

# ESP32-C6 Series

## Datasheet

Ultra-low-power SoC with RISC-V single-core microprocessor

2.4 GHz Wi-Fi 6 (802.11ax), Bluetooth® 5 (LE), Zigbee and Thread (802.15.4)

Optional 4 MB flash in the chip's package

30 or 22 GPIOs, rich set of peripherals

QFN40 (5×5 mm) or QFN32 (5×5 mm) package

### Including:

ESP32-C6

ESP32-C6FH4

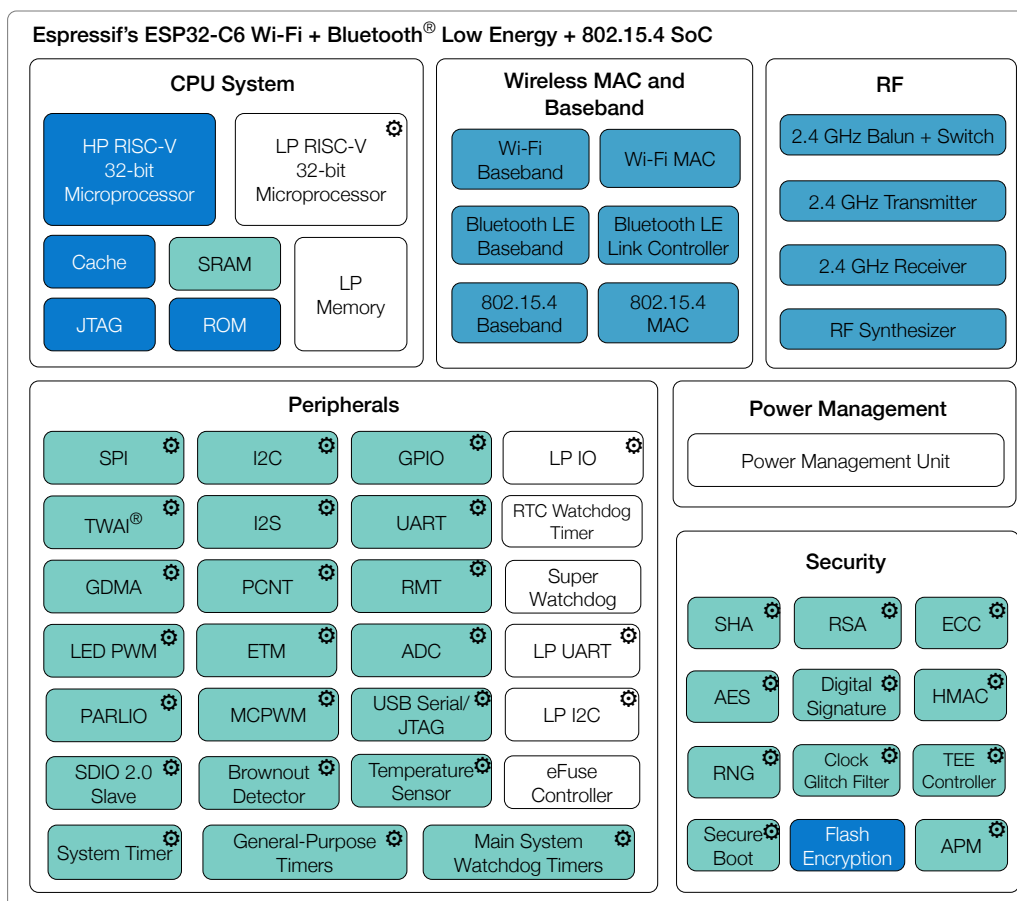


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Espressif Systems  
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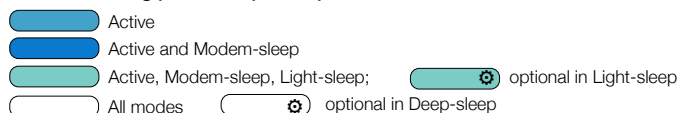
# Product Overview

The ESP32-C6 SoC (System on Chip) supports Wi-Fi 6 in 2.4 GHz band, Bluetooth 5, Zigbee 3.0 and Thread 1.3. It consists of a high-performance (HP) 32-bit RISC-V processor, an low-power (LP) 32-bit RISC-V processor, wireless baseband and MAC (Wi-Fi, Bluetooth LE, and 802.15.4), RF module, and numerous peripherals. Wi-Fi, Bluetooth and 802.15.4 coexist with each other and share the same antenna.

The functional block diagram of the SoC is shown below.



Modules having power in specific power modes:



**ESP32-C6 Functional Block Diagram**

For more information on power consumption, see Section [3.9 Low Power Management](#).

# Features

## Wi-Fi

- 1T1R in 2.4 GHz band
- Operating frequency: 2412 ~ 2484 MHz
- IEEE 802.11ax-compliant
  - 20 MHz-only non-AP mode
  - MCS0 ~MCS9
  - Uplink and downlink OFDMA, especially suitable for simultaneous connections in high-density environments
  - Downlink MU-MIMO (multi-user, multiple input, multiple output) to increase network capacity
  - Beamformee that improves signal quality
  - Channel quality indication (CQI)
  - DCM (dual carrier modulation) to improve link robustness
  - Spatial reuse to maximize parallel transmissions
  - Target wake time (TWT) that optimizes power saving mechanisms
- Fully compatible with IEEE 802.11b/g/n protocol
  - 20 MHz and 40 MHz bandwidth
  - 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-C6 scans in Station mode, the SoftAP channel will change along with the Station channel*

- Antenna diversity
- 802.11mc FTM

## Bluetooth®

- Bluetooth LE: Bluetooth 5.3 certified
- 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
- LE power control
- Internal co-existence mechanism between Wi-Fi and Bluetooth to share the same antenna

## IEEE 802.15.4

- Compliant with IEEE 802.15.4-2015 protocol
- OQPSK PHY in 2.4 GHz band
- Data rate: 250 Kbps
- Thread 1.3
- Zigbee 3.0

## CPU and Memory

- HP RISC-V processor:
  - Clock speed: up to 160 MHz
  - Four stage pipeline
  - CoreMark® score: 441.32 CoreMark; 2.76 CoreMark/MHz (160 MHz)
- LP RISC-V processor:
  - Clock speed: up to 20 MHz
  - Two stage pipeline

- L1 cache: 32 KB
- ROM: 320 KB
- HP SRAM: 512 KB
- LP SRAM: 16 KB
- Supported SPI protocols: SPI, Dual SPI, Quad SPI, QPI interfaces that allow connection to flash and other SPI devices off the chip's package
- Flash controller with cache is supported
- Flash in-Circuit Programming (ICP) is supported

### Advanced Peripheral Interfaces

- 30 × GPIOs (QFN40), or 22 × GPIOs (QFN32)
- Analog interfaces:
  - 1 × 12-bit SAR ADC, up to 7 channels
  - 1 × temperature sensor
- Digital interfaces:
  - 2 × UART
  - 1 × Low-power (LP) UART
  - 2 × SPI ports for communication with flash
  - 1 × General purpose SPI port
  - 1 × I2C
  - 1 × Low-power (LP) I2C
  - 1 × I2S
  - 1 × Pulse count controller
  - 1 × USB Serial/JTAG controller
  - 2 × TWAI® controller, compatible with ISO 11898-1 (CAN Specification 2.0)
  - 1 × SDIO 2.0 slave controller
  - LED PWM controller, up to 6 channels
  - 1 × Motor Control PWM (MCPWM)
  - 1 × Remote control peripheral (TX/RX)
  - 1 × Parallel IO interface (PARLIO)
  - General DMA controller, with 3 transmit channels and 3 receive channels
  - Event task matrix (ETM)

- Timers:
  - 1 × 52-bit system timer
  - 2 × 54-bit general-purpose timers
  - 3 × digital watchdog timers
  - 1 × analog watchdog 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 7  $\mu$ A
- Low-power (LP) 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
- Trusted execution environment (TEE) controller and access permission management (APM)
- Cryptographic hardware acceleration:
  - AES-128/256 (FIPS PUB 197)
  - ECC
  - HMAC
  - RSA
  - SHA
  - Digital signature
  - Hash (FIPS PUB 180-4)
- External Memory Encryption and Decryption (XTS\_AES)
- Random Number Generator (RNG)

## 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 +19.5 dBm of power for an 802.11ax transmission
- Up to -106 dBm of sensitivity for Bluetooth LE receiver (125 Kbps)

## Applications

With low power consumption, ESP32-C6 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

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# 1 ESP32-C6 Series Comparison

## 1.1 Nomenclature

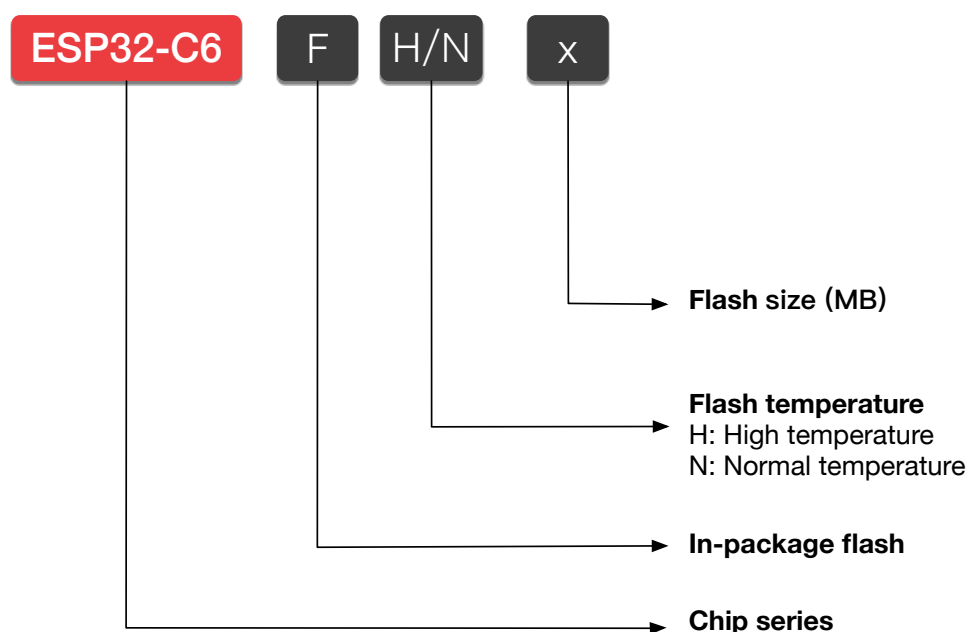


Figure 1-1. ESP32-C6 Series Nomenclature

## 1.2 Comparison

Table 1-1. ESP32-C6 Series Comparison

Ordering Code <sup>1</sup>	In-Package Flash	Ambient Temp. <sup>2</sup> (°C)	Package
ESP32-C6	— <sup>3</sup>	–40 ~ 105	QFN40 (5×5 mm)
ESP32-C6FH4	4 MB (Quad SPI) <sup>4</sup>	–40 ~ 105	QFN32 (5×5 mm)

<sup>1</sup> For details on chip marking and packing, see Section [6 Packaging](#).

<sup>2</sup> Ambient temperature specifies the recommended temperature range of the environment immediately outside an Espressif chip.

<sup>3</sup> Can connect a flash outside the chip package. For details, see Section [3.1.4 Off-package Flash](#).

<sup>4</sup> For details about SPI modes, see Section [2.7 Pin Mapping Between Chip and Flash](#).

## 2 Pins

### 2.1 Pin Layout

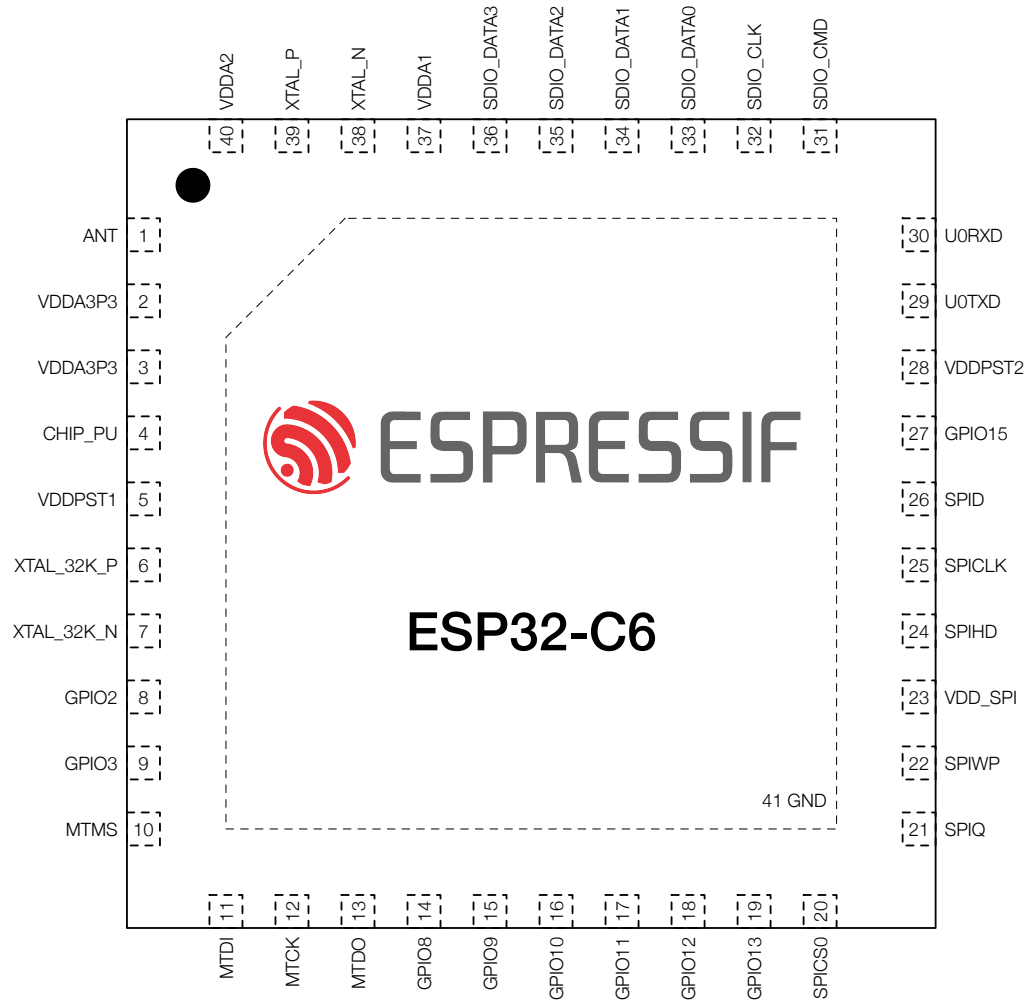


Figure 2-1. ESP32-C6 Pin Layout (QFN40, Top View)

