UUID_CHAR_AGG_FORMAT (C 宏), 97
ESP_GATT_UUID_CHAR_CLIENT_CONFIG (C 宏), 97
ESP_GATT_UUID_CHAR_DECLARE (C 宏), 97
ESP_GATT_UUID_CHAR_DESCRIPTION (C 宏), 97
ESP_GATT_UUID_CHAR_EXT_PROP (C 家)，97
ESP_GATT_UUID_CHAR_PRESENT_FORMAT (C 家)，97
ESP_GATT_UUID_CHAR_SRVR_CONFIG (C 家)，97
ESP_GATT_UUID_CHAR_VALID_RANGE (C 家)，97
ESP_GATT_UUID_CONT_GLUCOSE_MONITOR_SVC (C 家)，97
ESP_GATT_UUID_CSC_FEATURE (C 家)，99
ESP_GATT_UUID_CSC_MEASUREMENT (C 家)，99
ESP_GATT_UUID_CSC_CURRENT_TIME (C 家)，98
ESP_GATT_UUID_CSC_CURRENT_TIME_SVC (C 家)，98
ESP_GATT_UUID_CSC_CYCLING_POWER_SVC (C 家)，
ESP_GATT_UUID_CSC_CURRENT_TIME_SVC (C 家)，
ESP_GATT_UUID_CYCLING_SPEED_CADENCE_SVC (C 家)，97
ESP_GATT_UUID_CYCLING_POWER_SVC (C 家)，97
ESP_GATT_UUID_CYCLING_SVC (C 家)，97
ESP_GATT_UUID_CHAR_VALID_RANGE (C 家)，97
ESP_GATT_UUID_CHAR_SRVR_CONFIG (C 家)，97
ESP_GATT_UUID_CHAR_PRESENT_FORMAT (C 家)，97
ESP_GATT_UUID_CHAR_EXT_PROP (C 家)，97
ESP_GATT_UUID_LINK_PG_ID (C 家)，97
ESP_GATT_UUID_LINK_LINK_SVC (C 家)，97
ESP_GATT_UUID_LINK_LINK_PARAM (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_Link_Protocol_Param (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
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ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家)，97
ESP_GATT_UUID_LINK_LINK.Invariant (C 家), 97
ESP_GATTC_EXEC_EVT (C++ enumerator), 129
ESP_GATTC_ADV_DATA_EVT (C++ enumerator), 129
ESP_GATTC_ADV_VSC_EVT (C++ enumerator), 129
ESP_GATTC_BTH_SCAN_CFG_EVT (C++ enumerator), 129
ESP_GATTC_BTH_SCAN_DIS_EVT (C++ enumerator), 129
ESP_GATTC_BTH_SCAN_ENB_EVT (C++ enumerator), 129
ESP_GATTC_BTH_SCAN_PARAM_EVT (C++ enumerator), 129
ESP_GATTC_BTH_SCAN_RD_EVT (C++ enumerator), 129
ESP_GATTC_BTH_SCAN_THR_EVT (C++ enumerator), 129
ESP_GATTC_CANCEL_OPEN_EVT (C++ enumerator), 129
esp_gattc_cb_event_t (C++ enum), 128
esp_gattc_cb_t (C++ type), 128
ESP_GATTC_CFG_MTU_EVT (C++ enumerator), 129
gattc_char_elem_t (C++ class), 95
gattc_char_elem_t::char_handle (C++ member), 96
gattc_char_elem_t::properties (C++ member), 96
gattc_char_elem_t::uuid (C++ member), 96
ESP_GATTC_CLOSE_EVT (C++ enumerator), 128
ESP_GATTC_CONN_GAT_EVT (C++ enumerator), 129
ESP_GATTC_CONN_GAT_EVT (C++ enumerator), 130
gattc_db_elem_t (C++ class), 95
gattc_db_elem_t::attribute_handle (C++ member), 95
gattc_db_elem_t::end_handle (C++ member), 95
gattc_db_elem_t::properties (C++ member), 95
gattc_db_elem_t::start_handle (C++ member), 95
gattc_db_elem_t::type (C++ member), 95
gattc_db_elem_t::uuid (C++ member), 95
gattc_descr_elem_t (C++ class), 96
gattc_descr_elem_t::handle (C++ member), 96
gattc_descr_elem_t::uuid (C++ member), 96
ESP_GATTC_DIS_SRVC_CMPL_EVT (C++ enumerator), 130
ESP_GATTC_DISCONNECT_EVT (C++ enumerator), 130
ESP_GATTC_ENC_CMPL_CB_EVT (C++ enumerator), 129
ESP_GATTC_EXEC_EVT (C++ enumerator), 129
ESP_GATTC_GET_ADDR_LIST_EVT (C++ enumerator), 130
gattc_incl_svc_elem_t (C++ class), 96
gattc_incl_svc_elem_t::handle (C++ member), 96
gattc_incl_svc_elem_t::inclSvc_e_handle (C++ member), 96
gattc_incl_svc_elem_t::inclSvc_s_handle (C++ member), 96
gattc_incl_svc_elem_t::uuid (C++ member), 96
ESP_GATTC_MULTI_ADV_DATA_EVT (C++ enumerator), 129
ESP_GATTC_MULTI_ADV_DIS_EVT (C++ enumerator), 129
ESP_GATTC_MULTI_ADV_ENB_EVT (C++ enumerator), 129
ESP_GATTC_MULTI_ADV_UPD_EVT (C++ enumerator), 129
gattc_multi_t (C++ class), 95
gattc_multi_t::handles (C++ member), 95
gattc_multi_t::num_attr (C++ member), 95
ESP_GATTC_NOTIFY_EVT (C++ enumerator), 128
ESP_GATTC_OPEN_EVT (C++ enumerator), 128
ESP_GATTC_PREP_WRITE_EVT (C++ enumerator), 129
ESP_GATTC_QUEUE_FULL_EVT (C++ enumerator), 130
ESP_GATTC_READ_CHAR_EVT (C++ enumerator), 128
ESP_GATTC_READ_DESCR_EVT (C++ enumerator), 128
ESP_GATTC_READ_MULTIPLE_EVT (C++ enumerator), 130
ESP_GATTC_REG_EVT (C++ enumerator), 128
ESP_GATTC_REG_FOR_NOTIFY_EVT (C++ enumerator), 130
ESP_GATTC_SCAN_FLT_CFG_EVT (C++ enumerator), 129
ESP_GATTC_SCAN_FLT_PARAM_EVT (C++ enumerator), 129
ESP_GATTC_SCAN_FLT_STATUS_EVT (C++ enumerator), 129
ESP_GATTC_SEARCH_CMPL_EVT (C++ enumerator), 128
ESP_GATTC_SEARCH_RES_EVT (C++ enumerator), 128
gattc_service_elem_t (C++ class), 95
gattc_service_elem_t::end_handle (C++ member), 95
gattc_service_elem_t::is_primary (C++ member), 95
gattc_service_elem_t::start_handle (C++ member), 95
gattc_service_elem_t::uuid (C++ member), 95
ESP_GATTS_SET_ASSOC_EVT (C++ enumerator), 130
ESP_GATTS_SRVC_CHG_EVT (C++ enumerator), 129
ESP_GATTS_UNREG_EVT (C++ enumerator), 128
ESP_GATTS_UNREG_FOR_NOTIFY_EVT (C++ enumerator), 130
ESP_GATTS_WRITE_CHAR_EVT (C++ enumerator), 128
ESP_GATTS_WRITE_DESCR_EVT (C++ enumerator), 128
ESP_GATTS_ADD_CHAR_DESCR_EVT (C++ enumerator), 113
ESP_GATTS_ADD_CHAR_EVT (C++ enumerator), 113
ESP_GATTS_INCL_SRVC_EVT (C++ enumerator), 113
esp_gatts_attr_db_t::attr_desc (C++ function), 965
esp_gatts_attr_db_t::attr_control (C++ function), 113
esp_gatts_attr_db_t::attr_hdl (C++ enumerator), 94
esp_gatts_incl128_svc_desc_t (C++ class), 94
esp_gatts_incl128_svc_desc_t::end_hdl (C++ function), 94
esp_gatts_incl128_svc_desc_t::start_hdl (C++ function), 94
esp_gatts_incl_svc_desc_t (C++ enumerator), 94
esp_gatts_incl_svc_desc_t::end_hdl (C++ function), 94
esp_gatts_incl_svc_desc_t::start_hdl (C++ function), 94
esp_gatts_incl_svc_desc_t::uuid (C++ function), 94
ESP_GATTS_LISTEN_EVT (C++ enumerator), 114
ESP_GATTS_MTU_EVT (C++ enumerator), 113
ESP_GATTS_OPEN_EVT (C++ enumerator), 114
ESP_GATTS_READ_EVT (C++ enumerator), 113
ESP_GATTS_REG_EVT (C++ enumerator), 113
ESP_GATTS_RESPONSE_EVT (C++ enumerator), 114
ESP_GATTS_SEND_SERVICE_CHANGE_EVT (C++ enumerator), 114
ESP_GATTS_SET_ATTR_VAL_EVT (C++ enumerator), 114
ESP_GATTS_START_EVT (C++ enumerator), 114
ESP_GATTS_STOP_EVT (C++ enumerator), 114
ESP_GATTS_UNREG_EVT (C++ enumerator), 113
ESP_GATTS_WRITE_EVT (C++ enumerator), 113
esp_get_deep_sleep_wake_stub (C++ function), 1187
esp_get_flash_encryption_mode (C++ function), 190
esp_get_free_heap_size (C++ function), 1160
esp_get_free_internal_heap_size (C++ function), 1160
esp_get_idf_version (C++ function), 1163
esp_get_minimum_free_heap_size (C++ function), 1160
esp_hf_answer_call_cmd_callback (C++ type), 185
ESP_HF_AT_RESPONSE_CODE_BLACKLISTED
(C++ enumerator), 190
ESP_HF_AT_RESPONSE_CODE_BUSY (C++ enumerator), 190
ESP_HF_AT_RESPONSE_CODE_CME (C++ enumerator), 190
ESP_HF_AT_RESPONSE_CODE_DELAYED (C++ enumerator), 190
ESP_HF_AT_RESPONSE_CODE_ERR (C++ enumerator), 190
ESP_HF_AT_RESPONSE_CODE_NO_ANSWER
(C++ enumerator), 190
ESP_HF_AT_RESPONSE_CODE_NO_CARRIER
(C++ enumerator), 190
ESP_HF_AT_RESPONSE_CODE_OK (C++ enumerator),
ESP_HF_AT_RESPONSE_CODE_OK (C++ enum), 190
esp_hf_at_response_t (C++ enum), 190
ESP_HF_AT_RESPONSE_CODE_OK (C++ enum), 190
esp_hf_at_response_code_t (C++ enum), 190
ESP_HF_AT_RESPONSE_ERROR (C++ enum), 190
ESP_HF_AT_RESPONSE_ERROR (C++ enum), 190
ESP_HF_AT_RESPONSE_OK (C++ enum), 190
esp_hf_at_response_t (C++ enum), 190
ESP_HF_AT_REG_EVT (C++ enum), 128
ESP_HF_BCS_RESPONSE_EVT (C++ enum), 186
ESP_HF_BCS_RESPONSE_EVT (C++ enum), 186
ESP_HF_BCS_RESPONSE_EVT (C++ enum), 186
ESP_HF_BCS_RESPONSE_EVT (C++ enum), 186
ESP_HF_BCS_RESPONSE_EVT (C++ enum), 186
ESP_HF_BTRH_CMD_ACCEPT (C++ enumerator), 189
ESP_HF_BTRH_CMD_HOLD (C++ enumerator), 189
ESP_HF_BTRH_CMD_REJECT (C++ enumerator), 189
esp_hf_btrh_cmd_t (C++ enum), 188
ESP_HF_BTRH_STATUS_ACCEPTED (C++ enumerator), 188
ESP_HF_BTRH_STATUS_HELD (C++ enumerator), 188
ESP_HF_BTRH_STATUS_REJECTED (C++ enumerator), 188
esp_hf_btrh_status_t (C++ enum), 188
ESP_HF_BVRA_RESPONSE_EVT (C++ enumerator), 212
ESP_HF_CALL_ADDR_TYPEINTERNATIONAL (C++ enumerator), 188
esp_hf_call_addr_type_t (C++ enum), 188
ESP_HF_CALL_ADDR_TYPEUNKNOWN (C++ enumerator), 188
ESP_HF_CALL_HELD_STATUSHELD (C++ enumerator), 187
ESP_HF_CALL_HELD_STATUSHELDANDACTIVE (C++ enumerator), 187
ESP_HF_CALL_HELD_STATUSNONE (C++ enumerator), 187
esp_hf_call_status_t (C++ enum), 187
ESP_HF_CALL_SETUPSTATUS_IDLE (C++ enumerator), 187
ESP_HF_CALL_SETUPSTATUS_INCOMING (C++ enumerator), 187
ESP_HF_CALL_SETUPSTATUSOUTGOING ALERTING (C++ enumerator), 187
ESP_HF_CALL_SETUPSTATUSOUTGOING DIALING (C++ enumerator), 187
esp_hf_call_setup_status_t (C++ enum), 187
ESP_HF_CALL_STATUS_CALL_INPROGRESS (C++ enumerator), 186
ESP_HF_CALL_STATUS NO CALLS (C++ enumerator), 186
esp_hf_call_status_t (C++ enum), 186
ESP_HF_CALL_WAITING_ACTIVE (C++ enumerator), 189
ESP_HF_CALL_WAITING_INACTIVE (C++ enumerator), 189
esp_hf_call_waiting_status_t (C++ enum), 189
esp_hf_cb_event_t (C++ enum), 212
esp_hf_cb_param_t (C++ union), 208
esp_hf_cb_param_t::audio_stat (C++ member), 208
esp_hf_cb_param_t::bcs_rep (C++ member), 209
esp_hf_cb_param_t::cind (C++ member), 208
esp_hf_cb_param_t::conn_stat (C++ member), 208
esp_hf_cb_param_t::hf_audio_stat_param (C++ class), 209
esp_hf_cb_param_t::hf_audio_stat_param::remote_addr (C++ member), 209
esp_hf_cb_param_t::hf_audio_stat_param::state (C++ member), 209
esp_hf_cb_param_t::hf_bcs_rep_param (C++ class), 209
esp_hf_cb_param_t::hf_bcs_rep_param::mode (C++ member), 209
esp_hf_cb_param_t::hf_cind_param (C++ class), 209
esp_hf_cb_param_t::hf_cind_param::battery_level (C++ member), 209
esp_hf_cb_param_t::hf_cind_param::call_limit_status (C++ member), 209
esp_hf_cb_param_t::hf_cind_param::call_setup_status (C++ member), 209
esp_hf_cb_param_t::hf_cind_param::call_status (C++ member), 209
esp_hf_cb_param_t::hf_cind_param::call_wait_status (C++ member), 209
esp_hf_cb_param_t::hf_cind_param::call_volume (C++ member), 209
esp_hf_cb_param_t::hf_cind_param::chld_feat (C++ member), 209
esp_hf_cb_param_t::hf_cind_param::cmd (C++ member), 209
esp_hf_cb_param_t::hf_cind_param::cmd_status (C++ member), 209
esp_hf_cb_param_t::hf_cind_param::cmd_type (C++ member), 209
esp_hf_cb_param_t::hf_cind_param::cmd_value (C++ member), 209
esp_hf_cb_param_t::hf_cind_param::msg (C++ member), 209
esp_hf_cb_param_t::hf_cind_param::nrec_param (C++ class), 210
esp_hf_cb_param_t::hf_cind_param::nrec_param::remote_addr (C++ member), 210
esp_hf_cb_param_t::hf_cind_param::nrec_param::state (C++ member), 210
esp_hf_cb_param_t::hf_conn_stat_param (C++ class), 210
esp_hf_cb_param_t::hf_conn_stat_param::cmd (C++ member), 210
esp_hf_cb_param_t::hf_conn_stat_param::cmd_status (C++ member), 210
esp_hf_cb_param_t::hf_conn_stat_param::cmd_type (C++ member), 210
esp_hf_cb_param_t::hf_conn_stat_param::cmd_value (C++ member), 210
esp_hf_cb_param_t::hf_nrec_param::state (C++ member), 210
esp_hf_cb_param_t::hf_nrec_param::state (C++ member), 210
esp_hf_cb_param_t::hf_out_call_param (C++ class), 210
esp_hf_cb_param_t::hf_out_call_param::num_or_loc (C++ member), 210
esp_hf_cb_param_t::hf_out_call_param::remote_addr (C++ member), 210
esp_hf_cb_param_t::hf_unat_rep_param (C++ class), 210
esp_hf_cb_param_t::hf_volume_control_param (C++ class), 210
esp_hf_cb_param_t::hf_volume_control_param::type (C++ member), 210
esp_hf_cb_param_t::hf_volume_control_param::value (C++ member), 210
esp_hf_cb_param_t::hf_vra_rep_param (C++ class), 210

Espressif Systems Release v4.3-dev-1561-g357a277603
Submit Document Feedback
esp_hf_cb_param_t::hf_vra_rep_param::value ESP_HF_CLIENT_AT_RESPONSE_EVT (C++ enumerator), 202
esp_hf_cb_param_t::hf_vra_rep_param::value ESP_HF_CLIENT_AUDIO_STATE_CONNECTED (C++ enumerator), 201
esp_hf_cb_param_t::hf_vts_rep_param ESP_HF_CLIENT_AUDIO_STATE_CONNECTED_MSBC (C++ enumerator), 202
esp_hf_cb_param_t::hf_vts_rep_param::value ESP_HF_CLIENT_AUDIO_STATE_CONNECTING (C++ enumerator), 201
esp_hf_cb_param_t::hf_wbs_rep_param ESP_HF_CLIENT_AUDIO_STATE_DISCONNECTED (C++ enumerator), 201
esp_hf_cb_param_t::hf_wbs_rep_param::value ESP_HF_CLIENT_AUDIO_STATE_EVT (C++ enumerator), 202
esp_hf_cb_param_t::hf_wbs_rep_param::value esp_hf_client_audio_state_t (C++ enumerator), 201
esp_hf_cb_param_t::out_call (C++ member), 208
esp_hf_cb_param_t::unat_rep (C++ member), 208
esp_hf_cb_param_t::volume_control (C++ member), 208
esp_hf_cb_param_t::vra_rep (C++ member), 208
esp_hf_cb_param_t::vts_rep (C++ member), 208
esp_hf_cb_param_t::wbs_rep (C++ member), 209
espf_hf_cb_t (C++ type), 212
espf_hf_child_cmd_callback (C++ type), 185
ESP_HF_CHILD_FEAT_HOLD_ACC (C++ member), 211
ESP_HF_CHILD_FEAT_MERGE (C++ member), 211
ESP_HF_CHILD_FEAT_MERGE_DETACH (C++ member), 211
ESP_HF_CHILD_FEAT_PRIV_X (C++ member), 211
ESP_HF_CHILD_FEAT_REL (C++ member), 211
ESP_HF_CHILD_FEAT_REL_ACC (C++ member), 211
ESP_HF_CHILD_FEAT_REL_X (C++ member), 211
ESP_HF_CHILD_TYPE_HOLD_ACC (C++ enumerator), 189
ESP_HF_CHILD_TYPE_MERGE (C++ enumerator), 190
ESP_HF_CHILD_TYPE_MERGE_DETACH (C++ enumerator), 190
ESP_HF_CHILD_TYPE_PRIV_X (C++ enumerator), 190
ESP_HF_CHILD_TYPE_REL (C++ enumerator), 189
ESP_HF_CHILD_TYPE_REL_ACC (C++ enumerator), 189
ESP_HF_CHILD_TYPE_REL_X (C++ enumerator), 190
esp_hf_child_type_t (C++ enum), 189
ESP_HF_CHUP_RESPONSE_EVT (C++ enumerator), 212
espf_hf_child_cmd_callback (C++ type), 185
ESP_HF_CIND_RESPONSE_EVT (C++ enumerator), 212
espf_hf_cind_cmd_callback (C++ type), 185
ESP_HF_CLCC_RESPONSE_EVT (C++ enumerator), 212
espf_hf_clcc_cmd_callback (C++ type), 185
esp_hf_client_answer_call (C++ function), 194
ESP_HF_CLIENT_CHLD_FEAT_PRIV_X (C++ enumerator), 202
ESP_HF_CLIENT_CHLD_FEAT_REL (C++ enumerator), 200
ESP_HF_CLIENT_CHLD_FEAT_REL_ACC (C++ enumerator), 200
ESP_HF_CLIENT_CHLD_FEAT_REL_X (C++ enumerator), 200
ESP_HF_CLIENT_CIND_BATTERY_LEVEL_EVT (C++ enumerator), 202
ESP_HF_CLIENT_CIND_CALL_EVT (C++ enumerator), 202
ESP_HF_CLIENT_CIND_CALL_HLD_EVT (C++ enumerator), 202
ESP_HF_CLIENT_CIND_CALL_SET_EV (C++ enumerator), 202
ESP_HF_CLIENT_CIND_ROAMING_STATUS_EVT (C++ enumerator), 202
ESP_HF_CLIENT_CIND_SERVICE_AVAILABILITY_EVT (C++ enumerator), 202
ESP_HF_CLIENT_CIND_SIGNAL_STRENGTH_EVT (C++ enumerator), 202
ESP_HF_CLIENT_CLCC_EVT (C++ enumerator), 202
ESP_HF_CLIENT_CNUM_EVT (C++ enumerator), 202
espf_client_connect (C++ function), 192
espf_client_connect_audio (C++ function), 192
ESP_HF_CLIENT_CONNECTION_STATE_CONNECT_EVT (C++ enumerator), 201
ESP_HF_CLIENT_CONNECTION_STATE_DISCONNECT_EVT (C++ enumerator), 201
ESP_HF_CLIENT_CONNECTION_STATE_DISCONNECTED_EVT (C++ enumerator), 201
ESP_HF_CLIENT_CONNECTION_STATE_EVT (C++ enumerator), 202
espf_client_disconnect (C++ function), 192
espf_client_disconnect_audio (C++ function), 192
esp_hf_client_disconnect (C++ function), 201
esp_hf_client_disconnect_data_callback (C++ function), 192
esp_hf_client_disconnect_voice_recognition (C++ function), 192
esp_hf_client_disconnect_audio (C++ function), 192
esp_hf_client_disconnect (C++ function), 192
ESP_HF_CLIENT_COPS_CURRENT_OPERATOR_EVT (C++ enumerator), 202
esp_hf_client_deinit (C++ function), 192
espf_client_deinit (C++ function), 192
esp_hf_client_dial (C++ function), 193
espf_client_dial (C++ function), 193
espf_client_dial_memory (C++ function), 193
espf_client_dial_audio (C++ function), 193
espf_client_dial (C++ function), 193
espf_client_dial_audio (C++ function), 193
espf_client_dial_memory (C++ function), 193
esp_hf_client_stop_voice_recognition (C++ function), 193
esp_hf_client_start_voice_recognition (C++ function), 193
ESP_HF_CLIENT_PEER_FEAT_VTAG (C++ type), 200
ESP_HF_CLIENT_PEER_FEAT_REJECT (C++ type), 200
ESP_HF_CLIENT_PEER_FEAT_VREC (C++ type), 200
ESP_HF_CLIENT_PEER_FEAT_VTWIN (C++ type), 200
ESP_HF_CLIENT_PEER_FEAT_ECC (C++ type), 200
ESP_HF_CLIENT_PEER_FEAT_ECS (C++ type), 200
ESP_HF_CLIENT_PEER_FEAT_EXTERR (C++ type), 200
ESP_HF_CLIENT_PEER_FEAT_INBAND (C++ type), 200
ESP_HF_CLIENT_PEER_FEAT_INBAND (C++ type), 200
espf_client_register_callback (C++ function), 192
esp_hf_client_register_callback (C++ function), 192
esp_hf_client_register_data_callback (C++ function), 195
esp_hf_client_register_voice_recognition (C++ function), 195
esp_hf_client_register_voice_recognition (C++ function), 195
espf_client_register_voice_recognition (C++ function), 195
esp_hf_client_register_voice_recognition (C++ function), 195
ESP_HF_CLIENT_PEER_FEAT_3WAY (C++ type), 200
ESP_HF_CLIENT_PEER_FEAT_CODEC (C++ type), 200
ESP_HF_CLIENT_PEER_FEAT_CODEC (C++ type), 200
ESP_HF_CLIENT_PEER_FEAT_CODEC (C++ type), 200
ESP_HF_CLIENT_PEER_FEAT_CODEC (C++ type), 200
ESP_HF_CLIENT_PEER_FEAT_CODEC (C++ type), 200
Espressif Systems 1828 Release v4.3-dev-1561-g357a277603
Submit Document Feedback
ESP_HF_CME_DIAL_STRING_TOO_LONG (C++ enumerator), 191

