ESP32-MINI-1U

Datasheet

Containing Ultra-Low-Power SoC with SingleCore CPU
Supporting 2.4 GHz Wi-Fi, Bluetooth, and Bluetooth LE

Pre-release v0.5
Espressif Systems

About This Document

This document provides specifications for the ESP32-MINI-1U 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.

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1 Module Overview

1.1 Features

MCU

- ESP32-U4WDH embedded, Xtensa® single-core 32-bit LX6 microprocessor, up to 160 MHz
- 448 KB ROM
- 520 KB SRAM
- 16 KB SRAM in RTC

Wi-Fi

- 802.11b/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

  Power Conducted:15dBm

  Bluetooth®

- Bluetooth V4.2 BR/EDR and Bluetooth LE specification

  Power Conducted:7dBm

- Class-1, class-2, and class-3 transmitter
- AFH
- CVSD and SBC

Hardware

- Interfaces: SD card, UART, SPI, SDIO, I2C, LED PWM, motor PWM, I2S, infrared remote controller, pulse counter, GPIO, touch sensor, ADC, DAC, Two-Wire Automotive Interface (TWAI®, compatible with ISO11898-1)
- 40 MHz crystal oscillator
- 4 MB SPI flash
- Operating voltage/Power supply: 3.0 ~ 3.6 V
- Operating temperature range: –40 ~ 85 °C
- Dimensions: (13.20 ± 0.15) × (13.50 ± 0.15) × (2.40 ± 0.15) mm (including shield cover)

Certification

- Green certification: REACH/RoHS

1.2 Description

ESP32-MINI-1U is a highly-integrated, small-sized Wi-Fi + Bluetooth + Bluetooth LE MCU module that has a rich set of peripherals. This module is an ideal choice for a wide variety of IoT applications, ranging from home automation, smart building, consumer electronics to industrial control, especially suitable for applications within a compact space, such as bulbs, switches and sockets.

ESP32-MINI-1U is an SMD module, with 4 MB SPI flash and a U.FL to connect with an external IPEX antenna. At the core of this module is ESP32-U4WDH*, an Xtensa 32-bit LX6 CPU that operates at up to 160 MHz. The user can power off the CPU and make use of the low-power coprocessor to constantly monitor the peripherals for changes or exceeding of thresholds.

This ESP32 chip integrates a rich set of peripherals, ranging from capacitive touch sensor, Hall sensor, SD card interface, Ethernet, high-speed SPI, UART, I2S, I2C, etc.

> **Note:**
> * For more information on ESP32 chips, please refer to *ESP32 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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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 Section 7.1 *Physical Dimensions*.

