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Manual

ESP-32U

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Achieve Update

Date	Version	Content
2018-1-10	V1.0	Inition
2018-11-1	V2.0	Revise the Definition of Pins

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1. Introduction

ESP-WROOM-32 module is a universal WiFi-BT-BLE MCU module with powerful functions and wide applications. It can be used in low-power sensor networks and high-demand tasks, such as voice coding, audio streaming and MP3 decoding. The core of this module is ESP32 chip, which is scalable and adaptive. Two CPU cores can be controlled or powered on separately. The adjustable range of clock frequency is from 80 MHz to 240 MHz. Users can cut off CPU power and use low-power coprocessors to continuously monitor the state changes of peripherals or whether some analog quantities exceed the threshold. ESP-WROOM-32 module also integrates a wealth of peripherals, including capacitive touch sensor, Hall sensor, low noise sensor amplifier, SD card interface, Ethernet interface, high-speed SDIO/SPI, UART, I2S and I2C. ESP-WROOM-32 module is hereinafter referred to as ESP32.

ESP-32 integrates traditional Bluetooth, low-power Bluetooth and Wi-Fi, and has a wide range of applications: Wi-Fi supports a wide range of communication connections, but also supports direct Internet connection through routers; Bluetooth allows users to connect to mobile phones or broadcast BLE Beacon for signal detection. The sleep current of ESP32 chip is less than 5uA, which makes it suitable for wearable electronic devices powered by batteries. The data transmission rate supported by ESP-32 is up to 150 Mbps. After power amplifier, the output power can reach 22 dBm, which can realize the maximum range of wireless communication. Therefore, the chip has the industry's leading technical specifications, and has the best performance in high integration, wireless transmission distance, power consumption and network connectivity. ESP3 2's operating system is free RTOS with LWIP, and TLS 1.2 with hardware acceleration function is built-in. The chip also supports OTA encryption upgrades, and developers can continue to upgrade after the product is released. Software releases are included in the ESP32 bug reward program, and users can report any bugs to bug-bounty@espressif.com.

Users can send feedback on modules, chips, APIs and firmware to yichone@doit.am.

Table 1 ESP32 specifications

Type	Item	Specifications
Wi-Fi	standard	FCC/CE/TELEC/KCC
	protocol	802.11 b/g/n/d/e/i/k/r (802.11n, speed 150 Mbps)
		A-MPDU and A-MSDU aggregates to support 0.4us protection interval
	frequency	2.4~2.5 GHz
Bluetooth	protocol	Compliance with Bluetooth v4.2 BR/EDR and BLE standards
	RF	NZIF Receiver with-98 dBm Sensitivity
		Class-1, Class-2 and Class-3 transmitter

		AFH
	audio frequency	CVSD and SBC Audio frequency
Hard ware	Interface	SD, UART, SPI, SDIO, I2C, LED PWM, motor PWM, I2S, I2C, IR
		GPIO, Capacitive Touch Sensor, ADC, DACLNA Preamplifier
	On-chip sensor	Hall Sensor and Temperature Sensor
	On-board clock	26 MHz crystal oscillator and 32 kHz crystal oscillator
	working voltage	2.2~3.6V
	working current	Mean: 80 mA
	Working temperature range	-40°C~+85°C 1)
	Ambient temperature range	Normal temperature
	Packaging dimensions	18 mm x 20 mm x 3 mm
Softw are	Wi-Fi mode	Station/softAP/SoftAP+station/P2P
	Security mechanism	WPA/WPA2/WPA2-Enterprise/WPS
	Encryption type	AES/RSA/ECC/SHA
	Firmware update	UART download / OTA (download and write firmware via network / host)
	software development	Supporting Cloud Server Development/SDK for User Firmware Development
	Network Protocol	IPv4、IPv6、SSL、TCP/UDP/HTTP/FTP/MQTT
	User Configuration	AT+Instruction Set, Cloud Server, Android/iOS APP

