ESP32-H2-MINI-1

Datasheet

Bluetooth® Low Energy and IEEE 802.15.4 module
Built around ESP32-H2 series of SoCs, RISC-V single-core 32-bit microprocessor
2 MB or 4 MB flash in chip package
19 GPIOs
On-board PCB antenna

ESP32-H2-MINI-1

Pre-release v0.2
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://espressif.com/documentation/esp32-h2-mini-1_datasheet_en.pdf

1.1 Features

CPU and On-Chip Memory

- 32-bit RISC-V single-core processor, up to 96 MHz
- 128 KB ROM
- 320 KB SRAM
- 4 KB LP Memory
- 2 MB or 4 MB SiP flash

Bluetooth

- Bluetooth Low Energy (Bluetooth 5 compliant)
- Bluetooth mesh v1.0.1 (and the later versions in draft)
- Bluetooth Low Energy long range (Coded PHY, 125 Kbps and 500 Kbps)
- Bluetooth Low Energy high speed (2 Mbps)
- Bluetooth Low Energy advertising extensions and Multiple advertising sets
- Simultaneous Broadcaster, Observer, Peripheral and Central
- Multiple connections

IEEE 802.15.4

- IEEE Standard 802.15.4-2015 compliant
- Supports 250 Kbps data rate in 2.4 GHz band and OQPSK PHY
- Supports Thread 1.1 (and the later versions in draft)
- Supports Zigbee 3.0
- Supports Matter
- Supports other application-layer protocols (HomeKit, MQTT, etc)

Peripherals

- GPIO, I2C, I2S, SPI, UART, ADC, LED PWM, ETM, GDMA, PCNT, PARLIO, RMT, TWAI, MCPWM, USB Serial/JTAG, temperature sensor, general-purpose timers, system timer, watchdog timer

Integrated Components on Module

- 32 MHz crystal oscillator

Antenna Options

- On-board PCB antenna

Operating Conditions

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

1.2 Description

ESP32-H2-MINI-1 is a powerful, generic Bluetooth® Low Energy and IEEE 802.15.4 combo module that has a rich set of peripherals. This module is an ideal choice for a wide variety of application scenarios related to Internet of Things (IoT), such as embedded systems, smart home, wearable electronics, etc.

The series comparison for ESP32-H2-MINI-1 is as follows:

Table 1: ESP32-H2-MINI-1 Series Comparison

Ordering Code	Flash	Ambient Temp.[1] (°C)	Size[2] (mm)
ESP32-H2-MINI-1-H2	2 MB (Quad SPI)[3]	–40 ~105	13.2 × 16.6 × 2.4
ESP32-H2-MINI-1-H4	4 MB (Quad SPI)[3]	–40 ~105	13.2 × 16.6 × 2.4

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

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

[3] The flash is integrated in the chip's package.

At the core of this module is ESP32-H2, a 32-bit RISC-V single-core CPU that operates at up to 96 MHz. You can power off the CPU and make use of the low-power coprocessor to constantly monitor the peripherals for changes or crossing of thresholds.

ESP32-H2 integrates a rich set of peripherals including I2C, I2S, SPI, UART, ADC, LED PWM, ETM, GDMA, PCNT, PARLIO, RMT, TWAI, MCPWM, USB Serial/JTAG, temperature sensor, general-purpose timers, system timer, watchdog timer as well as up to 19 GPIOs.

1.3 Applications

- Smart Home
- Industrial Automation
- Health Care
- Consumer Electronics
- Smart Agriculture
- Retail and Catering
- Generic Low-power IoT Sensor Hubs
- Generic Low-power IoT Data Loggers

Contents

List of Tables

List of Figures

2 Block Diagram

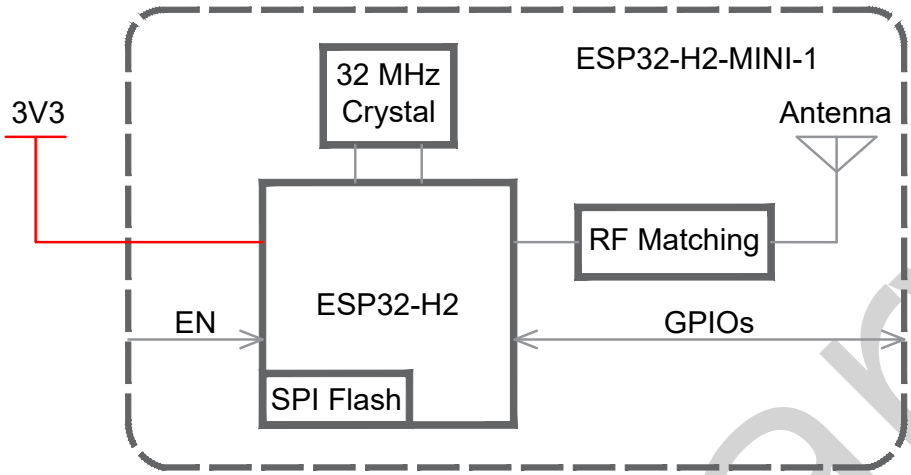

Figure 1: ESP32-H2-MINI-1 Block Diagram

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*.