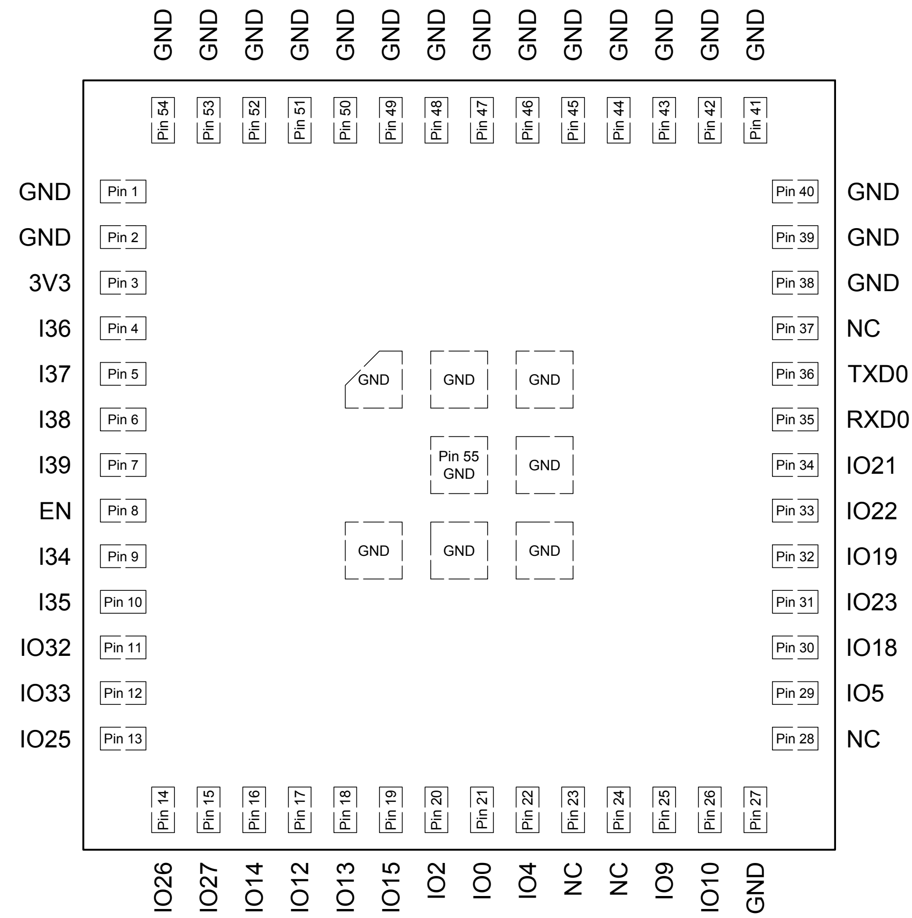


Figure 2: Pin Layout (Top View)

3.2 Pin Description

ESP32-MINI-1U has 55 pins. See pin definitions in Table 1.

Table 1: Pin Definitions

Name	No.	Type	Function
GND	1, 2, 27, 38 ~ 55	P	Ground
3V3	3	P	Power supply
I36	4	I	GPIO36, ADC1_CH0, RTC_GPIO0
I37	5	I	GPIO37, ADC1_CH1, RTC_GPIO1
I38	6	I	GPIO38, ADC1_CH2, RTC_GPIO2
I39	7	I	GPIO39, ADC1_CH3, RTC_GPIO3

Cont'd on next page

Table 1 – cont'd from previous page

Name	No.	Type	Function
EN	8	I	High: enables the chip Low: the chip powers off Note: do not leave the pin floating
I34	9	I	GPIO34, ADC1_CH6, RTC_GPIO4
I35	10	I	GPIO35, ADC1_CH7, RTC_GPIO5
IO32	11	I/O	GPIO32, XTAL_32K_P (32.768 kHz crystal oscillator input), ADC1_CH4, TOUCH9, RTC_GPIO9
IO33	12	I/O	GPIO33, XTAL_32K_N (32.768 kHz crystal oscillator output), ADC1_CH5, TOUCH8, RTC_GPIO8
IO25	13	I/O	GPIO25, DAC_1, ADC2_CH8, RTC_GPIO6, EMAC_RXD0
IO26	14	I/O	GPIO26, DAC_2, ADC2_CH9, RTC_GPIO7, EMAC_RXD1
IO27	15	I/O	GPIO27, ADC2_CH7, TOUCH7, RTC_GPIO17, EMAC_RX_DV
IO14	16	I/O	GPIO14, ADC2_CH6, TOUCH6, RTC_GPIO16, MTMS, HSPICLK, HS2_CLK, SD_CLK, EMAC_TXD2
IO12	17	I/O	GPIO12, ADC2_CH5, TOUCH5, RTC_GPIO15, MTDI, HSPIQ, HS2_DATA2, SD_DATA2, EMAC_TXD3
IO13	18	I/O	GPIO13, ADC2_CH4, TOUCH4, RTC_GPIO14, MTCK, HSPID, HS2_DATA3, SD_DATA3, EMAC_RX_ER
IO15	19	I/O	GPIO15, ADC2_CH3, TOUCH3, RTC_GPIO13, MTDO, HSPICS0, HS2_CMD, SD_CMD, EMAC_RXD3
IO2	20	I/O	GPIO2, ADC2_CH2, TOUCH2, RTC_GPIO12, HSPIWP, HS2_DATA0, SD_DATA0
IO0	21	I/O	GPIO0, ADC2_CH1, TOUCH1, RTC_GPIO11, CLK_OUT1, EMAC_TX_CLK
IO4	22	I/O	GPIO4, ADC2_CH0, TOUCH0, RTC_GPIO10, HSPIHD, HS2_DATA1, SD_DATA1, EMAC_TX_ER
NC	23	-	No connect
NC	24	-	No connect
IO9	25	I/O	GPIO9, HS1_DATA2, U1RXD, SD_DATA2
IO10	26	I/O	GPIO10, HS1_DATA3, U1TXD, SD_DATA3
NC	28	-	No connect
IO5	29	I/O	GPIO5, HS1_DATA6, VSPICS0, EMAC_RX_CLK
IO18	30	I/O	GPIO18, HS1_DATA7, VSPICLK
IO23	31	I/O	GPIO23, HS1_STROBE, VSPID
IO19	32	I/O	GPIO19, VSPIQ, U0CTS, EMAC_TXD0
IO22	33	I/O	GPIO22, VSPIWP, U0RTS, EMAC_TXD1
IO21	34	I/O	GPIO21, VSPIHD, EMAC_TX_EN
RXD0	35	I/O	GPIO3, U0RXD, CLK_OUT2
TXD0	36	I/O	GPIO1, U0TXD, CLK_OUT3, EMAC_RXD2
NC	37	-	No connect