2 Pins Definition

2.1 Layout

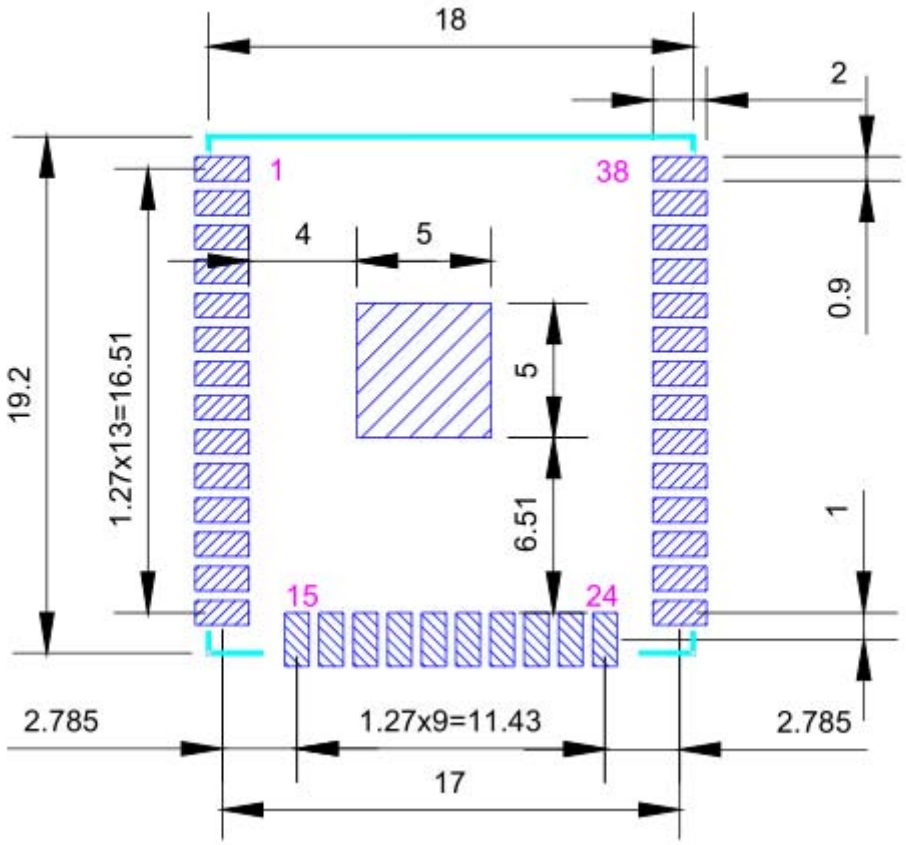


Figure 1 ESP32 size

Table 2 ESP32 size

length	width	heigth	PAD(bottom)	Distance between pins	Shield Cover Height	PCB thickness
18 mm	19.2±0.1mm	2.8 ± 0.1 mm	0.45 mm x 0.9 mm	1.27 mm	2 mm	0.8 ± 0.1 mm

2.2 pins description

ESP32 has 38 pins, which are shown in Table 3.

Table3 ESP32 pins definition

Name	Num	Function
GND	1	GND
3V3	2	power
EN	3	Enabling chip, high level effective.
SENSOR_VP	4	GPI36, SENSOR_VP, ADC_H, ADC1_CH0, RTC_GPIO0

