ESP-WROOM-03

Specifications

Version 1.0

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About This Guide

This document introduces the user to the specifications of ESP-WROOM-03 hardware, including the following topics:

Chapter	Title	Subject
Chapter 1	Preface	Provides a preview of ESP-WROOM-03.
Chapter 2	Pin Definitions	Introduces the pin layout and relevant descriptions.
Chapter 3	Functional Descriptions	Describes major functional modules and protocols applied on WROOM-03, including the CPU and internal memory, external flash and SRAM, crystal oscillators, and peripheral interfaces.
Chapter 4	Electrical Characteristics	Lists the electrical data of WROOM-03.
Chapter 5	Schematics	Illustrates the schematics of WROOM-03.

Release Notes

Date	Version	Release notes
2015.12	V1.0	First release.

Note :

This current version is an early release to support initial product developers. The content is subject to change without advance notice.

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1. Preface

ESP-WROOM-03 is a generic but powerful WiFi-BT-BLE MCU module that targets a wide variety of applications ranging from low power sensor networks to the most demanding tasks such as voice encoding, music streaming and MP3 decoding. The core of this module is the ESP32 chip, which is designed to be scalable and adaptive. There are 2 CPU cores that can be individually controlled or powered, and the clock frequency is adjustable from 80 MHz to 240 MHz. The user could even power off the CPU and make use of the low power coprocessor to constantly monitor the peripherals for changes or crossing of thresholds. ESP32 also integrates a rich set of peripherals, ranging from capacitive touch sensors, Hall sensors, low noise sense amplifiers, SD card interface, Ethernet, high speed SDIO/SPI, UART, I2S and I2C. The integration of both Bluetooth, Bluetooth LE and Wi-Fi ensures that a wide range of applications can be targeted, and that it is future proof: using Wi-Fi allows a large physical range and direct connection to the Internet through a Wi-Fi router, while using Bluetooth allows the user to conveniently connect to the phone or broadcast low energy beacons for its detection. The sleep current of the ESP32 chip is less than 5 uA, making it suitable for battery powered and wearable electronics applications. WROOM-03 supports data rates up to 150 Mbps, and 22 dBm output power at the PA to ensure the widest physical range. As such the chip does offer industry leading specifications and the best optimized performance for electronic integration, range and power consumption, and connectivity.

The operating system that has been chosen for ESP32 is freeRTOS with LWIP; TLS 1.2 with hardware acceleration has been built in as well. Encrypted over the air (OTA) upgrade is also supported, so that developers can continually upgrade their products even after their release. New SDK feature, tutorials and example applications will be released over the next few months. The software releases are covered under the ESP32 bug bounty program and any bugs can be reported to bugbounty@espressif.com. As the SDK of WROOM-03 or ESP32 is open-source, the user can build his own platforms and operating systems. For more in-depth discussion of this, the developer can contact john.lee@espressif.com.

WROOM-03 has Espressif's long term support — ESP32 will be covered under Espressif's longevity program and be available for the next 12 years. The design of WROOM-03 will be open-source when it has been fully optimized. FCC, CE, TELEC and KCC certification will be available in Q1 of 2016. It is noted that several TVS components have been integrated in the current version of the module to protect the touch sensor pins of the module from ESD events, since it is expected that many developers will be testing this with their bare fingers. These TVS components will be removed from the module after the beta program. Feedback about the module, chip, API or firmware can be sent to feedback@espressif.com or beta@espressif.com.

The ESP32 chip will be in small volume mass production in February 2016, and mass volume production will be in April 2016. More engineering samples will be available for sale starting in January 2016.

