# ESP32-S3-WROOM-2

## Datasheet

2.4 GHz Wi-Fi (802.11 b/g/n) and Bluetooth® 5 (LE) module
Built around ESP32-S3R8V SoC, Xtensa® dual-core 32-bit LX7 microprocessor
Flash up to 32 MB (Octal), 8 MB PSRAM (Octal)
33 GPIOs, rich set of peripherals
On-board PCB antenna


ESP32-S3-WROOM-2

Version 1.0
Espressif Systems

# 1 Module Overview

**Note:**

Check the link or the QR code to make sure that you use the latest version of this document:
https://www.espressif.com/documentation/esp32-s3-wroom-2_datasheet_en.pdf

## 1.1 Features

### CPU and On-Chip Memory

- ESP32-S3R8V SoC embedded, Xtensa® dual-core 32-bit LX7 microprocessor (with single precision FPU), up to 240 MHz
- 384 KB ROM
- 512 KB SRAM
- 16 KB SRAM in RTC
- 8 MB PSRAM

### Wi-Fi

- 802.11 b/g/n
- Bit rate: 802.11n up to 150 Mbps
- A-MPDU and A-MSDU aggregation
- 0.4 $\mu$s guard interval support
- Center frequency range of operating channel: 2412 ~ 2484 MHz

### Bluetooth

- Bluetooth LE: Bluetooth 5, Bluetooth mesh
- Speed: 125 Kbps, 500 Kbps, 1 Mbps, 2 Mbps
- Advertising extensions
- Multiple advertisement sets
- Channel selection algorithm #2
- Internal co-existence mechanism between Wi-Fi and Bluetooth to share the same antenna

### Peripherals

- GPIO, SPI, LCD interface, Camera interface, UART, I2C, I2S, remote control, pulse counter, LED PWM, USB 1.1 OTG, USB Serial/JTAG controller, MCPWM, SDIO host, GDMA, TWAI® controller (compatible with ISO 11898-1), ADC, touch sensor, temperature sensor, timers and watchdogs

### Integrated Components on Module

- 40 MHz crystal oscillator
- Up to 32 MB Octal SPI flash

### Antenna Options

- On-board PCB antenna

### Operating Conditions

- Operating voltage/Power supply: 3.0 ~ 3.6 V
- Operating ambient temperature: –40 ~ 65 °C

### Certification

- RF certification: See certificates for ESP32-S3-WROOM-2
- Green certification: RoHS/REACH

### Test

- HTOL/HTSL/uHAST/TCT/ESD

## 1.2 Description

ESP32-S3-WROOM-2 is a powerful, generic Wi-Fi + Bluetooth LE MCU module that has a rich set of peripherals. It provides acceleration for neural network computing and signal processing workloads. It is an ideal choice for a wide variety of application scenarios related to AI and Artificial Intelligence of Things (AIoT), such as wake word detection and speech commands recognition, face detection and recognition, smart home, smart appliances, smart control panel, smart speaker, etc.

ESP32-S3-WROOM-2 comes with a PCB antenna. It has ESP32-S3R8V SoC embedded. A selection of module variants are available for customers with flash memory of 16/32 MB and PSRAM memory of 8 MB. Please note that for R8 series modules (8-line PSRAM embedded), if the PSRAM ECC function is enabled, the maximum ambient temperature can be improved to 85 °C, while the usable size of PSRAM will be reduced by 1/16.

The series comparison for ESP32-S3-WROOM-2 is as follows:

**Table 1: ESP32-S3-WROOM-2 Series Comparison**

| Ordering Code | Flash[1] | PSRAM | Ambient Temp.[2] (°C) | Size[3] (mm) |
|---|---|---|---|---|
| ESP32-S3-WROOM-2-N16R8V | 16 MB (Octal SPI) | 8 MB (Octal SPI) | –40 ~ 65 | 18 × 25.5 × 3.1 |
| ESP32-S3-WROOM-2-N32R8V | 32 MB (Octal SPI) | 8 MB (Octal SPI) | –40 ~ 65 | |

[1] This module uses flash integrated in the chip's package.

[2] Ambient temperature specifies the recommended temperature range of the environment immediately outside the Espressif module.

[3] For details, refer to Section 7.1 *Physical Dimensions*.

At the core of the modules is an ESP32-S3R8V, an Xtensa® 32-bit LX7 CPU that operates at up to 240 MHz. You can 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-S3R8V integrates a rich set of peripherals including SPI, LCD interface, Camera interface, UART, I2C, I2S, remote control, pulse counter, LED PWM, USB Serial/JTAG controller, MCPWM, SDIO host, GDMA, TWAI® controller (compatible with ISO 11898-1), ADC, touch sensor, temperature sensor, timers and watchdogs, as well as up to 45 GPIOs. It also includes a full-speed USB 1.1 On-The-Go (OTG) interface to enable USB communication.

**Note:**

* For more information on ESP32-S3, please refer to *ESP32-S3 Series Datasheet*.

## 1.3 Applications

- Generic Low-power IoT Sensor Hub
- Generic Low-power IoT Data Loggers
- Cameras for Video Streaming
- Over-the-top (OTT) Devices
- USB Devices
- Speech Recognition
- Image Recognition
- Mesh Network

- Home Automation
- Smart Building
- Industrial Automation
- Smart Agriculture
- Audio Applications
- Health Care Applications
- Wi-Fi-enabled Toys
- Wearable Electronics
- Retail & Catering Applications

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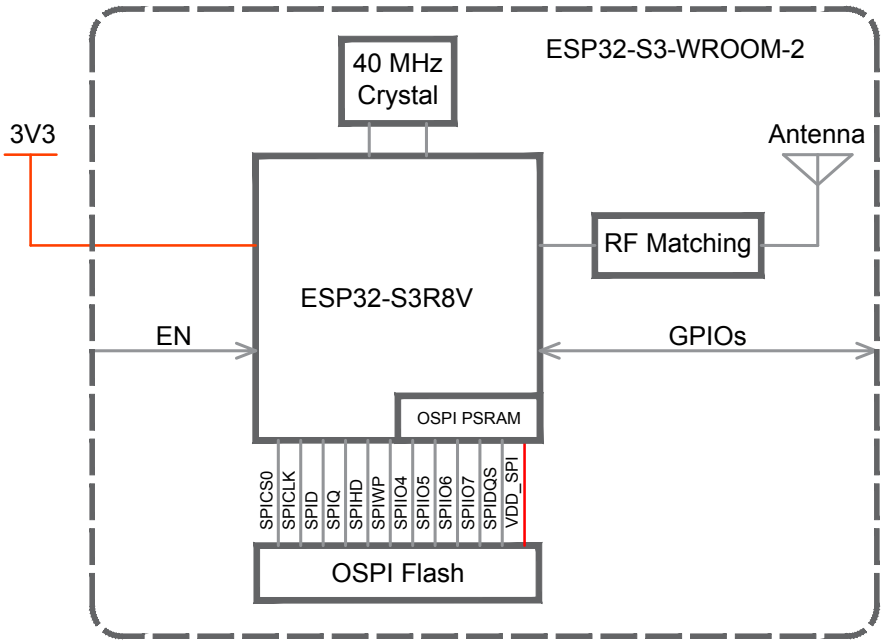


**Figure 1: ESP32-S3-WROOM-2 Block Diagram**

# 3 Pin Definitions

## 3.1 Pin Layout

The pin diagram below shows the approximate location of pins on the module. For the actual diagram drawn to scale, please refer to Figure 7.1 *Physical Dimensions*.

