

ESP-WROOM-32D/ESP32-WROOM-32U

Datasheet



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About This Guide

This document provides the specifications for the ESP-WROOM-32D and ESP32-WROOM-32U modules.

Release Notes

| Date | Version | Release notes |
|---------|---------|----------------|
| 2017.11 | V1.0 | First release. |

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1. Overview

ESP-WROOM-32D and ESP32-WROOM-32U are powerful, generic Wi-Fi+BT+BLE MCU modules that target a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks, such as voice encoding, music streaming and MP3 decoding. ESP32-WROOM-32U is different from ESP-WROOM-32D in that ESP32-WROOM-32U integrates a U.FL connector. For detailed information of the U.FL connector please see Chapter 9.

Table 2: ESP-WROOM-32D vs. ESP32-WROOM-32U

| Module | ESP-WROOM-32D | ESP32-WROOM-32U |
|--------------------------|---|--|
| Core | ESP32-D0WD | ESP32-D0WD |
| SPI Flash | 32 Mbits, 3.3V | 32 Mbits, 3.3V |
| Crystal | 40 MHz | 40 MHz |
| Antenna | onboard antenna | external IPEX antenna |
| Dimensions (Unit: mm) | 18±0.2 x 25.5±0.2 x 3.1±0.15 (See Figure 6 for details) | 18±0.1 x 19.2±0.1 x 3.2±0.1 (See Figure 7 for details) |
| Schematics | See Figure 3 for details. | See Figure 4 for details. |

At the core of the two modules are the ESP32-D0WD chip*. The chip embedded is designed to be scalable and adaptive. There are two CPU cores that can be individually controlled, and the clock frequency is adjustable from 80 MHz to 240 MHz. The user may also power off the CPU and make use of the low-power co-processor to constantly monitor the peripherals for changes or crossing of thresholds. ESP32 integrates a rich set of peripherals, ranging from capacitive touch sensors, Hall sensors, low-noise sense amplifiers, SD card interface, Ethernet, high-speed SPI, UART, I2S and I2C.

Note:

* For details on the part number of the ESP32 series, please refer to the document [ESP32 Datasheet](#).

The integration of Bluetooth, Bluetooth LE and Wi-Fi ensures that a wide range of applications can be targeted, and that the module is future proof: using Wi-Fi allows a large physical range and direct connection to the internet through a Wi-Fi router, while using Bluetooth allows the user to conveniently connect to the phone or broadcast low energy beacons for its detection. The sleep current of the ESP32 chip is less than 5 μ A, making it suitable for battery powered and wearable electronics applications. ESP32 supports a data rate of up to 150 Mbps, and 20.5 dBm output power at the antenna to ensure the widest physical range. As such the chip does offer industry-leading specifications and the best performance for electronic integration, range, power consumption, and connectivity.

The operating system chosen for ESP32 is freeRTOS with LwIP; TLS 1.2 with hardware acceleration is built in as well. Secure (encrypted) over the air (OTA) upgrade is also supported, so that developers can continually upgrade their products even after their release.

Table 3 provides the specifications of ESP-WROOM-32D and ESP32-WROOM-32U.

Table 3: ESP-WROOM-32D/ESP32-WROOM-32U Specifications

| Categories | Items | Specifications |
|------------|---|---|
| Wi-Fi | Protocols | 802.11 b/g/n/e/i (802.11n up to 150 Mbps) A-MPDU and A-MSDU aggregation and 0.4 μ s guard interval support |
| | Frequency range | 2.4 ~ 2.5 GHz |
| Bluetooth | Protocols | Bluetooth v4.2 BR/EDR and BLE specification |
| | Radio | NZIF receiver with -97 dBm sensitivity |
| | | Class-1, class-2 and class-3 transmitter AFH |
| Audio | CVSD and SBC | |
| Hardware | Module interface | SD card, UART, SPI, SDIO, I2C, LED PWM, Motor PWM, I2S, IR |
| | | GPIO, capacitive touch sensor, ADC, DAC, LNA pre-amplifier |
| | On-chip sensor | Hall sensor, temperature sensor |
| | On-board clock | 40 MHz crystal |
| | Operating voltage/Power supply | 2.7 ~ 3.6V |
| | Operating current | Average: 80 mA |
| | Minimum current delivered by power supply | 500 mA |
| | Operating temperature range | -40°C ~ +85°C |
| | Ambient temperature range | Normal temperature |
| | Wi-Fi mode | Station/SoftAP/SoftAP+Station/P2P |
| Software | Wi-Fi Security | WPA/WPA2/WPA2-Enterprise/WPS |
| | Encryption | AES/RSA/ECC/SHA |
| | Firmware upgrade | UART Download / OTA (download and write firmware via network or host) |
| | Software development | Supports Cloud Server Development / SDK for custom firmware development |
| | Network protocols | IPv4, IPv6, SSL, TCP/UDP/HTTP/FTP/MQTT |
| | User configuration | AT instruction set, cloud server, Android/iOS app |

2. Pin Definitions

2.1 Pin Layout

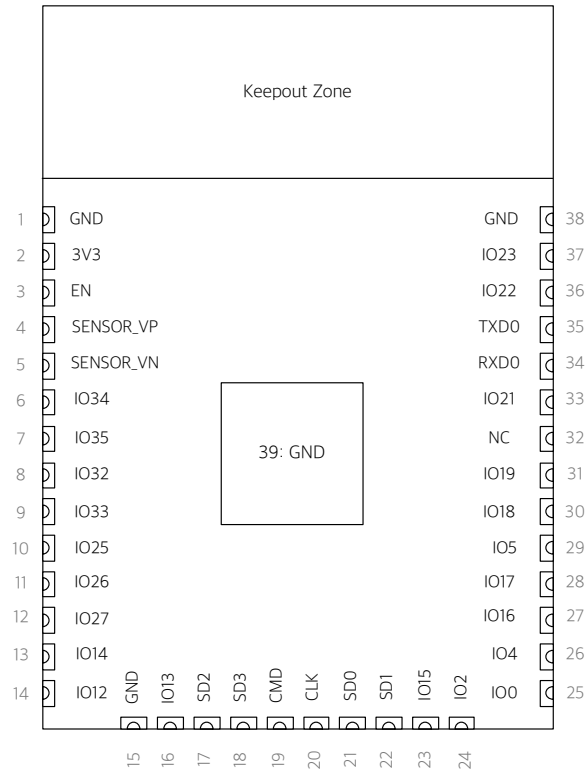


Figure 1: ESP-WROOM-32D Pin layout

Note:

The pin layout of ESP32-WROOM-32U is the same as that of ESP-WROOM-32D, except that ESP32-WROOM-32U has no keepout zone.

2.2 Pin Description

ESP-WROOM-32D and ESP32-WROOM-32U have 38 pins. See pin definitions in Table 4.