ESP_HF_CME_ERR_T (C++ enum), 190

ESP_HF_CME_INVALID_PASSWORD (C++ enumerator), 191

ESP_HF_CME_INVALID_CHARACTERS_IN_DIAL_STRING_TOO_LONG (C++ enumerator), 191

ESP_HF_CONNECTION_STATE_EVT (C++ enum), 189

ESP_HF_CONNECTION_STATE_DISCONNECTING (C++ enum), 185

ESP_HF_CONNECTION_STATE_DISCONNECTED (C++ enum), 185

ESP_HF_CONNECTION_STATE_CONNECTING (C++ enum), 185

ESP_HF_CONNECTION_STATE_CONNECTED (C++ enum), 185

ESP_HF_CME_RESPONSE_EVT (C++ enum), 212

esp_hf_cme_cmd_callback (C++ type), 212

ESP_HF_CME_SIM_PIN_REQUIRED (C++ enum), 190

ESP_HF_CME_SIM_PIN2_REQUIRED (C++ enum), 190

ESP_HF_CME_SIM_PUK_REQUIRED (C++ enum), 190

ESP_HF_CME_SIM_PUK2_REQUIRED (C++ enum), 190

ESP_HF_CME_SIM_MEMORY_FAILURE (C++ enum), 190

ESP_HF_CME_SIM_MEMORY_FULL (C++ enum), 190

ESP_HF_HANGUP_CALL_CMD_CALLBACK (C++ type), 185

ESP_HF_CURRENT_CALL_DIRECTION_INCOMING (C++ enum), 188

ESP_HF_CURRENT_CALL_DIRECTION_OUTGOING (C++ enum), 188

esp_hf_current_call_direction_t (C++ enum), 187

ESP_HF_CURRENT_CALL_MODE_DATA (C++ enum), 188

esp_hf_current_call_mode_t (C++ enum), 187

ESP_HF_CURRENT_CALL_MODE_FAX (C++ enum), 188

ESP_HF_CURRENT_CALL_MODE_VOICE (C++ enum), 188

ESP_HF_CURRENT_CALL_MPTY_TYPE_MULTI (C++ enum), 188

ESP_HF_CURRENT_CALL_MPTY_TYPE_SINGLE (C++ enum), 188

esp_hf_current_call_mpty_type_t (C++ enum), 187

ESP_HF_CURRENT_CALL_STATUS_ACTIVE (C++ enum), 187

ESP_HF_CURRENT_CALL_STATUS_ALERTING (C++ enum), 187

ESP_HF_CURRENT_CALL_STATUS_DIALED (C++ enum), 187

ESP_HF_CURRENT_CALL_STATUS_HELD (C++ enum), 187

ESP_HF_CURRENT_CALL_STATUS_HELD_BY_RESP_HOLD (C++ enum), 187

esp_hf_current_call_status_t (C++ enum), 187

ESP_HF_CURRENT_CALL_STATUS_INCOMING (C++ enum), 187

ESP_HF_CURRENT_CALL_STATUS_WAITING (C++ enum), 187

esp_hf_dial_call_cmd_callback (C++ type), 185

ESP_HF_DIAL_EVT (C++ enum), 213

esp_hf_dtmf_cmd_callback (C++ type), 185

ESP_HF_HANGUP_CALL_CMD_CALLBACK (C++ type), 185

esp_hf_in_band_ring_state_t (C++ enum), 185

ESP_HF_IN_BAND_RINGTONE_NOT_PROVIDED (C++ enum), 185

ESP_HF_IN_BAND_RINGTONE_PROVIDED (C++ enum), 185

esp_hf_incoming_data_cb_t (C++ type), 211

ESP_HF_IND_UPDATE_EVT (C++ enum), 212

esp_hf_key_pressed_cmd_callback (C++ type), 212

Espressif Systems 1829

Submit Document Feedback
ESP_HF_NETWORK_STATE_AVAILABLE  (C++ enumerator), 186
ESP_HF_NETWORK_STATE_NOT_AVAILABLE  (C++ enumerator), 186
esp_hf_network_state_t (C++ enum), 186
esp_hf_nrec_cmd_callback (C++ type), 185
ESP_HF_NREC_RESPONSE_EVT (C++ enumerator), 212
ESP_HF_NREC_START (C++ enumerator), 189
ESP_HF_NREC_STOP (C++ enumerator), 189
esp_hf_nrec_t (C++ enum), 189
esp_hf_outgoing_dataCb_t (C++ type), 212
esp_hf_outgoing_data_ready (C++ function), 208
ESP_HF_PEER_FEAT_3WAY (C 宏), 211
ESP_HF_PEER_FEAT_CODEC (C 宏), 211
ESP_HF_PEER_FEAT_ECC (C 宏), 211
ESP_HF_PEER_FEAT_ECN (C 宏), 211
ESP_HF_PEER_FEAT_EXTERN (C 宏), 211
ESP_HF_PEER_FEAT_INBAND (C 宏), 211
ESP_HF_PEER_FEAT_REJECT (C 宏), 211
ESP_HF_PEER_FEAT_VREC (C 宏), 211
ESP_HF_PEER_FEAT_VTAG (C 宏), 211
ESP_HF_ROAMING_STATUS_ACTIVE  (C++ enumerator), 187
ESP_HF_ROAMING_STATUS_INACTIVE  (C++ enumerator), 187
esp_hf_roaming_status_t (C++ enum), 187
ESP_HF_SERVICE_TYPE_HOME  (C++ enumerator), 186
ESP_HF_SERVICE_TYPE_ROAMING  (C++ enumerator), 186
esp_hf_service_type_t (C++ enum), 186
ESP_HF_SUBSCRIBER_SERVICE_TYPE_FAX  (C++ enumerator), 188
esp_hf_subscriber_service_type_t (C++ enum), 188
ESP_HF_SUBSCRIBER_SERVICE_TYPE_UNKNOWN  (C++ enumerator), 188
ESP_HF_SUBSCRIBER_SERVICE_TYPE_VOICE  (C++ enumerator), 188
esp_hf_unat_response (C++ function), 204
ESP_HF_UNAT_RESPONSE_EVT (C++ enumerator), 212
esp_hf_unknown_at_cmd_callback (C++ type), 185
esp_hf_volume_cmd_callback (C++ type), 185
ESP_HF_VOLUME_CONTROL_EVT  (C++ enumerator), 212
ESP_HF_VOLUME_CONTROL_TARGET_MIC  (C++ enumerator), 186
ESP_HF_VOLUME_CONTROL_TARGET_SPK  (C++ enumerator), 186
esp_hf_volume_control_target_t (C++ enum), 186
ESP_HF_VOLUME_TYPE_MIC  (C++ enumerator), 186
ESP_HF_VOLUME_TYPE_SPK  (C++ enumerator), 186
esp_hf_volume_type_t (C++ enum), 186
esp_hf_vr_cmd_callback (C++ type), 185
ESP_HF_VR_STATE_DISABLED  (C++ enumerator), 186
ESP_HF_VR_STATE_ENABLED  (C++ enumerator), 186
esp_hf_vr_state_t (C++ enum), 186
ESP_HF_VTS_RESPONSE_EVT  (C++ enumerator), 212
esp_hf_wbs_callback (C++ type), 185
esp_hf_wbs_config_t (C++ enum), 189
ESP_HF_WBS_NO  (C++ enumerator), 189
ESP_HF_WBS_NONE  (C++ enumerator), 189
esp_hf_wbs_response_EVT  (C++ enumerator), 213
esp_hf_wbs_yes (C++ enum), 189
esp_himem_alloc (C++ function), 1142
esp_himem_alloc_map_range  (C++ function), 1142
ESP_HIMEM_BLKSIZE (C 宏), 1143
esp_himem_free  (C++ function), 1143
esp_himem_free_map_range  (C++ function), 1143
esp_himem_get_free_size  (C++ function), 1143
esp_himem_get_phys_size  (C++ function), 1143
esp_himem_handle_t  (C++ type), 1143
esp_himem_map  (C++ function), 1142
ESP_HIMEM_MAPFLAG_RO  (C 宏), 1143
esp_himem_rangehandle_t  (C++ type), 1143
esp_himem_reserved_area_size  (C++ function), 1143
esp_himem_unmap  (C++ function), 1143
esp_http_client_add_auth  (C++ function), 774
esp_http_client_auth_type_t  (C++ enum), 779
esp_http_client_cleanup  (C++ function), 774
esp_http_client_close  (C++ function), 774
esp_http_client_config_t::auth_type  (C++ member), 776
esp_http_client_config_t::auth_type::buffer_size  (C++ member), 776
esp_http_client_config_t::auth_type::buffer_size::buffer_size  (C++ member), 777
esp_http_client_config_t::buffer_size::buffer_size_tx  (C++ member), 777
esp_http_client_config_t::cert_pem  (C++ member), 776
esp_http_client_config_t::client_cert_pem  (C++ member), 776
esp_http_client_config_t::client_key_pem  (C++ member), 776
esp_http_client_config_t::disable_auto_redirect  (C++ member), 776

Espresif Systems 1830 Release v4.3-dev-1561-g357a277603
Submit Document Feedback
esp_http_client_config_t::event_handler (C++ function), 775
esp_http_client_config_t::host (C++ member), 776
esp_http_client_config_t::is_async (C++ member), 777
esp_http_client_config_t::max_authorization_retries (C++ member), 776
esp_http_client_config_t::max_redirects (C++ member), 776
esp_http_client_config_t::method (C++ member), 776
esp_http_client_config_t::password (C++ member), 776
esp_http_client_config_t::path (C++ member), 776
esp_http_client_config_t::port (C++ member), 776
esp_http_client_config_t::query (C++ member), 776
esp_http_client_config_t::skip_cert_common_name_check (C++ member), 777
esp_http_client_config_t::timeout_ms (C++ member), 776
esp_http_client_config_t::transport_type (C++ member), 776
esp_http_client_config_t::url (C++ member), 776
esp_http_client_config_t::use_global_cacert (C++ member), 777
esp_http_client_config_t::user_data (C++ member), 777
esp_http_client_config_t::username (C++ member), 776
esp_http_client_delete_header (C++ function), 772
esp_http_client_event (C++ class), 775
esp_http_client_event::client (C++ member), 775
esp_http_client_event::data (C++ member), 775
esp_http_client_event::data_len (C++ member), 775
esp_http_client_event::event_id (C++ member), 776
esp_http_client_event::header_key (C++ member), 776
esp_http_client_event::header_value (C++ member), 776
esp_http_client_event::user_data (C++ type), 777
esp_http_client_event_handle_t (C++ type), 777
esp_http_client_event_id_t (C++ enum), 777
esp_http_client_fetch_headers (C++ function), 777
esp_http_client_flush_response (C++ function), 775
esp_http_client_get_chunk_length (C++ function), 775
esp_http_client_get_content_length (C++ function), 773
esp_http_client_get_header (C++ function), 771
esp_http_client_get_password (C++ function), 772
esp_http_client_get_post_field (C++ function), 771
esp_http_client_get_status_code (C++ function), 773
esp_http_client_get_transport_type (C++ function), 774
esp_http_client_get_url (C++ function), 775
esp_http_client_get_username (C++ function), 771
esp_http_client_handle_t (C++ type), 777
esp_http_client_init (C++ function), 770
esp_http_client_is_choked_response (C++ function), 773
esp_http_client_is_complete_data_received (C++ function), 774
esp_http_client_method_t (C++ enum), 778
esp_http_client_open (C++ function), 772
esp_http_client_perform (C++ function), 770
esp_http_client_read (C++ function), 773
esp_http_client_read_response (C++ function), 774
esp_http_client_set_auth_type (C++ function), 772
esp_http_client_set_password (C++ function), 772
esp_http_client_set_post_field (C++ function), 771
esp_http_client_set_redirection (C++ function), 774
esp_http_client_set_url (C++ function), 770
esp_http_client_set_username (C++ function), 771
esp_http_client_transport_t (C++ enum), 778
esp_http_client_write (C++ function), 773
esp_https_ota (C++ function), 986
esp_https_ota_begin (C++ function), 987
esp_https_ota_config_t (C++ class), 988
esp_https_ota_config_t::bulk_flash_erase (C++ member), 988
esp_https_ota_config_t::http_client_init_cb (C++ member), 988
esp_https_ota_config_t::http_config (C++ function), 988

esp_intr_set_in_iram (C++ function), 1150
ESP_IO_CAP_IN (C宏), 84
ESP_IO_CAP_IO (C宏), 84
ESP_IO_CAP_KBDISP (C宏), 84
ESP_IO_CAP_NONE (C宏), 84
ESP_IO_CAP_OUT (C宏), 84
esp_ip4addr_aton (C++ function), 519
esp_ipc_call (C++ function), 1144
esp_ipc_call_blocking (C++ function), 1144
esp_LE_AUTH_BOND (C宏), 83
ESP_LE_AUTH_NO_BOND (C宏), 83
ESP_LE_AUTH_REQ_BOND_MITM (C宏), 83
ESP_LE_AUTH_REQ_MITM (C宏), 83
ESP_LE_AUTH_REQ_SC_BOND (C宏), 84
ESP_LE_AUTH_REQ_SC_MITM (C宏), 84
ESP_LE_AUTH_REQ_SC_MITM_BOND (C宏), 84
ESP_LE_AUTH_REQ_SC_ONLY (C宏), 84
ESP_LE_KEY_LCSRK (C宏), 83
ESP_LE_KEY_LEN (C宏), 83
ESP_LE_KEY_LID (C宏), 83
ESP_LE_KEY_LLK (C宏), 83
ESP_LE_KEY_NONE (C宏), 83
ESP_LE_KEY_PCSRK (C宏), 83
ESP_LE_KEY_PENC (C宏), 83
esp_link_key (C++ func-

ction), 62
esp_local_ctrl_add_property (C++ func-
tion), 832
esp_local_ctrl_config (C++ class), 835
esp_local_ctrl_config::handlers (C++
member), 836
esp_local_ctrl_config::max_properties (C++
member), 836
esp_local_ctrl_config::transport (C++
member), 835
esp_local_ctrl_config::transport_config (C++
member), 835
esp_local_ctrl_config_t (C++ type), 836
esp_local_ctrl_get_property (C++ func-
tion), 832
esp_local_ctrl_get_transport_ble (C++
function), 832
esp_local_ctrl_get_transport_httpd (C++
function), 832
esp_local_ctrl_handlers (C++ class), 834
esp_local_ctrl_handlers::get_prop_value (C++
member), 835
esp_local_ctrl_handlers::set_prop_value (C++
member), 835
esp_local_ctrl_handlers::usr_ctx (C++
member), 835
esp_local_ctrl_handlers::usr_ctx_free (C++
member), 835
esp_local_ctrl_prop (C++ class), 834
esp_local_ctrl_prop::ctx (C++ member),
834
esp_local_ctrl_prop::ctx_free_fn (C++
member), 834
esp_local_ctrl_prop::flags (C++ member),
834
esp_local_ctrl_prop::name (C++ member),
834
esp_local_ctrl_prop::size (C++ member),
834
esp_local_ctrl_prop::type (C++ member),
834
esp_local_ctrl_prop_t (C++ type), 836
esp_local_ctrl_prop_val (C++ class), 834
esp_local_ctrl_prop_val::data (C++
member), 834
esp_local_ctrl_prop_val::free_fn (C++
member), 834
esp_local_ctrl_prop_val::size (C++
member), 834
esp_local_ctrl_remove_property (C++
function), 833
esp_local_ctrl_set_handler (C++ func-
tion), 833
esp_local_ctrl_start (C++ function), 832
esp_local_ctrl_stop (C++ function), 832
ESP_LOCAL_CTRL_TRANSPORT_BLE (C宏), 836
esp_local_ctrl_transport_config_ble_t
(C++ type), 836
esp_local_ctrl_transport_config_httpd_t
(C++ type), 836
esp_local_ctrl_transport_config_t
(C++ union), 833
esp_local_ctrl_transport_config_t::ble
(C++ member), 833
esp_local_ctrl_transport_config_t::httpd
(C++ member), 833
ESP_LOCAL_CTRL_TRANSPORT_HTTPD (C宏),
836
esp_local_ctrl_transport_t (C++ type), 836
ESP_LOG_BUFFER_CHAR (C宏), 1155
ESP_LOG_BUFFER_CHAR_LEVEL (C宏), 1154
ESP_LOG_BUFFER_HEX (C宏), 1155
ESP_LOG_BUFFER_HEX_LEVEL (C宏), 1154
ESP_LOG_BUFFER_HEXDUMP (C宏), 1154
ESP_LOG_DEBUG (C++ enumerator), 1157
ESP_LOG_ERROR (C++ enumerator), 1156
ESP_LOG_INFO (C++ enumerator), 1156
ESP_LOG_LEVEL (C宏), 1156
ESP_LOG_LEVEL_LOCAL (C宏), 1156
esp_log_level_t (C++ enum), 1156
ESP_LOG_NONE (C++ enumerator), 1156
esp_log_set_vprintf (C++ function), 1153

ESpressif Systems
1833
Release v4.3-dev-1561-g357a277603
Submit Document Feedback
esp_log_system_timestamp (C++ function), 1154
esp_log_timestamp (C++ function), 1153
ESP_LOG_VERBOSE (C++ enumerator), 1157
ESP_LOG_WARN (C++ enumerator), 1156
esp_log_write (C++ function), 1154
esp_log_writev (C++ function), 1154
ESP_LOGD (C), 1155
ESP_LOGE (C), 1155
ESP_LOGI (C), 1155
ESP_LOGV (C), 1155
ESP_LOGW (C), 1155
ESP_MAC_BT (C++ enumerator), 1162
ESP_MAC_ETH (C++ enumerator), 1162
esp_mac_type_t (C++ enum), 1162
ESP_MAC_WIFI_SOFTAP (C++ enumerator), 1162
ESP_MAC_WIFI_STA (C++ enumerator), 1162
esp_mesh_allow_root_conflicts (C++ function), 476
esp_mesh_available_txupQ_num (C++ function), 476
esp_mesh_connect (C++ function), 480
esp_mesh_deinit (C++ function), 468
esp_mesh_delete_group_id (C++ function), 477
esp_mesh_disable_ps (C++ function), 481
esp_mesh_disconnect (C++ function), 480
esp_mesh_enable_ps (C++ function), 478
esp_mesh_fix_root (C++ function), 478
esp_mesh_flush_scan_result (C++ function), 480
esp_mesh_flush_upstream_packets (C++ function), 479
esp_mesh_get_active_duty_cycle (C++ function), 481
esp_mesh_get_ap_assoc_expire (C++ function), 475
esp_mesh_get_ap_authmode (C++ function), 473
esp_mesh_get_ap_connections (C++ function), 473
esp_mesh_get_capacity_num (C++ function), 477
esp_mesh_get_config (C++ function), 471
esp_mesh_get_group_list (C++ function), 477
esp_mesh_get_group_num (C++ function), 477
esp_mesh_get_id (C++ function), 472
esp_mesh_get_ie_crypto_key (C++ function), 478
esp_mesh_get_layer (C++ function), 473
esp_mesh_get_max_layer (C++ function), 473
esp_mesh_get_network_duty_cycle (C++ function), 482
esp_mesh_get_parent_bssid (C++ function), 474
esp_mesh_get_root_bssid (C++ function), 478
esp_mesh_get_router (C++ function), 472