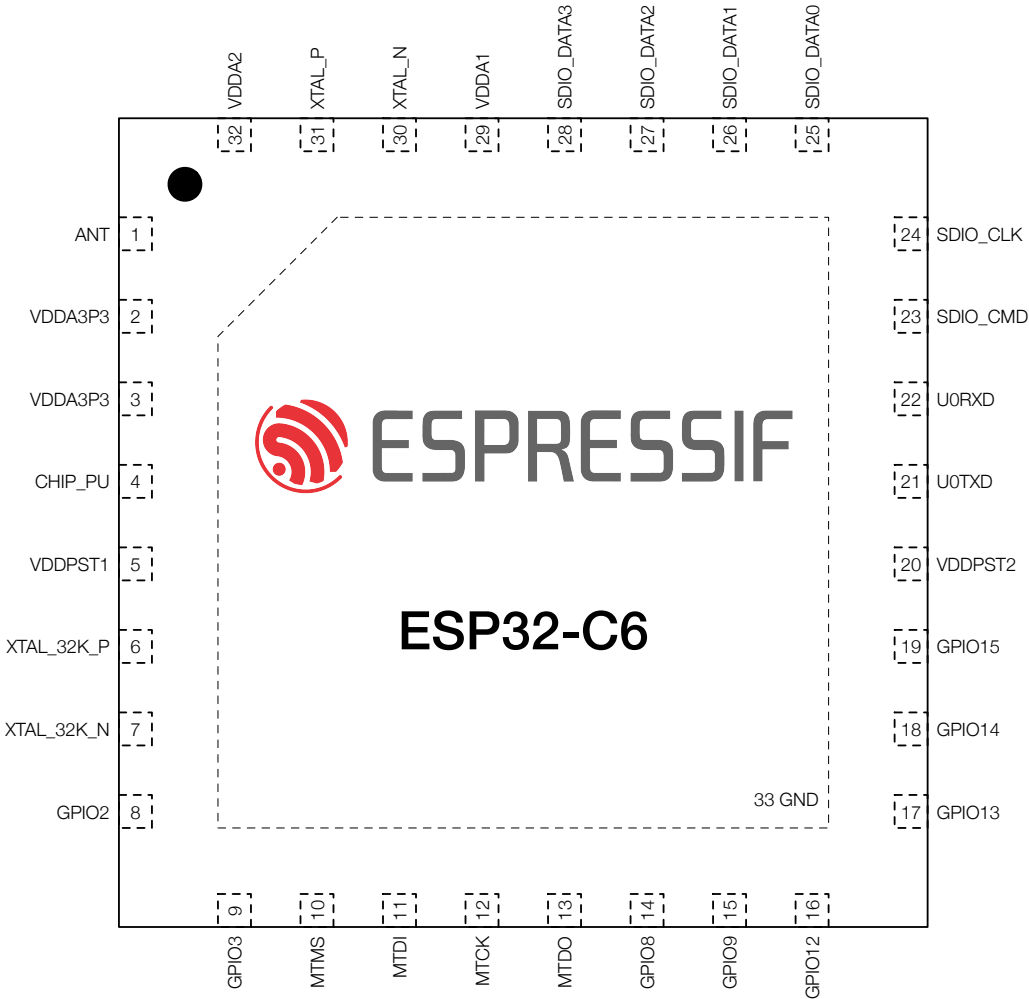


Figure 2-2. ESP32-C6 Pin Layout (QFN32, Top View)

## 2.2 Pin Overview

The ESP32-C6 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-C6 Technical Reference Manual](#) > Chapter *IO MUX and GPIO Matrix*).

All in all, the ESP32-C6 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 QFN40 IO MUX Pin Functions](#) or Table [2-4 QFN32 IO MUX Pin Functions](#)
  - **Some** IO pins have predefined **LP IO MUX functions** – see Table [2-5 LP IO MUX Functions](#)
  - **Some** IO pins have predefined **analog functions** – see Table [2-6 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 [2-7 Analog Pins](#)
- **Power pins** supply power to the chip components and non-power pins – see Table [2-8 Power Pins](#)

**Notes for Table [2-1 QFN40 Pin Overview](#) or Table [2-2 QFN32 Pin Overview](#)** (see below):

1. For more information, see respective sections below. Alternatively, see [Appendix A – ESP32-C6 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 [2.6.2 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. Except for GPIO12 and GPIO13 whose default drive strength is 40 mA, the default drive strength for all the other pins is 20 mA.
5. 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., GPIO12 and GPIO13), 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-C6 Technical Reference Manual](#) > Chapter *USB Serial/JTAG Controller*).

- When the USB function is disabled, USB pins are used as regular GPIOs. At reset, GPIO13's internal weak pull-up resistor is disabled by default. After reset, GPIO13's internal weak pull-up resistor is enabled by default. A pin's internal weak pull-up and pull-down resistors are configurable by IO\_MUX\_FUN\_WPU/VPD.

6. 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)

7. Output enabled

**Table 2-1. QFN40 Pin Overview**

Pin No.	Pin Name	Pin Type <sup>1</sup>	Pin Providing Power <sup>3-5</sup>	Pin Settings <sup>6,7</sup>		Pin Function Sets <sup>1,2</sup>		
				At Reset	After Reset	IO MUX	LP IO MUX	Analog
1	ANT	Analog						
2	VDDA3P3	Power						
3	VDDA3P3	Power						
4	CHIP_PU	Analog	VDDPST1					
5	VDDPST1	Power						
6	XTAL_32K_P	IO	VDDPST1			<b>IO MUX</b>	LP IO MUX	Analog
7	XTAL_32K_N	IO	VDDPST1			<b>IO MUX</b>	LP IO MUX	Analog
8	GPIO2	IO	VDDPST1	IE	IE	<b>IO MUX</b>	LP IO MUX	Analog
9	GPIO3	IO	VDDPST1	IE	IE	<b>IO MUX</b>	LP IO MUX	Analog
10	MTMS	IO	VDDPST1	IE	IE	<b>IO MUX</b>	LP IO MUX	Analog
11	MTDI	IO	VDDPST1	IE	IE	<b>IO MUX</b>	LP IO MUX	Analog
12	MTCK	IO	VDDPST1		IE, WPU <sup>6</sup>	<b>IO MUX</b>	LP IO MUX	Analog
13	MTDO	IO	VDDPST1		IE	<b>IO MUX</b>	LP IO MUX	
14	GPIO8	IO	VDDPST2	IE	IE	<b>IO MUX</b>		
15	GPIO9	IO	VDDPST2	IE, WPU	IE, WPU	<b>IO MUX</b>		
16	GPIO10	IO	VDDPST2		IE	<b>IO MUX</b>		
17	GPIO11	IO	VDDPST2		IE	<b>IO MUX</b>		
18	GPIO12	IO	VDDPST2		IE	IO MUX		<b>Analog</b>
19	GPIO13	IO	VDDPST2	USB_PU	IE, USB_PU	IO MUX		<b>Analog</b>
20	SPICS0	IO	VDD_SPI	WPU	IE, WPU	<b>IO MUX</b>		
21	SPIQ	IO	VDD_SPI	WPU	IE, WPU	<b>IO MUX</b>		
22	SPIWP	IO	VDD_SPI	WPU	IE, WPU	<b>IO MUX</b>		
23	VDD_SPI	Power/IO	—			IO MUX		<b>Analog</b>
24	SPIHD	IO	VDD_SPI	WPU	IE, WPU	<b>IO MUX</b>		
25	SPICLK	IO	VDD_SPI	WPU	IE, WPU	<b>IO MUX</b>		
26	SPID	IO	VDD_SPI	WPU	IE, WPU	<b>IO MUX</b>		
27	GPIO15	IO	VDDPST2	IE	IE	<b>IO MUX</b>		
28	VDDPST2	Power						
29	U0TXD	IO	VDDPST2		WPU <sup>7</sup>	<b>IO MUX</b>		
30	U0RXD	IO	VDDPST2		IE, WPU	<b>IO MUX</b>		
31	SDIO_CMD	IO	VDDPST2	WPU	IE	<b>IO MUX</b>		
32	SDIO_CLK	IO	VDDPST2	WPU	IE	<b>IO MUX</b>		
33	SDIO_DATA0	IO	VDDPST2	WPU	IE	<b>IO MUX</b>		

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Table 2-1 – cont'd from previous page

Pin No.	Pin Name	Pin Type <sup>1</sup>	Pin Providing Power <sup>3-5</sup>	Pin Settings <sup>6,7</sup>		Pin Function Sets <sup>1,2</sup>		
				At Reset	After Reset	IO MUX	LP IO MUX	Analog
34	SDIO_DATA1	IO	VDDPST2	WPU	IE	IO MUX		
35	SDIO_DATA2	IO	VDDPST2	WPU	IE	IO MUX		
36	SDIO_DATA3	IO	VDDPST2	WPU	IE	IO MUX		
37	VDDA1	Power						
38	XTAL_N	Analog						
39	XTAL_P	Analog						
40	VDDA2	Power						
41	GND	Power						

Table 2-2. QFN32 Pin Overview

Pin No.	Pin Name	Pin Type <sup>1</sup>	Pin Providing Power <sup>3-5</sup>	Pin Settings <sup>6,7</sup>		Pin Function Sets <sup>1,2</sup>		
				At Reset	After Reset	IO MUX	LP IO MUX	Analog
1	ANT	Analog						
2	VDDA3P3	Power						
3	VDDA3P3	Power						
4	CHIP_PU	Analog	VDDPST1					
5	VDDPST1	Power						
6	XTAL_32K_P	IO	VDDPST1			IO MUX	LP IO MUX	Analog
7	XTAL_32K_N	IO	VDDPST1			IO MUX	LP IO MUX	Analog
8	GPIO2	IO	VDDPST1	IE	IE	IO MUX	LP IO MUX	Analog
9	GPIO3	IO	VDDPST1	IE	IE	IO MUX	LP IO MUX	Analog
10	MTMS	IO	VDDPST1	IE	IE	IO MUX	LP IO MUX	Analog
11	MTDI	IO	VDDPST1	IE	IE	IO MUX	LP IO MUX	Analog
12	MTCK	IO	VDDPST1		IE, WPU <sup>6</sup>	IO MUX	LP IO MUX	Analog
13	MTDO	IO	VDDPST1		IE	IO MUX	LP IO MUX	
14	GPIO8	IO	VDDPST2	IE	IE	IO MUX		
15	GPIO9	IO	VDDPST2	IE, WPU	IE, WPU	IO MUX		
16	GPIO12	IO	VDDPST2		IE	IO MUX		Analog
17	GPIO13	IO	VDDPST2	USB_PU	IE, USB_PU	IO MUX		Analog
18	GPIO14	IO	VDDPST2		IE	IO MUX		
19	GPIO15	IO	VDDPST2	IE	IE	IO MUX		
20	VDDPST2	Power						
21	U0TXD	IO	VDDPST2		WPU <sup>7</sup>	IO MUX		
22	U0RXD	IO	VDDPST2		IE, WPU	IO MUX		
23	SDIO_CMD	IO	VDDPST2	WPU	IE	IO MUX		
24	SDIO_CLK	IO	VDDPST2	WPU	IE	IO MUX		
25	SDIO_DATA0	IO	VDDPST2	WPU	IE	IO MUX		
26	SDIO_DATA1	IO	VDDPST2	WPU	IE	IO MUX		
27	SDIO_DATA2	IO	VDDPST2	WPU	IE	IO MUX		
28	SDIO_DATA3	IO	VDDPST2	WPU	IE	IO MUX		
29	VDDA1	Power						
30	XTAL_N	Analog						
31	XTAL_P	Analog						

Cont'd on next page

Table 2-2 – cont'd from previous page

Pin No.	Pin Name	Pin Type <sup>1</sup>	Pin Providing Power <sup>3-5</sup>	Pin Settings <sup>6,7</sup>		Pin Function Sets <sup>1,2</sup>		
				At Reset	After Reset	IO MUX	LP IO MUX	Analog
32	VDDA2	Power						
33	GND	Power						

## 2.3 IO Pins

For details on configuring IO pins, see [《ESP32-C6 技术参考手册》](#) > Chapter *IO MUX and GPIO pins*.

### 2.3.1 IO MUX and GPIO Pin Functions

The pins of ESP32-C6 can be assigned any function (F0-F2) from their respective sets of IO MUX functions as listed in Table 2-3 *QFN40 IO MUX Pin Functions* or Table 2-4 *QFN32 IO MUX Pin 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 2-3 QFN40 IO MUX Pin Functions or Table 2-4 QFN32 IO MUX Pin Functions:**

- Bold** marks the default pin functions in the default boot mode. See Section 2.6.2 *Chip Boot Mode Control*.
- Regarding **highlighted** cells, see Section 2.3.4 *Restrictions for GPIOs and LP GPIOs*.
- Each IO MUX function ( $F_n$ ,  $n = 0 \sim 2$ ) 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.
- Function names:
 

GPIO...	General-purpose input/output with signals routed via the GPIO matrix. For more details on the GPIO matrix, see <a href="#">ESP32-C6 Technical Reference Manual</a> > Chapter <i>IO MUX and GPIO Matrix</i> .
U...RXD	} UART0/1 receive/transmit signals.
U...TXD	
SDIO...	SDIO interface signals.
- Groups of functions (see the markings in the table):
  - JTAG interface for debugging.
  - UART interface for debugging.
  - SPI0/1 interface for connection to in-package or off-package flash via SPI bus. See also Section 2.7 *Pin Mapping Between Chip and Flash*.
  - SPI2 main interface for fast SPI connection. Among these pins, FSPICS0 is for input or output signals in master or slave mode, whereas FSPICS1 ~ FSPICS5 are for output signals in master mode.

Table 2-3. QFN40 IO MUX Pin Functions

Pin No.	IO MUX / GPIO Name	IO MUX Function					
		0	Type	1	Type	2	Type
6	GPIO0	GPIO0	I/O/T	GPIO0	I/O/T		
7	GPIO1	GPIO1	I/O/T	GPIO1	I/O/T		
8	GPIO2	GPIO2	I/O/T	GPIO2	I/O/T	FSPIQ	I1/O/T
9	GPIO3	GPIO3	I/O/T	GPIO3	I/O/T		
10	GPIO4	MTMS	I1	GPIO4	I/O/T	FSPIHD	I1/O/T
11	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		
17	GPIO11	GPIO11	I/O/T	GPIO11	I/O/T		
18	GPIO12	GPIO12	I/O/T	GPIO12	I/O/T		
19	GPIO13	GPIO13	I/O/T	GPIO13	I/O/T		
20	GPIO24	SPICS0	O/T	GPIO24	I/O/T		
21	GPIO25	SPIQ	I1/O/T	GPIO25	I/O/T		
22	GPIO26	SPIWP	I1/O/T	GPIO26	I/O/T		
23	GPIO27	GPIO27	I/O/T	GPIO27	I/O/T		
24	GPIO28	SPIHD	I1/O/T	GPIO28	I/O/T		
25	GPIO29	SPICLK	O/T	GPIO29	I/O/T		
26	GPIO30	SPID	I1/O/T	GPIO30	I/O/T		
27	GPIO15	GPIO15	I/O/T	GPIO15	I/O/T		
29	GPIO16	U0TXD	O	GPIO16	I/O/T	FSPICS0	I1/O/T
30	GPIO17	U0RXD	I1	GPIO17	I/O/T	FSPICS1	O/T
31	GPIO18	SDIO_CMD	I1/O/T	GPIO18	I/O/T	FSPICS2	O/T
32	GPIO19	SDIO_CLK	I1	GPIO19	I/O/T	FSPICS3	O/T
33	GPIO20	SDIO_DATA0	I1/O/T	GPIO20	I/O/T	FSPICS4	O/T
34	GPIO21	SDIO_DATA1	I1/O/T	GPIO21	I/O/T	FSPICS5	O/T
35	GPIO22	SDIO_DATA2	I1/O/T	GPIO22	I/O/T		
36	GPIO23	SDIO_DATA3	I1/O/T	GPIO23	I/O/T		

Table 2-4. QFN32 IO MUX Pin Functions

Pin No.	IO MUX / GPIO Name	IO MUX Function					
		0	Type	1	Type	2	Type
6	GPIO0	GPIO0	I/O/T	GPIO0	I/O/T		
7	GPIO1	GPIO1	I/O/T	GPIO1	I/O/T		

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Table 2-4 – cont'd from previous page

Pin No.	IO MUX / GPIO Name	IO MUX Function					
		0	Type	1	Type	2	Type
8	GPIO2	GPIO2	I/O/T	GPIO2	I/O/T	FSPIQ	I1/O/T
9	GPIO3	GPIO3	I/O/T	GPIO3	I/O/T		
10	GPIO4	MTMS	I1	GPIO4	I/O/T	FSPIHD	I1/O/T
11	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	GPIO12	GPIO12	I/O/T	GPIO12	I/O/T		
17	GPIO13	GPIO13	I/O/T	GPIO13	I/O/T		
18	GPIO14	GPIO14	I/O/T	GPIO14	I/O/T		
19	GPIO15	GPIO15	I/O/T	GPIO15	I/O/T		
21	GPIO16	U0TXD	O	GPIO16	I/O/T	FSPICS0	I1/O/T
22	GPIO17	U0RXD	I1	GPIO17	I/O/T	FSPICS1	O/T
23	GPIO18	SDIO_CMD	I1/O/T	GPIO18	I/O/T	FSPICS2	O/T
24	GPIO19	SDIO_CLK	I1	GPIO19	I/O/T	FSPICS3	O/T
25	GPIO20	SDIO_DATA0	I1/O/T	GPIO20	I/O/T	FSPICS4	O/T
26	GPIO21	SDIO_DATA1	I1/O/T	GPIO21	I/O/T	FSPICS5	O/T
27	GPIO22	SDIO_DATA2	I1/O/T	GPIO22	I/O/T		
28	GPIO23	SDIO_DATA3	I1/O/T	GPIO23	I/O/T		

### 2.3.2 LP IO MUX Functions

LP IO MUX functions are activated if the HP digital system is turned off to save power. LP IO MUX functions and data input/output are configured by the LP CPU.