[1] Pins GPIO6, GPIO7, GPIO8, GPIO11, GPIO16, and GPIO17 on the ESP32-U4WDH chip are connected to the SPI flash integrated on the module and are not led out.

[2] For peripheral pin configurations, please refer to *ESP32 Series Datasheet*.

3.3 Strapping Pins

ESP32 has five strapping pins, 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

<table>
<tr><th colspan="6">Voltage of Internal LDO (VDD_SDIO)</th></tr>
<tr><td>Pin</td><td>Default</td><td colspan="2">3.3 V</td><td colspan="2">1.8 V</td></tr>
<tr><td>MTDI</td><td>Pull-down</td><td colspan="2">0</td><td colspan="2">1</td></tr>
<tr><th colspan="6">Booting Mode</th></tr>
<tr><td>Pin</td><td>Default</td><td colspan="2">SPI Boot</td><td colspan="2">Download Boot</td></tr>
<tr><td>GPIO0</td><td>Pull-up</td><td colspan="2">1</td><td colspan="2">0</td></tr>
<tr><td>GPIO2</td><td>Pull-down</td><td colspan="2">Don’t-care</td><td colspan="2">0</td></tr>
<tr><th colspan="6">Enabling/Disabling Debugging Log Print over U0TXD During Booting</th></tr>
<tr><td>Pin</td><td>Default</td><td colspan="2">U0TXD Active</td><td colspan="2">U0TXD Silent</td></tr>
<tr><td>MTDO</td><td>Pull-up</td><td colspan="2">1</td><td colspan="2">0</td></tr>
<tr><th colspan="6">Timing of SDIO Slave</th></tr>
<tr><td>Pin</td><td>Default</td><td>FE Sampling
FE Output</td><td>FE Sampling
RE Output</td><td>RE Sampling
FE Output</td><td>RE Sampling
RE Output</td></tr>
<tr><td>MTDO</td><td>Pull-up</td><td>0</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>GPIO5</td><td>Pull-up</td><td>0</td><td>1</td><td>0</td><td>1</td></tr>
</table>

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 module integrates a 3.3 V SPI flash, so the pin MTDI cannot be set to 1 when the module is powered up.

4 Electrical Characteristics

4.1 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	–0.3	3.6	V
T_{store}	Storage temperature	–40	85	°C

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

4.2 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

4.3 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
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

Symbol	Parameter	Min	Typ	Max	Unit
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 Series Datasheet* 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, 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.

4.4 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 Series Datasheet*.