Espressif Systems 1834 Release v4.3-dev-1561-g357a277603
Submit Document Feedback


esp_mesh_set_ie_crypto_key (C++ function), 477
esp_mesh_set_max_layer (C++ function), 472
esp_mesh_set_network_duty_cycle (C++ function), 481
esp_mesh_set_parent (C++ function), 478
esp_mesh_set_root_healing_delay (C++ function), 478
esp_mesh_set_router (C++ function), 472
esp_mesh_set_self_organized (C++ function), 474
esp_mesh_set_topology (C++ function), 480
esp_mesh_set_type (C++ function), 472
esp_mesh_set_vote_percentage (C++ function), 475
esp_mesh_set_xon_qsize (C++ function), 476
esp_mesh_start (C++ function), 468
esp_mesh_stop (C++ function), 469
esp_mesh_switch_channel (C++ function), 480
esp_mesh_topology_t (C++ enum), 494
esp_mesh_waive_root (C++ function), 474
esp_mqtt_client_config_t (C++ class), 820
esp_mqtt_client_config_t::alpn_protos
  (C++ member), 821
esp_mqtt_client_config_t::buffer_size
  (C++ member), 821
esp_mqtt_client_config_t::cert_len
  (C++ member), 821
esp_mqtt_client_config_t::cert_pem
  (C++ member), 821
esp_mqtt_client_config_t::cert_key_len
esp_mqtt_client_config_t::client_cert_len
  (C++ member), 821
esp_mqtt_client_config_t::client_cert_pem
  (C++ member), 821
esp_mqtt_client_config_t::client_id
  (C++ member), 820
esp_mqtt_client_config_t::client_key_len
esp_mqtt_client_config_t::client_key
  (C++ member), 821
esp_mqtt_client_config_t::client_key_pem
  (C++ member), 821
esp_mqtt_client_config_t::clientkey_password
  (C++ member), 822
esp_mqtt_client_config_t::clientkey_password_len
  (C++ member), 822
esp_mqtt_client_config_t::clientkey_password_str
  (C++ member), 822
esp_mqtt_client_config_t::clientkey_username
  (C++ member), 820
esp_mqtt_client_config_t::disable_auto_reconnect
  (C++ member), 821
esp_mqtt_client_config_t::disable_clean_session
  (C++ member), 821
esp_mqtt_client_config_t::ds_data
  (C++ member), 822
esp_mqtt_client_config_t::event_handle
esp_mqtt_client_config_t::event_loop_handle
  (C++ member), 820
esp_mqtt_client_config_t::host
  (C++ member), 820
esp_mqtt_client_config_t::keepalive
  (C++ member), 821
esp_mqtt_client_config_t::lwt_msg
  (C++ member), 820
esp_mqtt_client_config_t::lwt_msg_len
  (C++ member), 820
esp_mqtt_client_config_t::lwt_qos
  (C++ member), 820
esp_mqtt_client_config_t::lwt_retain
  (C++ member), 820
esp_mqtt_client_config_t::lwt_topic
  (C++ member), 820
esp_mqtt_client_config_t::out_buffer_size
  (C++ member), 822
esp_mqtt_client_config_t::password
  (C++ member), 820
esp_mqtt_client_config_t::port
  (C++ member), 820
esp_mqtt_client_config_t::protocol_version
  (C++ member), 822
esp_mqtt_client_config_t::psk_hint_key
  (C++ member), 821
esp_mqtt_client_config_t::reconnect_timeout_ms
  (C++ member), 821
esp_mqtt_client_config_t::refresh_connection_after_ms
  (C++ member), 821
esp_mqtt_client_config_t::skip_cert_common_name_check
  (C++ member), 822
esp_mqtt_client_config_t::task_stack
  (C++ member), 820
esp_mqtt_client_config_t::task_prio
  (C++ member), 820
esp_mqtt_client_config_t::use_secure_element
  (C++ member), 821
esp_mqtt_client_config_t::use_global_ca_store
  (C++ member), 821
esp_mqtt_client_disconnect (C++ function), 818
esp_mqtt_client_disconnect (C++ function), 847
esp_mqtt_client_handle_t (C++ type), 822
esp_mqtt_client_init (C++ function), 817
esp_mqtt_client_publish (C++ function), 818
esp_mqtt_client_reconnect (C++ function), 817
esp_mqtt_client_register_event
  (C++ function), 819
esp_mqtt_client_set_uri (C++ function), 817
esp_mqtt_client_start (C++ function), 817
esp_mqtt_client_subscribe (C++ function), 818
esp_mqtt_client_unsubscribe (C++ function), 521
esp_mqtt_connect_return_code_t (C++ enum), 823
esp_mqtt_error_codes (C++ class), 819
esp_mqtt_error_code;::connect_return_code (C++ member), 819
esp_mqtt_error_code;::error_type (C++ member), 819
esp_mqtt_error_code;::tls_cert_verify_flags (C++ member), 819
esp_mqtt_error_code;::tls_last_error (C++ member), 819
esp_mqtt_error_code;::stack_errors (C++ member), 819
esp_mqtt_event_t (C++ type), 822
esp_mqtt_event_type_t (C++ enum), 823
esp_mqtt_event_handle_t (C++ type), 822
esp_mqtt_event_id_t (C++ enum), 822
esp_mqtt_event_t (C++ class), 819
esp_mqtt_event_t;::client (C++ member), 819
esp_mqtt_event_t;::current_data_offset (C++ member), 820
esp_mqtt_event_t;::data (C++ member), 820
esp_mqtt_event_t;::data_len (C++ member), 820
esp_mqtt_event_t;::error_handle (C++ member), 820
esp_mqtt_event_t;::event_id (C++ member), 819
esp_mqtt_event_t;::msg_id (C++ member), 820
esp_mqtt_event_t;::session_present (C++ member), 820
esp_mqtt_event_t;::topic (C++ member), 820
esp_mqtt_event_t;::topic_len (C++ member), 820
esp_mqtt_event_t;::total_data_len (C++ member), 820
esp_mqtt_event_t;::user_context (C++ member), 819
esp_mqtt_protocol_ver_t (C++ enum), 824
esp_mqtt_set_config (C++ function), 818
esp_mqtt_transport_t (C++ enum), 823
esp_netif_action_connected (C++ function), 513
esp_netif_action_disconnected (C++ function), 514
esp_netif_action_get_ip (C++ function), 514
esp_netif_action_start (C++ function), 513
esp_netif_action_stop (C++ function), 513
esp_netif_attach (C++ function), 513
esp_netif_attach_wifi_ap (C++ function), 521
esp_netif_attach_wifi_station (C++ function), 521
esp_netif_create_default_wifi_ap (C++ function), 521
esp_netif_create_default_wifi_mesh_netifs (C++ function), 522
esp_netif_create_default_wifi_station (C++ function), 522
esp_netif_create_ip6_linklocal (C++ function), 518
esp_netif_create_wifi (C++ function), 522
esp_net_deinit (C++ function), 512
esp_netif_destroy (C++ function), 512
esp_netif_dhcpc_get_status (C++ function), 517
esp_netif_dhcp_option (C++ function), 516
esp_netif_dhcpc_start (C++ function), 517
esp_netif_dhcpc_stop (C++ function), 517
esp_netif_dhcps_get_status (C++ function), 517
esp_netif_dhcps_option (C++ function), 516
esp_netif_dhcps_start (C++ function), 517
esp_netif_dhcps_stop (C++ function), 518
esp_netif_free_rx_buffer (C++ function), 525
esp_netif_get_all_ip6 (C++ function), 519
esp_netif_get_desc (C++ function), 520
esp_netif_get_dns_info (C++ function), 518
esp_netif_get_event_id (C++ function), 520
esp_netif_get_flags (C++ function), 520
esp_netif_get_handle_from_ifkey (C++ function), 520
esp_netif_get_handle_from_netif_impl (C++ function), 525
esp_netif_get_hostname (C++ function), 514
esp_netif_get_ifkey (C++ function), 520
esp_netif_get_io_driver (C++ function), 520
esp_netif_get_ip6_global (C++ function), 519
esp_netif_get_ip6_linklocal (C++ function), 519
esp_netif_get_ip_info (C++ function), 515
esp_netif_get_mac (C++ function), 514
esp_netif_get_netif_impl (C++ function), 525
esp_netif_get_netif_impl_index (C++ function), 516
esp_netif_get_netif_impl_name (C++ function), 516
esp_netif_get_nr_of_ifs (C++ function), 520
esp_netif_get_old_ip_info (C++ function), 515
esp_netif_get_route_prio (C++ function), 520
esp_netif_init (C++ function), 512
esp_netif_is_netif_up (C++ function), 515
esp_netif_netstack_buf_free (C++ function), 521
esp_netif_netstack_buf_ref (C++ function), 521
esp_netif_new (C++ function), 512
esp_pthread_get_cfg (C++ function), 990
esp_pthread_init (C++ function), 990
esp_pthread_set_cfg (C++ function), 990
ESP_PWR_LVL_N0 (C++ enumerator), 60
ESP_PWR_LVL_N1 (C++ enumerator), 60
ESP_PWR_LVL_N12 (C++ enumerator), 60
ESP_PWR_LVL_N14 (C++ enumerator), 60
ESP_PWR_LVL_N2 (C++ enumerator), 60
ESP_PWR_LVL_N3 (C++ enumerator), 60
ESP_PWR_LVL_N5 (C++ enumerator), 60
ESP_PWR_LVL_N6 (C++ enumerator), 60
ESP_PWR_LVL_N8 (C++ enumerator), 60
ESP_PWR_LVL_N9 (C++ enumerator), 60
ESP_PWR_LVL_P1 (C++ enumerator), 60
ESP_PWR_LVL_P3 (C++ enumerator), 60
ESP_PWR_LVL_P4 (C++ enumerator), 60
ESP_PWR_LVL_P6 (C++ enumerator), 60
ESP_PWR_LVL_P7 (C++ enumerator), 60
ESP_PWR_LVL_P9 (C++ enumerator), 60
esp_random (C++ function), 1160
esp_read_mac (C++ function), 1161
esp_register_freertos_idle_hook (C++ function), 1115
esp_register_freertos_idle_hook_for_cpu (C++ function), 1114
esp_register_freertos_tick_hook (C++ function), 1115
esp_register_freertos_tick_hook_for_cpu (C++ function), 1115
esp_register_shutdown_handler (C++ function), 1159
esp_reset_reason (C++ function), 1159
esp_reset_reason_t (C++ enum), 1162
esp_restart (C++ function), 1159
esp_rom_delay_us (C++ function), 1196
esp_rom_disable_logging (C++ function), 1196
esp_rom_install_channel_putchar (C++ function), 1196
esp_rom_printf (C++ function), 1196
ESP_RST_BROWNOUT (C++ enumerator), 1163
ESP_RST_DEEPSLEEP (C++ enumerator), 1163
ESP_RST_EXT (C++ enumerator), 1162
ESP_RST_INT_WDT (C++ enumerator), 1162
ESP_RST_PANIC (C++ enumerator), 1162
ESP_RST_POWERON (C++ enumerator), 1162
ESP_RST_SDIO (C++ enumerator), 1163
ESP_RST_SW (C++ enumerator), 1162
ESP_RST_TASK_WDT (C++ enumerator), 1162
ESP_RST_UNKNOWN (C++ enumerator), 1162
ESP_RST_WDT (C++ enumerator), 1163
 ESP_SCO_DATA_PATH_HCI (C++ enumerator), 60
 ESP_SCO_DATA_PATH_PCM (C++ enumerator), 60
 esp_service_source_t (C++ enum), 102
 esp_set_deep_sleep_wake_stub (C++ function), 1186

Espresif Systems 1839  Release v4.3-dev-1561-g357a277603
Submit Document Feedback
esp_sleep_disable_wakeup_source (C++ function), 1183
esp_sleep_enable_ext0_wakeup (C++ function), 1184
esp_sleep_enable_ext1_wakeup (C++ function), 1184
esp_sleep_enable_gpio_wakeup (C++ function), 1185
esp_sleep_enable_timer_wakeup (C++ function), 1184
esp_sleep_enable_touchpad_wakeup (C++ function), 1184
esp_sleep_enable_uart_wakeup (C++ function), 1185
esp_sleep_enable_ulp_wakeup (C++ function), 1184
esp_sleep_enable_wifi_wakeup (C++ function), 1185
esp_sleep_ext1_wakeup_mode_t (C++ enum), 1187
esp_sleep_get_ext1_wakeup_status (C++ function), 1185
esp_sleep_get_touchpad_wakeup_status (C++ function), 1184
esp_sleep_get_wakeup_cause (C++ function), 1186
esp_sleep_get_wakeup_reason (C++ function), 1188
ESP_SLEEP_WAKEUP_COCPU (C++ enumerator), 1188
ESP_SLEEP_WAKEUP_COCPU_TRAP_TRIG (C++ enumerator), 1188
ESP_SLEEP_WAKEUP_EXT0 (C++ enumerator), 1188
ESP_SLEEP_WAKEUP_EXT1 (C++ enumerator), 1188
ESP_SLEEP_WAKEUP_GPIO (C++ enumerator), 1188
ESP_SLEEP_WAKEUP_TIMER (C++ enumerator), 1188
ESP_SLEEP_WAKEUP_TOUCHPAD (C++ enumerator), 1188
ESP_SLEEP_WAKEUP_UART (C++ enumerator), 1188
ESP_SLEEP_WAKEUP_ULP (C++ enumerator), 1188
ESP_SLEEP_WAKEUP_UNDEFINED (C++ enumerator), 1188
ESP_SLEEP_WAKEUP_WIFI (C++ enumerator), 1188
esp_smartconfig_fast_mode (C++ function), 456
esp_smartconfig_get_version (C++ function), 455
esp_smartconfig_set_type (C++ function), 456
esp_smartconfig_start (C++ function), 456
esp_smartconfig_stop (C++ function), 456
esp_spiffs_format (C++ function), 179
esp_spiffs_info (C++ function), 179
esp_spiffs Mounted (C++ function), 179
ESP_SPP_BUSY (C++ enumerator), 183
esp_spp_cb_event_t (C++ enum), 179
esp_spp_cb_param_t (C++ union), 179
esp_spp_cb_param_t::cl_init (C++ member), 179
esp_spp_cb_param_t::close (C++ member), 179
esp_spp_cb_param_t::cong (C++ member), 179
esp_spp_cb_param_t::data_ind (C++ member), 179
esp_spp_cb_param_t::disc_comp (C++ member), 179
esp_spp_cb_param_t::init (C++ member), 179
esp_spp_cb_param_t::open (C++ member), 179
esp_spp_cb_param_t::spp_cl_init_evt_param (C++ class), 179
esp_spp_cb_param_t::spp_cl_init_evt_param::handle (C++ member), 180
esp_spp_cb_param_t::spp_cl_init_evt_param::sec_id (C++ member), 180
esp_spp_cb_param_t::spp_cl_init_evt_param::status (C++ member), 180
esp_spp_cb_param_t::spp_cl_init_evt_param::use_cong (C++ member), 180
esp_spp_cb_param_t::spp_close_evt_param (C++ class), 180
esp_spp_cb_param_t::spp_close_evt_param::async (C++ member), 180
esp_spp_cb_param_t::spp_close_evt_param::handle (C++ member), 180
esp_spp_cb_param_t::spp_close_evt_param::port_status (C++ member), 180
esp_spp_cb_param_t::spp_close_evt_param::status (C++ member), 180
esp_spp_cb_param_t::spp_cong_evt_param (C++ class), 180
esp_spp_cb_param_t::spp_cong_evt_param::cong (C++ member), 180
esp_spp_cb_param_t::spp_cong_evt_param::handle (C++ member), 180
esp_spp_cb_param_t::spp_data_ind_evt_param (C++ class), 180
esp_spp_cb_param_t::spp_data_ind_evt_param::data (C++ member), 180
esp_spp_cb_param_t::spp_data_ind_evt_param::handle (C++ member), 180
esp_spp_cb Param_t::spp_data_ind_evt_param::len (C++ member), 180

Espressif Systems 1840
Submit Document Feedback
Espresif Systems

Submit Document Feedback
esp_vfs_spiffs_conf_t::format_if_mount_failed (C++ member), 934
esp_vfs_spiffs_conf_t::max_files (C++ member), 953
esp_vfs_spiffs_conf_t::partition_label (C++ member), 953
esp_vfs_spiffs_unregister (C++ function), 952
esp_vfs_stat (C++ function), 934
esp_vfs_t::access (C++ member), 939
esp_vfs_t::close (C++ member), 937
esp_vfs_t::closedir (C++ member), 938
esp_vfs_t::end_select (C++ member), 940
esp_vfs_t::fcntl1 (C++ member), 939
esp_vfs_t::fcntl1_p (C++ member), 938
esp_vfs_t::flags (C++ member), 937
esp_vfs_t::fstat (C++ member), 937
esp_vfs_t::fstat_p (C++ member), 937
esp_vfs_t::fsync (C++ member), 939
esp_vfs_t::fsync_p (C++ member), 939
esp_vfs_t::get_socket_select_semaphore (C++ member), 940
esp_vfs_t::ioctl (C++ member), 939
esp_vfs_t::ioctl_p (C++ member), 939
esp_vfs_t::link (C++ member), 938
esp_vfs_t::link_p (C++ member), 938
esp_vfs_t::lseek (C++ member), 937
esp_vfs_t::lseek_p (C++ member), 937
esp_vfs_t::mkdir (C++ member), 938
esp_vfs_t::mkdir_p (C++ member), 938
esp_vfs_t::open (C++ member), 937
esp_vfs_t::open_p (C++ member), 937
esp_vfs_t::opendir (C++ member), 938
esp_vfs_t::opendir_p (C++ member), 938
esp_vfs_t::pread (C++ member), 937
esp_vfs_t::pread_p (C++ member), 937
esp_vfs_t::pread (C++ member), 937
esp_vfs_t::pwrite (C++ member), 937
esp_vfs_t::pwrite_p (C++ member), 937
esp_vfs_t::read (C++ member), 937
esp_vfs_t::read (C++ member), 937
esp_vfs_t::read_p (C++ member), 937
esp_vfs_t::readdir (C++ member), 938
esp_vfs_t::readdir_p (C++ member), 938
esp_vfs_t::readdir_r (C++ member), 938
esp_vfs_t::readdir_r_p (C++ member), 938
esp_vfs_t::rename (C++ member), 938
esp_vfs_t::rename_p (C++ member), 938
esp_vfs_t::rmdir (C++ member), 938
esp_vfs_t::rmdir_p (C++ member), 938
esp_vfs_t::seekdir (C++ member), 938
esp_vfs_t::seekdir_p (C++ member), 938
esp_vfs_t::socket_select (C++ member), 940
esp_vfs_t::start_select (C++ member), 940
esp_vfs_t::stat (C++ member), 937
esp_vfs_t::stat_p (C++ member), 937
esp_vfs_t::stop_socket_select (C++ member), 940
esp_vfs_t::stop_socket_select_isr (C++ member), 940
esp_vfs_t::tcdrain (C++ member), 939
esp_vfs_t::tcdrain_p (C++ member), 939
esp_vfs_t::tcflow (C++ member), 939
esp_vfs_t::tcflush (C++ member), 939
esp_vfs_t::tcflush_p (C++ member), 939
esp_vfs_t::tcgetattr (C++ member), 939
esp_vfs_t::tcgetattr_p (C++ member), 939
esp_vfs_t::tcgetattr (C++ member), 939
esp_vfs_t::tcgetattr_p (C++ member), 939
esp_vfs_t::tcgetid (C++ member), 939
esp_vfs_t::tcgetid_p (C++ member), 939
esp_vfs_t::tcsetxattr (C++ member), 939
esp_vfs_t::tcsetxattr_p (C++ member), 939
esp_vfs_t::tcsendbreak (C++ member), 940
esp_vfs_t::tcsendbreak_p (C++ member), 940
esp_vfs_t::tcsetattr (C++ member), 939
esp_vfs_t::tcsetattr_p (C++ member), 939
esp_vfs_t::tcflush (C++ member), 939
esp_vfs_t::tcflush_p (C++ member), 939
esp_vfs_t::tcflush (C++ member), 939
esp_vfs_t::tcflush_p (C++ member), 939
esp_vfs_t::tcgetattr (C++ member), 939
esp_vfs_t::tcgetattr_p (C++ member), 939
esp_vfs_t::tcgetattr (C++ member), 939
esp_vfs_t::tcgetattr_p (C++ member), 939
esp_vfs_t::tcgetid (C++ member), 939
esp_vfs_t::tcgetid_p (C++ member), 939
esp_vfs_t::tcsetxattr (C++ member), 939
esp_vfs_t::tcsetxattr_p (C++ member), 939
esp_websocket_client_config_t::cert.pem
(\texttt{C++ member}, 785)
esp_websocket_client_init (\texttt{C++ function}, 781)
esp_websocket_client_is_connected (\texttt{C++ function}, 783)
esp_websocket_client_send (\texttt{C++ function}, 782)
esp_websocket_client_send_bin (\texttt{C++ function}, 782)
esp_websocket_client_send_text (\texttt{C++ function}, 783)
esp_websocket_client_set_uri (\texttt{C++ function}, 781)
esp_websocket_client_start (\texttt{C++ function}, 782)
esp_websocket_client_stop (\texttt{C++ function}, 782)
esp_websocket_event_data_t (\texttt{C++ class}), 784
esp_websocket_event_data_t::client
(\texttt{C++ member}, 784)


