ESP32-S3-WROOM-1
ESP32-S3-WROOM-1U

Datasheet

2.4 GHz Wi-Fi (802.11 b/g/n) and Bluetooth® 5 (LE) module
Built around ESP32-S3 series of SoCs, Xtensa® dual-core 32-bit LX7 microprocessor
Flash up to 16 MB, PSRAM up to 8 MB
36 GPIOs, rich set of peripherals
On-board PCB antenna

ESP32-S3-WROOM-1

ESP32-S3-WROOM-1U

Version 1.1
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-1_wroom-1u_datasheet_en.pdf

1.1 Features

CPU and On-Chip Memory

- ESP32-S3 series of SoCs embedded, Xtensa® dual-core 32-bit LX7 microprocessor, up to 240 MHz
- 384 KB ROM
- 512 KB SRAM
- 16 KB SRAM in RTC
- Up to 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 μs 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 16 MB Quad SPI flash

Antenna Options

- On-board PCB antenna (ESP32-S3-WROOM-1)
- External antenna via a connector (ESP32-S3-WROOM-1U)

Operating Conditions

- Operating voltage/Power supply: 3.0 ~ 3.6 V
- Operating ambient temperature:
  - 65 °C version: –40 ~ 65 °C
  - 85 °C version: –40 ~ 85 °C
  - 105 °C version: –40 ~ 105 °C

Certification

- RF certification: See certificates for ESP32-S3-WROOM-1 and ESP32-S3-WROOM-1U
- Green certification: RoHS/REACH

Test

- HTOL/HTSL/uHAST/TCT/ESD

1.2 Description

ESP32-S3-WROOM-1 and ESP32-S3-WROOM-1U are two powerful, generic Wi-Fi + Bluetooth LE MCU modules that are built around the ESP32-S3 series of SoCs. On top of a rich set of peripherals, the acceleration for neural network computing and signal processing workloads provided by the SoC make the modules an ideal choice for a wide variety of application scenarios related to AI and Artificial Intelligence of Things (AIoT), such as wake word detection, speech commands recognition, face detection and recognition, smart home, smart appliances, smart control panel, smart speaker, etc.

ESP32-S3-WROOM-1 comes with a PCB antenna. ESP32-S3-WROOM-1U comes with an external antenna connector. A wide selection of module variants are available for customers as shown in Table 1 and 2. Among the module variants, those embed ESP32-S3R8 operate at –40 ~ 65 °C ambient temperature, ESP32-S3-WROOM-1-H4 and ESP32-S3-WROOM-1U-H4 operate at –40 ~ 105 °C ambient temperature, and other module variants operate at –40 ~ 85 °C ambient temperature. 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.

Table 1: ESP32-S3-WROOM-1 Series Comparison[1]

Ordering Code	Flash[2]	PSRAM	Ambient Temp.[3] (°C)	Size[4] (mm)
ESP32-S3-WROOM-1-N4	4 MB (Quad SPI)	-	–40 ~ 85	18.0 x 25.5 x 3.1
ESP32-S3-WROOM-1-N8	8 MB (Quad SPI)	-	–40 ~ 85	
ESP32-S3-WROOM-1-N16	16 MB (Quad SPI)	-	–40 ~ 85	
ESP32-S3-WROOM-1-H4	4 MB (Quad SPI)	-	–40 ~ 105	
ESP32-S3-WROOM-1-N4R2	4 MB (Quad SPI)	2 MB (Quad SPI)	–40 ~ 85	
ESP32-S3-WROOM-1-N8R2	8 MB (Quad SPI)	2 MB (Quad SPI)	–40 ~ 85	
ESP32-S3-WROOM-1-N16R2	16 MB (Quad SPI)	2 MB (Quad SPI)	–40 ~ 85	
ESP32-S3-WROOM-1-N4R8	4 MB (Quad SPI)	8 MB (Octal SPI)	–40 ~ 65	
ESP32-S3-WROOM-1-N8R8	8 MB (Quad SPI)	8 MB (Octal SPI)	–40 ~ 65	
ESP32-S3-WROOM-1-N16R8	16 MB (Quad SPI)	8 MB (Octal SPI)	–40 ~ 65	

[1] This table shares the same notes presented in Table 2 below.

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

Ordering Code	Flash[2]	PSRAM	Ambient Temp.[3] (°C)	Size[4] (mm)
ESP32-S3-WROOM-1U-N4	4 MB (Quad SPI)	-	–40 ~ 85	18.0 x 19.2 x 3.2
ESP32-S3-WROOM-1U-N8	8 MB (Quad SPI)	-	–40 ~ 85	
ESP32-S3-WROOM-1U-N16	16 MB (Quad SPI)	-	–40 ~ 85	
ESP32-S3-WROOM-1U-H4	4 MB (Quad SPI)	-	–40 ~ 105	
ESP32-S3-WROOM-1U-N4R2	4 MB (Quad SPI)	2 MB (Quad SPI)	–40 ~ 85	
ESP32-S3-WROOM-1U-N8R2	8 MB (Quad SPI)	2 MB (Quad SPI)	–40 ~ 85	
ESP32-S3-WROOM-1U-N16R2	16 MB (Quad SPI)	2 MB (Quad SPI)	–40 ~ 85	
ESP32-S3-WROOM-1U-N4R8	4 MB (Quad SPI)	8 MB (Octal SPI)	–40 ~ 65	
ESP32-S3-WROOM-1U-N8R8	8 MB (Quad SPI)	8 MB (Octal SPI)	–40 ~ 65	
ESP32-S3-WROOM-1U-N16R8	16 MB (Quad SPI)	8 MB (Octal SPI)	–40 ~ 65	

[2] The modules use flash integrated in the chip's package.

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

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

At the core of the modules is an ESP32-S3 series of SoC *, 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-S3 integrates a rich set of peripherals including SPI, LCD, 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 series of SoCs, 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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2 Block Diagram

