# THE DATASHEET OF

# ESP32-C3FN4

# ESP32-C3 Series

## Datasheet

Ultra-Low-Power SoC with RISC-V Single-Core CPU
2.4 GHz Wi-Fi (802.11b/g/n) and Bluetooth® 5 (LE)
Optional 4 MB flash in the chip's package
QFN32 (5×5 mm) package

### Including:

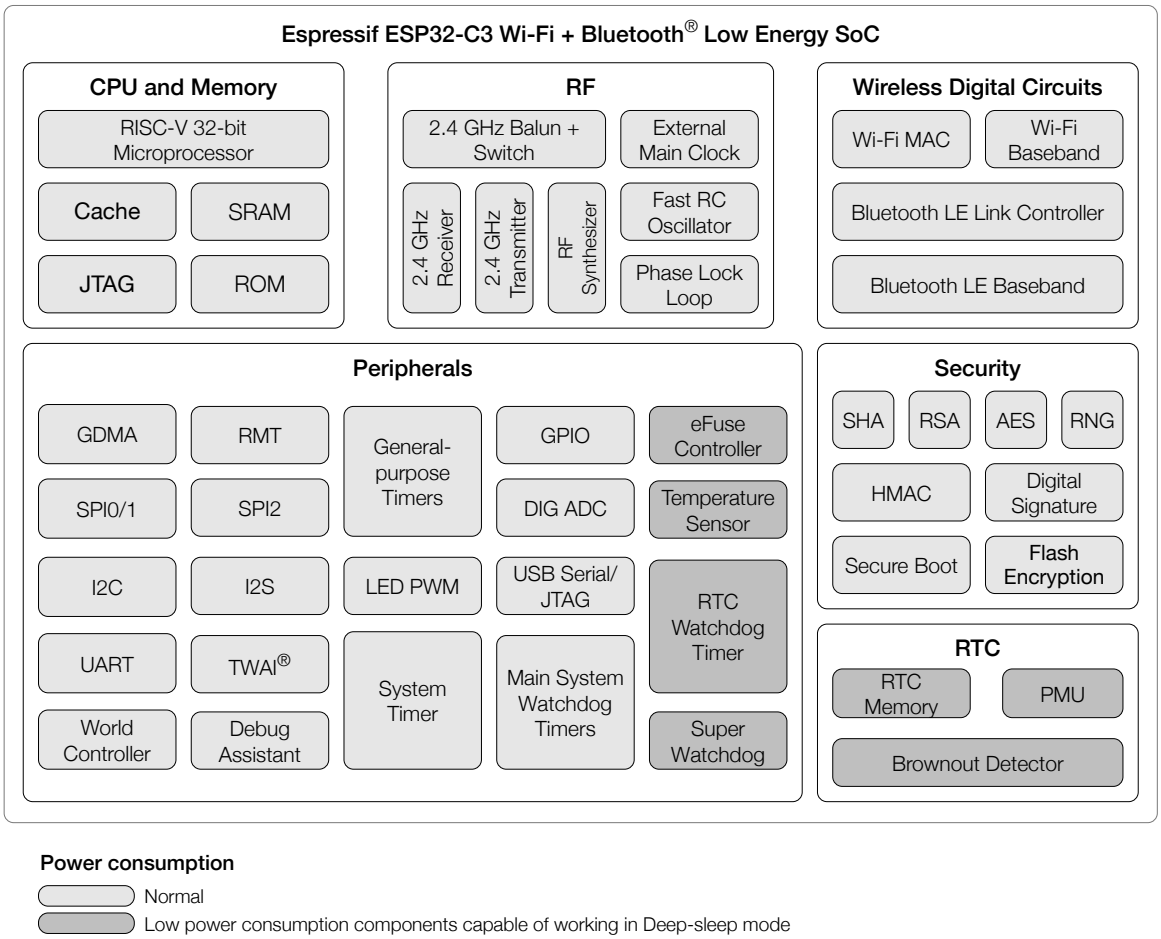
- ESP32-C3
- ESP32-C3FN4 – End of life
- ESP32-C3FH4
- ESP32-C3FH4AZ – Not Recommended for New Designs (NRND)
- ESP32-C3FH4X – Recommended
- ESP32-C3FH4XAZ

Version 1.7
Espressif Systems

# Product Overview

ESP32-C3 is an low-power and highly-integrated MCU-based solution that supports 2.4 GHz Wi-Fi and Bluetooth® Low Energy (Bluetooth LE).

The functional block diagram of the SoC is shown below.




**ESP32-C3 Functional Block Diagram**

For more information on power consumption, see Section 3.7 Power Management.

# Features

### Wi-Fi

- IEEE 802.11b/g/n-compliant
- Supports 20 MHz, 40 MHz bandwidth in 2.4 GHz band
- 1T1R mode with data rate up to 150 Mbps
- Wi-Fi Multimedia (WMM)
- TX/RX A-MPDU, TX/RX A-MSDU
- Immediate Block ACK
- Fragmentation and defragmentation
- Transmit opportunity (TXOP)
- Automatic Beacon monitoring (hardware TSF)
- 4 × virtual Wi-Fi interfaces
- Simultaneous support for Infrastructure BSS in Station mode, SoftAP mode, Station + SoftAP mode, and promiscuous mode
  *Note that when ESP32-C3 scans in Station mode, the SoftAP channel will change along with the Station channel*
- Antenna diversity
- 802.11mc FTM

### Bluetooth®

- Bluetooth LE: Bluetooth 5, Bluetooth mesh
- High power mode (20 dBm)
- Speed: 125 Kbps, 500 Kbps, 1 Mbps, 2 Mbps
- Advertising extensions
- Multiple advertisement sets
- Channel selection algorithm #2
- Internal co-existence mechanism between Wi-Fi and Bluetooth to share the same antenna

### CPU and Memory

- 32-bit RISC-V single-core processor, up to 160 MHz
- CoreMark® score:
  - 1 core at 160 MHz: 407.22 CoreMark; 2.55 CoreMark/MHz
- 384 KB ROM
- 400 KB SRAM (16 KB for cache)

- 8 KB SRAM in RTC
- In-package flash (see details in Chapter 1 *ESP32-C3 Series Comparison*)
- SPI, Dual SPI, Quad SPI, and QPI interfaces that allow connection to multiple off-package flash
- Access to flash accelerated by cache
- Supports flash in-Circuit Programming (ICP)

### Advanced Peripheral Interfaces

- 22 or 16 programmable GPIOs
- Digital interfaces:
  - 3 × SPI
  - 2 × UART
  - 1 × I2C
  - 1 × I2S
  - Remote control peripheral, with 2 transmit channels and 2 receive channels
  - LED PWM controller, with up to 6 channels
  - Full-speed USB Serial/JTAG controller
  - General DMA controller (GDMA), with 3 transmit channels and 3 receive channels
  - 1 × TWAI® controller compatible with ISO 11898-1 (CAN Specification 2.0)
- Analog interfaces:
  - 2 × 12-bit SAR ADCs, up to 6 channels
  - 1 × temperature sensor
- Timers:
  - 2 × 54-bit general-purpose timers
  - 3 × digital watchdog timers
  - 1 × analog watchdog timer
  - 1 × 52-bit system timer

### Power Management

- Fine-resolution power control through a selection of clock frequency, duty cycle, Wi-Fi operating modes, and individual power control of internal components
- Four power modes designed for typical scenarios: Active, Modem-sleep, Light-sleep, Deep-sleep
- Power consumption in Deep-sleep mode is 5 $\mu$A
- RTC memory remains powered on in Deep-sleep mode

### Security

- Secure boot - permission control on accessing internal and external memory
- Flash encryption - memory encryption and decryption
- 4096-bit OTP, up to 1792 bits for users
- Cryptographic hardware acceleration:
  - AES-128/256 (FIPS PUB 197)
  - SHA Accelerator (FIPS PUB 180-4)
  - RSA Accelerator
  - Random Number Generator (RNG)
  - HMAC
  - Digital signature

### RF Module

- Antenna switches, RF balun, power amplifier, low-noise receive amplifier
- Up to +21 dBm of power for an 802.11b transmission
- Up to +20 dBm of power for an 802.11n transmission
- Up to -105 dBm of sensitivity for Bluetooth LE receiver (125 Kbps)

## Applications

With low power consumption, ESP32-C3 is an ideal choice for IoT devices in the following areas:

- 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

**Note:**

Check the link or the QR code to make sure that you use the latest version of this document:
https://www.espressif.com/documentation/esp32-c3_datasheet_en.pdf

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# 1 ESP32-C3 Series Comparison

## 1.1 Nomenclature

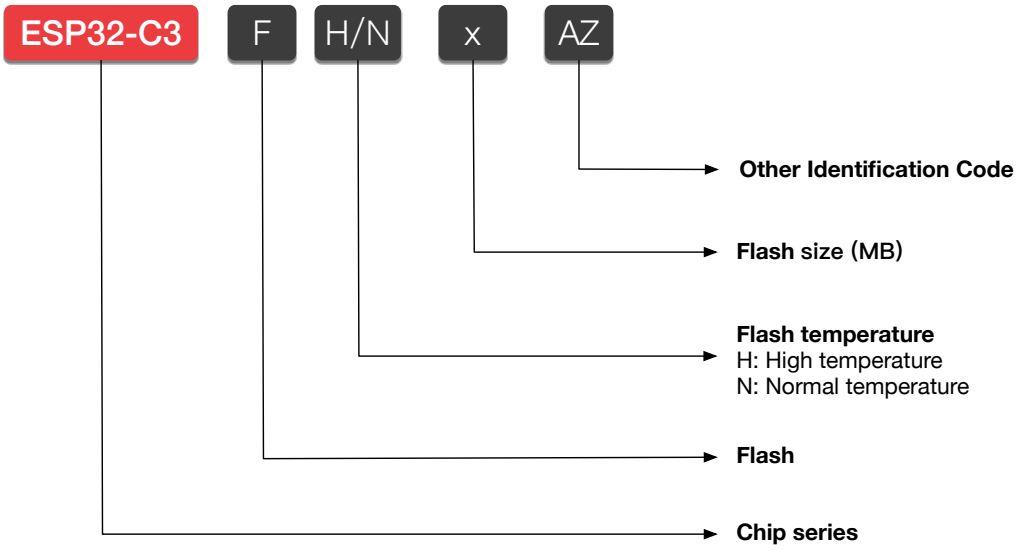


Figure 1-1. ESP32-C3 Series Nomenclature

## 1.2 Comparison

Table 1-1. ESP32-C3 Series Comparison

| Ordering Code[1] | In-Package Flash | Ambient Temp.[2] (°C) | Package (mm) | GPIO No.[4] | Chip Revision[5] |
|---|---|---|---|---|---|
| ESP32-C3[3] | — | –40 ~ 105 | QFN32 (5*5) | 22 | v0.4 |
| ESP32-C3FN4 (End of life) | 4 MB | –40 ~ 85 | QFN32 (5*5) | 22 | v0.4 |
| ESP32-C3FH4 | 4 MB | –40 ~ 105 | QFN32 (5*5) | 22 | v0.4 |
| ESP32-C3FH4AZ (NRND) | 4 MB | –40 ~ 105 | QFN32 (5*5) | 16 | v0.4 |
| ESP32-C3FH4X (Recommended) | 4 MB | –40 ~ 105 | QFN32 (5*5) | 22 | v1.1 |
| ESP32-C3FH4XAZ | 4 MB | –40 ~ 105 | QFN32 (5*5) | 16 | v1.1 |

[1] For details on chip marking and packing, see Section 5 Packaging.

[2] Ambient temperature specifies the recommended temperature range of the environment immediately outside an Espressif chip.

[3] ESP32-C3 requires an SPI flash off the chip's package. For details about SPI modes, see Section 2.7 Pin Mapping Between Chip and Flash.

[4] SPIO/SPI1 pins for flash connection are not bonded for variants with 16 GPIOs.

[5] All chip revisions have the same SRAM size, but chip revision v1.1 (i.e. ESP32-C3FH4X and ESP32-C3FH4XAZ) has around 35 KB more available space for users than chip revision v0.4. For how to identify chip revisions, please refer to *ESP32-C3 Errata*.

# 2 Pins

## 2.1 Pin Layout

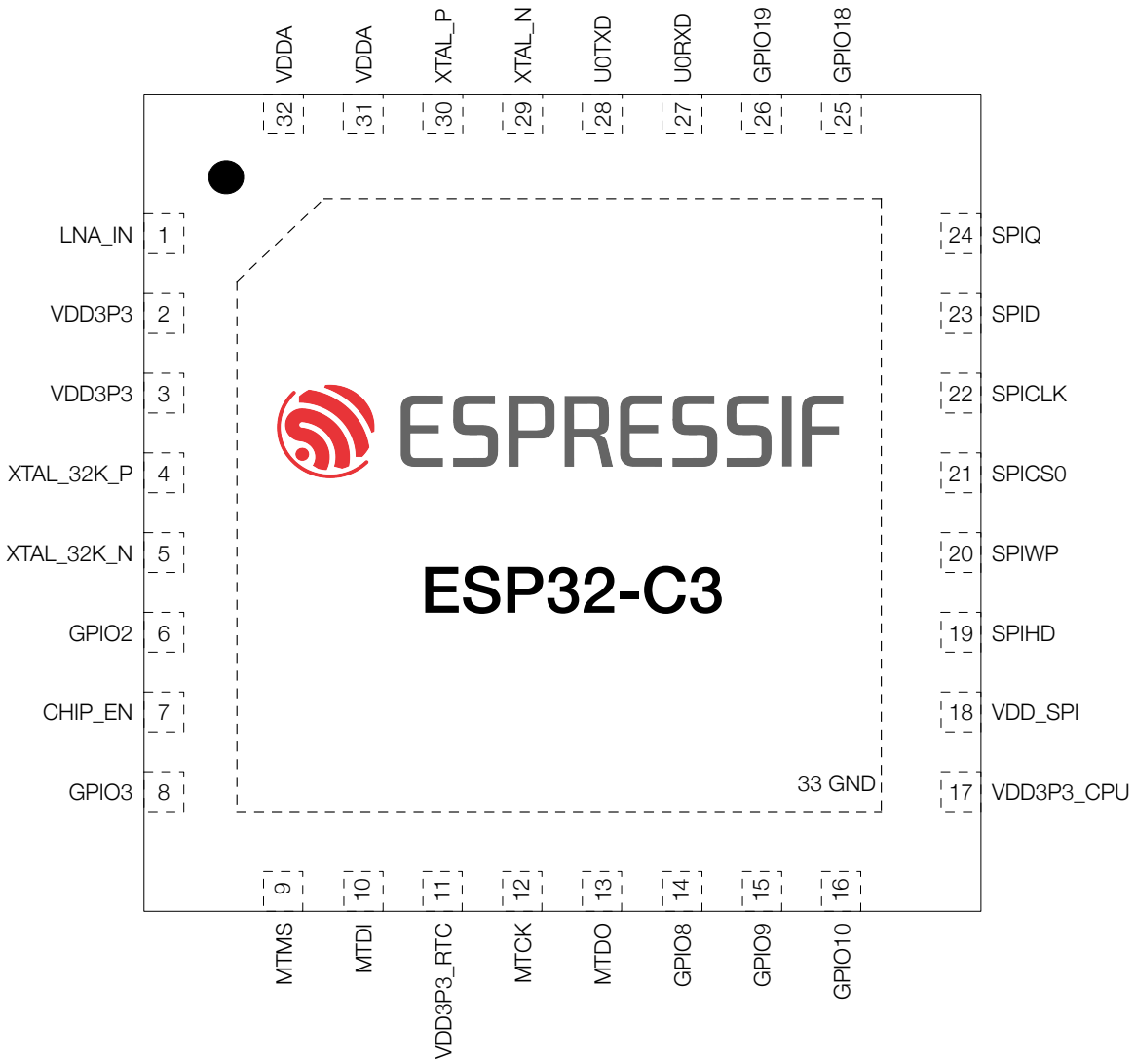


Figure 2-1. ESP32-C3 Pin Layout (Top View)

