# ESP32-WROVER-E & ESP32-WROVER-IE

Datasheet Version 2.0



# **About This Document**

This document provides the specifications for the ESP32-WROVER-E and ESP32-WROVER-IE modules.

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# **Revision History**

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# 1 Module Overview

#### Note:

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## 1.1 Features

#### CPU and On-Chip Memory

- ESP32-DOWD-V3 or ESP32-DOWDR2-V3 embedded, Xtensa dual-core 32-bit LX6 microprocessor, up to 240 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  $\mu$ s guard interval support
- Center frequency range of operating channel:
   2412 ~ 2484 MHz

#### Bluetooth®

- Bluetooth V4.2 BR/EDR and Bluetooth LE specification
- Class-1, class-2 and class-3 transmitter
- AFH
- CVSD and SBC

#### Peripherals

- Up to 24 GPIOs
  - 5 strapping GPIOs

 SD card, UART, SPI, SDIO, I2C, LED PWM, Motor PWM, I2S, IR, pulse counter, GPIO, capacitive touch sensor, ADC, DAC, TWAI® (compatible with ISO 11898-1, i.e. CAN Specification 2.0)

## Integrated Components on Module

- 40 MHz crystal oscillator
- 4/8/16 MB SPI flash
- ESP32-DOWDR2-V3 also provides 2 MB PSRAM

#### **Antenna Options**

- ESP32-WROVER-E: On-board PCB antenna
- ESP32-WROVER-IE: external antenna via a connector

#### **Operating Conditions**

- Operating voltage/Power supply: 3.0 ~ 3.6 V
- Operating ambient temperature: −40 ~ 85 °C

## Certification

- Bluetooth certification: BQB
- RF certification: See certificates for ESP32-WROVER-E and ESP32-WROVER-IE
- Green certification: REACH/RoHS

#### Test

• HTOL/HTSL/uHAST/TCT/ESD

# 1.2 Series Comparison

ESP32-WROVER-E and ESP32-WROVER-IE are two powerful, generic Wi-Fi + Bluetooth + Bluetooth LE MCU modules that target a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks, such as voice encoding, music streaming and MP3 decoding.

ESP32-WROVER-E comes with a PCB antenna, and ESP32-WROVER-IE with a connector for an external antenna. The information in this datasheet is applicable to both modules.

The Series Comparison for the two modules is as follows:

Table 1: ESP32-WROVER-E Series Comparison<sup>1</sup>

Ordering Code	Flash <sup>5</sup>	PSRAM	Ambient Temp. <sup>2</sup> (°C)	Size <sup>3</sup> (mm)
ESP32-WROVER-E-N4R8	4 MB (Quad SPI)	8 MB (Quad SPI)	-40 <b>~</b> 85	
ESP32-WROVER-E-N8R8	8 MB (Quad SPI)	8 MB (Quad SPI)	-40 <b>~</b> 85	
ESP32-WROVER-E-N16R8	16 MB (Quad SPI)	8 MB (Quad SPI)	-40 <b>~</b> 85	18.0 x 31.4 x 3.3
ESP32-WROVER-E-N4R2	4 MB (Quad SPI)	2 MB (Quad SPI) <sup>4</sup>	-40 <b>~</b> 85	10.0 % 31.4 % 3.3
ESP32-WROVER-E-N8R2	8 MB (Quad SPI)	2 MB (Quad SPI) <sup>4</sup>	-40 <b>~</b> 85	
ESP32-WROVER-E-N16R2	16 MB (Quad SPI)	2 MB (Quad SPI) <sup>4</sup>	-40 <b>~</b> 85	

<sup>&</sup>lt;sup>1</sup> This table shares the same notes presented in the table 2 below.

Table 2: ESP32-WROVER-IE Series Comparison

Ordering Code	Flash <sup>5</sup>	PSRAM	Ambient Temp. <sup>2</sup> (°C)	Size <sup>3</sup> (mm)
ESP32-WROVER-IE-N4R8	4 MB (Quad SPI)	8 MB (Quad SPI)	-40 <b>~</b> 85	
ESP32-WROVER-IE-N8R8	8 MB (Quad SPI)	8 MB (Quad SPI)	-40 <b>~</b> 85	
ESP32-WROVER-IE-N16R8	16 MB (Quad SPI)	8 MB (Quad SPI)	-40 <b>~</b> 85	18.0 x 31.4 x 3.3
ESP32-WROVER-IE-N4R2	4 MB (Quad SPI)	2 MB (Quad SPI) <sup>4</sup>	-40 <b>~</b> 85	10.0 % 31.4 % 3.3
ESP32-WROVER-IE-N8R2	8 MB (Quad SPI)	2 MB (Quad SPI) <sup>4</sup>	-40 <b>~</b> 85	
ESP32-WROVER-IE-N16R2	16 MB (Quad SPI)	2 MB (Quad SPI) <sup>4</sup>	-40 <b>~</b> 85	

<sup>&</sup>lt;sup>2</sup> Ambient temperature specifies the recommended temperature range of the environment immediately outside the Espressif module.

- More than 100,000 program/erase cycles
- More than 20 years data retention time

At the core of the module is the ESP32-DOWD-V3 chip or ESP32-DOWDR2-V3 chip\*. ESP32-DOWD-V3 chip and ESP32-DOWDR2-V3 chip\* are designed to be scalable and adaptive. There are two CPU cores that can be individually controlled, and the CPU clock frequency is adjustable from 80 MHz to 240 MHz. The chip also has a low-power coprocessor that can be used instead of the CPU to save power while performing tasks that do not require much computing power, such as monitoring of peripherals.

<sup>&</sup>lt;sup>3</sup> For details, refer to Section 10.1 *Module Dimensions*.

<sup>&</sup>lt;sup>4</sup> This module uses PSRAM integrated in the chip's package.

<sup>&</sup>lt;sup>5</sup> The integrated flash supports:

#### Note:

- For details on the part numbers of the ESP32 family of chips, please refer to the document <u>ESP32 Datasheet</u>.
- For chip revision identification, ESP-IDF release that supports a specific chip revision, and other information on chip revisions, please refer to ESP32 Series SoC Errata > Section Chip Revision Identification.

# 1.3 Applications

- Smart Home
- Industrial Automation
- Health Care
- Consumer Electronics
- Smart Agriculture
- POS Machines
- Service Robot

- Audio Devices
- Generic Low-power IoT Sensor Hubs
- Generic Low-power IoT Data Loggers
- Cameras for Video Streaming
- Speech Recognition
- Image Recognition
- SDIO Wi-Fi + Bluetooth Networking Card

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# 2 Block Diagram

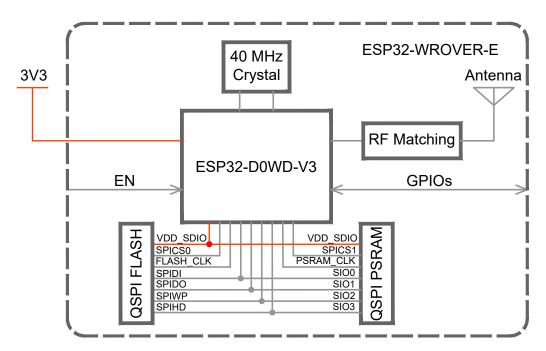


Figure 1: ESP32-WROVER-E Block Diagram (with ESP32-DOWD-V3 embedded)

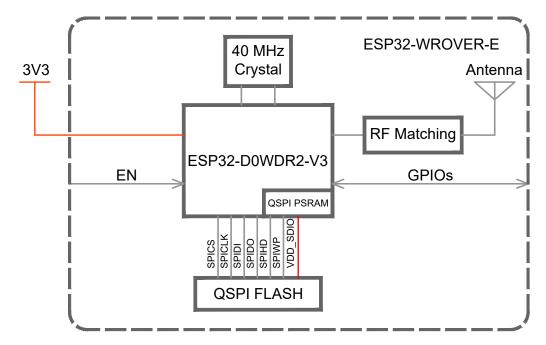


Figure 2: ESP32-WROVER-E Block Diagram (with ESP32-DOWDR2-V3 embedded)

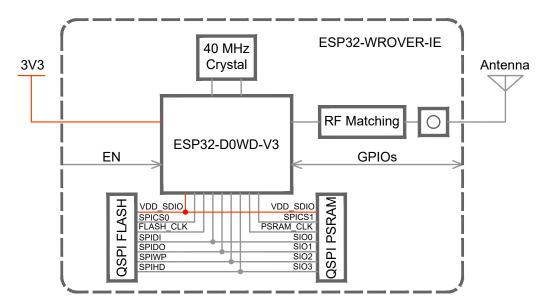


Figure 3: ESP32-WROVER-IE Block Diagram (with ESP32-DOWD-V3 embedded)

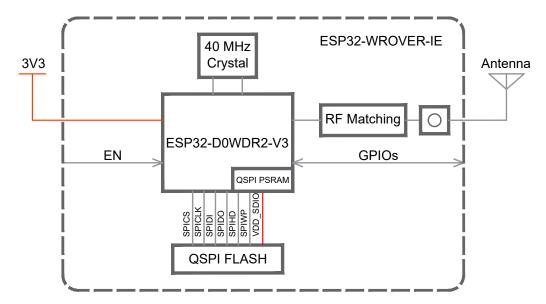


Figure 4: ESP32-WROVER-IE Block Diagram (with ESP32-DOWDR2-V3 embedded)

#### **Pin Definitions** 3

#### Pin Layout 3.1

The pin diagram below shows the approximate location of pins on the module. For the actual diagram drawn to scale, please refer to Figure 10.1 Module Dimensions.