Table 4: Pin Definitions

| Name | No. | Type | Function |
|-----------|-----|------|---|
| GND | 1 | P | Ground |
| 3V3 | 2 | P | Power supply. |
| EN | 3 | I | Chip-enable signal. Active high. |
| SENSOR_VP | 4 | I | GPIO36, SENSOR_VP, ADC_H, ADC1_CH0, RTC_GPIO0 |
| SENSOR_VN | 5 | I | GPIO39, SENSOR_VN, ADC1_CH3, ADC_H, RTC_GPIO3 |
| IO34 | 6 | I | GPIO34, ADC1_CH6, RTC_GPIO4 |
| IO35 | 7 | I | GPIO35, ADC1_CH7, RTC_GPIO5 |

| Name | No. | Type | Function |
|----------|-----|------|--|
| IO32 | 8 | I/O | GPIO32, XTAL_32K_P (32.768 kHz crystal oscillator input), ADC1_CH4, TOUCH9, RTC_GPIO9 |
| IO33 | 9 | I/O | GPIO33, XTAL_32K_N (32.768 kHz crystal oscillator output), ADC1_CH5, TOUCH8, RTC_GPIO8 |
| IO25 | 10 | I/O | GPIO25, DAC_1, ADC2_CH8, RTC_GPIO6, EMAC_RXD0 |
| IO26 | 11 | I/O | GPIO26, DAC_2, ADC2_CH9, RTC_GPIO7, EMAC_RXD1 |
| IO27 | 12 | I/O | GPIO27, ADC2_CH7, TOUCH7, RTC_GPIO17, EMAC_RX_DV |
| IO14 | 13 | I/O | GPIO14, ADC2_CH6, TOUCH6, RTC_GPIO16, MTMS, HSPICLK, HS2_CLK, SD_CLK, EMAC_TXD2 |
| IO12 | 14 | I/O | GPIO12, ADC2_CH5, TOUCH5, RTC_GPIO15, MTDI, HSPIQ, HS2_DATA2, SD_DATA2, EMAC_TXD3 |
| GND | 15 | P | Ground |
| IO13 | 16 | I/O | GPIO13, ADC2_CH4, TOUCH4, RTC_GPIO14, MTCK, HSPID, HS2_DATA3, SD_DATA3, EMAC_RX_ER |
| SHD/SD2* | 17 | I/O | GPIO9, SD_DATA2, SPIHD, HS1_DATA2, U1RXD |
| SWP/SD3* | 18 | I/O | GPIO10, SD_DATA3, SPIWP, HS1_DATA3, U1TXD |
| SCS/CMD* | 19 | I/O | GPIO11, SD_CMD, SPICS0, HS1_CMD, U1RTS |
| SCK/CLK* | 20 | I/O | GPIO6, SD_CLK, SPICLK, HS1_CLK, U1CTS |
| SDO/SD0* | 21 | I/O | GPIO7, SD_DATA0, SPIQ, HS1_DATA0, U2RTS |
| SDI/SD1* | 22 | I/O | GPIO8, SD_DATA1, SPID, HS1_DATA1, U2CTS |
| IO15 | 23 | I/O | GPIO15, ADC2_CH3, TOUCH3, MTDO, HSPICS0, RTC_GPIO13, HS2_CMD, SD_CMD, EMAC_RXD3 |
| IO2 | 24 | I/O | GPIO2, ADC2_CH2, TOUCH2, RTC_GPIO12, HSPIWP, HS2_DATA0, SD_DATA0 |
| IO0 | 25 | I/O | GPIO0, ADC2_CH1, TOUCH1, RTC_GPIO11, CLK_OUT1, EMAC_TX_CLK |
| IO4 | 26 | I/O | GPIO4, ADC2_CH0, TOUCH0, RTC_GPIO10, HSPiHD, HS2_DATA1, SD_DATA1, EMAC_TX_ER |
| IO16 | 27 | I/O | GPIO16, HS1_DATA4, U2RXD, EMAC_CLK_OUT |
| IO17 | 28 | I/O | GPIO17, HS1_DATA5, U2TXD, EMAC_CLK_OUT_180 |
| IO5 | 29 | I/O | GPIO5, VSPICS0, HS1_DATA6, EMAC_RX_CLK |
| IO18 | 30 | I/O | GPIO18, VSPICLK, HS1_DATA7 |
| IO19 | 31 | I/O | GPIO19, VSPIQ, U0CTS, EMAC_TXD0 |
| NC | 32 | - | - |
| IO21 | 33 | I/O | GPIO21, VSPIHD, EMAC_TX_EN |
| FXD0 | 34 | I/O | GPIO3, U0RXD, CLK_OUT2 |
| TXD0 | 35 | I/O | GPIO1, U0TXD, CLK_OUT3, EMAC_RXD2 |
| IO22 | 36 | I/O | GPIO22, VSPIWP, U0RTS, EMAC_TXD1 |
| IO23 | 37 | I/O | GPIO23, VSPID, HS1_STROBE |
| GND | 38 | P | Ground |

Note:

* Pins SCK/CLK, SDO/SD0, SDI/SD1, SHD/SD2, SWP/SD3 and SCS/CMD, namely, GPIO6 to GPIO11 are connected to the integrated SPI flash integrated on ESP-WROOM-32D and are not recommended for other uses.

2.3 Strapping Pins

ESP32 has five strapping pins, which can be seen in Chapter 6 Schematics:

- MTDI
- GPIO0
- GPIO2
- MTDO
- GPIO5

Software can read the value of these five bits from the register "GPIO_STRAPPING".

During the chip's system reset (power-on reset, RTC watchdog reset and brownout reset), the latches of the strapping pins sample the voltage level as strapping bits of "0" or "1", and hold these bits until the chip is powered down or shut down. The strapping bits configure the device boot mode, the operating voltage of VDD_SDIO and other system initial settings.

Each strapping pin is connected with its internal pull-up/pull-down during the chip reset. Consequently, if a strapping pin is unconnected or the connected external circuit is high-impedance, the internal weak pull-up/pull-down will determine the default input level of the strapping pins.

To change the strapping bit values, users can apply the external pull-down/pull-up resistances, or apply the host MCU's GPIOs to control the voltage level of these pins when powering on ESP32.

After reset, the strapping pins work as the normal functions pins.

Refer to Table 5 for detailed boot modes' configuration by strapping pins.

Table 5: Strapping Pins

| Voltage of Internal LDO (VDD_SDIO) | | | | | |
|---|-----------|---|--|--|---|
| Pin | Default | 3.3V | | 1.8V | |
| MTDI | Pull-down | 0 | | 1 | |
| Bootling Mode | | | | | |
| Pin | Default | SPI Boot | | Download Boot | |
| GPIO0 | Pull-up | 1 | | 0 | |
| GPIO2 | Pull-down | Don't-care | | 0 | |
| Debugging Log Printed on U0TXD During Bootling? | | | | | |
| Pin | Default | U0TXD Toggling | | U0TXD Silent | |
| MTDO | Pull-up | 1 | | 0 | |
| Timing of SDIO Slave | | | | | |
| Pin | Default | Falling-edge Input Falling-edge Output | Falling-edge Input Rising-edge Output | Rising-edge Input Falling-edge Output | Rising-edge Input Rising-edge Output |
| MTDO | Pull-up | 0 | 0 | 1 | 1 |
| GPIO5 | Pull-up | 0 | 1 | 0 | 1 |

Note:

- Firmware can configure register bits to change the settings of "Voltage of Internal LDO (VDD_SDIO)" and "Timing of SDIO Slave" after booting.
- Both ESP-WROOM-32D and ESP32-WROOM-32U integrate a 3.3V SPI flash, so the pin MTDI cannot be set to 1 when the modules are powered up.