#### Notes for Table 2-5 LP IO MUX Functions:

1. **Bold** marks the default pin functions in the default boot mode. See Section 2.6.2 Chip Boot Mode Control.
2. Regarding highlighted cells, see Section 2.3.4 Restrictions for GPIOs and LP GPIOs.
3. Function names:

LP\_GPIO... General-purpose input/output configured by LP CPU.

LP\_UART... LP UART functions.

LP\_I2C... LP I2C functions.

**Table 2-5. LP IO MUX Functions**

Pin No.	LP IO Name	LP IO MUX Function	
		0	1
6	LP_GPIO0	LP_GPIO0	LP_UART_DTRN
7	LP_GPIO1	LP_GPIO1	LP_UART_DSRN
8	LP_GPIO2	LP_GPIO2	LP_UART_RTSN
9	LP_GPIO3	LP_GPIO3	LP_UART_CTSN
10	LP_GPIO4	LP_GPIO4	LP_UART_RXD
11	LP_GPIO5	LP_GPIO5	LP_UART_TXD
12	LP_GPIO6	LP_GPIO6	LP_I2C_SDA
13	LP_GPIO7	LP_GPIO7	LP_I2C_SCL

### 2.3.3 Analog Functions

Analog functions can operate in any power mode.

#### Notes for Table 2-6 Analog Functions:

1. **Bold** marks the default pin functions in SPI Boot mode.
2. Regarding highlighted cells, see Section 2.3.4 Restrictions for GPIOs and LP GPIOs.
3. Function names:
  - XTAL\_32K\_P } 32 kHz external clock input/output connected to ESP32-C6's oscillator.
  - XTAL\_32K\_N } P/N means differential clock positive/negative.
  - ADC1\_CH... Analog to digital conversion channel for ADC1.
  - USB\_D- } USB Serial/JTAG function. USB signal is a differential signal transmitted
  - USB\_D+ } over a pair of D+ and D- wires.

Table 2-6. Analog Functions

QFN40 Pin No.	QFN32 Pin No.	Analog IO Name	Analog Function	
			0	1
6	6	GPIO0	XTAL_32K_P	ADC1_CH0
7	7	GPIO1	XTAL_32K_N	ADC1_CH1
8	8	GPIO2		ADC1_CH2
9	9	GPIO3		ADC1_CH3
10	10	GPIO4		ADC1_CH4
11	11	GPIO5		ADC1_CH5
12	12	GPIO6		ADC1_CH6
18	16	GPIO12	USB_D-	
19	17	GPIO13	USB_D+	
23	—	GPIO27	VDD_SPI	

### 2.3.4 Restrictions for GPIOs and LP GPIOs

All IO pins of the ESP32-C6 have GPIO and some have LP 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 tables in Section [2.3 IO Pins](#), some pin functions are highlighted. The non-highlighted GPIO or LP GPIO pins are recommended for use first. If more pins are needed, the highlighted GPIOs or LP 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 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.
  - **JTAG interface** – often used for debugging. See Table [2-3 QFN40 IO MUX Pin Functions](#) or Table [2-4 QFN32 IO MUX Pin Functions](#), note [5a](#). To free these pins up, the pin functions USB\_D+/- of the USB Serial/JTAG Controller can be used instead. See also Section [2.6.4 JTAG Signal Source Control](#).
  - **UART interface** – often used for debugging. See Table [2-3 QFN40 IO MUX Pin Functions](#) or Table [2-4 QFN32 IO MUX Pin Functions](#), note [5b](#).

See also [Appendix A – ESP32-C6 Consolidated Pin Overview](#).



## 2.4 Analog Pins

Table 2-7. Analog Pins

QFN40 Pin No.	QFN32 Pin No.	Pin Name	Pin Type	Pin Function
1	1	ANT	I/O	RF input and output
4	4	CHIP_PU	—	High: on, enables the chip (Powered up). Low: off, the chip powers off (powered down). Note: Do not leave the CHIP_PU pin floating.
38	30	XTAL_N	—	External clock input/output connected to chip's crystal or oscillator. P/N means differential clock positive/negative.
39	31	XTAL_P	—	

## 2.5 Power Supply

### 2.5.1 Power Pins

The chip is powered via the power pins described in Table 2-8 *Power Pins*.

**Table 2-8. Power Pins**

QFN40 Pin No.	QFN32 Pin No.	Pin Name	Direction	Power Supply <sup>1,2</sup>	
				Power Domain / Other	IO Pins <sup>4</sup>
2	2	VDDA3P3	Input	Analog power domain	
3	3	VDDA3P3	Input	Analog power domain	
5	5	VDDPST1	Input	LP digital and part of analog pin power domains	LP IO
23	—	VDD_SPI <sup>3</sup>	Input	In-package flash (backup power line)	
			Output	In-package flash and off-package flash	
28	20	VDDPST2	Input	HP digital power domain	HP IO
37	29	VDDA1	Input	Analog power domain	
40	32	VDDA2	Input	Analog power domain	
41	33	GND	—	External ground connection	

<sup>1</sup> See in conjunction with Section 2.5.2 *Power Scheme*.

<sup>2</sup> For recommended and maximum voltage and current, see Section 4.1 *Absolute Maximum Ratings* and Section 4.2 *Recommended Power Supply Characteristics*.

<sup>3</sup> To configure VDD\_SPI as input or output, see [ESP32-C6 Technical Reference Manual](#) > Chapter *Low-power Management*.

<sup>4</sup> LP IO pins are those powered by VDDPST1 and so on, as shown in Figure 2-3 *ESP32-C6 Power Scheme*. See also Table 2-3 *QFN40 IO MUX Pin Functions* or Table 2-4 *QFN32 IO MUX Pin Functions* > Column *Pin Providing Power*.

### 2.5.2 Power Scheme

The power scheme is shown in Figure 2-3 *ESP32-C6 Power Scheme*.

The components on the chip are powered via voltage regulators.

**Table 2-9. Voltage Regulators**

Voltage Regulator	Output	Power Supply
HP	1.1 V	HP power domain
LP	1.1 V	LP power domain

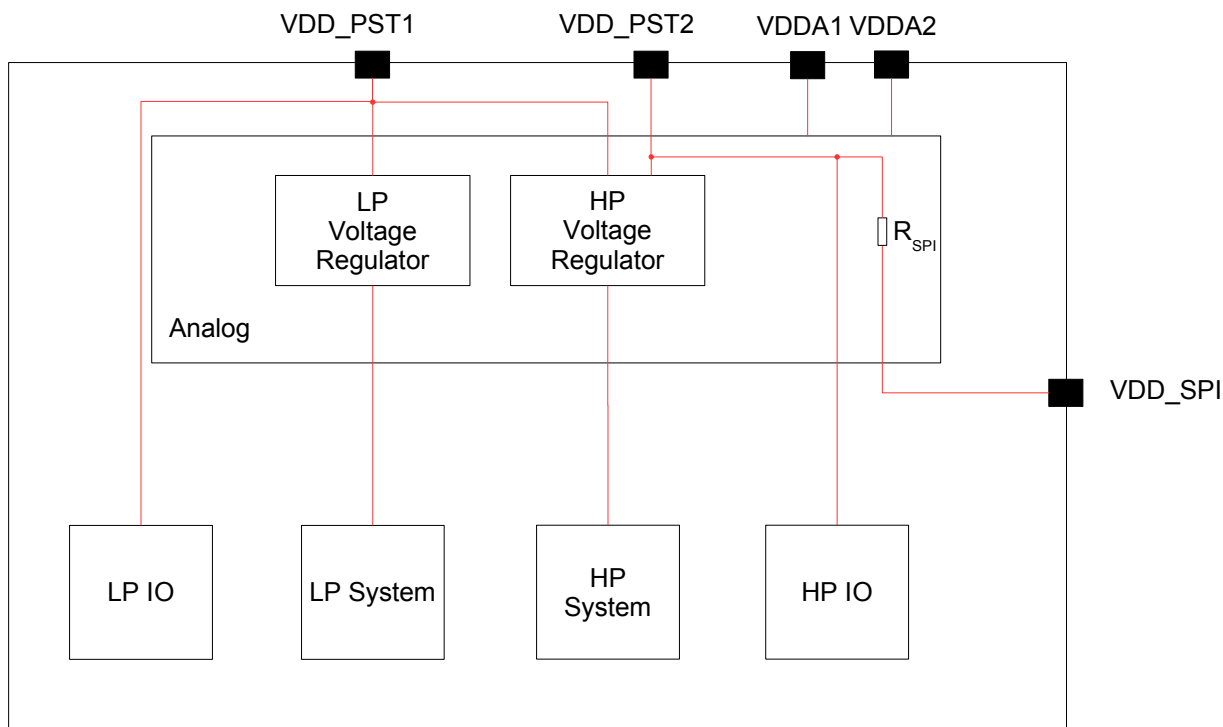


Figure 2-3. ESP32-C6 Power Scheme

### 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\_PU – the pin used for power-up and reset – is pulled high to activate the chip. For information on CHIP\_PU as well as power-up and reset timing, see Figure 2-4 and Table 2-10.

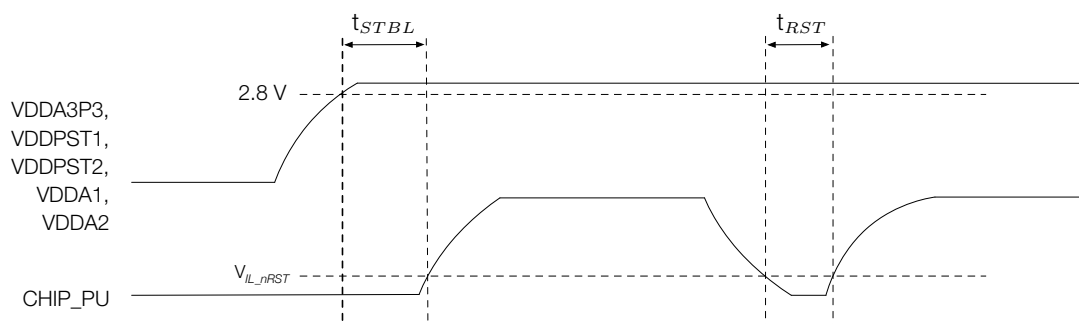


Figure 2-4. Visualization of Timing Parameters for Power-up and Reset

Table 2-10. Description of Timing Parameters for Power-up and Reset

Parameter	Description	Min ( $\mu$ s)
$t_{STBL}$	Time reserved for the power rails of VDDA3P3, VDDPST1, VDDPST2, VDDA1 and VDDA2 to stabilize before the CHIP_PU pin is pulled high to activate the chip	50
$t_{RST}$	Time reserved for CHIP_PU 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:

- **SDIO sampling and driving clock edge** – MTMS and MTDI
- **Chip boot mode** – GPIO8 and GPIO9
- **ROM code printing to UART** – GPIO8
- **JTAG signal source** – GPIO15

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

**Table 2-11. Default Configuration of Strapping Pins**

Strapping Pin	Default Configuration	Bit Value
MTMS	Floating	–
MTDI	Floating	–
GPIO8	Floating	–
GPIO9	Pull-up	1
GPIO15	Floating	–

To change the bit values, the strapping pins should be connected to external pull-down/pull-up resistances. If the ESP32-C6 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 2-12 and Figure 2-5.

**Table 2-12. Description of Timing Parameters for the Strapping Pins**

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

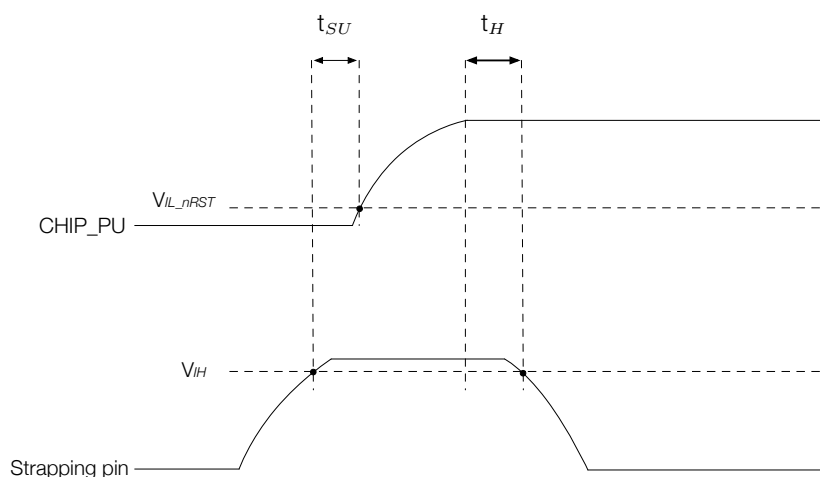


Figure 2-5. Visualization of Timing Parameters for the Strapping Pins

### 2.6.1 SDIO Sampling and Driving Clock Edge Control

The strapping pin MTMS and MTDI can be used to decide on which clock edge to sample signals and drive output lines. See Table 2-13 SDIO Input Sampling Edge/Output Driving Edge Control.

Table 2-13. SDIO Input Sampling Edge/Output Driving Edge Control

MTMS	MTDI	Edge behavior
– (Floating)	– (Floating)	Default Configuration
0	0	Falling edge sampling, falling edge output
0	1	Falling edge sampling, rising edge output
1	0	Rising edge sampling, falling edge output
1	1	Rising edge sampling, rising edge output

### 2.6.2 Chip Boot Mode Control

GPIO8 and GPIO9 control the boot mode after the reset is released. See Table 2-14 Boot Mode Control Boot Mode Control.

Table 2-14. Boot Mode Control

Boot Mode	GPIO8	GPIO9
Default Configuration	– (Floating)	1 (Pull-up)
<b>SPI Boot</b> (default)	Any value	1
<b>Download Boot</b>	1	0
Invalid combination <sup>1</sup>	0	0

<sup>1</sup> This combination triggers unexpected behavior and should be avoided.

### 2.6.3 ROM Messages Printing Control

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

- **(Default) UART0 and USB Serial/JTAG controller**
- **USB Serial/JTAG controller**
- **UART0**

EFUSE\_UART\_PRINT\_CONTROL and GPIO8 control ROM messages printing to **UART0** as shown in Table 2-15 [ROM Messages Printing Control](#).