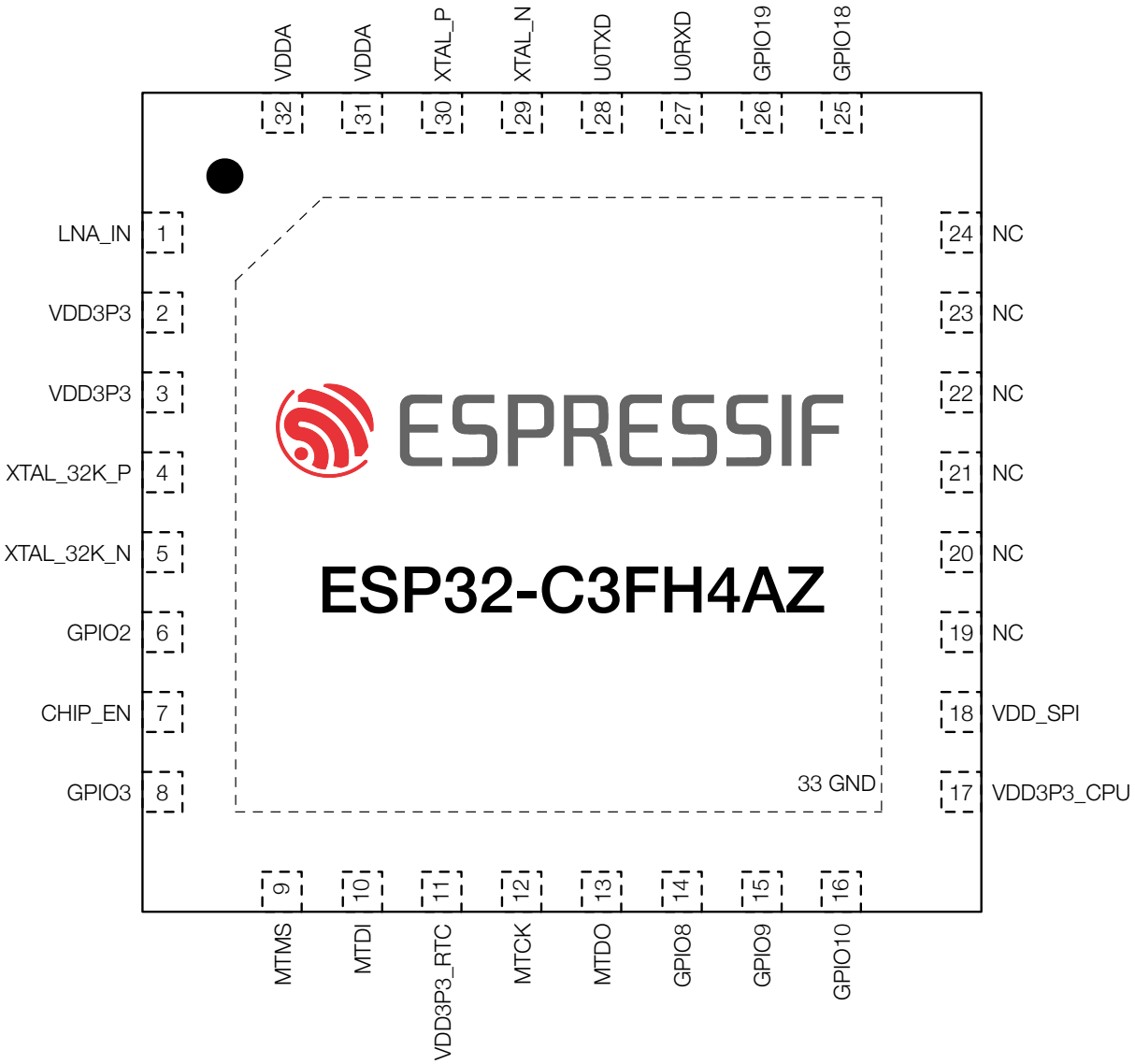


Figure 2-2. ESP32-C3FH4AZ Pin Layout (Top View)

## 2.2 Pin Overview

The ESP32-C3 chip integrates multiple peripherals that require communication with the outside world. To keep the chip package size reasonably small, the number of available pins has to be limited. So the only way to route all the incoming and outgoing signals is through pin multiplexing. Pin muxing is controlled via software programmable registers (see *ESP32-C3 Technical Reference Manual* > Chapter *IO MUX and GPIO Matrix*).

All in all, the ESP32-C3 chip has the following types of pins:

- **IO pins** with the following predefined sets of functions to choose from:
  - **Each** IO pin has predefined **IO MUX and GPIO functions** – see Table 2-3 *IO MUX and GPIO Functions*
  - **Some** IO pins have predefined **analog functions** – see Table 2-4 *Analog Functions*

  *Predefined functions* means that each IO pin has a set of direct connections to certain on-chip components. During run-time, the user can configure which component from a predefined set to connect to a certain pin at a certain time via memory mapped registers (see the TRM).
- **Analog pins** that have exclusively-dedicated **analog functions** – see Table 2-5 *Analog Pins*
- **Power pins** supply power to the chip components and non-power pins – see Table 2-6 *Power Pins*

**Notes for Table 2-1 Pin Overview** (see below):

1. For more information, see respective sections below. Alternatively, see Appendix A – ESP32-C3 Consolidated Pin Overview.
2. **Bold** marks the pin function set in which a pin has its default function in the default boot mode. See Section 2.6.1 Chip Boot Mode Control.
3. In column **Pin Providing Power**, regarding pins powered by VDD_SPI:
   - Power actually comes from the internal power rail supplying power to VDD_SPI. For details, see Section 2.5.2 Power Scheme.
4. In column **Pin Providing Power**, regarding pins powered by VDD3P3_CPU / VDD_SPI:
   - Pin Providing Power (either VDD3P3_CPU or VDD_SPI) can be configured via a register, see *ESP32-C3 Technical Reference Manual* > Chapter *IO MUX and GPIO pins*.
5. Except for GPIO18 and GPIO19 whose default drive strength is 40 mA, the default drive strength for all the other pins is 20 mA.
6. Column **Pin Settings** shows predefined settings at reset and after reset with the following abbreviations:
   - IE – input enabled
   - WPU – internal weak pull-up resistor enabled
   - WPD – internal weak pull-down resistor enabled
   - USB_PU – USB pull-up resistor enabled
     - By default, the USB function is enabled for USB pins (i.e., GPIO18 and GPIO19), and the pin pull-up is decided by the USB pull-up resistor. The USB pull-up resistor is controlled by USB_SERIAL_JTAG_DP/DM_PULLUP and the pull-up value is controlled by

USB_SERIAL_JTAG_PULLUP_VALUE. For details, see *ESP32-C3 Technical Reference Manual* > Chapter *USB Serial/JTAG Controller*)

- When the USB function is disabled, USB pins are used as regular GPIOs and the pin's internal weak pull-up and pull-down resistors are disabled by default (configurable by IO_MUX_FUN_WPU/WPD)

7. Depends on the value of EFUSE_DIS_PAD_JTAG
   - `0` - default value. Input enabled, and internal weak pull-up resistor enabled (IE & WPU)
   - `1` - input enabled (IE)
8. Output enabled
9. By default VDD_SPI is the power supply pin for in-package and off-package flash. It can be reconfigured as a GPIO pin, if the chip is connected to an off-package flash, and this flash is powered by an external power supply. For details about reconfiguration, please refer to *ESP32-C3 Technical Reference Manual* > Chapter *IO MUX and GPIO Matrix*.
10. For ESP32-C3FH4AZ, pins within the frame (namely pin 19 ~ pin 24) are not bonded, and are labelled as "not connected".

**Table 2-1. Pin Overview**

| Pin No. | Pin Name | Pin Type [1] | Pin Providing Power [3-5] | Pin Settings [6] | | Pin Function Sets [1,2] | |
|---|---|---|---|---|---|---|---|
| | | | | At Reset | After Reset | IO MUX | Analog |
| 1 | LNA_IN | Analog | | | | | |
| 2 | VDD3P3 | Power | | | | | |
| 3 | VDD3P3 | Power | | | | | |
| 4 | XTAL_32K_P | IO | VDD3P3_RTC | | | **IO MUX** | Analog |
| 5 | XTAL_32K_N | IO | VDD3P3_RTC | | | **IO MUX** | Analog |
| 6 | GPIO2 | IO | VDD3P3_RTC | IE | IE | **IO MUX** | Analog |
| 7 | CHIP_EN | Analog | | | | | |
| 8 | GPIO3 | IO | VDD3P3_RTC | IE | IE | **IO MUX** | Analog |
| 9 | MTMS | IO | VDD3P3_RTC | | IE | **IO MUX** | Analog |
| 10 | MTDI | IO | VDD3P3_RTC | | IE | **IO MUX** | Analog |
| 11 | VDD3P3_RTC | Power | | | | | |
| 12 | MTCK | IO | VDD3P3_CPU | | IE [7] | **IO MUX** | |
| 13 | MTDO | IO | VDD3P3_CPU | | IE | **IO MUX** | |
| 14 | GPIO8 | IO | VDD3P3_CPU | IE | IE | **IO MUX** | |
| 15 | GPIO9 | IO | VDD3P3_CPU | IE, WPU | IE, WPU | **IO MUX** | |
| 16 | GPIO10 | IO | VDD3P3_CPU | | IE | **IO MUX** | |
| 17 | VDD3P3_CPU | Power | | | | | |
| 18 | VDD_SPI [9] [10] | Power | VDD3P3_CPU | | | IO MUX | |
| 19 | SPIHD | IO | VDD_SPI / VDD3P3_CPU | WPU | IE, WPU | **IO MUX** | |
| 20 | SPIWP | IO | VDD_SPI / VDD3P3_CPU | WPU | IE, WPU | **IO MUX** | |
| 21 | SPICS0 | IO | VDD_SPI / VDD3P3_CPU | WPU | IE, WPU | **IO MUX** | |
| 22 | SPICLK | IO | VDD_SPI / VDD3P3_CPU | WPU | IE, WPU | **IO MUX** | |
| 23 | SPID | IO | VDD_SPI / VDD3P3_CPU | WPU | IE, WPU | **IO MUX** | |
| 24 | SPIQ | IO | VDD_SPI / VDD3P3_CPU | WPU | IE, WPU | **IO MUX** | |
| 25 | GPIO18 | IO | VDD3P3_CPU | | | IO MUX | **Analog** |

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Table 2-1 – cont'd from previous page

| Pin No. | Pin Name | Pin Type [1] | Pin Providing Power [3-5] | Pin Settings [6] | | Pin Function Sets [1,2] | |
|---|---|---|---|---|---|---|---|
| | | | | At Reset | After Reset | IO MUX | Analog |
| 26 | GPIO19 | IO | VDD3P3_CPU | | USB_PU | IO MUX | **Analog** |
| 27 | U0RXD | IO | VDD3P3_CPU | | IE, WPU | **IO MUX** | |
| 28 | U0TXD | IO | VDD3P3_CPU | | WPU [8] | **IO MUX** | |
| 29 | XTAL_N | Analog | | | | | |
| 30 | XTAL_P | Analog | | | | | |
| 31 | VDDA | Power | | | | | |
| 32 | VDDA | Power | | | | | |
| 33 | GND | Power | | | | | |

Some pins have glitches during power-up. See details in Table 2-2.

**Table 2-2. Power-Up Glitches on Pins**

| Pin | Glitch[1] | Typical Time Period(ns) |
|---|---|---|
| MTCK | Low-level glitch | 5 |
| MTDO | Low-level glitch | 5 |
| GPIO10 | Low-level glitch | 5 |
| U0RXD | Low-level glitch | 5 |
| GPIO18 | High-level glitch | 50000 |

[1] Low-level glitch: the pin is at a low level output status during the time period;
High-level glitch: the pin is at a high level output status during the time period;
Pull-down glitch: the pin is at an internal weak pulled-down status during the time period;
Pull-up glitch: the pin is at an internal weak pulled-up status during the time period.
Please refer to Table 4-4 for detailed parameters about low/high-level and pull-down/up.

## 2.3 IO Pins

### 2.3.1 IO MUX and GPIO Functions

The pins of ESP32-C3 can be assigned any function (F0-F2) from their respective sets of IO MUX functions as listed in Table 2-3 *IO MUX and GPIO Functions*.

Each set of the IO MUX functions has a general purpose input/output (**GPIO0, GPIO1, etc.**) function. If a pin is assigned a GPIO function, this pin's signal is routed via the GPIO matrix, which incorporates internal signal routing circuitry for mapping signals programmatically. It gives the pin access to almost any IO MUX function. However, the flexibility of programmatic mapping comes at a cost as it might affect speed and latency of routed signals.

**Notes for Table 2-3 IO MUX and GPIO Functions:**

1. **Bold** marks the default pin functions in the default boot mode. See Section 2.6.1 Chip Boot Mode Control.
2. Regarding highlighted cells, see Section 2.3.3 Restrictions for GPIOs.
3. Each IO MUX function (F*n*, *n* = 0 ~ 2) is associated with a *type*. The description of *type* is as follows:
   - I – input. O – output. T – high impedance.
   - I1 – input; if the pin is assigned a function other than F*n*, the input signal of F*n* is always `1`.
   - I0 – input; if the pin is assigned a function other than F*n*, the input signal of F*n* is always `0`.
4. Function names:
   - GPIO... General-purpose input/output with signals routed via the GPIO matrix. For more details on the GPIO matrix, see *ESP32-C3 Technical Reference Manual* > Chapter *IO MUX and GPIO Matrix*.
   - U...RXD, U...TXD } UART0/1 receive/transmit signals.
5. Groups of functions (see the markings in the table):
   (a) JTAG interface for debugging.
   (b) UART interface for debugging.
   (c) SPI0/1 interface for connection to in-package or off-package flash via SPI bus. It supports 1-, 2-, 4-line SPI modes. See also Section 2.7 Pin Mapping Between Chip and Flash.
   (d) SPI2 main interface for fast SPI connection. It supports 1-, 2-, 4-line SPI modes.