3. Functional Description

This chapter describes the modules and functions integrated in ESP-WROOM-32D and ESP32-WROOM-32U.

3.1 CPU and Internal Memory

ESP32-D0WD contains a dual-core Xtensa® 32-bit LX6 MCU. The internal memory includes:

- 448 kB of ROM for booting and core functions.
- 520 kB (8 kB RTC FAST Memory included) of on-chip SRAM for data and instruction.
 - 8 kB of SRAM in RTC, which is called RTC FAST Memory and can be used for data storage; it is accessed by the main CPU during RTC Boot from the Deep-sleep mode.
- 8 kB of SRAM in RTC, which is called RTC SLOW Memory and can be accessed by the co-processor during the Deep-sleep mode.
- 1 kbit of eFuse, of which 256 bits are used for the system (MAC address and chip configuration) and the remaining 768 bits are reserved for customer applications, including Flash-Encryption and Chip-ID.

3.2 External Flash and SRAM

ESP32 supports up to four 16-MB of external QSPI flash and SRAM with hardware encryption based on AES to protect developers' programs and data.

ESP32 can access the external QSPI flash and SRAM through high-speed caches.

- Up to 16 MB of external flash are memory-mapped onto the CPU code space, supporting 8, 16 and 32-bit access. Code execution is supported.
- Up to 8 MB of external flash/SRAM are memory-mapped onto the CPU data space, supporting 8, 16 and 32-bit access. Data-read is supported on the flash and SRAM. Data-write is supported on the SRAM.

ESP-WROOM-32D and ESP32-WROOM-32U integrates 4 MB of external SPI flash. The 4-MB SPI flash can be memory-mapped onto the CPU code space, supporting 8, 16 and 32-bit access. Code execution is supported. The integrated SPI flash is connected to GPIO6, GPIO7, GPIO8, GPIO9, GPIO10 and GPIO11. These six pins cannot be used as regular GPIOs.

3.3 Crystal Oscillators

The ESP32 Wi-Fi/BT firmware can only support 40 MHz crystal oscillator for now.

3.4 RTC and Low-Power Management

With the use of advanced power management technologies, ESP32 can switch between different power modes (see Table 6).

- Power modes
 - Active mode: The chip radio is powered on. The chip can receive, transmit, or listen.
 - Modem-sleep mode: The CPU is operational and the clock is configurable. The Wi-Fi/Bluetooth baseband and radio are disabled.
 - Light-sleep mode: The CPU is paused. The RTC memory and RTC peripherals, as well as the ULP co-processor are running. Any wake-up events (MAC, host, RTC timer, or external interrupts) will wake up the chip.
 - Deep-sleep mode: Only the RTC memory and RTC peripherals are powered on. Wi-Fi and Bluetooth connection data are stored in the RTC memory. The ULP co-processor can work.
 - Hibernation mode: The internal 8-MHz oscillator and ULP co-processor are disabled. The RTC recovery memory is powered down. Only one RTC timer on the slow clock and some RTC GPIOs are active. The RTC timer or the RTC GPIOs can wake up the chip from the Hibernation mode.
- Sleep Patterns
 - Association sleep pattern: The power mode switches between the Active mode, Modem- and Light-sleep mode during this sleep pattern. The CPU, Wi-Fi, Bluetooth, and radio are woken up at predetermined intervals to keep Wi-Fi/BT connections alive.
 - ULP sensor-monitored pattern: The main CPU is in the Deep-sleep mode. The ULP co-processor takes sensor measurements and wakes up the main system, based on the data collected from sensors.

Table 6: Functionalities Depending on the Power Modes

| Power mode | Active | Modem-sleep | Light-sleep | Deep-sleep | Hibernation |
|--------------------------------|---------------------------|-------------|-------------|------------------------------|-------------|
| Sleep pattern | Association sleep pattern | | | ULP sensor-monitored pattern | - |
| CPU | ON | ON | PAUSE | OFF | OFF |
| Wi-Fi/BT baseband and radio | ON | OFF | OFF | OFF | OFF |
| RTC memory and RTC peripherals | ON | ON | ON | ON | OFF |
| ULP co-processor | ON | ON | ON | ON/OFF | OFF |

The power consumption varies with different power modes/sleep patterns and work statuses of functional modules. Please see Table 7 for details.

Table 7: Power Consumption by Power Modes

| Power mode | Description | Power consumption |
|---------------------|--|---|
| Active (RF working) | Wi-Fi Tx packet 14 dBm ~ 19.5 dBm | Please refer to ESP32 Datasheet . |
| | Wi-Fi / BT Tx packet 0 dBm | |
| | Wi-Fi / BT Rx and listening | |
| | Association sleep pattern (by Light-sleep) | 1 mA ~ 4 mA @DTIM3 |

| Power mode | Description | Power consumption |
|-------------|--|------------------------------------|
| Modem-sleep | The CPU is powered on. | Max speed 240 MHz: 30 mA ~ 50 mA |
| | | Normal speed 80 MHz: 20 mA ~ 25 mA |
| | | Slow speed 2 MHz: 2 mA ~ 4 mA |
| Light-sleep | - | 0.8 mA |
| Deep-sleep | The ULP co-processor is powered on. | 150 μ A |
| | ULP sensor-monitored pattern | 100 μ A @1% duty |
| | RTC timer + RTC memory | 10 μ A |
| Hibernation | RTC timer only | 5 μ A |
| Power off | CHIP_PU is set to low level, the chip is powered off | 0.1 μ A |

Note:

- When Wi-Fi is enabled, the chip switches between Active and Modem-sleep mode. Therefore, power consumption changes accordingly.
- In Modem-sleep mode, the CPU frequency changes automatically. The frequency depends on the CPU load and the peripherals used.
- During Deep-sleep, when the ULP co-processor is powered on, peripherals such as GPIO and I2C are able to work.
- When the system works in the ULP sensor-monitored pattern, the ULP co-processor works with the ULP sensor periodically; ADC works with a duty cycle of 1%, so the power consumption is 100 μ A.

4. Peripherals and Sensors

4.1 Peripherals and Sensors Description

Please refer to Section 4 Peripherals and Sensors in [ESP32 Datasheet](#).

Note:

- Functions of Motor PWM, LED PWM, UART, I2C, I2S, general purpose SPI and Remote Controller can be configured to any GPIO except GPIO6, GPIO7, GPIO8, GPIO9, GPIO10 and GPIO11.
- Users should note that pins of the embedded ESP32 chip, that are used for connecting peripherals are not recommended for other uses. For details, please see Section 6 Schematics.

5. Electrical Characteristics

Note:

The specifications in this chapter have been tested under the following general condition: $V_{DD} = 3.3V$, $T_A = 27^{\circ}C$, unless otherwise specified.