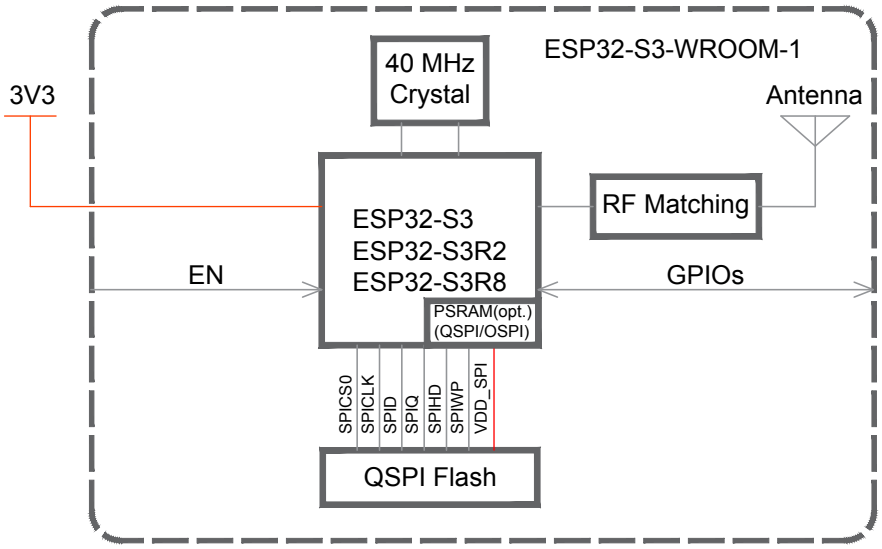

Figure 1: ESP32-S3-WROOM-1 Block Diagram

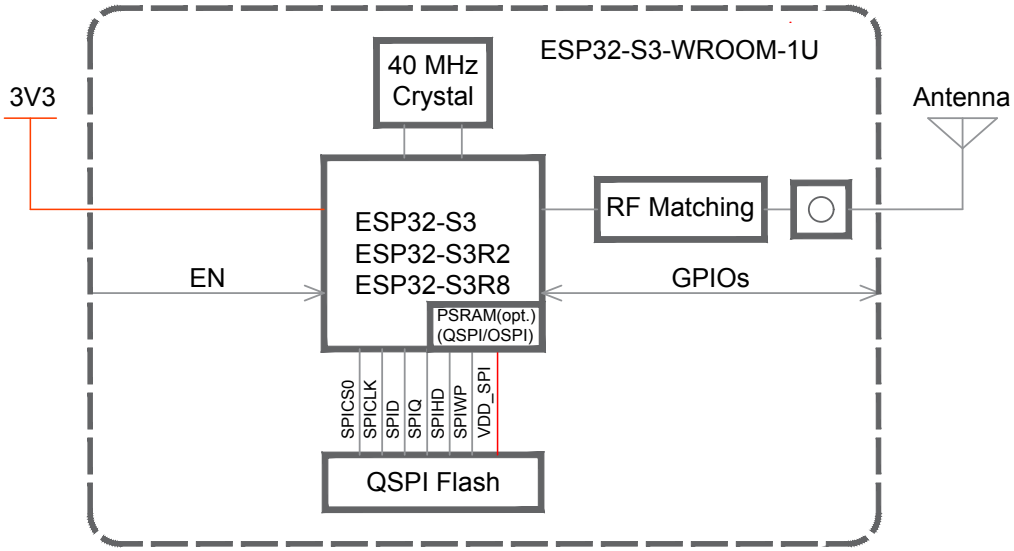

Figure 2: ESP32-S3-WROOM-1U Block Diagram

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*.

The pin diagram is applicable for ESP32-S3-WROOM-1 and ESP32-S3-WROOM-1U, but the latter has no keepout zone.

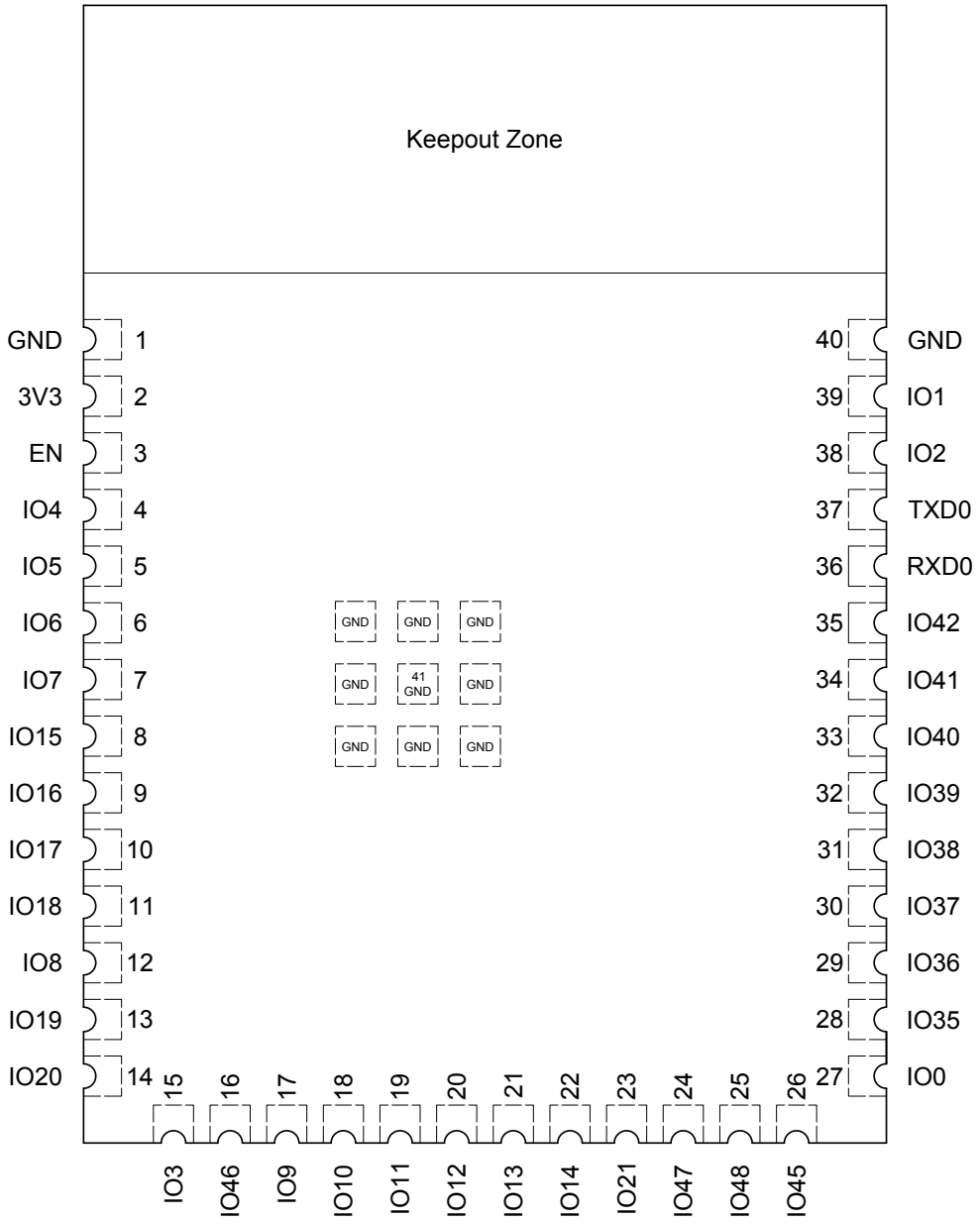

Figure 3: Pin Layout (Top View)

3.2 Pin Description

The module has 41 pins. See pin definitions in Table 3.