SENSOR_VN	5	GPI39, SENSOR_VN, ADC1_CH3, ADC_H, RTC_GPIO3
IO34	6	GPI34, ADC1_CH6, RTC_GPIO4
IO35	7	GPI35, ADC1_CH7, RTC_GPIO5
IO32	8	GPIO32, XTAL_32K_P (32.768 kHz crystal oscillator input), ADC1_CH4, TOUCH9, RTC_GPIO9
IO33	9	GPIO33, XTAL_32K_N (32.768 kHz crystal oscillator output), ADC1_CH5, TOUCH8, RTC_GPIO8
IO25	10	GPIO25, DAC_1, ADC2_CH8, RTC_GPIO6, EMAC_RXD0
IO26	11	GPIO26, DAC_2, ADC2_CH9, RTC_GPIO7, EMAC_RXD1
IO27	12	GPIO27, ADC2_CH7, TOUCH7, RTC_GPIO17, EMAC_RX_DV
IO14	13	GPIO14, ADC2_CH6, TOUCH6, RTC_GPIO16, MTMS, HSPICLK, HS2_CLK, SD_CLK, EMAC_TXD2
IO12	14	GPIO12, ADC2_CH5, TOUCH5, RTC_GPIO15, MTDI, HSPIQ, HS2_DATA2, SD_DATA2, EMAC_TXD3
GND	15	GND
IO13	16	GPIO13, ADC2_CH4, TOUCH4, RTC_GPIO14, MTCK, HSPID, HS2_DATA3, SD_DATA3, EMAC_RX_ER
SHD/SD2	17	GPIO9, SD_DATA2, SPIHD, HS1_DATA2, U1RXD
SWP/SD3	18	GPIO10, SD_DATA3, SPIWP, HS1_DATA3, U1TXD
SCS/CMD	19	GPIO11, SD_CMD, SPICS0, HS1_CMD, U1RTS
SCK/CLK	20	GPIO6, SD_CLK, SPICLK, HS1_CLK, U1CTS
SDO/SD0	21	GPIO7, SD_DATA0, SPIQ, HS1_DATA0, U2RTS
SDI/SD1	22	GPIO8, SD_DATA1, SPID, HS1_DATA1, U2CTS
IO15	23	GPIO15, ADC2_CH3, TOUCH3, MTDO, HSPICS0, RTC_GPIO13, HS2_CMD, SD_CMD, EMAC_RXD3
IO2	24	GPIO2, ADC2_CH2, TOUCH2, RTC_GPIO12, HSPIWP, HS2_DATA0, SD_DATA0
IO0	25	GPIO0, ADC2_CH1, TOUCH1, RTC_GPIO11, CLK_OUT1, EMAC_TX_CLK
IO4	26	GPIO4, ADC2_CH0, TOUCH0, RTC_GPIO10, HSPIHD, HS2_DATA1, SD_DATA1, EMAC_TX_ER
IO16	27	GPIO16, HS1_DATA4, U2RXD, EMAC_CLK_OUT
IO17	28	GPIO17, HS1_DATA5, U2TXD, EMAC_CLK_OUT_180
IO5	29	GPIO5, VSPICS0, HS1_DATA6, EMAC_RX_CLK
IO18	30	GPIO18, VSPICLK, HS1_DATA7
IO19	31	GPIO19, VSPIQ, U0CTS, EMAC_TXD0

NC	32	-
IO21	33	GPIO21, VSPIHD, EMAC_TX_EN
RXD0	34	GPIO3, U0RXD, CLK_OUT2
TXD0	35	GPIO1, U0TXD, CLK_OUT3, EMAC_RXD2
IO22	36	GPIO22, VSPIWP, U0RTS, EMAC_TXD1
IO23	37	GPIO23, VSPID, HS1_STROBE
GND	38	GND

2.3 Strapping pins

ESP32 has six Strapping pins. The software can read the values of these six bits in the register "GPIO_STRAPPING". During the reset process, the Strapping pin sampled the level and stored it in the latch. The latch was "0" or "1" and remained until the chip turned off or turned off.

Each Strapping pin is connected to an internal pull-up/pull-down. If a Strapping pin is not connected or the connected external line is in a high impedance state, the internal weak pull-up/pull-down will determine the default value of the input level of the Strapping pin. To change the value of Strapping bits, users can apply external pull-down/pull-up resistors or apply GPIO of host MCU to control the Strapping pin level when ESP32 is powered on and reset. After reduction, the function of Strapping pin is the same as that of common pin. Detailed startup mode for configuring Strapping pins is shown in Table 4.