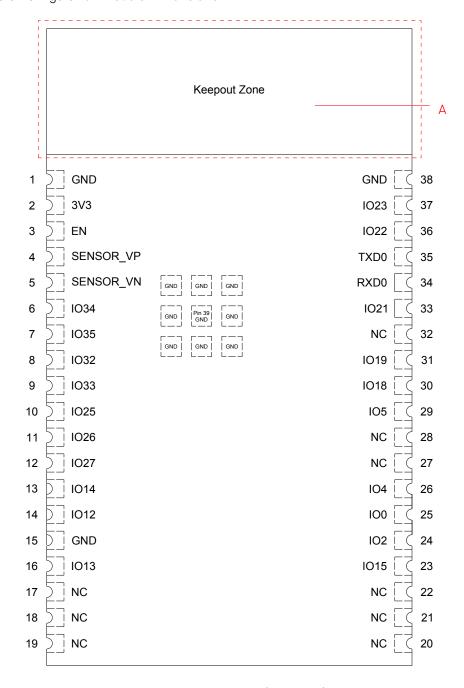


Figure 5: Pin Layout (Top View)

#### Note A:

- The zone marked with dotted lines is the antenna keepout zone. The pin layout of ESP32-WROVER-IE is the same as that of ESP32-WROVER-E, except that ESP32-WROVER-IE has no keepout zone.
- To learn more about the keepout zone for module's antenna on the base board, please refer to ESP32 Hardware Design Guidelines > Section Positioning a Module on a Base Board.

#### **Pin Description** 3.2

The module has 38 pins. See pin definitions in Table 3 Pin Description.

For peripheral pin configurations, please refer to Section 5.2 Digital Peripherals.

Table 3: Pin Definitions

Name	No.	Type <sup>1</sup>	Function	
GND	1	Р	Ground	
3V3	2	Р	Power supply	
EN	3	I	Module-enable signal. Active high.	
SENSOR_VP	4	I	GPIO36, ADC1_CHO, RTC_GPIO0	
SENSOR_VN	5	I	GPIO39, ADC1_CH3, RTC_GPIO3	
1034	6	I	GPIO34, ADC1_CH6, RTC_GPIO4	
1035	7	I	GPIO35, ADC1_CH7, RTC_GPIO5	
1032	8	1/0	GPIO32, XTAL_32K_P (32.768 kHz crystal oscillator input), ADC1_CH4,	
1032	0	1/0	TOUCH9, RTC_GPIO9	
1033	9	1/0	GPIO33, XTAL_32K_N (32.768 kHz crystal oscillator output),	
1033	9	1/0	ADC1_CH5, TOUCH8, RTC_GPIO8	
1025	10	1/0	GPIO25, DAC_1, ADC2_CH8, RTC_GPIO6, EMAC_RXDO	
1026	11	1/0	GPIO26, DAC_2, ADC2_CH9, RTC_GPIO7, EMAC_RXD1	
1027	12	1/0	GPIO27, ADC2_CH7, TOUCH7, RTC_GPIO17, EMAC_RX_DV	
1014	13	1/0	GPIO14, ADC2_CH6, TOUCH6, RTC_GPIO16, MTMS, HSPICLK,	
1014	13	1/0	HS2_CLK, SD_CLK, EMAC_TXD2	
1012	14	1/0	GPIO12, ADC2_CH5, TOUCH5, RTC_GPIO15, MTDI, HSPIQ, HS2_DATA2,	
1012	14	1/0	SD_DATA2, EMAC_TXD3	
GND	15	Р	Ground	
1013	16	1/0	GPIO13, ADC2_CH4, TOUCH4, RTC_GPIO14, MTCK, HSPID, HS2_DATA3,	
1013	10	1/0	SD_DATA3, EMAC_RX_ER	
NC	17	-	See note <sup>2</sup>	
NC	18	-	See note <sup>2</sup>	
NC	19	-	See note <sup>2</sup>	
NC	20	-	See note <sup>2</sup>	
NC	21	-	See note <sup>2</sup>	
NC	22	-	See note <sup>2</sup>	
1015	23	1/0	GPIO15, ADC2_CH3, TOUCH3, MTDO, HSPICSO, RTC_GPIO13,	
		1/0	HS2_CMD, SD_CMD, EMAC_RXD3	

Cont'd on next page

Table 3 - cont'd from previous page

Name	No.	Type <sup>1</sup>	Function		
102	24	1/0	GPIO2, ADC2_CH2, TOUCH2, RTC_GPIO12, HSPIWP, HS2_DATAO,		
102	24   1/0		SD_DATAO		
100	25	1/0	GPIOO, ADC2_CH1, TOUCH1, RTC_GPIO11, CLK_OUT1, EMAC_TX_CLK		
104	26	1/0	GPIO4, ADC2_CHO, TOUCHO, RTC_GPIO10, HSPIHD, HS2_DATA1,		
104	20	1/0	SD_DATA1, EMAC_TX_ER		
NC	27	-	-		
NC	28	-	-		
105	29	1/0	GPIO5, VSPICSO, HS1_DATA6, EMAC_RX_CLK		
IO18	30	1/0	GPI018, VSPICLK, HS1_DATA7		
IO19	31	1/0	GPI019, VSPIQ, UOCTS, EMAC_TXDO		
NC	32	-	-		
1021	33	1/0	GPIO21, VSPIHD, EMAC_TX_EN		
RXDO	34	1/0	GPIO3, UORXD, CLK_OUT2		
TXDO	35	1/0	GPIO1, UOTXD, CLK_OUT3, EMAC_RXD2		
1022	36	1/0	GPIO22, VSPIWP, UORTS, EMAC_TXD1		
1023	37	1/0	GPIO23, VSPID, HS1_STROBE		
GND	38	Р	Ground		

<sup>&</sup>lt;sup>1</sup> P: power supply; I: input; O: output.

 $<sup>^2</sup>$  Pins GPI06 to GPI011 on the ESP32-D0WD-V3/ESP32-D0WDR2-V3 chip are connected to the SPI flash integrated on the module and are not led out.

# 4 Boot Configurations

#### Note:

The content below is excerpted from <u>ESP32 Series Datasheet</u> > Section Boot Configurations. For the strapping pin mapping between the chip and modules, please refer to Chapter 8 <u>Module Schematics</u>.

The chip allows for configuring the following boot parameters through strapping pins and eFuse bits at power-up or a hardware reset, without microcontroller interaction.

#### Chip boot mode

- Strapping pin: GPIOO and GPIO2

## • Internal LDO (VDD\_SDIO) Voltage

- Strapping pin: MTDI

- eFuse bit: EFUSE\_SDIO\_FORCE and EFUSE\_SDIO\_TIEH

## UOTXD printing

- Strapping pin: MTDO

## • Timing of SDIO Slave

- Strapping pin: MTDO and GPIO5

### JTAG signal source

- Strapping pin: MTCK, MTMS, MTDI and MTDO

- eFuse bit: EFUSE\_DISABLE\_JTAG

The default values of all the above eFuse bits are 0, which means that they are not burnt. Given that eFuse is one-time programmable, once an eFuse bit is programmed to 1, it can never be reverted to 0. For how to program eFuse bits, please refer to ESP32 Technical Reference Manual > Chapter eFuse Controller.

The default values of the strapping pins, namely the logic levels, are determined by pins' internal weak pull-up/pull-down resistors at reset if the pins are not connected to any circuit, or connected to an external high-impedance circuit.

Table 4: Default Configuration of Strapping Pins

Strapping Pin	Default Configuration	Bit Value
GPI00	Pull-up	1
GPIO2	Pull-down	0
MTDI	Pull-down	0
MTDO	Pull-up	1
GPIO5	Pull-up	1

To change the bit values, the strapping pins should be connected to external pull-down/pull-up resistances. If the ESP32 is used as a device by a host MCU, the strapping pin voltage levels can also be controlled by the host MCU.

All strapping pins have latches. At system reset, the latches sample the bit values of their respective strapping pins and store them until the chip is powered down or shut down. The states of latches cannot be changed in

any other way. It makes the strapping pin values available during the entire chip operation, and the pins are freed up to be used as regular IO pins after reset.

The timing of signals connected to the strapping pins should adhere to the setup time and hold time specifications in Table 5 and Figure 6.

Table 5: Description of Timing Parameters for the Strapping Pins

Parameter	Description	Min (ms)
+	Setup time is the time reserved for the power rails to stabilize be-	0
$t_{SU}$	fore the CHIP_PU pin is pulled high to activate the chip.	
	Hold time is the time reserved for the chip to read the strapping	
$ t_H $	pin values after CHIP_PU is already high and before these pins	1
	start operating as regular IO pins.	

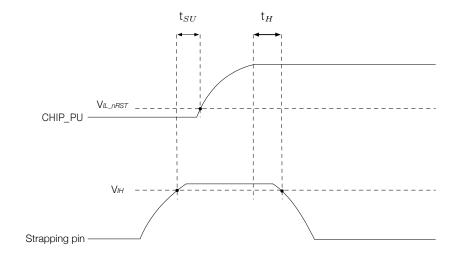


Figure 6: Visualization of Timing Parameters for the Strapping Pins

#### **Chip Boot Mode Control** 4.1

GPIOO and GPIO2 control the boot mode after the reset is released. See Table 6 Chip Boot Mode Control.

Table 6: Chip Boot Mode Control

Boot Mode	GPI00	GPI02
SPI Boot Mode	1	Any value
Joint Download Boot Mode <sup>2</sup>	0	0

<sup>&</sup>lt;sup>1</sup> **Bold** marks the default value and configuration.

