ESP32-PICO-V3-ZERO

User Manual

Version 1.0

Espressif Systems

About This Document

This document provides the specifications for the ESP32-PICO-V3-ZERO module.

Document Updates

Please always refer to the latest version on https://www.espressif.com/en/support/download/documents.

Revision History

For revision history of this document, please refer to the last page.

Documentation Change Notification

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Certification

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1. Module Overview

1.1 Features

MCU

- ESP32 embedded, Xtensa® dual-core 32-bit LX6 microprocessor, up to 240 MHz
- 448 KB ROM for booting and core functions
- 520 KB SRAM for data and instructions
- 16 KB SRAM in RTC

Wi-Fi

- 802.11b/g/n20/n40
- 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 ~ 2462 MHz

Bluetooth®

- Bluetooth V4.2 BR/EDR and Bluetooth LE specification
- NZIF receiver with –97 dBm sensitivity
- Class-1, class-2 and class-3 transmitter
- AFH
- CVSD and SBC

Hardware

- Interfaces: 3 × UART, I^2C, I^2S, SPI, SDIO, touch pin, EN pin, interrupt pin and other GPIOs
- 40 MHz crystal oscillator
- 4 MB SPI flash
- Operating voltage/Power supply: 3.0 ~ 3.6 V
- Operating temperature range: –40 ~ 85 °C
- Dimensions: (16 × 23 × 2.3) mm

Certification

- Bluetooth certification: BQB
- RF certification: FCC/CE-RED/SRRC/IC
- Green certification: REACH/RoHS

1.2 Description

The ESP32-PICO-V3-ZERO is a module that is based on ESP32-PICO-V3, a System-in-Package (SiP) device. It provides complete Wi-Fi and Bluetooth® functionalities. The module integrates a 4 MB SPI flash.

At the core of this module is the ESP32 chip, which is a single 2.4 GHz Wi-Fi and Bluetooth combo chip designed with TSMC's 40 nm low-power technology. ESP32-PICO-V3-ZERO integrates all peripheral components seamlessly, including a crystal oscillator, flash, filter capacitors and RF matching links in one single package. Module assembly and testing are already done at SiP level. As such, ESP32-PICO-V3-ZERO reduces the complexity of supply chain and improves control efficiency.

With its ultra-small size, robust performance and low-energy consumption, ESP32-PICO-V3-ZERO is well suited for any space-limited or battery-operated applications, such as wearable electronics, medical equipment, sensors and other IoT products.

Note:

- For more information on ESP32, please refer to *ESP32 User Manual*.
- For more information on ESP32-PICO-V3, please refer to *ESP32-PICO-V3 User Manual*.

1.3 Applications

- Generic Low-power IoT Sensor Hub
- Generic Low-power IoT Data Loggers
- Cameras for Video Streaming
- Over-the-top (OTT) 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