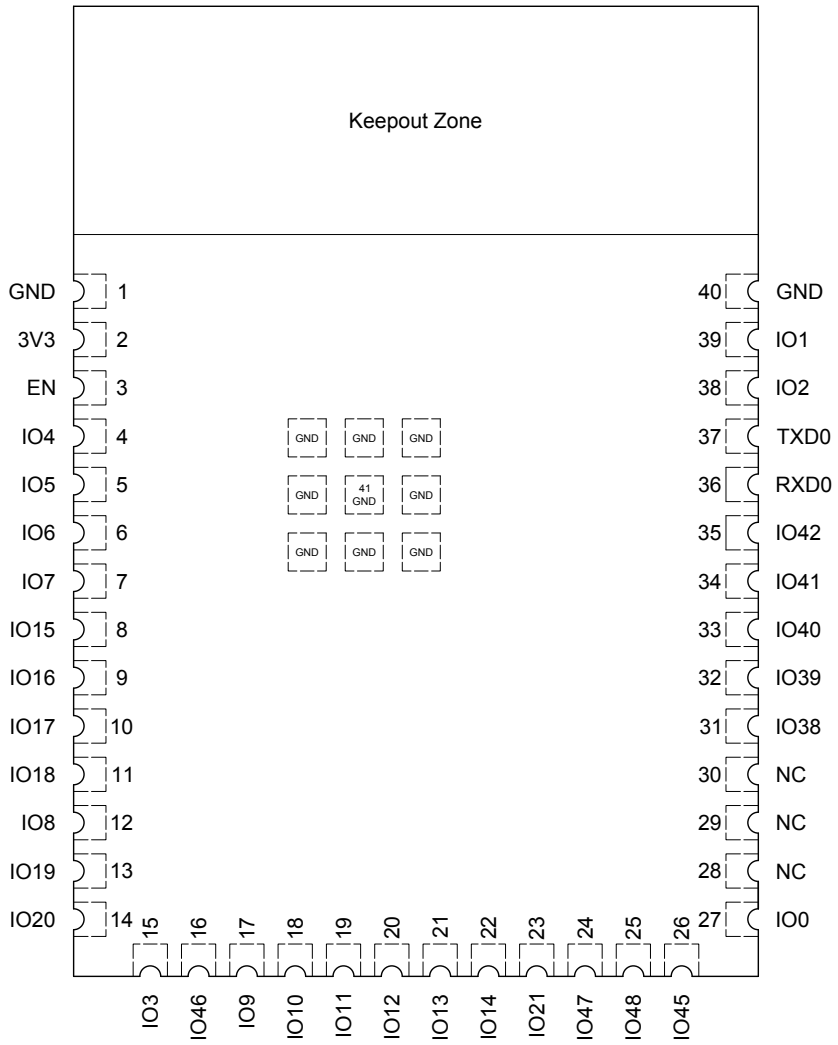


**Figure 2: Pin Layout (Top View)**

## 3.2 Pin Description

The module has 41 pins. See pin definitions in Table 2.

For explanations of pin names and function names, as well as configurations of peripheral pins, please refer to *ESP32-S3 Series Datasheet*.

**Table 2: Pin Definitions**

| Name | No. | Type [1] | Function |
|---|---|---|---|
| GND | 1 | P | GND |

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Table 2 – cont'd from previous page

| Name | No. | Type [1] | Function |
|---|---|---|---|
| 3V3 | 2 | P | Power supply |
| EN | 3 | I | High: on, enables the chip.<br>Low: off, the chip powers off.<br>Note: Do not leave the EN pin floating. |
| IO4 | 4 | I/O/T | RTC_GPIO4, **GPIO4**, TOUCH4, ADC1_CH3 |
| IO5 | 5 | I/O/T | RTC_GPIO5, **GPIO5**, TOUCH5, ADC1_CH4 |
| IO6 | 6 | I/O/T | RTC_GPIO6, **GPIO6**, TOUCH6, ADC1_CH5 |
| IO7 | 7 | I/O/T | RTC_GPIO7, **GPIO7**, TOUCH7, ADC1_CH6 |
| IO15 | 8 | I/O/T | RTC_GPIO15, **GPIO15**, U0RTS, ADC2_CH4, XTAL_32K_P |
| IO16 | 9 | I/O/T | RTC_GPIO16, **GPIO16**, U0CTS, ADC2_CH5, XTAL_32K_N |
| IO17 | 10 | I/O/T | RTC_GPIO17, **GPIO17**, U1TXD, ADC2_CH6 |
| IO18 | 11 | I/O/T | RTC_GPIO18, **GPIO18**, U1RXD, ADC2_CH7, CLK_OUT3 |
| IO8 | 12 | I/O/T | RTC_GPIO8, **GPIO8**, TOUCH8, ADC1_CH7, SUBSPICS1 |
| IO19 | 13 | I/O/T | RTC_GPIO19, GPIO19, U1RTS, ADC2_CH8, CLK_OUT2, **USB_D-** |
| IO20 | 14 | I/O/T | RTC_GPIO20, GPIO20, U1CTS, ADC2_CH9, CLK_OUT1, **USB_D+** |
| IO3 | 15 | I/O/T | RTC_GPIO3, **GPIO3**, TOUCH3, ADC1_CH2 |
| IO46 | 16 | I/O/T | **GPIO46** |
| IO9 | 17 | I/O/T | RTC_GPIO9, **GPIO9**, TOUCH9, ADC1_CH8, FSPIHD, SUBSPIHD |
| IO10 | 18 | I/O/T | RTC_GPIO10, **GPIO10**, TOUCH10, ADC1_CH9, FSPICS0, FSPIIO4, SUBSPICS0 |
| IO11 | 19 | I/O/T | RTC_GPIO11, **GPIO11**, TOUCH11, ADC2_CH0, FSPID, FSPIIO5, SUBSPID |
| IO12 | 20 | I/O/T | RTC_GPIO12, **GPIO12**, TOUCH12, ADC2_CH1, FSPICLK, FSPIIO6, SUBSPICLK |
| IO13 | 21 | I/O/T | RTC_GPIO13, **GPIO13**, TOUCH13, ADC2_CH2, FSPIQ, FSPIIO7, SUBSPIQ |
| IO14 | 22 | I/O/T | RTC_GPIO14, **GPIO14**, TOUCH14, ADC2_CH3, FSPIWP, FSPIDQS, SUBSPIWP |
| IO21 | 23 | I/O/T | RTC_GPIO21, **GPIO21** |
| IO47 | 24 | I/O/T | SPICLK_P_DIFF, **GPIO47**[2], SUBSPICLK_P_DIFF |
| IO48 | 25 | I/O/T | SPICLK_N_DIFF, **GPIO48**[2], SUBSPICLK_N_DIFF |
| IO45 | 26 | I/O/T | **GPIO45** |
| IO0 | 27 | I/O/T | RTC_GPIO0, **GPIO0** |
| NC | 28 | - | NC |
| NC | 29 | - | NC |
| NC | 30 | - | NC |
| IO38 | 31 | I/O/T | **GPIO38**, FSPIWP, SUBSPIWP |
| IO39 | 32 | I/O/T | **MTCK**, GPIO39, CLK_OUT3, SUBSPICS1 |
| IO40 | 33 | I/O/T | **MTDO**, GPIO40, CLK_OUT2 |
| IO41 | 34 | I/O/T | **MTDI**, GPIO41, CLK_OUT1 |
| IO42 | 35 | I/O/T | **MTMS**, GPIO42 |
| RXD0 | 36 | I/O/T | **U0RXD**, GPIO44, CLK_OUT2 |

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Table 2 – cont'd from previous page

| Name | No. | Type [1] | Function |
|---|---|---|---|
| TXD0 | 37 | I/O/T | **U0TXD**, GPIO43, CLK_OUT1 |
| IO2 | 38 | I/O/T | RTC_GPIO2, **GPIO2**, TOUCH2, ADC1_CH1 |
| IO1 | 39 | I/O/T | RTC_GPIO1, **GPIO1**, TOUCH1, ADC1_CH0 |
| GND | 40 | P | GND |
| EPAD | 41 | P | GND |

[1] P: power supply; I: input; O: output; T: high impedance. Bold font is the default function of the pin.

[2] As the VDD_SPI voltage of the ESP32-S3R8V chip has been set to 1.8 V, the working voltage for GPIO47 and GPIO48 would also be 1.8 V, which is different from other GPIOs.

## 3.3 Strapping Pins

**Note:**
The content below is excerpted from Section Strapping Pins in *ESP32-S3 Series Datasheet*. For the strapping pin mapping between the chip and modules, please refer to Chapter 5 *Module Schematics*.

ESP32-S3 has four strapping pins:

- GPIO0
- GPIO45
- GPIO46
- GPIO3

Software can read the values of corresponding bits from register "GPIO_STRAPPING".

During the chip's system reset (power-on-reset, RTC watchdog reset, brownout reset, analog super watchdog reset, and crystal clock glitch detection 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.