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Espressif Systems 1846 Release v4.3-dev-1561-g357a277603

Submit Document Feedback
eth_phy_config_t::phy_addr (C++ member), 508
eth_phy_config_t::reset_gpio_num (C++ member), 509
eth_phy_config_t::reset_timeout_ms (C++ member), 508
ETH_PHY_DEFAULT_CONFIG (C), 509
ETH_SPEED_100M (C++ enumerator), 501
ETH_SPEED_10M (C++ enumerator), 501
eth_speed_t (C++ enum), 501
ETH_STATE_DEINIT (C++ enumerator), 500
ETH_STATE_DUPLEX (C++ enumerator), 500
ETH_STATE_LINK (C++ enumerator), 500
ETH_STATE_PAUSE (C++ enumerator), 500
ETH_STATE_LLINIT (C++ enumerator), 500
ETH_STATE_SPEED (C++ enumerator), 500
ETH_VLAN_TAG_LEN (C), 500
ETHERNET_EVENT_CONNECTED (C++ enumerator), 501
ETHERNET_EVENT_DISCONNECTED (C++ enumerator), 501
ETHERNET_EVENT_START (C++ enumerator), 501
ETHERNET_EVENT_STOP (C++ enumerator), 501
ETS_INTERNAL_INTR_SOURCE (C), 1151
ETS_INTERNAL_TIMER0_INTR_SOURCE (C), 1151
ETS_INTERNAL_TIMER1_INTR_SOURCE (C), 1151
ETS_INTERNAL_TIMER2_INTR_SOURCE (C), 1151
EventBits_t (C++ type), 1084
EventGroupHandle_t (C++ type), 1084

G
gpio_config (C++ function), 546
gpio_config_t (C++ class), 551
gpio_config_t::intr_type (C++ member), 551
gpio_config_t::mode (C++ member), 551
gpio_config_t::pin_bit_mask (C++ member), 551
gpio_config_t::pull_down_mask (C++ member), 551
gpio_config_t::pull_up_mask (C++ member), 551
gpio_deep_sleep_hold_dis (C++ function), 551
gpio_deep_sleep_hold_en (C++ function), 550
GPIO_DRIVE_CAP_0 (C++ enumerator), 555
GPIO_DRIVE_CAP_1 (C++ enumerator), 555
GPIO_DRIVE_CAP_2 (C++ enumerator), 555
GPIO_DRIVE_CAP_3 (C++ enumerator), 555
GPIO_DRIVE_CAP_DEFAULT (C++ enumerator), 555
GPIO_DRIVE_CAP_MAX (C++ enumerator), 555
gpio_get_drive_cap (C++ function), 550
gpio_get_level (C++ function), 547
gpio_hold_dis (C++ function), 550
gpio_hold_en (C++ function), 550
gpio_install_isr_service (C++ function), 549
gpio_int_type_t (C++ enum), 553
GPIO_INTR_ANYEDGE (C++ enumerator), 554
GPIO_INTR_DISABLE (C++ enumerator), 553
gpio_intr_disable (C++ function), 547
gpio_intr_enable (C++ function), 546
GPIO_INTR_HIGH_LEVEL (C++ enumerator), 554
GPIO_INTR_LOW_LEVEL (C++ enumerator), 554
GPIO_INTR_MAX (C++ enumerator), 554
GPIO_INTR_NEGEDGE (C++ enumerator), 554
gpio_intr_posedge (C++ function), 554
gpio_iomux_in (C++ function), 551
gpio_iomux_out (C++ function), 551
GPIO_IS_VALID_GPIO (C), 551
GPIO_IS_VALID_OUTPUT_GPIO (C), 551
gpio_isr_handle_t (C++ type), 551
gpio_isr_handler_add (C++ function), 549
gpio_isr_handler_remove (C++ function), 549
gpio_isr_register (C++ function), 548
gpio_isr_t (C++ type), 552
GPIO_MODE_DISABLE (C++ enumerator), 554
GPIO_MODE_INPUT (C++ enumerator), 554
GPIO_MODE_INPUT_OUTPUT (C++ enumerator), 554
GPIO_MODE_INPUT_OUTPUT_OD (C++ enumerator), 554
GPIO_MODE_OUTPUT (C++ enumerator), 554
GPIO_MODE_OUTPUT_OD (C++ enumerator), 554

filter_cb_t (C++ type), 704
GPIO NUM_0 (C++ enumerator), 552
GPIO NUM_1 (C++ enumerator), 552
GPIO NUM_10 (C++ enumerator), 552
GPIO NUM_11 (C++ enumerator), 552
GPIO NUM_12 (C++ enumerator), 552
GPIO NUM_13 (C++ enumerator), 552
GPIO NUM_14 (C++ enumerator), 552
GPIO NUM_15 (C++ enumerator), 552
GPIO NUM_16 (C++ enumerator), 552
GPIO NUM_17 (C++ enumerator), 552
GPIO NUM_18 (C++ enumerator), 553
GPIO NUM_19 (C++ enumerator), 553
GPIO NUM_2 (C++ enumerator), 552
GPIO NUM_20 (C++ enumerator), 553
GPIO NUM_21 (C++ enumerator), 553
GPIO NUM_22 (C++ enumerator), 553
GPIO NUM_23 (C++ enumerator), 553
GPIO NUM_24 (C++ enumerator), 553
GPIO NUM_25 (C++ enumerator), 553
GPIO NUM_26 (C++ enumerator), 553
GPIO NUM_27 (C++ enumerator), 553
GPIO NUM_28 (C++ enumerator), 553
GPIO NUM_29 (C++ enumerator), 553
GPIO NUM_3 (C++ enumerator), 552
GPIO NUM_30 (C++ enumerator), 553
GPIO NUM_31 (C++ enumerator), 553
GPIO NUM_32 (C++ enumerator), 553
GPIO NUM_33 (C++ enumerator), 553
GPIO NUM_34 (C++ enumerator), 553
GPIO NUM_35 (C++ enumerator), 553
GPIO NUM_36 (C++ enumerator), 553
GPIO NUM_37 (C++ enumerator), 553
GPIO NUM_38 (C++ enumerator), 553
GPIO NUM_39 (C++ enumerator), 553
GPIO NUM_4 (C++ enumerator), 552
GPIO NUM_5 (C++ enumerator), 552
GPIO NUM_6 (C++ enumerator), 552
GPIO NUM_7 (C++ enumerator), 552
GPIO NUM_8 (C++ enumerator), 552
GPIO NUM_9 (C++ enumerator), 552
GPIO NUM_MAX (C++ enumerator), 553
GPIO NUM_NC (C++ enumerator), 552
gpio_num_t (C++ enum), 552
GPIO_PIN_COUNT (C function), 551
GPIO_PORT_0 (C++ enumerator), 552
GPIO_PORT_MAX (C++ enumerator), 552
gpio_port_t (C++ enum), 552
gpio_pull_mode_t (C++ enum), 554
gpio_pulldown_dis (C++ function), 549
GPIO_PULLDOWN_DISABLE (C++ enumerator), 554
gpio_pulldown_en (C++ function), 548
GPIO_PULLDOWN_ENABLE (C++ enumerator), 554
gpio_pulldown_only (C++ enumerator), 554
gpio_pulldown_t (C++ enum), 554
gpio_reset_pin (C++ function), 546
gpio_set_direction (C++ function), 547
gpio_set_drive_capability (C++ function), 550
gpio_set_intr_type (C++ function), 546
gpio_set_level (C++ function), 547
gpio_set_pull_mode (C++ function), 547
gpio_uninstall_isr_service (C++ function), 549
gpio_wakeup_disable (C++ function), 548
gpio_wakeup_enable (C++ function), 548

H

hall_sensor_read (C++ function), 529
heap_caps_add_region (C++ function), 1123
heap_caps_add_region_with_caps (C++ function), 1124
heap_caps_aligned_alloc (C++ function), 1118
heap_caps_aligned_malloc (C++ function), 1119
heap_caps_memalign (C++ function), 1119
heap_caps_set_malloc (C++ function), 1121
heap_caps_check_integrity (C++ function), 1120
heap_caps_check_integrity_addr (C++ function), 1120
heap_caps_check_integrity_all (C++ function), 1120
heap_caps_dump (C++ function), 1121
heap_caps_dump_all (C++ function), 1121
heap_caps_enable_nonos_stack_heaps (C++ function), 1123
heap_caps_free (C++ function), 1118
heap_caps_get_allocated_size (C++ function), 1122
heap_caps_get_free_size (C++ function), 1119
heap_caps_get_info (C++ function), 1120
heap_caps_get_largest_free_block (C++ function), 1120
heap_caps_get_minimum_free_size (C++ function), 1119
heap_caps_get_total_size (C++ function), 1119
heap_caps_init (C++ function), 1123
heap_caps_malloc (C++ function), 1118
heap_caps_malloc_extmem_enable (C++ function), 1121
heap_caps_mallocprefer (C++ function), 1121
heap_caps_print_heap_info (C++ function), 1120
heap_caps_realloc (C++ function), 1118
heap_caps_realloc_prefer (C++ function), 1121
heap_caps_register_failed_alloc_callback (C++ function), 1118
HEAP_TRACE_ALL (C++ enumerator), 1137
heap_trace_dump (C++ function), 1137
heap_trace_get (C++ function), 1137
heap_trace_get_count (C++ function), 1136
heap_trace_init_standalone (C++ function), 1136
heap_trace_init_tohost (C++ function), 1136
HEAP_TRACE_LEAKS (C++ enumerator), 1137
heap_trace_mode_t (C++ enum), 1137
heap_trace_record_t (C++ class), 1137
heap_trace_record_t::address (C++ member), 1137
heap_trace_record_t::allocated_by (C++ member), 1137
heap_trace_record_t::cccount (C++ member), 1137
heap_trace_record_t::freed_by (C++ member), 1137
heap_trace_record_t::size (C++ member), 1137
heap_trace_resume (C++ function), 1136
heap_trace_start (C++ function), 1136
HTTP_AUTH_TYPE_BASIC (C++ enumerator), 779
HTTP_AUTH_TYPE_DIGEST (C++ enumerator), 779
HTTP_AUTH_TYPE_NONE (C++ enumerator), 779
http_client_init_cb_t (C++ type), 988
HTTP_EVENT_DISCONNECTED (C++ enumerator), 778
HTTP_EVENT_ERROR (C++ enumerator), 777
http_event_handle_cb (C++ type), 777
HTTP_EVENT_HEADER_SENT (C++ enumerator), 778
HTTP_EVENT_HEADERS_SENT (C++ enumerator), 777
HTTP_EVENT_ON_CONNECTED (C++ enumerator), 777
HTTP_EVENT_ON_DATA (C++ enumerator), 778
HTTP_EVENT_ON_FINISH (C++ enumerator), 778
HTTP_EVENT_ON_HEADER (C++ enumerator), 778
HTTP_METHOD_COPY (C++ enumerator), 778
HTTP_METHOD_DELETE (C++ enumerator), 778
HTTP_METHOD_GET (C++ enumerator), 778
HTTP_METHOD_HEAD (C++ enumerator), 778
HTTP_METHOD_MAX (C++ enumerator), 779
HTTP_METHOD_MKCOL (C++ enumerator), 779
HTTP_METHOD_MOVE (C++ enumerator), 778
HTTP_METHOD_NOTIFY (C++ enumerator), 778
HTTP_METHOD_OPTIONS (C++ enumerator), 778
HTTP_METHOD_PATCH (C++ enumerator), 778
HTTP_METHOD_POST (C++ enumerator), 778
HTTP_METHOD_PROPPATCH (C++ enumerator), 779
HTTP_METHOD_PROPFind (C++ enumerator), 779
HTTP_METHOD_PUT (C++ enumerator), 778
HTTP_METHOD_SUBSCRIBE (C++ enumerator), 778
HTTP_METHOD_UNLOCK (C++ enumerator), 779
HTTP_METHOD_UNSUBSCRIBE (C++ enumerator), 778
HTTP_TRANSPORT_OVER_SSL (C++ enumerator), 778
HTTP_TRANSPORT_OVER_TCP (C++ enumerator), 778
HTTP_TRANSPORT_UNKNOWN (C++ enumerator), 778
HTTPD_200 (C enum), 803
HTTPD_204 (C enum), 803
HTTPD_207 (C enum), 803
HTTPD_400 (C enum), 803
HTTPD_400_BAD_REQUEST (C++ enumerator), 806
HTTPD_404 (C enum), 803
HTTPD_404_NOT_FOUND (C++ enumerator), 807
HTTPD_405_METHOD_NOT_ALLOWED (C++ enumerator), 807
HTTPD_408 (C enum), 803
HTTPD_408_REQ_TIMEOUT (C++ enumerator), 807
HTTPD_411_LENGTH_REQUIRED (C++ enumerator), 807
HTTPD_414_URI_TOO_LONG (C++ enumerator), 807
HTTPD_431_REQ_HDR_FIELDS_TOO_LARGE (C++ enumerator), 807
HTTPD_500 (C enum), 803
HTTPD_500_INTERNAL_SERVER_ERROR (C++ enumerator), 806
HTTPD_501_METHOD_NOT_IMPLEMENTED (C++ enumerator), 806
HTTPD_505_VERSION_NOT_SUPPORTED (C++ enumerator), 806
http_close_func_t (C++ type), 806
http_config (C++ class), 801
http_config::backlog_conn (C++ member), 801
http_config::close_fn (C++ member), 802
http_config::core_id (C++ member), 801
http_config::ctrl_port (C++ member), 801
http_config::global_transport_ctx (C++ member), 801
http_config::global_transport_ctx_free_fn (C++ member), 801
http_config::global_user_ctx (C++ member), 801
http_config::global_user_ctx_free_fn (C++ member), 801
http_config::lru_purge_enable (C++ member), 801
http_config::max_open_sockets (C++ member), 801
http_config::max_resp_headers (C++ member), 801
http_config::max_uri_handlers (C++
HTTPD_SSL_CONFIG_DEFAULT (C 枚举), 809
httpd_ssl_config_t (C++ type), 809
httpd_ssl_start (C++ function), 808
httpd_ssl_stop (C++ function), 808
HTTPD_SSL_TRANSPORT_INSECURE (C++ enumeration), 809
httpd_ssl_transport_mode_t (C++ enumeration), 809
HTTPD_SSL_TRANSPORT_SECURE (C++ enumeration), 809
httpd_start (C++ function), 798
httpd_stop (C++ function), 798
HTTPD_TYPE_JSON (C 枚举), 804
HTTPD_TYPE_OCTET (C 枚举), 804
HTTPD_TYPE_TEXT (C 枚举), 804
httpd_unregister_uri (C++ function), 789
httpd_unregister_uri_handler (C++ function), 789
httpd_uri (C++ class), 803
httpd_uri::handler (C++ member), 803
httpd_uri::method (C++ member), 803
httpd_uri::uri (C++ member), 803
httpd_uri::user_ctx (C++ member), 803
httpd_uri_match_func_t (C++ type), 806
httpd_uri_match_wildcard (C++ function), 792
httpd_uri_t (C++ type), 804
httpd_work_fn_t (C++ type), 806
HttpStatus_Code (C++ enum), 779
HttpStatus_Forbidden (C++ enumeration), 779
HttpStatus_Found (C++ enumeration), 779
HttpStatus_InternalError (C++ enumeration), 779
HttpStatus_MovedPermanently (C++ enumeration), 779
HttpStatus_NotFound (C++ enumeration), 779
HttpStatus_TemporaryRedirect (C++ enumeration), 779
HttpStatus_Unauthorized (C++ enumeration), 779

i2c_ack_type_t (C++ enum), 571
I2C_ADDR_BIT_10 (C++ enumeration), 571
I2C_ADDR_BIT_7 (C++ enumeration), 571
I2C_ADDR_BIT_MAX (C++ enumeration), 571
i2c_addr_mode_t (C++ enum), 571
I2C_APB_CLK_FREQ (C 宏), 569
I2C_CMD_END (C++ enumeration), 570
i2c_cmd_handle_t (C++ type), 569
i2c_cmd_link_create (C++ function), 564
i2c_cmd_link_delete (C++ function), 564
I2C_CMD_READ (C++ enumeration), 570
I2C_CMD_RESTART (C++ enumeration), 570
I2C_CMD_STOP (C++ enumeration), 570
I2C_CMD_WRITE (C++ enumeration), 570
i2c_config_t (C++ class), 569
i2c_config_t::addr_10bit_en (C++ member), 570
i2c_config_t::clk_speed (C++ member), 570
i2c_config_t::master (C++ member), 570
i2c_config_t::mode (C++ member), 569
i2c_config_t::scl_io_num (C++ member), 570
i2c_config_t::scl_pullup_en (C++ member), 570
i2c_config_t::sda_io_num (C++ member), 569
i2c_config_t::sda_pullup_en (C++ member), 570
i2c_config_t::slave (C++ member), 570
i2c_config_t::slave_addr (C++ member), 570
I2C_DATA_MODE_LSB_FIRST (C++ enumeration), 571
I2C_DATA_MODE_MAX (C++ enumeration), 571
I2C_DATA_MODE_MSB_FIRST (C++ enumeration), 571
i2c_driver_delete (C++ function), 563
dr i2c_driver_install (C++ function), 563
i2c_filter_disable (C++ function), 567
i2c_filter_enable (C++ function), 567
i2c_get_data_mode (C++ function), 569
i2c_get_data_timing (C++ function), 568
i2c_get_period (C++ function), 567
i2c_get_start_timing (C++ function), 567
i2c_get_stop_timing (C++ function), 568
i2c_get_timeout (C++ function), 568
i2c_isr_free (C++ function), 564
i2c_isr_register (C++ function), 564
I2C_MASTER_ACK (C++ enumeration), 571
I2C_MASTER_ACK_MAX (C++ enumeration), 571
i2c_master.Cmd Begin (C++ function), 566
I2C_MASTER_LAST_NACK (C++ enumeration), 571
I2C_MASTER_ACK (C++ enumeration), 571
I2C_MASTER_READ (C++ enumeration), 570
i2c_master_read (C++ function), 565
i2c_master_read_byte (C++ function), 565
i2c_master_start (C++ function), 564
i2c_master_stop (C++ function), 566
I2C_MASTER_WRITE (C++ enumeration), 570
i2c_master_write (C++ function), 565
i2c_master_write_byte (C++ function), 565
I2C_MODE_MASTER (C++ enumeration), 570
I2C_MODE_MAX (C++ enumeration), 570
I2C_MODE_SLAVE (C++ enumeration), 570
i2c_mode_t (C++ enum), 570
I2C_NUM_0 (C 宏), 569
I2C_NUM_1 (C 宏), 569
I2C_NUM_MAX (C 宏), 569
i2c_opmode_t (C++ enum), 570
i2c_param_config (C++ function), 563
i2c_port_t (C++ type), 570
i2c_reset_rx_fifo (C++ function), 563
i2c_reset_tx_fifo (C++ function), 563
I2S_NUM_MAX (C++ enumerator), 580
I2S_PDM_DSR_16S (C++ enumerator), 582
I2S_PDM_DSR_8S (C++ enumerator), 582
I2S_PDM_MAX (C++ enumerator), 582
i2s_pdm_dsr_t (C++ enum), 582
i2s_pin_config_t (C++ class), 579
i2s_pin_config_t::bck_io_num (C++ member), 579
i2s_pin_config_t::data_in_num (C++ member), 580
i2s_pin_config_t::data_out_num (C++ member), 579
i2s_pin_config_t::ws_io_num (C++ member), 579
I2S_PIN_NO_CHANGE (C), 578
i2s_port_t (C++ enum), 580
i2s_read (C++ function), 576
i2s_set_adc_mode (C++ function), 578
i2s_set_clk (C++ function), 577
i2s_set_dac_mode (C++ function), 575
i2s_set_pdm_rx_down_sample (C++ function), 575
i2s_set_pin (C++ function), 574
i2s_set_sample_rates (C++ function), 577
i2s_start (C++ function), 577
i2s_stop (C++ function), 577
i2s_write (C++ function), 576
i2s_write_exp (C++ function), 576
i2s_zero_dma_buffer (C++ function), 577
I_ADDI (C), 1533
I_ADDR (C), 1532
I_ANDI (C), 1533
I_ANDR (C), 1532
I_BGE (C), 1532
I_BL (C), 1532
I_BXFI (C), 1532
I_BXFR (C), 1532
I_BXI (C), 1532
I_BXR (C), 1532
I_BXZI (C), 1532
I_BXZR (C), 1532
I_DELAY (C), 1531
I_END (C), 1531
I_HALT (C), 1531
I_LD (C), 1532
I_LSHI (C), 1533
I_LSHR (C), 1533
I_MOVI (C), 1533
I_MOVR (C), 1533
I_ORI (C), 1533
I_ORR (C), 1532
I_RD_REG (C), 1532
I_RSFI (C), 1533
I_RSHI (C), 1533
I_RSHR (C), 1533
I_ST (C), 1531
I_SUBI (C), 1533
I_SUBR (C), 1532
I_WR_REG (C), 1532
intr_handle_data_t (C++ type), 1151
intr_handle_t (C++ type), 1151
intr_handler_t (C++ type), 1151