2. Pin Definitions

2.1 Pin Layout

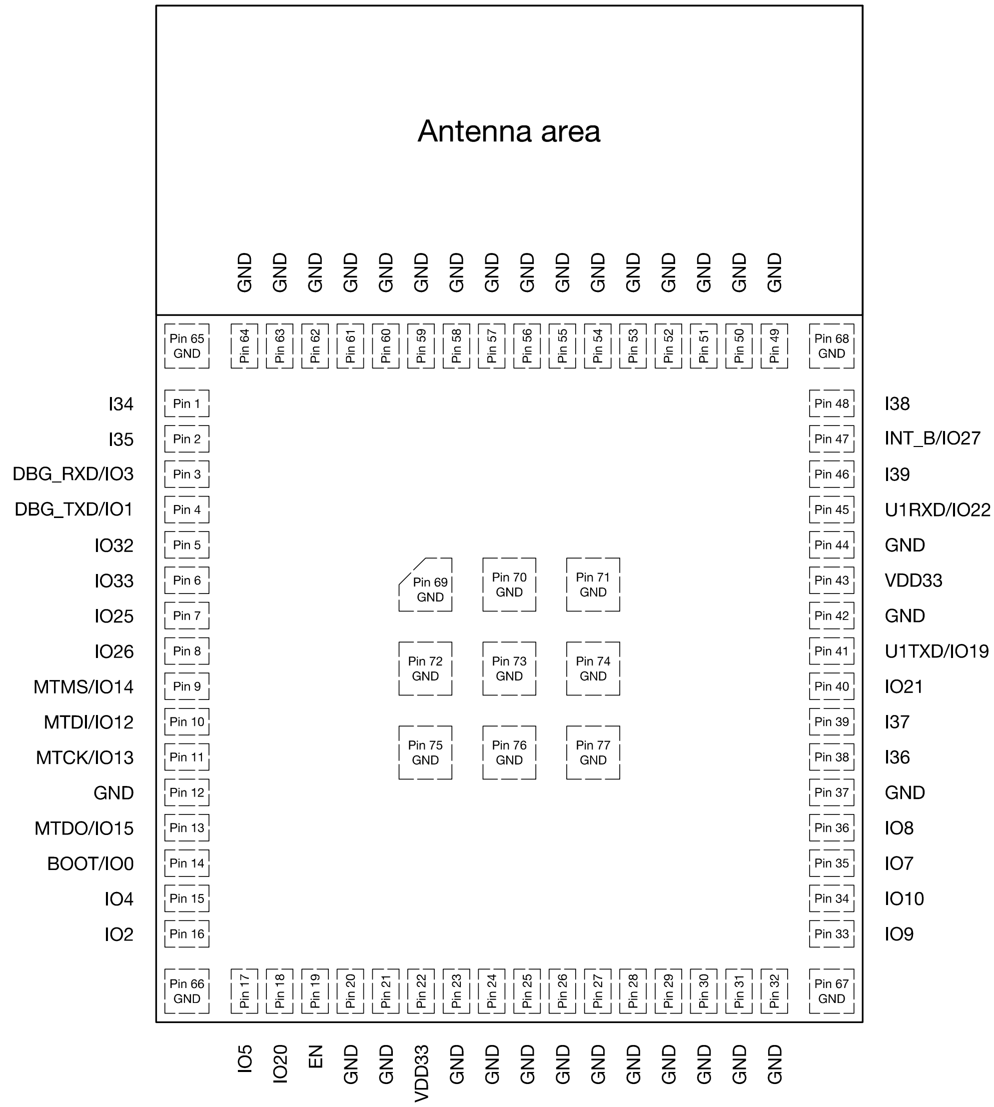


Figure 1: Pin Layout of ESP32-PICO-V3-ZERO (Top View)

> **Note:**
> The pin diagram shows the approximate location of pins on the module. For the actual mechanical diagram, please refer to Figure 7 *Physical Dimensions*.

2.2 Pin Description

The ESP32-PICO-V3-ZERO module has 77 pins. See pin definitions in Table 1.

Table 1: Pin Definitions

Name	No.	Type	Function
I34	1	I	GPIO34
I35	2	I	GPIO35
DBG_RXD/IO3	3	I/O	GPIO3, Debugging UART RX
DBG_TXD/IO0	4	I/O	GPIO1, Debugging UART TX
IO32	5	I/O	GPIO32
IO33	6	I/O	GPIO33
IO25	7	I/O	GPIO25
IO26	8	I/O	GPIO26
MTMS/IO14	9	I/O	GPIO14, MTMS
MTDI/IO12	10	I/O	GPIO12, MTDI
MTCK/IO13	11	I/O	GPIO13, MTCK
MTDO/IO15	13	I/O	GPIO15, MTDO
BOOT/IO0	14	I/O	GPIO0
IO4	15	I/O	GPIO4
IO2	16	I/O	GPIO2
IO5	17	I/O	GPIO5
IO20	18	I/O	GPIO20. See note 1 under the table.
EN	19	I	High: On; enables the module Low: Off; the module powers off Note: Do not leave this pin floating.
VDD33	22	P	Power supply (3.0 V ~ 3.6 V)
IO9	33	I/O	GPIO9. See note 1 under the table.
IO10	34	I/O	GPIO10. See note 1 under the table.
IO7	35	I/O	GPIO7. See note 1 under the table.
IO8	36	I/O	GPIO8. See note 1 under the table.
I36	38	I	GPIO36
I37	39	I	GPIO37
IO21	40	I/O	GPIO21
U1TXD/IO19	41	O	UART TX, connected to host RX, GPIO19
VDD33	43	P	Power supply (3.0 V ~ 3.6 V)
U1RXD/IO22	45	I	UART RX, connected to host TX, GPIO22
I39	46	I	GPIO39
INT_B/IO27	47	O	Host interrupt, connected to host GPIO, GPIO27
I38	48	I	GPIO38
GND	12, 20, 21, 23 ~ 32, 37, 42, 44, 49 ~ 77	P	Ground

Note:

1. IO7/IO8/IO9/IO10/IO20 belong to VDD_SDIO power domain and cannot work when VDD_SDIO power shuts down.
2. For peripheral pin configurations, please refer to *ESP32 User Manual*.

2.3 Strapping Pins

ESP32 has five strapping pins: MTDI, GPIO0, GPIO2, MTDO, GPIO5. The pin-pin mapping between ESP32 and the module is as follows, which can be seen in Chapter 5 *Schematics*:

- MTDI = IO12
- GPIO0 = BOOT/IO0
- GPIO2 = IO2
- MTDO = IO15
- GPIO5 = IO5

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

During the chip's system reset release (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's boot mode, the operating voltage of VDD_SDIO and other initial system settings.

Each strapping pin is connected to 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 use the host MCU's GPIOs to control the voltage level of these pins when powering on ESP32.

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

Refer to Table 2 for a detailed boot-mode configuration by strapping pins.