GPIO0, GPIO45 and GPIO46 are connected to the chip's internal weak pull-up/pull-down during the chip reset. Consequently, if they are unconnected or the connected external circuit is high-impedance, the internal weak pull-up/pull-down will determine the default input level of these strapping pins.

GPIO3 is floating by default. Its strapping value can be configured to determine the source of the JTAG signal inside the CPU, as shown in Table 4. In this case, the strapping value is controlled by the external circuit that cannot be in a high impedance state. Table 3 shows more configuration combinations of EFUSE_DIS_USB_JTAG, EFUSE_DIS_PAD_JTAG, and EFUSE_STRAP_JTAG_SEL that determine the JTAG signal source.

Table 3: JTAG Signal Source Selection

| EFUSE_STRAP_JTAG_SEL | EFUSE_DIS_USB_JTAG | EFUSE_DIS_PAD_JTAG | JTAG Signal Source |
|---|---|---|---|
| 1 | 0 | 0 | Refer to Table 4 |
| 0 | 0 | 0 | USB Serial/JTAG controller |
| don't care | 0 | 1 | USB Serial/JTAG controller |
| don't care | 1 | 0 | On-chip JTAG pins |
| don't care | 1 | 1 | N/A |

To change the strapping bit values, users can apply the external pull-down/pull-up resistances, or use the host MCU's GPIOs to control the voltage level of these pins when powering on ESP32-S3.

After reset, the strapping pins work as normal-function pins.

Refer to Table 4 for a detailed configuration of the strapping pins.

**Table 4: Strapping Pins**

| **VDD_SPI Voltage** | | | |
|---|---|---|---|
| Pin | Default | 3.3 V | 1.8 V |
| GPIO45 | Pull-down | 0 | 1 |
| **Booting Mode** [1] | | | |
| Pin | Default | SPI Boot | Download Boot |
| GPIO0 | Pull-up | 1 | 0 |
| GPIO46 | Pull-down | Don't care | 0 |
| **Enabling/Disabling ROM Messages Print During Booting** [2] [3] | | | |
| Pin | Default | Enabled | Disabled |
| GPIO46 | Pull-down | See the fourth note | See the fourth note |
| **JTAG Signal Selection** | | | |
| Pin | Default | EFUSE_DIS_USB_JTAG = 0, EFUSE_DIS_PAD_JTAG = 0, EFUSE_STRAP_JTAG_SEL=1 | |
| GPIO3 | N/A | 0: JTAG signal from on-chip JTAG pins<br>1: JTAG signal from USB Serial/JTAG controller | |

**Note:**

1. The strapping combination of GPIO46 = 1 and GPIO0 = 0 is invalid and will trigger unexpected behavior.
2. By default, the ROM boot messages are printed over UART0 (U0TXD pin) and USB Serial/JTAG controller together. The ROM code printing can be disabled through configuration register and eFuse. For detailed information, please refer to Chapter Chip Boot Control in *ESP32-S3 Technical Reference Manual*.

VDD_SPI voltage is determined either by the strapping value of GPIO45 or by EFUSE_VDD_SPI_TIEH. When EFUSE_VDD_SPI_FORCE is 0, VDD_SPI voltage is determined by the strapping value of GPIO45; when EFUSE_VDD_SPI_FORCE is 1, VDD_SPI voltage is determined by EFUSE_VDD_SPI_TIEH. The VDD_SPI voltage of the ESP32-S3R8V chip has been set to 1.8 V by eFuse VDD_SPI_TIEH and VDD_SPI_FORCE, and is no longer controlled by GPIO45. Please refer to the following table for default configurations:

**Table 5: The Default Value for VDD_SPI Voltage**

| Chip Variant | EFUSE_VDD_SPI_FORCE | EFUSE_VDD_SPI_TIEH | VDD_SPI Voltage |
|---|---|---|---|
| ESP32-S3 | 0 | 0 | Determined by GPIO45 |
| ESP32-S3R2 | 1 | 1 | Force to 3.3 V |
| ESP32-S3R8 | 1 | 1 | Force to 3.3 V |
| ESP32-S3R8V | 1 | 0 | Force to 1.8 V |
| ESP32-S3FN8 | 1 | 1 | Force to 3.3 V |
| ESP32-S3FH4R2 | 1 | 1 | Force to 3.3 V |

Figure 3 shows the setup and hold times for the strapping pin before and after the CHIP_PU signal goes high. Details about the parameters are listed in Table 6.

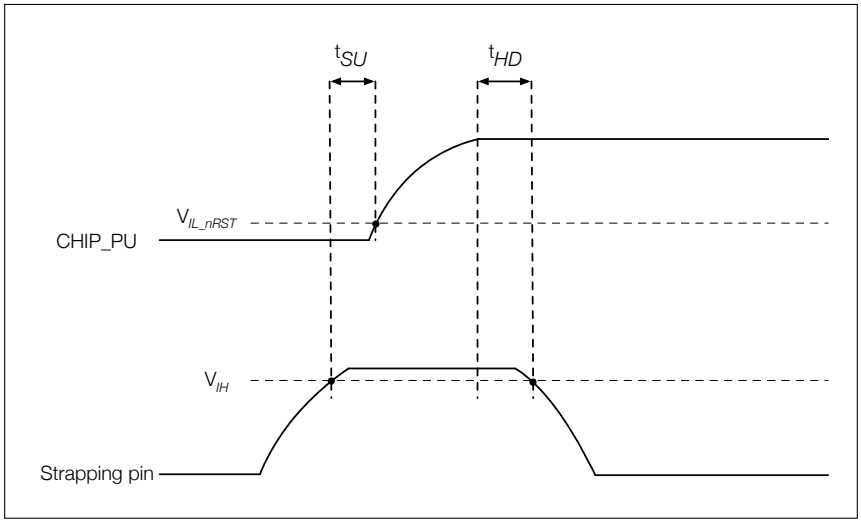


**Figure 3: Setup and Hold Times for the Strapping Pin**

**Table 6: Parameter Descriptions of Setup and Hold Times for the Strapping Pin**

| Parameter | Description | Min (ms) |
|---|---|---|
| $t_{SU}$ | Setup time before CHIP_PU goes from low to high | 0 |
| $t_{HD}$ | Hold time after CHIP_PU goes high | 3 |

# 4 Electrical Characteristics

## 4.1 Absolute Maximum Ratings

Stresses above those listed in *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

**Table 7: Absolute Maximum Ratings**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| VDD33 | Power supply voltage | –0.3 | 3.6 | V |
| $T_{STORE}$ | Storage temperature | –40 | 105 | °C |

## 4.2 Recommended Operating Conditions

**Table 8: Recommended Operating Conditions**

| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| VDD33 | Power supply voltage | 3.0 | 3.3 | 3.6 | V |
| $I_{VDD}$ | Current delivered by external power supply | 0.5 | — | — | A |
| $T_A$ | Operating ambient temperature | –40 | — | 65 | °C |

## 4.3 DC Characteristics (3.3 V, 25 °C)

**Table 9: DC Characteristics (3.3 V, 25 °C)**

| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $C_{IN}$ | Pin capacitance | — | 2 | — | pF |
| $V_{IH}$ | High-level input voltage | 0.75 × VDD[1] | — | VDD[1]+ 0.3 | V |
| $V_{IL}$ | Low-level input voltage | –0.3 | — | 0.25 × VDD[1] | V |
| $I_{IH}$ | High-level input current | — | — | 50 | nA |
| $I_{IL}$ | Low-level input current | — | — | 50 | nA |
| $V_{OH}$[2] | High-level output voltage | 0.8 × VDD[1] | — | — | V |
| $V_{OL}$[2] | Low-level output voltage | — | — | 0.1 × VDD[1] | V |
| $I_{OH}$ | High-level source current (VDD[1]= 3.3 V, $V_{OH}$ >= 2.64 V, PAD_DRIVER = 3) | — | 40 | — | mA |
| $I_{OL}$ | Low-level sink current (VDD[1]= 3.3 V, $V_{OL}$ = 0.495 V, PAD_DRIVER = 3) | — | 28 | — | mA |
| $R_{PU}$ | Internal weak pull-up resistor | — | 45 | — | kΩ |
| $R_{PD}$ | Internal weak pull-down resistor | — | 45 | — | kΩ |
| $V_{IH\_nRST}$ | Chip reset release voltage (EN voltage is within the specified range) | 0.75 × VDD[1] | — | VDD[1]+ 0.3 | V |

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| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $V_{IL\_nRST}$ | Chip reset voltage (EN voltage is within the specified range) | –0.3 | — | 0.25 × VDD[1] | V |

[1] VDD is the I/O voltage for pins of a particular power domain.