5.1 Absolute Maximum Ratings

Table 8: Absolute Maximum Ratings

| Parameter | Symbol | Min | Typ | Max | Unit |
|---|-----------|------------------------|-----|------------------------|-------------|
| Power supply | VDD | 2.7 | 3.3 | 3.6 | V |
| Minimum current delivered by power supply | I_{VDD} | 0.5 | - | - | A |
| Input low voltage | V_{IL} | -0.3 | - | $0.25 \times V_{IO}^1$ | V |
| Input high voltage | V_{IH} | $0.75 \times V_{IO}^1$ | - | $V_{IO}^1 + 0.3$ | V |
| Input leakage current | I_{IL} | - | - | 50 | nA |
| Input pin capacitance | C_{pad} | - | - | 2 | pF |
| Output low voltage | V_{OL} | - | - | $0.1 \times V_{IO}^1$ | V |
| Output high voltage | V_{OH} | $0.8 \times V_{IO}^1$ | - | - | V |
| Maximum output drive capability | I_{MAX} | - | - | 40 | mA |
| Storage temperature range | T_{STR} | -40 | - | 85 | $^{\circ}C$ |
| Operating temperature range | T_{OPR} | -40 | - | 85 | $^{\circ}C$ |

1. V_{IO} is the power supply for a specific pad. More details can be found in the [ESP32 Datasheet](#), Appendix IO_MUX. For example, the power supply for SD_CLK is the VDD_SDIO.

5.2 Wi-Fi Radio

Table 9: Wi-Fi Radio Characteristics

| Description | Min | Typical | Max | Unit |
|----------------------------------|------|---------|------|----------|
| Input frequency | 2412 | - | 2484 | MHz |
| Output impedance | - | * | - | Ω |
| Input reflection | - | - | -10 | dB |
| Tx power | | | | |
| Output power of PA for 72.2 Mbps | 13 | 14 | 15 | dBm |
| Output power of PA for 11b mode | 19.5 | 20 | 20.5 | dBm |
| Sensitivity | | | | |
| DSSS, 1 Mbps | - | -98 | - | dBm |
| CCK, 11 Mbps | - | -91 | - | dBm |
| OFDM, 6 Mbps | - | -93 | - | dBm |
| OFDM, 54 Mbps | - | -75 | - | dBm |
| HT20, MCS0 | - | -93 | - | dBm |

| Description | Min | Typical | Max | Unit |
|----------------------------|-----|---------|-----|------|
| HT20, MCS7 | - | -73 | - | dBm |
| HT40, MCS0 | - | -90 | - | dBm |
| HT40, MCS7 | - | -70 | - | dBm |
| MCS32 | - | -89 | - | dBm |
| Adjacent channel rejection | | | | |
| OFDM, 6 Mbps | - | 37 | - | dB |
| OFDM, 54 Mbps | - | 21 | - | dB |
| HT20, MCS0 | - | 37 | - | dB |
| HT20, MCS7 | - | 20 | - | dB |

*For the module that uses an IPEX antenna, the output impedance is 50Ω.

5.3 BLE Radio

5.3.1 Receiver

Table 10: Receiver Characteristics – BLE

| Parameter | Conditions | Min | Typ | Max | Unit |
|------------------------------------|---------------------|-----|-----|-----|------|
| Sensitivity @30.8% PER | - | - | -97 | - | dBm |
| Maximum received signal @30.8% PER | - | 0 | - | - | dBm |
| Co-channel C/I | - | - | +10 | - | dB |
| Adjacent channel selectivity C/I | F = F0 + 1 MHz | - | -5 | - | dB |
| | F = F0 - 1 MHz | - | -5 | - | dB |
| | F = F0 + 2 MHz | - | -25 | - | dB |
| | F = F0 - 2 MHz | - | -35 | - | dB |
| | F = F0 + 3 MHz | - | -25 | - | dB |
| | F = F0 - 3 MHz | - | -45 | - | dB |
| Out-of-band blocking performance | 30 MHz ~ 2000 MHz | -10 | - | - | dBm |
| | 2000 MHz ~ 2400 MHz | -27 | - | - | dBm |
| | 2500 MHz ~ 3000 MHz | -27 | - | - | dBm |
| | 3000 MHz ~ 12.5 GHz | -10 | - | - | dBm |
| Intermodulation | - | -36 | - | - | dBm |

5.3.2 Transmitter

Table 11: Transmitter Characteristics – BLE

| Parameter | Conditions | Min | Typ | Max | Unit |
|------------------------|------------|-----|-----|-----|------|
| RF transmit power | - | - | 0 | - | dBm |
| Gain control step | - | - | ±3 | - | dBm |
| RF power control range | - | -12 | - | +12 | dBm |

| Parameter | Conditions | Min | Typ | Max | Unit |
|-----------------------------------|------------------|-----|-------|-----|----------------|
| Adjacent channel transmit power | F = F0 + 1 MHz | - | -14.6 | - | dBm |
| | F = F0 - 1 MHz | - | -12.7 | - | dBm |
| | F = F0 + 2 MHz | - | -44.3 | - | dBm |
| | F = F0 - 2 MHz | - | -38.7 | - | dBm |
| | F = F0 + 3 MHz | - | -49.2 | - | dBm |
| | F = F0 - 3 MHz | - | -44.7 | - | dBm |
| | F = F0 + > 3 MHz | - | -50 | - | dBm |
| | F = F0 - > 3 MHz | - | -50 | - | dBm |
| Δf_{1avg} | - | - | - | 265 | kHz |
| Δf_{2max} | - | 247 | - | - | kHz |
| $\Delta f_{2avg}/\Delta f_{1avg}$ | - | - | -0.92 | - | - |
| ICFT | - | - | -10 | - | kHz |
| Drift rate | - | - | 0.7 | - | kHz/50 μ s |
| Drift | - | - | 2 | - | kHz |