Table 4 Strapping pins

Built-in LDO (VDD_SDIO) voltage				
PIN	default	3.3V		1.8V
MTDI/GPIO12	Pull down	0		1
System start mode				
pin	default	SPI Flash start mode		Download start mode
GPIO0	Pull-up	1		0
GPIO2	Pull-down	none		0
During system start-up, U0TXD outputs log print information				
Pin	default	U0TXD flip		U0TXD static
MTDO/GPIO15	Pull up	1		0
SDIO Slave signal input and output timing				
PIN	default	Drop edge input Drop Edge	Drop edge input Rising edge output	Rising edge input Drop Edge	Rising edge input Rising edge

		Output		Output	output
MTDO/GPIO15	Pull up	0	0	1	1
GPIO5	Pull up	0	1	0	1

3 Function description

3.1 CPU and memory

ESP32 has two low power Xtensa < 32-bit LX6 MCUs built in. On-chip storage includes:
1. ROM of 448KBytes for program startup and kernel function call
2. 520 KBytes on-chip SRAM for data and instruction storage
3. The SRAM of 8KBytes in RTC, which is RTC slow memory, can be accessed by coprocessor in Deep-sleep mode.
4. The SRAM of 8kBytes in RTC, namely RTC fast memory, can be used for data storage and access by the main CPU when RTC starts in Deep-sleep mode.
5 and 1 kbit EFUSE, 256 bits of which are system-specific (MAC address and chip settings); the remaining 768 bits are reserved for user applications, including Flash encryption and chip ID.

3.2 external Flash and SRAM

ESP32 supports up to four 16 MBytes of external QSPI Flash and static random access memory (SRAM) with hardware encryption based on AES, thus protecting developers' programs and data.

ESP32 accesses external QSPI Flash and SRAM through caching. Up to 16 MBytes, Flash maps to CPU code space, supports 8-bit, 16-bit and 32-bit access, and executes code.

Up to 8 MBytes of external Flash and SRAM are mapped to the CPU data space, supporting 8-bit, 16-bit and 32-bit access. Flash only supports read operations, while SRAM supports read and write operations.

3.3 Crystal oscillator

The support frequencies are 40 MHz, 26 MHz and 24 MHz. The accuracy of the crystal oscillator is between (+10 PPM) and the working temperature range is from - 40 C to 85 C.

Choose the correct crystal type when using the download tool. In the circuit design, the ground regulating capacitors C1 and C2 are added to the input and output terminals of the crystal oscillator respectively. The values of the two capacitors can be set flexibly, ranging from 6 pF to 22 pF. However, the specific capacitance value can not be determined until the overall performance of the whole circuit is matched. Generally speaking, if the frequency of crystal oscillation is 26 MHz, the capacitance value of C1 and C2 is less than 10 pF; if the frequency of crystal oscillation is 40 MHz, the capacitance value of C1 and C2 is 10 pF < C1, C2 < 22 pF.

The frequency of RTC crystal oscillator is usually 32 kHz or 32.768 kHz. Because internal calibration is used to correct the frequency offset, the frequency of crystal oscillator may exceed (+20 PPM). When the chip works in low power mode, the device should choose external low speed 32 kHz crystal clock instead of internal RC oscillator to obtain accurate wake-up time.

3.4 Power consumption

ESP32 has advanced power management technology and can switch between various power saving modes.

1. Power saving mode

Active mode: The chip RF is working. The chip can receive, transmit and listen to signals.

Modem-sleep mode: The CPU keeps running and the clock can be configured. Wi-Fi/Bluetooth baseband and RF turn off.

Light-sleep mode: CPU pauses. RTC and ULP coprocessors run. Any wake-up event (MAC, host, RTC timer or external interrupt) wakes up the chip.

Deep-sleep mode: Only RTC is working. Wi-Fi and Bluetooth connection data are stored in RTC. The ULP coprocessor keeps running.