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

Table 3: Pin Definitions

Name	No.	Type [a]	Function
GND	1	P	GND
3V3	2	P	Power supply
EN	3	I	High: on, enables the chip. Low: off, the chip powers off. 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**, SUBSPICLK_P_DIFF
IO48	25	I/O/T	SPICLK_N_DIFF,**GPIO48**, SUBSPICLK_N_DIFF
IO45	26	I/O/T	**GPIO45**
IO0	27	I/O/T	RTC_GPIO0, **GPIO0**
IO35 [b]	28	I/O/T	SPIIO6, **GPIO35**, FSPID, SUBSPID
IO36 [b]	29	I/O/T	SPIIO7, **GPIO36**, FSPICLK, SUBSPICLK

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Table 3 – cont'd from previous page

Name	No.	Type [a]	Function
IO37 [b]	30	I/O/T	SPIDQS, **GPIO37**, FSPIQ, SUBSPIQ
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
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

[a] P: power supply; I: input; O: output; T: high impedance. Pin functions in bold font are the default pin functions. For pin 28 ~ 30, the default function is decided by eFuse bit.

[b] In module variants that have embedded OSPI PSRAM, i.e., that embed ESP32-S3R8, pins IO35, IO36, and IO37 connect to the OSPI PSRAM and are not available for other uses.

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 5. In this case, the strapping value is controlled by the external circuit that cannot be in a high impedance state. Table 4 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 4: 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 5
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 5 for a detailed configuration of the strapping pins.

Table 5: 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]			
Pin	Default	Enabled	Disabled
GPIO46	Pull-down	See the 2nd note	See the 2nd 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 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. Please refer to the following table for default configurations:

Table 6: 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 4 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 7.

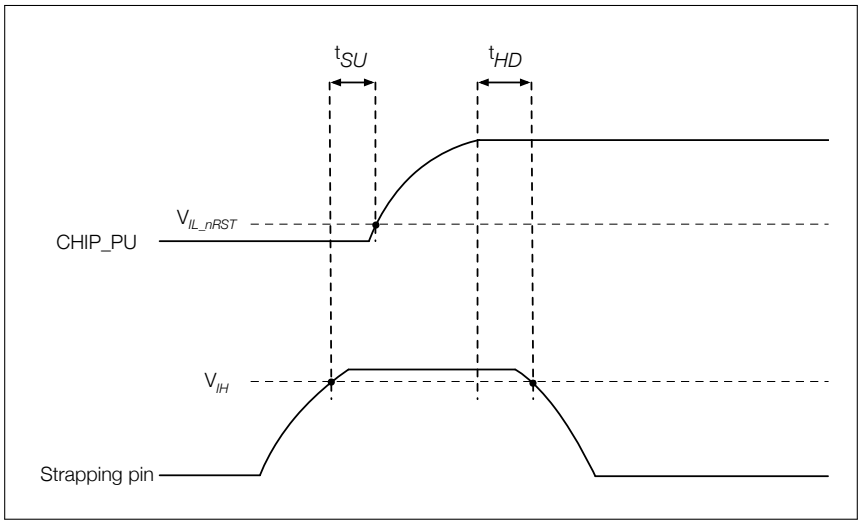

Figure 4: Setup and Hold Times for the Strapping Pin

Table 7: 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 8: 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 9: 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	65 °C version	–40	—	65	°C
		85 °C version			85	
		105 °C version			105	

4.3 DC Characteristics (3.3 V, 25 °C)

Table 10: 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

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Symbol	Parameter	Min	Typ	Max	Unit
V_{IH_nRST}	Chip reset release voltage (EN voltage is within the specified range)	0.75 × VDD[1]	—	VDD[1]+ 0.3	V
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 11: 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.

Note that the data in Table 12 only applies to the module variants that embed the chip variant ESP32-S3.

Table 12: 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 13: 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 11g: 6, 9, 12, 18, 24, 36, 48, 54 Mbps 11n: MCS0-7, 72.2 Mbps (Max)
	40 MHz	11n: MCS0-7, 150 Mbps (Max)
Antenna type		PCB antenna, external antenna via the connector [2]

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

[2] For the modules that use external antennas, the output impedance is 50 Ω. For other modules without external antennas, the output impedance is irrelevant.

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 14.

Table 14: 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 15: 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

Cont'd on next page

Table 15 – cont'd from previous page

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 16: 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 17: 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 18: 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 19: 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 20: Transmitter Characteristics - Bluetooth LE 1 Mbps

Parameter	Description	Min	Typ	Max	Unit
RF transmit power	RF power control range	–25.00	0	20.00	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 20 – 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 21: Transmitter Characteristics - Bluetooth LE 2 Mbps

Parameter	Description	Min	Typ	Max	Unit
RF transmit power	RF power control range	–25.00	0	20.00	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 22: Transmitter Characteristics - Bluetooth LE 125 Kbps

Parameter	Description	Min	Typ	Max	Unit
RF transmit power	RF power control range	–25.00	0	20.00	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 23: Transmitter Characteristics - Bluetooth LE 500 Kbps

Parameter	Description	Min	Typ	Max	Unit
RF transmit power	RF power control range	–25.00	0	20.00	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 24: 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	—	8	—	dB
Adjacent channel selectivity C/I	F = F0 + 1 MHz	—	4	—	dB
	F = F0 – 1 MHz	—	4	—	dB
	F = F0 + 2 MHz	—	–23	—	dB
	F = F0 – 2 MHz	—	–23	—	dB
	F = F0 + 3 MHz	—	–34	—	dB
	F = F0 – 3 MHz	—	–34	—	dB
	F > F0 + 3 MHz	—	–36	—	dB
	F > F0 – 3 MHz	—	–37	—	dB
Image frequency	—	—	–36	—	dB
Adjacent channel to image frequency	F = F_{image} + 1 MHz	—	–39	—	dB
	F = F_{image} – 1 MHz	—	–34	—	dB
Out-of-band blocking performance	30 MHz ~ 2000 MHz	—	–12	—	dBm
	2003 MHz ~ 2399 MHz	—	–18	—	dBm
	2484 MHz ~ 2997 MHz	—	–16	—	dBm
	3000 MHz ~ 12.75 GHz	—	–10	—	dBm
Intermodulation	—	—	–29	—	dBm