Table 2: Strapping Pins

Voltage of Internal LDO (VDD_SDIO)					
Pin	Default	3.3 V		1.8 V	
MTDI	Pull-down	0		1	
Booting Mode					
Pin	Default	SPI Boot		Download Boot	
GPIO0	Pull-up	1		0	
GPIO2	Pull-down	Don't-care		0	
Enabling/Disabling Debugging Log Print over U0TXD During Booting					
Pin	Default	U0TXD Active		U0TXD Silent	
MTDO	Pull-up	1		0	
Timing of SDIO Slave					
Pin	Default	FE Sampling FE Output	FE Sampling RE Output	RE Sampling FE Output	RE Sampling RE Output
MTDO	Pull-up	0	0	1	1
GPIO5	Pull-up	0	1	0	1

Note:

- FE: falling-edge, RE: rising-edge.
- Firmware can configure register bits to change the settings of ”Voltage of Internal LDO (VDD_SDIO)” and ”Timing of SDIO Slave”, after booting.
- The operating voltage of ESP32-PICO-V3-ZERO’s integrated external SPI flash is 3.3 V. Therefore, the strapping pin MTDI should hold bit ”0” during the module power-on reset.

3. Electrical Characteristics

3.1 Absolute Maximum Ratings

Stresses beyond the absolute maximum ratings listed in the table below may cause permanent damage to the device. These are stress ratings only, and do not refer to the functional operation of the device that should follow the recommended operating conditions.

Table 3: Absolute Maximum Ratings

Symbol	Parameter	Min	Max	Unit
VDD33	Power supply voltage	3.0	3.6	V
T_{STORE}	Storage temperature	–40	85	°C

Note:
Please see Appendix IO_MUX of *ESP32 User Manual* for IO's power domain.

3.2 Recommended Operating Conditions

Table 4: 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	Operating temperature	–40	—	85	°C
Humidity	Humidity condition	—	85	—	%RH

3.3 DC Characteristics (3.3 V, 25 °C)

Table 5: 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}	High-level output voltage	0.8×VDD[1]	-	-	V
V_{OL}	Low-level output voltage	-	-	0.1×VDD[1]	V

Symbol	Parameter		Min	Typ	Max	Unit
I_{OH}	High-level source current (VDD[1] = 3.3 V, V_{OH} >= 2.64 V, output drive strength set to the maximum)	VDD3P3_CPU power domain [1, 2]	-	40	-	mA
		VDD3P3_RTC power domain [1, 2]	-	40	-	mA
		VDD_SDIO power domain [1, 3]	-	20	-	mA
I_{OL}	Low-level sink current (VDD[1] = 3.3 V, V_{OL} = 0.495 V, output drive strength set to the maximum)		-	28	-	mA
R_{PU}	Resistance of internal pull-up resistor		-	45	-	kΩ
R_{PD}	Resistance of internal pull-down resistor		-	45	-	kΩ
V_{IL_nRST}	Low-level input voltage of CHIP_PU to power off the chip		-	-	0.6	V

Note:

1. Please see Appendix IO_MUX of ESP32 *User Manual* for IO's power domain. VDD is the I/O voltage for a particular power domain of pins.
2. For VDD3P3_CPU and VDD3P3_RTC power domain, per-pin current sourced in the same domain is gradually reduced from around 40 mA to around 29 mA, V_{OH}>=2.64 V, as the number of current-source pins increases.
3. Pins occupied by flash and/or PSRAM in the VDD_SDIO power domain were excluded from the test.

3.4 Current Consumption Characteristics

With the use of advanced power-management technologies, ESP32 can switch between different power modes. For details on different power modes, please refer to Section *RTC and Low-Power Management* in ESP32 *User Manual*.

Table 6: Current Consumption Depending on RF Modes

Work mode	Description		Average (mA)	Peak (mA)
Active (RF working)	TX	802.11b, 20 MHz, 1 Mbps	233	368
		802.11g, 20 MHz, 54 Mbps	181	258
		802.11n, 20 MHz, MCS7	178	248
		802.11n, 40 MHz, MCS7	162	205
	RX	802.11b/g/n, 20 MHz	110	111
		802.11n, 40 MHz	116	117

Note:

- 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 50% duty cycle.
- The current consumption figures for in RX mode are for cases when the peripherals are disabled and the CPU idle.

Table 7: Current Consumption Depending on Work Modes

Work mode	Description		Current consumption (Typ)
Modem-sleep	The CPU is powered on	240 MHz	30 ~ 68 mA
		160 MHz	27 ~ 44 mA
		Normal speed: 80 MHz	20 ~ 31 mA
Light-sleep	—		0.8 mA
Deep-sleep	The ULP co-processor is powered on.		150 μA
	ULP sensor-monitored pattern		100 μA @1% duty
	RTC timer + RTC memory		10 μA
	RTC timer only		5 μA
Power off	CHIP_PU is set to low level, the chip is powered off.		1 μA

Note:

- The current consumption figures in Modem-sleep mode are for cases where the CPU is powered on and the cache idle.
- When Wi-Fi is enabled, the chip switches between Active and Modem-sleep modes. Therefore, current 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 operate.
- The "ULP sensor-monitored pattern" refers to the mode where the ULP coprocessor or the sensor works periodically. When ADC works with a duty cycle of 1%, the typical current consumption is 100 μA.