Table 2-3. IO MUX Pin Functions

| Pin No. | IO MUX / GPIO Name | IO MUX Function [1,4] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | Type [3] | 1 | Type | 2 | Type |
| 4 | GPIO0 | GPIO0 | I/O/T | **GPIO0** | I/O/T | | |
| 5 | GPIO1 | GPIO1 | I/O/T | **GPIO1** | I/O/T | | |
| 6 | GPIO2 | GPIO2 | I/O/T | **GPIO2** | I/O/T | FSPIQ [5d] | I1/O/T |
| 8 | GPIO3 | GPIO3 [5a] | I/O/T | **GPIO3** | I/O/T | | |
| 9 | GPIO4 | **MTMS** | I1 | GPIO4 | I/O/T | FSPIHD | I1/O/T |
| 10 | GPIO5 | **MTDI** | I1 | GPIO5 | I/O/T | FSPIWP | I1/O/T |
| 12 | GPIO6 | **MTCK** | I1 | GPIO6 | I/O/T | FSPICLK | I1/O/T |
| 13 | GPIO7 | **MTDO** | O/T | GPIO7 | I/O/T | FSPID | I1/O/T |
| 14 | GPIO8 | GPIO8 | I/O/T | **GPIO8** | I/O/T | | |
| 15 | GPIO9 | GPIO9 | I/O/T | **GPIO9** | I/O/T | | |
| 16 | GPIO10 | GPIO10 | I/O/T | **GPIO10** | I/O/T | FSPICS0 | I1/O/T |
| 18 | GPIO11 | GPIO11 [5c] | I/O/T | GPIO11 | I/O/T | | |
| 19 | GPIO12 | SPIHD | I1/O/T | **GPIO12** | I/O/T | | |
| 20 | GPIO13 | SPIWP | I1/O/T | **GPIO13** | I/O/T | | |
| 21 | GPIO14 | **SPICS0** | O/T | GPIO14 | I/O/T | | |
| 22 | GPIO15 | **SPICLK** | O/T | GPIO15 | I/O/T | | |
| 23 | GPIO16 | **SPID** | I1/O/T | GPIO16 | I/O/T | | |
| 24 | GPIO17 | **SPIQ** | I1/O/T | GPIO17 | I/O/T | | |
| 25 | GPIO18 | GPIO18 | I/O/T | GPIO18 | I/O/T | | |
| 26 | GPIO19 | GPIO19 [5b] | I/O/T | GPIO19 | I/O/T | | |
| 27 | GPIO20 | **U0RXD** | I1 | GPIO20 | I/O/T | | |
| 28 | GPIO21 | **U0TXD** | O | GPIO21 | I/O/T | | |

### 2.3.2 Analog Functions

**Notes for Table 2-4 Analog Functions:**

1. **Bold** marks the default pin functions in the default boot mode. See Section 2.6.1 Chip Boot Mode Control.
2. Regarding highlighted cells, see Section 2.3.3 Restrictions for GPIOs.
3. Function names:

| | |
|---|---|
| XTAL_32K_P<br>XTAL_32K_N | 32 kHz external clock input/output connected to ESP32-C3's oscillator. P/N means differential clock positive/negative. |
| ADC1_CH...<br>ADC2_CH... | Analog to digital conversion channel for ADC1 or ADC2. |
| USB_D-<br>USB_D+ | USB Serial/JTAG function. USB signal is a differential signal transmitted over a pair of D+ and D- wires. |

**Table 2-4. RTC and Analog Functions**

| Pin No. | Analog IO Name | Analog Function [3] | |
|---|---|---|---|
| | | 0 | 1 |
| 4 | GPIO0 | XTAL_32K_P | ADC1_CH0 |
| 5 | GPIO1 | XTAL_32K_N | ADC1_CH1 |
| 6 | GPIO2 | | ADC1_CH2 |
| 8 | GPIO3 | | ADC1_CH3 |
| 9 | GPIO4 | | ADC1_CH4 |
| 10 | GPIO5 | | ADC2_CH0 |
| 25 | GPIO18 | **USB_D-** | |
| 26 | GPIO19 | **USB_D+** | |

### 2.3.3 Restrictions for GPIOs

All IO pins of the ESP32-C3 have GPIO pin functions. However, the IO pins are multiplexed and have other important pin functions. This should be taken into account while certain pins are chosen for general purpose input output.

In Table 2-3 *IO MUX and GPIO Functions* and Table 2-4 *Analog Functions* some pin functions are highlighted. The non-highlighted GPIO pins are recommended for use first. If more pins are needed, the highlighted GPIOs should be chosen carefully to avoid conflicts with important pin functions.

The highlighted IO pins have the following important pin functions:

- GPIO – allocated for communication with in-package flash and NOT recommended for other uses. For details, see Section 2.7 Pin Mapping Between Chip and Flash.
- GPIO – have one of the following important functions:
  - **Strapping pins** – need to be at certain logic levels at startup. See Section 2.6 Strapping Pins.
  - **USB_D+/-** – by default, connected to the USB Serial/JTAG Controller. To function as GPIOs, these pins need to be reconfigured by referring to *ESP32-C3 Technical Reference Manual* > Chapter *IO MUX and GPIO Matrix*.
  - **JTAG interface** – often used for debugging. See Table 2-3 IO MUX and GPIO Functions, note 5a. To free these pins up, the pin functions USB_D+/- of the *ESP32-C3 Technical Reference Manual* *USB Serial/JTAG Controller* can be used instead.
  - **UART interface** – often used for debugging. See Table 2-3 IO MUX and GPIO Functions, note 5b.
  - **ADC2** – no restrictions, unless there is an on-going **Wi-Fi** connection. ADC**2**_CH... analog functions (see Table 2-4 Analog Functions) cannot be used with Wi-Fi simultaneously.

See also Appendix A – ESP32-C3 Consolidated Pin Overview.

## 2.4 Analog Pins

Table 2-5. Analog Pins

| Pin No. | Pin Name | Pin Type | Pin Function |
|---|---|---|---|
| 1 | LNA_IN | I/O | Low Noise Amplifier (RF LNA) input / output signals |
| 7 | CHIP_EN | I | High: on, the chip is started up.<br>Low: off, the chip is shut down.<br>Note: Do not leave the CHIP_EN pin floating. |
| 29 | XTAL_N | — | External clock input/output connected to the chip's oscillator. P/N means differential clock positive/negative. |
| 30 | XTAL_P | — | |

## 2.5 Power Supply

### 2.5.1 Power Pins

The chip is powered via the power pins described in Table 2-6 *Power Pins*.

**Table 2-6. Power Pins**

| Pin No. | Pin Name | Direction | Power Supply [1,2] Power Domain / Other | Power Supply [1,2] IO Pins [3] |
|---|---|---|---|---|
| 2 | VDD3P3 | Input | Analog power domain | |
| 3 | VDD3P3 | Input | Analog power domain | |
| 11 | VDD3P3_RTC | Input | RTC and part of Digital power domains | RTC IO |
| 17 | VDD3P3_CPU | Input | Digital power domain | Digital IO |
| 18 | VDD_SPI [4] | Input | In-package flash (backup power line) | |
| | | Output | In-package and off-package flash | SPI IO |
| 31 | VDDA | Input | Analog power domain | |
| 32 | VDDA | Input | Analog power domain | |
| 33 | GND | — | External ground connection | |

[1] See in conjunction with Section 2.5.2 Power Scheme.

[2] For recommended and maximum voltage and current, see Section 4.1 Absolute Maximum Ratings and Section 4.2 Recommended Operating Conditions.

[3] Digital IO pins are those powered by VDD3P3_CPU, and RTC IO pins are those powered by VDD3P3_RTC and so on, as shown in Figure 2-3 ESP32-C3 Power Scheme. See also Table 2-1 Pin Overview > Column *Pin Providing Power*.

[4] To configure VDD_SPI as input or output, see *ESP32-C3 Technical Reference Manual* > Chapter *Low-power Management*.

### 2.5.2 Power Scheme

The power scheme is shown in Figure 2-3 ESP32-C3 Power Scheme.

The components on the chip are powered via voltage regulators.

**Table 2-7. Voltage Regulators**

| Voltage Regulator | Output | Power Supply |
|---|---|---|
| Digital | 1.1 V | Digital power domain |
| Low-power | 1.1 V | RTC power domain |

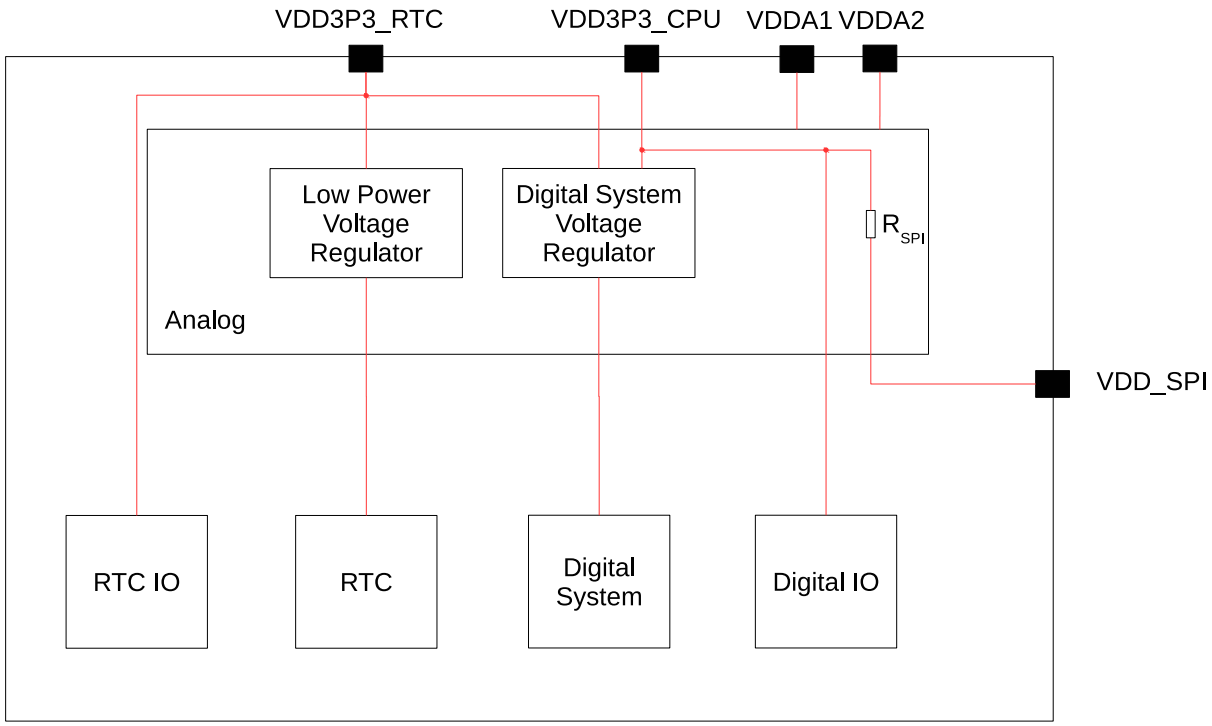


Figure 2-3. ESP32-C3 Power Scheme

### 2.5.3 Chip Power-up and Reset

Once the power is supplied to the chip, its power rails need a short time to stabilize. After that, CHIP_EN – the pin used for power-up and reset – is pulled high to activate the chip. For information on CHIP_EN as well as power-up and reset timing, see Figure 2-4 and Table 2-8.

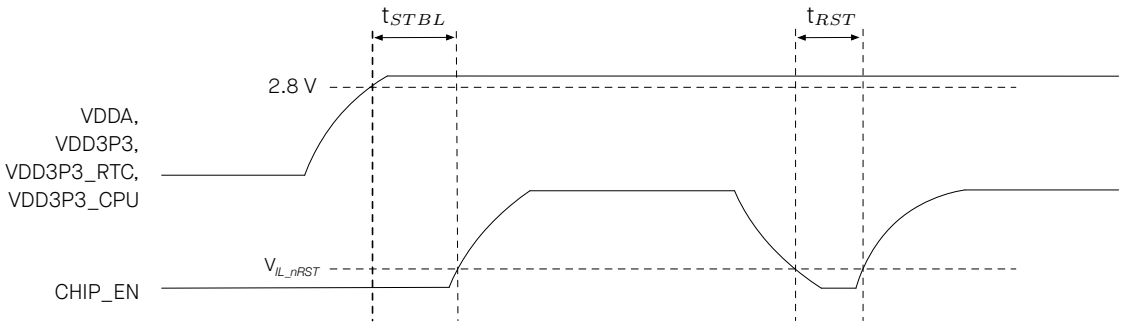


Figure 2-4. Visualization of Timing Parameters for Power-up and Reset

Table 2-8. Description of Timing Parameters for Power-up and Reset

| Parameter | Description | Min ($\mu$s) |
|---|---|---|
| $t_{STBL}$ | Time reserved for the power rails of VDDA, VDD3P3, VDD3P3_RTC, and VDD3P3_CPU to stabilize before the CHIP_EN pin is pulled high to activate the chip | 50 |
| $t_{RST}$ | Time reserved for CHIP_EN to stay below $V_{IL\_nRST}$ to reset the chip (see Table 4-4) | 50 |

## 2.6 Strapping Pins

At each startup or reset, a chip requires some initial configuration parameters, such as in which boot mode to load the chip, etc. These parameters are passed over via the strapping pins. After reset, the strapping pins operate as regular IO pins.

The parameters controlled by the given strapping pins at chip reset are as follows:

- **Chip boot mode** – GPIO2, GPIO8, and GPIO9
- **ROM messages printing** – GPIO8

GPIO9 connected to the chip's internal weak pull-up resistor at chip reset. This resistor determines the default bit value of GPIO9. Also, this resistor determines the bit value if GPIO9 is connected to an external high-impedance circuit.

**Table 2-9. Default Configuration of Strapping Pins**

| Strapping Pin | Default Configuration | Bit Value |
|---|---|---|
| **GPIO2** | Floating | – |
| **GPIO8** | Floating | – |
| **GPIO9** | Pull-up | 1 |

To change the bit values, the strapping pins should be connected to external pull-down/pull-up resistances. If the ESP32-C3 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.

Regarding the timing requirements for the strapping pins, there are such parameters as *setup time* and *hold time*. For more information, see Table 2-10 and Figure 2-5.

**Table 2-10. Description of Timing Parameters for the Strapping Pins**

| Parameter | Description | Min (ms) |
|---|---|---|
| $t_{SU}$ | *Setup time* is the time reserved for the power rails to stabilize before the CHIP_EN pin is pulled high to activate the chip. | 0 |
| $t_{H}$ | *Hold time* is the time reserved for the chip to read the strapping pin values after CHIP_EN is already high and before these pins start operating as regular IO pins. | 3 |

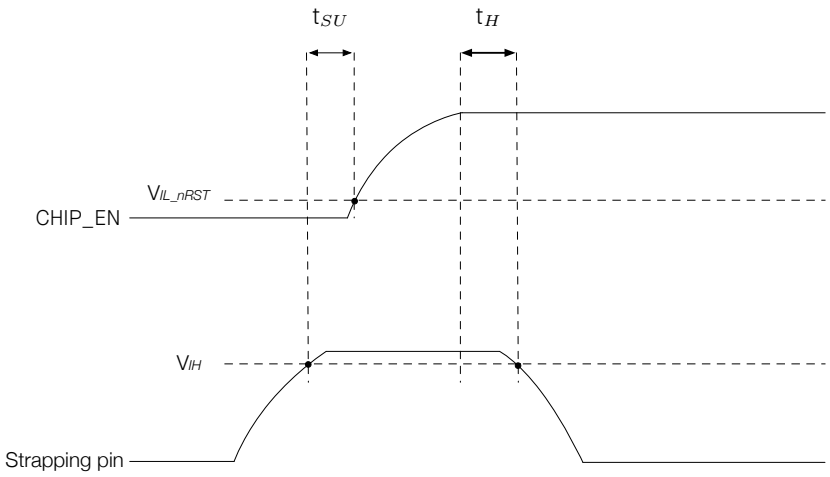


Figure 2-5. Visualization of Timing Parameters for the Strapping Pins

### 2.6.1 Chip Boot Mode Control

GPIO2, GPIO8, and GPIO9 control the boot mode after the reset is released. See Table 2-11 Chip Boot Mode Control.