**Table 2-15. ROM Messages Printing Control**

eFuse <sup>1</sup>	GPIO8	ROM Code Printing
0	Ignored	Always enabled
1	0	Enabled
	1	Disabled
2	0	Disabled
	1	Enabled
3	Ignored	Always disabled

<sup>1</sup> eFuse: EFUSE\_UART\_PRINT\_CONTROL

EFUSE\_DIS\_USB\_SERIAL\_JTAG\_ROM\_PRINT controls the printing to **USB Serial/JTAG controller**. When this bit is 1, printing to USB Serial/JTAG controller is disabled. When this bit is 0, and USB Serial/JTAG controller is enabled via EFUSE\_DIS\_USB\_SERIAL\_JTAG, ROM messages can be printed to USB Serial/JTAG controller.

## 2.6.4 JTAG Signal Source Control

The strapping pin GPIO15 can be used to control the source of JTAG signals during the early boot process. This pin does not have any internal pull resistors and the strapping value must be controlled by the external circuit that cannot be in a high impedance state.

As Table 2-16 shows, GPIO15 is used in combination with EFUSE\_DIS\_PAD\_JTAG, EFUSE\_DIS\_USB\_JTAG, and EFUSE\_JTAG\_SEL\_ENABLE.

**Table 2-16. JTAG Signal Source Control**

eFuse 1 <sup>a</sup>	eFuse 2 <sup>b</sup>	eFuse 3 <sup>c</sup>	GPIO15	JTAG Signal Source
0	0	0	Ignored	USB Serial/JTAG Controller
		1	0	JTAG pins MTDI, MTCK, MTMS, and MTDO
			1	USB Serial/JTAG Controller
0	1	Ignored	Ignored	JTAG pins MTDI, MTCK, MTMS, and MTDO
1	0	Ignored	Ignored	USB Serial/JTAG Controller
1	1	Ignored	Ignored	JTAG is disabled

<sup>a</sup> eFuse 1: EFUSE\_DIS\_PAD\_JTAG

<sup>b</sup> eFuse 2: EFUSE\_DIS\_USB\_JTAG

<sup>c</sup> eFuse 3: EFUSE\_JTAG\_SEL\_ENABLE

## 2.7 Pin Mapping Between Chip and Flash

Table 2-17 lists the pin mapping between the chip and off-package flash for all SPI modes.

For chip variants with in-package flash (namely variants in QFN32 package, see Table 1-1 [ESP32-C6 Series Comparison](#)), the pins allocated for communication with in-package flash are not routed out, but you can take Table 2-17 as a reference.

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 2-17. Pin Mapping Between QFN40 Chip and Off-package Flash**

QFN40 Pin No.	Pin Name	Single SPI Flash	Dual SPI Flash	Quad SPI Flash
25	SPICLK	CLK	CLK	CLK
20	SPICS0	CS#	CS#	CS#
26	SPID	MOSI	SIO0	SIO0
21	SPIQ	MISO	SIO1	SIO1
22	SPIWP	WP#		SIO2
24	SPIHD	HOLD#		SIO3

<sup>1</sup> SIO: Serial Data Input and Output



## 3 Functional Description

This chapter describes the functions of ESP32-C6.

### 3.1 CPU and Memory

#### 3.1.1 HP CPU

ESP32-C6 has a HP 32-bit RISC-V single-core processor with the following features:

- four-stage pipeline that supports a clock frequency of up to 160 MHz
- [RV32IMAC ISA](#) (instruction set architecture)
- 32-bit multiplier and 32-bit divider
- up to 28 vectored interrupts at 15 priority levels
- up to 4 hardware breakpoints/watchpoints
- up to 16 PMP/PMA regions
- JTAG for debugging
- compliant with RISC-V debug specification v0.13
- compliant with RISC-V Trace Specification v1.0

#### 3.1.2 LP CPU

ESP32-C6 integrates a LP 32-bit RISC-V processor. This LP CPU is designed as a simplified, low-power replacement of HP CPU in sleep modes. It can be also used to supplement the functions of the HP CPU in normal working mode. The LP CPU and LP memory remain powered on in Deep-sleep mode. Hence, the developer can store a program for the LP CPU in the LP memory to access LP IO, LP peripherals, and real-time timers in Deep-sleep mode.

**LP CPU has the following features:**

- two-stage pipeline that supports a clock frequency of up to 20 MHz
- [RV32IMAC ISA](#) (instruction set architecture)
- 32-bit general-purpose registers
- 32-bit multiplier and divider
- support for interrupts
- up to 2 hardware breakpoints/watchpoints
- JTAG for debugging
- compliant with RISC-V debug specification v0.13
- boot by the CPU, its dedicated timer, or LP IO

### 3.1.3 Internal Memory

ESP32-C6's internal memory includes:

- **320 KB of ROM:** for booting and core functions
- **HP memory:** 512 KB of SRAM for data and instructions
- **LP memory:** 16 KB of SRAM that can be accessed by HP CPU or LP 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-C6 Series Comparison](#)

### 3.1.4 Off-package Flash

ESP32-C6 supports SPI, Dual SPI, Quad SPI, and QPI interfaces that allow connection to multiple flash outside the chip's package.

CPU's instruction memory space and read-only data memory space can map into off-package flash of ESP32-C6, whose size can be 16 MB at most. ESP32-C6 supports hardware encryption/decryption based on XTS-AES to protect developers' programs and data in flash.

Through high-speed caches, ESP32-C6 can support at a time up to:

- 16 MB of instruction memory space which can map into flash as individual blocks of 64 KB. 32-bit fetch is supported
- 16 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-C6 is initialized, software can customize the mapping of off-package flash into the CPU address space.

### 3.1.5 Address Mapping Structure

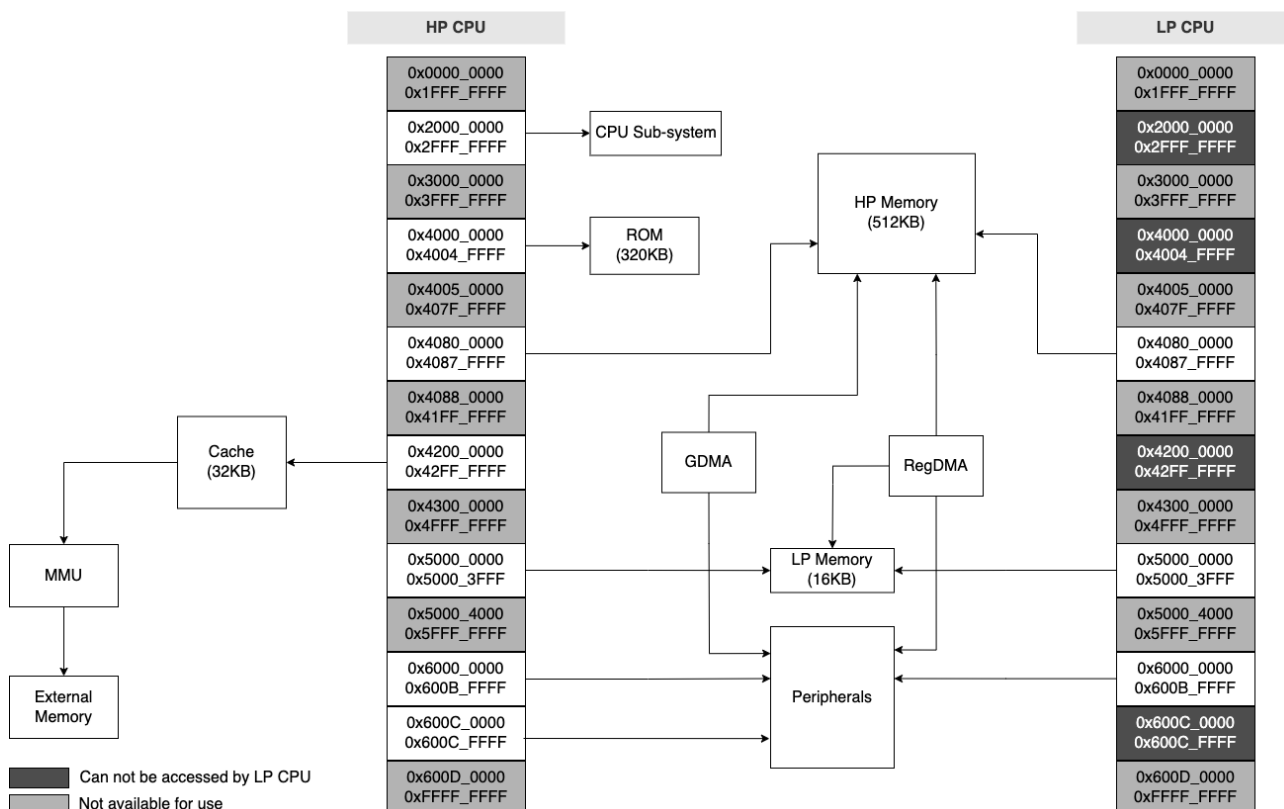


Figure 3-1. Address Mapping Structure

### 3.1.6 Cache

ESP32-C6 has an four-way set associative cache. This cache is read-only and has the following features:

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

### 3.1.7 TEE Controller

ESP32-C6 integrates a TEE (Trusted Execution Environment) controller to configure and extend security modes for masters in the system. The TEE controller has the following features:

- up to 32 masters
- four security modes
- accessible by the main master in TEE security mode

### 3.1.8 Access Permission Management (APM)

ESP32-C6 integrates an APM module to manage access permissions. The module compares information transmitted over the bus with predefined configurations and decides if to grant access. APM has the following

features:

- 16 regions with configurable addresses
- support for interrupts
- exception records
- accessible by the main master in TEE security mode

### 3.1.9 Timeout Protection

ESP32-C6 integrates a timeout protection module against bus being stuck. The module has the following features:

- up to 65535 configurable timeout periods (3 timeout modules in CPU peripherals, APB peripherals and LP peripherals)
- support for interrupts
- exception records

## 3.2 System Clocks

### 3.2.1 CPU Clock

The CPU clock has three possible sources:

- external main crystal clock
- internal fast RC oscillator clock (typically about 20 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. When the clock source is PLL clock, the clock frequency should be no more than 160 MHz. Once the CPU is reset, the default clock source would be the external main crystal clock divided by 1.

**Note:**

ESP32-C6 is unable to operate without an external main crystal clock.

### 3.2.2 Low-Power Clocks

The LP slow clock is used for RTC counter, RTC watchdog and the power management unit (PMU). It has four possible sources:

- internal low-speed RC oscillator (typically about 32 kHz, and adjustable)
- internal slow RC oscillator (typically about 150 kHz, and adjustable)
- external low-speed (32 kHz) crystal clock
- external IO clock (external clock source connected with digital IO)

The LP fast clock is used for low-power peripherals and sensor controllers. It has two possible sources:

- external main crystal clock divided by 2
- internal fast RC oscillator clock (typically about 20 MHz, and adjustable)

## 3.3 Analog Peripherals

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

ESP32-C6 integrates a 12-bit SAR ADC and supports measurements on 7 channels (analog-enabled pins).

For GPIOs assigned to ADC, please refer to Table 3-1.

### 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  $-40\text{ }^{\circ}\text{C}$  to  $125\text{ }^{\circ}\text{C}$ . 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 ambient temperature.

## 3.4 Digital Peripherals

### 3.4.1 Universal Asynchronous Receiver Transmitter (UART)

ESP32-C6 has three UART interfaces, i.e. UART0, UART1 and LP UART. All the three interfaces provide hardware flow control (CTS and RTS signals) and software flow control (XON and XOFF).

UART0 and UART 1 support IrDA and asynchronous communication (RS232 and RS485) at a speed of up to 5 Mbps. UART0 and UART1 connect to GDMA via UHCI0 interface (i.e. Universal Host Controller Interface), and can be accessed by the GDMA controller or directly by the CPU.

LP UART only supports asynchronous communication (RS232) at a speed of up to 1.25 Mbps. LP UART can only be accessed by the CPU.

For GPIOs assigned to UART, please refer to Table 3-1.

### 3.4.2 Serial Peripheral Interface (SPI)

ESP32-C6 features three SPI interfaces (SPI0, SPI1, and SPI2). SPI0 and SPI1 can be configured to operate in SPI memory mode, while SPI2 can be configured to operate in general-purpose SPI mode.

- **SPI Memory mode**

In SPI memory mode, SPI0 and SPI1 interface with external SPI memory. Data are transferred in unit of byte. Up to four-line STR reads and writes are supported. The clock frequency is configurable to a maximum of 120 MHz.

- **SPI2 General-purpose SPI (GP-SPI) mode**

SPI2 can operate in master and slave modes. SPI2 supports two-line full-duplex communication and single-/two-/four-line half-duplex communication in both master and slave modes. The host's clock

frequency is configurable. Data are transferred in unit of byte. The clock polarity (CPOL) and phase (CPHA) are also configurable. The SPI2 interface can connect to GDMA.

- In master mode, the clock frequency is 80 MHz at most, and the four modes of SPI transfer format are supported.
- In slave mode, the clock frequency is 60 MHz at most, and the four modes of SPI transfer format are also supported.

For the recommended pin mapping between ESP32-C6 and off-package flash, please see Table [2-17 Pin Mapping Between QFN40 Chip and Off-package Flash](#).

For GPIOs assigned to SPI, please refer to Table [3-1](#).

### 3.4.3 I2C Interface

ESP32-C6 has an I2C and a LP I2C bus interfaces. I2C is used for I2C master mode or slave mode, depending on your configuration, while LP I2C is always in master mode. Both interfaces support:

- 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 [3-1](#).

### 3.4.4 I2S Interface

ESP32-C6 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 supports TDM Philips, TDM MSB alignment, TDM PCM standard, PDM standard, and PCM-to-PDM TX interface. It connects to the GDMA controller.

For GPIOs assigned to I2S, please refer to Table [3-1](#).

### 3.4.5 Pulse Count Controller (PCNT)

The pulse count controller (PCNT) in ESP32-C6 captures pulses and counts pulse edges in seven modes. It has the following features:

- four independent pulse counters (units) that count from 1 to 65535
- each unit consists of two independent channels sharing one pulse counter
- all channels have input pulse signals (e.g. sig\_ch0\_0) with their corresponding control signals (e.g. ctrl\_ch0\_0)

- independently filter glitches of input pulse signals (sig\_ch0\_un and sig\_ch1\_un) and control signals (ctrl\_ch0\_un and ctrl\_ch1\_un) on each unit
- each channel has the following parameters:
  1. selection between counting on positive or negative edges of the input pulse signal
  2. configuration to Increment, Decrement, or Disable counter mode for control signal's high and low states
- Maximum frequency of pulses: 40 MHz

For GPIOs assigned to PCNT, please refer to Table 3-1.

### 3.4.6 USB Serial/JTAG Controller

ESP32-C6 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 3-1.

### 3.4.7 TWAI® Controller

ESP32-C6 has two TWAI® controllers 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 warning limit, error code capture, arbitration lost capture, automatic transceiver standby

For GPIOs assigned to TWAI®, please refer to Table 3-1.

### 3.4.8 SDIO 2.0 Slave Controller

ESP32-C6 integrates an SD device interface that conforms to the industry-standard SDIO Specification Version 2.0, and allows a host controller to access the SoC, using the SDIO bus interface and protocol. The host can access the registers of the SDIO interface directly and the shared memory via a DMA engine, thus maximizing performance without engaging the processor cores.

The SDIO 2.0 Slave Controller supports the following features:

- clock range: 0 to 50 MHz
- SPI, 1-bit SDIO, and 4-bit SDIO transfer modes
- configurable sampling and driving clock edges
- special registers for direct access by host
- interrupting host to initiate 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 GPIOs assigned to SDIO, please refer to Table 3-1.