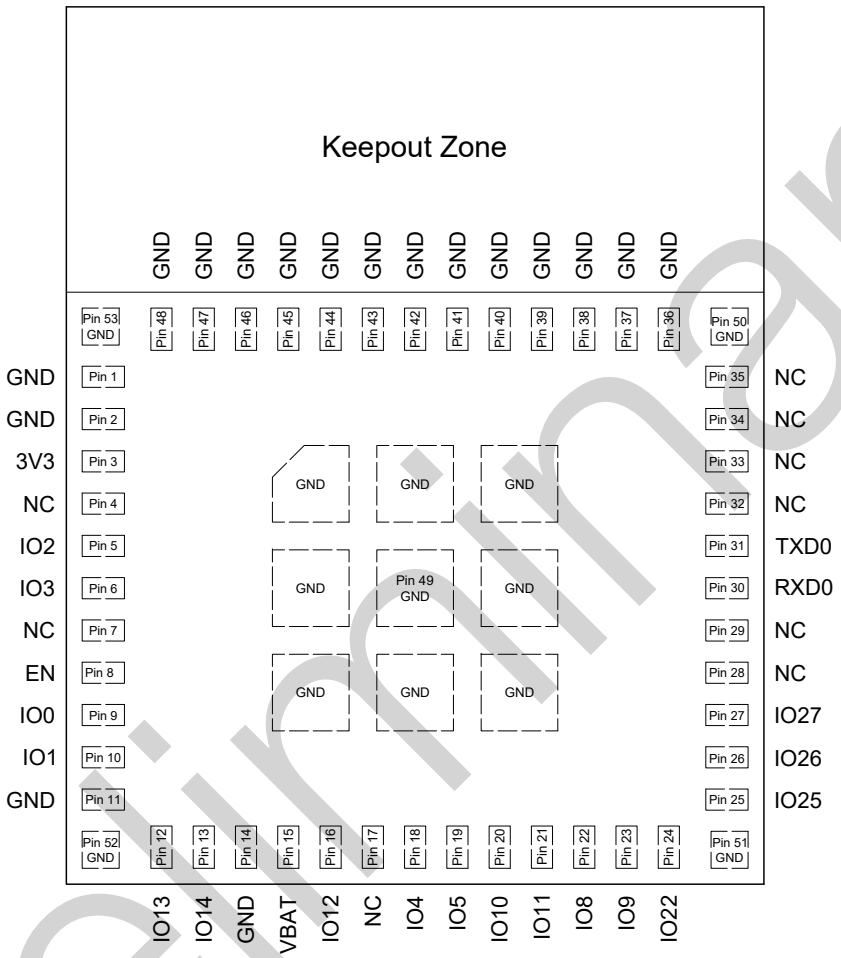

Figure 2: Pin Layout (Top View)

3.2 Pin Description

The module has 53 pins. See pin definitions in Table 2 *Pin Definitions*.

For peripheral pin configurations, please refer to *ESP32-H2 Series Datasheet*.

Table 2: Pin Definitions

Name	No.	Type[1]	Function
GND	1	P	Ground
GND	2	P	Ground
3V3	3	P	Power supply
NC	4	-	NC

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Table 2 – cont'd from previous page

Name	No.	Type[1]	Function
IO2	5	I/O/T	GPIO2, FSPIWP, ADC1_CH1, **MTMS**
IO3	6	I/O/T	GPIO3, FSPIHD, ADC1_CH2, **MTDO**
NC	7	-	NC
EN	8	I	High: on, enables the chip. Low: off, the chip powers off. Note: Do not leave the EN pin floating.
IO0	9	I/O/T	**GPIO0**, FSPIQ
IO1	10	I/O/T	**GPIO1**, FSPICS0, ADC1_CH0
GND	11	P	Ground
IO13	12	I/O/T	**GPIO13**, XTAL_32K_P
IO14	13	I/O/T	**GPIO14**, XTAL_32K_N
GND	14	P	Ground
VBAT	15	P	Be connected to internal 3V3 power supply (Default) or external battery power supply (2.7 ~ 3.6 V).
IO12	16	I/O/T	**GPIO12**
NC	17	-	NC
IO4	18	I/O/T	GPIO4, FSPICLK, ADC1_CH3, **MTCK**
IO5	19	I/O/T	GPIO5, FSPID, ADC1_CH4, **MTDI**
IO10	20	I/O/T	**GPIO10**, ZCD0
IO11	21	I/O/T	**GPIO11**, ZCD1
IO8	22	I/O/T	**GPIO8**
IO9	23	I/O/T	**GPIO9**
IO22	24	I/O/T	**GPIO22**
IO25	25	I/O/T	**GPIO25**, FSPICS3
IO26	26	I/O/T	GPIO26, FSPICS4, **USB_D-**
IO27	27	I/O/T	GPIO27, FSPICS5, **USB_D+**
NC	28	-	NC
NC	29	-	NC
RXD0	30	I/O/T	GPIO23, FSPICS1, **U0RXD**
TXD0	31	I/O/T	GPIO24, FSPICS2, **U0TXD**
NC	32	-	NC
NC	33	-	NC
NC	34	-	NC
NC	35	-	NC
GND	36 ~ 53	P	Ground

[1] P: power supply; I: input; O: output; T: high impedance.

3.3 Strapping Pins

ESP32-H2 has two strapping pins:

- GPIO8
- GPIO9

These strapping pins are used to control the following functions during chip power-on or hardware reset:

- Control chip boot mode
- Enable or disable ROM message printing to UART

Software can read the values of GPIO8 and GPIO9 from the GPIO_STRAPPING field in the GPIO_STRAP_REG register.