3.5 Wi-Fi RF Characteristics

3.5.1 Wi-Fi RF Standards

Table 8: Wi-Fi RF Standards

Name		Description
Center frequency range of operating channel ^{note1}		2412 ~ 2462MHz
Wi-Fi wireless standard		IEEE 802.11b/g/n20/n40
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

Note:

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 IPEX antennas, the output impedance is 50 Ω. For other modules without IPEX antennas, users do not need to concern about the output impedance.

3.5.2 Transmitter Characteristics

Table 9: Transmitter Characteristics

Parameter	Condition	Unit
TX Power ^{note}	802.11b: 24.41dBm 802.11g: 23.64dBm 802.11n20: 23.30dBm 802.11n40: 21.95dBm	dBm

Note:
Target TX power is configurable based on device or certification requirements.

3.5.3 Receiver Characteristics

Table 10: Receiver Characteristics

Parameter	Rate	Typ	Unit
RX Sensitivity	1 Mbps	–97	dBm
	2 Mbps	–94	
	5.5 Mbps	–91	
	11 Mbps	–88	
	6 Mbps	–92	
	9 Mbps	–91	
	12 Mbps	–89	
	18 Mbps	–87	
	24 Mbps	–84	
	36 Mbps	–80	
	48 Mbps	–76	
	54 Mbps	–75	
	11n, HT20, MCS0	–91	
	11n, HT20, MCS1	–88	
	11n, HT20, MCS2	–85	
	11n, HT20, MCS3	–83	
	11n, HT20, MCS4	–80	
	11n, HT20, MCS5	–75	
	11n, HT20, MCS6	–74	
	11n, HT20, MCS7	–72	
	11n, HT40, MCS0	–88	
	11n, HT40, MCS1	–85	
	11n, HT40, MCS2	–82	

Parameter	Rate	Typ	Unit
	11n, HT40, MCS3	–80	
	11n, HT40, MCS4	–76	
	11n, HT40, MCS5	–72	
	11n, HT40, MCS6	–71	
	11n, HT40, MCS7	–69	
RX Maximum Input Level	11b, 1 Mbps	5	dBm
	11b, 11 Mbps	5	
	11g, 6 Mbps	0	
	11g, 54 Mbps	–8	
	11n, HT20, MCS0	0	
	11n, HT20, MCS7	–8	
	11n, HT40, MCS0	0	
	11n, HT40, MCS7	–8	
Adjacent Channel Rejection	11b, 11 Mbps	35	dB
	11g, 6 Mbps	27	
	11g, 54 Mbps	13	
	11n, HT20, MCS0	26	
	11n, HT20, MCS7	12	
	11n, HT40, MCS0	16	
	11n, HT40, MCS7	7	

3.6 Bluetooth/LE Radio

3.6.1 Receiver – Basic Data Rate

Table 11: Receiver Characteristics – Basic Data Rate

Parameter	Conditions	Min	Typ	Max	Unit
Sensitivity @0.1% BER	-	-	–88	-	dBm
Maximum received signal @0.1% BER	-	0	-	-	dBm
Co-channel C/I	-	-	+7	-	dB
Adjacent channel selectivity C/I	F = F0 + 1 MHz	-	-	–6	dB
	F = F0 – 1 MHz	-	-	–6	dB
	F = F0 + 2 MHz	-	-	–25	dB
	F = F0 – 2 MHz	-	-	–33	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

Parameter	Conditions	Min	Typ	Max	Unit
Intermodulation	-	–36	-	-	dBm

3.6.2 Transmitter

Table 16: Transmitter Characteristics

Parameter	Conditions	Min	Typ	Max	Unit
RF Frequency	-	2402	-	2480	MHz
Gain control step	-	-	3	-	dB
RF power	-	BT3.0:8.74dBm;BLE:6.08dBm			dBm
Adjacent channel transmit power	F = F0 ± 2 MHz	-	–55	-	dBm
	F = F0 ± 3 MHz	-	–57	-	dBm
	F = F0 ± > 3 MHz	-	–59	-	dBm
$\Delta\ f1_{\text{avg}}$	-	-	-	265	kHz
$\Delta\ f2_{\text{max}}$	-	210	-	-	kHz
$\Delta\ f2_{\text{avg}}/\Delta\ f1_{\text{avg}}$	-	-	+0.92	-	-
ICFT	-	-	–10	-	kHz
Drift rate	-	-	0.7	-	kHz/50 μs
Drift	-	-	2	-	kHz

Note:
There are a total of eight power levels from 0 to 7, and the transmit power ranges from –12 dBm to 9 dBm. When the power level rises by 1, the transmit power increases by 3 dB. Power level 4 is used by default and the corresponding transmit power is 0 dBm.

Note:
To ensure the power supply to the ESP32 chip 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 = 0.1 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's power-up and reset sequence timing diagram, please refer to Section *Power Scheme* in ESP32 *User Manual*.