L
LEDC_APB_CLK (C++ enumerator), 593
LEDC_APB_CLK_HZ (C), 591
LEDC_AUTO_CLK (C++ enumerator), 593
ledc_bind_channel_timer (C++ function), 589
LEDC_CHANNEL_0 (C++ enumerator), 594
LEDC_CHANNEL_1 (C++ enumerator), 594
LEDC_CHANNEL_2 (C++ enumerator), 594
LEDC_CHANNEL_3 (C++ enumerator), 594
LEDC_CHANNEL_4 (C++ enumerator), 594
LEDC_CHANNEL_5 (C++ enumerator), 594
LEDC_CHANNEL_6 (C++ enumerator), 594
LEDC_CHANNEL_7 (C++ enumerator), 594
ledc_channel_conf (C++ function), 585
ledc_channel_config_t (C++ class), 592
ledc_channel_config_t::channel (C++ member), 592
ledc_channel_config_t::duty (C++ member), 592
ledc_channel_config_t::gpio_num (C++ member), 592
ledc_channel_config_t::hpoint (C++ member), 592
ledc_channel_config_t::intr_type (C++ member), 592
ledc_channel_config_t::speed_mode (C++ member), 592
ledc_channel_config_t::timer_sel (C++ member), 592
LEDC_CHANNEL_MAX (C++ enumerator), 594
ledc_channel_t (C++ enum), 594
ledc_clk_cfg_t (C++ enum), 593
ledc_clk_src_t (C++ enum), 593
LEDC_DUTY_DIR_DECREASE (C++ enumerator), 593
LEDC_DUTY_DIR_INCREASE (C++ enumerator), 593
LEDC_DUTY_MAX (C++ enumerator), 593
ledc_duty_direction_t (C++ enum), 593
LEDC_ERR_DUTY (C), 591
LEDC_ERR_VAL (C), 591
ledc_fade_func_install (C++ function), 590
ledc_fade_func_uninstall (C++ function), 590
LEDC_FADE_MAX (C++ enumerator), 595
ledc_fade_mode_t (C++ enum), 595
LEDC_FADE_NO_WAIT (C++ enumerator), 595
ledc_fade_start (C++ function), 590
LEDC_FADE_WAIT_DONE (C++ enumerator), 595
ledc_get_duty (C++ function), 587
ledc_get_freq (C++ function), 586
ledc_get_hpoint (C++ function), 587
LEDC_HIGH_SPEED_MODE (C++ enumerator), 592
LEDC_INTR_DISABLE (C++ enumerator), 593
LED_C_TM_CFG (C++ enumerator), 594
ledc_timer_config (C++ enum), 594
ledc_timer_type_t (C++ enum), 594
ledc_isr_handle_t (C++ type), 591
ledc_isr_register (C++ function), 588
LED_LOW_SPEED_MODE (C++ enumerator), 593
ledc_mode_t (C++ enum), 592
LED_REF_CLK_HZ (C), 591
LED_REF_TICK (C++ enumerator), 593
ledc_set_duty (C++ function), 587
ledc_set_duty_and_update (C++ function), 590
ledc_set_duty_with_hpoint (C++ function), 589
ledc_set_dut_with_time (C++ function), 590
ledc_set_freq (C++ function), 586
LED_TIMER_0 (C++ enumerator), 593
LED_TIMER_1 (C++ enumerator), 594
LED_TIMER_10_BIT (C++ enumerator), 595
LED_TIMER_11_BIT (C++ enumerator), 595
LED_TIMER_12_BIT (C++ enumerator), 595
LED_TIMER_13_BIT (C++ enumerator), 595
LED_TIMER_14_BIT (C++ enumerator), 595
LED_TIMER_15_BIT (C++ enumerator), 595
LED_TIMER_16_BIT (C++ enumerator), 595
LED_TIMER_17_BIT (C++ enumerator), 595
LED_TIMER_18_BIT (C++ enumerator), 595
LED_TIMER_19_BIT (C++ enumerator), 595
LED_TIMER_1 BIT (C++ enumerator), 594
LED_TIMER_2 (C++ enumerator), 594
LED_TIMER_20_BIT (C++ enumerator), 595
LED_TIMER_2 BIT (C++ enumerator), 594
LED_TIMER_3 (C++ enumerator), 594
LED_TIMER_4_BIT (C++ enumerator), 594
LED_TIMER_5_BIT (C++ enumerator), 594
LED_TIMER_6_BIT (C++ enumerator), 594
LED_TIMER_7_BIT (C++ enumerator), 594
LED_TIMER_8_BIT (C++ enumerator), 594
LED_TIMER_9_BIT (C++ enumerator), 594
LED_TIMER_BIT_MAX (C++ enumerator), 595
ledc_timer_bit_t (C++ enum), 594
ledc_timer_config (C++ function), 585
ledc_timer_config_t (C++ class), 592
ledc_timer_config_t::bit_num (C++ member), 592
ledc_timer_config_t::clk_cfg (C++ member), 592
ledc_timer_config_t::duty_resolution (C++ member), 592
ledc_timer_config_t::freq_hz (C++ member), 592
ledc_timer_config_t::speed_mode (C++ member), 592
LED_TIMER_MAX (C++ enumerator), 594
ledc_timer_pause (C++ function), 589
ledc_timer_resume (C++ function), 589
ledc_timer_rst (C++ function), 588
ledc_timer_set (C++ function), 588
ledc_timer_t (C++ enum), 593
ledc_update_duty (C++ function), 586
LED_USE_APB_CLK (C++ enumerator), 593
LED_USE_REF_TICK (C++ enumerator), 593
LED_USE_RTC8M_CLK (C++ enumerator), 593
linenoiseCompletions (C++ type), 973

M
M_BGE (C), 1533
M_BL (C), 1533
M_BX (C), 1533
M_BXF (C), 1533
M_BXZ (C), 1533
M_LABEL (C), 1533
MALLOC_CAP_32BIT (C), 1122
MALLOC_CAP_8BIT (C), 1122
MALLOC_CAP_DEFAULT (C), 1122
MALLOC_CAP_DMA (C), 1122
MALLOC_CAP_EXEC (C), 1122
MALLOC_CAP_INTERNAL (C), 1122
MALLOC_CAP_INVALID (C), 1122
MALLOC_CAP_IRAM_8BIT (C), 1122
MALLOC_CAP_PID2 (C), 1122
MALLOC_CAP_PID3 (C), 1122
MALLOC_CAP_PID4 (C), 1122
MALLOC_CAP_PID5 (C), 1122
MALLOC_CAP_PID6 (C), 1122
MALLOC_CAP_PID7 (C), 1122
MALLOC_CAP_SPIRAM (C), 1122
MAX_BLE_DEVNAME_LEN (C), 865
MAX_FDS (C), 940
MAX_PASSPHRASE_LEN (C), 448
MAX_SSID_LEN (C), 448
MAX_WPS_AP_CRED (C), 448
mbc_master_destroy (C++ function), 826
mbc_master_get_cid_info (C++ function), 828
mbc_master_get_parameter (C++ function), 828
mbc_master_init (C++ function), 824
mbc_master_init_tcp (C++ function), 825
mbc_master_send_request (C++ function), 827
mbc_master_set_descriptor (C++ function), 827
mbc_master_set_parameter (C++ function), 828
mbc_master_setup (C++ function), 825
mbc_master_start (C++ function), 826
mbc_slave_check_event (C++ function), 826
mbc_slave_destroy (C++ function), 826
mbc_slave_get_param_info (C++ function), 827
mbc_slave_init (C++ function), 824
mbc_slave_init_tcp (C++ function), 825
mbc_slave_set_descriptor (C++ function), 826
mbc_slave_setup (C++ function), 825
MCPWM0A (C++ enumerator), 611
MCPWM0B (C++ enumerator), 611
MCPWM1A (C++ enumerator), 611
MCPWM1B (C++ enumerator), 611
MCPWM2A (C++ enumerator), 611
MCPWM2B (C++ enumerator), 611
MCPWM_ACTION_FORCE_HIGH (C++ enumerator), 610
MCPWM_ACTION_FORCE_LOW (C++ enumerator), 610
MCPWM_ACTION_NO_CHANGE (C++ enumerator), 610
mc pwm_action_on_pwmxa_t (C++ type), 611
mc pwm_action_on_pwmxb_t (C++ type), 611
MCPWM_ACTION_TOGGLE (C++ enumerator), 601
MCPWM_ACTIVE_HIGH_COMPLIMENT_MODE (C++ enumerator), 602
MCPWM_ACTIVE_HIGH_MODE (C++ enumerator), 602
MCPWM_ACTIVE_LOW_COMPLIMENT_MODE (C++ enumerator), 602
MCPWM_ACTIVE_LOW_MODE (C++ enumerator), 602
MCPWM_ACTIVE_RED_FED_FROM_PWMA (C++ enumerator), 602
MCPWM_ACTIVE_RED_FED_FROM_PWMB (C++ enumerator), 602
MCPWM_BOTH_EDGE (C++ enumerator), 602
MCPWM_BYPASS_FED (C++ enumerator), 602
MCPWM_BYPASS_RED (C++ enumerator), 602
MCPWM_CAP_0 (C++ enumerator), 612
MCPWM_CAP_1 (C++ enumerator), 612
MCPWM_CAP_2 (C++ enumerator), 612
mc pwm_capture_disable (C++ function), 608
mc pwm_capture_enable (C++ function), 608
mc pwm_capture_on_edge_t (C++ enum), 602
mc pwm_capture_signal_get_edge (C++ function), 608
mc pwm_capture_signal_get_value (C++ function), 608
mc pwm_capture_signal_t (C++ enum), 613
mc pwm_carrier_config_t (C++ class), 610
mc pwm_carrier_config_t::carrier_duty (C++ member), 610
mc pwm_carrier_config_t::carrier_ivt_mode (C++ member), 610
mc pwm_carrier_config_t::carrier_os_mode (C++ member), 610
mc pwm_carrier_config_t::carrier_period (C++ member), 610
mc pwm_carrier_config_t::pulse_width_in_os (C++ member), 610
mc pwm_carrier_disable (C++ function), 605
mc pwm_carrier_enable (C++ function), 605
mc pwm_carrier_init (C++ function), 605
mc pwm_carrier_oneshot_mode_disable (C++ function), 606
mc pwm_carrier_oneshot_mode_enable (C++ function), 606
mc pwm_carrier_os_t (C++ enum), 612
MCPWM_CARRIER_OUT_IVT_DIS (C++ enumerator), 613
MCPWM_CARRIER_OUT_IVT_EN (C++ enumerator), 613
mc pwm_carrier_out_ivt_t (C++ enum), 613
mc pwm_carrier_output_invert (C++ function), 606
mc pwm_carrier_set_duty_cycle (C++ function), 606
mc pwm_carrier_set_period (C++ function), 605
mc pwm_config_t (C++ class), 610
mc pwm_config_t::cmpr_a (C++ member), 610
mc pwm_config_t::cmpr_b (C++ member), 610
mc pwm_config_t::counter_mode (C++ member), 610
mc pwm_config_t::duty_mode (C++ member), 610
mc pwm_config_t::frequency (C++ member), 610
MCPWM_COUNTER_MAX (C++ enumerator), 601
mc pwm_counter_type_t (C++ enum), 601
MCPWM_DEADTIME_BYPASS (C++ enumerator), 602
mc pwm_deadtime_disable (C++ function), 607
mc pwm_deadtime_enable (C++ function), 606
MCPWM_DEADTIME_TYPE_MAX (C++ enumerator), 602
mc pwm_deadtime_type_t (C++ enum), 601
MCPWM_DOWN_COUNTER (C++ enumerator), 601
MCPWM_DUTY_MODE_0 (C++ enumerator), 601
MCPWM_DUTY_MODE_1 (C++ enumerator), 601
MCPWM_DUTY_MODE_MAX (C++ enumerator), 601
mc pwm_duty_type_t (C++ enum), 601
MCPWM_FAULT_0 (C++ enumerator), 611
MCPWM_FAULT_1 (C++ enumerator), 612
MCPWM_FAULT_2 (C++ enumerator), 612
mc pwm_fault_deinit (C++ function), 608
mc pwm_fault_init (C++ function), 607
mc pwm_fault_input_level_t (C++ enum), 613
mc pwm_fault_set_cyc_mode (C++ function), 607
mc pwm_fault_set_oneshot_mode (C++ function), 607
mcpwm_fault_signal_t (C++ enum), 613
MCPWM_FORCE_MCPWMXA_HIGH (C宏), 611
MCPWM_FORCE_MCPWMXA_LOW (C宏), 611
MCPWM_FORCE_MCPWMXB_HIGH (C宏), 611
MCPWM_FORCE_MCPWMXB_LOW (C宏), 611
MCPWM_GEN_A (C++ enumerator), 612
MCPWM_GEN_B (C++ enumerator), 612
MCPWM_GEN_MAX (C++ enumerator), 612
mcpwm_generator_t (C++ enum), 612
mcpwm_get_duty (C++ function), 604
mcpwm_get_frequency (C++ function), 604
mcpwm_gpio_init (C++ function), 603
MCPWM_HAL_GENERATOR_MODE_FORCE_HIGH (C++ function), 601
MCPWM_HAL_GENERATOR_MODE_FORCE_LOW (C++ function), 601
MCPWM_HAL_GENERATOR_MODE_FORCE_TECH_H (C++ function), 601
MCPWM_HAL_GENERATOR_MODE_FORCE_TECH_L (C++ function), 601
MCPWM_HIGH_LEVEL_TGR (C++ enumerator), 613
mcpwm_init (C++ function), 603
mcpwm_intr_t (C++ enum), 601
mcpwm_io_signals_t (C++ function), 611
mcpwm_isr_register (C++ function), 609
MCPWM_LL_INTR_CAP0 (C++ enumerator), 601
MCPWM_LL_INTR_CAP1 (C++ enumerator), 601
MCPWM_LL_INTR_CAP2 (C++ enumerator), 601
MCPWM_LOW_LEVEL_TGR (C++ enumerator), 613
MCPWM_NEG_EDGE (C++ enumerator), 602
MCPWM_NO_CHANGE_IN_MCPWMXA (C宏), 611
MCPWM_NO_CHANGE_IN_MCPWMXB (C宏), 611
MCPWM_ONESHOT_MODE_DIS (C++ function), 612
MCPWM_ONESHOT_MODE_EN (C++ function), 612
mcpwm_operator_t (C++ type), 611
MCPWM_OPR_A (C宏), 611
MCPWM_OPR_B (C宏), 611
MCPWM_OPR_MAX (C宏), 611
mcpwm_output_action_t (C++ enum), 601
mcpwm_pin_config_t (C++ class), 609
mcpwm_pin_config_t::mcpwm0a_out_num (C++ member), 609
mcpwm_pin_config_t::mcpwm0b_out_num (C++ member), 609
mcpwm_pin_config_t::mcpwm1a_out_num (C++ member), 609
mcpwm_pin_config_t::mcpwm1b_out_num (C++ member), 609
mcpwm_pin_config_t::mcpwm2a_out_num (C++ member), 609
mcpwm_pin_config_t::mcpwm2b_out_num (C++ member), 609
mcpwm_pin_config_t::mcpwm_cap0_in_num (C++ member), 610
mcpwm_pin_config_t::mcpwm_cap1_in_num (C++ member), 610
mcpwm_pin_config_t::mcpwm_cap2_in_num (C++ member), 610
mcpwm_pin_config_t::mcpwm_fault0_in_num (C++ member), 610
mcpwm_pin_config_t::mcpwm_fault1_in_num (C++ member), 610
mcpwm_pin_config_t::mcpwm_fault2_in_num (C++ member), 610
mcpwm_pin_config_t::mcpwm_sync0_in_num (C++ member), 609
mcpwm_pin_config_t::mcpwm_sync1_in_num (C++ member), 609
mcpwm_pin_config_t::mcpwm_sync2_in_num (C++ member), 609
MCPWM_POS_EDGE (C++ function), 602
MCPWM_SELECT_CAP0 (C++ function), 613
MCPWM_SELECT_CAP1 (C++ function), 613
MCPWM_SELECT_CAP2 (C++ function), 613
MCPWM_SELECT_F0 (C++ function), 613
MCPWM_SELECT_F1 (C++ function), 613
MCPWM_SELECT_F2 (C++ function), 613
MCPWM_SELECT_SYNC0 (C++ function), 602
MCPWM_SELECT_SYNC1 (C++ function), 602
MCPWM_SELECT_SYNC2 (C++ function), 602
mcpwm_set_duty (C++ function), 603
mcpwm_set_duty_in_us (C++ function), 603
mcpwm_set_duty_type (C++ function), 604
mcpwm_set_frequency (C++ function), 603
mcpwm_set_pin (C++ function), 603
mcpwm_set_signal_high (C++ function), 604
mcpwm_set_signal_low (C++ function), 604
mcpwm_start (C++ function), 605
mcpwm_stop (C++ function), 605
MCPWM_SYNC_0 (C++ function), 611
MCPWM_SYNC_1 (C++ function), 611
MCPWM_SYNC_2 (C++ function), 611
mcpwm_sync_disable (C++ function), 609
mcpwm_sync_enable (C++ function), 608
mcpwm_sync_signal_t (C++ function), 602
MCPWM_TIMER_0 (C++ function), 612
MCPWM_TIMER_1 (C++ function), 612
MCPWM_TIMER_2 (C++ function), 612
MCPWM_TIMER_MAX (C++ function), 612
mcpwm_timer_t (C++ function), 612
MCPWM_TOG_MCPWMXA (C宏), 611
MCPWM_TOG_MCPWMXB (C宏), 611
MCPWM_UNIT_0 (C++ function), 612
MCPWM_UNIT_1 (C++ function), 612
MCPWM_UNIT_MAX (C++ function), 612
mcpwm_unit_t (C++ function), 612
MCPWM_UP_COUNTER (C++ function), 601
MCPWM_UP_DOWN_COUNTER (C++ function), 601
mdns_free (C++ function), 751
mdns_handle_system_event (C++ function), 754
mdns_hostname_set (C++ function), 751
MDNS_IF_AP (C++ function), 756
MDNS_IF_ETH (C++ function), 756
mdns_if_internal (C++ enum), 756
MDNS_IF_MAX (C++ function), 756
MDNS_IF_STA (C++ function), 756
mdns_if_t (C++ type), 756