5.4 Reflow Profile

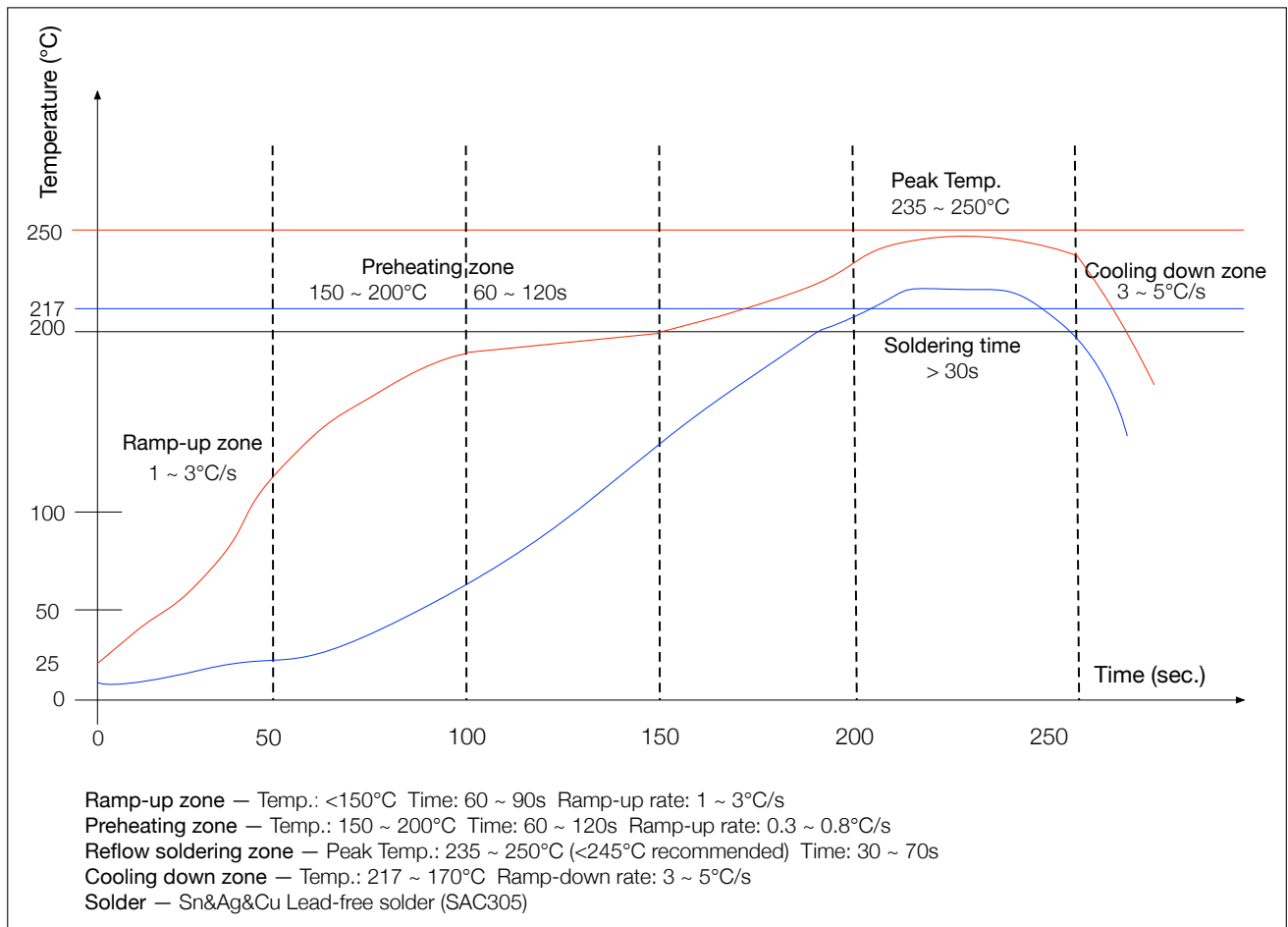


Figure 2: Reflow Profile

6. Schematics

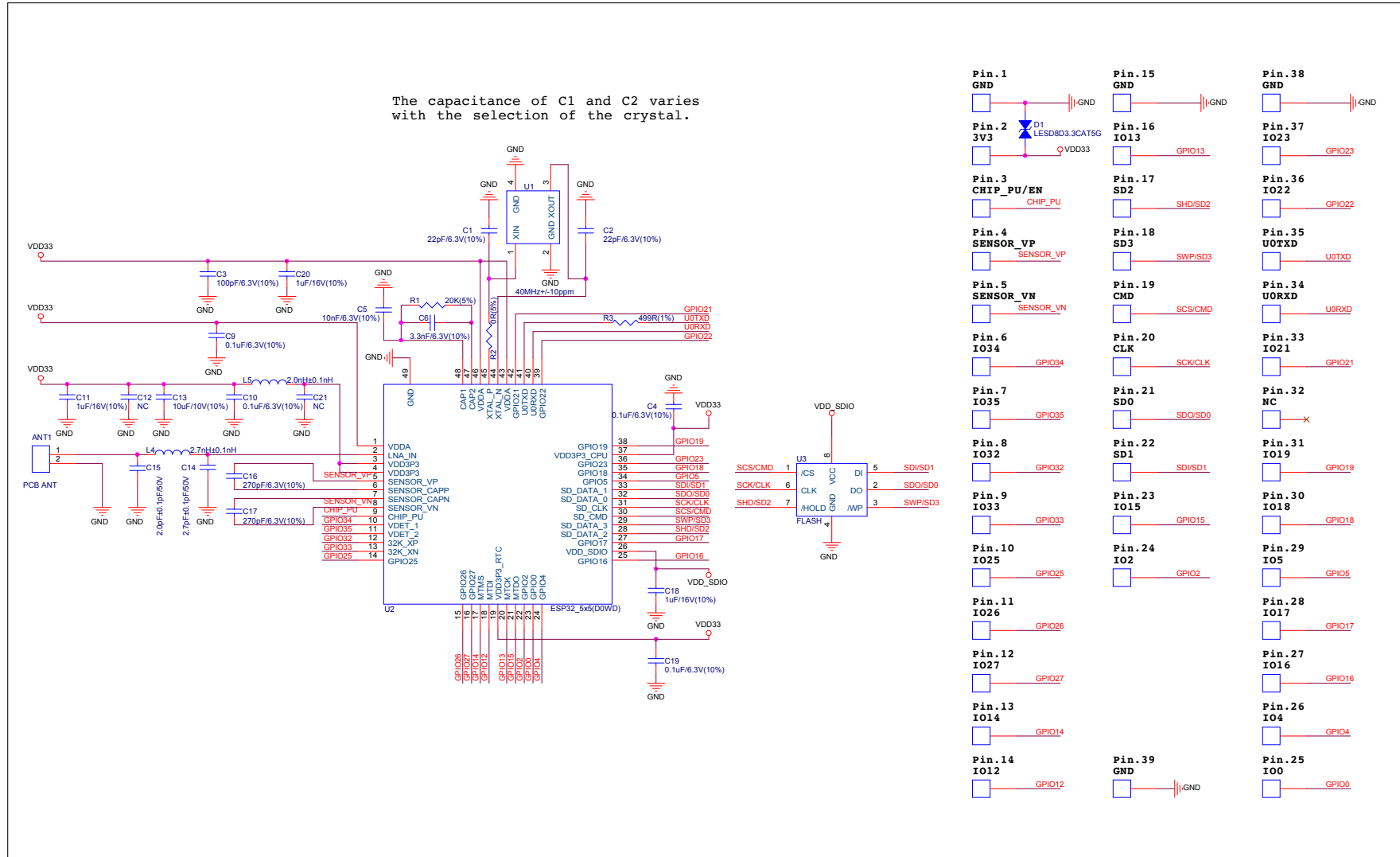


Figure 3: ESP-WROOM-32D Schematics

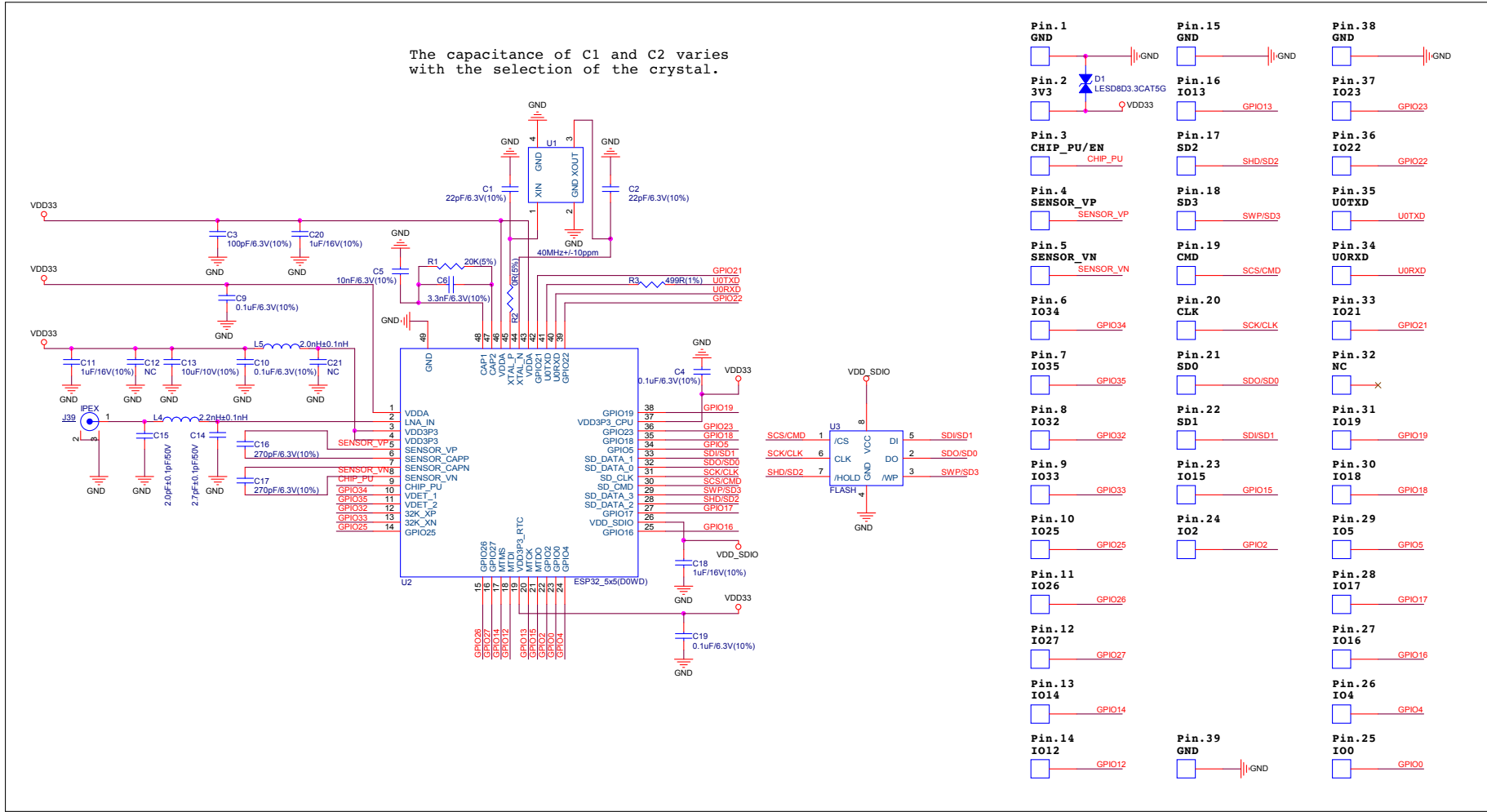


Figure 4: ESP32-WROOM-32U Schematics

7. Peripheral Schematics