During the chip's system 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.

Types of system reset include:

- Power-on reset
- RTC watchdog reset
- Brownout reset
- Analog super watchdog reset
- Crystal clock glitch detection reset

By default, GPIO8 and GPIO9 are connected to the internal pull-up resistor. If GPIO8 and GPIO9 are not connected or connected to an external high-impedance circuit, the latched bit value will be "1"

To change the strapping bit values, you can apply the external pull-down/pull-up resistors, or use the host MCU's GPIOs to control the voltage level of these pins when powering on ESP32-H2.

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

Refer to Table 3 for a detailed explanation of functionality enabled by specific values on the strapping pins.

Table 3: Strapping Pins

Booting Mode [1]			
Pin	Default	SPI Boot	Download Boot
GPIO8	Internal weak pull-up	Don't care	1
GPIO9	Internal weak pull-up	1	0
Enabling/Disabling ROM Code Print During Booting			
Pin	Default	Functionality	
GPIO8	Internal pull-up	When the value of the eFuse field EFUSE_UART_PRINT_CONTROL is 0 (default), print is enabled and not controlled by GPIO8. 1, if GPIO8 is 0, print is enabled; if GPIO8 is 1, it is disabled. 2, if GPIO8 is 0, print is disabled; if GPIO8 is 1, it is enabled. 3, print is disabled and not controlled by GPIO8	

[1] The strapping combination of GPIO8 = 0 and GPIO9 = 0 is invalid and will trigger unexpected behavior.

Figure 3 shows the setup and hold time for the strapping pin before and after the CHIP_EN signal goes high. Details about the parameters are listed in Table 4.

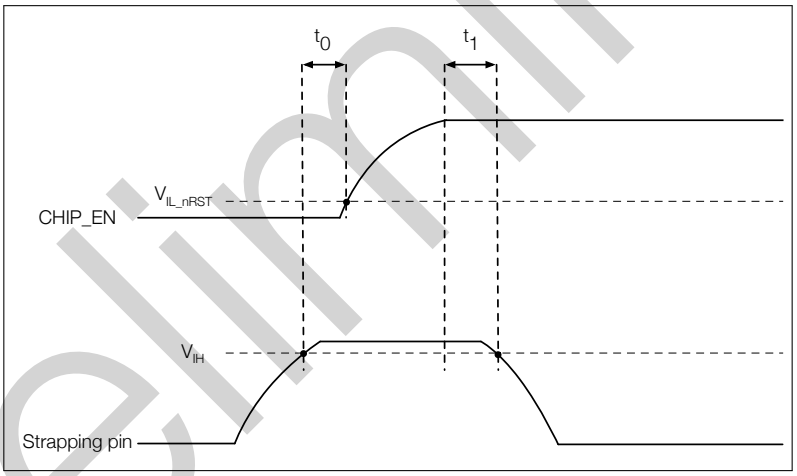

Figure 3: Setup and Hold Times for the Strapping Pin

Table 4: Parameter Descriptions of the Setup and Hold Time for the Strapping Pin

Parameter	Description	Min (ms)
t_0	Setup time before CHIP_EN goes from low to high	0
t_1	Hold time after CHIP_EN goes high	3

4 Electrical Characteristics

The values presented in this section are preliminary and may change with the final release of this datasheet.

4.1 Absolute Maximum Ratings

Stresses above those listed in Table 5 *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 5: 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 6: 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	—	105	°C

4.3 802.15.4 Radio

4.3.1 802.15.4 RF Transmitter Specification

Table 7: 802.15.4 O-QPSK Frequency

Parameters	Min (MHz)	Typ (MHz)	Max (MHz)
Center frequency of operating channel	2405	—	2480

Table 8: 802.15.4 O-QPSK Transmitter Characteristics - 250 Kbps

Parameters	Min	Typ	Max	Unit
TX power	-24.00	—	18.00	dBm
EVM	—	0.04	—	—

4.3.2 802.15.4 RF Receiver Specification

Table 9: 802.15.4 O-QPSK Receiver Characteristics - 250 Kbps

Parameters		Min	Typ	Max	Unit
Sensitivity @30.8% PER		—	-100.5	—	dBm
Maximum received signal @30.8% PER		—	10	—	dBm
Adjacent channel relative jamming level	F = F0 + 5 MHz	—	30	—	dB
	F = F0 - 5 MHz	—	40	—	dB
Alternate channel relative jamming level	F = F0 + 10 MHz	—	46	—	dB
	F = F0 - 10 MHz	—	46	—	dB

4.4 Bluetooth LE Radio

Table 10: Bluetooth LE Frequency

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

4.4.1 Bluetooth LE RF Transmitter Specifications

Table 11: Transmitter Characteristics - Bluetooth LE 1 Mbps

Parameter	Description	Min	Typ	Max	Unit
RF transmit power	RF power control range	–24.00	-	18.00	dBm