Table 2-11. Chip Boot Mode Control

| Boot Mode | GPIO2 [a] | GPIO8 | GPIO9 |
|---|---|---|---|
| Default configuration | – (Floating) | – (Floating) | 1 (Pull-up) |
| **SPI Boot** (default) | 1 | Any value | 1 |
| **Joint Download Boot** [b] | 1 | 1 | 0 |

[a] GPIO2 actually does not determine SPI Boot and Joint Download Boot mode, but it is recommended to pull this pin up due to glitches.

[b] Joint Download Boot mode supports the following download methods:

- USB-Serial-JTAG Download Boot
- UART Download Boot

In SPI Boot mode, the ROM bootloader loads and executes the program from SPI flash to boot the system.

In Joint Download Boot mode, users can download binary files into flash using UART0 or USB interface. It is also possible to download binary files into SRAM and execute it from SRAM.

### 2.6.2 ROM Messages Printing Control

During boot process the messages by the ROM code can be printed to:

- **USB Serial/JTAG controller**. For this, set EFUSE_USB_PRINT_CHANNEL and EFUSE_DIS_USB_SERIAL_JTAG to 0.
- **UART**. For this, set EFUSE_DIS_USB_SERIAL_JTAG to 1. In this case, EFUSE_UART_PRINT_CONTROL and GPIO8 control ROM messages printing as shown in Table 2-12 ROM Messages Printing Control.

Table 2-12. ROM Messages Printing Control

| eFuse[1] | GPIO8 | ROM Messages Printing |
|---|---|---|
| 0 | Ignored | Always enabled |
| 1 | 0 | Enabled |
| | 1 | Disabled |
| 2 | 0 | Disabled |
| | 1 | Enabled |
| 3 | Ignored | Always disabled |

[1] eFuse: EFUSE_UART_PRINT_CONTROL

## 2.7 Pin Mapping Between Chip and Flash

Table 2-13 lists the pin mapping between the chip and flash for all SPI modes.

For chip variants with in-package flash (see Table 1-1 Comparison), the pins allocated for communication with in-package flash can be identified depending on the SPI mode used.

For off-package flash, these are the recommended pin mappings.

For more information on SPI controllers, see also Section 3.4.2 Serial Peripheral Interface (SPI).

**Notice:**

It is not recommended to use the pins connected to flash for any other purposes.

**Table 2-13. Pin Mapping Between Chip and In-package Flash**

| Pin No. | Pin Name | Single SPI Flash | Dual SPI Flash | Quad SPI / QPI Flash |
|---|---|---|---|---|
| 22 | SPICLK | CLK | CLK | CLK |
| 21 | SPICSO [1] | CS# | CS# | CS# |
| 23 | SPID | DI | DI | DI |
| 24 | SPIQ | DO | DO | DO |
| 20 | SPIWP | WP# | WP# | WP# |
| 19 | SPIHD | HOLD# | HOLD# | HOLD# |

[1] CSO is for in-package flash

# 3 Functional Description

This chapter describes the functions of ESP32-C3.

## 3.1 CPU and Memory

### 3.1.1 CPU

ESP32-C3 has a low-power 32-bit RISC-V single-core microprocessor with the following features:

- four-stage pipeline that supports a clock frequency of up to 160 MHz
- RV32IMC ISA
- 32-bit multiplier and 32-bit divider
- up to 32 vectored interrupts at seven priority levels
- up to 8 hardware breakpoints/watchpoints
- up to 16 PMP regions
- JTAG for debugging

For more information, please refer to Chapter ESP-RISC-V CPU in *ESP32-C3 Technical Reference Manual*.

### 3.1.2 Internal Memory

ESP32-C3's internal memory includes:

- **384 KB of ROM**: for booting and core functions.
- **400 KB of on-chip SRAM**: for data and instructions, running at a configurable frequency of up to 160 MHz. Of the 400 KB SRAM, 16 KB is configured for cache.
- **RTC FAST memory**: 8 KB of SRAM that can be accessed by the main CPU. It can retain data in Deep-sleep mode.
- **4 Kbit of eFuse**: 1792 bits are reserved for your data, such as encryption key and device ID.
- **In-package flash** : See details in Chapter 1 *ESP32-C3 Series Comparison*.

For more information, please refer to Chapter System and Memory in *ESP32-C3 Technical Reference Manual*.

### 3.1.3 Off-package Flash

ESP32-C3 supports SPI, Dual SPI, Quad SPI, and QPI interfaces that allow connection to multiple off-package flash, i.e. flash outside the chip's pacakge.

CPU's instruction memory space and read-only data memory space can map into the off-package flash of ESP32-C3, whose size can be 16 MB at most. ESP32-C3 supports hardware encryption/decryption based on XTS-AES to protect developers' programs and data in flash.

Through high-speed caches, ESP32-C3 can support at a time up to:

- 8 MB of instruction memory space which can map into flash as individual blocks of 64 KB. 8-bit, 16-bit and 32-bit reads are supported.
- 8 MB of data memory space which can map into flash as individual blocks of 64 KB. 8-bit, 16-bit and 32-bit reads are supported.

**Note:**
After ESP32-C3 is initialized, software can customize the mapping of off-package flash into the CPU address space.

For more information, please refer to Chapter System and Memory in *ESP32-C3 Technical Reference Manual*.

### 3.1.4 Address Mapping Structure

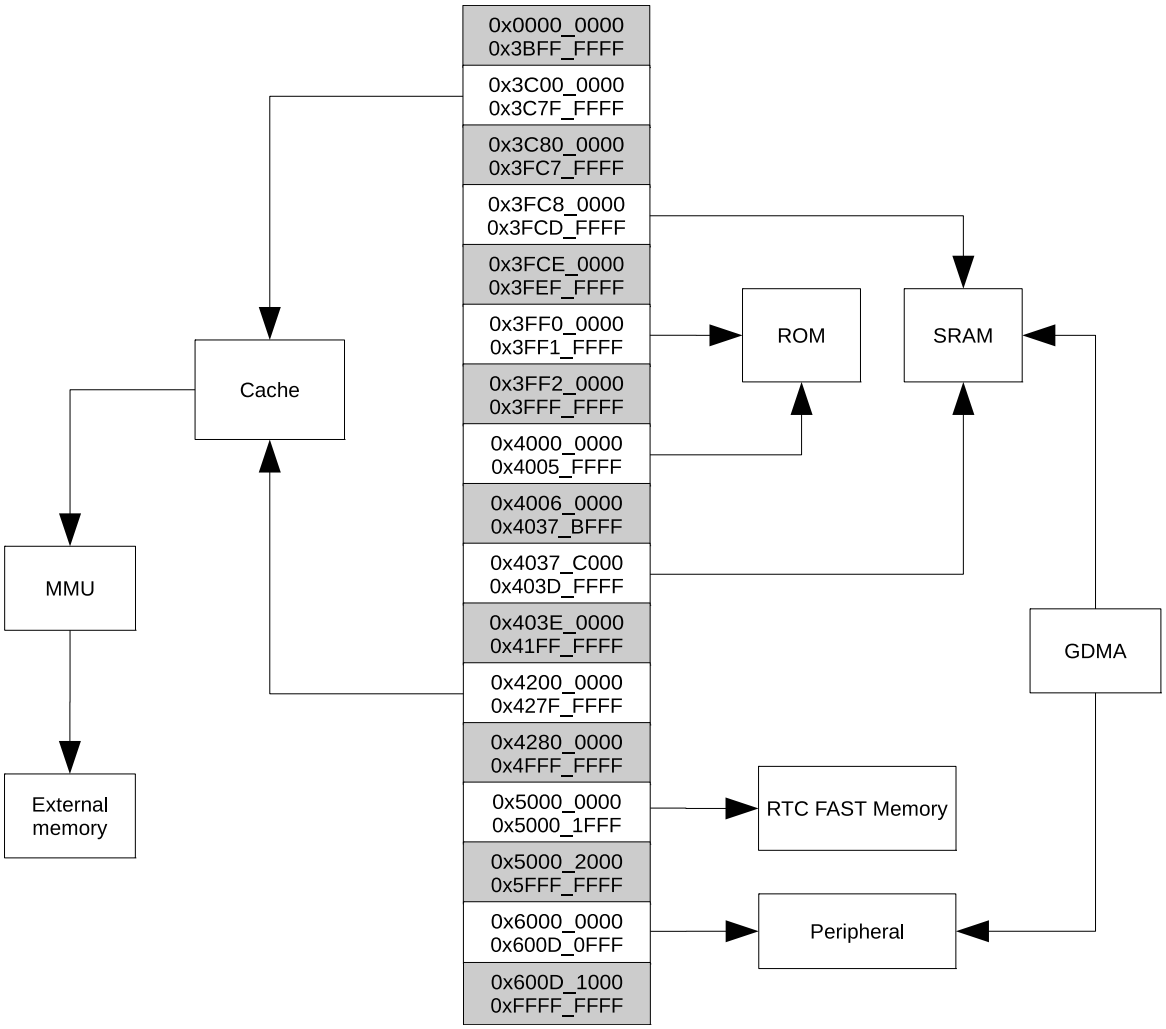


Figure 3-1. Address Mapping Structure

**Note:**
The memory space with gray background is not available for use.

### 3.1.5 Cache

ESP32-C3 has an eight-way set associative cache. This cache is read-only and has the following features:

- size: 16 KB
- block size: 32 bytes
- pre-load function
- lock function
- critical word first and early restart

## 3.2 System Clocks

For more information, please refer to Chapter Reset and Clock in *ESP32-C3 Technical Reference Manual*.

### 3.2.1 CPU Clock

The CPU clock has three possible sources:

- external main crystal clock
- fast RC oscillator (typically about 17.5 MHz, and adjustable)
- PLL clock

The application can select the clock source from the three clocks above. The selected clock source drives the CPU clock directly, or after division, depending on the application. Once the CPU is reset, the default clock source would be the external main crystal clock divided by 2.

**Note:**
ESP32-C3 is unable to operate without an external main crystal clock.

### 3.2.2 RTC Clock

The RTC slow clock is used for RTC counter, RTC watchdog and low-power controller. It has three possible sources:

- external low-speed (32 kHz) crystal clock
- internal slow RC oscillator (typically about 136 kHz, and adjustable)
- internal fast RC oscillator divided clock (derived from the fast RC oscillator divided by 256)

The RTC fast clock is used for RTC peripherals and sensor controllers. It has two possible sources:

- external main crystal clock divided by 2
- internal fast RC oscillator divide-by-N clock (typically about 17.5 MHz, and adjustable)

## 3.3 Analog Peripherals

For more information, please refer to Chapter On-Chip Sensors and Analog Signal Processing in *ESP32-C3 Technical Reference Manual*.

### 3.3.1 Analog-to-Digital Converter (ADC)

ESP32-C3 integrates two 12-bit SAR ADCs.

- ADC1 supports measurements on 5 channels, and is factory-calibrated.
- ADC2 supports measurements on 1 channel, and is not factory-calibrated.

> **Note:**
> ADC2 of some chip revisions is not operable. For details, please refer to ESP32-C3 Series SoC Errata.

For ADC characteristics, please refer to Table 4.5.

For GPIOs assigned to ADC, please refer to Table 3-2.

### 3.3.2 Temperature Sensor

The temperature sensor generates a voltage that varies with temperature. The voltage is internally converted via an ADC into a digital value.

The temperature sensor has a range of –40 °C to 125 °C. It is designed primarily to sense the temperature changes inside the chip. The temperature value depends on factors like microcontroller clock frequency or I/O load. Generally, the chip's internal temperature is higher than the operating ambient temperature.

## 3.4 Digital Peripherals

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

ESP32-C3 has 22 or 16 GPIO pins which can be assigned various functions by configuring corresponding registers. Besides digital signals, some GPIOs can be also used for analog functions, such as ADC.

All GPIOs have selectable internal pull-up or pull-down, or can be set to high impedance. When these GPIOs are configured as an input, the input value can be read by software through the register. Input GPIOs can also be set to generate edge-triggered or level-triggered CPU interrupts. All 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 UART, SPI, etc. For low-power operations, the GPIOs can be set to holding state.

The IO MUX and the GPIO matrix are used to route signals from peripherals to GPIO pins. Together they provide highly configurable I/O. Using GPIO Matrix, peripheral input signals can be configured from any IO pins while peripheral output signals can be configured to any IO pins.

For more information, please refer to Chapter IO MUX and GPIO Matrix (GPIO, IO_MUX) in *ESP32-C3 Technical Reference Manual*.

### 3.4.2 Serial Peripheral Interface (SPI)

ESP32-C3 has the following SPI interfaces:

- **SPI0** used by ESP32-C3's GDMA controller and cache to access in-package or off-package flash
- **SPI1** used by the CPU to access in-package or off-package flash
- **SPI2** is a general purpose SPI controller with access to a DMA channel allocated by the GDMA controller

#### Features of SPI0 and SPI1

- Supports Single SPI, Dual SPI, and Quad SPI, QPI modes
- Configurable clock frequency with a maximum of 120 MHz in Single Transfer Rate (STR) mode
- Data transmission is in bytes

#### Features of SPI2

- Supports operation as a master or slave
- Connects to a DMA channel allocated by the GDMA controller
- Supports Single SPI, Dual SPI, and Quad SPI, QPI
- Configurable clock polarity (CPOL) and phase (CPHA)
- Configurable clock frequency
- Data transmission is in bytes
- Configurable read and write data bit order: most-significant bit (MSB) first, or least-significant bit (LSB) first
- As a master
  - Supports 2-line full-duplex communication with clock frequency up to 80 MHz
  - Supports 1-, 2-, 4-line half-duplex communication with clock frequency up to 80 MHz
  - Provides six SPI_CS pins for connection with six independent SPI slaves
  - Configurable CS setup time and hold time
- As a slave
  - Supports 2-line full-duplex communication with clock frequency up to 60 MHz
  - Supports 1-, 2-, 4-line half-duplex communication with clock frequency up to 60 MHz

For GPIOs assigned to SPI, please refer to Table 3-2.

For more information, please refer to Chapter SPI Controller (SPI) in *ESP32-C3 Technical Reference Manual*.

### 3.4.3 Universal Asynchronous Receiver Transmitter (UART)

ESP32-C3 has two UART interfaces, i.e. UART0 and UART1, which support IrDA and asynchronous communication (RS232 and RS485) at a speed of up to 5 Mbps. The UART controller provides hardware flow

control (CTS and RTS signals) and software flow control (XON and XOFF). Both UART interfaces connect to GDMA via UHCI0, and can be accessed by the GDMA controller or directly by the CPU.

For GPIOs assigned to UART, please refer to Table 3-2.

For more information, please refer to Chapter UART Controller (UART) in *ESP32-C3 Technical Reference Manual*.

### 3.4.4 I2C Interface

ESP32-C3 has an I2C bus interface which is used for I2C master mode or slave mode, depending on your configuration. The I2C interface supports:

- standard mode (100 Kbit/s)
- fast mode (400 Kbit/s)
- up to 800 Kbit/s (constrained by SCL and SDA pull-up strength)
- 7-bit and 10-bit addressing mode
- double addressing mode
- 7-bit broadcast address

You can configure instruction registers to control the I2C interface for more flexibility.