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Table 1-1. WROOM-03 specifications

Categories	Items	Specifications
Wi-Fi	Standards	FCC, CE, TELEC, KCC
	Protocols	802.11 b/g/n/d/e/i/k/r (802.11n up to 150 Mbps)
		A-MPDU and A-MSDU aggregation and 0.4μs guard interval support
	Frequency range	2.4GHz - 2.5GHz
Bluetooth	Protocols	Bluetooth v4.2 BR/EDR and BLE specification
	Radio	NZIF receiver with -90 dBm sensitivity
		Class-1, class-2 and class-3 transmitter
		AFH
	Audio	CVSD and SBC
Hardware	Module interface	SD card, UART, SPI, SDIO, I2C, LED PWM, Motor PWM, I2S, I2C, IR
		GPIO, Capacitive touch sensor, ADC, DAC, LNA pre-amplier
	On-chip sensor	Hall sensor, temperature sensor
	On-board clock	26 MHz crystal, 32 kHz crystal
	Operating voltage	3.0~3.6V
	Operating current	Average: 80 mA
	Operating temperature range	-40° ~ 125°
	Ambient temperature range	Normal temperature
	Package size	18mm x 20mm x 3mm
Software	Wi-Fi mode	station/softAP/SoftAP+station/P2P
	Security	WPA/WPA2, WPS, TLS
	Encryption	WEP/TKIP/AES/RSA/SHA
	Firmware upgrade	UART Download / OTA (via network) / download and write firmware via host
	Software development	Supports Cloud Server Development / SDK for custom firmware development
	Network protocols	IPv4, IPv6, SSL, TCP/UDP/HTTP/FTP
	User configuration	AT Instruction Set, Cloud Server, Android/iOS App

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2. Pin Definition

The pin distribution of ESP-WROOM-03 Module is illustrated in Figure 1.