Cont'd on next page

Table 11 – cont'd from previous page

Parameter	Description	Min	Typ	Max	Unit
	Gain control step	—	3.00	—	dB
Carrier frequency offset and drift	Max $\lvert f_n \rvert_{n=0,\,1,\,2,\,..k}$	—	5.90	—	kHz
	Max $\lvert f_0 - f_n \rvert$	—	4.30	—	kHz
	Max $\lvert f_n - f_{n-5} \rvert$	—	1.70	—	kHz
	$\lvert f_1 - f_0 \rvert$	—	3.60	—	kHz
Modulation characteristics	$\Delta\, f1_{avg}$	—	252.00	—	kHz
	Min $\Delta\, f2_{max}$ (for at least 99.9% of all $\Delta\, f2_{max}$)	—	193.00	—	kHz
	$\Delta\, f2_{avg}/\Delta\, f1_{avg}$	—	0.89	—	—
In-band spurious emissions	± 2 MHz offset	—	–35.00	—	dBm
	± 3 MHz offset	—	–44.00	—	dBm
	> ± 3 MHz offset	—	–48.00	—	dBm

Table 12: Transmitter Characteristics - Bluetooth LE 2 Mbps

Parameter	Description	Min	Typ	Max	Unit
RF transmit power	RF power control range	–24.00	-	18.00	dBm
	Gain control step	—	3.00	—	dB
Carrier frequency offset and drift	Max $\lvert f_n \rvert_{n=0,\,1,\,2,\,..k}$	—	13.90	—	kHz
	Max $\lvert f_0 - f_n \rvert$	—	3.20	—	kHz
	Max $\lvert f_n - f_{n-5} \rvert$	—	1.60	—	kHz
	$\lvert f_1 - f_0 \rvert$	—	1.10	—	kHz
Modulation characteristics	$\Delta\, f1_{avg}$	—	490.00	—	kHz
	Min $\Delta\, f2_{max}$ (for at least 99.9% of all $\Delta\, f2_{max}$)	—	400.00	—	kHz
	$\Delta\, f2_{avg}/\Delta\, f1_{avg}$	—	0.95	—	—
In-band spurious emissions	± 4 MHz offset	—	–45.00	—	dBm
	± 5 MHz offset	—	–49.00	—	dBm
	> ± 5 MHz offset	—	–49.00	—	dBm

Table 13: Transmitter Characteristics - Bluetooth LE 125 Kbps

Parameter	Description	Min	Typ	Max	Unit
RF transmit power	RF power control range	–24.00	-	18.00	dBm
	Gain control step	—	3.00	—	dB
Carrier frequency offset and drift	Max $\lvert f_n \rvert_{n=0,\,1,\,2,\,..k}$	—	21.70	—	kHz
	Max $\lvert f_0 - f_n \rvert$	—	0.70	—	kHz
	Max $\lvert f_n - f_{n-3} \rvert$	—	0.90	—	kHz
	$\lvert f_0 - f_3 \rvert$	—	1.20	—	kHz
Modulation characteristics	$\Delta\, f1_{avg}$	—	252.00	—	kHz
	Min $\Delta\, f1_{max}$ (for at least 99.9% of all $\Delta\, f1_{max}$)	—	197.00	—	kHz

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Table 13 – cont'd from previous page

Parameter	Description	Min	Typ	Max	Unit
In-band spurious emissions	± 2 MHz offset	—	–36.00	—	dBm
	± 3 MHz offset	—	–42.00	—	dBm
	> ± 3 MHz offset	—	–45.00	—	dBm

Table 14: Transmitter Characteristics - Bluetooth LE 500 Kbps

Parameter	Description	Min	Typ	Max	Unit
RF transmit power	RF power control range	–24.00	-	18.00	dBm
	Gain control step	—	3.00	—	dB
Carrier frequency offset and drift	Max $\lvert f_n \rvert_{n=0,\,1,\,2,\,..k}$	—	18.20	—	kHz
	Max $\lvert f_0 - f_n \rvert$	—	0.60	—	kHz
	Max $\lvert f_n - f_{n-3} \rvert$	—	0.90	—	kHz
	$\lvert f_0 - f_3 \rvert$	—	0.35	—	kHz
Modulation characteristics	$\Delta\ f2_{avg}$	—	226.00	—	kHz
	Min $\Delta\ f2_{max}$ (for at least 99.9% of all $\Delta\ f2_{max}$)	—	207.00	—	kHz
In-band spurious emissions	± 2 MHz offset	—	–36.00	—	dBm
	± 3 MHz offset	—	–42.00	—	dBm
	> ± 3 MHz offset	—	–45.00	—	dBm

4.4.2 Bluetooth LE RF Receiver Specifications

Table 15: Receiver Characteristics - Bluetooth LE 1 Mbps

Parameter		Description	Min	Typ	Max	Unit
Sensitivity @30.8% PER		—	—	–98	—	dBm
Maximum received signal @30.8% PER		—	—	8	—	dBm
Adjacent channel selectivity C/I	Co-channel	F = F0 MHz	—	7	—	dB
	Adjacent channel	F = F0 + 1 MHz	—	4	—	dB
		F = F0 – 1 MHz	—	3	—	dB
		F = F0 + 2 MHz	—	–24	—	dB
		F = F0 – 2 MHz	—	–24	—	dB
		F = F0 + 3 MHz	—	–34	—	dB
		F = F0 – 3 MHz	—	–40	—	dB
		F ≥ F0 + 4 MHz	—	–38	—	dB
		F ≤ F0 – 4 MHz	—	–40	—	dB
	Image frequency	—	—	–34	—	dB
	Adjacent channel to image frequency	F = F_{image} + 1 MHz	—	–38	—	dB
		F = F_{image} – 1 MHz	—	–24	—	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