For GPIOs assigned to I2C, please refer to Table 3-2.

For more information, please refer to Chapter I2C Controller (I2C) in *ESP32-C3 Technical Reference Manual*.

### 3.4.5 I2S Interface

ESP32-C3 includes a standard I2S interface. This interface can operate as a master or a slave in full-duplex mode or half-duplex mode, and can be configured for 8-bit, 16-bit, 24-bit, or 32-bit serial communication. BCK clock frequency, from 10 kHz up to 40 MHz, is supported.

The I2S interface connects to the GDMA controller. The interface supports TDM PCM, TDM MSB alignment, TDM standard, and PDM standard.

For GPIOs assigned to I2S, please refer to Table 3-2.

For more information, please refer to Chapter I2S Controller (I2S) in *ESP32-C3 Technical Reference Manual*.

### 3.4.6 Remote Control Peripheral

The Remote Control Peripheral (RMT) supports two channels of infrared remote transmission and two channels of infrared remote reception. By controlling pulse waveform through software, it supports various infrared and other single wire protocols. All four channels share a 192 × 32-bit memory block to store transmit or receive waveform.

For GPIOs assigned to the Remote Control Peripheral, please refer to Table 3-2.

For more information, please refer to Chapter Remote Control Peripheral (RMT) in *ESP32-C3 Technical Reference Manual*.

### 3.4.7 LED PWM Controller

The LED PWM controller can generate independent digital waveform on six channels. The LED PWM controller:

- can generate digital waveform with configurable periods and duty cycle. The resolution of duty cycle can be up to 14 bits.
- has multiple clock sources, including APB clock and external main crystal clock.
- can operate when the CPU is in Light-sleep mode.
- supports gradual increase or decrease of duty cycle, which is useful for the LED RGB color-gradient generator.

For GPIOs assigned to LED PWM, please refer to Table 3-2.

For more information, please refer to Chapter LED PWM Controller (LEDC) in *ESP32-C3 Technical Reference Manual*.

### 3.4.8 General DMA Controller

ESP32-C3 has a general DMA controller (GDMA) with six independent channels, i.e. three transmit channels and three receive channels. These six channels are shared by peripherals with DMA feature. The GDMA controller implements a fixed-priority scheme among these channels, whose priority can be configured.

The GDMA controller controls data transfer using linked lists. It allows peripheral-to-memory and memory-to-memory data transfer at a high speed. All channels can access internal RAM.

Peripherals on ESP32-C3 with DMA feature are SPI2, UHCI0, I2S, AES, SHA, and ADC.

For more information, please refer to Chapter GDMA Controller (GDMA) in *ESP32-C3 Technical Reference Manual*.

### 3.4.9 USB Serial/JTAG Controller

ESP32-C3 integrates a USB Serial/JTAG controller. This controller has the following features:

- CDC-ACM virtual serial port and JTAG adapter functionality
- USB 2.0 full speed compliant, capable of up to 12 Mbit/s transfer speed (Note that this controller does not support the faster 480 Mbit/s high-speed transfer mode)
- programming in-package/off-package flash
- CPU debugging with compact JTAG instructions
- a full-speed USB PHY integrated in the chip

For GPIOs assigned to USB Serial/JTAG, please refer to Table 3-2.

For more information, please refer to Chapter USB Serial/JTAG Controller (USB_SERIAL_JTAG) in *ESP32-C3 Technical Reference Manual*.

### 3.4.10 TWAI® Controller

ESP32-C3 has a TWAI® controller with the following features:

- 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 1 Kbit/s to 1 Mbit/s
- multiple modes of operation: Normal, Listen Only, and Self-Test (no acknowledgment required)
- 64-byte receive FIFO
- acceptance filter (single and dual filter modes)
- error detection and handling: error counters, configurable error interrupt threshold, error code capture, arbitration lost capture

For GPIOs assigned to TWAI, please refer to Table 3-2.

For more information, please refer to Chapter Two-wire Automotive Interface (TWAI) in *ESP32-C3 Technical Reference Manual*.

## 3.5 Radio and Wi-Fi

ESP32-C3 radio consists of the following blocks:

- 2.4 GHz receiver
- 2.4 GHz transmitter
- bias and regulators
- balun and transmit-receive switch
- clock generator

### 3.5.1 2.4 GHz Receiver

The 2.4 GHz receiver demodulates the 2.4 GHz RF signal to quadrature baseband signals and converts them to the digital domain with two high-resolution, high-speed ADCs. To adapt to varying signal channel conditions, ESP32-C3 integrates RF filters, Automatic Gain Control (AGC), DC offset cancelation circuits, and baseband filters.

### 3.5.2 2.4 GHz Transmitter

The 2.4 GHz transmitter modulates the quadrature baseband signals to the 2.4 GHz RF signal, and drives the antenna with a high-powered CMOS power amplifier. The use of digital calibration further improves the linearity of the power amplifier.

Additional calibrations are integrated to cancel any radio imperfections, such as:

- carrier leakage
- I/Q amplitude/phase matching
- baseband nonlinearities
- RF nonlinearities
- antenna matching

These built-in calibration routines reduce the cost, time, and specialized equipment required for product testing.

### 3.5.3 Clock Generator

The clock generator produces quadrature clock signals of 2.4 GHz for both the receiver and the transmitter. All components of the clock generator are integrated into the chip, including inductors, varactors, filters, regulators and dividers.

The clock generator has built-in calibration and self-test circuits. Quadrature clock phases and phase noise are optimized on chip with patented calibration algorithms which ensure the best performance of the receiver and the transmitter.

### 3.5.4 Wi-Fi Radio and Baseband

ESP32-C3 Wi-Fi radio and baseband support the following features:

- 802.11b/g/n
- 802.11n MCS0-7 that supports 20 MHz and 40 MHz bandwidth
- 802.11n MCS32
- 802.11n 0.4 $\mu$s guard interval
- data rate up to 150 Mbps
- RX STBC (single spatial stream)
- adjustable transmitting power
- antenna diversity
  ESP32-C3 supports antenna diversity with an external RF switch. This switch is controlled by one or more GPIOs, and used to select the best antenna to minimize the effects of channel imperfections.

### 3.5.5 Wi-Fi MAC

ESP32-C3 implements the full 802.11 b/g/n Wi-Fi MAC protocol. It supports the Basic Service Set (BSS) STA and SoftAP operations under the Distributed Control Function (DCF). Power management is handled automatically with minimal host interaction to minimize the active duty period.

ESP32-C3 Wi-Fi MAC applies the following low-level protocol functions automatically:

- 4 × virtual Wi-Fi interfaces
- infrastructure BSS in Station mode, SoftAP mode, Station + SoftAP mode, and promiscuous mode
- RTS protection, CTS protection, Immediate Block ACK
- fragmentation and defragmentation
- TX/RX A-MPDU, TX/RX A-MSDU
- transmit opportunity (TXOP)
- Wi-Fi multimedia (WMM)
- GCMP, CCMP, TKIP, WAPI, WEP, BIP, WPA2-PSK/WPA2-Enterprise, and WPA3-PSK/WPA3-Enterprise

- automatic beacon monitoring (hardware TSF)
- 802.11mc FTM

### 3.5.6 Networking Features

Espressif provides libraries for TCP/IP networking, ESP-WIFI-MESH networking, and other networking protocols over Wi-Fi. TLS 1.0, 1.1 and 1.2 is also supported.

## 3.6 Bluetooth LE

ESP32-C3 includes a Bluetooth Low Energy subsystem that integrates a hardware link layer controller, an RF/modem block and a feature-rich software protocol stack. It supports the core features of Bluetooth 5 and Bluetooth mesh.

### 3.6.1 Bluetooth LE Radio and PHY

Bluetooth Low Energy radio and PHY in ESP32-C3 support:

- 1 Mbps PHY
- 2 Mbps PHY for higher data rates
- coded PHY for longer range (125 Kbps and 500 Kbps)
- HW Listen before talk (LBT)

### 3.6.2 Bluetooth LE Link Layer Controller

Bluetooth Low Energy Link Layer Controller in ESP32-C3 supports:

- LE advertising extensions, to enhance broadcasting capacity and broadcast more intelligent data
- multiple advertisement sets
- simultaneous advertising and scanning
- multiple connections in simultaneous central and peripheral roles
- adaptive frequency hopping and channel assessment
- LE channel selection algorithm #2
- connection parameter update
- high duty cycle non-connectable advertising
- LE privacy 1.2
- LE data packet length extension
- link layer extended scanner filter policies
- low duty cycle directed advertising
- link layer encryption
- LE Ping

## 3.7 Power Management

The ESP32-C3 has an advanced Power Management Unit (PMU). It can be flexibly configured to power up different power domains of the chip to achieve the best balance between chip performance, power consumption, and wakeup latency.

Configuring the PMU is a complex procedure. To simplify power management for typical scenarios, there are the following **predefined power modes** that power up different combinations of power domains:

- **Active mode** – The CPU, RF circuits, and all peripherals are on. The chip can process data, receive, transmit, and listen.
- **Modem-sleep mode** – The CPU is on, but the clock frequency can be reduced. The wireless connections can be configured to remain active as RF circuits are periodically switched on when required.
- **Light-sleep mode** – The CPU stops running, and can be optionally powered on. The chip can be woken up via all wake up mechanisms: MAC, RTC timer, or external interrupts. Wireless connections can remain active. Some groups of digital peripherals can be optionally shut down.
- **Deep-sleep mode** – Only RTC is powered on. Wireless connection data is stored in RTC memory.

For power consumption in different power modes, see Section 4.6 Current Consumption.

Figure 3-2 Components and Power Domains and the following Table 3-1 show the distribution of chip components between power domains and power subdomains.

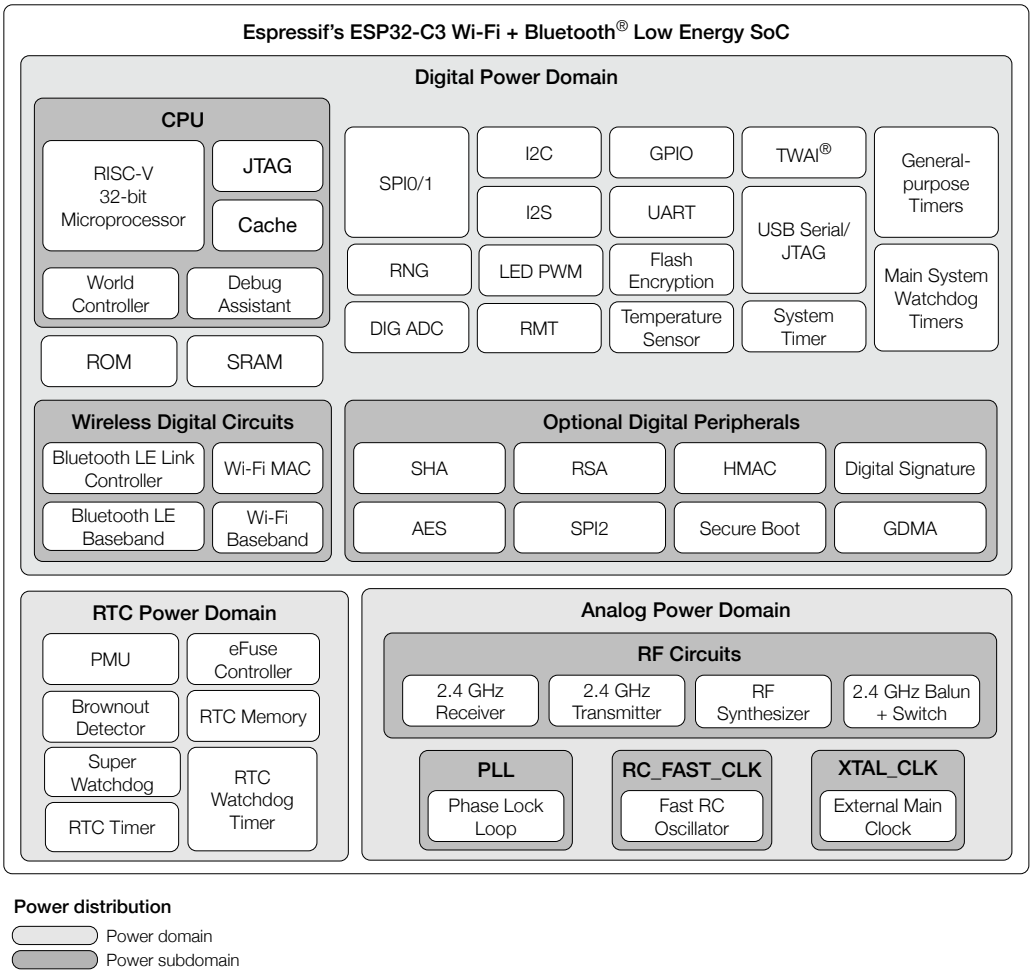


Figure 3-2. Components and Power Domains

Table 3-1. Components and Power Domains

| Power Domain / Power Mode | RTC | Digital | | | | Analog | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | CPU | Optional Digital Periph | Wireless Digital Circuits | | FOSC_ CLK | XTAL_ CLK | PLL | RF Circuits |
| Active | ON | ON | ON | ON | ON | ON | ON | ON | ON | ON |
| Modem-sleep | ON | ON | ON | ON | ON[1] | ON | ON | ON | ON | OFF[2] |
| Light-sleep | ON | ON | OFF[1] | ON[1] | OFF[1] | ON | OFF | OFF | OFF | OFF[2] |
| Deep-sleep | ON | OFF | OFF | OFF | OFF | ON | OFF | OFF | OFF | OFF |

[1] Configurable, see the TRM.

[2] If Wireless Digital Circuits are on, RF circuits are periodically switched on when required by internal operation to keep active wireless connections running.

For more information, please refer to Chapter Low-Power Management (RTC_CNTL) in *ESP32-C3 Technical Reference Manual*.

## 3.8 Timers

### 3.8.1 General Purpose Timers

ESP32-C3 has two 54-bit general-purpose timers, which are based on 16-bit prescalers and 54-bit auto-reload-capable up/down-timers.

The timers' features are summarized as follows:

- a 16-bit clock prescaler, from 1 to 65536
- a 54-bit time-base counter programmable to be incrementing or decrementing
- able to read real-time value of the time-base counter
- halting and resuming the time-base counter
- programmable alarm generation
- level interrupt generation

For more information, please refer to Chapter Timer Group (TIMG) in *ESP32-C3 Technical Reference Manual*.

### 3.8.2 System Timer

ESP32-C3 integrates a 52-bit system timer, which has two 52-bit counters and three comparators. The system timer has the following features:

- counters with a fixed clock frequency of 16 MHz
- three types of independent interrupts generated according to alarm value
- two alarm modes: target mode and period mode
- 52-bit target alarm value and 26-bit periodic alarm value
- automatic reload of counter value
- counters can be stalled if the CPU is stalled or in OCD mode

For more information, please refer to Chapter System Timer (SYSTIMER) in *ESP32-C3 Technical Reference Manual*.

### 3.8.3 Watchdog Timers

For more information, please refer to Chapter Watchdog Timers (WDT) in *ESP32-C3 Technical Reference Manual*.

#### Digital Watchdog Timers

ESP32-C3 contains three digital watchdog timers: one in each of the two timer groups (called Main System Watchdog Timers, or MWDT) and one in the RTC module (called the RTC Watchdog Timer, or RWDT).