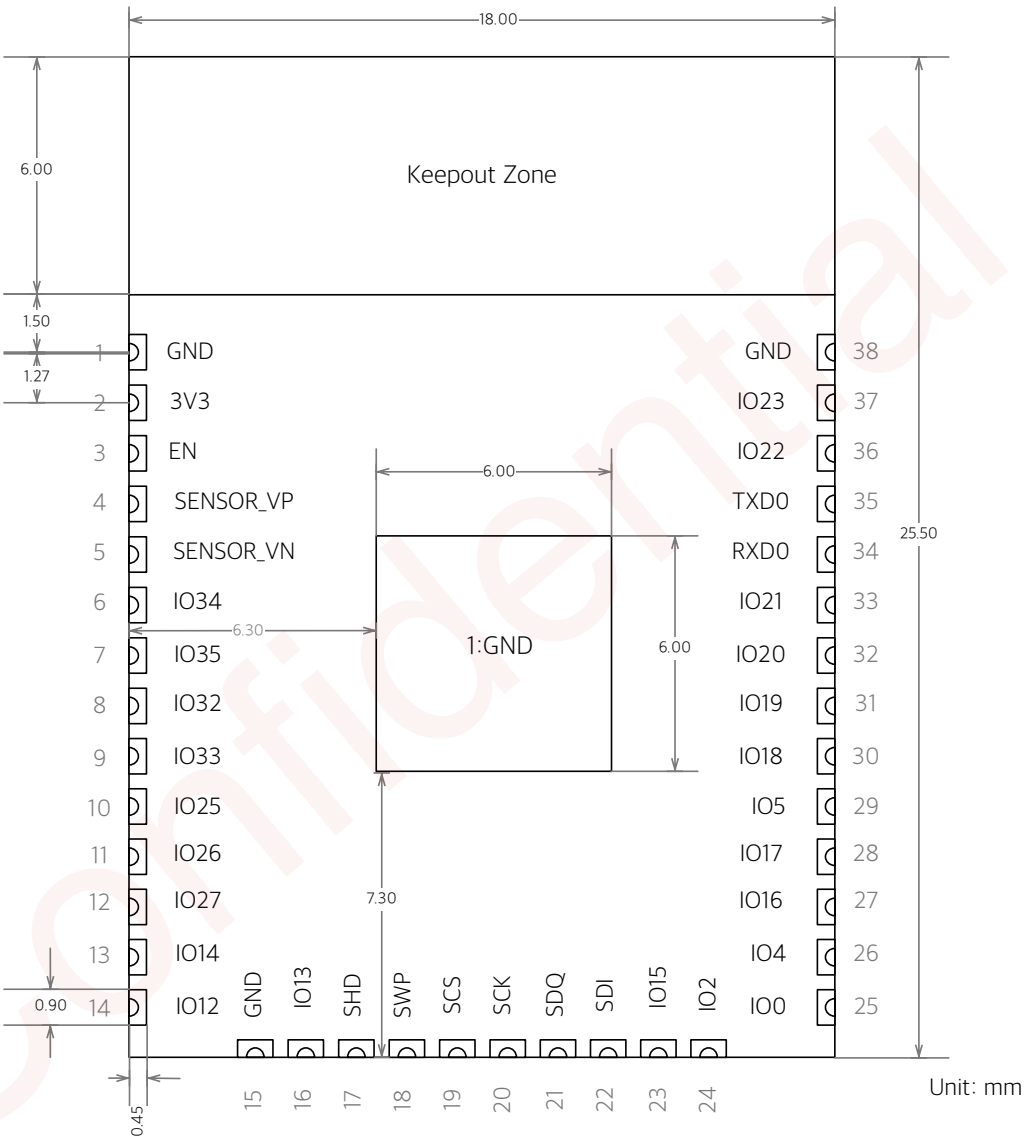

Figure 1. Top view of ESP-WROOM-03

Table 2-1. WROOM-03 dimensions

Length	Width	Height	PAD size (bottom)	Pin pitch
18 mm	25.5 mm	2.55 mm	0.45 mm x 0.9 mm	1.27 mm

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WROOM-03 has 38 pins. Please see the pin definitions in Table 2-2.

Table 2-2. WROOM-03 pin definitions

No.	Name	Function
1	GND	Ground
2	3V3	Power supply
3	EN	Chip-enable signal. Active high.
4	SENSOR_VP	GPI36; ADC_H; ADC1_CH0
5	SENSOR_VN	GPI39; ADC_H; ADC1_CH3
6	IO34	GPI34; ADC1_CH6
7	IO35	GPI35; ADC1_CH7
8	IO32	GPIO32; XTAL_32K_P; ADC1_CH4; TOUCH9
9	IO33	GPIO33; XTAL_32K_N; ADC1_CH5; TOUCH8
10	IO25	GPIO25; DAC_1; ADC2_CH8
11	IO26	GPIO26; DAC_2; ADC2_CH9
12	IO27	GPIO27; ADC2_CH7; TOUCH7
13	IO14	GPIO14; ADC2_CH6; TOUCH6; MTMS; HSPICLK
14	IO12	GPIO12; ADC2_CH5; TOUCH5; MTDI; HSPIQ
15	GND	Ground
16	IO13	GPIO13; ADC2_CH4; TOUCH4; MTCK; HSPID; U0CTS
17	SHD	GPIO9; SD_DATA2; SPIHD; HS1_DATA2; U1RXD
18	SWP	GPIO10; SD_DATA3; SPIWP; HS1_DATA3; U1TXD
19	SCS	GPIO11; SD_CMD; SPICS0; HS1_CMD; U1RTS
20	SCK	GPIO6; SD_CLK; SPICLK; HS1_CLK; U1CTS
21	SDO	GPIO7; SD_DATA0; SPIQ; HS1_DATA0
22	SDI	GPIO8; SD_DATA1; SPID; HS1_DATA1
23	IO15	GPIO15; ADC2_CH3; TOUCH3; MTDO; HSPICS0; U0RTS
24	IO2	GPIO2; ADC2_CH2; TOUCH2; HSPIWP
25	IO0	GPIO0; ADC2_CH1; TOUCH1; CLK_OUT1
26	IO4	GPIO4; ADC2_CH0; TOUCH0; HSPIHD
27	IO16	GPIO16; HS1_DATA4
28	IO17	GPIO17; HS1_DATA5