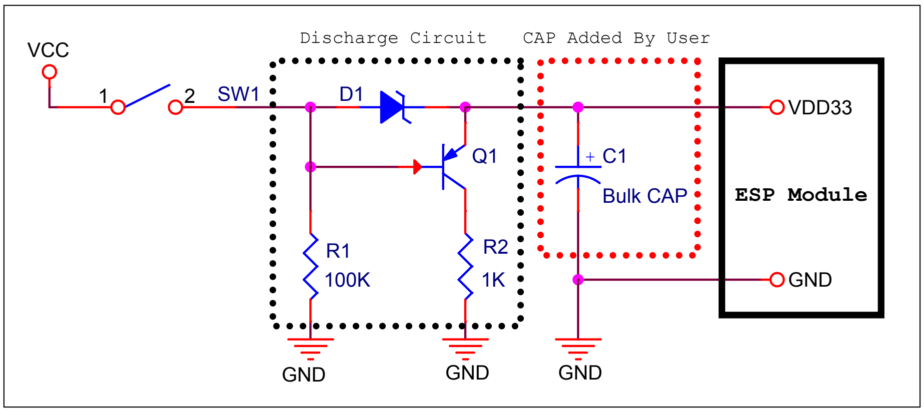


Figure 2: Discharge Circuit for VDD33 Rail

Note:
The discharge circuit can be applied in scenarios where ESP32 is powered on and off repeatedly by switching the power rails, and there is a large capacitor on the VDD33 rail. For details, please refer to Section *Power Scheme* in ESP32 *User Manual*.

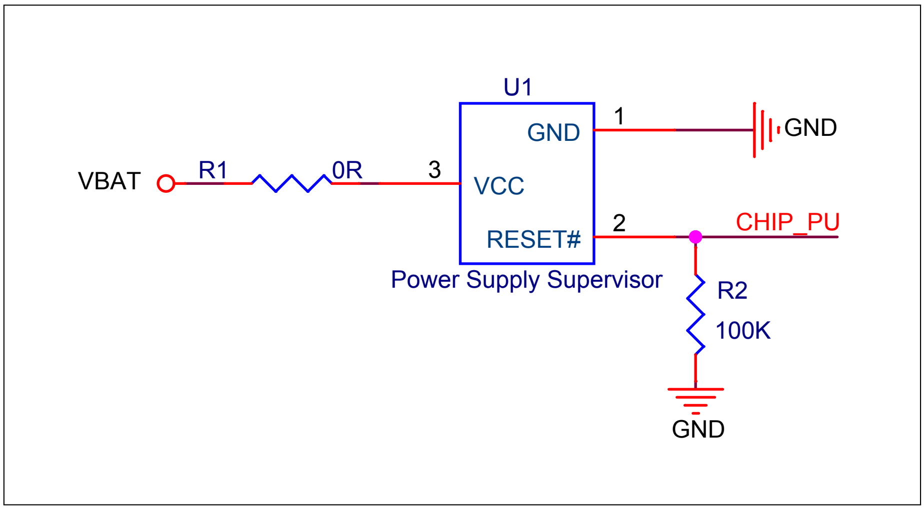


Figure 3: Reset Circuit

Note:
When battery is used as the power supply for ESP32 series of chips and modules, a supply voltage supervisor is recommended to avoid boot failure due to low voltage. Users are recommended to pull CHIP_PU low if the power supply for ESP32 is below 3.0 V.