Table 6: Current Consumption Depending on RF Modes

Work mode	Description		Peak (mA)
Active (RF working)	TX	802.11b, 20 MHz, 1 Mbps, @15 dBm	379
		802.11g, 20 MHz, 54 Mbps, @15 dBm	276
		802.11n, 20 MHz, MCS7, @13 dBm	258
		802.11n, 40 MHz, MCS7, @13 dBm	260
	RX	802.11b/g/n, 20 MHz	112
		802.11n, 40 MHz	118

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 100% 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 [1, 2]	The CPU is powered on [3]	160 MHz	27 ~ 34 mA
		Normal speed: 80 MHz	20 ~ 25 mA
Light-sleep	—		0.8 mA
Deep-sleep	The ULP co-processor is powered on [4]		150 μA
	ULP sensor-monitored pattern [5]		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

[1] The current consumption figures in Modem-sleep mode are for cases where the CPU is powered on and the cache idle.

[2] When Wi-Fi is enabled, the chip switches between Active and Modem-sleep modes. Therefore, current consumption changes accordingly.

[3] In Modem-sleep mode, the CPU frequency changes automatically. The frequency depends on the CPU load and the peripherals used.

[4] During Deep-sleep, when the ULP coprocessor is powered on, peripherals such as GPIO and RTC I2C are able to operate.

[5] 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.

4.5 Wi-Fi RF Characteristics

4.5.1 Wi-Fi RF Standards

Table 8: 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		IPEX antenna[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 IPEX antennas, the output impedance is 50 Ω. For other modules without IPEX antennas, users do not need to concern about the output impedance.

4.5.2 Transmitter Characteristics

Target TX power is configurable based on device or certification requirements. The default characteristics are provided in Table 9.

Table 9: Transmitter Characteristics

Parameter	Rate	Typ	Unit
TX Power	11b, 1 Mbps	15	dBm
	11b, 11 Mbps	15	
	11g, 6 Mbps	15	
	11g, 54 Mbps	15	
	11n, HT20, MCS0	15	
	11n, HT20, MCS7	15	
	11n, HT40, MCS0	15	
	11n, HT40, MCS7	15	

4.5.3 Receiver Characteristics

Table 10: Receiver Characteristics

Parameter	Rate	Typ	Unit
RX Sensitivity	1 Mbps	–97	dBm
	2 Mbps	–94	
	5.5 Mbps	–92	
	11 Mbps	–88	
	6 Mbps	–93	
	9 Mbps	–91	
	12 Mbps	–89	
	18 Mbps	–87	
	24 Mbps	–84	
	36 Mbps	–80	
	48 Mbps	–77	
	54 Mbps	–75	
	11n, HT20, MCS0	–92	
	11n, HT20, MCS1	–88	
	11n, HT20, MCS2	–86	
	11n, HT20, MCS3	–83	
	11n, HT20, MCS4	–80	
	11n, HT20, MCS5	–76	
	11n, HT20, MCS6	–74	
	11n, HT20, MCS7	–72	
	11n, HT40, MCS0	–89	
	11n, HT40, MCS1	–85	
	11n, HT40, MCS2	–83	
	11n, HT40, MCS3	–80	
	11n, HT40, MCS4	–76	
	11n, HT40, MCS5	–72	
	11n, HT40, MCS6	–71	
	11n, HT40, MCS7	–69	

Parameter	Rate	Typ	Unit
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	27	
	11n, HT20, MCS7	12	
	11n, HT40, MCS0	16	
	11n, HT40, MCS7	7	

4.6 Bluetooth Radio

4.6.1 Receiver –Basic Data Rate

Table 11: Receiver Characteristics –Basic Data Rate

Parameter	Conditions	Min	Typ	Max	Unit
Sensitivity @0.1% BER	-	–90	–89	–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

4.6.2 Transmitter –Basic Data Rate

Table 12: Transmitter Characteristics –Basic Data Rate

Parameter	Conditions	Min	Typ	Max	Unit
RF transmit power (see note under Table 12)	-	-	0	-	dBm

Parameter	Conditions	Min	Typ	Max	Unit
Gain control step	-	-	3	-	dB
RF power control range	-	–12	-	+9	dBm
+20 dB bandwidth	-	-	0.9	-	MHz
Adjacent channel transmit power	F = F0 ± 2 MHz	-	–55	-	dBm
	F = F0 ± 3 MHz	-	–55	-	dBm
	F = F0 ± > 3 MHz	-	–59	-	dBm
$\Delta f1_{avg}$	-	-	-	155	kHz
$\Delta f2_{max}$	-	127	-	-	kHz
$\Delta f2_{avg}/\Delta f1_{avg}$	-	-	0.92	-	-
ICFT	-	-	–7	-	kHz
Drift rate	-	-	0.7	-	kHz/50 μs
Drift (DH1)	-	-	6	-	kHz
Drift (DH5)	-	-	6	-	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.