[2] $V_{OH}$ and $V_{OL}$ are measured using high-impedance load.

## 4.4 Current Consumption Characteristics

With the use of advanced power-management technologies, the module can switch between different power modes. For details on different power modes, please refer to Section *Low Power Management* in *ESP32-S3 Series Datasheet*.

**Table 10: Current Consumption Depending on RF Modes**

| Work mode | Description | | Peak (mA) |
|---|---|---|---|
| Active (RF working) | TX | 802.11b, 1 Mbps, @20.5 dBm | 355 |
| | | 802.11g, 54 Mbps, @18 dBm | 297 |
| | | 802.11n, HT20, MCS 7, @17.5 dBm | 286 |
| | | 802.11n, HT40, MCS 7, @17 dBm | 285 |
| | RX | 802.11b/g/n, HT20 | 95 |
| | | 802.11n, HT40 | 97 |

[1] The current consumption measurements are taken with a 3.3 V supply at 25 °C of ambient temperature at the RF port. All transmitters' measurements are based on a 100% duty cycle.

[2] The current consumption figures for in RX mode are for cases when the peripherals are disabled and the CPU idle.

**Table 11: Current Consumption Depending on Work Modes**

| Work mode | Description | Typ[2] | Unit |
|---|---|---|---|
| Light-sleep | — | —[1] | μA |
| Deep-sleep | RTC memory and RTC peripherals are powered on. | 8 | μA |
| | RTC memory is powered on. RTC peripherals are powered off. | 7 | μA |
| Power off | CHIP_PU is set to low level. The chip is powered off. | 1 | μA |

[1] Please refer to the current consumption of the chip, and add corresponding PSRAM consumption values, e.g., 140 μA for 8 MB 8-line PSRAM (3.3 V), 200 μA for 8 MB 8-line PSRAM (1.8 V) and 40 μA for 2 MB 4-line PSRAM (3.3 V).

[2] Please refer to *ESP32-S3 Series Datasheet* if there are any inconsistencies.

## 4.5 Wi-Fi RF Characteristics

### 4.5.1 Wi-Fi RF Standards

**Table 12: Wi-Fi RF Standards**

| Name | | Description |
|---|---|---|
| Center frequency range of operating channel [1] | | 2412 ~ 2484 MHz |
| Wi-Fi wireless standard | | IEEE 802.11b/g/n |
| Data rate | 20 MHz | 11b: 1, 2, 5.5 and 11 Mbps<br>11g: 6, 9, 12, 18, 24, 36, 48, 54 Mbps<br>11n: MCS0-7, 72.2 Mbps (Max) |
| | 40 MHz | 11n: MCS0-7, 150 Mbps (Max) |
| Antenna type | | PCB antenna |

[1] Device should operate in the center frequency range allocated by regional regulatory authorities. Target center frequency range is configurable by software.

### 4.5.2 Wi-Fi RF Transmitter (TX) Specifications

Target TX power is configurable based on device or certification requirements. The default characteristics are provided in Table 13.

**Table 13: TX Power with Spectral Mask and EVM Meeting 802.11 Standards**

| Rate | Min (dBm) | Typ (dBm) | Max (dBm) |
|---|---|---|---|
| 802.11b, 1 Mbps | — | 20.5 | — |
| 802.11b, 11 Mbps | — | 20.5 | — |
| 802.11g, 6 Mbps | — | 20.0 | — |
| 802.11g, 54 Mbps | — | 18.0 | — |
| 802.11n, HT20, MCS 0 | — | 19.0 | — |
| 802.11n, HT20, MCS 7 | — | 17.5 | — |
| 802.11n, HT40, MCS 0 | — | 18.5 | — |
| 802.11n, HT40, MCS 7 | — | 17.0 | — |

**Table 14: TX EVM Test**

| Rate | Min (dB) | Typ (dB) | SL[1] (dB) |
|---|---|---|---|
| 802.11b, 1 Mbps, @20.5 dBm | — | –24.5 | –10 |
| 802.11b, 11 Mbps, @20.5 dBm | — | –24.5 | –10 |
| 802.11g, 6 Mbps, @20 dBm | — | –23.0 | –5 |
| 802.11g, 54 Mbps, @18 dBm | — | –29.5 | –25 |
| 802.11n, HT20, MCS 0, @19 dBm | — | –24.0 | –5 |
| 802.11n, HT20, MCS 7, @17.5 dBm | — | –30.5 | –27 |

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| Rate | Min (dB) | Typ (dB) | SL[1] (dB) |
|---|---|---|---|
| 802.11n, HT40, MCS 0, @18.5 dBm | — | –25.0 | –5 |
| 802.11n, HT40, MCS 7, @17 dBm | — | –30.0 | –27 |

[1] SL stands for standard limit value.

### 4.5.3 Wi-Fi RF Receiver (RX) Specifications

Table 15: RX Sensitivity

| Rate | Min (dBm) | Typ (dBm) | Max (dBm) |
|---|---|---|---|
| 802.11b, 1 Mbps | — | –98.2 | — |
| 802.11b, 2 Mbps | — | –95.6 | — |
| 802.11b, 5.5 Mbps | — | –92.8 | — |
| 802.11b, 11 Mbps | — | –88.5 | — |
| 802.11g, 6 Mbps | — | –93.0 | — |
| 802.11g, 9 Mbps | — | –92.0 | — |
| 802.11g, 12 Mbps | — | –90.8 | — |
| 802.11g, 18 Mbps | — | –88.5 | — |
| 802.11g, 24 Mbps | — | –85.5 | — |
| 802.11g, 36 Mbps | — | –82.2 | — |
| 802.11g, 48 Mbps | — | –78.0 | — |
| 802.11g, 54 Mbps | — | –76.2 | — |
| 802.11n, HT20, MCS 0 | — | –93.0 | — |
| 802.11n, HT20, MCS 1 | — | –90.6 | — |
| 802.11n, HT20, MCS 2 | — | –88.4 | — |
| 802.11n, HT20, MCS 3 | — | –84.8 | — |
| 802.11n, HT20, MCS 4 | — | –81.6 | — |
| 802.11n, HT20, MCS 5 | — | –77.4 | — |
| 802.11n, HT20, MCS 6 | — | –75.6 | — |
| 802.11n, HT20, MCS 7 | — | –74.2 | — |
| 802.11n, HT40, MCS 0 | — | –90.0 | — |
| 802.11n, HT40, MCS 1 | — | –87.5 | — |
| 802.11n, HT40, MCS 2 | — | –85.0 | — |
| 802.11n, HT40, MCS 3 | — | –82.0 | — |
| 802.11n, HT40, MCS 4 | — | –78.5 | — |
| 802.11n, HT40, MCS 5 | — | –74.4 | — |
| 802.11n, HT40, MCS 6 | — | –72.5 | — |
| 802.11n, HT40, MCS 7 | — | –71.2 | — |

Table 16: Maximum RX Level

| Rate | Min (dBm) | Typ (dBm) | Max (dBm) |
|---|---|---|---|
| 802.11b, 1 Mbps | — | 5 | — |
| 802.11b, 11 Mbps | — | 5 | — |
| 802.11g, 6 Mbps | — | 5 | — |
| 802.11g, 54 Mbps | — | 0 | — |
| 802.11n, HT20, MCS 0 | — | 5 | — |
| 802.11n, HT20, MCS 7 | — | 0 | — |
| 802.11n, HT40, MCS 0 | — | 5 | — |
| 802.11n, HT40, MCS 7 | — | 0 | — |