Table 25: Receiver Characteristics - Bluetooth LE 2 Mbps

Parameter	Description	Min	Typ	Max	Unit
Sensitivity @30.8% PER	—	—	–92	—	dBm
Maximum received signal @30.8% PER	—	—	3	—	dBm
Co-channel C/I	F = F0 MHz	—	8	—	dB
Adjacent channel selectivity C/I	F = F0 + 2 MHz	—	4	—	dB
	F = F0 – 2 MHz	—	4	—	dB
	F = F0 + 4 MHz	—	–27	—	dB
	F = F0 – 4 MHz	—	–27	—	dB
	F = F0 + 6 MHz	—	–38	—	dB
	F = F0 – 6 MHz	—	–38	—	dB
	F > F0 + 6 MHz	—	–41	—	dB
	F > F0 – 6 MHz	—	–41	—	dB
Image frequency	—	—	–27	—	dB
Adjacent channel to image frequency	F = F_{image} + 2 MHz	—	–38	—	dB
	F = F_{image} – 2 MHz	—	4	—	dB
Out-of-band blocking performance	30 MHz ~ 2000 MHz	—	–15	—	dBm
	2003 MHz ~ 2399 MHz	—	–21	—	dBm
	2484 MHz ~ 2997 MHz	—	–21	—	dBm
	3000 MHz ~ 12.75 GHz	—	–9	—	dBm
Intermodulation	—	—	–29	—	dBm

Table 26: 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	—	4	—	dB
Adjacent channel selectivity C/I	F = F0 + 1 MHz	—	1	—	dB
	F = F0 – 1 MHz	—	2	—	dB
	F = F0 + 2 MHz	—	–26	—	dB
	F = F0 – 2 MHz	—	–26	—	dB
	F = F0 + 3 MHz	—	–36	—	dB
	F = F0 – 3 MHz	—	–39	—	dB
	F > F0 + 3 MHz	—	–42	—	dB
	F > F0 – 3 MHz	—	–43	—	dB
Image frequency	—	—	–42	—	dB
Adjacent channel to image frequency	F = F_{image} + 1 MHz	—	–43	—	dB
	F = F_{image} – 1 MHz	—	–36	—	dB

Table 27: 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	—	1	—	dB
	F = F0 – 1 MHz	—	0	—	dB
	F = F0 + 2 MHz	—	–24	—	dB
	F = F0 – 2 MHz	—	–24	—	dB
	F = F0 + 3 MHz	—	–37	—	dB
	F = F0 – 3 MHz	—	–39	—	dB
	F > F0 + 3 MHz	—	–38	—	dB
	F > F0 – 3 MHz	—	–42	—	dB
Image frequency	—	—	–38	—	dB
Adjacent channel to image frequency	F = F_{image} + 1 MHz	—	–42	—	dB
	F = F_{image} – 1 MHz	—	–37	—	dB

5 Module Schematics

This is the reference design of the module.