- SDIO Download Boot
- UART Download Boot

In Joint Download Boot mode, the detailed boot flow of the chip is put below 7.

<sup>&</sup>lt;sup>2</sup> Joint Download Boot mode supports the following download methods:

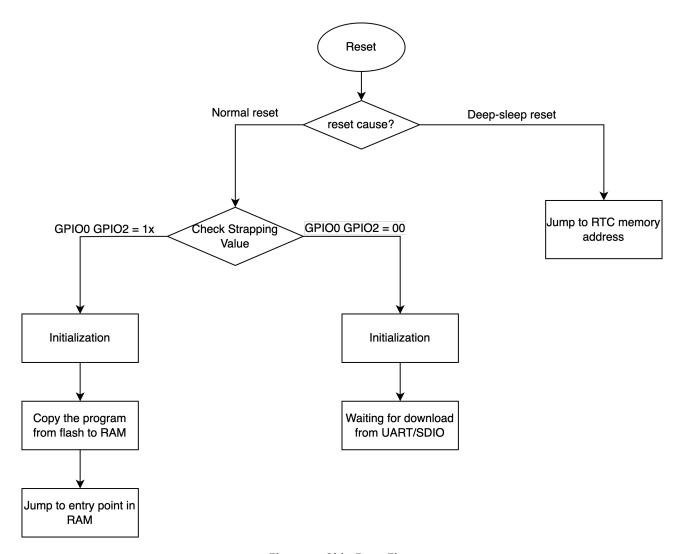


Figure 7: Chip Boot Flow

uart\_download\_dis controls boot mode behaviors:

It permanently disables Download Boot mode when uart\_download\_dis is set to 1 (valid only for ESP32 ECO V3).

# 4.2 Internal LDO (VDD\_SDIO) Voltage Control

MTDI is used to select the VDD\_SDIO power supply voltage at reset:

- MTDI = 0 (by default), VDD\_SDIO pin is powered directly from VDD3P3\_RTC. Typically this voltage is 3.3 V. For more information, see *ESP32 Series Datasheet* > Section *Power Scheme*.
- MTDI = 1, VDD\_SDIO pin is powered from internal 1.8 V LDO.

This functionality can be overridden by setting EFUSE\_SDIO\_FORCE to 1, in which case the EFUSE\_SDIO\_TIEH determines the VDD\_SDIO voltage:

- EFUSE\_SDIO\_TIEH = 0, VDD\_SDIO connects to 1.8 V LDO.
- EFUSE\_SPI\_TIEH = 1, VDD\_SDIO connects to VDD3P3\_RTC.

#### **UOTXD Printing Control** 4.3

During booting, the strapping pin MTDO can be used to control the UOTXD Printing, as Table 7 shows.

Table 7: UOTXD Printing Control

UOTXD Printing Control	MTDO
Enabled <sup>1</sup>	1
Disabled	0

<sup>&</sup>lt;sup>1</sup> Bold marks the default value and configuration.

# **Timing Control of SDIO Slave**

The strapping pin MTDO and GPIO5 can be used to control the timing of SDIO slave, see Table 8 Timing Control of SDIO Slave.

Table 8: Timing Control of SDIO Slave

Edge behavior	MTDO	GPI05
Falling edge sampling, falling edge output	0	0
Falling edge sampling, rising edge output	0	1
Rising edge sampling, falling edge output	1	0
Rising edge sampling, rising edge output	1	1

<sup>&</sup>lt;sup>1</sup> **Bold** marks the default value and configuration.

# **JTAG Signal Source Control**

The strapping pin MTCK, MTMS, MTDI and MTDO can be used to control the source of JTAG signals during the early boot process.

If EFUSE\_DISABLE\_JTAG is set to 1, the source of JTAG signals can be disabled.

# 5 Peripherals

# 5.1 Peripheral Overview

ESP32-DOWD-V3 chip and ESP32-DOWDR2-V3 chip integrate a rich set of peripherals including SPI, I2S, UART, I2C, pulse count controller, TWAI®, ADC, DAC, touch sensor, etc.

To learn more about on-chip components, please refer to <u>ESP32 Series Datasheet</u> > Section Functional Description.

#### Note:

- The content below is sourced from <u>ESP32 Series Datasheet</u> > Section Functional Description. Some information
  may not be applicable to ESP32-WROVER-E and ESP32-WROVER-IE as not all the IO signals are exposed on the
  module.
- To learn more about peripheral signals, please refer to <u>ESP32 Technical Reference Manual</u> > Section Peripheral Signal List.

# 5.2 Digital Peripherals

## 5.2.1 General Purpose Input / Output Interface (GPIO)

ESP32 has 34 GPIO pins which can be assigned various functions by programming the appropriate registers. There are several kinds of GPIOs: digital-only, analog-enabled, capacitive-touch-enabled, etc. Analog-enabled GPIOs and Capacitive-touch-enabled GPIOs can be configured as digital GPIOs.

Most of the digital GPIOs can be configured as internal pull-up or pull-down, or set to high impedance. When configured as an input, the input value can be read through the register. The input can also be set to edge-trigger or level-trigger to generate CPU interrupts. Most of the digital IO pins are bi-directional, non-inverting and tristate, including input and output buffers with tristate control. These pins can be multiplexed with other functions, such as the SDIO, UART, SPI, etc. (More details can be found in <a href="ESP32 Series Datasheet">ESP32 Series Datasheet</a> > Appendix, Table IO\_MUX. ) For low-power operations, the GPIOs can be set to hold their states.

For details, see <u>ESP32 Series Datasheet</u> > Section Peripheral Pin Configurations, <u>ESP32 Series Datasheet</u> > Appendix A – ESP32 Pin Lists and <u>ESP32 Technical Reference Manual</u> > Chapter IO\_MUX and GPIO Matrix.

## 5.2.2 Serial Peripheral Interface (SPI)

ESP32 features three SPIs (SPI, HSPI and VSPI) in slave and master modes in 1-line full-duplex and 1/2/4-line half-duplex communication modes.

#### Features of General Purpose SPI (GP-SPI)

- Programmable data transfer length, in multiples of 1 byte
- Four-line full-duplex/half-duplex communication and three-line half-duplex communication support
- Master mode and slave mode

- Programmable CPOL and CPHA
- Programmable clock

For details, see ESP32 Technical Reference Manual > Chapter SPI Controller.

#### Pin Assignment

For SPI, the pins are multiplexed with GPIO6 ~ GPIO11 via the IO MUX. For HSPI, the pins are multiplexed with GPIO2, GPIO4, GPIO12 ~ GPIO15 via the IO MUX. For VSPI, the pins are multiplexed with GPIO5, GPIO18 ~ GPI019, GPI021 ~ GPI023 via the IO MUX.

For more information about the pin assignment, see ESP32 Series Datasheet > Section Peripheral Pin Configurations and ESP32 Technical Reference Manual > Chapter IO\_MUX and GPIO Matrix.

## Universal Asynchronous Receiver Transmitter (UART)

The UART in the ESP32 chip facilitates the transmission and reception of asynchronous serial data between the chip and external UART devices. It consists of two UARTs in the main system, and one low-power LP UART.

#### **Feature List**

- Programmable baud rate
- RAM shared by TX FIFOs and RX FIFOs
- Supports input baud rate self-check
- Support for various lengths of data bits and stop bits
- Parity bit support
- Asynchronous communication (RS232 and RS485) and IrDA support
- Supports DMA to communicate data in high speed
- Supports UART wake-up
- Supports both software and hardware flow control

For details, see ESP32 Technical Reference Manual > Chapter UART Controller.

#### Pin Assignment

The pins for UART can be chosen from any GPIOs via the GPIO Matrix.

For more information about the pin assignment, see ESP32 Series Datasheet > Section Peripheral Pin Configurations and ESP32 Technical Reference Manual > Chapter IO\_MUX and GPIO Matrix.

#### 5.2.4 I2C Interface

ESP32 has two I2C bus interfaces which can serve as I2C master or slave, depending on the user's configuration.

#### **Feature List**

- Two I2C controllers: one in the main system and one in the low-power system
- Standard mode (100 Kbit/s)
- Fast mode (400 Kbit/s)
- Up to 5 MHz, yet constrained by SDA pull-up strength
- Support for 7-bit and 10-bit addressing, as well as dual address mode
- Supports continuous data transmission with disabled Serial Clock Line (SCL)
- Supports programmable digital noise filter

Users can program command registers to control I2C interfaces, so that they have more flexibility.

For details, see ESP32 Technical Reference Manual > Chapter I2C Controller.

#### Pin Assignment

For regular I2C, the pins used can be chosen from any GPIOs via the GPIO Matrix.

For more information about the pin assignment, see ESP32 Series Datasheet > Section Peripheral Pin Configurations and ESP32 Technical Reference Manual > Chapter IO\_MUX and GPIO Matrix.

#### 5.2.5 I2S Interface

The I2S Controller in the ESP32 chip provides a flexible communication interface for streaming digital data in multimedia applications, particularly digital audio applications.

#### **Feature List**

- Master mode and slave mode
- Full-duplex and half-duplex communications
- · A variety of audio standards supported
- Configurable high-precision output clock
- Supports PDM signal input and output
- Configurable data transmit and receive modes

For details, see ESP32 Technical Reference Manual > Chapter I2S Controller.

### Pin Assignment

The pins for the I2S Controller can be chosen from any GPIOs via the GPIO Matrix.