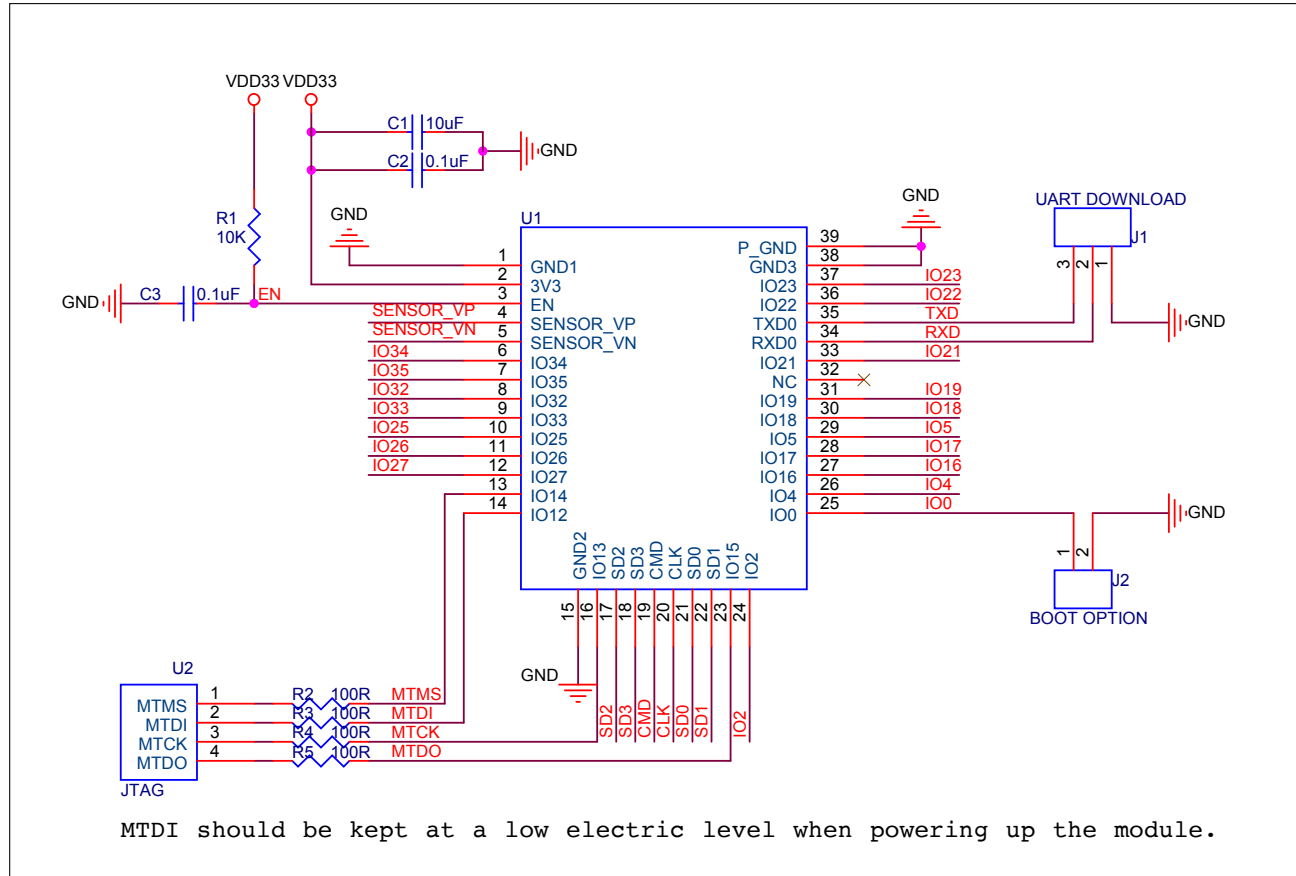


Figure 5: ESP-WROOM-32D/ESP32-WROOM-32U Peripheral Schematics

Note:

It is recommended that users do not solder Pad 39 to the base board. If users do want to solder it, they need to ensure that the correct quantity of soldering paste is applied.