During the flash boot process, RWDT and the MWDT in timer group 0 (TIMG0) are enabled automatically in order to detect and recover from booting errors.

Digital watchdog timers have the following features:

- four stages, each with a programmable timeout value. Each stage can be configured, enabled and disabled separately

- interrupt, CPU reset, or core reset for MWDT upon expiry of each stage; interrupt, CPU reset, core reset, or system reset for RWDT upon expiry of each stage
- 32-bit expiry counter
- write protection, to prevent RWDT and MWDT configuration from being altered inadvertently
- flash boot protection
  If the boot process from an SPI flash does not complete within a predetermined period of time, the watchdog will reboot the entire main system.

#### Analog Watchdog Timer

ESP32-C3 also has one analog watchdog timer: RTC super watchdog timer (SWD). It is an ultra-low-power circuit in analog domain that helps to prevent the system from operating in a sub-optimal state and resets the system if required.

SWD has the following features:

- Ultra-low power
- Interrupt to indicate that the SWD timeout period is close to expiring
- Various dedicated methods for software to feed SWD, which enables SWD to monitor the working state of the whole operating system

## 3.9 Cryptographic Hardware Accelerators

ESP32-C3 is equipped with hardware accelerators of general algorithms, such as AES-128/AES-256 (FIPS PUB 197), ECB/CBC/OFB/CFB/CTR (NIST SP 800-38A), SHA1/SHA224/SHA256 (FIPS PUB 180-4), and RSA3072. The chip also supports independent arithmetic, such as large-number modular multiplication and large-number multiplication. The maximum operation length for RSA and large-number modular multiplication is 3072 bits. The maximum operand length for large-number multiplication is 1536 bits.

## 3.10 Physical Security Features

- Transparent off-package flash encryption (AES-XTS algorithm) with software inaccessible key prevents unauthorized readout of your application code or data.
- Secure boot feature uses a hardware root of trust to ensure only signed firmware (with RSA-PSS signature) can be booted.
- HMAC module can use a software inaccessible MAC key to generate MAC signatures for identity verification and other purposes.
- Digital Signature module can use a software inaccessible secure key to generate RSA signatures for identity verification.
- World Controller provides two running environments for software. All hardware and software resources are sorted to two groups, and placed in either secure or general world. The secure world cannot be accessed by hardware in the general world, thus establishing a security boundary.

## 3.11 Peripheral Pin Configurations

Table 3-2. Peripheral Pin Configurations

| Interface | Signal | Pin | Function |
|---|---|---|---|
| ADC | ADC1_CH0 | XTAL_32K_P | Two 12-bit SAR ADCs |
| | ADC1_CH1 | XTAL_32K_N | |
| | ADC1_CH2 | GPIO2 | |
| | ADC1_CH3 | GPIO3 | |
| | ADC1_CH4 | MTMS | |
| | ADC2_CH0 | MTDI | |
| JTAG | MTDI | MTDI | JTAG for software debugging |
| | MTCK | MTCK | |
| | MTMS | MTMS | |
| | MTDO | MTDO | |
| UART | U0RXD_in | Any GPIO pins | Two UART channels with hardware flow control and GDMA |
| | U0CTS_in | | |
| | U0DSR_in | | |
| | U0TXD_out | | |
| | U0RTS_out | | |
| | U0DTR_out | | |
| | U1RXD_in | | |
| | U1CTS_in | | |
| | U1DSR_in | | |
| | U1TXD_out | | |
| | U1RTS_out | | |
| | U1DTR_out | | |
| I2C | I2CEXT0_SCL_in | Any GPIO pins | One I2C channel in slave or master mode |
| | I2CEXT0_SDA_in | | |
| | I2CEXT0_SCL_out | | |
| | I2CEXT0_SDA_out | | |
| LED PWM | ledc_ls_sig_out0~5 | Any GPIO pins | Six independent PWM channels |
| I2S | I2S0O_BCK_in | Any GPIO pins | Stereo input and output from/to the audiocodec |
| | I2S_MCLK_in | | |
| | I2SO_WS_in | | |
| | I2SI_SD_in | | |
| | I2SI_BCK_in | | |
| | I2SI_WS_in | | |
| | I2SO_BCK_out | | |
| | I2S_MCLK_out | | |
| | I2SO_WS_out | | |
| | I2SO_SD_out | | |
| | I2SI_BCK_out | | |
| | I2SI_WS_out | | |
| | I2SO_SD1_out | | |

| Interface | Signal | Pin | Function |
|---|---|---|---|
| Remote Control Peripheral | RMT_SIG_IN0~1 | Any GPIO pins | Two channels for an IR transceiver of various waveforms |
| | RMT_SIG_OUT0~1 | | |
| SPI0/1 | SPICLK_out_mux | SPICLK | Support Standard SPI, Dual SPI, Quad SPI, and QPI that allow connection to off-package flash |
| | SPICS0_out | SPICS0 | |
| | SPICS1_out | Any GPIO pins | |
| | SPID_in/_out | SPID | |
| | SPIQ_in/_out | SPIQ | |
| | SPIWP_in/_out | SPIWP | |
| | SPIHD_in/_out | SPIHD | |
| SPI2 | FSPICLK_in/_out_mux | Any GPIO pins | • Master mode and slave mode of SPI, Dual SPI, Quad SPI, and QPI<br>• Connection to off-package flash, RAM, and other SPI devices<br>• Four modes of SPI transfer format<br>• Configurable SPI frequency<br>• 64-byte FIFO or GDMA buffer |
| | FSPICS0_in/_out | | |
| | FSPICS1~5_out | | |
| | FSPID_in/_out | | |
| | FSPIQ_in/_out | | |
| | FSPIWP_in/_out | | |
| | FSPIHD_in/_out | | |
| USB Serial/JTAG | USB_D+ | GPIO19 | USB-to-serial converter, and USB-to-JTAG converter |
| | USB_D- | GPIO18 | |
| TWAI | twai_rx | Any GPIO pins | Compatible with ISO 11898-1 protocol |
| | twai_tx | | |
| | twai_bus_off_on | | |
| | twai_clkout | | |

# 4 Electrical Characteristics

## 4.1 Absolute Maximum Ratings

Stresses above those listed in Table 4-1 *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only and normal operation of the device at these or any other conditions beyond those indicated in Section 4.2 Recommended Operating Conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

**Table 4-1. Absolute Maximum Ratings**

| Parameter | Description | Min | Max | Unit |
|---|---|---|---|---|
| Input power pins[1] | Allowed input voltage | –0.3 | 3.6 | V |
| $I_{output}$[2] | Cumulative IO output current | — | 1000 | mA |
| $T_{STORE}$ | Storage temperature | –40 | 150 | °C |

[1] For more information on input power pins, see Section 2.5 Power Supply.

[2] The product proved to be fully functional after all its IO pins were pulled high while being connected to ground for 24 consecutive hours at ambient temperature of 25 °C.

## 4.2 Recommended Operating Conditions

For recommended ambient temperature, see Section 1 ESP32-C3 Series Comparison.

**Table 4-2. Recommended Operating Conditions**

| Parameter [1] | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| VDDA, VDD3P3, VDD3P3_RTC | Recommended input voltage | 3.0 | 3.3 | 3.6 | V |
| VDD3P3_CPU [2, 3] | Recommended input voltage | 3.0 | 3.3 | 3.6 | V |
| VDD_SPI (as input) | — | 3.0 | 3.3 | 3.6 | V |
| $I_{VDD}$ | Cumulative input current | 0.5 | — | — | A |

[1] See in conjunction with Section 2.5 Power Supply.

[2] If writing to eFuses, the voltage on VDD3P3_CPU should not exceed 3.3 V as the circuits responsible for burning eFuses are sensitive to higher voltages.

[3] If VDD3P3_CPU is used to power VDD_SPI (see Section 2.5.2 Power Scheme), the voltage drop on $R_{SPI}$ should be accounted for. See also Section 4.3 VDD_SPI Output Characteristics.

## 4.3 VDD_SPI Output Characteristics

Table 4-3. VDD_SPI Internal and Output Characteristics

| Parameter | Description [1] | Typ | Unit |
|---|---|---|---|
| $R_{SPI}$ | VDD_SPI powered by VDD3P3_CPU via $R_{SPI}$ for 3.3 V flash_CPU [2] | 7.5 | Ω |

[1] See in conjunction with Section 2.5.2 Power Scheme.

[2] VDD3P3_CPU must be more than *VDD_flash_min* + *I_flash_max* * $R_{SPI}$; where

- *VDD_flash_min* – minimum operating voltage of flash_CPU
- *I_flash_max* – maximum operating current of flash_CPU

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

Table 4-4. DC Characteristics (3.3 V, 25 °C)

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $C_{IN}$ | Pin capacitance | — | 2 | — | pF |
| $V_{IH}$ | High-level input voltage | 0.75 × VDD[1] | — | VDD[1] + 0.3 | V |
| $V_{IL}$ | Low-level input voltage | –0.3 | — | 0.25 × VDD[1] | V |
| $I_{IH}$ | High-level input current | — | — | 50 | nA |
| $I_{IL}$ | Low-level input current | — | — | 50 | nA |
| $V_{OH}$[2] | High-level output voltage | 0.8 × VDD[1] | — | — | V |
| $V_{OL}$[2] | Low-level output voltage | — | — | 0.1 × VDD[1] | V |
| $I_{OH}$ | High-level source current (VDD[1] = 3.3 V, $V_{OH}$ >= 2.64 V, PAD_DRIVER = 3) | — | 40 | — | mA |
| $I_{OL}$ | Low-level sink current (VDD[1] = 3.3 V, $V_{OL}$ = 0.495 V, PAD_DRIVER = 3) | — | 28 | — | mA |
| $R_{PU}$ | Internal weak pull-up resistor | — | 45 | — | kΩ |
| $R_{PD}$ | Internal weak pull-down resistor | — | 45 | — | kΩ |
| $V_{IH\_nRST}$ | Chip reset release voltage CHIP_EN voltage is within the specified range) | 0.75 × VDD[1] | — | VDD[1] + 0.3 | V |
| $V_{IL\_nRST}$ | Chip reset voltage (CHIP_EN voltage is within the specified range) | –0.3 | — | 0.25 × VDD[1] | V |

[1] VDD – voltage from a power pin of a respective power domain.

[2] $V_{OH}$ and $V_{OL}$ are measured using high-impedance load.

## 4.5 ADC Characteristics

Table 4-5. ADC Characteristics

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| DNL (Differential nonlinearity) [1] | ADC connected to an external 100 nF capacitor; DC signal input; Ambient temperature at 25 °C; Wi-Fi off | –7 | 7 | LSB |
| INL (Integral nonlinearity) | | –12 | 12 | LSB |
| Sampling rate | — | — | 100 | kSPS [2] |

[1] To get better DNL results, you can sample multiple times and apply a filter, or calculate the average value.

[2] kSPS means kilo samples-per-second.

The calibrated ADC results after hardware calibration and software calibration are shown in Table 4-6. For higher accuracy, you may implement your own calibration methods.

Table 4-6. ADC Calibration Results

| Parameter | Description | Min | Max | Unit |
|---|---|---|---|---|
| Total error | ATTEN0, effective measurement range of 0 ~ 750 | –10 | 10 | mV |
| | ATTEN1, effective measurement range of 0 ~ 1050 | –10 | 10 | mV |
| | ATTEN2, effective measurement range of 0 ~ 1300 | –10 | 10 | mV |
| | ATTEN3, effective measurement range of 0 ~ 2500 | –35 | 35 | mV |

## 4.6 Current Consumption

### 4.6.1 RF Current Consumption in Active Mode

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.

Table 4-7. Wi-Fi Current Consumption Depending on RF Modes

| Work Mode [1] | Description | | Peak (mA) |
|---|---|---|---|
| Active (RF working) | TX | 802.11b, 1 Mbps, @21 dBm | 335 |
| | | 802.11g, 54 Mbps, @19 dBm | 285 |
| | | 802.11n, HT20, MCS7, @18.5 dBm | 276 |
| | | 802.11n, HT40, MCS7, @18.5 dBm | 278 |
| | RX | 802.11b/g/n, HT20 | 84 |
| | | 802.11n, HT40 | 87 |

### 4.6.2 Current Consumption in Other Modes

Table 4-8. Current Consumption in Modem-sleep Mode

| Mode | CPU Frequency (MHz) | Description | Typ | |
|---|---|---|---|---|
| | | | All Peripherals Clocks Disabled (mA) | All Peripherals Clocks Enabled (mA)[1] |
| Modem-sleep[2,3] | 160 | CPU is running | 23 | 28 |
| | | CPU is idle | 16 | 21 |
| | 80 | CPU is running | 17 | 22 |
| | | CPU is idle | 13 | 18 |

[1] In practice, the current consumption might be different depending on which peripherals are enabled.

[2] In Modem-sleep mode, Wi-Fi is clock gated.

[3] In Modem-sleep mode, the consumption might be higher when accessing flash. For a flash rated at 80 Mbit/s, in SPI 2-line mode the consumption is 10 mA.

Table 4-9. Current Consumption in Low-Power Modes

| Mode | Description | Typ ($\mu$A) |
|---|---|---|
| Light-sleep | VDD_SPI and Wi-Fi are powered down, and all GPIOs are high-impedance | 130 |
| Deep-sleep | RTC timer + RTC memory | 5 |
| Power off | CHIP_EN is set to low level, the chip is powered off | 1 |

## 4.7 Reliability

Table 4-10. Reliability Qualifications

| Test Item | Test Conditions | Test Standard |
|---|---|---|
| HTOL (High Temperature Operating Life) | 125 °C, 1000 hours | JESD22-A108 |
| ESD (Electro-Static Discharge Sensitivity) | HBM (Human Body Mode)[1] ± 2000 V | JS-001 |
| | CDM (Charge Device Mode)[2] ± 1000 V | JS-002 |
| Latch up | Current trigger ± 200 mA | JESD78 |
| | Voltage trigger 1.5 × $VDD_{max}$ | |
| Preconditioning | Bake 24 hours @125 °C<br>Moisture soak (level 3: 192 hours @30 °C, 60% RH)<br>IR reflow solder: 260 + 0 °C, 20 seconds, three times | J-STD-020, JESD47, JESD22-A113 |
| TCT (Temperature Cycling Test) | –65 °C / 150 °C, 500 cycles | JESD22-A104 |
| uHAST (Highly Accelerated Stress Test, unbiased) | 130 °C, 85% RH, 96 hours | JESD22-A118 |
| HTSL (High Temperature Storage Life) | 150 °C, 1000 hours | JESD22-A103 |

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Table 4-10 – cont'd from previous page

| Test Item | Test Conditions | Test Standard |
|---|---|---|
| LTSL (Low Temperature Storage Life) | –40 °C, 1000 hours | JESD22-A119 |

[1] JEDEC document JEP155 states that 500 V HBM allows safe manufacturing with a standard ESD control process.

[2] JEDEC document JEP157 states that 250 V CDM allows safe manufacturing with a standard ESD control process.