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29	IO5	GPIO5; VSPICS0; HS1_DATA6
30	IO18	GPIO18; VSPICLK; HS1_DATA7
31	IO19	GPIO19; VSPIQ; HS2_DATA2
32	IO20	GPIO20; VSPID; HS2_DATA3
33	IO21	GPIO21; VSPIHD; HS2_CMD
34	RXD	GPIO3; U0RXD; CLK_OUT2; HS2_DATA0
35	TXD	GPIO1; U0TXD; CLK_OUT3; HS2_DATA1
36	IO22	GPIO22; VSPIWP; HS2_CLK
37	IO23	GPIO23
38	GND	Ground

Strapping pins are sampled during system reset, and the sample values configure ESP32 into specific boot modes.

Please refer to Table 2-3 for detailed boot modes configuration by strapping pins.

Table 2-3. Strapping pin lists

Booting Strapping Configuration			
Pin	Default	SPI Boot	Download Boot
IO0	Pull-up	1	0
TXD0	Pull-up	1	x
IO2	Pull-down	x	0
IO5	Pull-up	1	x

For example, if TXD0, IO2, and IO5 are floating, then IO0 determines which boot mode is used (If IO0 is high, the device is switched to SPI Boot mode. If IO0 is low, the device is switched to Download Boot mode).

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3. Function Description

This chapter describes the modules and functions implemented in WROOM-03.

3.1. CPU and Internal Memory

ESP32 is embedded with two low-power Xtensa® 32-bit LX6 microprocessors. The internal memory includes:

- 128 kBytes ROM for booting and core functions. The two cores have dedicated ROM blocks.
- 416 kBytes on-chip SRAM which are split into 13 blocks of 32 kBytes. Each block of SRAM has an arbiter to mitigate the access conflicts from different CPU and AHB buses. Programmable space accessible to user in heap + data section is around 150 kBytes, and that in code section is about 60 kBytes.
- 8 kBytes SRAM in RTC, which is called recovery memory and can be used for data storage during the deep sleep mode.
- 1 kbits of EFUSE, of which 256 bits are used for the system (MAC address and chip configuration) and the remaining 768 bits are reserved for customer applications, including Flash-Cryption and Chip-ID.

3.2. External Flash and SRAM

WROOM-03 is mounted with a 4 MB external SPI flash to store user programs. If larger definable storage space is required, an SPI flash with larger memory size is preferred. Theoretically speaking, ESP32 supports up to 4 x 16 MBytes external QSPI flash and SRAM.

- OTA is disabled: the minimum flash memory that can be supported is 512 kB.
- OTA is enabled: the minimum flash memory that can be supported is 1 MB.

Several SPI modes can be supported, including Standard SPI, Dual SPI, and Quad SPI.

Therefore, select the correct SPI mode when downloading programs into the flash; otherwise the firmwares/programs you downloaded may not work in the right way.

> **Note:**
>
> Select the correct SPI mode when downloading programs into the flash; otherwise errors might be caused.

ESP32 accesses external QSPI flash and SRAM by the high-speed caches. Up to 8 MBytes of external flash are memory mapped into the CPU code space, supporting 8, 16 and 32-bit access. Code execution is supported. Up to 1 MBytes of external flash and SRAM are memory

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mapped into the CPU data space, supporting 8, 16 and 32-bit access. Data read is supported on the flash and SRAM. Data read/write is supported on the SRAM.

3.3. Crystal Oscillators

The frequencies of the main crystal oscillator supported include 40 MHz, 26 MHz and 24 MHz. The accuracy of crystal oscillators applied should be ±10 PPM, and the operating temperature range should be between -40°C and 125°C.

When using the downloading tools, remember to select the right crystal oscillator type. In circuit design, capacitors C1 and C2, which are connected to the earth, are added to the input and output terminals of the crystal oscillator respectively. The values of the two capacitors can be flexible, ranging from 6 pF to 22 pF. However, the specific capacitive values of C1 and C2 depend on further testing and adjustment of the overall performance of the whole circuit. Normally, the capacitive values of C1 and C2 are within 10 pF if the crystal oscillator frequency is 26 MHz, while the values of C1 and C2 are 10pF<C1, C2<22pF if the crystal oscillator frequency is 40 MHz.