Table 17: RX Adjacent Channel Rejection

| Rate | Min (dB) | Typ (dB) | Max (dB) |
|---|---|---|---|
| 802.11b, 1 Mbps | — | 35 | — |
| 802.11b, 11 Mbps | — | 35 | — |
| 802.11g, 6 Mbps | — | 31 | — |
| 802.11g, 54 Mbps | — | 14 | — |
| 802.11n, HT20, MCS 0 | — | 31 | — |
| 802.11n, HT20, MCS 7 | — | 13 | — |
| 802.11n, HT40, MCS 0 | — | 19 | — |
| 802.11n, HT40, MCS 7 | — | 8 | — |

## 4.6 Bluetooth LE Radio

Table 18: Bluetooth LE Frequency

| Parameter | Min (MHz) | Typ (MHz) | Max (MHz) |
|---|---|---|---|
| Center frequency of operating channel | 2402 | — | 2480 |

### 4.6.1 Bluetooth LE RF Transmitter (TX) Specifications

Table 19: Transmitter Characteristics - Bluetooth LE 1 Mbps

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| RF transmit power | RF power control range | –24.00 | 0 | 21.00 | dBm |
| | Gain control step | — | 3.00 | — | dB |
| Carrier frequency offset and drift | Max $\lvert f_n \rvert_{n=0,\,1,\,2,\,..k}$ | — | 2.50 | — | kHz |
| | Max $\lvert f_0 - f_n \rvert$ | — | 2.00 | — | kHz |
| | Max $\lvert f_n - f_{n-5} \rvert$ | — | 1.40 | — | kHz |

Cont'd on next page

**Table 19 – cont'd from previous page**

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| | $\|f_1 - f_0\|$ | — | 1.00 | — | kHz |
| Modulation characteristics | $\Delta\ f1_{avg}$ | — | 249.00 | — | kHz |
| | Min $\Delta\ f2_{max}$ (for at least 99.9% of all $\Delta\ f2_{max}$) | — | 198.00 | — | kHz |
| | $\Delta\ f2_{avg}/\Delta\ f1_{avg}$ | — | 0.86 | — | — |
| In-band spurious emissions | ±2 MHz offset | — | –37.00 | — | dBm |
| | ±3 MHz offset | — | –42.00 | — | dBm |
| | >±3 MHz offset | — | –44.00 | — | dBm |

**Table 20: Transmitter Characteristics - Bluetooth LE 2 Mbps**

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| RF transmit power | RF power control range | –24.00 | 0 | 21.00 | dBm |
| | Gain control step | — | 3.00 | — | dB |
| Carrier frequency offset and drift | Max $\|f_n\|_{n=0,\ 1,\ 2,\ ..k}$ | — | 2.50 | — | kHz |
| | Max $\|f_0 - f_n\|$ | — | 2.00 | — | kHz |
| | Max $\|f_n - f_{n-5}\|$ | — | 1.40 | — | kHz |
| | $\|f_1 - f_0\|$ | — | 1.00 | — | kHz |
| Modulation characteristics | $\Delta\ f1_{avg}$ | — | 499.00 | — | kHz |
| | Min $\Delta\ f2_{max}$ (for at least 99.9% of all $\Delta\ f2_{max}$) | — | 416.00 | — | kHz |
| | $\Delta\ f2_{avg}/\Delta\ f1_{avg}$ | — | 0.89 | — | — |
| In-band spurious emissions | ±4 MHz offset | — | –42.00 | — | dBm |
| | ±5 MHz offset | — | –44.00 | — | dBm |
| | >±5 MHz offset | — | –47.00 | — | dBm |

**Table 21: Transmitter Characteristics - Bluetooth LE 125 Kbps**

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| RF transmit power | RF power control range | –24.00 | 0 | 21.00 | dBm |
| | Gain control step | — | 3.00 | — | dB |
| Carrier frequency offset and drift | Max $\|f_n\|_{n=0,\ 1,\ 2,\ ..k}$ | — | 0.80 | — | kHz |
| | Max $\|f_0 - f_n\|$ | — | 1.00 | — | kHz |
| | $\|f_n - f_{n-3}\|$ | — | 0.30 | — | kHz |
| | $\|f_0 - f_3\|$ | — | 1.00 | — | kHz |
| Modulation characteristics | $\Delta\ f1_{avg}$ | — | 248.00 | — | kHz |
| | Min $\Delta\ f1_{max}$ (for at least 99.9% of all$\Delta\ f1_{max}$) | — | 222.00 | — | kHz |
| In-band spurious emissions | ±2 MHz offset | — | –37.00 | — | dBm |
| | ±3 MHz offset | — | –42.00 | — | dBm |
| | >±3 MHz offset | — | –44.00 | — | dBm |

Table 22: Transmitter Characteristics - Bluetooth LE 500 Kbps

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| RF transmit power | RF power control range | –24.00 | 0 | 21.00 | dBm |
| | Gain control step | — | 3.00 | — | dB |
| Carrier frequency offset and drift | Max $\|f_n\|_{n=0,\ 1,\ 2,\ ..k}$ | — | 0.80 | — | kHz |
| | Max $\|f_0 - f_n\|$ | — | 1.00 | — | kHz |
| | $\|f_n - f_{n-3}\|$ | — | 0.85 | — | kHz |
| | $\|f_0 - f_3\|$ | — | 0.34 | — | kHz |
| Modulation characteristics | $\Delta\ f2_{avg}$ | — | 213.00 | — | kHz |
| | Min $\Delta\ f2_{max}$ (for at least 99.9% of all $\Delta\ f2_{max}$) | — | 196.00 | — | kHz |
| In-band spurious emissions | ±2 MHz offset | — | –37.00 | — | dBm |
| | ±3 MHz offset | — | –42.00 | — | dBm |
| | >±3 MHz offset | — | –44.00 | — | dBm |

### 4.6.2 Bluetooth LE RF Receiver (RX) Specifications

Table 23: Receiver Characteristics - Bluetooth LE 1 Mbps

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Sensitivity @30.8% PER | — | — | –96.5 | — | dBm |
| Maximum received signal @30.8% PER | — | — | 8 | — | dBm |
| Co-channel C/I | F = F0 MHz | — | 9 | — | dB |
| Adjacent channel selectivity C/I | F = F0 + 1 MHz | — | –3 | — | dB |
| | F = F0 – 1 MHz | — | –3 | — | dB |
| | F = F0 + 2 MHz | — | –28 | — | dB |
| | F = F0 – 2 MHz | — | –30 | — | dB |
| | F = F0 + 3 MHz | — | –31 | — | dB |
| | F = F0 – 3 MHz | — | –33 | — | dB |
| | F > F0 + 3 MHz | — | –32 | — | dB |
| | F > F0 – 3 MHz | — | –36 | — | dB |
| Image frequency | — | — | –32 | — | dB |
| Adjacent channel to image frequency | F = $F_{image}$ + 1 MHz | — | –39 | — | dB |
| | F = $F_{image}$ – 1 MHz | — | –31 | — | dB |
| Out-of-band blocking performance | 30 MHz ~ 2000 MHz | — | –9 | — | dBm |
| | 2003 MHz ~ 2399 MHz | — | –18 | — | dBm |
| | 2484 MHz ~ 2997 MHz | — | –15 | — | dBm |
| | 3000 MHz ~ 12.75 GHz | — | –5 | — | dBm |
| Intermodulation | — | — | –29 | — | dBm |

**Table 24: Receiver Characteristics - Bluetooth LE 2 Mbps**

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Sensitivity @30.8% PER | — | — | –92.5 | — | dBm |
| Maximum received signal @30.8% PER | — | — | 3 | — | dBm |
| Co-channel C/I | F = F0 MHz | — | 10 | — | dB |
| Adjacent channel selectivity C/I | F = F0 + 2 MHz | — | –8 | — | dB |
| | F = F0 – 2 MHz | — | –5 | — | dB |
| | F = F0 + 4 MHz | — | –31 | — | dB |
| | F = F0 – 4 MHz | — | –33 | — | dB |
| | F = F0 + 6 MHz | — | –37 | — | dB |
| | F = F0 – 6 MHz | — | –37 | — | dB |
| | F > F0 + 6 MHz | — | –40 | — | dB |
| | F > F0 – 6 MHz | — | –40 | — | dB |
| Image frequency | — | — | –31 | — | dB |
| Adjacent channel to image frequency | F = $F_{image}$ + 2 MHz | — | –37 | — | dB |
| | F = $F_{image}$ – 2 MHz | — | –8 | — | dB |
| Out-of-band blocking performance | 30 MHz ~ 2000 MHz | — | –15 | — | dBm |
| | 2003 MHz ~ 2399 MHz | — | –19 | — | dBm |
| | 2484 MHz ~ 2997 MHz | — | –15 | — | dBm |
| | 3000 MHz ~ 12.75 GHz | — | –6 | — | dBm |
| Intermodulation | — | — | –29 | — | dBm |