## 4.8 Wi-Fi Radio

Table 4-11. Wi-Fi Frequency

| Parameter | Min (MHz) | Typ (MHz) | Max (MHz) |
|---|---|---|---|
| Center frequency of operating channel | 2412 | — | 2484 |

### 4.8.1 Wi-Fi RF Transmitter (TX) Specifications

Table 4-12. TX Power with Spectral Mask and EVM Meeting 802.11 Standards

| Rate | Min (dBm) | Typ (dBm) | Max (dBm) |
|---|---|---|---|
| 802.11b, 1 Mbps | — | 21.0 | — |
| 802.11b, 11 Mbps | — | 21.0 | — |
| 802.11g, 6 Mbps | — | 21.0 | — |
| 802.11g, 54 Mbps | — | 19.0 | — |
| 802.11n, HT20, MCS0 | — | 20.0 | — |
| 802.11n, HT20, MCS7 | — | 18.5 | — |
| 802.11n, HT40, MCS0 | — | 20.0 | — |
| 802.11n, HT40, MCS7 | — | 18.5 | — |

Table 4-13. TX EVM Test

| Rate | Min (dB) | Typ (dB) | SL[1] (dB) |
|---|---|---|---|
| 802.11b, 1 Mbps, @21 dBm | — | –24.5 | –10 |
| 802.11b, 11 Mbps, @21 dBm | — | –25.0 | –10 |
| 802.11g, 6 Mbps, @21 dBm | — | –23.0 | –5 |
| 802.11g, 54 Mbps, @19 dBm | — | –27.5 | –25 |
| 802.11n, HT20, MCS0, @20 dBm | — | –22.5 | –5 |
| 802.11n, HT20, MCS7, @18.5 dBm | — | –29.0 | –27 |
| 802.11n, HT40, MCS0, @20 dBm | — | –22.5 | –5 |
| 802.11n, HT40, MCS7, @18.5 dBm | — | –28.0 | –27 |

[1] SL stands for standard limit value.

### 4.8.2 Wi-Fi RF Receiver (RX) Specifications

Table 4-14. RX Sensitivity

| Rate | Min (dBm) | Typ (dBm) | Max (dBm) |
|---|---|---|---|
| 802.11b, 1 Mbps | — | –98.4 | — |
| 802.11b, 2 Mbps | — | –96.0 | — |
| 802.11b, 5.5 Mbps | — | –93.0 | — |
| 802.11b, 11 Mbps | — | –88.6 | — |
| 802.11g, 6 Mbps | — | –93.8 | — |
| 802.11g, 9 Mbps | — | –92.2 | — |
| 802.11g, 12 Mbps | — | –91.0 | — |
| 802.11g, 18 Mbps | — | –88.4 | — |
| 802.11g, 24 Mbps | — | –85.8 | — |
| 802.11g, 36 Mbps | — | –82.0 | — |
| 802.11g, 48 Mbps | — | –78.0 | — |
| 802.11g, 54 Mbps | — | –76.6 | — |
| 802.11n, HT20, MCS0 | — | –93.6 | — |
| 802.11n, HT20, MCS1 | — | –90.8 | — |
| 802.11n, HT20, MCS2 | — | –88.4 | — |
| 802.11n, HT20, MCS3 | — | –85.0 | — |
| 802.11n, HT20, MCS4 | — | –81.8 | — |
| 802.11n, HT20, MCS5 | — | –77.8 | — |
| 802.11n, HT20, MCS6 | — | –76.0 | — |
| 802.11n, HT20, MCS7 | — | –74.8 | — |
| 802.11n, HT40, MCS0 | — | –90.0 | — |
| 802.11n, HT40, MCS1 | — | –88.0 | — |
| 802.11n, HT40, MCS2 | — | –85.2 | — |
| 802.11n, HT40, MCS3 | — | –82.0 | — |
| 802.11n, HT40, MCS4 | — | –78.8 | — |
| 802.11n, HT40, MCS5 | — | –74.6 | — |
| 802.11n, HT40, MCS6 | — | –73.0 | — |
| 802.11n, HT40, MCS7 | — | –71.4 | — |

Table 4-15. Maximum RX Level

| Rate | Min (dBm) | Typ (dBm) | Max (dBm) |
|---|---|---|---|
| 802.11b, 1 Mbps | — | 5 | — |
| 802.11b, 11 Mbps | — | 5 | — |
| 802.11g, 6 Mbps | — | 5 | — |
| 802.11g, 54 Mbps | — | 0 | — |
| 802.11n, HT20, MCS0 | — | 5 | — |

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Table 4-15 – cont'd from previous page

| Rate | Min (dBm) | Typ (dBm) | Max (dBm) |
|---|---|---|---|
| 802.11n, HT20, MCS7 | – | 0 | – |
| 802.11n, HT40, MCS0 | – | 5 | – |
| 802.11n, HT40, MCS7 | – | 0 | – |

Table 4-16. RX Adjacent Channel Rejection

| Rate | Min (dB) | Typ (dB) | Max (dB) |
|---|---|---|---|
| 802.11b, 1 Mbps | – | 35 | – |
| 802.11b, 11 Mbps | – | 35 | – |
| 802.11g, 6 Mbps | – | 31 | – |
| 802.11g, 54 Mbps | – | 20 | – |
| 802.11n, HT20, MCS0 | – | 31 | – |
| 802.11n, HT20, MCS7 | – | 16 | – |
| 802.11n, HT40, MCS0 | – | 25 | – |
| 802.11n, HT40, MCS7 | – | 11 | – |

## 4.9 Bluetooth LE Radio

Table 4-17. Bluetooth LE Frequency

| Parameter | Min (MHz) | Typ (MHz) | Max (MHz) |
|---|---|---|---|
| Center frequency of operating channel | 2402 | – | 2480 |

### 4.9.1 Bluetooth LE RF Transmitter (TX) Specifications

Table 4-18. Transmitter Characteristics - Bluetooth LE 1 Mbps

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| RF transmit power | RF power control range | –24.00 | 0 | 20.00 | dBm |
| | Gain control step | – | 3.00 | – | dB |
| Carrier frequency offset and drift | Max $\lvert f_n \rvert_{n=0,\,1,\,2,\,..k}$ | – | 17.00 | – | kHz |
| | Max $\lvert f_0 - f_n \rvert$ | – | 1.75 | – | kHz |
| | Max $\lvert f_n - f_{n-5} \rvert$ | – | 1.46 | – | kHz |
| | $\lvert f_1 - f_0 \rvert$ | – | 0.80 | – | kHz |
| Modulation characteristics | $\Delta\, f1_{avg}$ | – | 250.00 | – | kHz |
| | Min $\Delta\, f2_{max}$ (for at least 99.9% of all $\Delta\, f2_{max}$) | – | 190.00 | – | kHz |
| | $\Delta\, f2_{avg}/\Delta\, f1_{avg}$ | – | 0.83 | – | – |

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Table 4-18 – cont'd from previous page

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| In-band spurious emissions | ± 2 MHz offset | — | –37.62 | — | dBm |
| | ± 3 MHz offset | — | –41.95 | — | dBm |
| | > ± 3 MHz offset | — | –44.48 | — | dBm |

Table 4-19. Transmitter Characteristics - Bluetooth LE 2 Mbps

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| RF transmit power | RF power control range | –24.00 | 0 | 20.00 | dBm |
| | Gain control step | — | 3.00 | — | dB |
| Carrier frequency offset and drift | Max $\lvert f_n \rvert_{n=0,\ 1,\ 2,\ ..k}$ | — | 20.80 | — | kHz |
| | Max $\lvert f_0 - f_n \rvert$ | — | 1.30 | — | kHz |
| | Max $\lvert f_n - f_{n-5} \rvert$ | — | 1.33 | — | kHz |
| | $\lvert f_1 - f_0 \rvert$ | — | 0.70 | — | kHz |
| Modulation characteristics | $\Delta\ f1_{avg}$ | — | 498.00 | — | kHz |
| | Min $\Delta\ f2_{max}$ (for at least 99.9% of all $\Delta\ f2_{max}$) | — | 430.00 | — | kHz |
| | $\Delta\ f2_{avg}/\Delta\ f1_{avg}$ | — | 0.93 | — | — |
| In-band spurious emissions | ± 4 MHz offset | — | –43.55 | — | dBm |
| | ± 5 MHz offset | — | –45.26 | — | dBm |
| | > ± 5 MHz offset | — | –45.26 | — | dBm |

Table 4-20. Transmitter Characteristics - Bluetooth LE 125 Kbps

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| RF transmit power | RF power control range | –24.00 | 0 | 20.00 | dBm |
| | Gain control step | — | 3.00 | — | dB |
| Carrier frequency offset and drift | Max $\lvert f_n \rvert_{n=0,\ 1,\ 2,\ ..k}$ | — | 17.50 | — | kHz |
| | Max $\lvert f_0 - f_n \rvert$ | — | 0.45 | — | kHz |
| | $\lvert f_n - f_{n-3} \rvert$ | — | 0.70 | — | kHz |
| | $\lvert f_0 - f_3 \rvert$ | — | 0.30 | — | kHz |
| Modulation characteristics | $\Delta\ f1_{avg}$ | — | 250.00 | — | kHz |
| | Min $\Delta\ f1_{max}$ (for at least 99.9% of all$\Delta\ f2_{max}$) | — | 235.00 | — | kHz |
| In-band spurious emissions | ± 2 MHz offset | — | –37.90 | — | dBm |
| | ± 3 MHz offset | — | –41.00 | — | dBm |
| | > ± 3 MHz offset | — | –42.50 | — | dBm |

Table 4-21. Transmitter Characteristics - Bluetooth LE 500 Kbps

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| RF transmit power | RF power control range | –24.00 | 0 | 20.00 | dBm |
| | Gain control step | — | 3.00 | — | dB |

Cont'd on next page

Table 4-21 – cont'd from previous page

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Carrier frequency offset and drift | Max $\lvert f_n \rvert_{n=0,\ 1,\ 2,\ ..k}$ | — | 17.00 | — | kHz |
| | Max $\lvert f_0 - f_n \rvert$ | — | 0.88 | — | kHz |
| | $\lvert f_n - f_{n-3} \rvert$ | — | 1.00 | — | kHz |
| | $\lvert f_0 - f_3 \rvert$ | — | 0.20 | — | kHz |
| Modulation characteristics | $\Delta\ f2_{avg}$ | — | 208.00 | — | kHz |
| | Min $\Delta\ f2_{max}$ (for at least 99.9% of all $\Delta\ f2_{max}$) | — | 190.00 | — | kHz |
| In-band spurious emissions | ± 2 MHz offset | — | –37.90 | — | dBm |
| | ± 3 MHz offset | — | –41.30 | — | dBm |
| | > ± 3 MHz offset | — | –42.80 | — | dBm |

### 4.9.2 Bluetooth LE RF Receiver (RX) Specifications

Table 4-22. Receiver Characteristics - Bluetooth LE 1 Mbps

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Sensitivity @30.8% PER | — | — | –97 | — | dBm |
| Maximum received signal @30.8% PER | — | — | 5 | — | dBm |
| Co-channel C/I | — | — | 8 | — | dB |
| Adjacent channel selectivity C/I | F = F0 + 1 MHz | — | –3 | — | dB |
| | F = F0 – 1 MHz | — | –4 | — | dB |
| | F = F0 + 2 MHz | — | –29 | — | dB |
| | F = F0 – 2 MHz | — | –31 | — | dB |
| | F = F0 + 3 MHz | — | –33 | — | dB |
| | F = F0 – 3 MHz | — | –27 | — | dB |
| | F ≥ F0 + 4 MHz | — | –29 | — | dB |
| | F ≤ F0 – 4 MHz | — | –38 | — | dB |
| Image frequency | — | — | –29 | — | dB |
| Adjacent channel to image frequency | F = $F_{image}$ + 1 MHz | — | –41 | — | dB |
| | F = $F_{image}$ – 1 MHz | — | –33 | — | dB |
| Out-of-band blocking performance | 30 MHz ~ 2000 MHz | — | –5 | — | dBm |
| | 2003 MHz ~ 2399 MHz | — | –18 | — | dBm |
| | 2484 MHz ~ 2997 MHz | — | –15 | — | dBm |
| | 3000 MHz ~ 12.75 GHz | — | –5 | — | dBm |
| Intermodulation | — | — | –30 | — | dBm |

Table 4-23. Receiver Characteristics - Bluetooth LE 2 Mbps

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Sensitivity @30.8% PER | — | — | –93 | — | dBm |
| Maximum received signal @30.8% PER | — | — | 3 | — | dBm |
| Co-channel C/I | — | — | 10 | — | dB |

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Table 4-23 – cont'd from previous page

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Adjacent channel selectivity C/I | F = F0 + 2 MHz | — | –7 | — | dB |
| | F = F0 – 2 MHz | — | –7 | — | dB |
| | F = F0 + 4 MHz | — | –28 | — | dB |
| | F = F0 – 4 MHz | — | –26 | — | dB |
| | F = F0 + 6 MHz | — | –26 | — | dB |
| | F = F0 – 6 MHz | — | –27 | — | dB |
| | F $\geq$ F0 + 8 MHz | — | –29 | — | dB |
| | F $\leq$ F0 – 8 MHz | — | –28 | — | dB |
| Image frequency | — | — | –28 | — | dB |
| Adjacent channel to image frequency | F = $F_{image}$ + 2 MHz | — | –26 | — | dB |
| | F = $F_{image}$ – 2 MHz | — | –7 | — | dB |
| Out-of-band blocking performance | 30 MHz ~ 2000 MHz | — | –5 | — | dBm |
| | 2003 MHz ~ 2399 MHz | — | –19 | — | dBm |
| | 2484 MHz ~ 2997 MHz | — | –16 | — | dBm |
| | 3000 MHz ~ 12.75 GHz | — | –5 | — | dBm |
| Intermodulation | — | — | –29 | — | dBm |