8. Dimensions

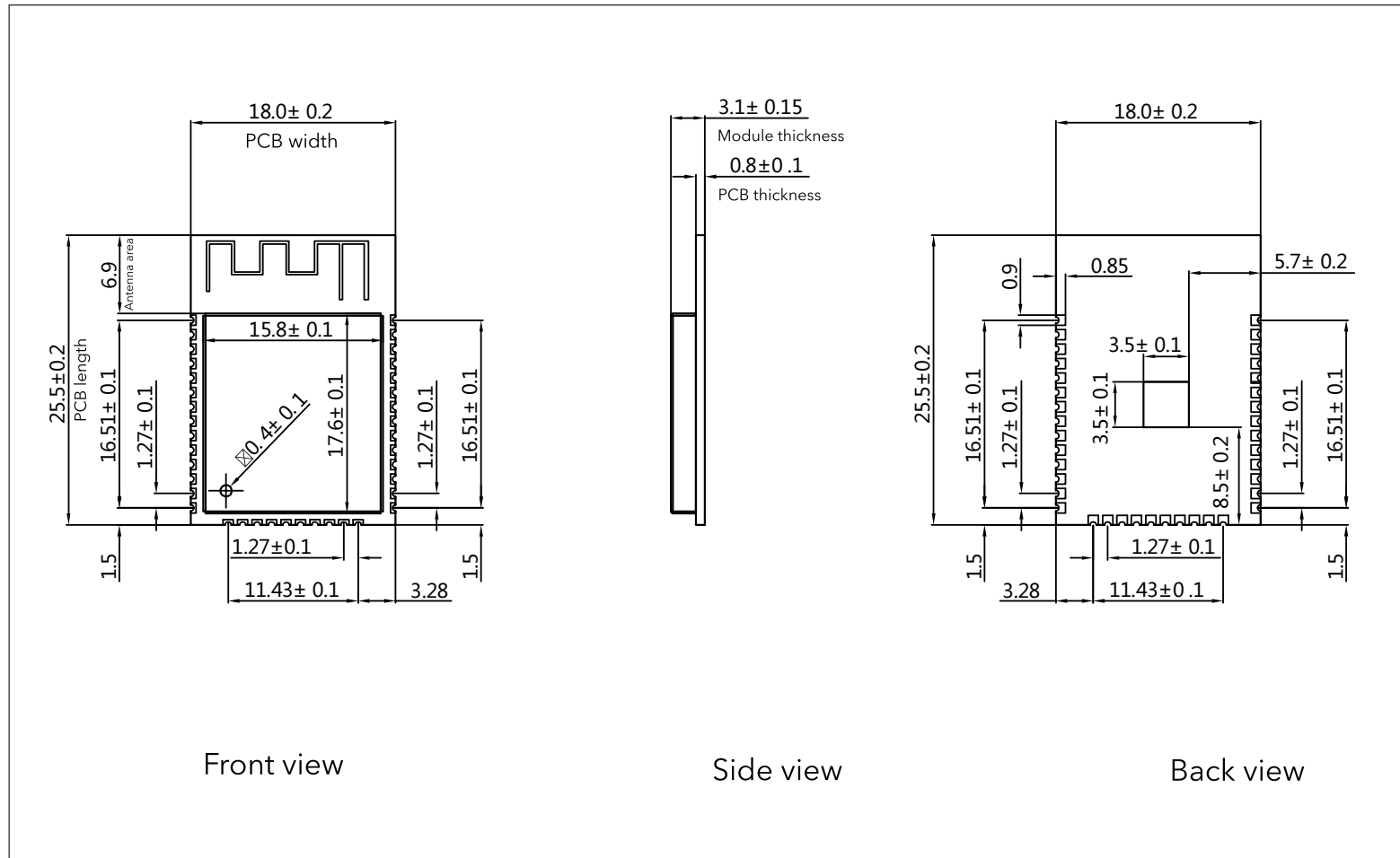


Figure 6: Dimensions of ESP-WROOM-32D

Note:

All dimensions are in millimeters.