**Table 25: Receiver Characteristics - Bluetooth LE 125 Kbps**

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Sensitivity @30.8% PER | — | — | –103.5 | — | dBm |
| Maximum received signal @30.8% PER | — | — | 8 | — | dBm |
| Co-channel C/I | F = F0 MHz | — | 6 | — | dB |
| Adjacent channel selectivity C/I | F = F0 + 1 MHz | — | –6 | — | dB |
| | F = F0 – 1 MHz | — | –5 | — | dB |
| | F = F0 + 2 MHz | — | –32 | — | dB |
| | F = F0 – 2 MHz | — | –39 | — | dB |
| | F = F0 + 3 MHz | — | –35 | — | dB |
| | F = F0 – 3 MHz | — | –45 | — | dB |
| | F > F0 + 3 MHz | — | –35 | — | dB |
| | F > F0 – 3 MHz | — | –48 | — | dB |
| Image frequency | — | — | –35 | — | dB |
| Adjacent channel to image frequency | F = $F_{image}$ + 1 MHz | — | –49 | — | dB |
| | F = $F_{image}$ – 1 MHz | — | –32 | — | dB |

**Table 26: Receiver Characteristics - Bluetooth LE 500 Kbps**

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Sensitivity @30.8% PER | — | — | –100 | — | dBm |
| Maximum received signal @30.8% PER | — | — | 8 | — | dBm |
| Co-channel C/I | F = F0 MHz | — | 4 | — | dB |
| Adjacent channel selectivity C/I | F = F0 + 1 MHz | — | –5 | — | dB |
| | F = F0 – 1 MHz | — | –5 | — | dB |
| | F = F0 + 2 MHz | — | –28 | — | dB |
| | F = F0 – 2 MHz | — | –36 | — | dB |
| | F = F0 + 3 MHz | — | –36 | — | dB |
| | F = F0 – 3 MHz | — | –38 | — | dB |
| | F > F0 + 3 MHz | — | –37 | — | dB |
| | F > F0 – 3 MHz | — | –41 | — | dB |
| Image frequency | — | — | –37 | — | dB |
| Adjacent channel to image frequency | F = $F_{image}$ + 1 MHz | — | –44 | — | dB |
| | F = $F_{image}$ – 1 MHz | — | –28 | — | dB |

# 5 Module Schematics

This is the reference design of the module.

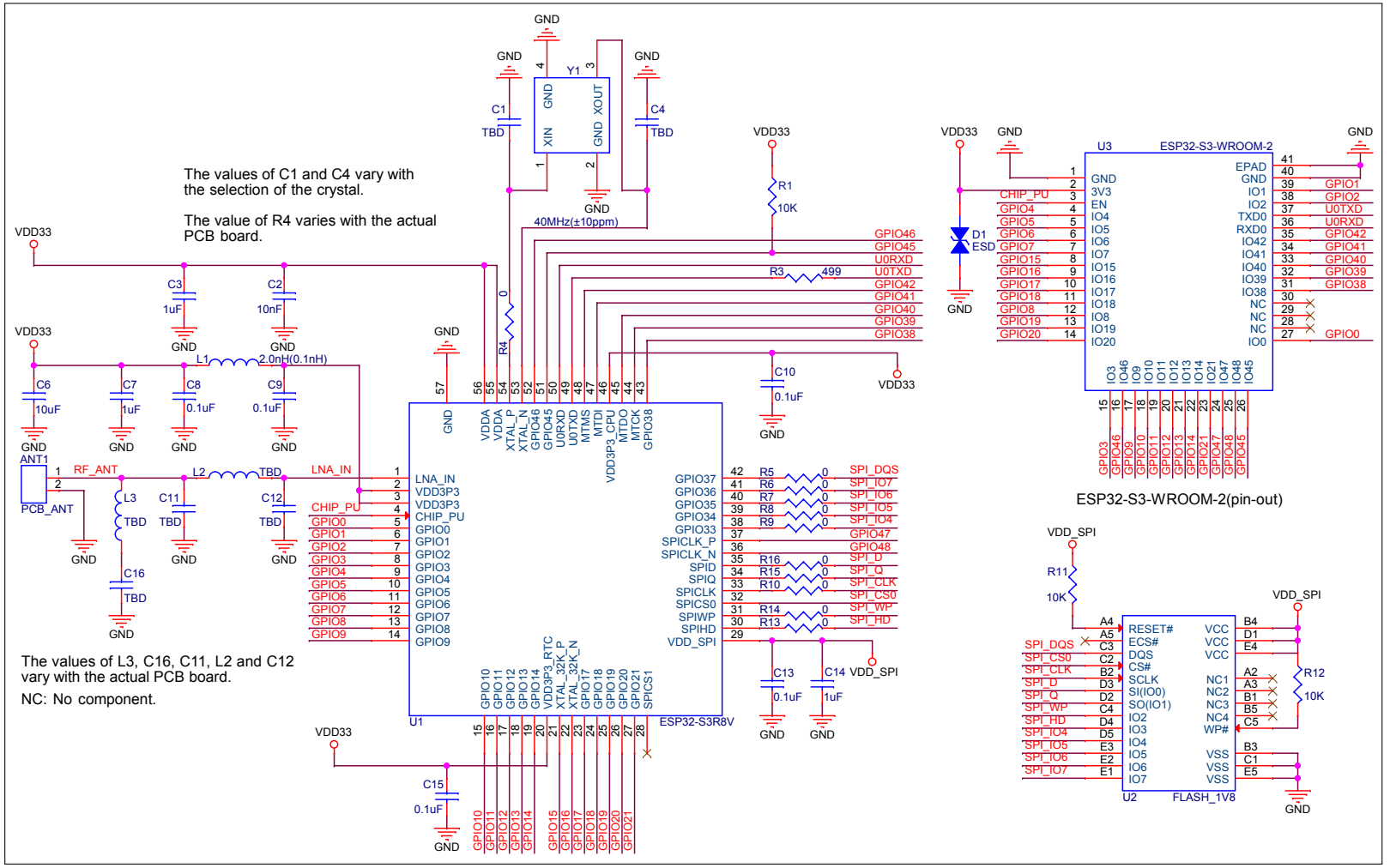



**Figure 4: ESP32-S3-WROOM-2 Schematics**

Note that for ESP32_S3R8V, VDD_SPI has been set to 1.8 V by eFuse VDD_SPI_TIEH and VDD_SPI_FORCE.

# 6 Peripheral Schematics

This is the typical application circuit of the module connected with peripheral components (for example, power supply, antenna, reset button, JTAG interface, and UART interface).