Hibernation mode: The built-in 8 MHz oscillator and ULP coprocessor are disabled. RTC memory recovery power was cut off. Only one RTC clock timer on a slow clock and some RTC GPIO are active. RTC timer or RTC GPIO can wake up the chip from Hibernation mode.

2、Sleep patterns

Associated Sleep Mode: Power-saving mode switching between Active mode and Modem-sleep mode/Light-sleep mode. CPU, Wi-Fi, Bluetooth and RF are waked up in accordance with the predetermined period to ensure Wi-Fi/Bluetooth connection.

Ultra-low power sensor monitoring mode: the main system is in Deep-sleep mode, ULP coprocessor is regularly turned on or off to measure sensor data. Based on the data measured by the sensor, the ULP coprocessor decides whether to wake up the main system. Power consumption varies with the mode of power saving/sleep mode and the working state of functional modules (see Table 5).

Table 5 Power consumption under different power-saving modes

Power saving mode	Description	Power consuption
Active (RF)	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
	Associated Sleep Patterns (Associated with Light-sleep Patterns)	0.9 mA@DTIM3, 1.2 mA@DTIM1
Modem-sleep	CPU in working state	Max speed: 20 mA
		Normal speed: 5~10 mA
		Slow speed: 3 mA
Light-sleep	-	0.8 mA
Deep-sleep	ULP coprocessor in working state	0.5 mA
	Ultra-Low Power Sensor Monitoring Mode	25 uA @1 % duty

	RTC Timer + RTC Memory	20uA
Hibernation	Only RTC timer is in working state.	2.5 uA

3.5 Peripheral Interface

Table 6: Interface description

Interface	Signal	Pins	Function
ADC	ADC1_CH0	SENSOR_VP	Two 12-bit SAR ADCs
	ADC1_CH3	SENSOR_VN	
	ADC1_CH4	IO32	
	ADC1_CH5	IO33	
	ADC1_CH6	IO34	
	ADC1_CH7	IO35	
	ADC2_CH0	IO4	
	ADC2_CH1	IO0	
	ADC2_CH2	IO2	
	ADC2_CH3	IO15	
	ADC2_CH4	IO13	
	ADC2_CH5	IO12	
	ADC2_CH6	IO14	
	ADC2_CH7	IO27	
	ADC2_CH8	IO25	
	ADC2_CH9	IO26	
Ultra-low Noise Pre-analog Amplifier	SENSOR_VP	IO36	The larger capacitance on the PCB provides about 60 dB gain for the ADC.
	SENSOR_VN	IO39	
DAC	DAC_1	IO25	Two 8-bit DACs
	DAC_2	IO26	
Touch Sensor	TOUCH0	IO4	Capacitive Touch Sensor
	TOUCH1	IO0	
	TOUCH2	IO2	
	TOUCH3	IO15	
	TOUCH4	IO13	
	TOUCH5	IO12	
	TOUCH6	IO14	
	TOUCH7	IO27	
	TOUCH8	IO33	
	TOUCH9	IO32	

SDSDIO / MMC host controller	HS2_CLK	MTMS	SD Card Complying with V3.01 Standard
	HS2_CMD	MTDO	
	HS2_DATA0	IO2	
	HS2_DATA1	IO4	
	HS2_DATA2	MTDI	
	HS2_DATA3	MTCK	
Motor PWM	PWM0_OUT0~2	Any GPIO	Three 16-bit timers generate PWM waveforms. Each channel contains a pair of output signals. Three fault detection signals. Three even capture signals. Three synchronous signals.
	PWM1_OUT_IN0~2		
	PWM0_FLT_IN0~2		
	PWM1_FLT_IN0~2		
	PWM0_CAP_IN0~2		
	PWM1_CAP_IN0~2		
	PWM0_SYNC_IN0~2		
	PWM1_SYNC_IN0~2		
LED PWM	ledc_hs_sig_out0~7	Any GPIO	16 separate channels running at 80 MHz clock or RTC clock. Duty cycle accuracy: 16-bit.
	ledc_ls_sig_out0~7		
UART	U0RXD_in	Any GPIO	Two UART devices with hardware flow control and DMA
	U0CTS_in		
	U0DSR_in		
	U0TXD_out		
	U0RTS_out		
	U0DTR_out		
	U1RXD_in		
	U1CTS_in		
	U1TXD_out		
	U1RTS_out		
	U2RXD_in		
	U2CTS_in		
	U2TXD_out		
	U2RTS_out		
I2C	I2CEXT0_SCL_in	Any GPIO	Two I2C devices working in slave or host