Cont'd on next page

Table 15 – cont'd from previous page

Parameter	Description	Min	Typ	Max	Unit
Intermodulation	—	—	–29	—	dBm

Table 16: Receiver Characteristics - Bluetooth LE 2 Mbps

Parameter		Description	Min	Typ	Max	Unit
Sensitivity @30.8% PER		—	—	–94	—	dBm
Maximum received signal @30.8% PER		—	—	8	—	dBm
Adjacent channel selectivity C/I	Co-channel	F = F0 MHz	—	8	—	dB
	Adjacent channel	F = F0 + 2 MHz	—	2	—	dB
		F = F0 – 2 MHz	—	1	—	dB
		F = F0 + 4 MHz	—	–27	—	dB
		F = F0 – 4 MHz	—	–27	—	dB
		F = F0 + 6 MHz	—	–41	—	dB
		F = F0 – 6 MHz	—	–41	—	dB
		F ≥ F0 + 8 MHz	—	–43	—	dB
		F ≤ F0 – 8 MHz	—	–43	—	dB
	Image frequency	—	—	–27	—	dB
	Adjacent channel to image frequency	F = F_{image} + 2 MHz	—	–41	—	dB
		F = F_{image} – 2 MHz	—	2	—	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 17: Receiver Characteristics - Bluetooth LE 125 Kbps

Parameter		Description	Min	Typ	Max	Unit
Sensitivity @30.8% PER		—	—	–105	—	dBm
Maximum received signal @30.8% PER		—	—	8	—	dBm
Adjacent channel selectivity C/I	Co-channel	F = F0 MHz	—	2	—	dB
	Adjacent channel	F = F0 + 1 MHz	—	-2	—	dB
		F = F0 – 1 MHz	—	-3	—	dB
		F = F0 + 2 MHz	—	–30	—	dB
		F = F0 – 2 MHz	—	–31	—	dB
		F = F0 + 3 MHz	—	–41	—	dB
		F = F0 – 3 MHz	—	–46	—	dB
		F ≥ F0 + 4 MHz	—	–44	—	dB
		F ≤ F0 – 4 MHz	—	–45	—	dB
	Image frequency	—	—	–41	—	dB
	Adjacent channel to image frequency	F = F_{image} + 1 MHz	—	–44	—	dB
		F = F_{image} – 1 MHz	—	–30	—	dB

Table 18: Receiver Characteristics - Bluetooth LE 500 Kbps

Parameter		Description	Min	Typ	Max	Unit
Sensitivity @30.8% PER		—	—	–101	—	dBm
Maximum received signal @30.8% PER		—	—	8	—	dBm
Adjacent channel selectivity C/I	Co-channel	F = F0 MHz	—	4	—	dB
	Adjacent channel	F = F0 + 1 MHz	—	0	—	dB
		F = F0 – 1 MHz	—	-2	—	dB
		F = F0 + 2 MHz	—	–26	—	dB
		F = F0 – 2 MHz	—	–26	—	dB
		F = F0 + 3 MHz	—	–38	—	dB
		F = F0 – 3 MHz	—	–40	—	dB
		F $\geq$ F0 + 4 MHz	—	–42	—	dB
		F $\leq$ F0 – 4 MHz	—	–43	—	dB
	Image frequency	—	—	–38	—	dB
	Adjacent channel to image frequency	F = F_{image} + 1 MHz	—	–42	—	dB
		F = F_{image} – 1 MHz	—	–26	—	dB

5 Module Schematics

This is the reference design of the module.