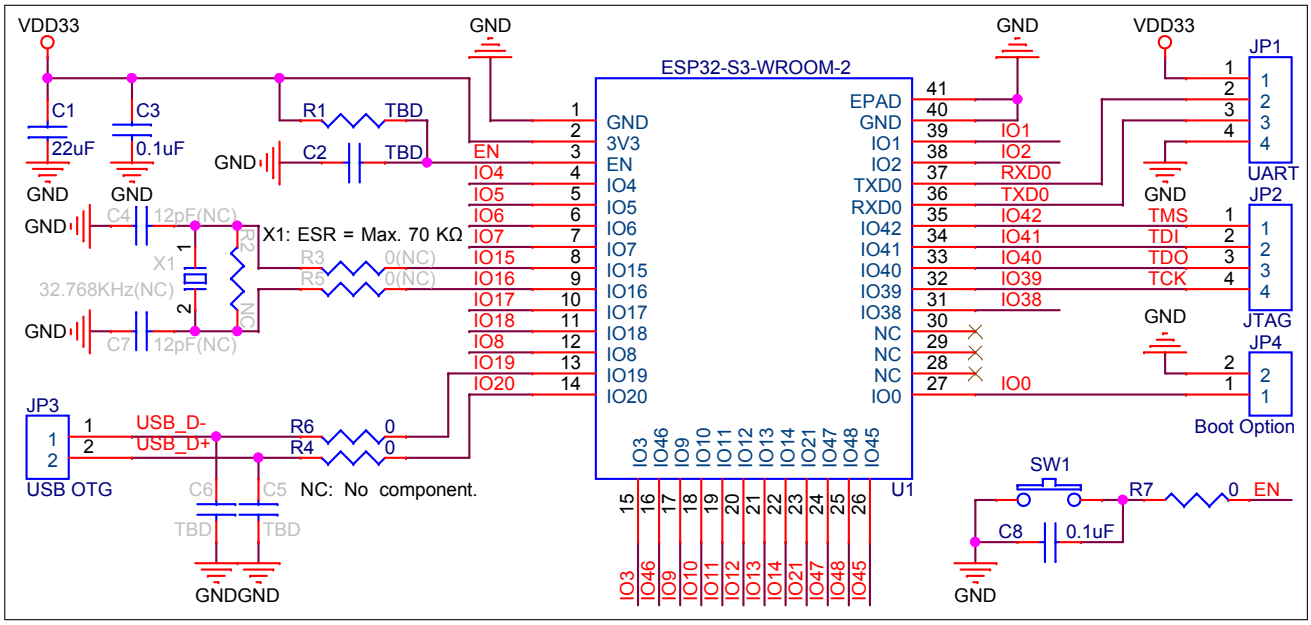



**Figure 5: Peripheral Schematics**

- Soldering the EPAD to the ground of the base board is not a must, however, it can optimize thermal performance. If you choose to solder it, please apply the correct amount of soldering paste.
- To ensure that the power supply to the ESP32-S3 chip is stable during power-up, it is advised to add an RC delay circuit at the EN pin. The recommended setting for the RC delay circuit is usually R = 10 kΩ and C = 1 $\mu$F. However, specific parameters should be adjusted based on the power-up timing of the module and the power-up and reset sequence timing of the chip. For ESP32-S3's power-up and reset sequence timing diagram, please refer to Section *Power Scheme* in *ESP32-S3 Series Datasheet*.

# 7 Physical Dimensions and PCB Land Pattern

## 7.1 Physical Dimensions

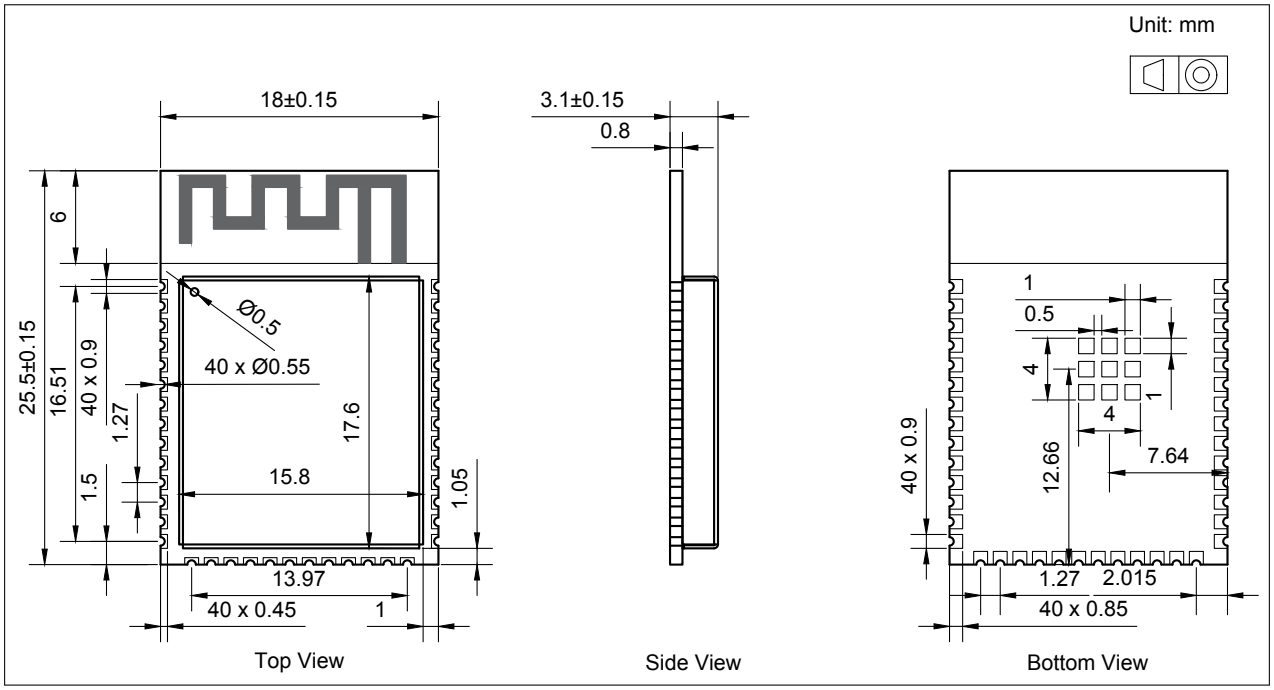



**Figure 6: ESP32-S3-WROOM-2 Physical Dimensions**

**Note:**
For information about tape, reel, and product marking, please refer to *Espressif Module Package Information*.

## 7.2 Recommended PCB Land Pattern

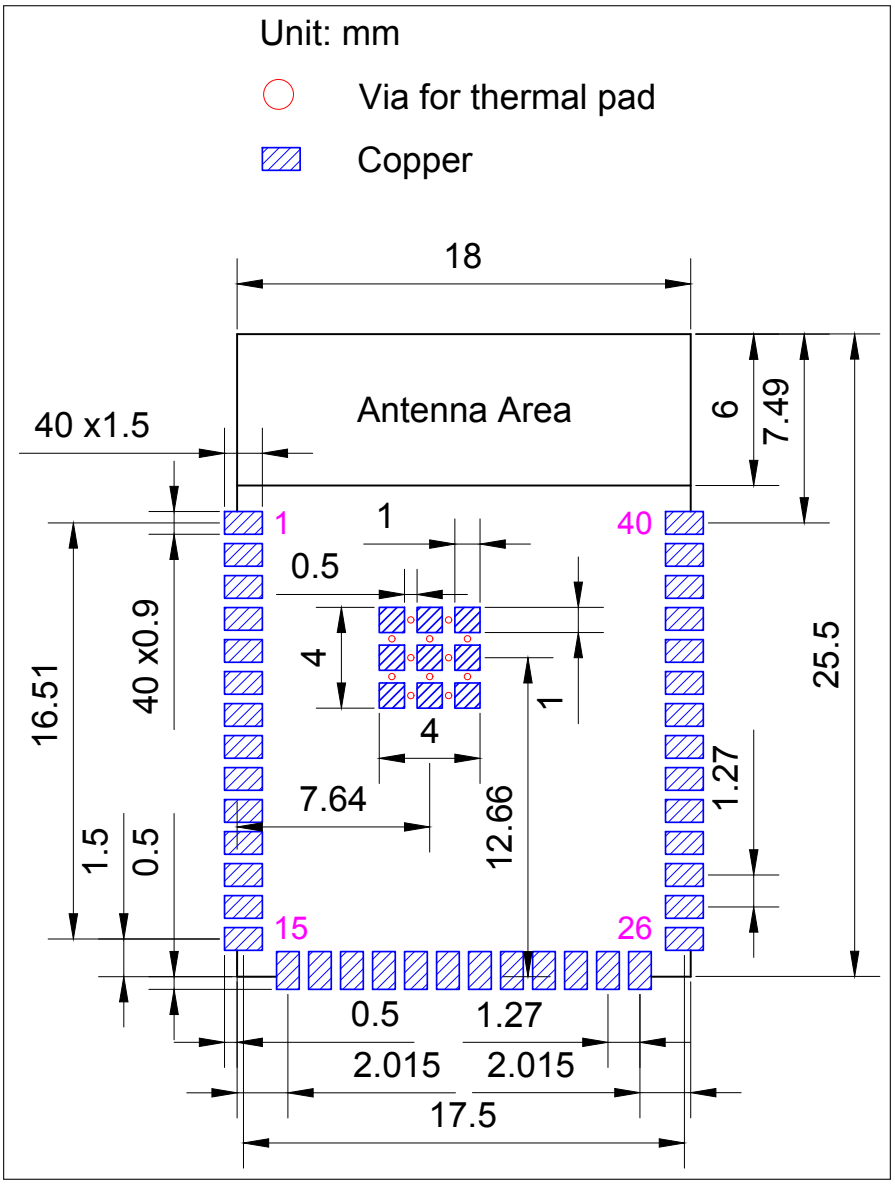



**Figure 7: ESP32-S3-WROOM-2 Recommended PCB Land Pattern**

# 8 Product Handling

## 8.1 Storage Conditions

The products sealed in moisture barrier bags (MBB) should be stored in a non-condensing atmospheric environment of < 40 °C and /90%RH. The module is rated at the moisture sensitivity level (MSL) of 3.