### 3.4.9 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 20 bits
- has multiple clock sources, including 80 MHz PLL clock, external main crystal clock, and internal fast RC oscillator
- can operate when the CPU is in low-power mode (Light-sleep mode)
- supports gradual increase or decrease of duty cycle, which is useful for the LED RGB color-gradient generator
- up to 16 duty cycle ranges for each PWM generator to generate gamma curve signals - each range can be independently configured in terms of fading direction (increase or decrease), fading amount (the amount by which the duty cycle increases or decreases each time), the number of fades (how many times the duty cycle fades in one range), and fading frequency

For GPIOs assigned to LED PWM, please refer to Table 3-1.

### 3.4.10 Motor Control PWM (MCPWM)

ESP32-C6 integrates a MCPWM that can be used to drive digital motors and smart light. This controller has a clock divider (prescaler), three PWM timers, three PWM operators, and a dedicated capture submodule.

PWM timers are used to generate timing references. The PWM operators generate desired waveform based on the timing references. By configuration, a PWM operator can use the timing reference of any PWM timer, and use the same timing reference with other PWM operators. PWM operators can also use different PWM timers' values to produce independent PWM signals. PWM timers can be synchronized.

For GPIOs assigned to MCPWM, please refer to Table 3-1.



### 3.4.11 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  $192 \times 32$ -bit memory block to store transmit or receive waveform.

For GPIOs assigned to RMT, please refer to Table 3-1.

### 3.4.12 Parallel IO (PARLIO) Controller

ESP32-C6 integrates a PARLIO controller for parallel data transfer. It has a transmitter and a receiver, connected with the GDMA controller. In full-duplex mode the PARLIO controller supports up to 8-bit parallel data transfer, while in half-duplex mode it supports up to 16-bit parallel data transfer.

The PARLIO controller has the following features:

- multiple clock sources and clock division, with clock frequency up to 40 MHz
- clock edge sampling
- 1/2/4/8/16-bit data transfer
- changeable sample sequence for data to be transmitted and received in 1-bit, 2-bit, and 4-bit mode
- support for multiple data sampling mode by the receiver
- support for multiple EOF signal generation modes by the receiver
- support for transmitter clock gating

For GPIOs assigned to PARLIO, please refer to Table 3-1.

### 3.4.13 General DMA Controller (GDMA)

ESP32-C6 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.

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-C6 with DMA feature are SPI2, UHCI0, I2S, AES, SHA, ADC, and PARLIO.

### 3.4.14 Event Task Matrix (ETM)

ESP32-C6 integrates a SOC ETM with multiple channels. Each input event on channels is mapped to an output task. Events are generated by peripherals, while tasks are received by peripherals. The SOC ETM has the following features:

- up to 50 mapping channels, each connected to an event and a task and controlled independently
- an event or a task can be mapped to any tasks or events in the matrix. That is to say, one event can be mapped to different tasks via multiple channels, or different events can be mapped to the same task via their individual channels

- peripherals supporting ETM include GPIO, LED PWM, general-purpose timers, RTC Timer, system timer, MCPWM, temperature sensor, ADC, I2S, LP CPU, GDMA, and PMU

## 3.5 Radio

The ESP32-C6 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-C6 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.

## 3.6 Wi-Fi

### 3.6.1 Wi-Fi Radio and Baseband

The ESP32-C6 Wi-Fi radio and baseband support the following features:

- compliant with IEEE 802.11b/g/n/ax
- 1T1R in 2.4 GHz band
- 802.11ax
  - 20 MHz-only non-AP mode
  - MCS0 ~MCS9
  - uplink and downlink OFDMA
  - downlink MU-MIMO (multi-user, multiple input, multiple output)
  - longer OFDM symbol, with 0.8, 1.6, 3.2  $\mu$ s guard interval
  - DCM (dual carrier modulation), up to 16-QAM
  - single-user/multi-user beamformee
  - channel quality indication (CQI)
  - RX STBC (single spatial stream)
- 802.11b/g/n
  - MCS0 ~MCS7 that supports 20 MHz and 40 MHz bandwidth
  - MCS32
  - data rate up to 150 Mbps
  - 0.4  $\mu$ s guard interval
- adjustable transmitting power
- antenna diversity

ESP32-C6 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.

### 3.6.2 Wi-Fi MAC

ESP32-C6 implements the full IEEE 802.11 b/g/n/ax 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.

The ESP32-C6 Wi-Fi MAC applies the following low-level protocol functions automatically:

- 4  $\times$  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, and WPA3-PSK
- automatic beacon monitoring (hardware TSF)
- 802.11mc FTM
- 802.11ax supports:
  - target wake time (TWT) requester
  - multiple BSSIDs
  - triggered response scheduling
  - uplink power headroom
  - operating mode
  - buffer status report
  - Multi-user Request-to-Send (MU-RTS), Multi-user Block ACK Request (MU-BAR), and Multi-STA Block ACK (M-BA) frame
  - intra-PPDU power saving mechanism
  - two network allocation vectors (NAV)
  - BSS coloring
  - spatial reuse
  - uplink power headroom
  - operating mode control
  - buffer status report
  - TXOP duration RTS threshold
  - UL-OFDMA random access (UORA)

### 3.6.3 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.

## 3.7 Bluetooth LE

ESP32-C6 includes a Bluetooth Low Energy subsystem that integrates a hardware link controller, an RF/modem block and a feature-rich software protocol stack. It supports the core features of Bluetooth 5 and Bluetooth mesh.

### 3.7.1 Bluetooth LE PHY

Bluetooth Low Energy PHY in ESP32-C6 supports:

- 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)

### 3.7.2 Bluetooth LE Link Controller

Bluetooth Low Energy Link Controller in ESP32-C6 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
- LE power control
- 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

## 3.8 802.15.4

ESP32-C6 includes an IEEE Standard 802.15.4 subsystem that integrates PHY and MAC layer. It supports various software stacks including Thread, Zigbee, Matter, HomeKit, MQTT and so on.

### 3.8.1 802.15.4 PHY

ESP32-C6 's 802.15.4 PHY supports:

- O-QPSK PHY in 2.4 GHz
- 250 Kbps data rate
- RSSI and LQI supported

### 3.8.2 802.15.4 MAC

ESP32-C6 supports most key features defined in [IEEE Standard 802.15.4-2015](#), including:

- CSMA/CA
- active scan and energy detect
- HW frame filter
- HW auto acknowledge
- HW auto frame pending
- coordinated sampled listening (CSL)

## 3.9 Low Power Management

With the use of advanced power-management technologies, ESP32-C6 can switch between different power modes. ESP32-C6 supports:

- Active mode: CPU and chip radio are powered on. The chip can receive, transmit, or listen.
- Modem-sleep mode: The CPU is operational and the clock frequency can be reduced. Wi-Fi base band and radio are disabled, but Wi-Fi connection can remain active.
- Light-sleep mode: The CPU is paused. Any wake-up events (wireless power management module, SDIO host, RTC timer, or external interrupts) will wake up the chip. Wi-Fi base band and radio are disabled, but Wi-Fi connection can remain active. Users can disable the CPU and most peripherals except SRAM and wireless power management module (as shown in [ESP32-C6 Functional Block Diagram](#)) to further reduce current consumption.
- Deep-sleep mode: CPU, SRAM, and most peripherals are powered down. Only the LP memory is powered on. LP peripheral states can be configured. Wi-Fi connection data are stored in the LP memory. The LP CPU is operational.

## 3.10 Timers

### 3.10.1 System Timer

ESP32-C6 integrates a 52-bit system timer, which has two 52-bit counters and three comparators. The system timer has the following features:

- counters with an average 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 alarm values and 26-bit alarm periods
- automatic reload of counter value
- counters can be stalled if the CPU is stalled or in OCD mode
- real-time alarm events

### 3.10.2 General Purpose Timers

ESP32-C6 is embedded with 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 2 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
- real-time alarm events
- tasks in response to ETM, including enable and disable timers, enable alarms, read the timer's real-time values, reload the timer's values

### 3.10.3 Watchdog Timers

#### Digital Watchdog Timers

The ESP32-C6 contains three digital watchdog timers: one in each of the two timer groups (called Main System Watchdog Timers, or MWDT) and one in the low-power system (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.

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

The ESP32-C6 also has one analog watchdog timer: RTC super watchdog timer (SWD). Super watchdog (SWD) 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 (system reset) if required. SWD contains a watchdog circuit that needs to be fed for

at least once during its timeout period, which is slightly less than one second. About 100 ms before watchdog timeout, it will also send out a WD\_INTR signal as a request to remind the system to feed the watchdog.

If the system does not respond to SWD feed request and watchdog finally times out, SWD will generate a system level signal SWD\_RSTB to reset whole digital circuits on the chip (system reset).

The source of the clock for SWD is constant and can not be selected.

SWD has the following features:

- ultra-low power
- interrupt to indicate that the SWD is about to time out
- various dedicated methods for software to feed SWD, which enables SWD to monitor the working state of the whole operating system

## 3.11 Cryptography/Security Components

### 3.11.1 AES Accelerator (AES)

ESP32-C6 integrates an Advanced Encryption Standard (AES) accelerator, which is a hardware device that speeds up computation using AES algorithm significantly, compared to AES algorithms implemented solely in software. The AES accelerator integrated in ESP32-C6 has two working modes, which are Typical AES and DMA-AES.

The following functionality is supported:

- typical AES working mode
  - AES-128/AES-256 encryption and decryption
- DMA-AES working mode
  - AES-128/AES-256 encryption and decryption
  - Block cipher mode
    - \* ECB (Electronic Codebook)
    - \* CBC (Cipher Block Chaining)
    - \* OFB (Output Feedback)
    - \* CTR (Counter)
    - \* CFB8 (8-bit Cipher Feedback)
    - \* CFB128 (128-bit Cipher Feedback)
  - interrupt on completion of computation

### 3.11.2 ECC Accelerator (ECC)

Elliptic Curve Cryptography (ECC) is an approach to public-key cryptography based on the algebraic structure of elliptic curves. ECC allows smaller keys compared to RSA cryptography while providing equivalent security.



ESP32-C6's ECC Accelerator can complete various calculations based on different elliptic curves, thus accelerating the ECC algorithm and ECC-derived algorithms (such as ECDSA).

ESP32-C6's ECC Accelerator has the following features:

- two different elliptic curves, namely P-192 and P-256 defined in [FIPS 186-3](#)
- six working modes
- interrupt upon completion of calculation

### 3.11.3 HMAC Accelerator (HMAC)

The Hash-based Message Authentication Code (HMAC) module computes Message Authentication Codes (MACs) using Hash algorithm SHA-256 and keys as described in RFC 2104. The 256-bit HMAC key is stored in an eFuse key block and can be set as read-protected, i. e., the key is not accessible from outside the HMAC accelerator.

Main features are as follows:

- standard HMAC-SHA-256 algorithm
- Hash result only accessible by configurable hardware peripheral (in downstream mode)
- compatibility with challenge-response authentication algorithm
- required keys for the Digital Signature (DS) peripheral (in downstream mode)
- re-enabled soft-disabled JTAG (in downstream mode)

### 3.11.4 RSA Accelerator (RSA)

The RSA accelerator provides hardware support for high-precision computation used in various RSA asymmetric cipher algorithms, significantly improving their run time and reducing their software complexity. Compared with RSA algorithms implemented solely in software, this hardware accelerator can speed up RSA algorithms significantly. The RSA accelerator also supports operands of different lengths, which provides more flexibility during the computation.

The following functionality is supported:

- large-number modular exponentiation with two optional acceleration options
- large-number modular multiplication, up to 3072 bits
- large-number multiplication, with operands up to 1536 bits
- operands of different lengths
- interrupt on completion of computation

### 3.11.5 SHA Accelerator (SHA)

ESP32-C6 integrates an SHA accelerator, which is a hardware device that speeds up the SHA algorithm significantly, compared to a SHA algorithm implemented solely in software. The SHA accelerator integrated in ESP32-C6 has two working modes, which are Typical SHA and DMA-SHA.

The following functionality is supported:

- the following hash algorithms introduced in [FIPS PUB 180-4 Spec](#)

- SHA-1
  - SHA-224
  - SHA-256
- two working modes
  - typical SHA
  - DMA-SHA
- interleaved function when working in Typical SHA working mode
- interrupt function when working in DMA-SHA working mode

### 3.11.6 Digital Signature (DS)

A Digital Signature (DS) is used to verify the authenticity and integrity of a message using a cryptographic algorithm. This can be used to validate a device's identity to a server, or to check the integrity of a message.

ESP32-C6 includes a Digital Signature (DS) module providing hardware acceleration of messages' signatures based on RSA. HMAC is used as the key derivation function to output the DS\_KEY key using eFuse as the input key. Subsequently, the DS module uses DS\_KEY to decrypt the pre-encrypted parameters and calculate the signature. The whole process happens in hardware so that neither the decryption key for the RSA parameters nor the input key for the HMAC key derivation function can be seen by users while calculating the signature.

The following functionality is supported:

- RSA digital signatures with key length up to 3072 bits
- encrypted private key data, only decryptable by DS module
- SHA-256 digest to protect private key data against tampering by an attacker

### 3.11.7 External Memory Encryption and Decryption (XTS\_AES)

The ESP32-C6 integrates an External Memory Encryption and Decryption module that complies with the XTS-AES standard algorithm specified in [IEEE Std 1619-2007](#), providing security for users' application code and data stored in the external memory (flash). Users can store proprietary firmware and sensitive data (e.g., credentials for gaining access to a private network) to the off-package flash.

The following functionality is supported:

- general XTS-AES algorithm, compliant with IEEE Std 1619-2007
- software-based manual encryption
- high-speed auto decryption without software's participation
- encryption and decryption functions jointly enabled/disabled by registers configuration, eFuse parameters, and boot mode
- configurable Anti-DPA

### 3.11.8 Random Number Generator (RNG)

The ESP32-C6 contains a true random number generator, which generates 32-bit random numbers that can be used for cryptographical operations, among other things.

The random number generator in ESP32-C6 generates true random numbers, which means random numbers generated from a physical process, rather than by means of an algorithm. No number generated within the specified range is more or less likely to appear than any other number.