	I2CEXT0_SDA_in		mode
	I2CEXT1_SCL_in		
	I2CEXT1_SDA_in		
	I2CEXT0_SCL_out		
	I2CEXT0_SDA_out		
	I2CEXT1_SCL_out		
	I2CEXT1_SDA_out		
I2S	I2S0I_DATA_in0~15	Any GPIO	For input and output of serial stereo data and output of parallel LCD data
	I2S0O_BCK_in		
	I2S0O_WS_in		
	I2S0I_BCK_in		
	I2S0I_WS_in		
	I2S0I_H_SYNC		
	I2S0I_V_SYNC		
	I2S0I_H_ENABLE		
	I2S0O_BCK_out		
	I2S0O_WS_out		
	I2S0I_BCK_out		
	I2S0I_WS_out		
	I2S0O_DATA_out0~23		
	I2S1I_DATA_in0~15		
	I2S1O_BCK_in		
	I2S1O_WS_in		
	I2S1I_BCK_in		
	I2S1I_WS_in		
	I2S1I_H_SYNC		
	I2S1I_V_SYNC		
	I2S1I_H_ENABLE		
	I2S1O_BCK_out		
	I2S1O_WS_out		
	I2S1I_BCK_out		
	I2S1I_WS_out		

	I2S1O_DATA_out0~23		
Infrared remote controller	RMT_SIG_IN0~7	Any GPIO	8-channel IR transceiver, supporting different waveform standards
	RMT_SIG_OUT0~7		
Parallel QSPI	SPIHD	SHD/SD2	Support Standard SPI, Dual SPI and Quad SPI, External Flash and SRAM can be connected
	SPIWP	SWP/SD3	
	SPICS0	SCS/CMD	
	SPICLK	SCK/CLK	
	SPIQ	SDO/SD0	
	SPID	SDI/SD1	
	HSPICLK	IO14	
	HSPICS0	IO15	
	HSPIQ	IO12	
	HSPID	IO13	
	HSPIHD	IO4	
	HSPIWP	IO2	
	VSPICLK	IO18	
	VSPICS0	IO5	
	VSPIQ	IO19	
	VSPID	IO23	
	VSPIHD	IO21	
	VSPIWP	IO22	
General SPI	HSPIQ_in/_out	Any GPIO	Standard SPI includes clock, chip selection, MOSI and MISO. These SPIs can connect LCD and other peripherals. It has the following characteristics: (a) Host and slave mode of operation; (b) Transmission in SPI format according to four modes of polarity (POL) and phase (PHA); (c) Configurable CLK frequency; (d) FIFO and DMA of 64 Byte.
	HSPID_in/_out		
	HSPICLK_in/_out		
	HSPI_CS0_in/_out		
	HSPI_CS1_out		
	HSPI_CS2_out		
	VSPIQ_in/_out		
	VSPID_in/_out		
	VSPICLK_in/_out		
	VSPI_CS0_in/_out		
	VSPI_CS1_out		