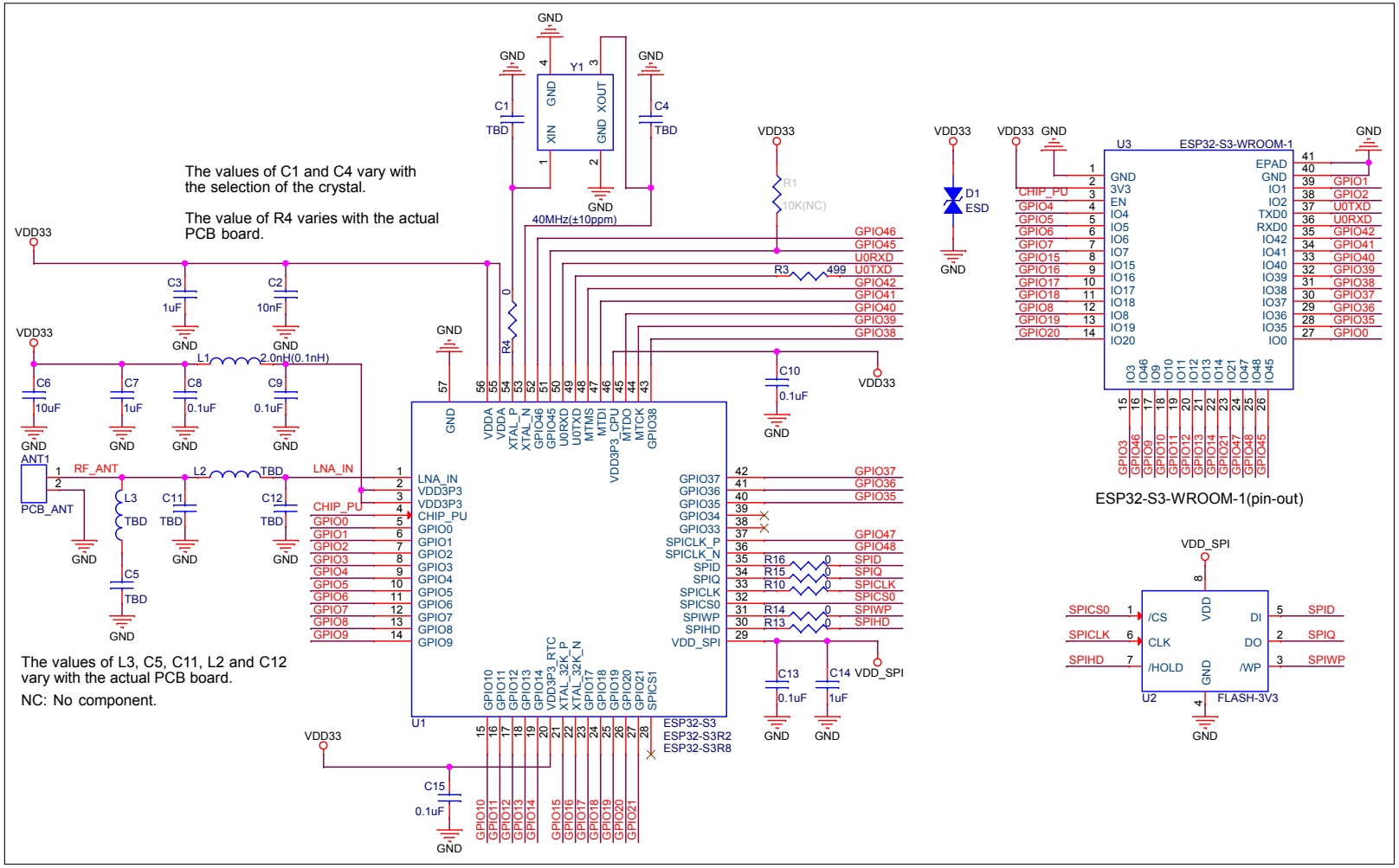

Figure 5: ESP32-S3-WROOM-1 Schematics

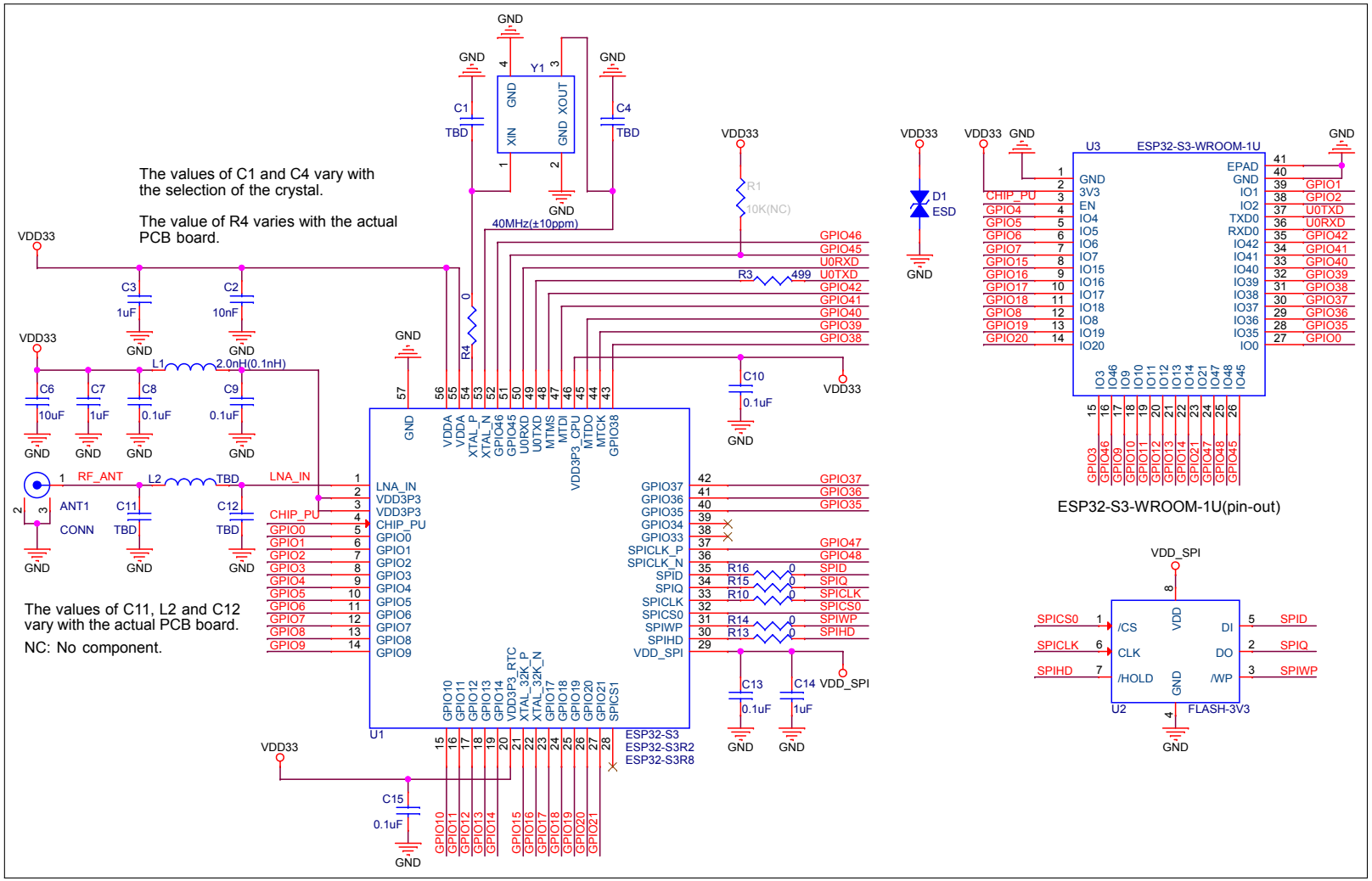

Figure 6: ESP32-S3-WROOM-1U Schematics

Internal pull-up resistor (R1) for IO45 is not populated in the module, as the flash in the module works at 3.3 V by default (output by VDD_SPI). Please make sure IO45 is not pulled high when the module is powered up by external circuit.

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).

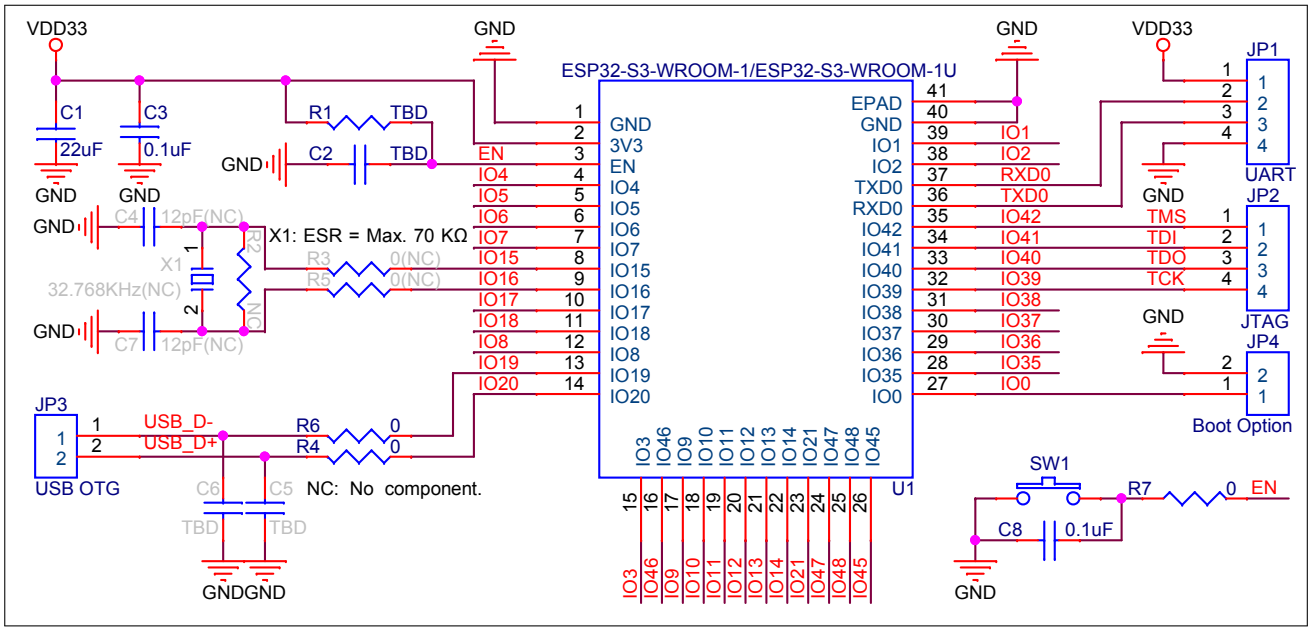

Figure 7: Peripheral Schematics

- 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 μF. 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