For more information about the pin assignment, see ESP32 Series Datasheet > Section Peripheral Pin Configurations and ESP32 Technical Reference Manual > Chapter IO\_MUX and GPIO Matrix.

#### 5.2.6 Remote Control Peripheral

The Remote Control Peripheral (RMT) controls the transmission and reception of infrared remote control signals.

#### **Feature List**

- Eight channels for sending and receiving infrared remote control signals
- Independent transmission and reception capabilities for each channel
- Clock divider counter, state machine, and receiver for each RX channel
- Supports various infrared protocols

For details, see ESP32 Technical Reference Manual > Chapter Remote Control Peripheral.

#### Pin Assignment

The pins for the Remote Control Peripheral can be chosen from any GPIOs via the GPIO Matrix.

For more information about the pin assignment, see <u>ESP32 Series Datasheet</u> > Section Peripheral Pin Configurations and <u>ESP32 Technical Reference Manual</u> > Chapter IO\_MUX and GPIO Matrix.

## 5.2.7 Pulse Counter Controller (PCNT)

The pulse counter controller (PCNT) is designed to count input pulses by tracking rising and falling edges of the input pulse signal.

#### **Feature List**

- Eight independent pulse counter units
- Each pulse counter unit has a 16-bit signed counter register and two channels
- Counter modes: increment, decrement, or disable
- Glitch filtering for input pulse signals and control signals
- Selection between counting on rising or falling edges of the input pulse signal

For details, see ESP32 Technical Reference Manual > Chapter Pulse Count Controller.

#### Pin Assignment

The pins for the Pulse Count Controller can be chosen from any GPIOs via the GPIO Matrix.

For more information about the pin assignment, see <u>ESP32 Series Datasheet</u> > Section Peripheral Pin Configurations and <u>ESP32 Technical Reference Manual</u> > Chapter IO\_MUX and GPIO Matrix.

#### 5.2.8 LED PWM Controller

The LED PWM Controller (LEDC) is designed to generate PWM signals for LED control.

#### **Feature List**

- Sixteen independent PWM generators
- Maximum PWM duty cycle resolution of 20 bits
- Eight independent timers with 20-bit counters, configurable fractional clock dividers and counter overflow values

- Adjustable phase of PWM signal output
- PWM duty cycle dithering
- Automatic duty cycle fading

For details, see ESP32 Technical Reference Manual > Chapter LED PWM Controller.

#### Pin Assignment

The pins for the LED PWM Controller can be chosen from any GPIOs via the GPIO Matrix.

For more information about the pin assignment, see ESP32 Series Datasheet > Section Peripheral Pin Configurations and ESP32 Technical Reference Manual > Chapter IO\_MUX and GPIO Matrix.

#### 5.2.9 Motor Control PWM

The Pulse Width Modulation (PWM) controller can be used for driving digital motors and smart lights. The controller consists of PWM timers, the PWM operator and a dedicated capture sub-module. Each timer provides timing in synchronous or independent form, and each PWM operator generates a waveform for one PWM channel. The dedicated capture sub-module can accurately capture events with external timing.

#### **Feature List**

- Three PWM timers for precise timing and frequency control
  - Every PWM timer has a dedicated 8-bit clock prescaler
  - The 16-bit counter in the PWM timer can work in count-up mode, count-down mode, or count-up-down mode
  - A hardware sync can trigger a reload on the PWM timer with a phase register. It will also trigger the prescaler' restart, so that the timer's clock can also be synced, with selectable hardware synchronization source
- Three PWM operators for generating waveform pairs
  - Six PWM outputs to operate in several topologies
  - Configurable dead time on rising and falling edges; each set up independently
  - Modulating of PWM output by high-frequency carrier signals, useful when gate drivers are insulated with a transformer
- Fault Detection module
  - Programmable fault handling in both cycle-by-cycle mode and one-shot mode
  - A fault condition can force the PWM output to either high or low logic levels
- Capture module for hardware-based signal processing
  - Speed measurement of rotating machinery
  - Measurement of elapsed time between position sensor pulses
  - Period and duty cycle measurement of pulse train signals

- Decoding current or voltage amplitude derived from duty-cycle-encoded signals of current/voltage sensors
- Three individual capture channels, each of which with a 32-bit time-stamp register
- Selection of edge polarity and prescaling of input capture signals
- The capture timer can sync with a PWM timer or external signals

For details, see ESP32 Technical Reference Manual > Chapter Motor Control PWM.

## Pin Assignment

The pins for the Motor Control PWM can be chosen from any GPIOs via the GPIO Matrix.

For more information about the pin assignment, see <u>ESP32 Series Datasheet</u> > Section Peripheral Pin Configurations and <u>ESP32 Technical Reference Manual</u> > Chapter IO\_MUX and GPIO Matrix.

#### 5.2.10 SD/SDIO/MMC Host Controller

An SD/SDIO/MMC host controller is available on ESP32.

#### **Feature List**

- Supports two external cards
- Supports SD Memory Card standard: version 3.0 and version 3.01)
- Supports SDIO Version 3.0
- Supports Consumer Electronics Advanced Transport Architecture (CE-ATA Version 1.1)
- Supports Multimedia Cards (MMC version 4.41, eMMC version 4.5 and version 4.51)

The controller allows up to 80 MHz clock output in three different data-bus modes: 1-bit, 4-bit, and 8-bit modes. It supports two SD/SDIO/MMC4.41 cards in a 4-bit data-bus mode. It also supports one SD card operating at 1.8 V.

For details, see ESP32 Technical Reference Manual > Chapter SD/MMC Host Controller.

#### Pin Assignment

The pins for SD/SDIO/MMC Host Controller are multiplexed with GPIO2, GPIO4, GPIO6 ~ GPIO15 via IO MUX.

For more information about the pin assignment, see <u>ESP32 Series Datasheet</u> > Section Peripheral Pin Configurations and <u>ESP32 Technical Reference Manual</u> > Chapter IO\_MUX and GPIO Matrix.

#### 5.2.11 SDIO/SPI Slave Controller

ESP32 integrates an SD device interface that conforms to the industry-standard SDIO Card Specification Version 2.0, and allows a host controller to access the SoC, using the SDIO bus interface and protocol. ESP32 acts as the slave on the SDIO bus. The host can access the SDIO-interface registers directly and can access shared memory via a DMA engine, thus maximizing performance without engaging the processor cores.

#### **Feature List**

The SDIO/SPI slave controller supports the following features:

- SPI, 1-bit SDIO, and 4-bit SDIO transfer modes over the full clock range from 0 to 50 MHz
- Configurable sampling and driving clock edge
- Special registers for direct access by host
- Interrupts to host for initiating data transfer
- Automatic loading of SDIO bus data and automatic discarding of padding data
- Block size of up to 512 bytes
- Interrupt vectors between the host and the slave, allowing both to interrupt each other
- Supports DMA for data transfer

For details, see ESP32 Technical Reference Manual > Chapter SDIO Slave Controller.

#### Pin Assignment

The pins for SDIO/SPI Slave Controller are multiplexed with GPIO2, GPIO4, GPIO6 ~ GPIO15 via IO MUX.

For more information about the pin assignment, see ESP32 Series Datasheet > Section Peripheral Pin Configurations and ESP32 Technical Reference Manual > Chapter IO\_MUX and GPIO Matrix.

#### 5.2.12 TWAI® Controller

The Two-wire Automotive Interface (TWAI®) is a multi-master, multi-cast communication protocol designed for automotive applications. The TWAI controller facilitates the communication based on this protocol.

#### **Feature List**

- Compatible with ISO 11898-1 protocol (CAN Specification 2.0)
- Standard frame format (11-bit ID) and extended frame format (29-bit ID)
- Bit rates:
  - From 25 Kbit/s to 1 Mbit/s in chip revision v0.0/v1.0/v1.1
  - From 12.5 Kbit/s to 1 Mbit/s in chip revision v3.0/v3.1
- Multiple modes of operation: Normal, Listen Only, and Self-Test
- 64-byte receive FIFO
- Special transmissions: single-shot transmissions and self reception
- Acceptance filter (single and dual filter modes)
- Error detection and handling: error counters, configurable error interrupt threshold, error code capture, arbitration lost capture

For details, see ESP32 Technical Reference Manual > Chapter Two-wire Automotive Interface (TWAI).

#### Pin Assignment

The pins for the Two-wire Automotive Interface can be chosen from any GPIOs via the GPIO Matrix.

For more information about the pin assignment, see ESP32 Series Datasheet > Section Peripheral Pin Configurations and ESP32 Technical Reference Manual > Chapter IO\_MUX and GPIO Matrix.

#### **Ethernet MAC Interface** 5.2.13

An IEEE-802.3-2008-compliant Media Access Controller (MAC) is provided for Ethernet LAN communications. ESP32 requires an external physical interface device (PHY) to connect to the physical LAN bus (twisted-pair, fiber, etc.). The PHY is connected to ESP32 through 17 signals of MII or nine signals of RMII.

#### **Feature List**

- 10 Mbps and 100 Mbps rates
- Dedicated DMA controller allowing high-speed transfer between the dedicated SRAM and Ethernet MAC
- Tagged MAC frame (VLAN support)
- Half-duplex (CSMA/CD) and full-duplex operation
- MAC control sublayer (control frames)
- 32-bit CRC generation and removal
- Several address-filtering modes for physical and multicast address (multicast and group addresses)
- 32-bit status code for each transmitted or received frame
- Internal FIFOs to buffer transmit and receive frames. The transmit FIFO and the receive FIFO are both 512 words (32-bit)
- Hardware PTP (Precision Time Protocol) in accordance with IEEE 1588 2008 (PTP V2)
- 25 MHz/50 MHz clock output

For details, see ESP32 Technical Reference Manual > Chapter Ethernet Media Access Controller (MAC).