## 3.12 Peripheral Pin Configurations

**Table 3-1. Peripheral Pin Configurations**

Interface	Signal	Pin	Function
ADC	ADC1_CH0	XTAL_32K_P	12-bit SAR ADC
	ADC1_CH1	XTAL_32K_N	
	ADC1_CH2	GPIO2	
	ADC1_CH3	GPIO3	
	ADC1_CH4	MTMS	
	ADC1_CH5	MTDI	
	ADC1_CH6	MTCK	
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		
LP UART	LP_UART_DTRN	XTAL_32K_P	One LP UART channel with hardware flow control and GDMA
	LP_UART_DSRN	XTAL_32K_N	
	LP_UART_RTSN	GPIO2	
	LP_UART_CTSN	GPIO3	
	LP_UART_RXD	MTMS	
	LP_UART_TXD	MTDI	
I2C	I2CEXT0_SCL_in	Any GPIO pins	One I2C channel in slave or master mode
	I2CEXT0_SDA_in		
	I2CEXT0_SCL_out		
	I2CEXT0_SDA_out		
LP I2C	LP_I2C_SDA	MTCK	One LP I2C channel in slave or master mode

Interface	Signal	Pin	Function
	LP_I2C_SCL	MTDO	
LED PWM	ledc_ls_sig_out0~5	Any GPIO pins	Six independent PWM channels
I2S	I2SOO_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		
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	The following functionality is supported: <ul style="list-style-type: none"> <li>• Master mode and slave mode of SPI, Dual SPI, Quad SPI, and QPI</li> <li>• Connection to off-package flash, RAM and other SPI devices</li> <li>• Four modes of SPI transfer format</li> <li>• Configurable SPI frequency</li> <li>• 64-byte FIFO or GDMA buffer</li> </ul>
	FSPICS0_in/_out		
	FSPICS1~5_out		
	FSPID_in/_out		
	FSPIQ_in/_out		
	FSPIWP_in/_out		
	FSPIHD_in/_out		
USB Serial/JTAG	USB_D+	GPIO13	USB-to-serial converter, and USB-to-JTAG converter
	USB_D-	GPIO12	
TWAI®	TWAI0_RX	Any GPIO pins	Compatible with ISO 11898-1 protocol
	TWAI0_TX		
	TWAI0_BUS_OFF_ON		
	TWAI0_CLKOUT		

Interface	Signal	Pin	Function
	TWAI0_STANDBY		
	TWAI1_RX		
	TWAI1_TX		
	TWAI1_BUS_OFF_ON		
	TWAI1_CLKOUT		
	TWAI1_STANDBY		
Pulse Count Controller	PCNT_SIG_CH0_in0~3	Any GPIO pins	Captures pulses and counts pulse edges in seven modes
	PCNT_SIG_CH1_in0~3		
	PCNT_CTRL_CH0_in0~3		
	PCNT_CTRL_CH1_in0~3		
MCPWM	PWM0_SYNC0~2_in	Any GPIO pins	One MCPWM to generate: <ul style="list-style-type: none"> <li>• differential PWM output signals</li> <li>• fault input signals to be detected</li> <li>• input signals to be captured</li> <li>• external synchronization signals for PWM timers</li> </ul>
	PWM0_out0a		
	PWM0_out0b		
	PWM0_out1a		
	PWM0_F0~2_in		
	PWM0_out1b		
	PWM0_out2a		
	PWM0_out2b		
	PWM0_CAP0~2_in		
PARLIO	PARL_RX_DATA0~15	Any GPIO pins	A module for parallel data transfer, with <ul style="list-style-type: none"> <li>• 16 pins to receive parallel data</li> <li>• 16 pins to transmit parallel data</li> <li>• 1 receiver clock pin (clock input)</li> <li>• 2 transmitter clock pins (clock input and output)</li> </ul>
	PARL_TX_DATA0~15		
	PARL_RX_CLK_in		
	PARL_TX_CLK_in/_out		
SDIO	SDIO_CMD	SDIO_CMD	SDIO interface, conforming to the industry standard SDIO Specification Version 2.0
	SDIO_CLK	SDIO_CLK	
	SDIO_DATA0	SDIO_DATA0	
	SDIO_DATA1	SDIO_DATA1	
	SDIO_DATA2	SDIO_DATA2	
	SDIO_DATA3	SDIO_DATA3	

## 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 Power Supply Characteristics* 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 <sup>1</sup>	Allowed input voltage	−0.3	3.6	V
T <sub>STORE</sub>	Storage temperature	−40	150	°C

<sup>1</sup> For more information on input power pins, see Section 2.5.1 *Power Pins*.

<sup>2</sup> 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 Power Supply Characteristics

For recommended ambient temperature, see Section 1 *ESP32-C6 Series Comparison*.

**Table 4-2. Recommended Power Characteristics**

Parameter <sup>1</sup>	Description	Min	Typ	Max	Unit
VDDA1, VDDA2, VDDA3P3	Recommended input voltage	3.0	3.3	3.6	V
VDDPST1	Recommended input voltage	3.0	3.3	3.6	V
VDD_SPI (as input)	—	3.0	3.3	3.6	V
VDDPST2 <sup>2, 3</sup>	Recommended input voltage	3.0	3.3	3.6	V
I <sub>VDD</sub>	Cumulative input current	0.5	—	—	A

<sup>1</sup> See in conjunction with Section 2.5 *Power Supply*.

<sup>2</sup> If VDDPST2 is used to power VDD\_SPI (see Section 2.5.2 *Power Scheme*), the voltage drop on R<sub>SPI</sub> should be accounted for. See also Section 4.3 *VDD\_SPI Output Characteristics*.

<sup>3</sup> If writing to eFuses, the voltage on VDDPST2 should not exceed 3.3 V as the circuits responsible for burning eFuses are sensitive to higher voltages.

### 4.3 VDD\_SPI Output Characteristics

Table 4-3. VDD\_SPI Internal and Output Characteristics

Parameter	Description <sup>1</sup>	Typ	Unit
$R_{SPI}$	VDD_SPI powered by VDD3P3_RTC via $R_{SPI}$ for 3.3 V flash <sup>2</sup>	7.5	$\Omega$

<sup>1</sup> See in conjunction with Section 2.5.2 Power Scheme.

<sup>2</sup> VDD3P3\_RTC must be more than  $VDD_{flash\_min} + I_{flash\_max} * R_{SPI}$ ;

where

- $VDD_{flash\_min}$  – minimum operating voltage of flash
- $I_{flash\_max}$  – maximum operating current of flash

### 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	$0.75 \times VDD^1$	—	$VDD^1 + 0.3$	V
$V_{IL}$	Low-level input voltage	-0.3	—	$0.25 \times VDD^1$	V
$I_{IH}$	High-level input current	—	—	50	nA
$I_{IL}$	Low-level input current	—	—	50	nA
$V_{OH}^2$	High-level output voltage	$0.8 \times VDD^1$	—	—	V
$V_{OL}^2$	Low-level output voltage	—	—	$0.1 \times VDD^1$	V
$I_{OH}$	High-level source current ( $VDD^1 = 3.3$ V, $V_{OH} \geq 2.64$ 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	—	k $\Omega$
$R_{PD}$	Internal weak pull-down resistor	—	45	—	k $\Omega$
$V_{IH\_nRST}$	Chip reset release voltage CHIP_PU voltage is within the specified range)	$0.75 \times VDD^1$	—	$VDD^1 + 0.3$	V
$V_{IL\_nRST}$	Chip reset voltage (CHIP_PU voltage is within the specified range)	-0.3	—	$0.25 \times VDD^1$	V

<sup>1</sup> VDD – voltage from a power pin of a respective power domain.

<sup>2</sup>  $V_{OH}$  and  $V_{OL}$  are measured using high-impedance load.

## 4.5 ADC Characteristics

The measurements in this section are taken with an external 100 nF capacitor connected to the ADC, using DC signals as input, and at an ambient temperature of 25 °C with disabled Wi-Fi.

**Table 4-5. ADC Characteristics**

Symbol	Min	Max	Unit
DNL (Differential nonlinearity) <sup>1</sup>	–8	12	LSB
INL (Integral nonlinearity)	–10	10	LSB
Sampling rate	—	100	kSPS <sup>2</sup>

<sup>1</sup> To get better DNL results, you can sample multiple times and apply a filter, or calculate the average value.

<sup>2</sup> 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 ~ 1000	–12	12	mV
	ATTEN1, effective measurement range of 0 ~ 1300	–12	12	mV
	ATTEN2, effective measurement range of 0 ~ 1900	–23	23	mV
	ATTEN3, effective measurement range of 0 ~ 3300	–40	40	mV

**Note:**

The above ADC measurement range and accuracy are applicable to chips manufactured on and after the Date Code **212023** on shielding cases, or assembled on and after the D/C 1 and D/C 2 **2321** on bar-code labels. For chips manufactured or assembled earlier than these date codes, please ask [our sales team](#) to provide the actual range and accuracy according to batch.

For details of Date Code and D/C, please refer to [Espressif Chip Packaging Information](#).

## 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 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 4-7. Current Consumption for Wi-Fi (2.4 GHz) in Active Mode

Work Mode	RF Condition	Description	Peak (mA)
Active (RF working)	TX	802.11b, 1 Mbps, DSSS @ 21.0 dBm	354
		802.11g, 54 Mbps, OFDM @ 19.5 dBm	300
		802.11n, HT20, MCS7 @ 18.5 dBm	280
		802.11n, HT40, MCS7 @ 18.0 dBm	268
		802.11ax, MCS9, @ 16.5 dBm	252
	RX	802.11b/g/n, HT20	78
		802.11n, HT40	82
		802.11ax, HE20	78

Table 4-8. Current Consumption for Bluetooth LE in Active Mode

Work Mode	RF Condition	Description	Peak (mA)
Active (RF working)	TX	Bluetooth LE @ 20.0 dBm	315
		Bluetooth LE @ 9.0 dBm	190
		Bluetooth LE @ 0 dBm	130
		Bluetooth LE @ -15.0 dBm	94
	RX	Bluetooth LE	71

Table 4-9. Current Consumption for 802.15.4 in Active Mode

Work Mode	RF Condition	Description	Peak (mA)
Active (RF working)	TX	802.15.4 @ 20.0 dBm	305
		802.15.4 @ 12.0 dBm	187
		802.15.4 @ 0 dBm	119
		802.15.4 @ -15.0 dBm	92
	RX	802.15.4	74

#### 4.6.2 Current Consumption in Other Modes

Table 4-10. Current Consumption in Modem-sleep Mode

Mode	CPU Frequency (MHz)	Description	Typ (mA)	
			All Peripherals Clocks Disabled	All Peripherals Clocks Enabled <sup>1</sup>
Modem-sleep <sup>2,3</sup>	160	CPU is running	27	38
		CPU is idle	17	28
	80	CPU is running	19	30
		CPU is idle	14	25

<sup>1</sup> In practice, the current consumption might be different depending on which peripherals are enabled.

<sup>2</sup> In Modem-sleep mode, Wi-Fi is clock gated.

<sup>3</sup> In Modem-sleep mode, the consumption might be higher when accessing flash.

Table 4-11. Current Consumption in Low-Power Modes

Mode	Description	Typ ( $\mu\text{A}$ )
Light-sleep	CPU and wireless communication modules are powered down, peripheral clocks are disabled, and all GPIOs are high-impedance	180
	CPU, wireless communication modules and peripherals are powered down, and all GPIOs are high-impedance	35
Deep-sleep	RTC timer and LP memory are powered on	7
Power off	CHIP_PU is set to low level, the chip is powered off	1

## 4.7 Reliability

Table 4-12. 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) <sup>1</sup> ± 2000 V	JS-001
	CDM (Charge Device Mode) <sup>2</sup> ± 1000 V	JS-002
Latch up	Current trigger ± 200 mA	JESD78
	Voltage trigger $1.5 \times V_{DD_{max}}$	
Preconditioning	Bake 24 hours @125 °C Moisture soak (level 3: 192 hours @30 °C, 60% RH) 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
LTSL (Low Temperature Storage Life)	−40 °C, 1000 hours	JESD22-A119

<sup>1</sup> JEDEC document JEP155 states that 500 V HBM allows safe manufacturing with a standard ESD control process.

<sup>2</sup> JEDEC document JEP157 states that 250 V CDM allows safe manufacturing with a standard ESD control process.

## 5 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 front-end circuit is a 0  $\Omega$  resistor.

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 [ESP RF Test 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.

### 5.1 Wi-Fi Radio

**Table 5-1. Wi-Fi RF Characteristics**

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

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

**Table 5-2. TX Power with Spectral Mask and EVM Meeting 802.11 Standards**

Rate	Min (dBm)	Typ (dBm)	Max (dBm)
802.11b, 1 Mbps, DSSS	—	21.0	—
802.11b, 11 Mbps, CCK	—	21.0	—
802.11g, 6 Mbps, OFDM	—	20.5	—
802.11g, 54 Mbps, OFDM	—	19.5	—
802.11n, HT20, MCS0	—	19.5	—
802.11n, HT20, MCS7	—	18.5	—
802.11n, HT40, MCS0	—	19.0	—
802.11n, HT40, MCS7	—	18.0	—
802.11ax, HE20, MCS0	—	19.5	—
802.11ax, HE20, MCS9	—	16.5	—

**Table 5-3. TX EVM Test<sup>1</sup>**

Rate	Min (dB)	Typ (dB)	Limit (dB)
802.11b, 1 Mbps, DSSS	—	-25.5	-10.0

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Table 5-3 – cont'd from previous page

Rate	Min (dB)	Typ (dB)	Limit (dB)
802.11b, 11 Mbps, CCK	—	–25.5	–10.0
802.11g, 6 Mbps, OFDM	—	–26.5	–5.0
802.11g, 54 Mbps, OFDM	—	–29.0	–25.0
802.11n, HT20, MCS0	—	–29.0	–5.0
802.11n, HT20, MCS7	—	–30.0	–27.0
802.11n, HT40, MCS0	—	–28.5	–5.0
802.11n, HT40, MCS7	—	–29.5	–27.0
802.11ax, HE20, MCS0	—	–29.0	–5.0
802.11ax, HE20, MCS9	—	–34.0	–32.0

<sup>1</sup> EVM is measured at the corresponding typical TX power provided in Table 5-2 *TX Power with Spectral Mask and EVM Meeting 802.11 Standards* above.

### 5.1.2 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/ax.

Table 5-4. RX Sensitivity

Rate	Min (dBm)	Typ (dBm)	Max (dBm)
802.11b, 1 Mbps, DSSS	—	–99.2	—
802.11b, 2 Mbps, DSSS	—	–96.8	—
802.11b, 5.5 Mbps, CCK	—	–93.8	—
802.11b, 11 Mbps, CCK	—	–90.0	—
802.11g, 6 Mbps, OFDM	—	–94.0	—
802.11g, 9 Mbps, OFDM	—	–93.2	—
802.11g, 12 Mbps, OFDM	—	–92.6	—
802.11g, 18 Mbps, OFDM	—	–90.0	—
802.11g, 24 Mbps, OFDM	—	–86.8	—
802.11g, 36 Mbps, OFDM	—	–83.2	—
802.11g, 48 Mbps, OFDM	—	–79.0	—
802.11g, 54 Mbps, OFDM	—	–77.6	—
802.11n, HT20, MCS0	—	–93.6	—
802.11n, HT20, MCS1	—	–92.4	—
802.11n, HT20, MCS2	—	–89.6	—
802.11n, HT20, MCS3	—	–86.2	—
802.11n, HT20, MCS4	—	–82.8	—
802.11n, HT20, MCS5	—	–78.8	—
802.11n, HT20, MCS6	—	–77.2	—

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Table 5-4 – cont'd from previous page

Rate	Min (dBm)	Typ (dBm)	Max (dBm)
802.11n, HT20, MCS7	—	–75.6	—
802.11n, HT40, MCS0	—	–91.0	—
802.11n, HT40, MCS1	—	–90.0	—
802.11n, HT40, MCS2	—	–87.4	—
802.11n, HT40, MCS3	—	–83.8	—
802.11n, HT40, MCS4	—	–80.8	—
802.11n, HT40, MCS5	—	–76.6	—
802.11n, HT40, MCS6	—	–75.0	—
802.11n, HT40, MCS7	—	–73.4	—
802.11ax, HE20, MCS0	—	–93.8	—
802.11ax, HE20, MCS1	—	–91.2	—
802.11ax, HE20, MCS2	—	–88.4	—
802.11ax, HE20, MCS3	—	–85.6	—
802.11ax, HE20, MCS4	—	–82.2	—
802.11ax, HE20, MCS5	—	–78.4	—
802.11ax, HE20, MCS6	—	–76.6	—
802.11ax, HE20, MCS7	—	–74.8	—
802.11ax, HE20, MCS8	—	–71.0	—
802.11ax, HE20, MCS9	—	–69.0	—