4.6.3 Receiver –Enhanced Data Rate

Table 13: Receiver Characteristics –Enhanced Data Rate

Parameter	Conditions	Min	Typ	Max	Unit
π/4 DQPSK					
Sensitivity @0.01% BER	-	–90	–89	–88	dBm
Maximum received signal @0.01% BER	-	-	0	-	dBm
Co-channel C/I	-	-	11	-	dB
Adjacent channel selectivity C/I	F = F0 + 1 MHz	-	–7	-	dB
	F = F0 –1 MHz	-	–7	-	dB
	F = F0 + 2 MHz	-	–25	-	dB
	F = F0 –2 MHz	-	–35	-	dB
	F = F0 + 3 MHz	-	–25	-	dB
	F = F0 –3 MHz	-	–45	-	dB
8DPSK					
Sensitivity @0.01% BER	-	–84	–83	–82	dBm
Maximum received signal @0.01% BER	-	-	–5	-	dBm
C/I c-channel	-	-	18	-	dB
Adjacent channel selectivity C/I	F = F0 + 1 MHz	-	2	-	dB
	F = F0 –1 MHz	-	2	-	dB
	F = F0 + 2 MHz	-	–25	-	dB
	F = F0 –2 MHz	-	–25	-	dB
	F = F0 + 3 MHz	-	–25	-	dB
	F = F0 –3 MHz	-	–38	-	dB

4.6.4 Transmitter –Enhanced Data Rate

Table 14: Transmitter Characteristics –Enhanced Data Rate

Parameter	Conditions	Min	Typ	Max	Unit
RF transmit power (see note under Table 12)	-	-	0	-	dBm
Gain control step	-	-	3	-	dB
RF power control range	-	–12	-	+9	dBm
$\pi/4$ DQPSK max w0	-	-	–0.72	-	kHz
$\pi/4$ DQPSK max wi	-	-	–6	-	kHz
$\pi/4$ DQPSK max |wi + w0|	-	-	–7.42	-	kHz
8DPSK max w0	-	-	0.7	-	kHz
8DPSK max wi	-	-	–9.6	-	kHz
8DPSK max |wi + w0|	-	-	–10	-	kHz
$\pi/4$ DQPSK modulation accuracy	RMS DEVM	-	4.28	-	%
	99% DEVM	-	100	-	%
	Peak DEVM	-	13.3	-	%
8 DPSK modulation accuracy	RMS DEVM	-	5.8	-	%
	99% DEVM	-	100	-	%
	Peak DEVM	-	14	-	%
In-band spurious emissions	F = F0 ± 1 MHz	-	–46	-	dBm
	F = F0 ± 2 MHz	-	–44	-	dBm
	F = F0 ± 3 MHz	-	–49	-	dBm
	F = F0 +/–> 3 MHz	-	-	–53	dBm
EDR differential phase coding	-	-	100	-	%

4.7 Bluetooth LE Radio

4.7.1 Receiver

Table 15: Receiver Characteristics –Bluetooth LE

Parameter	Conditions	Min	Typ	Max	Unit
Sensitivity @30.8% PER	-	–94	–93	–92	dBm
Maximum received signal @30.8% PER	-	0	-	-	dBm
Co-channel C/I	-	-	+10	-	dB
Adjacent channel selectivity C/I	F = F0 + 1 MHz	-	–5	-	dB
	F = F0 –1 MHz	-	–5	-	dB
	F = F0 + 2 MHz	-	–25	-	dB
	F = F0 –2 MHz	-	–35	-	dB
	F = F0 + 3 MHz	-	–25	-	dB
	F = F0 –3 MHz	-	–45	-	dB
Out-of-band blocking performance	30 MHz ~ 2000 MHz	–10	-	-	dBm
	2000 MHz ~ 2400 MHz	–27	-	-	dBm
	2500 MHz ~ 3000 MHz	–27	-	-	dBm
	3000 MHz ~ 12.5 GHz	–10	-	-	dBm
Intermodulation	-	–36	-	-	dBm

4.7.2 Transmitter

Table 16: Transmitter Characteristics –Bluetooth LE

Parameter	Conditions	Min	Typ	Max	Unit
RF transmit power (see note under Table 12)	-	-	0	-	dBm
Gain control step	-	-	3	-	dB
RF power control range	-	–12	-	+9	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

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.