5. Physical Dimensions and PCB Layout

5.1 Physical Dimensions

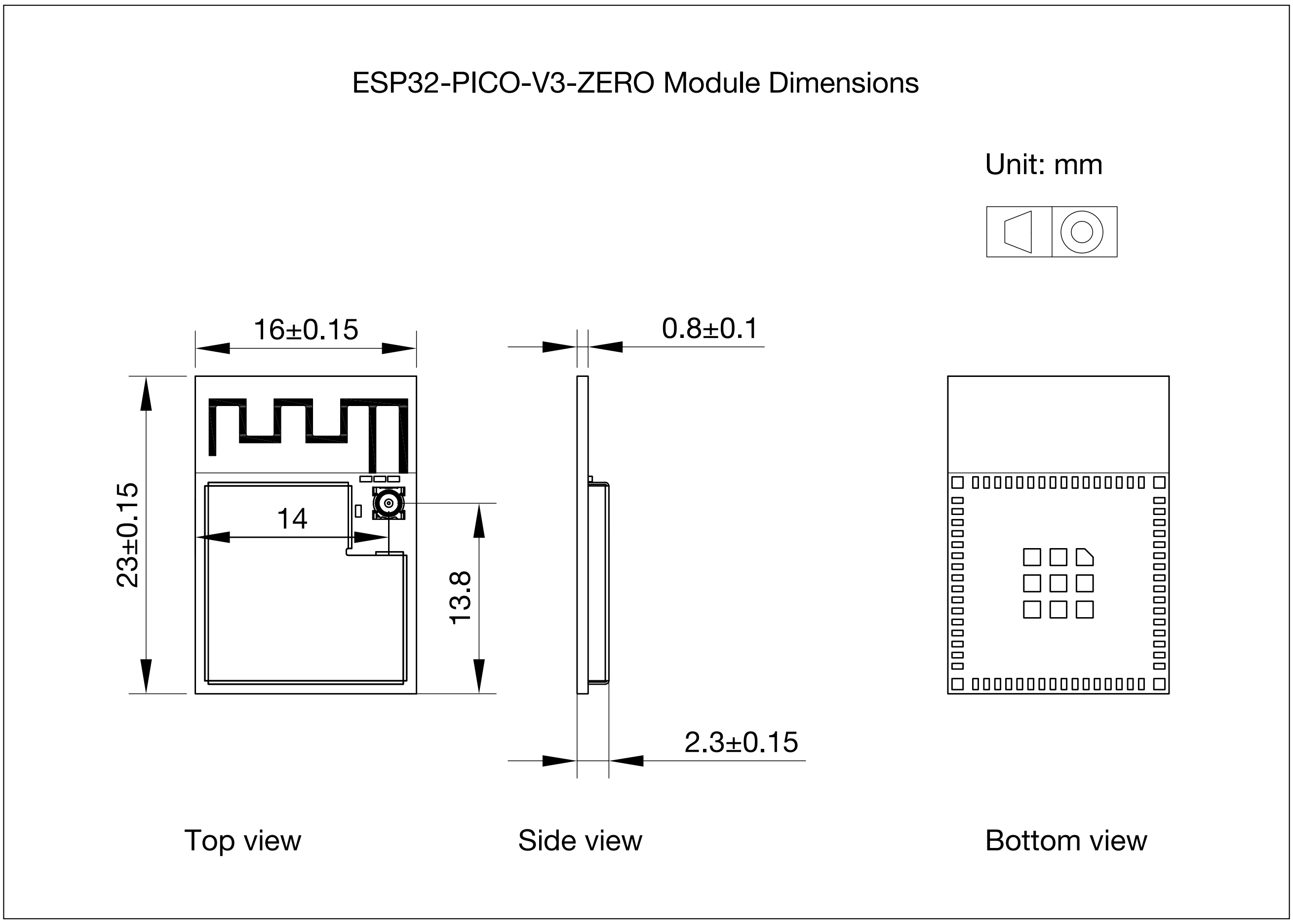


Figure4: Physical Dimensions

5.2 PCB Layout

5.2.1 Recommended PCB Land Pattern

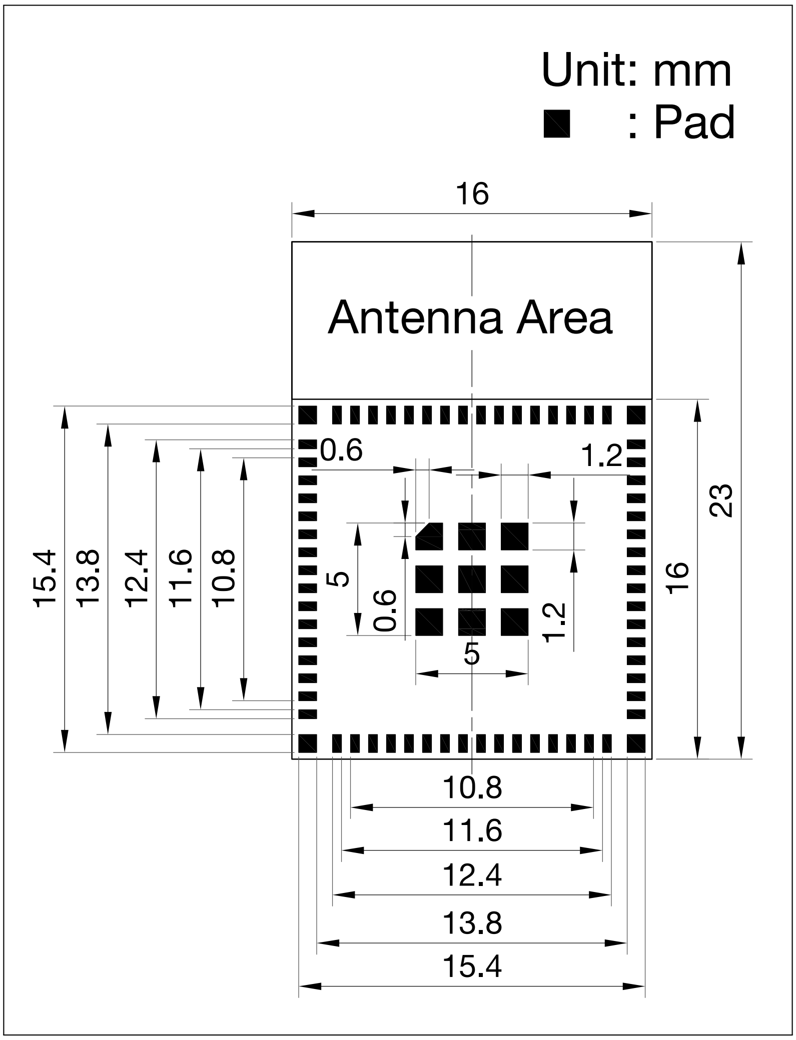


Figure 5: Recommended PCB Land Pattern

5.2.2 PCB Layout Guide

To achieve the optimum RF performance on a device with on-board antenna, please follow the guidelines below.