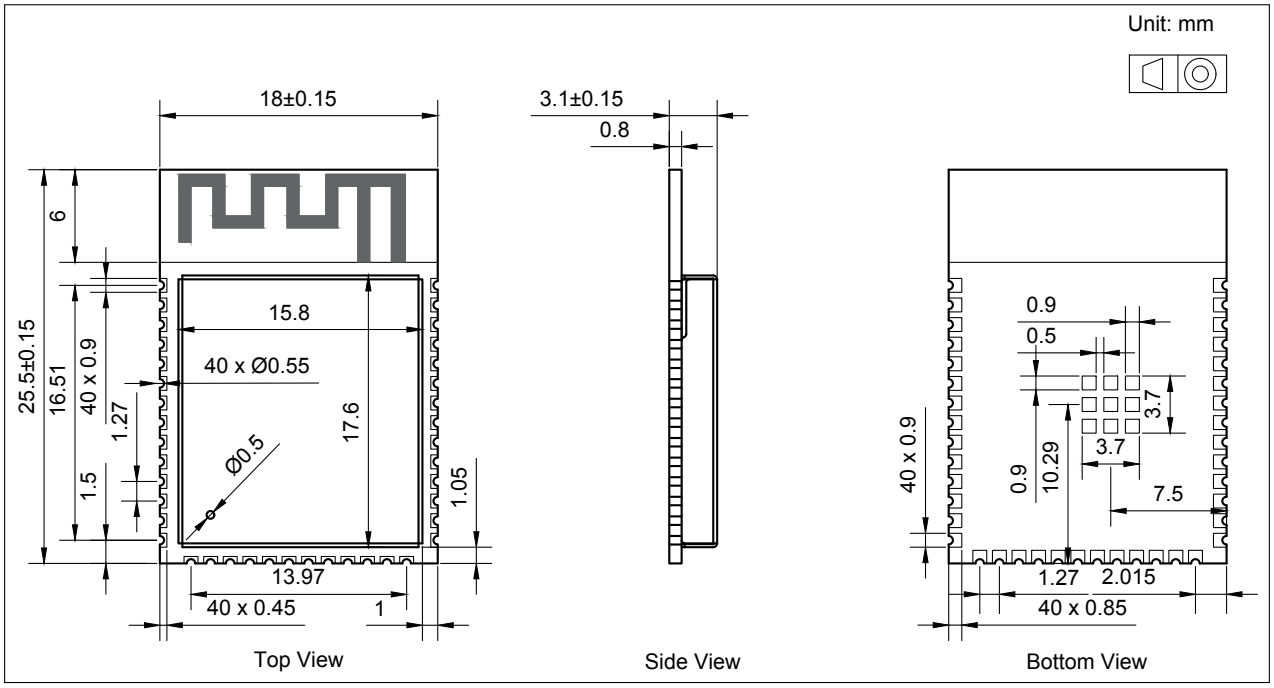

Figure 8: ESP32-S3-WROOM-1 Physical Dimensions

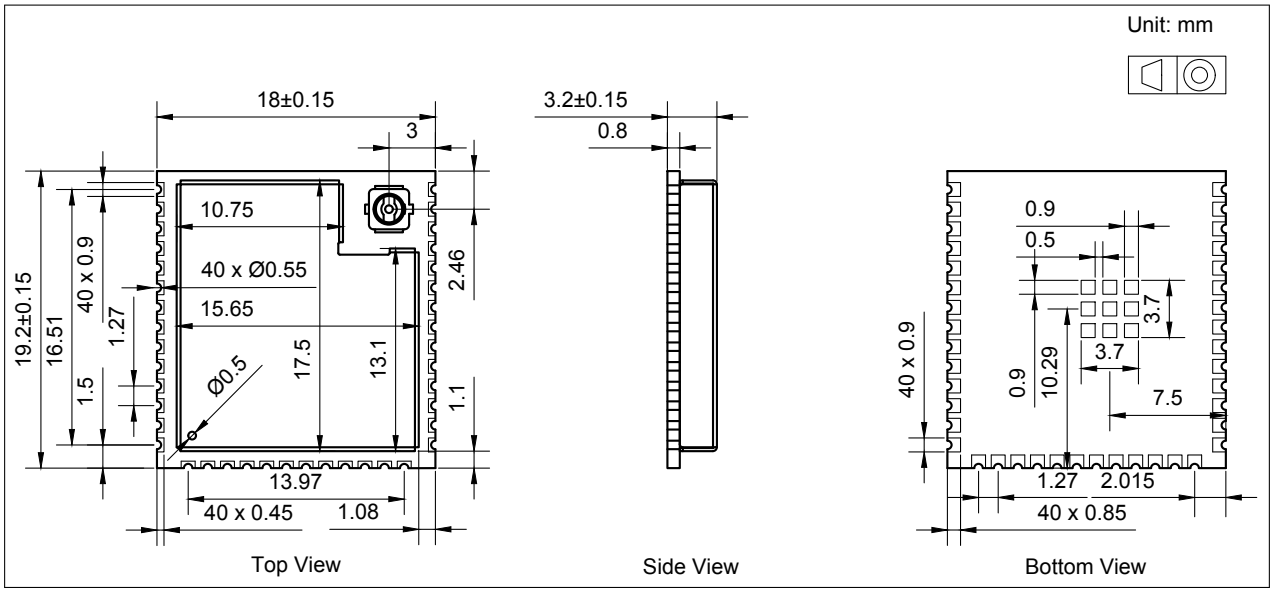

Figure 9: ESP32-S3-WROOM-1U Physical Dimensions

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

7.2 Recommended PCB Land Pattern

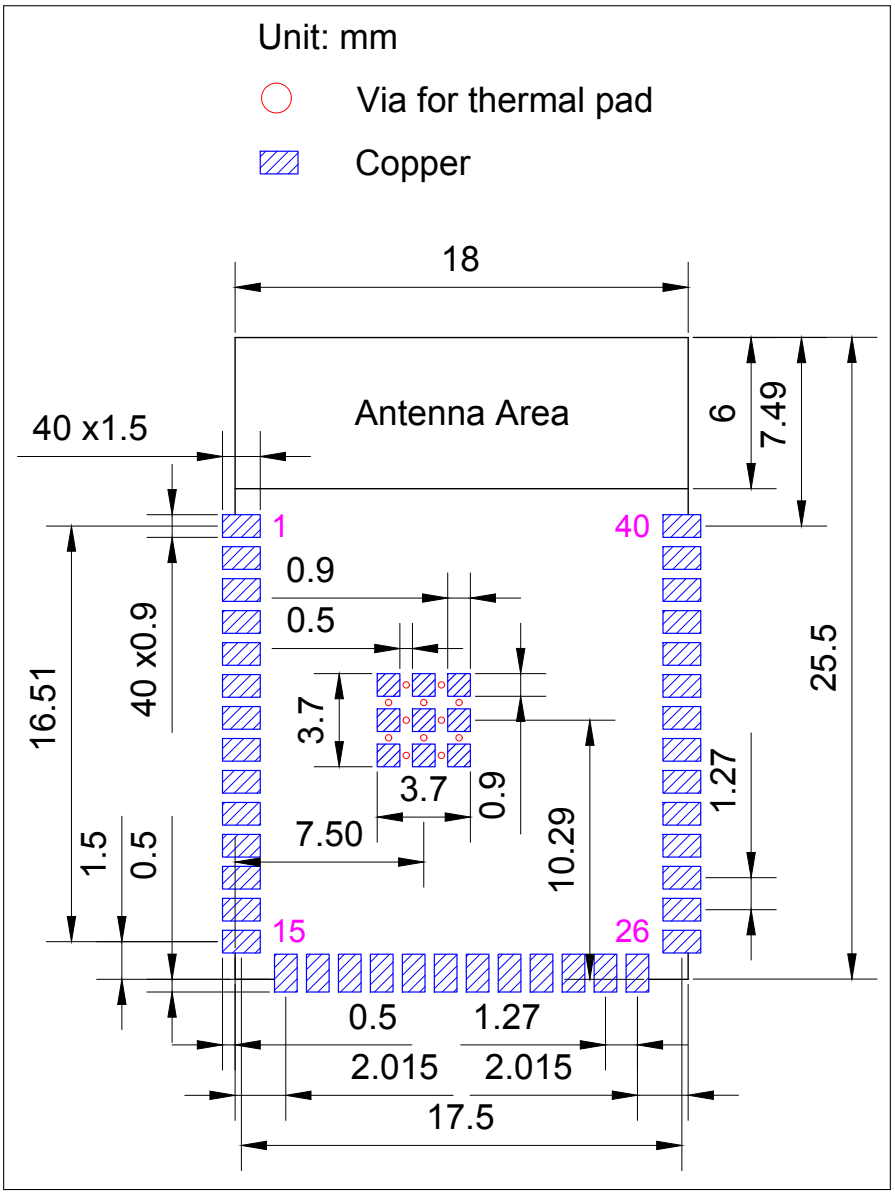

Figure 10: ESP32-S3-WROOM-1 Recommended PCB Land Pattern