The frequency of the RTC crystal oscillator is typically 32 kHz or 32.768 kHz. The accuracy of this crystal can be out of the range of ±20 PPM, since the internal calibration is applied to correct the frequency offset. When the chip operates in the low power modes, the application chooses the external low speed (32 kHz) crystal clock rather than the internal RC oscillators to achieve the accurate wakeup time.

3.4. Peripheral Interfaces

Table 3-1. Interface description

Interface	Signal	Pin	Function
ADC	ADC1_0 ADC1_3~7 ADC2_0~9	SENSOR_VP, SENSOR_VN, IO34, IO35, IO32, IO33, IO25, IO26, IO27, IO14, IO12, IO13, IO15, IO2, IO0, IO4	Two 12-bit SAR ADCs
Ultra Low Noise Analog Pre-Amplifier	SENSOR_VP SENSOR_VN	IO36, IO39	An ultra low noise analog pre-amplifier for the ADC provides about 60dB gain by using larger capacitors on PCB.
DAC	DAC_1, DAC_2	IO25, IO26	Two 8-bit DACs
Touch Sensor	Touch 0~9	IO4, IO0, IO2, IO15, IO13, IO12, IO14, IO27, IO33, IO32	Capacitive touch sensors
SD / SDIO / MMC Host Controller	SD card signals (HS2_CLK, HS2_CMD, HS2_DATA0~3)	IO22, IO21, RXD, TXD, IO19, IO20	Supports SD memory card V3.01 standard

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Interface	Signal	Pin	Function
Motor PWM	PWM_OUT0~7 PWM_FLT_IN0~1 PWM_CAP_IN0~2	Any GPIO	Four channels of 16-bit timers to generate PWM waveforms; each channel consists of a pair of output signals. Two fault detection signals.
LED PWM	LEDC_HS_SIG_OUT0~7	Any GPIO	8 independent channels running at 80MHz clock. Duty accuracy: 16bit@1kHz
UART	U0RXD_in U0CTS_in U0DSR_in U0TXD_out U0RTS_out U0DTR_out U1RXD_in U1CTS_in U1TXD_out U1RTS_out	Any GPIO	Two UART devices with hardware flow-control and DMA
I2C	I2CEXT0_SCL_in I2CEXT0_SDA_in I2CEXT1_SCL_in I2CEXT1_SDA_in I2CEXT0_SCL_out I2CEXT0_SDA_out I2CEXT1_SCL_out I2CEXT1_SDA_out	Any GPIO	Two I2C devices in slave or master modes
I2S	I2SO_DATA_in I2SO_BCK_in I2SO_WS_in I2SO_DATA_out I2SO_BCK_out I2SO_WS_out I2SI_DATA_in I2SI_BCK_in I2SI_WS_in I2SI_DATA_out I2SI_BCK_out I2SI_WS_out	Any GPIO	Stereo input and stereo output from/to the audio codec
Remote Controller	RMT_SIG_IN0~7 RMT_SIG_OUT0~7	Any GPIO	Eight channels of IR transmitter and receiver for various waveforms
Parallel QSPI	SPIHD, SPIWP, SPICS0, SPICLK, SPIQ, SPID	SHD, SWP, SCS, SCK, SDO, SDI	Supports Standard SPI, Dual SPI, and Quad SPI that can be connected to the external flash and SRAM.
	HSPICLK, HSPICS0, HSPIQ, HSPID, HSPIHD, HSPIWP	IO14, IO15, IO12, IO13, IO4, IO2	
	VSPICLK, VSPICS0, VSPIQ, VSPID, VSPIHD, VSPIWP	IO18, IO5, IO19, IO20, IO21, IO22	