The module uses an inverted-F antenna design, and the antenna area of the module should have specific placement against the base board. The feed point of the antenna should be as close to the board as possible. The PCB antenna area should be placed outside the base board whenever possible while the module be put as close as possible to the edge of the base board.

As is shown in Figure 9, examples 3 and 4 of the module position on the base board are highly recommended, while examples 1, 2, and 5 are not recommended.

6. Product Handling

6.1 Storage Condition

The products sealed in Moisture Barrier Bag (MBB) should be stored in a noncondensing atmospheric environment of < 40 °C/90%RH.

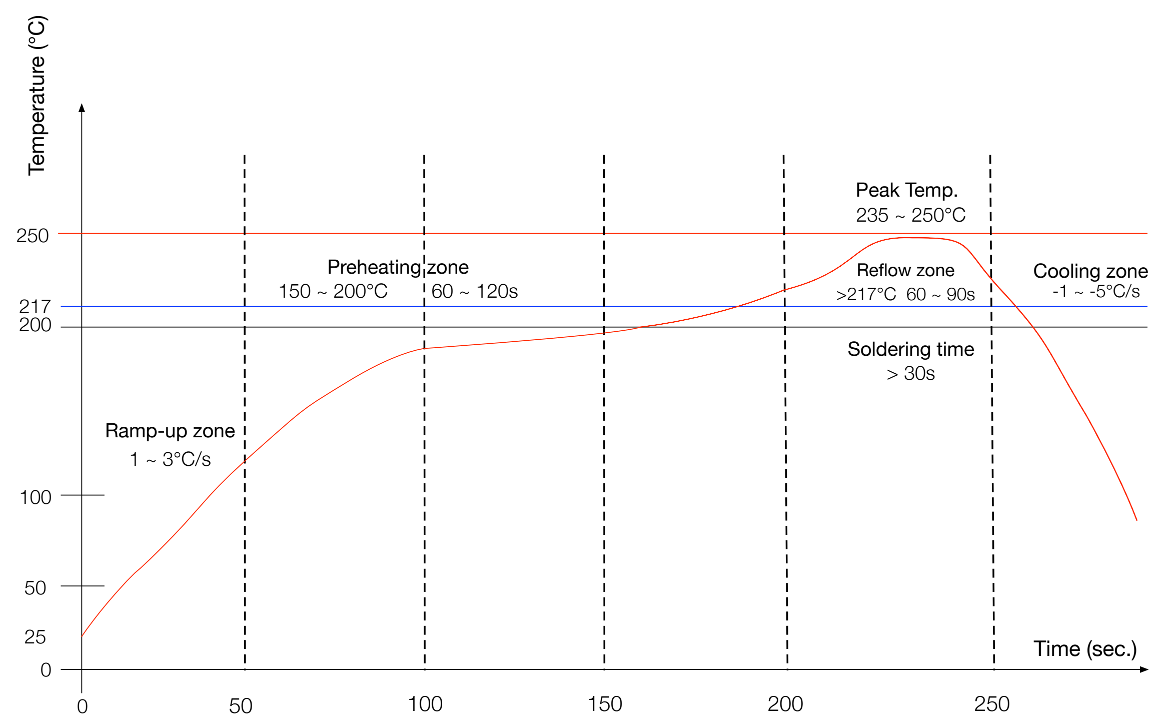
The module is rated at moisture sensitivity level (MSL) 3.

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

6.2 ESD

- Human body model (HBM): 2000 V
- Charged-device model (CDM): 500 V
- Air discharge: 6000 V
- Contact discharge: 4000 V

6.3 Reflow Profile



Ramp-up zone — Temp.: <150°C Time: 60 ~ 90s Ramp-up rate: 1 ~ 3°C/s
Preheating zone — Temp.: 150 ~ 200°C Time: 60 ~ 120s Ramp-up rate: 0.3 ~ 0.8°C/s
Reflow zone — Temp.: >217°C Time: 60 ~ 90s; Peak Temp.: 235 ~ 250°C (<245°C recommended) Time: 30 ~ 70s
Cooling zone — Peak Temp. ~ 180°C Ramp-down rate: -1 ~ -5°C/s
Solder — Sn&Ag&Cu Lead-free solder (SAC305)

Figure 6: Reflow Profile

> **Note:**
> Solder the module in a single reflow. If the PCBA requires multiple reflows, place the module on the PCB during the final reflow.