Espressif Systems

1856

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Release v4.3-dev-1561-g357a277603
mdns_init (C++ function), 751
mdns_instance_name_set (C++ function), 751
mdns_ip_addr_s (C++ class), 755
mdns_ip_addr_s::addr (C++ member), 755
mdns_ip_addr_s::next (C++ member), 755
mdns_ip_addr_t (C++ type), 756
MDNS_IP_PROTOCOL_MAX (C++ enumerator), 756
mdns_ip_protocol_t (C++ enum), 756
MDNS_IP_PROTOCOL_V4 (C++ enumerator), 756
MDNS_IP_PROTOCOL_V6 (C++ enumerator), 756
mdns_query (C++ function), 753
mdns_query_a (C++ function), 754
mdns_query_ptr (C++ function), 753
mdns_query_results_free (C++ function), 753
mdns_query_srv (C++ function), 753
dns_query_text (C++ function), 754
mdns_result_s (C++ class), 755
mdns_result_s::addr (C++ member), 755
mdns_result_s::hostname (C++ member), 755
mdns_result_s::instance_name (C++ member), 755
mdns_result_s::ip_protocol (C++ member), 755
mdns_result_s::next (C++ member), 755
mdns_result_s::port (C++ member), 755
mdns_result_s::tcpip_if (C++ member), 755
mdns_result_s::txt (C++ member), 755
mdns_result_s::txt_count (C++ member), 755
mdns_result_t (C++ type), 756
dns_service_add (C++ function), 751
dns_service_instance_name_set (C++ function), 751
dns_service_port_set (C++ function), 752
dns_service_remove (C++ function), 751
dns_service_remove_all (C++ function), 753
dns_service_txt_item_remove (C++ function), 752
dns_service_txt_item_set (C++ function), 752
dns_txt_item_t (C++ class), 754
dns_txt_item_t::key (C++ member), 755
dns_txt_item_t::value (C++ member), 755
MDNS_TYPE_A (C宏), 755
MDNS_TYPE_AAAA (C宏), 755
MDNS_TYPE_ANY (C宏), 755
MDNS_TYPE_NSEC (C宏), 755
MDNS_TYPE_OPT (C宏), 755
MDNS_TYPE_PTR (C宏), 755
MDNS_TYPE_SRV (C宏), 755
MDNS_TYPE_TXT (C宏), 755
mesh_addr_t (C++ union), 483
mesh_addr_t::addr (C++ member), 483
mesh_addr_t::mip (C++ member), 483
mesh_ap_cfg_t (C++ class), 487
mesh_ap_cfg_t::max_connection (C++ member), 487
mesh_ap_cfg_t::password (C++ member), 487
MESH_ASSOC_FLAG_NETWORK_FREE (C宏), 490
MESH_ASSOC_FLAG_ROOT_FIXED (C宏), 491
MESH_ASSOC_FLAG_ROOTS_FOUND (C宏), 491
MESH_ASSOC_FLAG_VOTE_IN_PROGRESS (C宏), 490
mesh_cfg_t (C++ class), 487
mesh_cfg_t::allow_channel_switch (C++ member), 488
mesh_cfg_t::channel (C++ member), 488
mesh_cfg_t::crypto_funcs (C++ member), 488
mesh_cfg_t::mesh_ap (C++ member), 488
mesh_cfg_t::mesh_id (C++ member), 488
mesh_cfg_t::router (C++ member), 488
MESH_DATA_PROP (C宏), 490
MESH_DATA_ENC (C宏), 490
MESH_DATA_FROMDS (C宏), 490
MESH_DATA_GROUP (C宏), 490
MESH_DATA_NONBLOCK (C宏), 490
MESH_DATA_P2P (C宏), 490
mesh_data_t (C++ class), 487
mesh_data_t::data (C++ member), 487
mesh_data_t::proto (C++ member), 487
mesh_data_t::size (C++ member), 487
mesh_data_t::tos (C++ member), 487
MESH_DATA_TODS (C宏), 490
mesh_disconnect_reason_t (C++ enum), 493
MESH_EVENT_CHANNEL_SWITCH (C++ enumerator), 491
mesh_event_channel_switch_t (C++ class), 484
mesh_event_channel_switch_t::channel (C++ member), 484
MESH_EVENT_CHILD_CONNECTED (C++ enumerator), 491
mesh_event_child_connected_t (C++ type), 491
MESH_EVENT_CHILD_DISCONNECTED (C++ enumerator), 491
mesh_event_child_disconnected_t (C++ type), 491
mesh_event_connected_t (C++ class), 484
mesh_event_connected_t::connected (C++ member), 484
mesh_event_connected_t::duty (C++ member), 485
mesh_event_connected_t::self_layer (C++ member), 484
mesh_event_connected_t::channel (C++ member), 485
mesh_event_find_network_t (C++ class), 485
mesh_event_find_network_t::channel (C++ member), 485
mesh_event_find_network_t::router_bssid
(C++ member), 485
mesh_event_id_t (C++ enum), 491
mesh_event_info_t (C++ union), 483
mesh_event_info_t::channel_switch (C++ member), 483
mesh_event_info_t::child_connected (C++ member), 483
mesh_event_info_t::child_disconnected (C++ member), 483
mesh_event_info_t::connected (C++ member), 483
mesh_event_info_t::disconnected (C++ member), 483
mesh_event_info_t::find_network (C++ member), 484
mesh_event_info_t::layer_change (C++ member), 483
mesh_event_info_t::network_state (C++ member), 484
mesh_event_info_t::no_parent (C++ member), 483
mesh_event_info_t::ps_duty (C++ member), 484
mesh_event_info_t::root_addr (C++ member), 483
mesh_event_info_t::root_conflict (C++ member), 483
mesh_event_info_t::root_fixed (C++ member), 484
mesh_event_info_t::router_switch (C++ member), 484
mesh_event_info_t::routing_table (C++ member), 483
mesh_event_info_t::scan_done (C++ member), 484
mesh_event_info_t::switch_req (C++ member), 483
mesh_event_info_t::toDS_state (C++ member), 483
mesh_event_info_t::vote_started (C++ member), 483
MESH_EVENT_LAYER_CHANGE (C++ enumerator), 492
mesh_event_layer_change_t (C++ class), 485
mesh_event_layer_change_t::new_layer (C++ member), 485
MESH_EVENT_MAX (C++ enumerator), 492
MESH_EVENT_NETWORK_STATE (C++ enumerator), 492
mesh_event_network_state_t (C++ class), 486
mesh_event_network_state_t::is_rootless (C++ member), 486
MESH_EVENT_NO_PARENT_FOUND (C++ enumera- tor), 492
mesh_event_no_parent_found_t (C++ class), 485
mesh_event_no_parent_found_t::scan_times (C++ member), 486
MESH_EVENT_PARENT_CONNECTED (C++ enumera- tor), 492
MESH_EVENT_PARENT_DISCONNECTED (C++ enumera- tor), 492
MESH_EVENT_PS_CHILD_DUTY (C++ enumera- tor), 492
mesh_event_ps_duty_t (C++ class), 486
mesh_event_ps_duty_t::child_connected (C++ member), 486
MESH_EVENT_PS_PARENT_DUTY (C++ enumera- tor), 492
MESH_EVENT_ROOT_ADDRESS (C++ enumera- tor), 492
mesh_event_root_address_t (C++ type), 491
MESH_EVENT_ROOT_ASKED_YIELD (C++ enumera- tor), 492
mesh_event_root_conflict_t (C++ class), 485
mesh_event_root_conflict_t::addr (C++ member), 486
mesh_event_root_conflict_t::capacity (C++ member), 486
mesh_event_root_conflict_t::rc_addr (C++ member), 486
MESH_EVENT_ROOT_FIXED (C++ enumerator), 492
mesh_event_root_fixed_t::is_fixed (C++ member), 486
MESH_EVENT_ROOT_SWITCH_ACK (C++ enumerator), 492
MESH_EVENT_ROOT_SWITCH_REQ (C++ enumer- ator), 492
mesh_event_root_switch_req_t (C++ class), 485
mesh_event_root_switch_req_t::rc_addr (C++ member), 485
MESH_EVENT_ROUTER_SWITCH (C++ enumerator), 492
mesh_event_router_switch_t (C++ class), 491
MESH_EVENT_ROUTING_TABLE_ADD (C++ enumera- tor), 491
mesh_event_routing_table_change_t (C++ class), 486
mesh_event_routing_table_change_t::rt_size_change (C++ member), 486
MESH_EVENT_ROUTING_TABLE_REMOVE (C++ enumera- tor), 491
mesh_event_scan_done_t (C++ class), 486
mesh_event_scan_done_t::rt_size_new (C++ member), 486
multi_heap_info_t
  (C++ class), 1124
MQTT_CONNECTION_ACCEPTED (C++ enumerator), 823
MQTT_CONNECTION_REFUSE_BAD_USERNAME (C++ enumerator), 823
MQTT_CONNECTION_REFUSE_ID_REJECTED (C++ enumerator), 823
MQTT_CONNECTION_REFUSE_NOTAUTHORIZED (C++ enumerator), 823
MQTT_CONNECTION_REFUSE_PROTOCOL (C++ enumerator), 823
MQTT_CONNECTION_REFUSE_SERVER_UNAVAILABLE (C++ enumerator), 823
MQTT_ERROR_TYPE_CONNECTION_REFUSED (C++ enumerator), 823
MQTT_ERROR_TYPE_ESP_TLS (C++ enumerator), 823
MQTT_EVENT_ANY (C++ enumerator), 822
MQTT_EVENT_BEFORE_CONNECT (C++ enumerator), 823
mqtt_event_callback_t (C++ type), 822
MQTT_EVENT_CONNECTED (C++ enumerator), 822
MQTT_EVENT_DATA (C++ enumerator), 823
MQTT_EVENT_DISCONNECTED (C++ enumerator), 822
MQTT_EVENT_ERROR (C++ enumerator), 822
MQTT_EVENT_PUBLISHED (C++ enumerator), 823
MQTT_EVENT_SUBSCRIBED (C++ enumerator), 823
MQTT_EVENT_UNSUBSCRIBED (C++ enumerator), 823
MQTT_PROTOCOL_UNDEFINED (C++ enumerator), 824
MQTT_PROTOCOL_V_3_1 (C++ enumerator), 824
MQTT_PROTOCOL_V_3_1_1 (C++ enumerator), 824
MQTT_TRANSPORT_OVER_SSL (C++ enumerator), 823
MQTT_TRANSPORT_OVER_TCP (C++ enumerator), 823
MQTT_TRANSPORT_OVER_WS (C++ enumerator), 824
MQTT_TRANSPORT_OVER_WSS (C++ enumerator), 824
MQTT_TRANSPORT UNKNOWN (C++ enumerator), 823
multi_heap_aligned_alloc (C++ function), 1124
multi_heap_aligned_free (C++ function), 1125
multi_heap_check (C++ function), 1126
multi_heap_dump (C++ function), 1126
multi_heap_free (C++ function), 1125
multi_heap_free_size (C++ function), 1126
multi_heap_get_allocated_size (C++ function), 1125
multi_heap_get_info (C++ function), 1126
multi_heap_handle_t (C++ type), 1127
multi_heap_info_t (C++ class), 1126
multi_heap_info_t::allocated_blocks (C++ member), 1127
multi_heap_info_t::free_blocks (C++ member), 1127
multi_heap_info_t::largest_free_block (C++ member), 1127
multi_heap_info_t::minimum_free_bytes (C++ member), 1127
multi_heap_info_t::total_allocated_bytes (C++ member), 1127
multi_heap_info_t::total_blocks (C++ member), 1127
multi_heap_info_t::total_free_bytes (C++ member), 1127
multi_heap_malloc (C++ function), 1124
multi_heap_realloc (C++ function), 1125
multi_heap_register (C++ function), 1125
multi_heap_set_lock (C++ function), 1125

N
name_uuid (C++ class), 865
name_uuid::name (C++ member), 865
name_uuid::uuid (C++ member), 865
nvs_close (C++ function), 921
nvs_commit (C++ function), 921
nvs_delete_all (C++ function), 922
nvs_delete_key (C++ function), 922
nvs_get (C++ function), 923
nvs_get_info (C++ function), 923
nvs_get_info_t::key (C++ member), 923
nvs_get_info_t::namespace_name (C++ member), 923
nvs_get_info_t::type (C++ member), 923
nvs_next (C++ function), 923
nvs_erase_all (C++ function), 921
nvs_erase_key (C++ function), 921
nvs_flash_deinit_partition (C++ function), 915
nvs_flash_deinit_partition (C++ function), 915
nvs_flash_erase (C++ function), 916
nvs_flash_erase_partition (C++ function), 916
nvs_flash_erase_partition_ptr (C++ function), 916
nvs_flash_generate_keys (C++ function), 917
nvs_flash_init (C++ function), 915
nvs_flash_init_partition (C++ function), 915
nvs_flash_init_partition_ptr (C++ function), 915
nvs_flash_read_security_cfg (C++ function), 917
nvs_flash_secure_init (C++ function), 916
nvs_flash_secure_init_partition (C++ function), 916
nvs_get_blob (C++ function), 919
nvs_get_i16 (C++ function), 919
nvs_get_i32 (C++ function), 919
nvs_get_i64 (C++ function), 919
nvs_get_i8 (C++ function), 918
nvs_get_stats (C++ function), 921
nvs_get_str (C++ function), 919
nvs_get_u16 (C++ function), 919
nvs_get_u32 (C++ function), 919
nvs_get_u64 (C++ function), 919
nvs_get_u8 (C++ function), 919
nvs_get_used_entry_count (C++ function), 922
nvs_handle (C++ type), 925
nvs_handle_t (C++ type), 925
nvs_iterator_t (C++ type), 925
NVS_KEY_NAME_MAX_SIZE (C 宏), 925
NVS_KEY_SIZE (C 宏), 917
nvs_open (C++ function), 919
nvs_open_from_partition (C++ function), 920
nvs_open_mode (C++ type), 925
nvs_open_mode_t (C++ enum), 925
NVS_PART_NAME_MAX_SIZE (C 宏), 925
NVS_READONLY (C++ enumerator), 925
NVS_READWRITE (C++ enumerator), 925
nvs_release_iterator (C++ function), 923
nvs_sec_cfg_t (C++ class), 917
nvs_sec_cfg_t::eky (C++ member), 917
nvs_sec_cfg_t::tky (C++ member), 917
nvs_set_blob (C++ function), 920
nvs_set_i16 (C++ function), 918
nvs_set_i32 (C++ function), 918
nvs_set_i64 (C++ function), 918
nvs_set_i8 (C++ function), 917
nvs_set_str (C++ function), 918
nvs_set_u16 (C++ function), 918
nvs_set_u32 (C++ function), 918
nvs_set_u64 (C++ function), 918
nvs_set_u8 (C++ function), 918
nvs_stats_t (C++ class), 923
nvs_stats_t::free_entries (C++ member), 924
nvs_stats_t::namespace_count (C++ member), 924
nvs_stats_t::total_entries (C++ member), 924
nvs_stats_t::used_entries (C++ member), 924
NVS_TYPE_ANY (C++ enumerator), 926
NVS_TYPE_BLOB (C++ enumerator), 926
NVS_TYPE_I16 (C++ enumerator), 926
NVS_TYPE_I32 (C++ enumerator), 926
NVS_TYPE_I64 (C++ enumerator), 926
NVS_TYPE_I8 (C++ enumerator), 926
NVS_TYPE_STR (C++ enumerator), 926
NVS_TYPE_U16 (C++ enumerator), 926
NVS_TYPE_U32 (C++ enumerator), 926
NVS_TYPE_U64 (C++ enumerator), 926
NVS_TYPE_U8 (C++ enumerator), 926

O
OTA_SIZE_UNKNOWN (C 宏), 1172
OTA_WITH_SEQUENTIAL_WRITES (C 宏), 1172

P
PCNT_CHANNEL_0 (C++ enumerator), 622
PCNT_CHANNEL_1 (C++ enumerator), 622
PCNT_CHANNEL_MAX (C++ enumerator), 622
PCNT_CHANNEL_t (C++ enum), 622
pcnt_config_t (C++ class), 620
pcnt_config_t::channel (C++ member), 620
pcnt_config_t::counter_h_lim (C++ member), 620
pcnt_config_t::counter_l_lim (C++ member), 620
pcnt_config_t::ctrl_gpio_num (C++ member), 620
pcnt_config_t::hctrl_mode (C++ member), 620
pcnt_config_t::lctrl_mode (C++ member), 620
pcnt_config_t::neg_mode (C++ member), 620
pcnt_config_t::-pos_mode (C++ member), 620
pcnt_config_t::pulse_gpio_num (C++ member), 620
pcnt_config_t::unit (C++ member), 620
PCNT_COUNT_DEC (C++ enumerator), 621
PCNT_COUNT_DIS (C++ enumerator), 621
PCNT_COUNT_INC (C++ enumerator), 621
PCNT_COUNT_MAX (C++ enumerator), 621
pcnt_count_mode_t (C++ enum), 621
pcnt_counter_clear (C++ function), 616
pcnt_counter_pause (C++ function), 615
pcnt_counter_resume (C++ function), 615
pcnt_ctrl_mode_t (C++ enum), 621
pcnt_event_disable (C++ function), 616
pcnt_event_enable (C++ function), 616
PCNT_EVT_H_LIM (C++ enumerator), 622
PCNT_EVT_L_LIM (C++ enumerator), 622
PCNT_EVT_MAX (C++ enumerator), 622
PCNT_EVT_THRES_0 (C++ enumerator), 622
PCNT_EVT_THRES_1 (C++ enumerator), 622
pcnt_evt_type_t (C++ enum), 622
PCNT_EVT_ZERO (C++ enumerator), 622
pcnt_filter_disable (C++ function), 618
pcnt_filter_enable (C++ function), 618
pcnt_get_counter_value (C++ function), 615
pcnt_get_event_status (C++ function), 617
pcnt_get_event_value (C++ function), 617
pcnt_get_filter_value (C++ function), 618
pcnt_intr_disable (C++ function), 616
pcnt_intr_enable (C++ function), 616
pcnt_isr_handle_t (C++ type), 620
pcnt_isr_handler_add (C++ function), 619
pcnt_isr_handler_remove (C++ function), 619
pcnt_isr_register (C++ function), 617
RMT_CHANNEL_UNINIT (C++ enumerator), 639
rmt_clr_intr_enable_mask (C++ function), 631
rmt_config (C++ function), 632
rmt_config_t (C++ class), 635
rmt_config_t::channel (C++ member), 635
rmt_config_t::clk_div (C++ member), 636
rmt_config_t::flags (C++ member), 636
rmt_config_t::gpio_div (C++ member), 636
rmt_config_t::mem_block_num (C++ member), 636
rmt_config_t::rmt_mode (C++ member), 635
rmt_config_t::rx_config (C++ function), 636
rmt_config_t::tx_config (C++ function), 636
RMT_DATA_MODE_FIFO (C++ enumerator), 638
RMT_DATA_MODE_MAX (C++ enumerator), 638
RMT_DATA_MODE_MEM (C++ enumerator), 638
data_mode_t (C++ enum), 638
RMT_DEFAULT_CONFIG_RX (C), 636
RMT_DEFAULT_CONFIG_TX (C), 636
rmt_driver_install (C++ function), 633
rmt_driver_uninstall (C++ function), 633
rmt_fill_tx_items (C++ function), 632
rmt_get_channel_status (C++ function), 633
rmt_get_clk_div (C++ function), 626
rmt_get_counter_clock (C++ function), 633
rmt_get_idle_level (C++ function), 630
rmt_get_mem_block_num (C++ function), 627
rmt_get_mem_pd (C++ function), 628
rmt_get_memory_owner (C++ function), 629
rmt_get_ringbuf_handle (C++ function), 634
rmt_get_rx_idle_thresh (C++ function), 627
rmt_get_source_clk (C++ function), 630
rmt_get_status (C++ function), 631
get_tx_loop_mode (C++ function), 629
RMT_IDLE_LEVEL_HIGH (C++ enumerator), 638
RMT_IDLE_LEVEL_LOW (C++ enumerator), 638
RMT_IDLE_LEVEL_MAX (C++ enumerator), 638
rmt_idle_level_t (C++ enum), 638
rmt_isr_deregister (C++ function), 632
rmt_isr_handle_t (C++ type), 636
rmt_isr_register (C++ function), 632
RMT_MEM_OWNER_MAX (C++ enumerator), 638
RMT_MEM_OWNER_RX (C++ enumerator), 637
rmt_mem_owner_t (C++ enum), 637
RMT_MEM_OWNER_TX (C++ enumerator), 637
rmt_memory_rw_rst (C++ function), 629
RMT_MODE_MAX (C++ enumerator), 638
RMT_MODE_RX (C++ enumerator), 638
rmt_mode_t (C++ enum), 638
RMT_MODE_TX (C++ enumerator), 638
rmt_register_rx_end_callback (C++ function), 634
rmt_rx_config_t (C++ class), 635
rmt_rx_config_t::filter_en (C++ member), 635
rmt_rx_config_t::filter_ticks_thresh (C++ member), 635
rmt_rx_config_t::filter_ticks_thresh (C++ member), 635
rmt_rx_config_t::idle_threshold (C++ member), 635
rmt_rx_start (C++ function), 629
rmt_rx_stop (C++ function), 629
rmt_set_err_intr_en (C++ function), 631
rmt_set_idle_level (C++ function), 630
rmt_set_intr_enable_mask (C++ function), 631
rmt_set_mem_block_num (C++ function), 627
rmt_set_mem_hd (C++ function), 628
rmt_set_memory_owner (C++ function), 629
rmt_set_pin (C++ function), 632
rmt_set_rx_filter (C++ function), 630
rmt_set_rx_idle_thresh (C++ function), 626
rmt_set_rx_intr_en (C++ function), 631
rmt_set_source_clk (C++ function), 630
rmt_set_tx_carrier (C++ function), 628
rmt_set_tx_intr_en (C++ function), 631
rmt_set_tx_loop_mode (C++ function), 629
rmt_set_tx_thr_intr_en (C++ function), 631
rmt_source_clk_t (C++ enum), 638
rmt_translator_init (C++ function), 634
rmt_tx_config_t (C++ class), 635
rmt_tx_config_t::carrier_dynamic_percent (C++ member), 635
rmt_tx_config_t::carrier_en (C++ member), 635
rmt_tx_config_t::carrier_freq_hz (C++ member), 635
rmt_tx_config_t::carrier_level (C++ member), 635
rmt_tx_config_t::idle_level (C++ member), 635
rmt_tx_config_t::idle_output_en (C++ member), 635
rmt_tx_config_t::loop_en (C++ member), 635
rmt_tx_end_callback_t (C++ class), 636
rmt_tx_end_callback_t::arg (C++ member), 636
rmt_tx_end_callback_t::function (C++ member), 636
rmt_tx_end_fn_t (C++ type), 636
rmt_tx_start (C++ function), 628
rmt_tx_stop (C++ function), 628
rmt_wait_tx_done (C++ function), 634
rmt_write_items (C++ function), 633
rmt_write_sample (C++ function), 634
ROLE_FAST_PROV (C++ enumerator), 262
ROLE_NODE (C++ enumerator), 262
ROLE_PROVISIONER (C++ enumerator), 262
tct_gpio_deinit (C++ function), 555
tct_gpio_force_hold_all (C++ function), 557
tct_gpio_force_hold_dis_all (C++ function), 558
tct_gpio_get_drive_capability (C++ function), 558
rmt_gpio_get_level (C++ function), 555
rmt_gpio_hold_dis (C++ function), 557
rmt_gpio_hold_en (C++ function), 557
rmt_gpio_init (C++ function), 555
RTC_GPIO_IS_VALID_GPIO (C++), 558
rmt_gpio_is_valid_gpio (C++ function), 555
rmt_gpio_isolate (C++ function), 557
RTC_GPIO_MODE_DISABLED (C++ enumerator), 559
RTC_GPIO_MODE_INPUT_INPUT (C++ enumerator), 559
RTC_GPIO_MODE_INPUT_OUTPUT (C++ enumerator), 559
RTC_GPIO_MODE_INPUT_OUTPUT_OD (C++ enumerator), 559
RTC_GPIO_MODE_OUTPUT (C++ enumerator), 559
rmt_gpio_mode_t (C++ enum), 558
rmt_gpio_pulldown_dis (C++ function), 557
rmt_gpio_pulldown_en (C++ function), 556
rmt_gpio_pullup_dis (C++ function), 557
rmt_gpio_pullup_en (C++ function), 556
rmt_gpio_set_direction (C++ function), 556
rmt_gpio_set_direction_in_sleep (C++ function), 556
rmt_gpio_set_drive_capability (C++ function), 558
rmt_gpio_set_level (C++ function), 556
rmt_gpio_wakeup_disable (C++ function), 558
rmt_gpio_wakeup_enable (C++ function), 558
rmt_io_number_get (C++ function), 555
RTC_SLOW_MEM (C++), 1534
Sample_to_rmt_t (C++ type), 636
SC_EVENT_FOUND_CHANNEL (C++ enumerator), 457
SC_EVENT_GET SSID_PSWD (C++ enumerator), 457
SC_EVENT_SCAN_DONE (C++ enumerator), 457
SC_EVENT_SEND_ACK DONE (C++ enumerator), 457
SC_TYPE_AIRKISS (C++ enumerator), 457
SC_TYPE_ESPTOUCH (C++ enumerator), 457
SC_TYPE_ESPTOUCH_AIRKISS (C++ enumerator), 457
sdio_event_cb_t (C++ type), 658
sdio_slave,buf_handle_t (C++ type), 658
sdio_slave_clear_host_int (C++ function), 657
sdio_slave_config_t (C++ class), 657
dsio_slave_config_t::event_cb (C++ member), 657
dsio_slave_config_t::flags (C++ member), 657
Espressif Systems