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Interface	Signal	Pin	Function
General Purpose SPI	HSPIQ_in/HSPIQ_out HSPID_out/HSPID_in HSPICLK_out/HSPICLK_in HSPI_CS0_out/ HSPI_CS0_in HSPI_CS1_out HSPI_CS2_out VSPIQ_in/VSPIQ_out VSPID_out/VSPID_in VSPICLK_out/VSPICLK_in VSPI_CS0_out/ VSPI_CS0_in VSPI_CS1_out| VSPI_CS2_out	Any GPIO	Standard SPI consists of clock, chip-select, MOSI and MISO. These SPIs can be connected to LCD and other external devices. They support the following features: (a) both master and slave modes (b) 4 sub-modes of the SPI format transfer that depend on the polarity (POL) and the phase (PHA) (c) CLK frequencies by a divider (d) up to 64byte FIFO and DMA
JTAG	MTDI, MTCK, MTMS, MTDO	IO12, IO13, IO14, IO15	JTAG for software debugging

Note:

Functions of Motor PWM, LED PWM, UART, I2C, I2S and Remote Controller can be configured to any GPIO.

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4. Electrical Characteristics

4.1. Absolute Maximum Ratings

Table 4-1. Absolute Maximum Ratings

Rating	Condition	Value	Unit
Storage temperatue	-	-40 ~ 125	℃
Maximum soldering temperature	-	260	℃
Supply voltage	IPC/JEDEC J-STD-020	+3.0 ~ +3.6	V

4.2. Recommended Operating Conditions

Table 4-2. Recommended operating conditions

Operating condition	Symbol	Min	Typ	Max	Unit
Operating temperature	-	-40	20	125	℃
Supply voltage	VDD	3.0	3.3	3.6	V

4.3. Digital Terminal Characteristics

Table 4-3. Digital terminal characteristics

Terminals	Symbol	Min	Typ	Max	Unit
General Specifications (V_{BAT} = 3.3V, T_A = 27°C, unless otherwise specified)					
Input logic level low	V_{IL}	-0.3	-	0.25VDD	V
Input logic level high	V_{IH}	0.75VDD	-	VDD+0.3	V
Output logic level low	V_{OL}	N	-	0.1VDD	V
Output logic level high	V_{OH}	0.8VDD	-	N	V

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4.4. Bluetooth LE Radio

4.4.1. Receiver

Table 4-4. Receiver characteristics - BLE

Parameter	Conditions	Min	Typ	Max	Unit
General Specifications (V_{BAT} = 3.3V, T_A = 27°C, unless otherwise specified)					
Sensitivity @0.1% BER		-	-92	-	dBm
Maximum received signal @0.1% BER		0	-	-	dBm
Co-channel C/I		-	+10	-	dB
Adjacent channel selectivity C/I	F=F0 + 1 MHz	-	-5	-	dB
	F=F0 - 1 MHz	-	-5	-	dB
	F=F0 + 2 MHz	-	-35	-	dB
	F=F0 - 2 MHz	-	-25	-	dB
	F=F0 + 3 MHz	-	-45	-	dB
	F=F0 - 3 MHz	-	-25	-	dB
Out-of-band blocking performance	30 MHz-2000 MHz	-10	-	-	dBm
	2000 MHz-2400 MHz	-27	-	-	dBm
	2500 MHz-3000 MHz	-27	-	-	dBm
	3000 MHz-12.5 GHz	-10	-	-	dBm
Intermodulation		-36	-	-	dBm