## Pin Assignment

For information about the pin assignment of Ethernet MAC Interface, see ESP32 Series Datasheet > Section Peripheral Pin Configurations and ESP32 Technical Reference Manual > Chapter IO\_MUX and GPIO Matrix.

#### 5.3 **Analog Peripherals**

## Analog-to-Digital Converter (ADC)

ESP32 integrates two 12-bit SAR ADCs and supports measurements on 18 channels (analog-enabled pins). The ULP coprocessor in ESP32 is also designed to measure voltage, while operating in the sleep mode, which enables low-power consumption. The CPU can be woken up by a threshold setting and/or via other triggers.

Table 9 describes the ADC characteristics.

Table 9: ADC Characteristics

Parameter	Description		Max	Unit
DNL (Differential nonlinearity)	RTC controller; ADC connected to an		7	LSB
DNE (Differential Horilineanty)	external 100 nF capacitor; DC signal input;		/	LOD
INL (Integral nonlinearity)	ambient temperature at 25 °C;	-12	12	LSB
inc (integral normineanty)	Wi-Fi&Bluetooth off	-12	۱۷	LOD
Compling rate	RTC controller	_	200	ksps
Sampling rate	DIG controller	_	2	Msps

#### Notes:

- When atten = 3 and the measurement result is above 3000 (voltage at approx. 2450 mV), the ADC accuracy will be worse than described in the table above.
- To get better DNL results, users can take multiple sampling tests with a filter, or calculate the average value.
- The input voltage range of GPIO pins within VDD3P3\_RTC domain should strictly follow the DC characteristics provided in Table 14. Otherwise, measurement errors may be introduced, and chip performance may be affected.

By default, there are ±6% differences in measured results between chips. ESP-IDF provides couple of <u>calibration methods</u> for ADC1. Results after calibration using eFuse Vref value are shown in Table 10. For higher accuracy, users may apply other calibration methods provided in ESP-IDF, or implement their own.

Table 10: ADC Calibration Results

Parameter	eter Description		Max	Unit
	Atten = 0, effective measurement range of 100 $\sim$ 950 mV	-23	23	mV
Total error	Atten = 1, effective measurement range of 100 $\sim$ 1250 mV	-30	30	mV
	Atten = 2, effective measurement range of 150 $\sim$ 1750 mV	-40	40	mV
	Atten = 3, effective measurement range of 150 $\sim$ 2450 mV	-60	60	mV

For details, see <u>ESP32 Technical Reference Manual</u> > Chapter On-Chip Sensors and Analog Signal Processing.

### Pin Assignment

With appropriate settings, the ADCs can be configured to measure voltage on 18 pins maximum. For detailed information about the pin assignment, see <u>ESP32 Series Datasheet</u> > Section Peripheral Pin Configurations and <u>ESP32 Technical Reference Manual</u> > Chapter IO\_MUX and GPIO Matrix.

## 5.3.2 Digital-to-Analog Converter (DAC)

Two 8-bit DAC channels can be used to convert two digital signals into two analog voltage signal outputs. The design structure is composed of integrated resistor strings and a buffer. This dual DAC supports power supply as input voltage reference. The two DAC channels can also support independent conversions.

For details, see <u>ESP32 Technical Reference Manual</u> > Chapter On-Chip Sensors and Analog Signal Processing.

## Pin Assignment

The DAC can be configured by GPIO 25 and GPIO 26. For detailed information about the pin assignment, see ESP32 Series Datasheet > Section Peripheral Pin Configurations and ESP32 Technical Reference Manual > Chapter IO\_MUX and GPIO Matrix.

#### 5.3.3 Touch Sensor

ESP32 has 10 capacitive-sensing GPIOs, which detect variations induced by touching or approaching the GPIOs with a finger or other objects. The low-noise nature of the design and the high sensitivity of the circuit allow relatively small pads to be used. Arrays of pads can also be used, so that a larger area or more points can be detected.

## Pin Assignment

The 10 capacitive-sensing GPIOs are listed in Table 11.

Table 11: Capacitive-Sensing GPIOs Available on ESP32

Capacitive-Sensing Signal Name	Pin Name
ТО	GPIO4
T1	GPI00
T2	GPI02
T3	MTDO
T4	MTCK
T5	MTDI
T6	MTMS
Т7	GPIO27
T8	32K_XN
T9	32K_XP

For details, see ESP32 Technical Reference Manual > Chapter On-Chip Sensors and Analog Signal Processing.

#### Note:

ESP32 Touch Sensor has not passed the Conducted Susceptibility (CS) test for now, and thus has limited application

# **Electrical Characteristics**

#### **Absolute Maximum Ratings** 6.1

Stresses above those listed in Table 12 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 Table 13 Recommended Operating Conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

Table 12: Absolute Maximum Ratings

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

# **Recommended Operating Conditions**

Table 13: Recommended Operating Conditions

Symbol	Parameter	Min	Тур	Max	Unit
VDD33	Power supply voltage	3.0	3.3	3.6	V
$ V_{VDD} $	Current delivered by external power supply	0.5	_	_	Α
Т	Operating temperature	-40	_	85	°C

#### DC Characteristics (3.3 V, 25 °C) 6.3

Table 14: DC Characteristics (3.3 V, 25 °C)

Symbol	Parameter	Min	Тур	Max	Unit
$C_{IN}$	Pin capacitance	-	2	-	pF
$V_{IH}$	High-level input voltage	0.75×VDD <sup>1</sup>	-	VDD1+0.3	V
$V_{IL}$	Low-level input voltage	-0.3	-	0.25×VDD <sup>1</sup>	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 <sup>1</sup>	-	-	٧
$V_{OL}$	Low-level output voltage	-	-	0.1×VDD <sup>1</sup>	V

Cont'd on next page

Symbol Unit Parameter Min Тур Max VDD3P3\_CPU High-level source current 40 mΑ power domain 1, 2  $(VDD^1 = 3.3 V,$ VDD3P3 RTC  $V_{OH} >= 2.64 \text{ V},$ 40 mΑ  $|_{OH}$ power domain 1, 2 output drive strength set VDD\_SDIO power to the maximum) 20 mΑ  ${\rm domain}^{\ 1,\ 3}$ Low-level sink current  $|_{OL}$  $(VDD^1 = 3.3 \text{ V}, V_{OL} = 0.495 \text{ V},$ 28 mΑ output drive strength set to the maximum) Resistance of internal pull-up resistor 45  $\mathsf{k}\Omega$  $R_{PU}$ Resistance of internal pull-down resistor  $R_{PD}$ 45  $\mathsf{k}\Omega$ Low-level input voltage of CHIP PU 0.6 V  $V_{IL\_nRST}$ to shut down the chip

Table 14 – cont'd from previous page

# 6.4 Current Consumption in Active Mode

The current consumption measurements are taken with a 3.3 V supply at 25 °C ambient temperature.

TX current consumption is rated at a 100% duty cycle.

RX current consumption is rated when the peripherals are disabled and the CPU idle.

Table 15: Current Consumption for Wi-Fi (2.4 GHz) in Active Mode

Work Mode	RF Condition	Description	Peak (mA)
		802.11b, 1 Mbps, DSSS @ 19.5 dBm	350
	TX	802.11g, 54 Mbps, OFDM @ 14.0 dBm	243
		802.11n, HT20, MCS7 @ 13.0 dBm	233
		802.11n, HT40, MCS7 @ 13.0 dBm	229
Active (RF working)	RX	802.11b/g/n, HT20	108
	KΛ	802.11n, HT40	113

<sup>&</sup>lt;sup>1</sup> Please see Appendix IO MUX of <u>ESP32 Series Datasheet</u> for IO's power domain. VDD is the I/O voltage for a particular power domain of pins.

<sup>&</sup>lt;sup>2</sup> 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.

 $<sup>^3</sup>$  Pins occupied by flash and/or PSRAM in the VDD\_SDIO power domain were excluded from the test.

# 7 RF Characteristics

This section contains tables with RF characteristics of the Espressif product.

The RF data is measured at the antenna port, where RF cable is connected, including the front-end loss. The external antennas used for the tests on the modules with external antenna connectors have an impedance of  $50 \Omega$ . Devices should operate in the center frequency range allocated by regional regulatory authorities. The target center frequency range and the target transmit power are configurable by software. See <u>ESP RF Test</u> Tool and Test Guide for instructions.

Unless otherwise stated, the RF tests are conducted with a 3.3 V ( $\pm 5\%$ ) supply at 25 °C ambient temperature.