Submit Document Feedback
system_event_info_t::disconnected (C++ member), 1003
system_event_info_t::got_ip6 (C++ member), 1004
system_event_info_t::scan_done (C++ member), 1003
system_event_info_t::sta_connected (C++ member), 1004
system_event_info_t::sta_disconnected (C++ member), 1004
system_event_info_t::sta_er_fail_reason (C++ member), 1004
system_event_info_t::sta_er_pin (C++ member), 1003

SPICOMMON_BUSFLAG_DUAL (C宏), 673
SPICOMMON_BUSFLAG_GPIO_PINS (C宏), 673
SPICOMMON_BUSFLAG_IOMUX_PINS (C宏), 673
SPICOMMON_BUSFLAG_MASTER (C宏), 673
SPICOMMON_BUSFLAG_MISO (C宏), 673
SPICOMMON_BUSFLAG_NATIVE_PINS (C宏), 673
SPICOMMON_BUSFLAG_quad (C宏), 673
SPICOMMON_BUSFLAG_SCLK (C宏), 673
SPICOMMON_BUSFLAG_SLAVE (C宏), 673
SPICOMMON_BUSFLAG_WPHD (C宏), 673
StaticRingbuffer_t (C++ type), 1113
StreamBufferHandle_t (C++ type), 1091

Submit Document Feedback

Espressif Systems 1870 Release v4.3-dev-1561-g357a277603
timer_get_counter_value (C++ function), 689
timer_get_counter_time_sec (C++ function), 689
timer_get_alarm_value (C++ function), 690
timer_get_config (C++ function), 692
timer_get_intr_status_in_isr (C++ function), 694
timer_group_enable_alarm_in_isr (C++ function), 693
timer_group_get_auto_reload_in_isr (C++ function), 694
timer_group_get_counter_value_in_isr (C++ function), 693
timer_group_get_intr_status_in_isr (C++ function), 694
timer_group_intr_enable (C++ function), 692
timer_group_intr_disable (C++ function), 693
timer_group_set_alarm_value_in_isr (C++ function), 693
timer_group_set_counter_enable_in_isr (C++ function), 693
timer_group_t (C++ enum), 695
timer_idx_t (C++ enum), 695
timer_init (C++ function), 691
timer Intr_LEVEL (C++ enum), 696
timer Intr_MAX (C++ enum), 696
timer Intr_NONE (C++ enum), 696
timer Intr_t (C++ enum), 696
timer Intr_T0 (C++ enum), 696
timer Intr_T1 (C++ enum), 696
timer Intr_WDT (C++ enum), 696
timer_isr_callback_add (C++ function), 691
timer_isr_callback_remove (C++ function), 691
timer_isr_handler_t (C++ type), 695
timer_isr_register (C++ type), 691
timer_isr_t (C++ type), 694
TIMER_MAX (C++ enum), 695
TIMER_PAUSE (C++ enum), 696
timer_pause (C++ function), 689
timer_set_alarm (C++ function), 690
timer_set_alarm_value (C++ function), 690
timer_set_auto_reload (C++ function), 690
timer_set_counter_mode (C++ function), 689
timer_set_counter_value (C++ function), 689
timer_set_divider (C++ function), 692
timer_set_intr (C++ function), 693
timer_set_enabled (C++ function), 692
timer_spinlock_give (C++ function), 692
timer_spinlock_take (C++ function), 694
TIMER_START (C++ enum), 696
timer_stop (C++ function), 689
timer_task_exit_critical (C++ function), 693
TASK_SWITCH_ISR (C++ function), 693
system_event_t (C++ class), 1004
system_event_t::event_id (C++ member), 1004
system_event_t::event_info (C++ member), 1004
system_event_t::event_info (C++ member), 1004
SYSTEM_EVENT_WIFI_READY (C++ enumerator), 1005

T

TaskDISABLE_INTERRUPTS (C enum), 1028
TaskENABLE_INTERRUPTS (C enum), 1028
TaskENTER_CRITICAL (C enum), 1027
TaskENTER_CRITICAL_FROM_ISR (C enum), 1027
TaskEXIT_CRITICAL (C enum), 1027
TaskEXIT_CRITICAL_FROM_ISR (C enum), 1027
TaskSCHEDULER_ABORTED (C enum), 1028
TaskSCHEDULER_INCOMPLETE (C enum), 1027
TaskSCHEDULER_RUNNING (C enum), 1028
taskYIELD (C enum), 1027
TIMERO (C enum), 695
TIMER1 (C enum), 695
TIMER_ALARM_DIS (C enum), 696
TIMER_ALARM_EN (C enum), 696
TIMER_ALARM_MAX (C enum), 696
timer_alarm_t (C enum), 696
TIMER_AUTORELOAD_DIS (C enum), 696
TIMER_AUTORELOAD_EN (C enum), 696
TIMER_AUTORELOAD_MAX (C enum), 696
timer auto reload t (C enum), 696
TIMER_BASE_CLK (C enum), 694
timer config_t (C class), 695
timer config_t::alarm_en (C member), 695
timer config_t::auto_reload (C member), 695
timer config_t::counter_dir (C member), 695
timer config_t::counter_en (C member), 695
timer config_t::divider (C member), 695
timer config_t::intr_type (C member), 695
timer count dir_t (C enum), 695
TIMER_COUNT_DOWN (C enum), 695
TIMER_COUNT_MAX (C enum), 696
TIMER_COUNT_UP (C enum), 696
timer deinit (C function), 692
timer disable intr (C function), 693
timer enable intr (C function), 692
timer get_alarm_value (C function), 690
timer get_config (C function), 692
timer get_counter_time_sec (C function), 689

(C++ type), 1004
(C++ class), 1004
(C++ member), 1004
(C++ member), 1004
(C++ member), 1005
(C++ function), 689
(C++ function), 693
(C++ function), 694
(C++ function), 693
(C++ function), 693
(C++ function), 695
(C++ function), 696
(C++ function), 695
(C++ function), 695
(C++ function), 695
(C++ function), 695
(C++ function), 695
(C++ function), 696
(C++ function), 696
(C++ function), 696
(C++ function), 696
(C++ function), 695
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(C++ function), 695
(C++ function), 696
(C++ function), 696
(C++ function), 693
(C++ function), 694
(C++ function), 694
(C++ function), 696
(C++ function), 696
(C++ function), 689
(C++ function), 690
(C++ function), 690
(C++ function), 689
(C++ function), 689
(C++ function), 689
(C++ function), 689
(C++ function), 689
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(C++ function), 689
(C++ function), 689
(C++ function), 689
(C++ function), 689
(C++ function), 689
(C++ function), 689
(C++ function), 689
(C++ function), 689
(C++ function), 689
(C++ function), 689
TimerCallbackFunction_t (C++ type), 1076
TimerHandle_t (C++ type), 1076
TlsDeleteCallbackFunction_t (C++ type), 1028
tmrCOMMANDCHANGE_PERIOD (C宏), 1067
tmrCOMMANDCHANGE_PERIOD_FROM_ISR (C宏), 1067
tmrCOMMANDDELETE (C宏), 1067
tmrCOMMANDEXECUTE_CALLBACK (C宏), 1067
tmrCOMMANDEXECUTE_CALLBACK_FROM_ISR (C宏), 1067
tmrCOMMANDRESET (C宏), 1067
tmrCOMMANDRESET_FROM_ISR (C宏), 1067
tmrCOMMANDSTART (C宏), 1067
tmrCOMMANDSTARTDONTTRACE (C宏), 1067
tmrCOMMANDSTART_FROM_ISR (C宏), 1067
tmrCOMMANDSTOP (C宏), 1067
tmrFIRST_FROM_ISR_COMMAND (C宏), 1067
touch_cnt_slope_t (C++ enum), 709
TOUCH_FSM_MODE_DEFAULT (C宏), 707
TOUCH_FSM_MODE_MAX (C++ enumerator), 709
TOUCH_FSM_MODE_SW (C++ enumerator), 709
touch_fsm_mode_t (C++ enum), 709
TOUCH_FSM_MODE_TIMER (C++ enumerator), 709
touch_high_volt_t (C++ enum), 708
TOUCH_HVOLTM24V (C++ enumerator), 708
TOUCH_HVOLTV25V (C++ enumerator), 708
TOUCH_HVOLTV26V (C++ enumerator), 708
TOUCH_HVOLTV27V (C++ enumerator), 708
TOUCH_HVOLTV_ATTEN_0V (C++ enumerator), 709
TOUCH_HVOLTV_ATTEN_0V5 (C++ enumerator), 708
TOUCH_HVOLTV_ATTEN_1V (C++ enumerator), 708
TOUCH_HVOLTV_ATTEN_1V5 (C++ enumerator), 708
TOUCH_HVOLTV_ATTEN_KEEP (C++ enumerator), 708
TOUCH_HVOLTV_ATTEN_MAX (C++ enumerator), 709
TOUCH_HVOLTV_KEEP (C++ enumerator), 708
TOUCH_HVOLTMAX (C++ enumerator), 708
touch_low_volt_t (C++ enum), 708
TOUCH_LVOLTM0V5 (C++ enumerator), 708
TOUCH_LVOLTM0V6 (C++ enumerator), 708
TOUCH_LVOLTM0V7 (C++ enumerator), 708
TOUCH_LVOLTM0V8 (C++ enumerator), 708
TOUCH_LVOLTM_MAX (C++ enumerator), 708
TOUCH_LVOLTV_MAX (C++ enumerator), 708
TOUCH_PADATTENVOLTAGE_THRESHOLD (C宏), 707
TOUCH_PAD_BIT_MASK_ALL (C宏), 707
TOUCH_PAD_BIT_MASK_MAX (C宏), 707
touch_pad_clear_group_mask (C++ function), 702
touch_pad_clear_status (C++ function), 706
touch_pad_config (C++ function), 699
touch_pad_deinit (C++ function), 704
touch_pad_filter_delete (C++ function), 703
touch_pad_filter_start (C++ function), 703
touch_pad_filter_stop (C++ function), 703
touch_pad_get_cnt_mode (C++ function), 705
touch_pad_get_filter_period (C++ function), 703
touch_pad_get_fsm_mode (C++ function), 705
touch_pad_get_group_mask (C++ function), 702
touch_pad_get_meas_time (C++ function), 701
touch_pad_get_status (C++ function), 706
touch_pad_get_thresh (C++ function), 701
touch_pad_get_trigger_mode (C++ function), 701
touch_pad_get_trigger_source (C++ function), 702
touch_pad_get_voltage (C++ function), 704
touch_pad_get_wakeup_status (C++ function), 705
TOUCH_PAD_GPIO100_CHANNEL (C宏), 706
TOUCH_PAD_GPIO1012_CHANNEL (C宏), 706
TOUCH_PAD_GPIO1013_CHANNEL (C宏), 706
TOUCH_PAD_GPIO1014_CHANNEL (C宏), 706
TOUCH_PAD_GPIO1015_CHANNEL (C宏), 706
TOUCH_PAD_GPIO1027_CHANNEL (C宏), 706
TOUCH_PAD_GPIO1028_CHANNEL (C宏), 706
TOUCH_PAD_GPIO1032_CHANNEL (C宏), 707
TOUCH_PAD_GPIO1033_CHANNEL (C宏), 706
TOUCH_PAD_GPIO104_CHANNEL (C宏), 706
TOUCH_PADHIGHVOLTAGE_THRESHOLD (C宏), 707
TOUCH_PAD_IDLECHANNELCONNECTDEFAULT (C宏), 707
touch_pad_init (C++ function), 704
touch_pad_intr_clear (C++ function), 703
touch_pad_intr_disable (C++ function), 703
touch_pad_intr_enable (C++ function), 702
touch_pad_io_init (C++ function), 704
touch_pad_isr_deregister (C++ function), 705
touch_pad_isr_register (C++ function), 705
TOUCH_PADLOWVOLTAGE_THRESHOLD (C宏), 707
TOUCH_PAD_MAX (C++ enumerator), 708
touch_pad_meas_is_done (C++ function), 706
TOUCH_PAD_MEASURECYCLEDEFAULT (C宏), 707
TOUCH_PAD_NUM0 (C++ enumerator), 707
TOUCH_PAD_NUM0_GPIO_NUM (C宏), 706
TOUCH_PAD_NUM1 (C++ enumerator), 707
TOUCH_PAD_NUM1_GPIO_NUM (C宏), 706
TOUCH_PAD_NUM2 (C++ enumerator), 707
TOUCH_PAD_NUM2_GPIO_NUM (C宏), 706
TOUCH_PAD_NUM3 (C++ enumerator), 707
TOUCH_PAD_NUM3_GPIO_NUM (C宏), 706
TOUCH_PAD_NUM4 (C++ enumerator), 707
TOUCH_PAD_NUM4_GPIO_NUM (C宏), 706
TOUCH_PAD_NUM5 (C++ enumerator), 707
TOUCH_PAD_NUM5_GPIO_NUM (C宏), 706
TOUCH_PAD_NUM6 (C++ enumerator), 707
TOUCH_PAD_NUM6_GPIO_NUM (C宏), 706
TOUCH_PAD_NUM7 (C++ enumerator), 708
TOUCH_PAD_NUM7_GPIO_NUM (C 宏), 706
TOUCH_PAD_NUM8 (C++ enumerator), 708
TOUCH_PAD_NUM8_GPIO_NUM (C 宏), 706
TOUCH_PAD_NUM9 (C++ enumerator), 708
TOUCH_PAD_NUM9_GPIO_NUM (C 宏), 707
touch_pad_read (C++ function), 699

touch_pad_read_filtered (C++ function), 700
touch_pad_read_raw_data (C++ function), 700
touch_pad_set_cnt_mode (C++ function), 705
touch_pad_set_filter_period (C++ function), 703
touch_pad_set_filter_read_cb (C++ function), 700
touch_pad_set_fsm_mode (C++ function), 705
touch_pad_set_group_mask (C++ function), 702
touch_pad_set_meas_time (C++ function), 701
touch_pad_set_trigger_mode (C++ function), 701
touch_pad_set_trigger_source (C++ function), 702
touch_pad_set_voltage (C++ function), 704
TOUCH_PAD_SLEEP_CYCLE_DEFAULT (C 宏), 707
TOUCH_PAD_SLOPE_0 (C++ enumerator), 709
TOUCH_PAD_SLOPE_1 (C++ enumerator), 709
TOUCH_PAD_SLOPE_2 (C++ enumerator), 709
TOUCH_PAD_SLOPE_3 (C++ enumerator), 709
TOUCH_PAD_SLOPE_4 (C++ enumerator), 709
TOUCH_PAD_SLOPE_5 (C++ enumerator), 709
TOUCH_PAD_SLOPE_6 (C++ enumerator), 709
TOUCH_PAD_SLOPE_7 (C++ enumerator), 709
TOUCH_PAD_SLOPE_DEFAULT (C 宏), 709
TOUCH_PAD_SLOPE_MAX (C++ enumerator), 709

touch_pad_sw_start (C++ function), 701
touch_pad_t (C++ enum), 707
TOUCH_PAD_THRESHOLD_MAX (C 宏), 707
TOUCH_PAD_TIE_OPT_DEFAULT (C 宏), 707
TOUCH_PAD_TIE_OPT_HIGH (C++ enumerator), 709

TOUCH_PAD_TIE_OPT_LOW (C++ enumerator), 709
TOUCH_PAD_TIE_OPT_MAX (C++ enumerator), 709

touch_pad_t (C++ enum), 709
TOUCH_TRIGGER_ABOVE (C++ enumerator), 709
TOUCH_TRIGGER_BELOW (C++ enumerator), 709
TOUCH_TRIGGER_MAX (C++ enumerator), 710
TOUCH_TRIGGER_MODE_DEFAULT (C 宏), 707
TOUCH_TRIGGER_MODE_DEFAULT (C 宏), 709
TOUCH_TRIGGER_MAX (C++ enumerator), 710
TOUCH_TRIGGER_MODE_DEFAULT (C 宏), 707


touch_pad_t (C++ enum), 709
TOUCH_TRIGGER_SOURCE_BOTH (C++ enumerator), 710
TOUCH_TRIGGER_SOURCE_DEFAULT (C 宏), 707
TOUCH_TRIGGER_SOURCE_MAX (C++ enumerator), 710
TOUCH_TRIGGER_SOURCE_SET1 (C++ enumerator), 710
touch_trigger_src_t (C++ enum), 710
touch_volt_atten_t (C++ enum), 708

touch_volt_atten_t (C++ enum), 708

touch_volt_atten_t (C++ enum), 708

transaction_cb_t (C++ type), 680
tskIDLE_PRIORITY (C 宏), 1027
tskKERNEL_VERSION(Build (C 宏), 1027
tskKERNEL_VERSION_MAJOR (C 宏), 1027
tskKERNEL_VERSION_MINOR (C 宏), 1027
tskKERNEL_VERSION_NUMBER (C 宏), 1027
tskMPU_REGIONDEVICE_MEMORY (C 宏), 1027

tskMPU_REGION_EXECUTE_NEVER (C 宏), 1027


tskMPU_REGION_NORMAL_MEMORY (C 宏), 1027
tskMPU_REGION_READ_ONLY (C 宏), 1027
tskNO AFFINITY (C 宏), 1027

tswana CLEAR_RECEIVE_QUEUE (C++ function), 723
tswana CLEAR_TRANSMIT_QUEUE (C++ function), 723
tswana DRIVER_INSTALL (C++ function), 721
tswana DRIVER_UNINSTALL (C++ function), 721

tswana_ERR_PASS_THRESH (C 宏), 720


tswana_EXTD_ID_MASK (C 宏), 720
tswana_FILTER_CONFIG_T (C++ class), 720
tswana_FILTER_CONFIG_T::acceptance_code (C++ member), 720
tswana_FILTER_CONFIG_T::acceptance_mask (C++ member), 720
tswana_FILTER_CONFIG_T::single_filter (C++ member), 720

tswana_FRAME_EXTD_ID_LEN_BYTES (C 宏), 720
tswana_FRAME_MAX_DLC (C 宏), 720

tswana_FRAME_STD_ID_LEN_BYTES (C 宏), 720
tswana_general_config_t (C++ class), 723
tswana_general_config_t::alerts_enabled (C++ member), 724
tswana_general_config_t::bus_off_io (C++ member), 724
tswana_general_config_t::clkout_divider (C++ member), 724

tswana_general_config_t::clkout_io (C++ member), 724
tswana_general_config_t::intr_flags (C++ member), 724

tswana_general_config_t::mode (C++ member), 723
tswana_general_config_t::rx_io (C++ member), 723

tswana_general_config_t::rx_queue_len (C++ member), 724

tswana_general_config_t::tx_io (C++ member), 723

tswana_general_config_t::tx_queue_len (C++ member), 724

tswana_get_status_info (C++ function), 723
tswana_initiate_recovery (C++ function), 723

tswana IO_UNUSED (C 宏), 724
tswana_message_t (C++ class), 719

tswana_message_t::data (C++ member), 719
tswana_message_t::data_length_code (C++ member), 719