Table 4-24. Receiver Characteristics - Bluetooth LE 125 Kbps

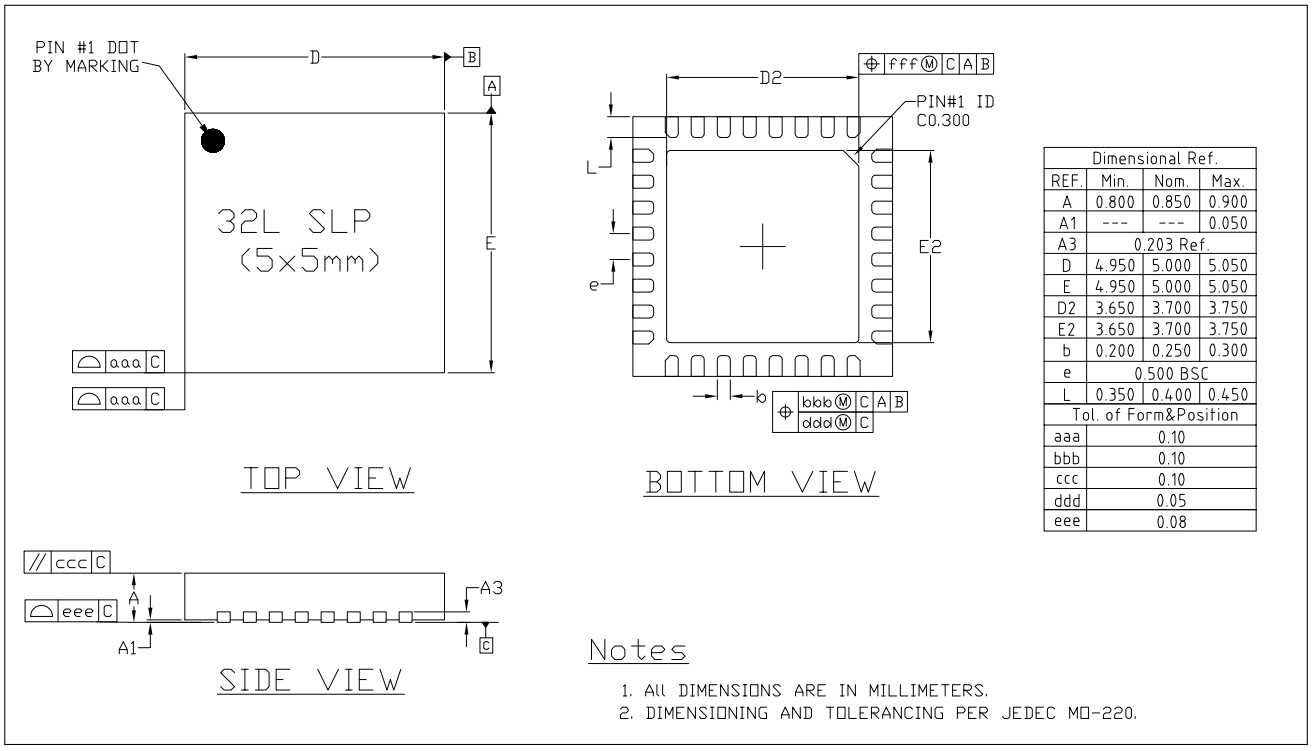
| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Sensitivity @30.8% PER | — | — | –105 | — | dBm |
| Maximum received signal @30.8% PER | — | — | 5 | — | dBm |
| Co-channel C/I | — | — | 3 | — | dB |
| Adjacent channel selectivity C/I | F = F0 + 1 MHz | — | –6 | — | dB |
| | F = F0 – 1 MHz | — | –6 | — | dB |
| | F = F0 + 2 MHz | — | –33 | — | dB |
| | F = F0 – 2 MHz | — | –43 | — | dB |
| | F = F0 + 3 MHz | — | –37 | — | dB |
| | F = F0 – 3 MHz | — | –47 | — | dB |
| | F $\geq$ F0 + 4 MHz | — | –40 | — | dB |
| | F $\leq$ F0 – 4 MHz | — | –50 | — | dB |
| Image frequency | — | — | –40 | — | dB |
| Adjacent channel to image frequency | F = $F_{image}$ + 1 MHz | — | –50 | — | dB |
| | F = $F_{image}$ – 1 MHz | — | –37 | — | dB |

Table 4-25. Receiver Characteristics - Bluetooth LE 500 Kbps

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Sensitivity @30.8% PER | — | — | –100 | — | dBm |
| Maximum received signal @30.8% PER | — | — | 5 | — | dBm |
| Co-channel C/I | — | — | 3 | — | dB |
| Adjacent channel selectivity C/I | F = F0 + 1 MHz | — | –2 | — | dB |
| | F = F0 – 1 MHz | — | –3 | — | dB |
| | F = F0 + 2 MHz | — | –32 | — | dB |
| | F = F0 – 2 MHz | — | –33 | — | dB |
| | F = F0 + 3 MHz | — | –23 | — | dB |
| | F = F0 – 3 MHz | — | –40 | — | dB |
| | F $\geq$ F0 + 4 MHz | — | –34 | — | dB |
| | F $\leq$ F0 – 4 MHz | — | –44 | — | dB |
| Image frequency | — | — | –34 | — | dB |
| Adjacent channel to image frequency | F = $F_{image}$ + 1 MHz | — | –46 | — | dB |
| | F = $F_{image}$ – 1 MHz | — | –23 | — | dB |

# 5 Packaging

- For information about tape, reel, and chip marking, please refer to *Espressif Chip Packaging Information*.
- The pins of the chip are numbered in anti-clockwise order starting from Pin 1 in the top view. For pin numbers and pin names, see also Figure 2-1 ESP32-C3 Pin Layout (Top View).
- The source file of recommended PCB land pattern is provided for your reference. You can view it with Autodesk Viewer.
- For reference PCB layout, please refer to ESP32-C3 Hardware Design Guidelines.




| Dimensional Ref. | | | |
|---|---|---|---|
| REF. | Min. | Nom. | Max. |
| A | 0.800 | 0.850 | 0.900 |
| A1 | --- | --- | 0.050 |
| A3 | 0.203 Ref. | | |
| D | 4.950 | 5.000 | 5.050 |
| E | 4.950 | 5.000 | 5.050 |
| D2 | 3.650 | 3.700 | 3.750 |
| E2 | 3.650 | 3.700 | 3.750 |
| b | 0.200 | 0.250 | 0.300 |
| e | 0.500 BSC | | |
| L | 0.350 | 0.400 | 0.450 |
| Tol. of Form&Position | | | |
| aaa | 0.10 | | |
| bbb | 0.10 | | |
| ccc | 0.10 | | |
| ddd | 0.05 | | |
| eee | 0.08 | | |

Figure 5-1. QFN32 (5×5 mm) Package

# Appendix A – ESP32-C3 Consolidated Pin Overview

| Pin No. | Pin Name | Pin Type | Pin Providing Power | Pin Settings | | Analog Function | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | At Reset | After Reset | 0 | 1 | 0 | T |
| 1 | LNA_IN | Analog | | | | | | | |
| 2 | VDD3P3 | Power | | | | | | | |
| 3 | VDD3P3 | Power | | | | | | | |
| 4 | XTAL_32K_P | IO | VDD3P3_RTC | | | XTAL_32K_P | ADC1_CH0 | GPIO0 | I/ |
| 5 | XTAL_32K_N | IO | VDD3P3_RTC | | | XTAL_32K_N | ADC1_CH1 | GPIO1 | I/ |
| 6 | GPIO2 | IO | VDD3P3_RTC | IE | IE | | ADC1_CH2 | GPIO2 | I/ |
| 7 | CHIP_EN | Analog | | | | | | | |
| 8 | GPIO3 | IO | VDD3P3_RTC | IE | IE | | ADC1_CH3 | GPIO3 | I/ |
| 9 | MTMS | IO | VDD3P3_RTC | | IE | | ADC1_CH4 | MTMS | I1 |
| 10 | MTDI | IO | VDD3P3_RTC | | IE | | ADC2_CH0 | MTDI | I1 |
| 11 | VDD3P3_RTC | Power | | | | | | | |
| 12 | MTCK | IO | VDD3P3_CPU | | IE | | | MTCK | I1 |
| 13 | MTDO | IO | VDD3P3_CPU | | IE | | | MTDO | O |
| 14 | GPIO8 | IO | VDD3P3_CPU | IE | IE | | | GPIO8 | I/ |
| 15 | GPIO9 | IO | VDD3P3_CPU | IE, WPU | IE, WPU | | | GPIO9 | I/ |
| 16 | GPIO10 | IO | VDD3P3_CPU | | IE | | | GPIO10 | I/ |
| 17 | VDD3P3_CPU | Power | | | | | | | |
| 18 | VDD_SPI | Power | VDD3P3_CPU | | | | | GPIO11 | I/ |
| 19 | SPIHD | IO | VDD_SPI / VDD3P3_CPU | WPU | IE, WPU | | | SPIHD | I1 |
| 20 | SPIWP | IO | VDD_SPI / VDD3P3_CPU | WPU | IE, WPU | | | SPIWP | I1 |
| 21 | SPICS0 | IO | VDD_SPI / VDD3P3_CPU | WPU | IE, WPU | | | SPICS0 | O |
| 22 | SPICLK | IO | VDD_SPI / VDD3P3_CPU | WPU | IE, WPU | | | SPICLK | O |
| 23 | SPID | IO | VDD_SPI / VDD3P3_CPU | WPU | IE, WPU | | | SPID | I1 |
| 24 | SPIQ | IO | VDD_SPI / VDD3P3_CPU | WPU | IE, WPU | | | SPIQ | I1 |
| 25 | GPIO18 | IO | VDD3P3_CPU | | | USB_D- | | GPIO18 | I/ |
| 26 | GPIO19 | IO | VDD3P3_CPU | | | USB_D+ | | GPIO19 | I/ |
| 27 | U0RXD | IO | VDD3P3_CPU | | IE, WPU | | | U0RXD | I1 |
| 28 | U0TXD | IO | VDD3P3_CPU | | WPU | | | U0TXD | O |
| 29 | XTAL_N | Analog | | | | | | | |
| 30 | XTAL_P | Analog | | | | | | | |
| 31 | VDDA | Power | | | | | | | |
| 32 | VDDA | Power | | | | | | | |
| 33 | GND | Power | | | | | | | |

* For details, see Section 2 Pins. Regarding highlighted cells, see Section 2.3.3 Restrictions for GPIOs.

# Related Documentation and Resources

## Related Documentation

- ESP32-C3 Technical Reference Manual – Detailed information on how to use the ESP32-C3 memory and peripherals.
- ESP32-C3 Hardware Design Guidelines – Guidelines on how to integrate the ESP32-C3 into your hardware product.
- ESP32-C3 Series SoC Errata – Descriptions of known errors in ESP32-C3 series of SoCs.
- *Certificates*
  https://espressif.com/en/support/documents/certificates
- *ESP32-C3 Product/Process Change Notifications (PCN)*
  https://espressif.com/en/support/documents/pcns?keys=ESP32-C3
- *ESP32-C3 Advisories* – Information on security, bugs, compatibility, component reliability.
  https://espressif.com/en/support/documents/advisories?keys=ESP32-C3
- *Documentation Updates and Update Notification Subscription*
  https://espressif.com/en/support/download/documents

## Developer Zone

- ESP-IDF Programming Guide for ESP32-C3 – 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-C3 Series SoCs* – Browse through all ESP32-C3 SoCs.
  https://espressif.com/en/products/socs?id=ESP32-C3
- *ESP32-C3 Series Modules* – Browse through all ESP32-C3-based modules.
  https://espressif.com/en/products/modules?id=ESP32-C3
- *ESP32-C3 Series DevKits* – Browse through all ESP32-C3-based devkits.
  https://espressif.com/en/products/devkits?id=ESP32-C3
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# Revision History

| Date | Version | Release notes |
|---|---|---|
| 2024-04-01 | v1.7 | • Marked the ESP32-C3FN4 variant as end of life<br>• Marked the ESP32-C3FH4AZ variant as NRND<br>• Marked the ESP32-C3FH4X variant as recommended |
| 2024-01-19 | v1.6 | • Added the new ESP32-C3FH4X and ESP32-C3FH4XAZ variants in Chapter 1 *ESP32-C3 Series Comparison*<br>• Corrected the PWM duty resolution to 14 bits in Section 3.4.7 *LED PWM Controller* |
| 2023-08-11 | v1.5 | • Marked ESP32-C3FN4 as NRND<br>• Improved the content in the following sections:<br>– Section *Product Overview*<br>– Section 2 *Pins*<br>– Section 3.7 *Power Management*<br>– Section 3.4.2 *Serial Peripheral Interface (SPI)*<br>– Section 4.1 *Absolute Maximum Ratings*<br>– Section 4.2 *Recommended Operating Conditions*<br>– Section 4.3 *VDD_SPI Output Characteristics*<br>– Section 4.5 *ADC Characteristics*<br>• Added *Appendix A*<br>• Updated the maximum value of "RF power control range" to 20 dBm in Section 4.9 *Bluetooth LE Radio*<br>• Other minor updates |
| 2022-12-15 | v1.4 | • Deleted feature "Antenna diversity" from Section 3.6.1 *Bluetooth LE Radio and PHY*<br>• Deleted feature "Supports external power amplifier"<br>• Updated the glitch type of GPIO18 to high-level glitch in Table *Pin Overview* |

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| Date | Version | Release notes |
|---|---|---|
| 2022-11-15 | v1.3 | • Updated notes for Table *Pin Overview*<br>• Added links to the Technical Reference Manual and Peripheral Pin Configurations in Chapter 3 *Functional Description*<br>• Added a note about ADC2 error in Section 3.3.1 *Analog-to-Digital Converter (ADC)*<br>• Updated Section 3.8.3 *Watchdog Timers*<br>• Added Table *ADC Characteristics*<br>• Updated Section 4.6.2 *Current Consumption in Other Modes*<br>• Updated RF transmit power in Section 4.9 *Bluetooth LE Radio*<br>• Updated the typo in Section 5 *Packaging*<br>• Updated Chapter *Related Documentation and Resources* |
| 2022-04-13 | v1.2 | • Added a new chip variant ESP32-C3FH4AZ;<br>• Updated Figure ESP32-C3 Functional Block Diagram;<br>• Added the wake up source for Deep-sleep mode in Section 3.7 *Power Management*. |
| 2021-10-26 | v1.1 | • Updated Figure ESP32-C3 Functional Block Diagram to show power modes;<br>• Added CoreMark score in Features;<br>• Updated Table Pin Description to show default pin functions;<br>• Updated Figure *ESP32-C3 Power Scheme* and related descriptions;<br>• Added Table SPI Signals;<br>• Added note 3 to Table *Recommended Operating Conditions*;<br>• Other updates to wording. |
| 2021-05-28 | v1.0 | • Updated power modes;<br>• Updated Section 2.6 *Strapping Pins*;<br>• Updated some clock names and their frequencies in Section 3.2 *System Clocks*;<br>• Added clarification about ADC1 and ADC2 in Section 3.3.1 *Analog-to-Digital Converter (ADC)*;<br>• Updated the default configuration of U0RXD and U0TXD after reset in Table IO MUX;<br>• Updated sampling rate in Table *ADC Characteristics*;<br>• Updated Table *Reliability*;<br>• Added the link to recommended PCB land pattern in Chapter 5 *Packaging*. |
| 2021-04-23 | v0.8 | Updated *Wi-Fi Radio* and *Bluetooth LE Radio* data. |

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| Date | Version | Release notes |
|---|---|---|
| 2021-04-07 | v0.7 | • Updated information about USB Serial/JTAG Controller;<br>• Added GPIO2 to Section 2.6 *Strapping Pins*;<br>• Updated Figure *Address Mapping Structure*;<br>• Added Table IO MUX and Table *Pin Overview* in Section 3.4.1 *General Purpose Input / Output Interface (GPIO)*;<br>• Updated information about SPI2 in Section 3.4.2 *Serial Peripheral Interface (SPI)*;<br>• Updated fixed-priority channel scheme in Section 3.4.8 *General DMA Controller*;<br>• Updated Table *Reliability*. |
| 2021-01-18 | v0.6 | • Clarified that of the 400 KB SRAM, 16 KB is configured as cache;<br>• Updated maximum value to standard limit value in Table *Wi-Fi RF Transmitter (TX) Specifications* in Section 4.8.1 *Wi-Fi RF Transmitter (TX) Specifications*. |
| 2021-01-13 | v0.5 | • Updated information about Wi-Fi;<br>• Added connection between in-package flash ports and chip pins to table notes in Section Pin Definitions;<br>• Updated Figure *ESP32-C3 Power Scheme*, added Figure *Visualization of Timing Parameters for Power-up and Reset* and Table *Description of Timing Parameters for Power-up and Reset* in Section 2.5.2 *Power Scheme*;<br>• Added Figure *Visualization of Timing Parameters for the Strapping Pins* and Table *Description of Timing Parameters for the Strapping Pins* in Section 2.6 *Strapping Pins*;<br>• Updated Table *Peripheral Pin Configurations* in Section 3.11 *Peripheral Pin Configurations*;<br>• Added Chapter 4 *Electrical Characteristics*;<br>• Added Chapter 5 *Packaging*. |
| 2020-11-27 | v0.4 | Preliminary version. |

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