7. MAC Addresses and eFuse

The eFuse in ESP32 has been burnt into 48-bit mac_address. The actual addresses the chip uses in station, AP, BLE, and Ethernet modes correspond to mac_address in the following way:

- Station mode: mac_address
- AP mode: mac_address + 1
- BLE mode: mac_address + 2
- Ethernet mode: mac_address + 3

In the 1 Kbit eFuse, 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.

8. Learning Resources

8.1 Must-Read Documents

The following link provides documents related to ESP32.

- *ESP32 User Manual*
  This document provides an introduction to the specifications of the ESP32 hardware, including overview, pin definitions, functional description, peripheral interface, electrical characteristics, etc.
- *ESP32 ECO V3 User Guide*
  This document describes differences between V3 and previous ESP32 silicon wafer revisions.
- *ECO and Workarounds for Bugs in ESP32*
  This document details hardware errata and workarounds in the ESP32.
- *ESP-IDF Programming Guide*
  It hosts extensive documentation for ESP-IDF ranging from hardware guides to API reference.
- *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 the ESP32 chip, the ESP32 modules and development boards.
- *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.
- *Espressif Products Ordering Information*

8.2 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.

Revision History

Date	Version	Release notes
2020-04-08	V1.0	First release.

OEM Guidance

1. Applicable FCC rules

   This module is granted by Single Modular Approval. It complies to the requirements of FCC part 15C, section 15.247 rules.

2. The specific operational use conditions

   This module can be used in IoT devices. The input voltage to the module is nominally 3.0V-3.6 V DC. The operational ambient temperature of the module is –40 °C ~ 85 °C. Only the embedded PCB antenna is allowed. Any other external antenna is prohibited.

3. Limited module procedures

   N/A

4. Trace antenna design

   N/A

5. RF exposure considerations

   The equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance 20cm between the radiator and your body. If the equipment built into a host as a portable usage, the additional RF exposure evaluation may be required as specified by 2.1093.

6. Antenna

Antenna type: PCB antenna Peak gain: 3dBi

7. Label and compliance information

An exterior label on OEM's end product can use wording such as the following:
"Contains Transmitter Module FCC ID: 2AC7Z-ESP32PICOZERO" or
"Contains FCC ID: 2AC7Z-ESP32PICOZERO"

8. Information on test modes and additional testing requirements

a)The modular transmitter has been fully tested by the module grantee on the required number of channels,modulation types, and modes, it should not be necessary for the host installer to re-test all the available transmitter modes or settings. It is recommended that the host product manufacturer, installing the modular transmitter,perform some investigative measurements to confirm that the resulting composite system does not exceed the spurious emissions limits or band edge limits (e.g., where a different antenna may be causing additional emissions).
b)The testing should check for emissions that may occur due to the intermixing of emissions with the other transmitters, digital circuitry, or due to physical properties of the host product (enclosure). This investigation is especially important when integrating multiple modular transmitters where the certification is based on testing each of them in a stand-alone configuration. It is important to note that host product manufacturers should not assume that because the modular transmitter is certified that they do not have any responsibility for final product compliance.
c)If the investigation indicates a compliance concern the host product manufacturer is obligated to mitigate the issue. Host products using a modular transmitter are subject to all the applicable individual technical rules as well as to the general conditions of operation in Sections 15.5, 15.15, and 15.29 to not cause interference. The operator of the host product will be obligated to stop operating the device until the interference have been corrected .

9. Additional testing, Part 15 Sub part B disclaimer The final host / module combination need to be evaluated against the FCC Part 15B criteria for unintentional radiators in order to be properly authorized for operation as a Part 15 digital device.

The host integrator installing this module into their product must ensure that the final composite product complies with the FCC requirements by a technical assessment or evaluation to the FCC rules, including the transmitter operation and should refer to guidance in KDB 996369. For host products with certified modular transmitter, the frequency range of investigation of the composite system is specified by rule in Sections 15.33(a)(1) through (a)(3), or the range applicable to the digital device, as shown in Section 15.33(b)(1), whichever is the higher frequency range of investigation When testing the host product, all the transmitters must be operating.The transmitters can be enabled by using publicly-available drivers and turned on, so the transmitters are active. In certain conditions it might be appropriate to use a technology-specific call box (test set) where accessory 50 devices or drivers are not available. When testing for emissions from the unintentional radiator, the transmitter shall be placed in the receive mode or idle mode, if possible. If receive mode only is not possible then, the radio shall be passive (preferred) and/or active scanning. In these cases, this would need to enable activity on the communication BUS (i.e., PCIe, SDIO, USB) to ensure the unintentional radiator circuitry is enabled. Testing laboratories may need to add attenuation or filters depending on the signal strength of any active beacons (if applicable) from the enabled radio(s). See ANSI C63.4, ANSI C63.10 and ANSI C63.26 for further general testing details.
The product under test is set into a link/association with a partnering device, as per the normal intended use of the product. To ease testing, the product under test is set to transmit at a high duty cycle, such as by sending a file or streaming some media content.

FCC Warning:
Any Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment. This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) This device must accept any interference received, including interference that may cause undesired operation