Espressif Systems 1873 Release v4.3-dev-1561-g357a277603
SubmitDocumentFeedback
twai_message_t::dlc_non_comp (C++ member), 719
 twai_message_t::extd (C++ member), 719
 twai_message_t::flags (C++ member), 719
 twai_message_t::identifier (C++ member), 719
 twai_message_t::reserved (C++ member), 719
 twai_message_t::rtr (C++ member), 719
 twai_message_t::self (C++ member), 719
 TWAI_MODE_LISTEN_ONLY (C++ enumerator), 719
 TWAI_MODE_NO_ACK (C++ enumerator), 720
 TWAI_MODE_NORMAL (C++ enumerator), 720
 twai_mode_t (C++ enum), 720
 twai_read_alerts (C++ function), 722
 twai_receive (C++ function), 722
 twai_reconfigure_alerts (C++ function), 722
 twai_start (C++ function), 721
 TWAI_STATE_BUS_OFF (C++ enumerator), 725
 TWAI_STATE_RECOVERING (C++ enumerator), 725
 TWAI_STATE_RUNNING (C++ enumerator), 725
 twai_state_t (C++ enum), 724
 twai_status_info_t (C++ class), 724
 twai_status_info_t::arb_lost_count (C++ member), 724
 twai_status_info_t::bus_error_count (C++ member), 724
 twai_status_info_t::msgs_to_rx (C++ member), 724
 twai_status_info_t::msgs_to_tx (C++ member), 724
 twai_status_info_t::rx_error_counter (C++ member), 724
 twai_status_info_t::rx_missed_count (C++ member), 724
 twai_status_info_t::state (C++ member), 724
 twai_status_info_t::tx_error_counter (C++ member), 724
 twai_status_info_t::tx_failed_count (C++ member), 724
 TWAI_STD_ID_MASK (C), 720
 twai_stop (C++ function), 721
 twai_timing_config_t (C++ class), 719
 twai_timing_config_t::brp (C++ member), 719
 twai_timing_config_t::sjw (C++ member), 720
 twai_timing_config_t::triple_sampling (C++ member), 720
 twai_timing_config_t::tseg_1 (C++ member), 719
 twai_timing_config_t::tseg_2 (C++ member), 719
 twai_transmit (C++ function), 721

uart_at_cmd_t (C++ class), 743
uart_at_cmd_t::char_num (C++ member), 743
uart_at_cmd_t::cmd_char (C++ member), 743
uart_at_cmd_t::gap_tout (C++ member), 743
uart_at_cmd_t::post_idle (C++ member), 743
uart_at_cmd_t::pre_idle (C++ member), 743
UART_BITRATE_MAX (C), 742
UART_BREAK (C++ enumerator), 743
UART_BUFFER_FULL (C++ enumerator), 743
uart_clear_intr_status (C++ function), 733
uart_config_t (C++ class), 744
uart_config_t::baud_rate (C++ member), 744
uart_config_t::data_bits (C++ member), 744
uart_config_t::flow_ctrl (C++ member), 744
uart_config_t::parity (C++ member), 744
uart_config_t::rx_flow_ctrl_thresh (C++ member), 744
uart_config_t::stop_bits (C++ member), 744
uart_config_t::use_ref_tick (C++ member), 744
UART_CTS_GPIO19_DIRECT_CHANNEL (C), 747
UART_CTS_GPIO19_DIRECT_CHANNEL (C), 747
UART_CTS_GPIO19_DIRECT_CHANNEL (C), 747
UART_DATA (C++ enumerator), 742
UART_DATA_5_BITS (C++ enumerator), 745
UART_DATA_6_BITS (C++ enumerator), 745
UART_DATA_7_BITS (C++ enumerator), 745
UART_DATA_8_BITS (C++ enumerator), 745
UART_DATA_BITS_MAX (C++ enumerator), 745
UART_DATA_BREAK (C++ enumerator), 743
uart_disable_pattern_det_intr (C++ function), 734
uart_disable_pattern_det_mask (C++ function), 734
uart_disable_pattern_det_pattern (C++ function), 734
uart_disable_rx_intr (C++ function), 734
uart_disable_tx_intr (C++ function), 734
uart_driver_delete (C++ function), 731
uart_enable_alarm (C++ function), 731
uart_enable_intr_mask (C++ function), 734
uart_enable_pattern_det_intr (C++ function), 738
uart_enable_pattern_det_mask (C++ function), 738
uart_enable_pattern_det_pattern (C++ function), 738
uart_enable_rx_intr (C++ function), 734
uart_enable_tx_intr (C++ function), 734
UART_EVENT_MAX (C++ enumerator), 743
uart_event_t (C++ class), 742
uart_event_t::size (C++ member), 742
uart_event_t::time (C++ member), 742
uart_event_t::time (C++ member), 742
uart_event_t::timeout_flag (C++ member), 742

Espressif Systems 1874 Release v4.3-dev-1561-g357a277603
uart_set_always_rx_timeout (C++ function), 741
uart_set_baudrate (C++ function), 732
uart_set_dtr (C++ function), 735
uart_set_hw_flow_ctrl (C++ function), 733
uart_set_line_inverse (C++ function), 733
uart_set_loop_back (C++ function), 741
uart_set_mode (C++ function), 739
uart_set_parity (C++ function), 732
uart_set_pin (C++ function), 735
uart_set_rts (C++ function), 735
uart_set_rx_full_threshold (C++ function), 739
uart_set_rx_timeout (C++ function), 740
uart_set_stop_bits (C++ function), 732
uart_set_sw_flow_ctrl (C++ function), 733
uart_set_tx_empty_threshold (C++ function), 740
uart_set_tx_idle_num (C++ function), 736
uart_set_wakeup_threshold (C++ function), 740
uart_set_word_length (C++ function), 732
UART_SIGNAL_CTS_INV (C++ enumerator), 746
UART_SIGNAL_DSR_INV (C++ enumerator), 746
UART_SIGNAL_DTR_INV (C++ enumerator), 746
UART_SIGNAL_INV_DISABLE (C++ enumerator), 746
uart_signal_inv_t (C++ enum), 745
UART_SIGNAL_IRDA_RX_INV (C++ enumerator), 746
UART_SIGNAL_IRDA_TX_INV (C++ enumerator), 746
UART_SIGNAL_RTS_INV (C++ enumerator), 746
UART_SIGNAL_RXD_INV (C++ enumerator), 746
UART_SIGNAL_TXD_INV (C++ enumerator), 746
UART_SIGNAL_RTS_INV (C++ enumerator), 746
UART_SIGNAL_TXD_INV (C++ enumerator), 746
UART_SIGNAL_INV_DISABLE (C++ enumerator), 746
UART_SIGNAL_INV_DISABLE (C++ function), 746
UART_SIGNAL_INV_DISABLE (C++ type), 746
UART_STOP_BITS_1 (C++ enumerator), 745
UART_STOP_BITS_1_5 (C++ enumerator), 745
UART_STOP_BITS_2 (C++ enumerator), 745
UART_STOP_BITS_MAX (C++ enumerator), 745
uart_stop_bits_t (C++ enum), 745
uart_stop_bits_t::xoff_char (C++ member), 743
uart_stop_bits_t::xoff_thrd (C++ member), 744
uart_stop_bits_t::xon_char (C++ member), 743
uart_stop_bits_t::xon_thrd (C++ member), 743
uart_word_length_t (C++ enum), 745
uart_write_bytes (C++ function), 736
uart_write_bytes_with_break (C++ function), 737
UINT16 (C++ type), 259
UINT32 (C++ type), 260
UINT64 (C++ type), 260
UINT8 (C++ type), 259
ulp_load_binary (C++ function), 1536, 1539
ulp_process_macros_and_load (C++ function), 1530
ulp_run (C++ function), 1530, 1536, 1540
ulp_set_wakeup_period (C++ function), 1537, 1540
ulTaskGetIdleRunTimeCounter (C++ function), 1022
ulTaskNotifyTake (C++ function), 1026
uxQueueMessagesWaiting (C++ function), 1034
uxQueueMessagesWaitingFromISR (C++ function), 1035
uxQueueSpacesAvailable (C++ function), 1034
uxSemaphoreGetCount (C++ member), 1059
uxTaskGetNumberOfTasks (C++ function), 1017
uxTaskGetStackHighWaterMark (C++ function), 1018
uxTaskGetStackHighWaterMark2 (C++ function), 1018
uxTaskGetSystemState (C++ function), 1020
uxTaskPriorityGet (C++ function), 1012
uxTaskPriorityGetFromISR (C++ function), 1013

V
vendor_ie_data_t (C++ class), 441
vendor_ie_data_t::element_id (C++ member), 442
vendor_ie_data_t::length (C++ member), 442
vendor_ie_data_t::payload (C++ member), 442
vendor_ie_data_t::vendor_oui (C++ member), 442
vendor_ie_data_t::vendor_oui_type (C++ member), 442
vEventGroupDelete (C++ function), 1082
vMessageBufferDelete (C++ member), 1097
vprintf (C++ function), 1156
vQueueAddToRegistry (C++ function), 1035
vQueueDelete (C++ function), 1034
vQueueUnregisterQueue (C++ function), 1036
vRingbufferDelete (C++ function), 1112
vRingbufferGetInfo (C++ function), 1113
vRingbufferReturnItem (C++ function), 1111
vRingbufferReturnItemFromISR (C++ function), 1111
vSemaphoreDelete (C++ member), 1059
vStreamBufferDelete (C++ function), 1088
vTaskAllocateMPURegions (C++ function), 1010
vTaskDelay (C++ function), 1011
vTaskDelayUntil (C++ function), 1011
vTaskDelete (C++ function), 1010
vTaskGetInfo (C++ function), 1013
vTaskGetRunTimeStats (C++ function), 1022
vTaskList (C++ function), 1021
vTaskNotifyGiveFromISR (C++ function), 1025
vTaskPrioritySet (C++ function), 1014
vTaskResume (C++ function), 1015
vTaskSetApplicationTaskTag (C++ function), 1019
vTaskSetThreadLocalStoragePointer (C++ function), 1019
vTaskSetThreadLocalStoragePointerAndDelete (C++ function), 1019
vTaskSuspend (C++ function), 1014
vTaskSuspendAll (C++ function), 1016
vTimerSetReloadMode (C++ function), 1066
vTimerSetTimerID (C++ function), 1064

W

WEBSOCKET_EVENT_ANY (C++ enumerator), 785
WEBSOCKET_EVENT_CLOSED (C++ enumerator), 785
WEBSOCKET_EVENT_CONNECTED (C++ enumerator), 785
WEBSOCKET_EVENT_DATA (C++ enumerator), 785
WEBSOCKET_EVENT_DISCONNECTED (C++ enumerator), 785
WEBSOCKET_EVENT_ERROR (C++ enumerator), 785
WEBSOCKET_EVENT_MAX (C++ enumerator), 785
WEBSOCKET_TRANSPORT_OVER_SSL (C++ enumerator), 785
WEBSOCKET_TRANSPORT_OVER_TCP (C++ enumerator), 785
WEBSOCKET_TRANSPORT_UNKNOWN (C++ enumerator), 785
wifi_active_scan_time_t (C++ class), 438
wifi_active_scan_time_t::max (C++ member), 438
wifi_active_scan_time_t::min (C++ member), 438
WIFI_ALL_CHANNEL_SCAN (C++ enumerator), 451
WIFI_AMPDU_RX_ENABLED (C++ member), 436
WIFI_AMPDU_TX_ENABLED (C++ member), 436
WIFI_ANT_ANT0 (C++ enumerator), 451
WIFI_ANT_ANT1 (C++ enumerator), 451
wifi_ant_config_t (C++ class), 445
wifi_ant_config_t::enabled_ant0 (C++ member), 445
wifi_ant_config_t::enabled_ant1 (C++ member), 445
wifi_ant_config_t::rx_ant_default (C++ member), 445
wifi_ant_config_t::rx_ant_mode (C++ member), 445
wifi_ant_config_t::tx_ant_mode (C++ member), 445
wifi_ant_gpio_config_t (C++ class), 444
wifi_ant_gpio_config_t::gpiocfg (C++ member), 445
wifi_ant_gpio_t (C++ class), 444
wifi_ant_gpio_t::gpio_num (C++ member), 444
wifi_api_config_t (C++ class), 440
wifi_api_config_t::authmode (C++ member), 440
wifi_api_config_t::channel (C++ member), 440
wifi_api_config_t::max_connection (C++ member), 440
wifi_api_config_t::password (C++ member), 440
wifi_api_config_t::ssid (C++ member), 440
wifi_api_config_t::ssid_hidden (C++ member), 440
wifi_api_config_t::ssid_len (C++ member), 440
wifi_api_record_t (C++ class), 439
wifi_api_record_t::authmode (C++ member), 439
wifi_api_record_t::channel (C++ member), 439
wifi_api_record_t::country (C++ member), 439
wifi_api_record_t::group_cipher (C++ member), 439
wifi_api_record_t::pairwise_cipher (C++ member), 439
wifi_api_record_t::phy_11b (C++ member), 439
wifi_api_record_t::phy_11g (C++ member), 439
wifi_api_record_t::phy_11n (C++ member), 439
wifi_api_record_t::phy_lr (C++ member), 439
wifi_api_record_t::primary (C++ member), 439
wifi_api_record_t::reserved (C++ member), 439
wifi_api_record_t::rssi (C++ member), 439
wifi_api_record_t::second (C++ member), 439
wifi_csi_config_t::channel_filter_en (C++ member), 444
wifi_csi_config_t::llttf_en (C++ member), 444
wifi_csi_config_t::ltf_merge_en (C++ member), 444
wifi_csi_config_t::manu_scale (C++ member), 444
wifi_csi_config_t::shift (C++ member), 444
wifi_csi_config_t::stbc_htltf2_en (C++ member), 444
WIFI_CSI_ENABLED (C 宏), 436
wifi_csi_info_t::buf (C++ class), 444
wifi_csi_info_t::first_word_invalid (C++ member), 444
wifi_csi_info_t::len (C++ member), 444
wifi_csi_info_t::mac (C++ member), 444
wifi_csi_info_t::rx_ctrl (C++ member), 444
WIFI_DEFAULT_RX_BA_WIN (C 宏), 436
WIFI_DYNAMIC_TX_BUFFER_NUM (C 宏), 436
wifi_err_reason_t (C++ enum), 449
wifi_event_ap_probe_req_rx_t (C++ class), 447
wifi_event_ap_probe_req_rx_t::mac (C++ member), 447
wifi_event_ap_probe_req_rx_t::rssi (C++ member), 447
WIFI_EVENT_AP_PROBEREQRECVED (C++ enumerator), 455
WIFI_EVENT_AP_STACONNECTED (C++ enumerator), 455
wifi_event_ap_staconnected_t::ap (C++ member), 446
wifi_event_ap_staconnected_t::aid (C++ member), 446
wifi_event_ap_staconnected_t::mac (C++ member), 446
WIFI_EVENT_AP_STADISCONNECTED (C++ enumerator), 455
wifi_event_ap_stadisconnected_t (C++ class), 446
wifi_event_ap_stadisconnected_t::aid (C++ member), 447
wifi_event_ap_stadisconnected_t::mac (C++ member), 447
WIFI_EVENT_AP_START (C++ enumerator), 454
WIFI_EVENT_AP_STOP (C++ enumerator), 455
WIFI_EVENT_FTM_REPORT (C++ enumerator), 455
WIFI_EVENT_MASK_ALL (C 宏), 448
WIFI_EVENT_MASK_AP_PROBEREQRECVED (C 宏), 448
WIFI_EVENT_MASK_NONE (C 宏), 448
WIFI_EVENT_MAX (C++ enumerator), 455
WIFI_EVENT_SCAN_DONE (C++ enumerator), 454
WIFI_EVENT_STA_AUTHMODE_CHANGE (C++
wifi_prov_config_get_data_t::conn_info (C++ member), 879
wifi_prov_config_get_data_t::fail_reason (C++ member), 879
wifi_prov_config_get_data_t::wifi_state (C++ member), 879
wifi_prov_config_handlers (C++ class), 880
wifi_prov_config_handlers::apply_config_handler (C++ member), 880
wifi_prov_config_handlers::ctx (C++ member), 880
wifi_prov_config_handlers::get_status_handler (C++ member), 880
wifi_prov_config_handlers::set_config_handler (C++ member), 880
wifi_prov_config_handlers_t (C++ type), 880
wifi_prov_config_set_data_t (C++ class), 879
wifi_prov_config_set_data_t::bssid (C++ member), 879
wifi_prov_config_set_data_t::channel (C++ member), 879
wifi_prov_config_set_data_t::password (C++ member), 879
wifi_prov_config_set_data_t::ssid (C++ member), 879
WIFI_PROV_CRED_FAIL (C++ enumerator), 877
WIFI_PROV_CRED_RECV (C++ enumerator), 877
WIFI_PROV_CRED_SUCCESS (C++ enumerator), 877
wifi_prov_ctx_t (C++ type), 880
WIFI_PROV_DEINIT (C++ enumerator), 877
WIFI_PROV_END (C++ enumerator), 877
WIFI_PROV_EVENT_HANDLER_NONE (C++ member), 877
wifi_prov_event_handler_t::user_data (C++ member), 875
WIFI_PROV_INIT (C++ enumerator), 877
wifi_prov_mgr_config_t (C++ class), 876
wifi_prov_mgr_config_t::app_event_handler (C++ member), 876
wifi_prov_mgr_config_t::scheme (C++ member), 876
wifi_prov_mgr_config_t::scheme_event_handler (C++ member), 876
wifi_prov_mgr_config_sta (C++ function), 875
wifi_prov_mgr_deinit (C++ function), 872
wifi_prov_mgr_disable_auto_stop (C++ function), 873
wifi_prov_mgr_endpoint_create (C++ function), 874
wifi_prov_mgr_endpoint_register (C++ function), 874
wifi_prov_mgr_endpoint_unregister
WIFI_REASON_GROUP_KEY_UPDATE_TIMEOUT (C++ enumerator), 449
WIFI_REASON_HANDSHAKE_TIMEOUT (C++ enumerator), 450
WIFI_REASON_IE_IN_4WAY_DIFFERS (C++ enumerator), 450
WIFI_REASON_IE_INVALID (C++ enumerator), 449
WIFI_REASON_INVALID_PMKID (C++ enumerator), 450
WIFI_REASON_INVALID_RSN_IE_CAP (C++ enumerator), 450
WIFI_REASON_MIC_FAILURE (C++ enumerator), 449
WIFI_REASON_NO_AP_FOUND (C++ enumerator), 450
WIFI_REASON_NOT_ASSOCED (C++ enumerator), 449
WIFI_REASON_NOT_AUTHED (C++ enumerator), 449
WIFI_REASON_PAIRWISE_CIPHER_INVALID (C++ enumerator), 450
WIFI_REASON_UNSPECIFIED (C++ enumerator), 449
WIFI_REASON_UNSUPP_RSN_IE_VERSION (C++ enumerator), 450
wifi_scan_config_t (C++ class), 438
wifi_scan_config_t::bssid (C++ member), 438
wifi_scan_config_t::channel (C++ member), 438
wifi_scan_config_t::scan_time (C++ member), 438
wifi_scan_config_t::scan_type (C++ member), 438
wifi_scan_config_t::show_hidden (C++ member), 438
wifi_scan_config_t::ssid (C++ member), 438
wifi_scan_method_t (C++ enum), 451
wifi_scan_threshold_t (C++ class), 439
wifi_scan_threshold_t::authmode (C++ member), 439
wifi_scan_threshold_t::rssi (C++ member), 439
wifi_scan_time_t (C++ class), 438
wifi_scan_time_t::active (C++ member), 438
wifi_scan_time_t::passive (C++ member), 438
WIFI_SCAN_TYPE_ACTIVE (C++ enumerator), 450
WIFI_SCAN_TYPE_PASSIVE (C++ enumerator), 450
wifi_second_chan_t (C++ enum), 450
WIFI_SECOND_CHAN_NONE (C++ enumerator), 450
WIFI second_chan_t (C++ enum), 450
WIFI_SOFTAP_BEACON_MAX_LEN (C 宏), 436
wifi_sort_method_t (C++ enum), 451
wifi_sta_config_t (C++ class), 440
wifi_sta_config_t::bssid (C++ member), 440
wifi_sta_config_t::bssid_set (C++ member), 440
wifi_sta_config_t::channel (C++ member), 440
wifi_sta_config_t::listen_interval (C++ member), 441
wifi_sta_config_t::password (C++ member), 440
wifi_sta_config_t::pmf_cfg (C++ member), 441
wifi_sta_config_t::scan_method (C++ member), 440
wifi_sta_config_t::sort_method (C++ member), 441
wifi_sta_config_t::ssid (C++ member), 440
wifi_sta_config_t::threshold (C++ member), 441
wifi_sta_info_t (C++ class), 441
wifi_sta_info_t::mac (C++ member), 441
wifi_sta_info_t::phy_11b (C++ member), 441
wifi_sta_info_t::phy_11g (C++ member), 441
wifi_sta_info_t::phy_11n (C++ member), 441
wifi_sta_info_t::phy_lr (C++ member), 441
wifi_sta_info_t::reserved (C++ member), 441
wifi_sta_info_t::rssi (C++ member), 441
wifi_sta_list_t (C++ class), 441
wifi_sta_list_t::num (C++ member), 441
wifi_sta_list_t::sta (C++ member), 441
WIFI_STATIC_TX_BUFFER_NUM (C 宏), 436
WIFI_STATIS_ALL (C 宏), 448
WIFI_STATIS_BUFFER (C 宏), 448
WIFI_STATIS_DIAG (C 宏), 448
WIFI_STATIS_HW (C 宏), 448
WIFI_STATIS_PS (C 宏), 448
WIFI_STATIS_RXTX (C 宏), 448
WIFI_STORAGE_FLASH (C++ enumerator), 451
WIFI_STORAGE_RAM (C++ enumerator), 451
wifi_storage_t (C++ enum), 451
WIFI_TASK_CORE_ID (C 宏), 436
WIFI_VENDOR_IE_ELEMENT_ID (C 宏), 447
wifi_vendor_ie_id (C++ enum), 452
wifi_vendor_ie_type (C++ enum), 451
WIFI_VND_IE_ID_0 (C++ enumerator), 452
WIFI_VND_IE_ID_1 (C++ enumerator), 452
WIFI_VND_IE_TYPE_ASSOC_REQ (C++ enumerator), 452
xTimerStopFromISR (C 宏), 1073

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环境变量
 CONFIG_EFUSE_CUSTOM_TABLE, 974
 CONFIG_EFUSE_MAX_BLK_LEN, 975
 CONFIG_EFUSE_VIRTUAL, 978
 CONFIG_ESPTOOLPY_FLASHSIZE, 881
 CONFIG_LOG_DEFAULT_LEVEL, 1152
 CONFIG_LWIP_Sntp_UPDATE_DELAY, 1194
 CONFIG_LWIP_USE_ONLY_LWIP_SELECT, 932
 CONFIG_SPIRAM_BANKSWITCH_ENABLE, 1141
 CONFIG_SPIRAM_BANKSWITCH_RESERVE, 1141
 EFUSE_CODE_SCHEME_SELECTOR, 976