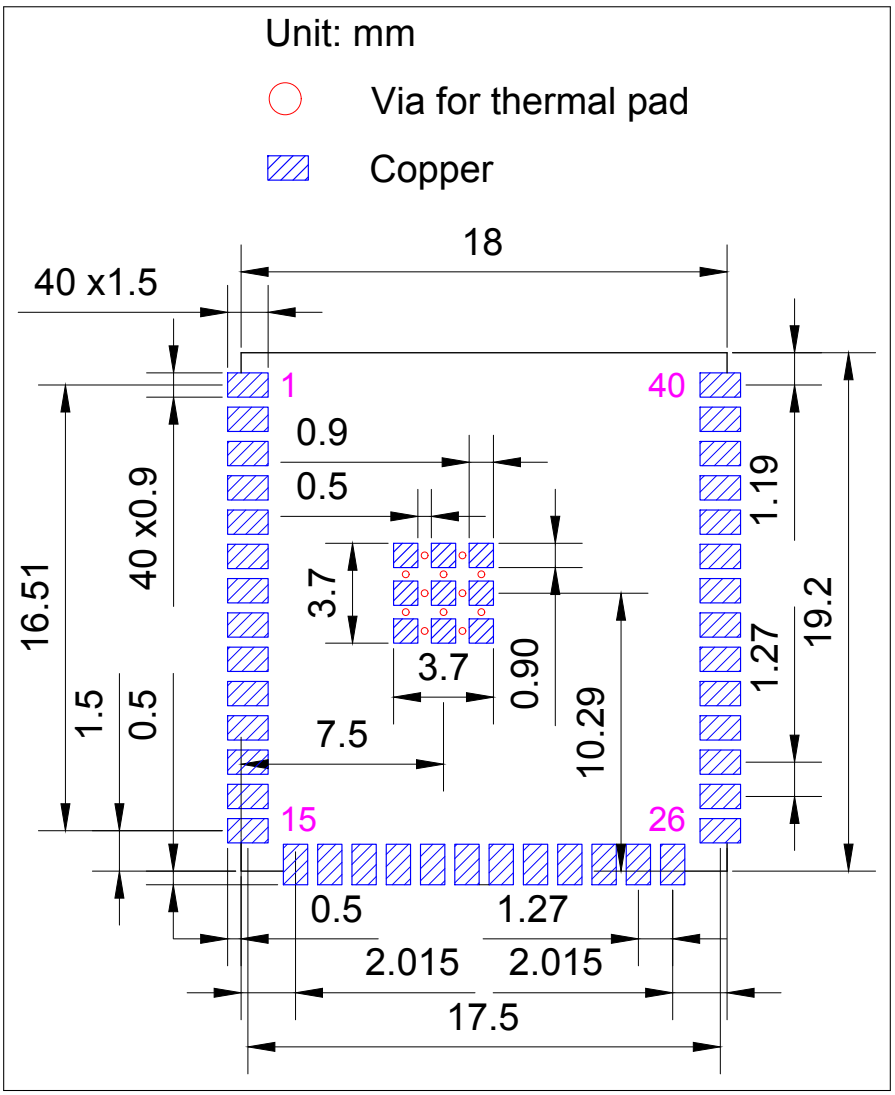

Figure 11: ESP32-S3-WROOM-1U Recommended PCB Land Pattern

7.3 Dimensions of External Antenna Connector

ESP32-S3-WROOM-1U uses the first generation external antenna connector as shown in Figure 12. This connector is compatible with the following connectors:

- U.FL Series connector from Hirose
- MHF I connector from I-PEX
- AMC connector from Amphenol