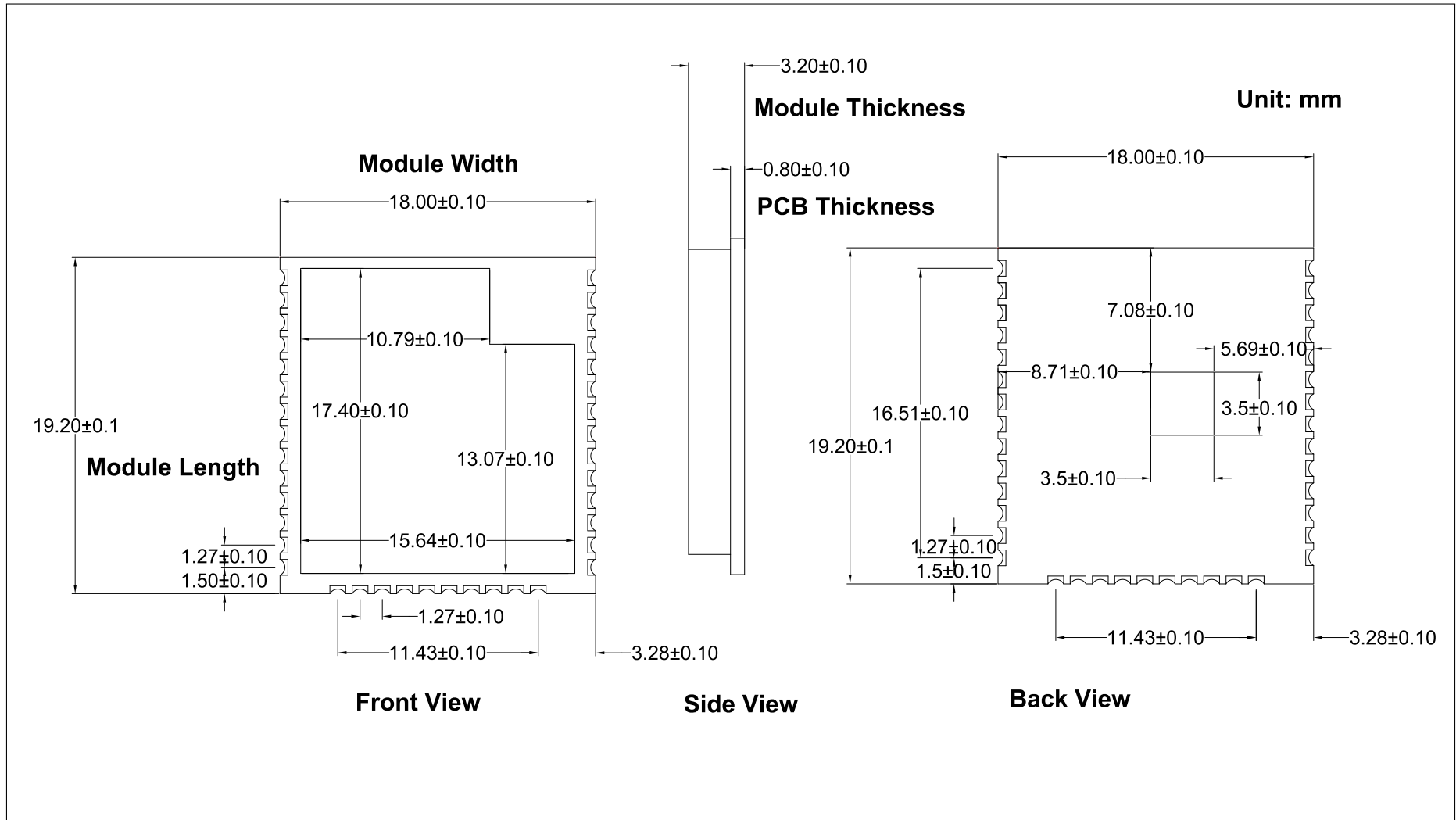


Figure 7: Dimensions of ESP32-WROOM-32U

9. U.FL Connector Dimensions

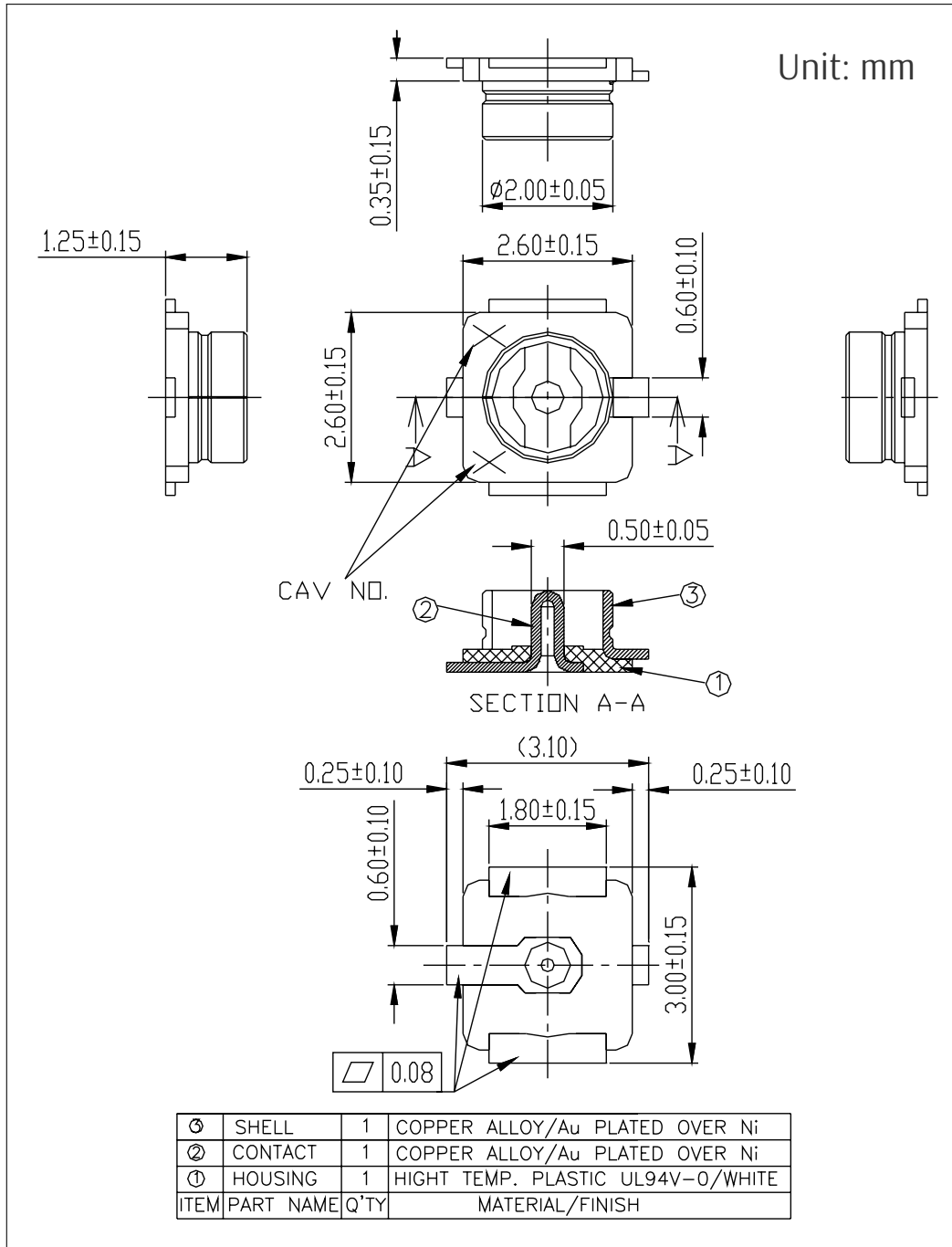


Figure 8: ESP32-WROOM-32U U.FL Dimensions

Note:

All dimensions are in millimeters.

10. Learning Resources

10.1 Must-Read Documents

The following link provides documents related to ESP32.

- [ESP32 Datasheet](#)
This document provides an introduction to the specifications of the ESP32 hardware, including overview, pin definitions, functional description, peripheral interface, electrical characteristics, etc.
- [ESP32 Technical Reference Manual](#)
The manual provides detailed information on how to use the ESP32 memory and peripherals.
- [ESP32 Hardware Resources](#)
The zip files include the schematics, PCB layout, Gerber and BOM list of ESP32 modules and development boards.
- [ESP32 Hardware Design Guidelines](#)
The guidelines outline recommended design practices when developing standalone or add-on systems based on the ESP32 series of products, including ESP32, the ESP-WROOM-32 module, and ESP32-DevKitC—the development board.
- [ESP32 AT Instruction Set and Examples](#)
This document introduces the ESP32 AT commands, explains how to use them, and provides examples of several common AT commands.

10.2 Must-Have Resources

Here are the ESP32-related must-have resources.

- [ESP32 BBS](#)
This is an Engineer-to-Engineer (E2E) Community for ESP32 where you can post questions, share knowledge, explore ideas, and help solve problems with fellow engineers.
- [ESP32 GitHub](#)
ESP32 development projects are freely distributed under Espressif's MIT license on GitHub. It is established to help developers get started with ESP32 and foster innovation and the growth of general knowledge about the hardware and software surrounding ESP32 devices.
- [ESP32 Tools](#)
This is a webpage where users can download ESP32 Flash Download Tools and the zip file "ESP32 Certification and Test".
- [ESP-IDF](#)
This webpage links users to the official IoT development framework for ESP32.
- [ESP32 Resources](#)
This webpage provides the links to all available ESP32 documents, SDK and tools.