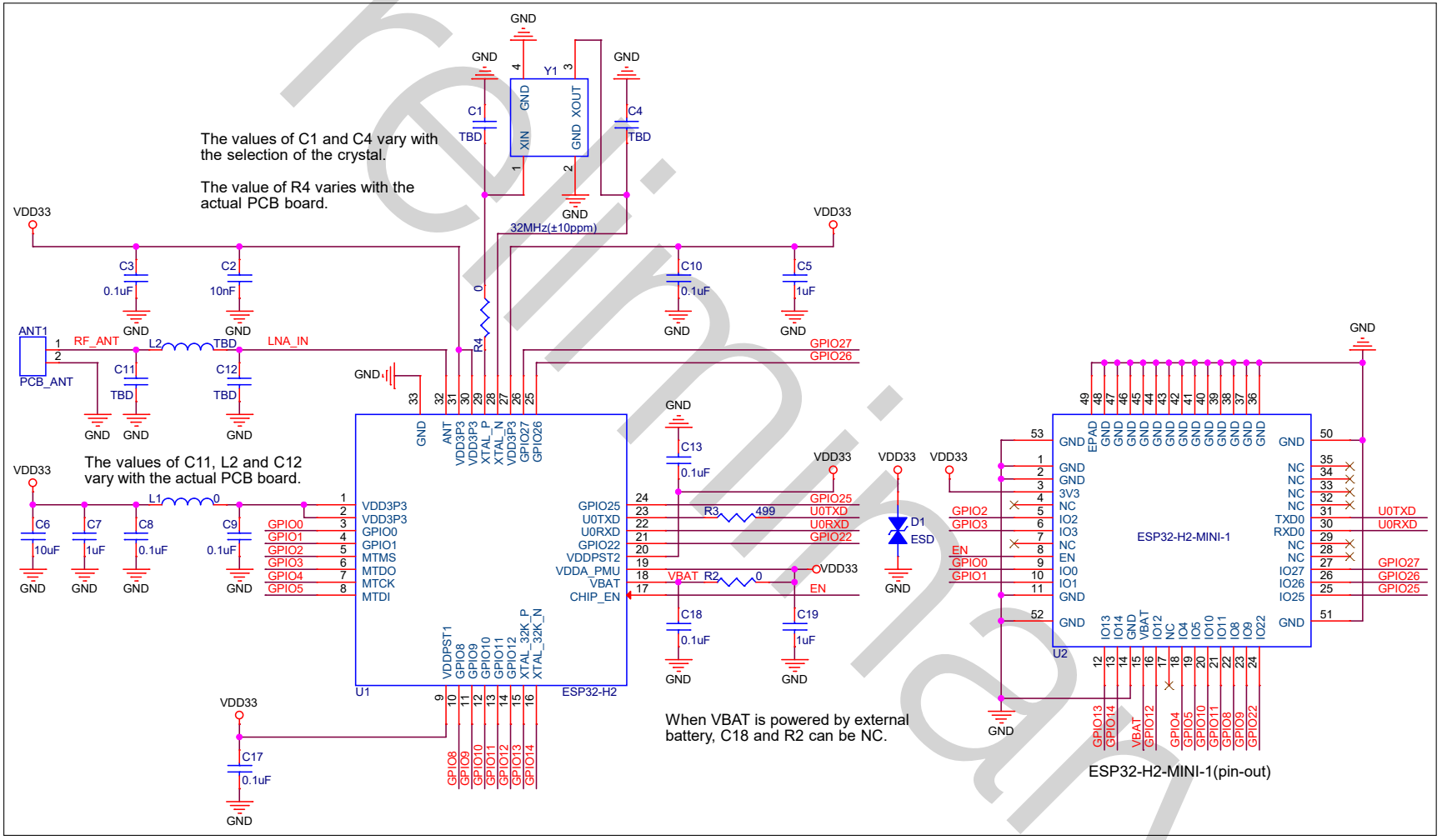

Figure 4: ESP32-H2-MINI-1 Schematics

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).

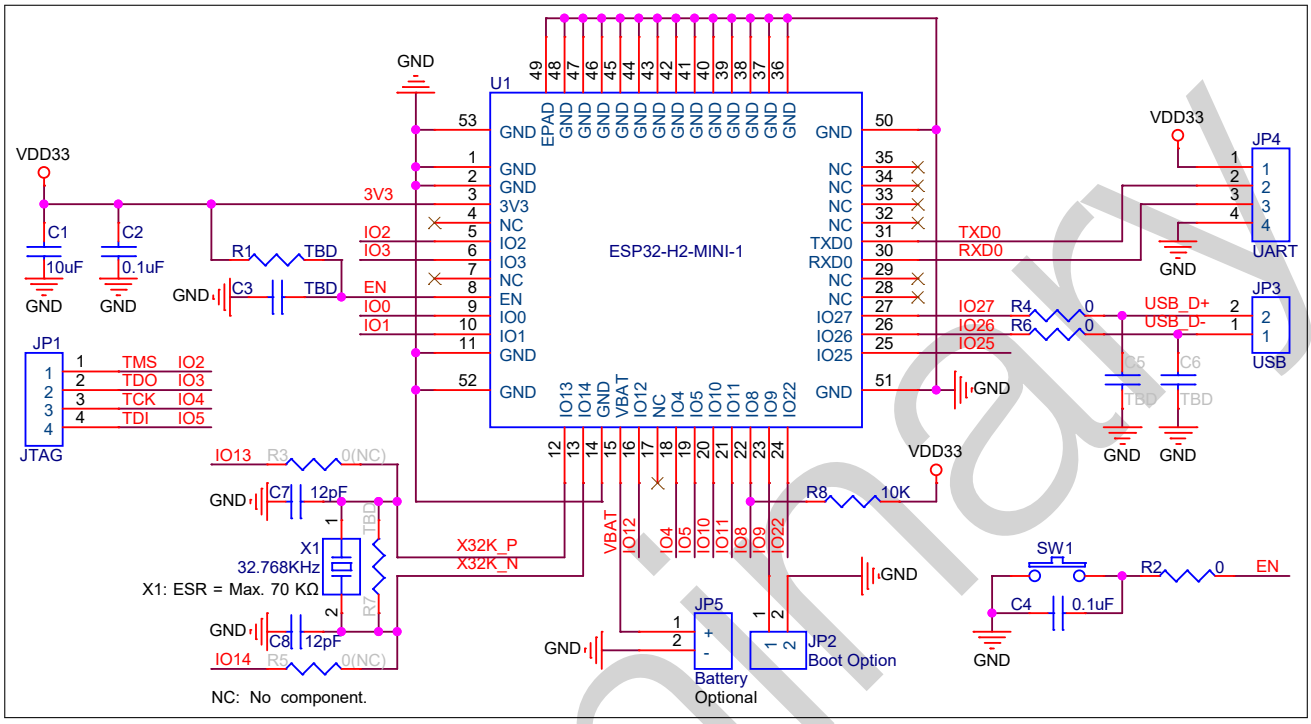

Figure 5: Peripheral Schematics

- 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-H2 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-H2's power-up and reset sequence timing diagram, please refer to *ESP32-H2 Series Datasheet* > Section *Power Supply*.