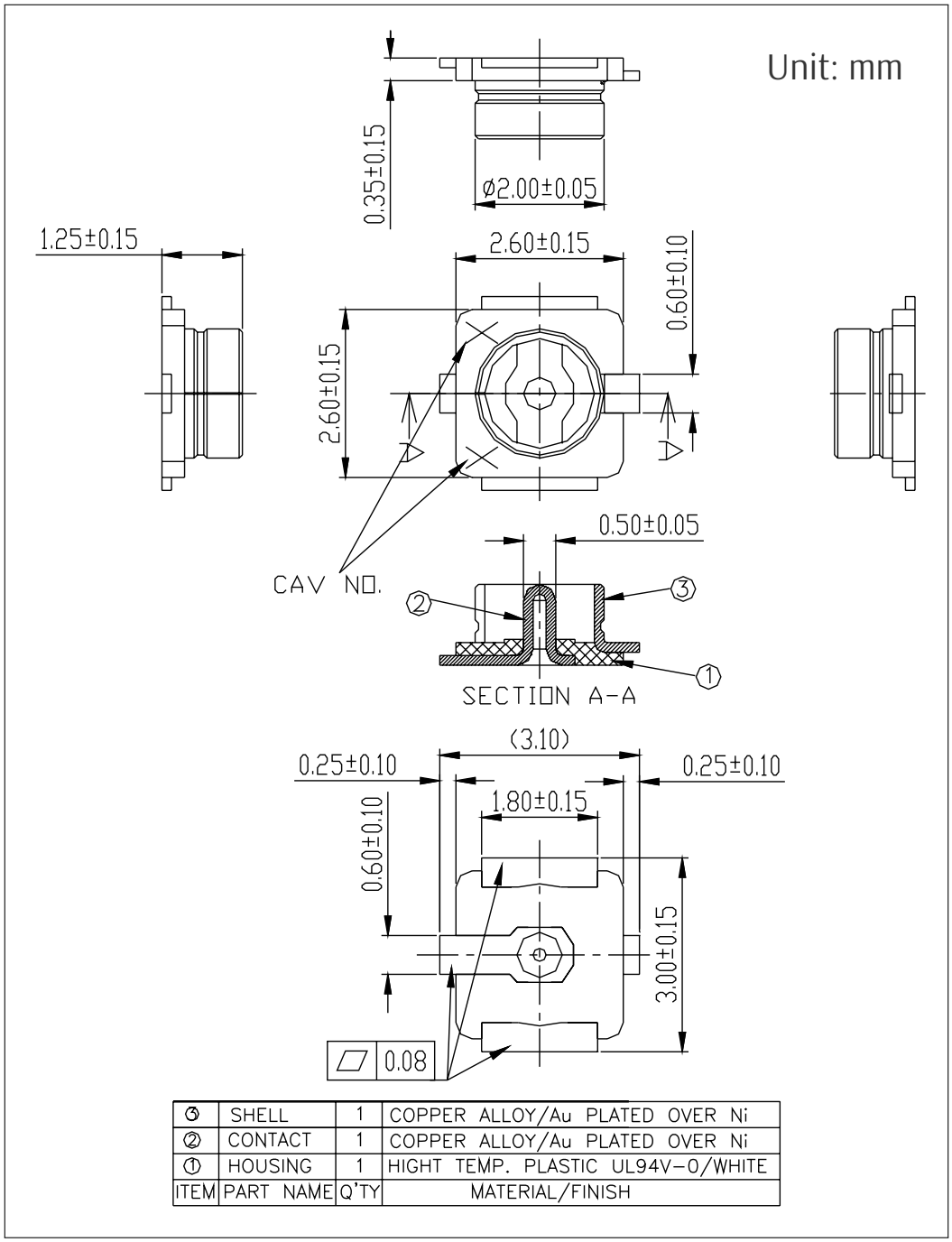

Figure 12: Dimensions of External Antenna Connector

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.

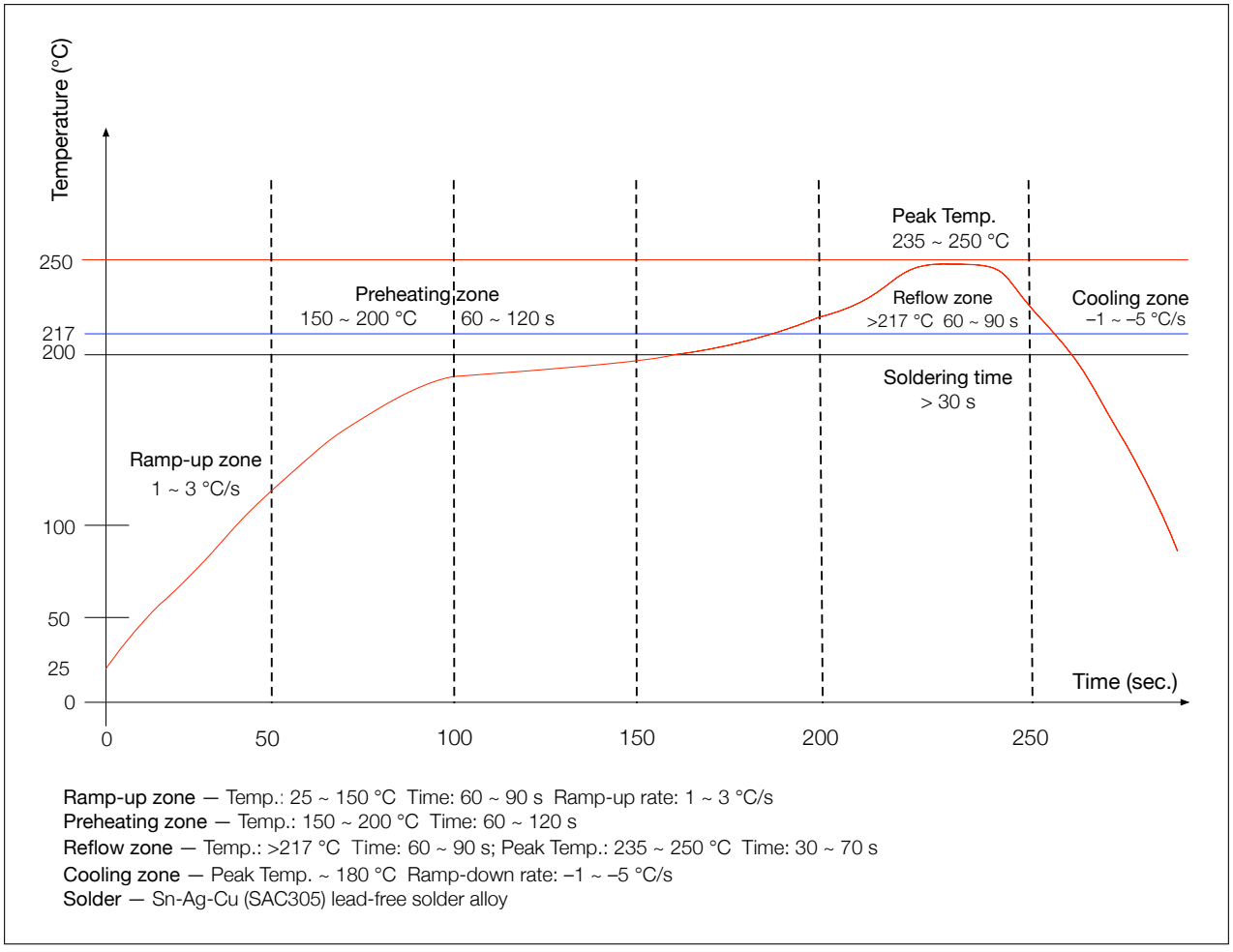

Figure 13: Reflow Profile

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
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Revision History

Date	Version	Release notes
2022-07-22	v1.1	• Update Table 1 and Table 2 • Other minor updates
2022-04-21	v1.0	• Update Bluetooth LE RF data • Update power consumption data in Table 12 • Add certification and test information • Add Table 6 and update description of ROM code printing in Section 3.3
2021-10-29	v0.6	Overall update for chip revision 1
2021-07-19	v0.5.1	Preliminary release, for chip revision 0

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