## 7.1 Wi-Fi Radio

Table 16: Wi-Fi RF Characteristics

Name	Description
Center frequency range of operating channel	2412 ~ 2484 MHz
Wi-Fi wireless standard	IEEE 802.11b/g/n

## 7.1.1 Wi-Fi RF Transmitter (TX) Characteristics

Table 17: TX Power with Spectral Mask and EVM Meeting 802.11 Standards

Rate	Min (dBm)	Typ (dBm)	Max (dBm)
802.11b, 1 Mbps	_	19.5	_
802.11b, 11 Mbps	_	19.5	_
802.11g, 6 Mbps	_	18.0	_
802.11g, 54 Mbps	_	14.0	_
802.11n, HT20, MCS0	_	18.0	_
802.11n, HT20, MCS7	_	13.0	_
802.11n, HT40, MCS0	_	18.0	_
802.11n, HT40, MCS7	_	13.0	_

Table 18: TX EVM Test1

	Min	Тур	Limit
Rate	(dB)	(dB)	(dB)
802.11b, 1 Mbps, DSSS	_	-25.0	-10.0
802.11b, 11 Mbps, CCK	_	-25.0	-10.0
802.11g, 6 Mbps, OFDM	_	-24.0	-5.0
802.11g, 54 Mbps, OFDM	_	-28.0	-25.0
802.11n, HT20, MCS0	_	-24.0	-5.0

Cont'd on next page

Table 18 - cont'd from previous page

	Min	Тур	Limit
Rate	(dB)	(dB)	(dB)
802.11n, HT20, MCS7	_	-30.0	-27.0
802.11n, HT40, MCS0	_	-24.0	-5.0
802.11n, HT40, MCS7	_	-30.0	-27.0

<sup>&</sup>lt;sup>1</sup> EVM is measured at the corresponding typical TX power provided in Table 17 Wi-Fi RF Transmitter (TX) Characteristics above.

# 7.1.2 Wi-Fi RF Receiver (RX) Characteristics

For RX tests, the PER (packet error rate) limit is 8% for 802.11b, and 10% for 802.11g/n.

Table 19: RX Sensitivity

Data	Min	Тур	Max
Rate	(dBm)	(dBm)	(dBm)
802.11b, 1 Mbps, DSSS	_	-97.0	_
802.11b, 2 Mbps, DSSS	_	-94.0	_
802.11b, 5.5 Mbps, CCK	_	-91.0	_
802.11b, 11 Mbps, CCK	_	-88.0	_
802.11g, 6 Mbps, OFDM	_	-93.0	_
802.11g, 9 Mbps, OFDM	_	-91.0	_
802.11g, 12 Mbps, OFDM	_	-90.0	_
802.11g, 18 Mbps, OFDM	_	-87.0	_
802.11g, 24 Mbps, OFDM	_	-84.0	_
802.11g, 36 Mbps, OFDM	_	-81.0	_
802.11g, 48 Mbps, OFDM	_	-77.0	_
802.11g, 54 Mbps, OFDM	_	-75.0	_
802.11n, HT20, MCS0	_	-91.0	_
802.11n, HT20, MCS1	_	-88.0	_
802.11n, HT20, MCS2	_	-86.0	_
802.11n, HT20, MCS3	_	-83.0	_
802.11n, HT20, MCS4	_	-80.0	_
802.11n, HT20, MCS5	_	-75.0	_
802.11n, HT20, MCS6	_	-73.0	_
802.11n, HT20, MCS7	_	-72.0	_
802.11n, HT40, MCS0	_	-88.0	_
802.11n, HT40, MCS1	_	-85.0	_
802.11n, HT40, MCS2	_	-83.0	_
802.11n, HT40, MCS3		-80.0	
802.11n, HT40, MCS4	_	-76.0	_
802.11n, HT40, MCS5	_	-72.0	_
802.11n, HT40, MCS6	_	-70.0	_
802.11n, HT40, MCS7	_	-69.0	_

Table 20: Maximum RX Level

Rate	Min (dBm)	Typ (dBm)	Max (dBm)
802.11b, 1 Mbps	_	5	_
802.11b, 11 Mbps	_	5	_
802.11g, 6 Mbps	_	0	_
802.11g, 54 Mbps	_	-8	_
802.11n, HT20, MCS0	_	0	_
802.11n, HT20, MCS7	_	-8	_
802.11n, HT40, MCS0	_	0	_
802.11n, HT40, MCS7	_	-8	_

Table 21: RX Adjacent Channel Rejection

Rate	Min (dB)	Typ (dB)	Max (dB)
802.11b, 1 Mbps, DSSS	_	35	_
802.11b, 11 Mbps, CCK	_	35	_
802.11g, 6 Mbps, OFDM	_	27	_
802.11g, 54 Mbps, OFDM	_	13	_
802.11n, HT20, MCS0	_	27	_
802.11n, HT20, MCS7	_	12	_
802.11n, HT40, MCS0	_	16	_
802.11n, HT40, MCS7	_	7	_

# 7.2 Bluetooth Radio

Table 22: Bluetooth LE RF Characteristics

Name	Description
Center frequency range of operating channel	2402 ~ 2480 MHz
RF transmit power range	-12.0 ~ 9.0 dBm

## 7.2.1 Receiver - Basic Data Rate

Table 23: Receiver Characteristics - Basic Data Rate

Parameter	Conditions	Min	Тур	Max	Unit
Sensitivity @0.1% BER	_	-90	-89	-88	dBm
Maximum received signal @0.1% BER	_	0	_	_	dBm
Co-channel C/I	_	_	+7	_	dB
	F = FO + 1 MHz	_	_	-6	dB
	F = FO – 1 MHz	_	_	-6	dB

Adjacent channel selectivity C/I

Cont'd on next page

Table 23 – cont'd from previous page

Parameter	Conditions	Min	Тур	Max	Unit
	F = F0 + 2 MHz	_	_	-25	dB
	F = F0 - 2 MHz	_	_	-33	dB
	F = F0 + 3 MHz	_		-25	dB
	F = F0 - 3 MHz	_	_	-45	dB
	30 MHz ~ 2000 MHz	-10	_	_	dBm
Out-of-band blocking performance	2000 MHz ~ 2400 MHz	-27	_	_	dBm
Out-of-balld blocking performance	2500 MHz ~ 3000 MHz	-27		_	dBm
	3000 MHz ~ 12.5 GHz	-10	_	_	dBm
Intermodulation	_	-36	_	_	dBm

## 7.2.2 Transmitter - Basic Data Rate

Table 24: Transmitter Characteristics - Basic Data Rate

Parameter	Conditions	Min	Тур	Max	Unit	
RF transmit power <sup>1</sup>	_	_	0	_	dBm	
Gain control step	_	_	3	_	dB	
RF power control range	_	-12	_	+9	dBm	
+20 dB bandwidth	_	_	0.9	_	MHz	
	F = F0 ± 2 MHz	_	-55	_	dBm	
Adjacent channel transmit power	$F = FO \pm 3 MHz$	−   −55		_	dBm	
	$F = FO \pm > 3 MHz$	_	-59	_	dBm	
$\Delta f1_{ ext{avg}}$	_	_	_	155	kHz	
$\Delta f2_{\sf max}$	_	127	_	_	kHz	
$\Delta~f2_{\rm avg}/\Delta~f1_{\rm avg}$	_	_	0.92	_	_	
ICFT	_	_	-7	_	kHz	
Drift rate	_	_	0.7	_	kHz/50 μs	
Drift (DH1)	_		6	_	kHz	
Drift (DH5)	_	_	6	_	kHz	

<sup>&</sup>lt;sup>1</sup> 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.

## 7.2.3 Receiver - Enhanced Data Rate

Table 25: Receiver Characteristics - Enhanced Data Rate

Conditions	Min	Тур	Max	Unit		
$\pi/4$ DQPSK						
_	-90	-89	-88	dBm		
_	_	0		dBm		
_	_	11	_	dB		
F = FO + 1 MHz	_	-7	_	dB		
F = FO – 1 MHz	_	-7	_	dB		
F = F0 + 2 MHz	_	-25		dB		
F = F0 – 2 MHz	_	-35	1	dB		
F = F0 + 3 MHz	_	-25		dB		
F = FO - 3 MHz	_	-45	1	dB		
DPSK						
_	-84	-83	-82	dBm		
_	_	-5	_	dBm		
_	_	18		dB		
F = FO + 1 MHz	_	2	_	dB		
F = FO – 1 MHz	_	2	_	dB		
	DQPSK  F = F0 + 1 MHz F = F0 - 1 MHz F = F0 - 2 MHz F = F0 - 3 MHz F = F0 - 3 MHz  DPSK  F = F0 + 1 MHz	POPSK	POPSK	DQPSK  - 90 -89 -88  - 0 - 0 -  - 11 -  F = F0 + 1 MHz - 7 -  F = F0 - 1 MHz7 -  F = F0 + 2 MHz25 -  F = F0 - 3 MHz25 -  F = F0 - 3 MHz45 -  DPSK  - 84 -83 -82  5 -  F = F0 + 1 MHz - 2 -  F = F0 + 1 MHz - 2 -		

Adjacent channel selectivity C/I

Cont'd on next page

Table 25 - cont'd from previous page

Parameter	Conditions	Min	Тур	Max	Unit
	F = F0 + 2 MHz	_	-25	_	dB
	F = F0 – 2 MHz	_	-25	_	dB
	F = FO + 3 MHz	_	-25	_	dB
	F = F0 – 3 MHz	_	-38	_	dB

## 7.2.4 Transmitter - Enhanced Data Rate

Table 26: Transmitter Characteristics - Enhanced Data Rate

Parameter	Conditions	Min	Тур	Max	Unit
RF transmit power (see note under Table 24)	_	_	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
	RMS DEVM	_	4.28	_	%
$\pi/4$ DQPSK modulation accuracy	99% DEVM	_	100	_	%
	Peak DEVM	_	13.3	_	%
	RMS DEVM	_	5.8	_	%
8 DPSK modulation accuracy	99% DEVM	_	100	_	%
	Peak DEVM	_	14	_	%
	$F = FO \pm 1 MHz$	_	-46	_	dBm
In-band spurious emissions	$F = F0 \pm 2 MHz$	_	-44	_	dBm
	$F = FO \pm 3 MHz$	_	-49	_	dBm
	F = F0 +/- > 3 MHz	_	_	-53	dBm
EDR differential phase coding	_		100	_	%