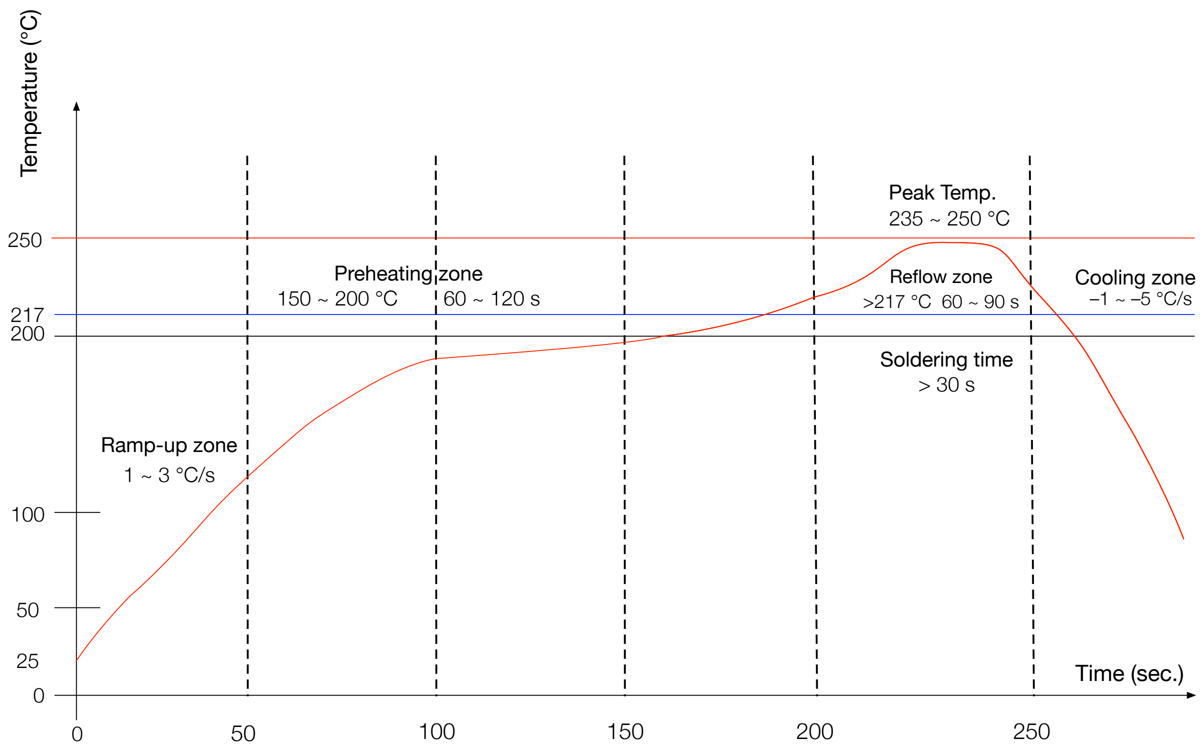
After unpacking, the module must be soldered within 168 hours with the factory conditions 25±5 °C and /60%RH. If the above conditions are not met, the module needs to be baked.

8.2 Electrostatic Discharge (ESD)

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

9 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, Bluetooth LE, and Ethernet modes correspond to mac_address in the following way:

- Station mode: mac_address
- AP mode: mac_address + 1
- Bluetooth LE 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.

10 Learning Resources

10.1 Must-Read Documents

Please familiarize yourself with the following documents:

- *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*

10.2 Must-Have Resources

Here are the ESP32-related must-have resources.

- 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
2021-05-25	V0.5	Pre-release