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4.4.2. Transmit

Table 4-5. Transmit characteristics - BLE

Parameter	Conditions	Min	Typ	Max	Unit
General Specifications (V_{BAT} = 3.3V, T_A = 27°C, unless otherwise specified)					
RF transmit power	-	-	+7.5	+10	dBm
RF power control range	-	-	25	-	dB
Adjacent channel transmit power	F=F0 + 1 MHz	-	-14.6	-	dBm
	F=F0 - 1 MHz	-	-12.7	-	dBm
	F=F0 + 2 MHz	-	-44.3	-	dBm
	F=F0 - 2 MHz	-	-38.7	-	dBm
	F=F0 + 3 MHz	-	-49.2	-	dBm
	F=F0 - 3 MHz	-	-44.7	-	dBm
	F=F0 + >3 MHz	-	-50	-	dBm
	F=F0 - > 3MHz	-	-50	-	dBm
$\triangle f1_{avg}$ Maximum modulation	-	-	265	-	kHz
$\triangle f2_{max}$ Minimum modulation	-	-	247	-	kHz
$\triangle f2_{avg}/\triangle f1_{avg}$	-	-	-0.92	-	-
ICFT	-	-	-10	-	kHz
Drift rate	-	-	0.7	-	kHz/50 us
Drift	-	-	2	-	kHz

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4.5. Wi-Fi Radio

Table 4-6. Wi-Fi radio characteristics

Description	Min	Typical	Max	Unit
General Characteristics (V_{BAT} = 3.3V, T_A = 27°C, unless otherwise specified)				
Input frequency	2412	-	2484	MHz
Input impedance	-	50	-	Ω
Input reflection	-	-	-10	dB
Output power of PA for 72.2 Mbps	15.5	16.5	17.5	dBm
Output power of PA for 11b mode	19.5	20.5	21.5	dBm
Sensitivity				
DSSS, 1 Mbps	-	-98	-	dBm
CCK, 11 Mbps	-	-91	-	dBm
OFDM, 6 Mbps	-	-93	-	dBm
OFDM, 54 Mbps	-	-75	-	dBm
HT20, MCS0	-	-93	-	dBm
HT20, MCS7	-	-73	-	dBm
HT40, MCS0	-	-90	-	dBm
HT40, MCS7	-	-70	-	dBm
MCS32	-	-89	-	dBm
Adjacent Channel Rejection				
OFDM, 6 Mbps	-	37	-	dB
OFDM, 54 Mbps	-	21	-	dB
HT20, MCS0	-	37	-	dB
HT20, MCS7	-	20	-	dB

4.6. Power Consumption

With the advanced power management technologies, ESP32 can be switched to different power modes as follows:

- **Power mode**

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- **Shutdown (Turn-off)**: RTC is disabled and all registers are cleared. The chip is totally powered down.
- **Active mode**: In the active mode, the chip radio is powered on. The chip can receive, transmit, or listen.
- **Modem sleep mode**: In the modem sleep mode, the CPU is operational and the clock is configurable. The Wi-Fi / Bluetooth baseband and radio are disabled.
- **Light sleep mode**: The CPU is paused in the light sleep mode. The RTC and ULP-coprocessor are running. Any wake-up events (MAC, host, RTC timer, or external interrupts) will wake up the chip.
- **Deep sleep mode**: Only RTC is powered on. Wi-Fi and Bluetooth connection data are stored in RTC memory. The ULP-coprocessor can work.

- **Sleep Pattern**
  - **Association sleep pattern**: The power mode switches between the active mode and light sleep mode during this sleep pattern. The CPU, Wi-Fi, Bluetooth, and radio are woken up at pre-determined intervals to keep Wi-Fi / BT connections alive.
  - **Sensor-monitored deep sleep pattern**: The ULP co-processor is enabled or disabled at intervals depending on the measured data from sensors.

The power consumption varies with different power modes/sleep patterns and work status of functional modules (see Table 4-7).

Table 4-7. Power consumption by power modes

Power mode	Comment	Power consumption
Active mode (RF working)	Wi-Fi Tx packet 13 dBm ~ 21 dBm	160 ~ 260 mA
	Wi-Fi / BT Tx packet 0 dBm	120 mA
	Wi-Fi / BT Rx and listening	80 ~ 90 mA
	Association sleep pattern (by light sleep)	0.9 mA@DTIM3 1.2 mA@DTIM1
Modem sleep	The CPU is powered on	Max speed: 20 mA Normal: 5 ~ 10 mA Slow speed: 3 mA
Light sleep		0.8 mA
Deep sleep	The ULP-coprocessor is powered on	0.5 mA
	Sensor-monitored deep sleep pattern	25 uA @1% duty
	RTC timer + recovery-memory	20 uA
	RTC timer only	5 uA
Shutdown (Turn-off)		2 uA