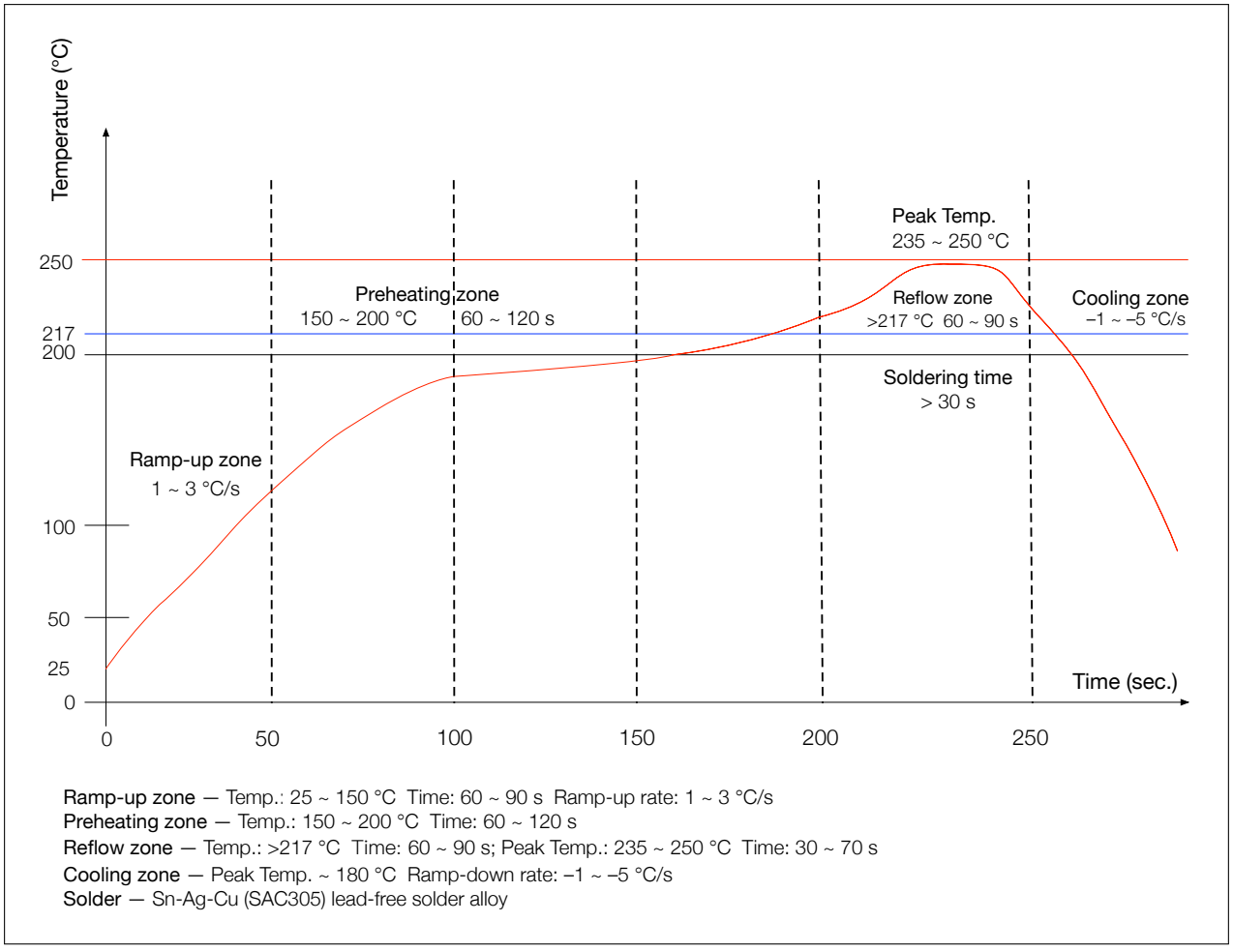
After unpacking, the module must be soldered within 168 hours with the factory conditions 25±5 °C and /60%RH. If the above conditions are not met, the module needs to be baked.

## 8.2 Electrostatic Discharge (ESD)

- Human body model (HBM): ±2000 V
- Charged-device model (CDM): ±500 V

## 8.3 Reflow Profile

Solder the module in a single reflow.




**Ramp-up zone** — Temp.: 25 ~ 150 °C Time: 60 ~ 90 s Ramp-up rate: 1 ~ 3 °C/s
**Preheating zone** — Temp.: 150 ~ 200 °C Time: 60 ~ 120 s
**Reflow zone** — Temp.: >217 °C Time: 60 ~ 90 s; Peak Temp.: 235 ~ 250 °C Time: 30 ~ 70 s
**Cooling zone** — Peak Temp. ~ 180 °C Ramp-down rate: –1 ~ –5 °C/s
**Solder** — Sn-Ag-Cu (SAC305) lead-free solder alloy

**Figure 8: Reflow Profile**

## 8.4 Ultrasonic Vibration

Avoid exposing Espressif modules to vibration from ultrasonic equipment, such as ultrasonic welders or ultrasonic cleaners. This vibration may induce resonance in the in-module crystal and lead to its malfunction or even failure. As a consequence, **the module may stop working or its performance may deteriorate**.

# 9 Related Documentation and Resources

## Related Documentation

- ESP32-S3 Series Datasheet – Specifications of the ESP32-S3 hardware.
- ESP32-S3 Technical Reference Manual – Detailed information on how to use the ESP32-S3 memory and peripherals.
- ESP32-S3 Hardware Design Guidelines – Guidelines on how to integrate the ESP32-S3 into your hardware product.
- *Certificates*
  https://espressif.com/en/support/documents/certificates
- *Documentation Updates and Update Notification Subscription*
  https://espressif.com/en/support/download/documents

## Developer Zone

- ESP-IDF Programming Guide for ESP32-S3 – Extensive documentation for the ESP-IDF development framework.
- *ESP-IDF* and other development frameworks on GitHub.
  https://github.com/espressif
- *ESP32 BBS Forum* – Engineer-to-Engineer (E2E) Community for Espressif products where you can post questions, share knowledge, explore ideas, and help solve problems with fellow engineers.
  https://esp32.com/
- *The ESP Journal* – Best Practices, Articles, and Notes from Espressif folks.
  https://blog.espressif.com/
- See the tabs *SDKs and Demos*, *Apps*, *Tools*, *AT Firmware*.
  https://espressif.com/en/support/download/sdks-demos

## Products

- *ESP32-S3 Series SoCs* – Browse through all ESP32-S3 SoCs.
  https://espressif.com/en/products/socs?id=ESP32-S3
- *ESP32-S3 Series Modules* – Browse through all ESP32-S3-based modules.
  https://espressif.com/en/products/modules?id=ESP32-S3
- *ESP32-S3 Series DevKits* – Browse through all ESP32-S3-based devkits.
  https://espressif.com/en/products/devkits?id=ESP32-S3
- *ESP Product Selector* – Find an Espressif hardware product suitable for your needs by comparing or applying filters.
  https://products.espressif.com/#/product-selector?language=en

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# Revision History

| Date | Version | Release notes |
|---|---|---|
| 2022-08-01 | v1.0 | • Add certification and test information<br>• Update Table 1 and Table 11 and add note<br>• Update note in Table 2<br>• Update BLE RF power control range in Table 19<br>• Other minor updates |
| 2022-05-09 | v0.7 | Update pin definitions table |
| 2021-12-31 | v0.6 | Overall update for chip revision 1 |
| 2021-07-13 | v0.1 | Preliminary release, for chip revision 0 |

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