Table 5-5. Maximum RX Level

Rate	Min (dBm)	Typ (dBm)	Max (dBm)
802.11b, 1 Mbps, DSSS	—	5	—
802.11b, 11 Mbps, CCK	—	5	—
802.11g, 6 Mbps, OFDM	—	5	—
802.11g, 54 Mbps, OFDM	—	0	—
802.11n, HT20, MCS0	—	5	—
802.11n, HT20, MCS7	—	0	—
802.11n, HT40, MCS0	—	5	—
802.11n, HT40, MCS7	—	0	—
802.11ax, HE20, MCS0	—	5	—
802.11ax, HE20, MCS9	—	0	—

Table 5-6. RX Adjacent Channel Rejection

Rate	Min (dB)	Typ (dB)	Max (dB)
802.11b, 1 Mbps, DSSS	—	38	—
802.11b, 11 Mbps, CCK	—	38	—
802.11g, 6 Mbps, OFDM	—	31	—
802.11g, 54 Mbps, OFDM	—	20	—
802.11n, HT20, MCS0	—	31	—
802.11n, HT20, MCS7	—	16	—
802.11n, HT40, MCS0	—	28	—
802.11n, HT40, MCS7	—	10	—
802.11ax, HE20, MCS0	—	25	—
802.11ax, HE20, MCS9	—	2	—

## 5.2 Bluetooth LE Radio

Table 5-7. Bluetooth LE RF Characteristics

Name	Description
Center frequency range of operating channel	2402 ~ 2480 MHz
RF transmit power range	-15.0 ~ 20.0 dBm

### 5.2.1 Bluetooth LE RF Transmitter (TX) Characteristics

Table 5-8. Bluetooth LE - Transmitter Characteristics - 1 Mbps

Parameter	Description	Min	Typ	Max	Unit
Carrier frequency offset and drift	Max. $ f_n _{n=0, 1, 2, 3, \dots k}$	—	1.3	—	kHz
	Max. $ f_0 - f_n _{n=2, 3, 4, \dots k}$	—	1.5	—	kHz
	Max. $ f_n - f_{n-5} _{n=6, 7, 8, \dots k}$	—	0.9	—	kHz
	$ f_1 - f_0 $	—	0.6	—	kHz
Modulation characteristics	$\Delta F1_{avg}$	—	249.9	—	kHz
	Min. $\Delta F2_{max}$ (for at least 99.9% of all $\Delta F2_{max}$ )	—	212.1	—	kHz
	$\Delta F2_{avg}/\Delta F1_{avg}$	—	0.88	—	—
In-band emissions	$\pm 2$ MHz offset	—	-29	—	dBm
	$\pm 3$ MHz offset	—	-36	—	dBm
	$> \pm 3$ MHz offset	—	-39	—	dBm

Table 5-9. Bluetooth LE - Transmitter Characteristics - 2 Mbps

Parameter	Description	Min	Typ	Max	Unit
Carrier frequency offset and drift	Max. $ f_n _{n=0, 1, 2, 3, \dots k}$	—	2.2	—	kHz
	Max. $ f_0 - f_n _{n=2, 3, 4, \dots k}$	—	1.1	—	kHz
	Max. $ f_n - f_{n-5} _{n=6, 7, 8, \dots k}$	—	1.1	—	kHz
	$ f_1 - f_0 $	—	0.5	—	kHz
Modulation characteristics	$\Delta F1_{avg}$	—	499.4	—	kHz
	Min. $\Delta F2_{max}$ (for at least 99.9% of all $\Delta F2_{max}$ )	—	443.5	—	kHz
	$\Delta F2_{avg}/\Delta F1_{avg}$	—	0.95	—	—
In-band emissions	$\pm 4$ MHz offset	—	-40	—	dBm
	$\pm 5$ MHz offset	—	-41	—	dBm
	$> \pm 5$ MHz offset	—	-42	—	dBm

Table 5-10. Bluetooth LE - Transmitter Characteristics - 125 Kbps

Parameter	Description	Min	Typ	Max	Unit
Carrier frequency offset and drift	Max. $ f_n _{n=0, 1, 2, 3, \dots k}$	—	0.7	—	kHz
	Max. $ f_0 - f_n _{n=1, 2, 3, \dots k}$	—	0.3	—	kHz
	$ f_0 - f_3 $	—	0.1	—	kHz
	Max. $ f_n - f_{n-3} _{n=7, 8, 9, \dots k}$	—	0.4	—	kHz
Modulation characteristics	$\Delta F1_{avg}$	—	250.0	—	kHz
	Min. $\Delta F1_{max}$ (for at least 99.9% of all $\Delta F1_{max}$ )	—	238.0	—	kHz
In-band emissions	$\pm 2$ MHz offset	—	-29	—	dBm
	$\pm 3$ MHz offset	—	-36	—	dBm
	$> \pm 3$ MHz offset	—	-39	—	dBm

Table 5-11. Bluetooth LE - Transmitter Characteristics - 500 Kbps

Parameter	Description	Min	Typ	Max	Unit
Carrier frequency offset and drift	Max. $ f_n _{n=0, 1, 2, 3, \dots k}$	—	0.5	—	kHz
	Max. $ f_0 - f_n _{n=1, 2, 3, \dots k}$	—	0.3	—	kHz
	$ f_0 - f_3 $	—	0.1	—	kHz
	Max. $ f_n - f_{n-3} _{n=7, 8, 9, \dots k}$	—	0.4	—	kHz
Modulation characteristics	$\Delta F2_{avg}$	—	230.7	—	kHz
	Min. $\Delta F2_{max}$ (for at least 99.9% of all $\Delta F2_{max}$ )	—	217.6	—	kHz
In-band emissions	$\pm 2$ MHz offset	—	-28	—	dBm
	$\pm 3$ MHz offset	—	-36	—	dBm
	$> \pm 3$ MHz offset	—	-39	—	dBm

## 5.2.2 Bluetooth LE RF Receiver (RX) Characteristics

Table 5-12. Bluetooth LE - Receiver Characteristics - 1 Mbps

Parameter		Description	Min	Typ	Max	Unit
Sensitivity @30.8% PER		—	—	−98.5	—	dBm
Maximum received signal @30.8% PER		—	—	8	—	dBm
C/I and receiver selectivity performance	Co-channel	F = F0 MHz	—	7	—	dB
	Adjacent channel	F = F0 + 1 MHz	—	4	—	dB
		F = F0 − 1 MHz	—	3	—	dB
		F = F0 + 2 MHz	—	−21	—	dB
		F = F0 − 2 MHz	—	−22	—	dB
		F = F0 + 3 MHz	—	−28	—	dB
		F = F0 − 3 MHz	—	−36	—	dB
		$F \geq F0 + 4 \text{ MHz}$	—	−27	—	dB
		$F \leq F0 - 4 \text{ MHz}$	—	−36	—	dB
	Image frequency	—	—	−26	—	dB
Adjacent channel to image frequency	F = F <sub>image</sub> + 1 MHz	—	−29	—	dB	
	F = F <sub>image</sub> − 1 MHz	—	−28	—	dB	
Out-of-band blocking performance		30 MHz ~ 2000 MHz	—	−16	—	dBm
		2003 MHz ~ 2399 MHz	—	−24	—	dBm
		2484 MHz ~ 2997 MHz	—	−16	—	dBm
		3000 MHz ~ 12.75 GHz	—	−1	—	dBm
Intermodulation		—	—	−27	—	dBm

Table 5-13. Bluetooth LE - Receiver Characteristics - 2 Mbps

Parameter	Description	Min	Typ	Max	Unit
Sensitivity @30.8% PER	—	—	-95.5	—	dBm
Maximum received signal @30.8% PER	—	—	8	—	dBm
C/I and receiver selectivity performance	Co-channel	$F = F_0 \text{ MHz}$	—	8	dB
	Adjacent channel	$F = F_0 + 2 \text{ MHz}$	—	3	dB
		$F = F_0 - 2 \text{ MHz}$	—	2	dB
		$F = F_0 + 4 \text{ MHz}$	—	-23	dB
		$F = F_0 - 4 \text{ MHz}$	—	-25	dB
		$F = F_0 + 6 \text{ MHz}$	—	-31	dB
		$F = F_0 - 6 \text{ MHz}$	—	-35	dB
		$F \geq F_0 + 8 \text{ MHz}$	—	-36	dB
		$F \leq F_0 - 8 \text{ MHz}$	—	-36	dB
	Image frequency	—	—	-23	dB
Adjacent channel to image frequency	Adjacent channel to image frequency	$F = F_{image} + 2 \text{ MHz}$	—	-30	dB
		$F = F_{image} - 2 \text{ MHz}$	—	3	dB

Cont'd on next page



Table 5-13 – cont'd from previous page

Parameter	Description	Min	Typ	Max	Unit
Out-of-band blocking performance	30 MHz ~ 2000 MHz	—	–18	—	dBm
	2003 MHz ~ 2399 MHz	—	–28	—	dBm
	2484 MHz ~ 2997 MHz	—	–16	—	dBm
	3000 MHz ~ 12.75 GHz	—	–1	—	dBm
Intermodulation	—	—	–29	—	dBm

Table 5-14. Bluetooth LE - Receiver Characteristics - 125 Kbps

Parameter	Description	Min	Typ	Max	Unit
Sensitivity @30.8% PER	—	—	–106.0	—	dBm
Maximum received signal @30.8% PER	—	—	8	—	dBm
C/I and receiver selectivity performance	Co-channel	$F = F_0 \text{ MHz}$	—	2	dB
	Adjacent channel	$F = F_0 + 1 \text{ MHz}$	—	–1	dB
		$F = F_0 - 1 \text{ MHz}$	—	–3	dB
		$F = F_0 + 2 \text{ MHz}$	—	–31	dB
		$F = F_0 - 2 \text{ MHz}$	—	–27	dB
		$F = F_0 + 3 \text{ MHz}$	—	–33	dB
		$F = F_0 - 3 \text{ MHz}$	—	–42	dB
		$F \geq F_0 + 4 \text{ MHz}$	—	–31	dB
		$F \leq F_0 - 4 \text{ MHz}$	—	–48	dB
	Image frequency	—	—	–31	dB
	Adjacent channel to image frequency	$F = F_{image} + 1 \text{ MHz}$	—	–36	dB
		$F = F_{image} - 1 \text{ MHz}$	—	–33	dB

Table 5-15. Bluetooth LE - Receiver Characteristics - 500 Kbps

Parameter	Description	Min	Typ	Max	Unit
Sensitivity @30.8% PER	—	—	–102.0	—	dBm
Maximum received signal @30.8% PER	—	—	8	—	dBm
C/I and receiver selectivity performance	Co-channel	$F = F_0 \text{ MHz}$	—	4	dB
	Adjacent channel	$F = F_0 + 1 \text{ MHz}$	—	1	dB
		$F = F_0 - 1 \text{ MHz}$	—	–1	dB
		$F = F_0 + 2 \text{ MHz}$	—	–23	dB
		$F = F_0 - 2 \text{ MHz}$	—	–24	dB
		$F = F_0 + 3 \text{ MHz}$	—	–33	dB
		$F = F_0 - 3 \text{ MHz}$	—	–41	dB
		$F \geq F_0 + 4 \text{ MHz}$	—	–31	dB
		$F \leq F_0 - 4 \text{ MHz}$	—	–41	dB
	Image frequency	—	—	–30	dB

Cont'd on next page

Table 5-15 – cont'd from previous page

Parameter		Description	Min	Typ	Max	Unit
	Adjacent channel to image frequency	$F = F_{image} + 1 \text{ MHz}$	—	–35	—	dB
		$F = F_{image} - 1 \text{ MHz}$	—	–27	—	dB

## 5.3 802.15.4 Radio

Table 5-16. 802.15.4 RF Characteristics

Name	Description
Center frequency range of operating channel	2405 ~ 2480 MHz

<sup>1</sup> Zigbee in the 2.4 GHz range supports 16 channels at 5 MHz spacing from channel 11 to channel 26.

### 5.3.1 802.15.4 RF Transmitter (TX) Characteristics

Table 5-17. 802.15.4 Transmitter Characteristics - 250 Kbps

Parameter	Min	Typ	Max	Unit
RF transmit power range	–15.0	—	20.0	dBm
EVM	—	13.0%	—	—

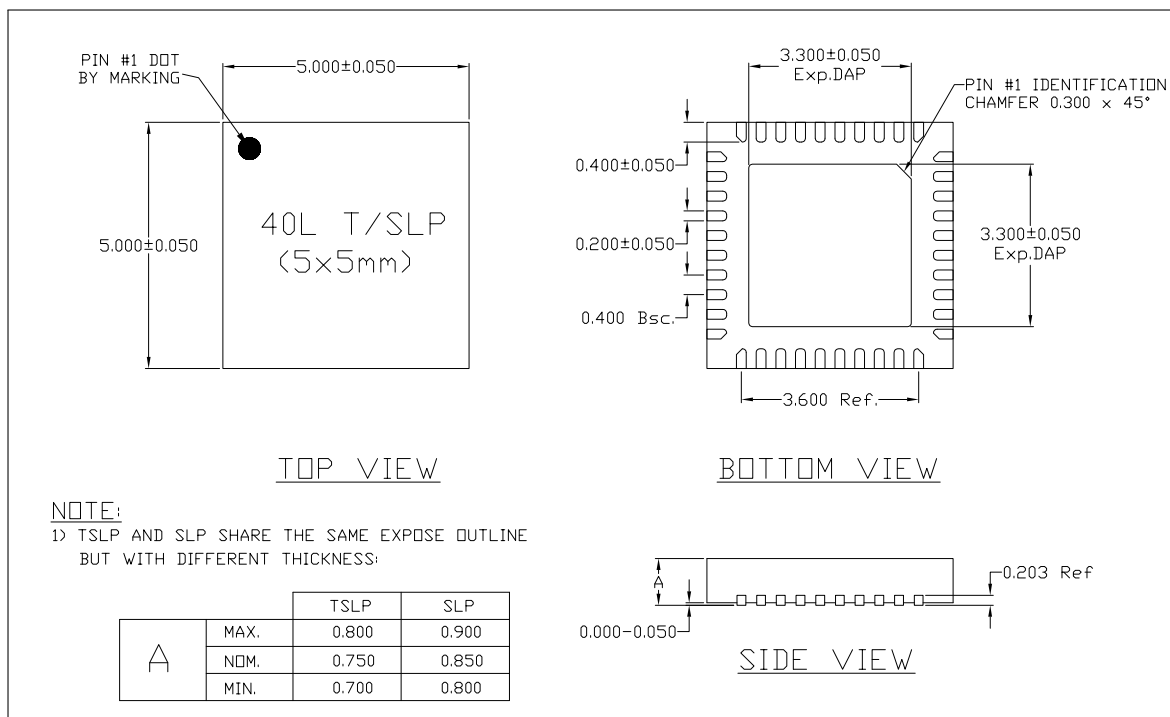
### 5.3.2 802.15.4 RF Receiver (RX) Characteristics