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4.7. Reflow Profile

Table 4-8. Reflow profile

T_S max to TL (Ramp-up Rate)	3℃/second max
Preheat Temperature Min. (T_S Min.) Temperature Typ. (T_S Typ.) Temperature Min. (T_S Max.) Time (T_S)	 150℃ 175℃ 200℃ 60~180 seconds
Ramp-up rate (T_L to T_P)	3℃/second max
Time maintained above: --Temperature(T_L)/ Time(T_L)	217℃/60 - 150 seconds
Peak temperature (T_P)	260℃ max , for 10 seconds
Target peak temperature (T_P Target)	260℃ +0/-5℃
Time within 5°C of actual peak(t_P)	20~40 second
T_S max to T_L (Ramp-down Rate)	6℃/second max
Tune 25°C to Peak Temperature (t)	8 minutes max

Note:

The 32 kHz crystal is on board connected to ESP32's GPIO32 and GPIO33. To use ADC, Touch or GPIO functions of IO32 and IO33, please remove the 32 kHz crystal and its capacitors — C13 and C17, and solder the 0ohm resisters — R5 and R6.

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5. Schematics

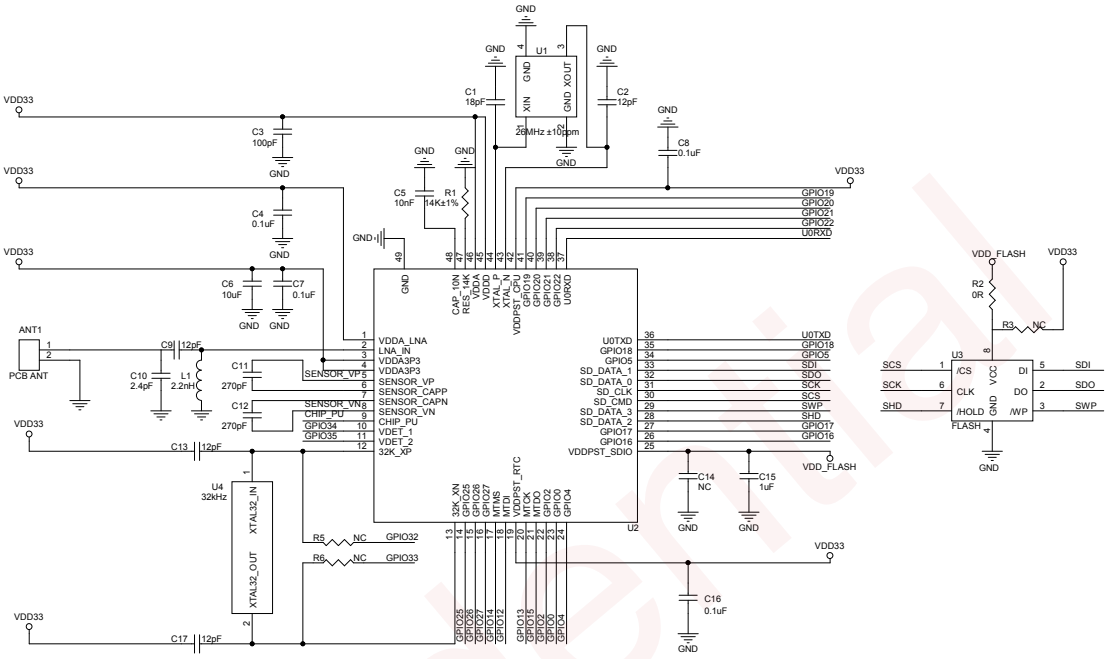

Figure 2. ESP-WROOM-03 schematics

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Espressif System

IOT Team

http://bbs.espressif.com

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