7 Physical Dimensions and PCB Land Pattern

7.1 Physical Dimensions

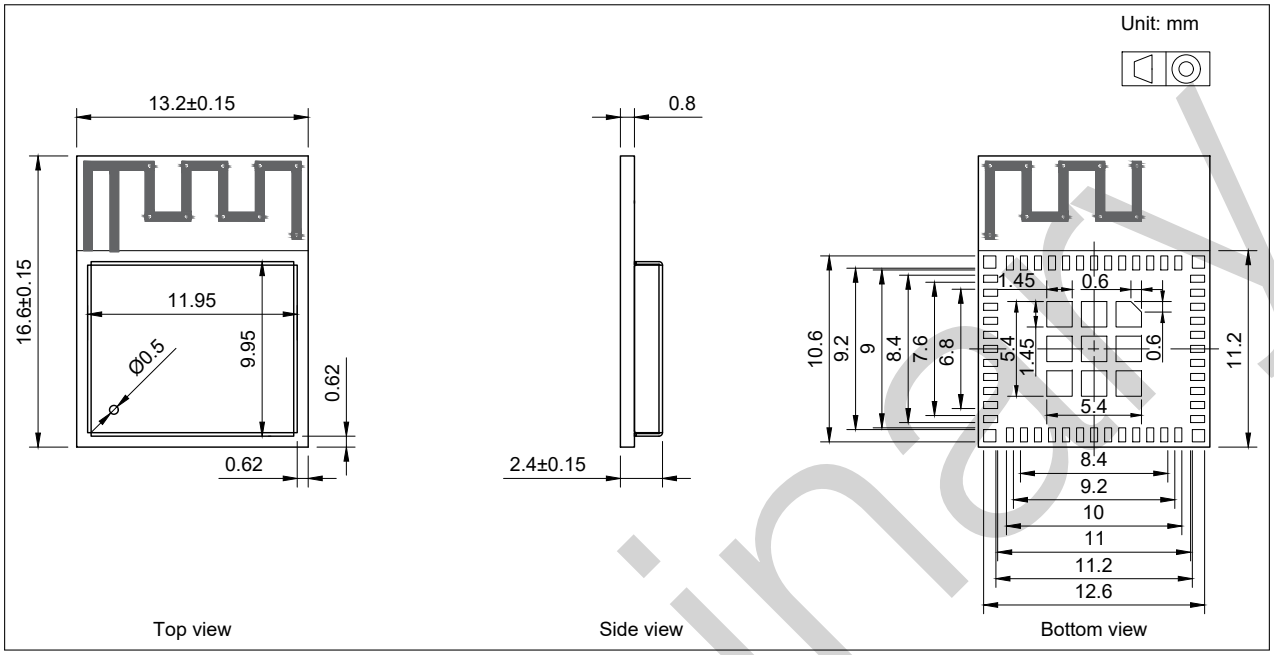

Figure 6: Physical Dimensions

Note:

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

7.2 Recommended PCB Land Pattern

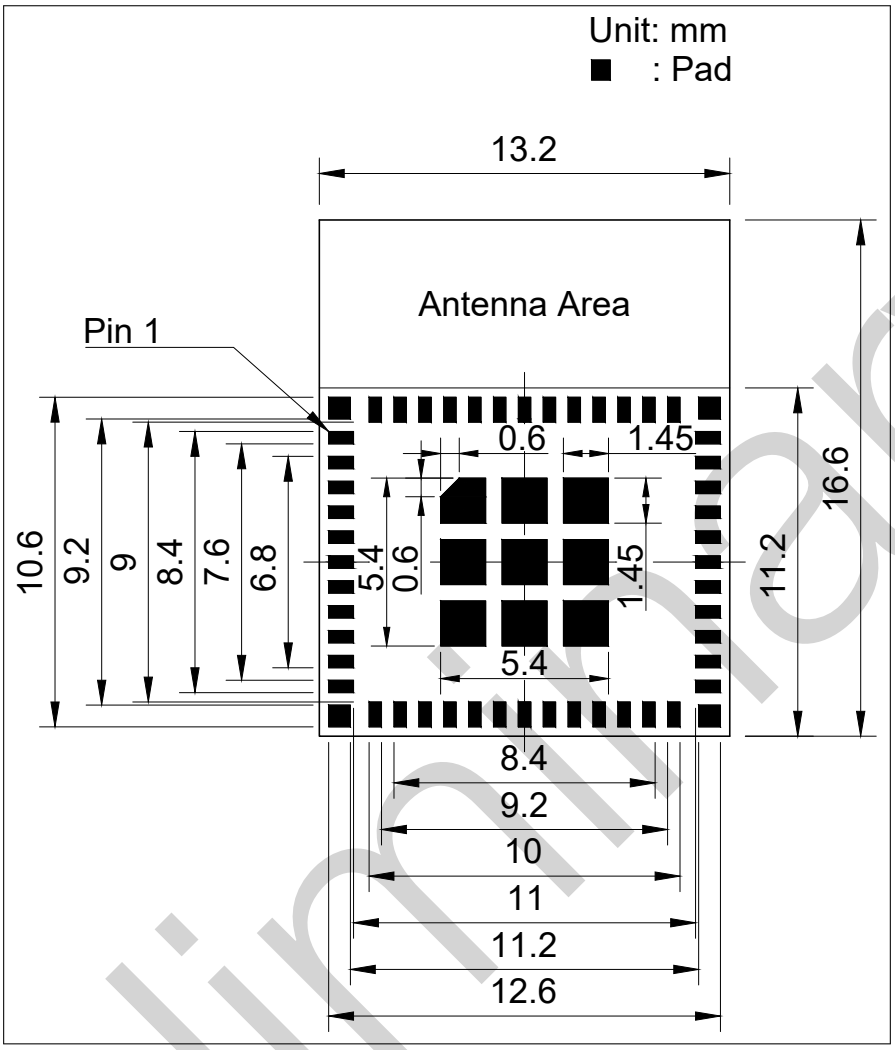

Figure 7: Recommended PCB Land Pattern

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 Soldering Profile

8.3.1 Reflow Profile

Solder the module in a single reflow.

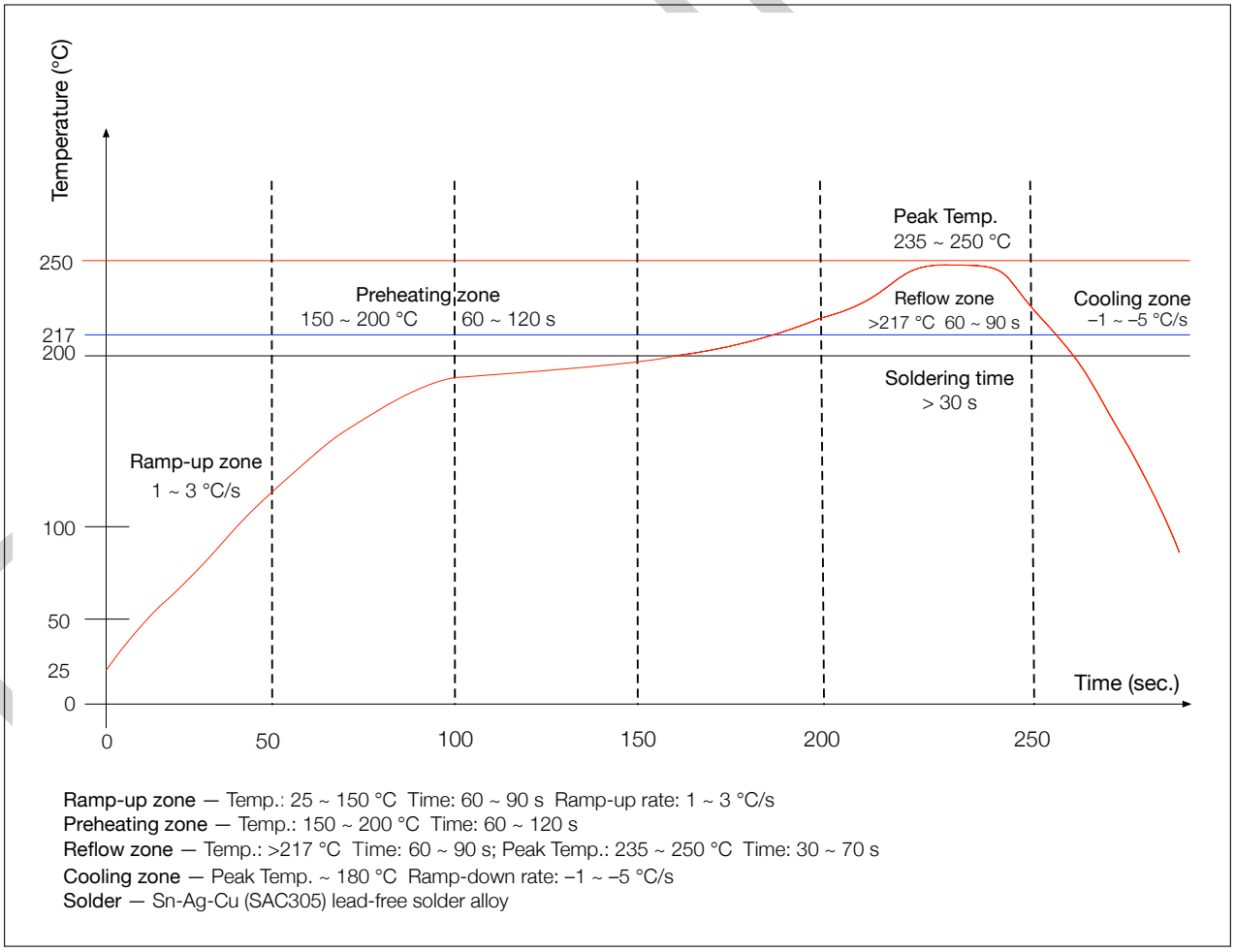

Figure 8: Reflow Profile

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**.

Revision History

Date	Version	Release notes
2022-12-7	V0.2	Due to a newly added VBAT pin: • Updated Table 2 *Pin Definitions* • Updated Figure 2 *Pin Layout (Top View)*, Figure 4 *ESP32-H2-MINI-1 Schematics*, and Figure 5 *Peripheral Schematics* Added a new module variant ESP32-H2-MINI-1-H4 (with 4 MB flash)
2022-08-29	V0.1	Preliminary release

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