#### Bluetooth LE Radio 7.3

## 7.3.1 Receiver

Table 27: Receiver Characteristics - Bluetooth LE

Parameter	Conditions	Min	Тур	Max	Unit
Sensitivity @30.8% PER	_	-94	-93	-92	dBm
Maximum received signal @30.8% PER	_	0	_	_	dBm
Co-channel C/I	_	_	+10	_	dB
	F = FO + 1 MHz	_	-5	_	dB
	F = F0 – 1 MHz		-5	_	dB

Parameter	Conditions	Min	Тур	Max	Unit
	F = F0 + 2 MHz	_	-25	_	dB
	F = F0 - 2 MHz		-35	_	dB
	F = F0 + 3 MHz	_	-25	_	dB
	F = F0 - 3 MHz	l	-45	_	dB
	30 MHz ~ 2000 MHz	-10	_	_	dBm
Out-of-band blocking performance	2000 MHz ~ 2400	-27	_	_	dBm
Out-or-band blocking penormance	MHz				
	2500 MHz ~ 3000	-27	_	_	dBm
	MHz				
	3000 MHz ~ 12.5 GHz	-10	_	_	dBm
Intermodulation	_	-36		_	dBm

# 7.3.2 Transmitter

Table 28: Transmitter Characteristics - Bluetooth LE

Parameter	Conditions	Min	Тур	Max	Unit
RF transmit power (see note under Table	_	_	0	_	dBm
24)					
Gain control step	_	_	3		dB
RF power control range	_	-12		+9	dBm
	F = F0 ± 2 MHz	_	-55		dBm
Adjacent channel transmit power	$F = FO \pm 3 MHz$	_	-57	1	dBm
	$F = F0 \pm > 3 MHz$	_	-59	l	dBm
$\Delta  f1_{ ext{avg}}$	_	_		265	kHz
$\Delta~f2_{\sf max}$	_	210	_		kHz
$\Delta f 2_{ m avg}/\Delta f 1_{ m avg}$	_	_	+0.92		_
ICFT	_	_	-10		kHz
Drift rate	_	_	0.7		kHz/50 $\mu$ s
Drift	_	_	2	_	kHz

 $| \infty |$ 

# 8 Module Schematics

This is the reference design of the module.

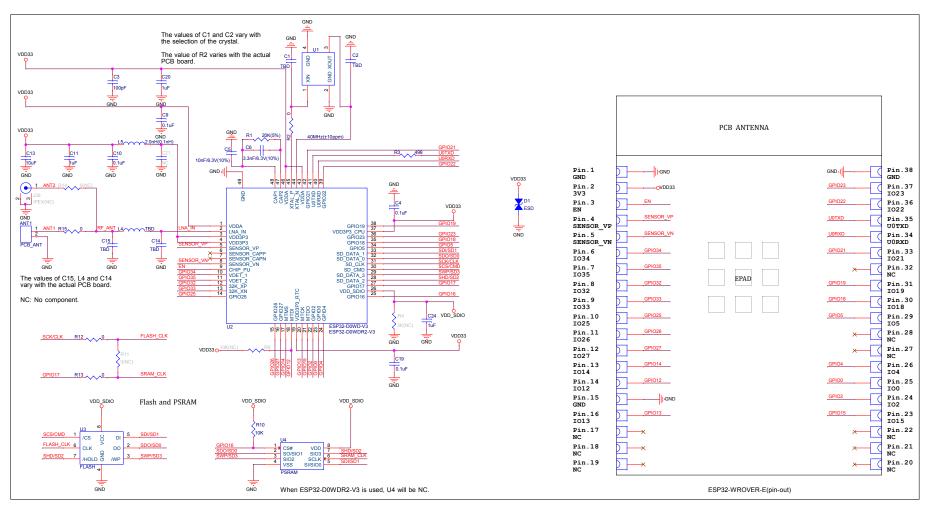


Figure 8: Schematics of ESP32-WROVER-E

 $| \infty |$ 

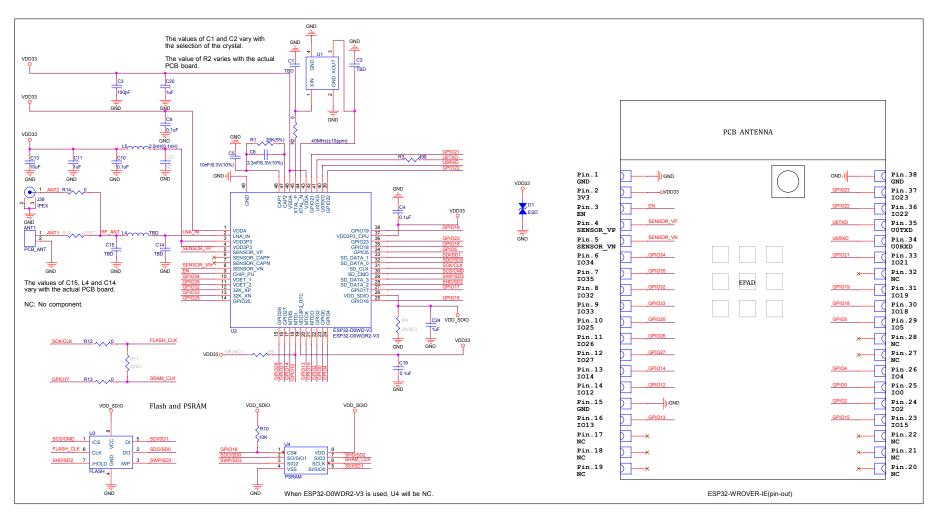


Figure 9: Schematics of ESP32-WROVER-IE

# 9 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).

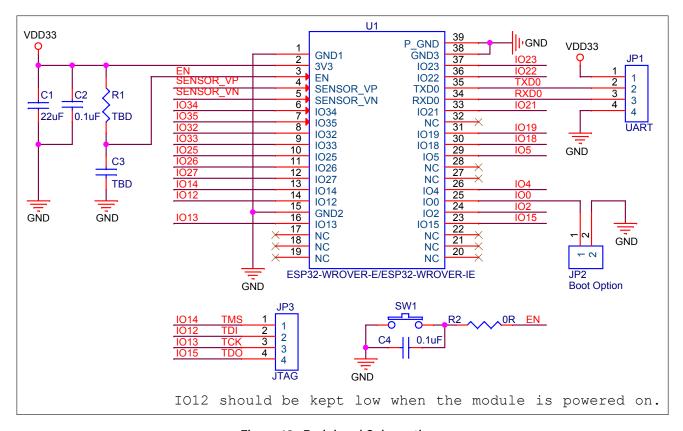


Figure 10: Peripheral Schematics

- Soldering Pad 39 to the ground of the base board is not a must. If you choose to solder it, please apply
  the correct amount of soldering paste. Too much soldering paste may increase the gap between the
  module and the baseboard. As a result, the adhesion between other pins and the baseboard may be
  poor.
- 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 k $\Omega$  and C = 1  $\mu$ F. However, specific parameters should be adjusted based on the power-up timing of the module and the power-up and reset sequence timing of the chip. For ESP32's power-up and reset sequence timing diagram, please refer to Section *Power Scheme* in *ESP32 Datasheet*.
- UARTO is used to download firmware and log output. When using the AT firmware, please note that the
  UART GPIO is already configured (refer to <u>Hardware Connection</u>). It is recommended to use the default
  configuration.

### **Physical Dimensions** 10

#### **Module Dimensions** 10.1

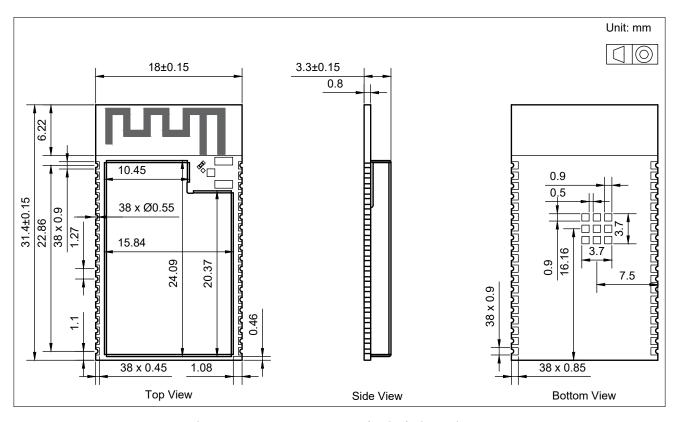


Figure 11: ESP32-WROVER-E Physical Dimensions

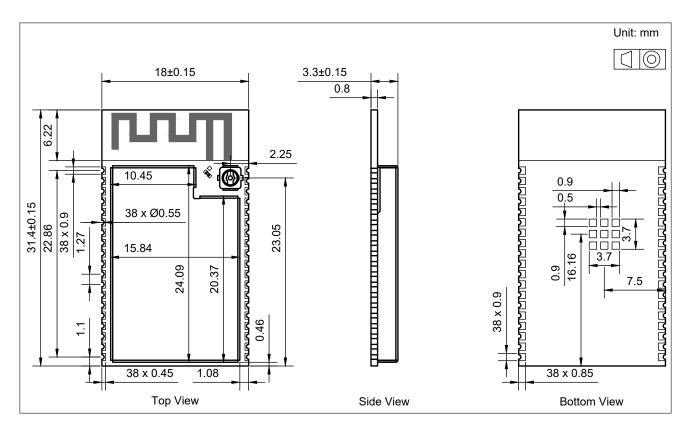


Figure 12: ESP32-WROVER-IE Physical Dimensions

### Note:

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

# 10.2 Dimensions of External Antenna Connector

ESP32-WROVER-IE uses the first generation external antenna connector as shown in Figure 13. This connector is compatible with the following connectors:

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

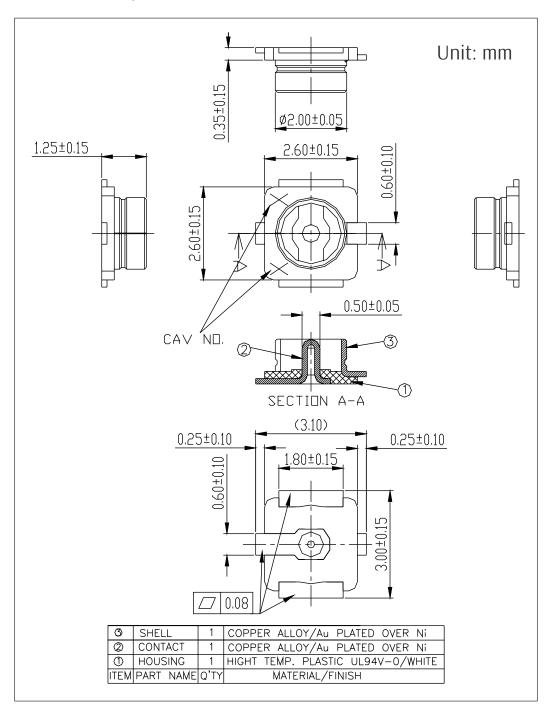


Figure 13: Dimensions of External Antenna Connector

# 11 PCB Layout Recommendations

# 11.1 PCB Land Pattern

This section provides the following resources for your reference:

- Figures for recommended PCB land patterns with all the dimensions needed for PCB design. See Figure 14 Recommended PCB Land Pattern.
- Source files of recommended PCB land patterns to measure dimensions not covered in Figure 14. You can view the source files for ESP32-WROVER-E and ESP32-WROVER-IE with Autodesk Viewer.
- 3D models of <u>ESP32-WROVER-E</u> and <u>ESP32-WROVER-IE</u>. Please make sure that you download the 3D model file in .STEP format (beware that some browsers might add .txt).

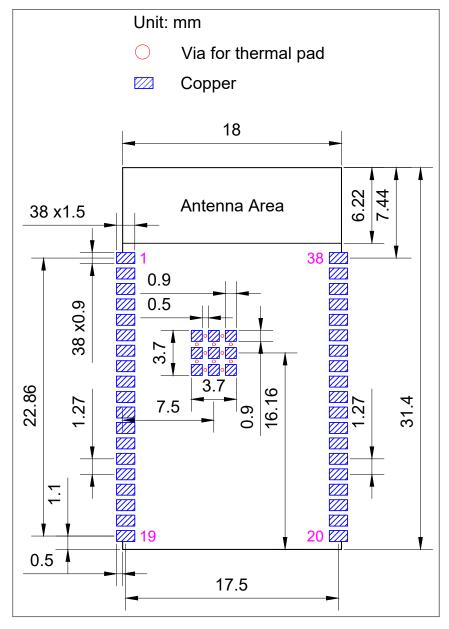


Figure 14: Recommended PCB Land Pattern

#### Module Placement for PCB Design 11.2

If module-on-board design is adopted, attention should be paid while positioning the module on the base board. The interference of the base board on the module's antenna performance should be minimized.

For details about module placement for PCB design, please refer to ESP32 Hardware Design Guidelines > Section Positioning a Module on a Base Board.

#### **Product Handling** 12

#### **Storage Conditions** 12.1

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.

#### **Electrostatic Discharge (ESD)** 12.2

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

#### **Reflow Profile** 12.3

Solder the module in a single reflow.

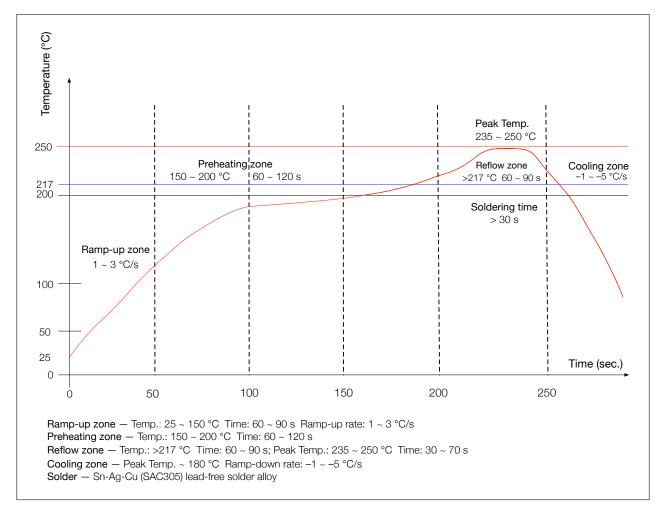


Figure 15: Reflow Profile

#### **Ultrasonic Vibration** 12.4

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.

# 13 Related Documentation and Resources

### **Related Documentation**

- ESP32 Series Datasheet Specifications of the ESP32 hardware.
- ESP32 Technical Reference Manual Detailed information on how to use the ESP32 memory and peripherals.
- ESP32 Hardware Design Guidelines Guidelines on how to integrate the ESP32 into your hardware product.
- ESP32 ECO and Workarounds for Bugs Correction of ESP32 design errors.
- ESP32 Series SoC Errata Descriptions of errors in ESP32 series of SoCs from chip revision 0 forward.
- Certificates

https://espressif.com/en/support/documents/certificates

• ESP32 Product/Process Change Notifications (PCN)

https://espressif.com/en/support/documents/pcns

• ESP32 Advisories - Information on security, bugs, compatibility, component reliability.

https://espressif.com/en/support/documents/advisories

 Documentation Updates and Update Notification Subscription https://espressif.com/en/support/download/documents

# **Developer Zone**

- ESP-IDF Programming Guide for ESP32 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 Series SoCs - Browse through all ESP32 SoCs.

https://espressif.com/en/products/socs?id=ESP32

• ESP32 Series Modules - Browse through all ESP32-based modules.

https://espressif.com/en/products/modules?id=ESP32

• ESP32 Series DevKits – Browse through all ESP32-based devkits.

https://espressif.com/en/products/devkits?id=ESP32

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# **Revision History**

Date	Version	Release notes	
2024-11-12	v2.0	<ul> <li>Improved the wording and structure of following sections:         <ul> <li>Updated Section "Strapping Pins" and renamed to Boot Configurations</li> <li>Added Chapter 5: Peripherals</li> <li>Updated Table "Wi-Fi RF Standards" and renamed to Wi-Fi RF Characteristics</li> <li>Section 9: Peripheral Schematics: Added a note about UART</li> </ul> </li> </ul>	
2023-11-21	v1.9	<ul> <li>Table 1: Series Comparison: Added information about flash</li> <li>Figure 9: Peripheral Schematics: Updated the note about soldering</li> <li>Section 10.2: Dimensions of External Antenna Connector: Added information about the antenna external connector</li> </ul>	
2023-02-09	v1.8	<ul> <li>Major updates:         <ul> <li>Removed contents about hall sensor according to PCN20221202</li> </ul> </li> <li>Other updates:         <ul> <li>Added source files of PCB land patterns and 3D models of the modules (if available) in Section 11.1: PCB Land Pattern</li> </ul> </li> </ul>	
2022-12-02	<b>∨1.7</b>	Updated Figure 10.1: Module Dimensions and 11.1: PCB Land Pattern	
2022-07-20	V1.6	<ul> <li>Added module variants embedded with ESP32-DOWDR2-V3 chip</li> <li>Added Table 1: ESP32-WROVER-E Series Comparison and Table 2         ESP32-WROVER-IE Series Comparison</li> <li>Added Figure 6: Visualization of Timing Parameters for the Strapping Pins and Table 5: Description of Timing Parameters for the Strapping Pins in Section 4: Boot Configurations</li> <li>Updated Related Documentation and Resources</li> </ul>	
2022-02-22	v1.5	<ul> <li>Replaced Espressif Product Ordering Information with ESP Product Selector</li> <li>Updated the description of TWAI in Section 1.1 Features</li> <li>Added a link to RF certificates in Section 1.1 Features</li> <li>Updated Ordering Information Table</li> <li>Updated Table 12: Absolute Maximum Ratings</li> <li>Fixed typos</li> </ul>	
2021-02-09	v1.4	<ul> <li>Updated Figure 11: ESP32-WROVER-E Physical Dimensions</li> <li>Updated Figure 14: Recommended PCB Land Pattern</li> </ul>	

Date	Version	Release notes
2021-02-02	v1.3	<ul> <li>Updated the trade mark from TWAI™ to TWAI®</li> <li>Deleted Reset Circuit and Discharge Circuit for VDD33 Rail in Section 9:         Peripheral Schematics     </li> <li>Modified the note below Figure 15: Reflow Profile</li> </ul>
2020-11-02	V1.2	<ul> <li>Updated Figure 3.1: Pin Layout</li> <li>Added a note to EPAD in Section 11.1: PCB Land Pattern</li> <li>Updated the note to RC delay circuit in Section 9: Peripheral Schematics</li> </ul>
2020-06-11	V1.1	<ul> <li>Updated the following figures:         <ul> <li>Figure 1: ESP32-WROVER-E Block Diagram (with ESP32-DOWD-V3 embedded)</li> <li>Figure 2: ESP32-WROVER-E Block Diagram (with ESP32-DOWDR2-V3 embedded)</li> </ul> </li> </ul>
2020-05-22	v1.0	Official release



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