Table 5-18. 802.15.4 Receiver Characteristics - 250 Kbps

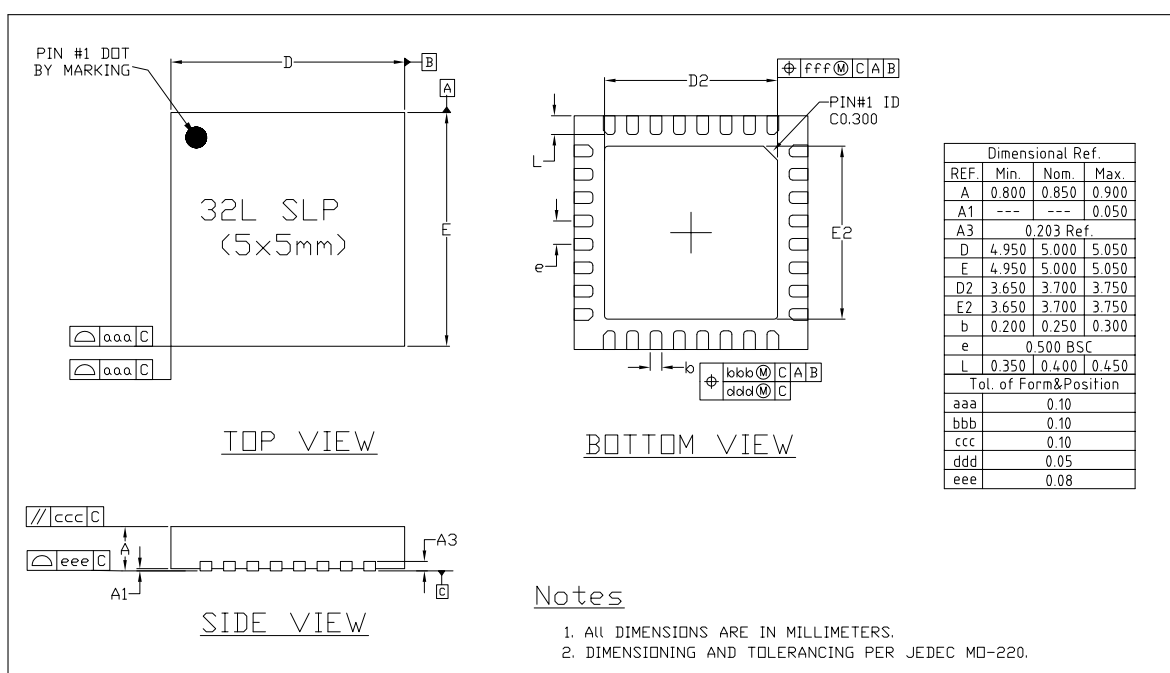
Parameter		Description	Min	Typ	Max	Unit
Sensitivity @1% PER		—	—	–104.0	—	dBm
Maximum received signal @1% PER		—	—	8	—	dBm
Relative jamming level	Adjacent channel	$F = F_0 + 5 \text{ MHz}$	—	27	—	dB
		$F = F_0 - 5 \text{ MHz}$	—	32	—	dB
	Alternate channel	$F = F_0 + 10 \text{ MHz}$	—	47	—	dB
		$F = F_0 - 10 \text{ MHz}$	—	50	—	dB

## 6 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-C6 Pin Layout (QFN40, Top View) and Figure 2-2 ESP32-C6 Pin Layout (QFN32, Top View).



**Figure 6-1. QFN40 (5x5 mm) Package**



**Figure 6-2. QFN32 (5x5 mm) Package**

## 7 Related Documentation and Resources

### Related Documentation

- [ESP32-C6 Technical Reference Manual](#) – Detailed information on how to use the ESP32-C6 memory and peripherals.
- [ESP32-C6 Hardware Design Guidelines](#) – Guidelines on how to integrate the ESP32-C6 into your hardware product.
- *Certificates*  
<https://espressif.com/en/support/documents/certificates>
- *Documentation Updates and Update Notification Subscription*  
<https://espressif.com/en/support/download/documents>

### Developer Zone

- [ESP-IDF Programming Guide for ESP32-C6](#) – 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-C6 Series SoCs* – Browse through all ESP32-C6 SoCs.  
<https://espressif.com/en/products/socs?id=ESP32-C6>
- *ESP32-C6 Series Modules* – Browse through all ESP32-C6-based modules.  
<https://espressif.com/en/products/modules?id=ESP32-C6>
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<https://espressif.com/en/products/devkits?id=ESP32-C6>
- *ESP Product Selector* – Find an Espressif hardware product suitable for your needs by comparing or applying filters.  
<https://products.espressif.com/#/product-selector?language=en>

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# Appendix A – ESP32-C6 Consolidated Pin Overview

Table 7-1. QFN40 Pin Overview

Pin No.	Pin Name	Pin Type	Pin Providing Power	Pin Settings		Analog Function		LP IO MUX Function		IO MUX Function					
				At Reset	After Reset	0	1	0	1	0	Type	1	Type	2	Type
1	ANT	Analog													
2	VDDA3P3	Power													
3	VDDA3P3	Power													
4	CHIP_PU	Analog													
5	VDDPST1	Power													
6	XTAL_32K_P	IO	VDDPST1			XTAL_32K_P	ADC1_CH0	LP_GPIO0	LP_UART_DTRN	<b>GPIO0</b>	I/O/T	GPIO0	I/O/T		
7	XTAL_32K_N	IO	VDDPST1			XTAL_32K_N	ADC1_CH1	LP_GPIO1	LP_UART_DSRN	<b>GPIO1</b>	I/O/T	GPIO1	I/O/T		
8	GPIO2	IO	VDDPST1	IE	IE		ADC1_CH2	LP_GPIO2	LP_UART_RTSN	<b>GPIO2</b>	I/O/T	GPIO2	I/O/T	FSPIQ	I1/O/T
9	GPIO3	IO	VDDPST1	IE	IE		ADC1_CH3	LP_GPIO3	LP_UART_CTSN	<b>GPIO3</b>	I/O/T	GPIO3	I/O/T		
10	MTMS	IO	VDDPST1	IE	IE		ADC1_CH4	LP_GPIO4	LP_UART_RXD	<b>MTMS</b>	I1	GPIO4	I/O/T	FSPiHD	I1/O/T
11	MTDI	IO	VDDPST1	IE	IE		ADC1_CH5	LP_GPIO5	LP_UART_TXD	<b>MTDI</b>	I1	GPIO5	I/O/T	FSPiWP	I1/O/T
12	MTCK	IO	VDDPST1		IE, WPU		ADC1_CH6	LP_GPIO6	LP_I2C_SDA	<b>MTCK</b>	I1	GPIO6	I/O/T	FSPiCLK	I1/O/T
13	MTDO	IO	VDDPST1		IE			LP_GPIO7	LP_I2C_SCL	<b>MTDO</b>	O/T	GPIO7	I/O/T	FSPiD	I1/O/T
14	GPIO8	IO	VDDPST2	IE	IE					<b>GPIO8</b>	I/O/T	GPIO8	I/O/T		
15	GPIO9	IO	VDDPST2	IE, WPU	IE, WPU					<b>GPIO9</b>	I/O/T	GPIO9	I/O/T		
16	GPIO10	IO	VDDPST2		IE					<b>GPIO10</b>	I/O/T	GPIO10	I/O/T		
17	GPIO11	IO	VDDPST2		IE					<b>GPIO11</b>	I/O/T	GPIO11	I/O/T		
18	GPIO12	IO	VDDPST2		IE	<b>USB_D-</b>				<b>GPIO12</b>	I/O/T	GPIO12	I/O/T		
19	GPIO13	IO	VDDPST2		IE, WPU	<b>USB_D+</b>				<b>GPIO13</b>	I/O/T	GPIO13	I/O/T		
20	SPICS0	IO	VDD_SPI	WPU	IE, WPU					<b>SPICS0</b>	O/T	GPIO24	I/O/T		
21	SPIQ	IO	VDD_SPI	WPU	IE, WPU					<b>SPIQ</b>	I1/O/T	GPIO25	I/O/T		
22	SPIWP	IO	VDD_SPI	WPU	IE, WPU					<b>SPIWP</b>	I1/O/T	<b>GPIO26</b>	I/O/T		
23	VDD_SPI	Power/IO	—			<b>VDD_SPI</b>				<b>GPIO27</b>	I/O/T	GPIO27	I/O/T		
24	SPIHD	IO	VDD_SPI	WPU	IE, WPU					<b>SPIHD</b>	I1/O/T	<b>GPIO28</b>	I/O/T		
25	SPiCLK	IO	VDD_SPI	WPU	IE, WPU					<b>SPiCLK</b>	O/T	GPIO29	I/O/T		
26	SPiD	IO	VDD_SPI	WPU	IE, WPU					<b>SPiD</b>	I1/O/T	GPIO30	I/O/T		
27	GPIO15	IO	VDDPST2	IE	IE					<b>GPIO15</b>	I/O/T	GPIO15	I/O/T		
28	VDDPST2	Power													
29	U0TXD	IO	VDDPST2		WPU					<b>U0TXD</b>	O	GPIO16	I/O/T	FSPiCS0	I1/O/T
30	U0RXD	IO	VDDPST2		IE, WPU					<b>U0RXD</b>	I1	GPIO17	I/O/T	FSPiCS1	O/T
31	SDIO_CMD	IO	VDDPST2	WPU	IE					<b>SDIO_CMD</b>	I1/O/T	GPIO18	I/O/T	FSPiCS2	O/T
32	SDIO_CLK	IO	VDDPST2	WPU	IE					<b>SDIO_CLK</b>	I1	GPIO19	I/O/T	FSPiCS3	O/T
33	SDIO_DATA0	IO	VDDPST2	WPU	IE					<b>SDIO_DATA0</b>	I1/O/T	GPIO20	I/O/T	FSPiCS4	O/T
34	SDIO_DATA1	IO	VDDPST2	WPU	IE					<b>SDIO_DATA1</b>	I1/O/T	GPIO21	I/O/T	FSPiCS5	O/T
35	SDIO_DATA2	IO	VDDPST2	WPU	IE					<b>SDIO_DATA2</b>	I1/O/T	GPIO22	I/O/T		
36	SDIO_DATA3	IO	VDDPST2	WPU	IE					<b>SDIO_DATA3</b>	I1/O/T	GPIO23	I/O/T		
37	VDDA1	Power													
38	XTAL_N	Analog													
39	XTAL_P	Analog													
40	VDDA2	Power													
41	GND	Power													

\* For details, see Section 2 Pins. Regarding highlighted cells, see Section 2.3.4 Restrictions for GPIOs and LP GPIOs.

Table 7-2. QFN32 Pin Overview

Pin No.	Pin Name	Pin Type	Pin Providing Power	Pin Settings		Analog Function		LP IO MUX Function		IO MUX Function					
				At Reset	After Reset	0	1	0	1	0	Type	1	Type	2	Type
1	ANT	Analog													
2	VDDA3P3	Power													
3	VDDA3P3	Power													
4	CHIP_PU	Analog													
5	VDDPST1	Power													
6	XTAL_32K_P	IO	VDDPST1			XTAL_32K_P	ADC1_CH0	LP_GPIO0	LP_UART_DTRN	<b>GPIO0</b>	I/O/T	GPIO0	I/O/T		
7	XTAL_32K_N	IO	VDDPST1			XTAL_32K_N	ADC1_CH1	LP_GPIO1	LP_UART_DSRN	<b>GPIO1</b>	I/O/T	GPIO1	I/O/T		
8	GPIO2	IO	VDDPST1	IE	IE		ADC1_CH2	LP_GPIO2	LP_UART_RTSN	<b>GPIO2</b>	I/O/T	GPIO2	I/O/T	FSPIQ	I1/O/T
9	GPIO3	IO	VDDPST1	IE	IE		ADC1_CH3	LP_GPIO3	LP_UART_CTSN	<b>GPIO3</b>	I/O/T	GPIO3	I/O/T		
10	MTMS	IO	VDDPST1	IE	IE		ADC1_CH4	LP_GPIO4	LP_UART_RXD	<b>MTMS</b>	I1	GPIO4	I/O/T	FSPICHD	I1/O/T
11	MTDI	IO	VDDPST1	IE	IE		ADC1_CH5	LP_GPIO5	LP_UART_TXD	<b>MTDI</b>	I1	GPIO5	I/O/T	FSPICWP	I1/O/T
12	MTCK	IO	VDDPST1		IE, WPU		ADC1_CH6	LP_GPIO6	LP_I2C_SDA	<b>MTCK</b>	I1	GPIO6	I/O/T	FSPICLK	I1/O/T
13	MTDO	IO	VDDPST1		IE			LP_GPIO7	LP_I2C_SCL	<b>MTDO</b>	O/T	GPIO7	I/O/T	FSPID	I1/O/T
14	GPIO8	IO	VDDPST2	IE	IE					<b>GPIO8</b>	I/O/T	GPIO8	I/O/T		
15	GPIO9	IO	VDDPST2	IE, WPU	IE, WPU					<b>GPIO9</b>	I/O/T	GPIO9	I/O/T		
16	GPIO12	IO	VDDPST2		IE	<b>USB_D-</b>				GPIO12	I/O/T	GPIO12	I/O/T		
17	GPIO13	IO	VDDPST2		IE, WPU	<b>USB_D+</b>				GPIO13	I/O/T	GPIO13	I/O/T		
18	GPIO14	IO	VDDPST2		IE					<b>GPIO14</b>	I/O/T	GPIO14	I/O/T		
19	GPIO15	IO	VDDPST2	IE	IE					<b>GPIO15</b>	I/O/T	GPIO15	I/O/T		
20	VDDPST2	Power													
21	U0TXD	IO	VDDPST2		WPU					<b>U0TXD</b>	O	GPIO16	I/O/T	FSPICS0	I1/O/T
22	U0RXD	IO	VDDPST2		IE, WPU					<b>U0RXD</b>	I1	GPIO17	I/O/T	FSPICS1	O/T
23	SDIO_CMD	IO	VDDPST2	WPU	IE					<b>SDIO_CMD</b>	I1/O/T	GPIO18	I/O/T	FSPICS2	O/T
24	SDIO_CLK	IO	VDDPST2	WPU	IE					<b>SDIO_CLK</b>	I1	GPIO19	I/O/T	FSPICS3	O/T
25	SDIO_DATA0	IO	VDDPST2	WPU	IE					<b>SDIO_DATA0</b>	I1/O/T	GPIO20	I/O/T	FSPICS4	O/T
26	SDIO_DATA1	IO	VDDPST2	WPU	IE					<b>SDIO_DATA1</b>	I1/O/T	GPIO21	I/O/T	FSPICS5	O/T
27	SDIO_DATA2	IO	VDDPST2	WPU	IE					<b>SDIO_DATA2</b>	I1/O/T	GPIO22	I/O/T		
28	SDIO_DATA3	IO	VDDPST2	WPU	IE					<b>SDIO_DATA3</b>	I1/O/T	GPIO23	I/O/T		
29	VDDA1	Power													
30	XTAL_N	Analog													
31	XTAL_P	Analog													
32	VDDA2	Power													
33	GND	Power													

\* For details, see Section 2 Pins. Regarding highlighted cells, see Section 2.3.4 Restrictions for GPIOs and LP GPIOs.

## Revision History

Date	Version	Release notes
2023-07-25	v1.0	<ul style="list-style-type: none"><li>• Added descriptions of USB_PU in Table 2-3 <i>QFN40 IO MUX Pin Functions</i> and Table 2-4 <i>QFN32 IO MUX Pin Functions</i>, note 5</li><li>• Updated Section 2.6.3 <i>ROM Messages Printing Control</i></li><li>• Added Section 4.5 <i>ADC Characteristics</i></li><li>• Updated the measurement conditions in Table 4-8 <i>Current Consumption for Bluetooth LE in Active Mode</i> and Table 4-9 <i>Current Consumption for 802.15.4 in Active Mode</i> from –24.0 dBm to –15.0 dBm, and the corresponding peak values</li><li>• Added Section 4.7 <i>Reliability</i></li><li>• Updated the minimum value of RF transmit power range to –15.0 dBm in Table 5-7 <i>Bluetooth LE RF Characteristics</i> and Table 5-17 <i>802.15.4 Transmitter Characteristics - 250 Kbps</i></li><li>• Updated Section 7 <i>Related Documentation and Resources</i></li><li>• Other minor changes</li></ul>
2023-01-16	v0.5	Preliminary release



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