	VSPI_CS2_out		
JTAG	MTDI	IO12	JTAG for Software Debugging
	MTCK	IO13	
	MTMS	IO14	
	MTDO	IO15	
SDIO slave	SD_CLK	IO6	SDIO interface conforms to V2.0 industry standard
	SD_CMD	IO11	
	SD_DATA0	IO7	
	SD_DATA1	IO8	
	SD_DATA2	IO9	
	SD_DATA3	IO10	
EMAC	EMAC_TX_CLK	IO0	Ethernet MAC with MII/RMII interface
	EMAC_RX_CLK	IO5	
	EMAC_TX_EN	IO21	
	EMAC_TXD0	IO19	
	EMAC_TXD1	IO22	
	EMAC_TXD2	IO14	
	EMAC_TXD3	IO12	
	EMAC_RX_ER	IO13	
	EMAC_RX_DV	IO27	
	EMAC_RXD0	IO25	
	EMAC_RXD1	IO26	
	EMAC_RXD2	TXD	
	EMAC_RXD3	IO15	
	EMAC_CLK_OUT	IO16	
	EMAC_CLK_OUT_180	IO17	
	EMAC_TX_ER	IO4	
	EMAC_MDC_out	Any GPIO	
	EMAC_MDI_in	Any GPIO	
	EMAC_MDO_out	Any GPIO	
	EMAC_CRS_out	Any GPIO	
	EMAC_COL_out	Any GPIO	

4 Electrical characteristics

Note: Without special instructions, the test environment for the specifications listed in this chapter is: VBAT= 3.3V, TA= 27 degrees °C.

4.1 Limit parameters

Table limit parameters

Rating value	Condition	Value	Unite
Storage temperature	-	-40~85	°C
Maximum welding temperature	-	260	°C
Power supply voltage	IPC/JEDEC J-STD-020	+2.2-+3.6	V

4.2 Recommended working conditions

Table 8 Recommended working conditions

work environment	Name	Min	Classical	Max	Unite
working temperature	-	-40	20	85	°C
Power supply voltage	VDD	2.2	3.3	3.6	V

4.3 Digital Port Characteristics

Table 9 Digital Port Characteristics

Port	Name	Min	Classical	Max	Unite
Low input logic level	V/L	-0.3	-	0.25VDD	V
High input logic level		0.75VDD	-	VDD+0.3	V
Low output logic level	VOL	N	-	0.1VDD	V
High output logic level		0.8VDD	-	N	V

4.4 Wi-Fi RF

Table 10 Wi-Fi RF characteristics

Description	Min	Classical	Max	Unite
Universal features				
Input frequency	2412	-	2484	MHz
Input impedance	-	50	-	Ω
Input Reflection	-	-	-10	dB

Output power of PA	15.5	16.5	21.5	dBm
Sensitivity				
DSSS, 1 Mbps	-	-98	-	dBm
CCK, 11 Mbps	-	-90	-	dBm
OFDM, 6 Mbps	-	-93	-	dBm
OFDM, 54 Mbps	-	-75	-	dBm
HT20, MCSO	-	-93	-	dBm
HT20, MCS7	-	-73	-	dBm
HT40, MCSO	-	-90	-	dBm
HT40, MCS7	-	-70	-	dBm
MCS32	-	-91	-	dBm
Neighborhood inhibition				
OFDM, 6 Mbps	-	37	-	dB
OFDM, 54 Mbps	-	21	-	dB
HT20, MCS0	-	37	-	dB
HT20, MCS7	-	20	-	dB

4.5 Low Power Bluetooth Radio Frequency

4.5.1 Receiver

Table 11 BLE receiver characteristics

Parameters	Condition	Min	Classical	Max	Unite
Sensitivity @0.1% BER	-	-	-98	-	dBm
Max received signal @0.1 % BER	-	0	-	-	dBm
Common Channel C/I	-	-	+10	-	dB
Neighborhood selectivity C/I	F = F0 + 1 MHz	-	-5	-	dB
	F = F0 - 1 MHz	-	-5	-	dB
	F = F0 + 2 MHz	-	-25	-	dB
	F = F0 - 2 MHz	-	-35	-	dB
	F = F0 + 3 MHz	-	-25	-	dB
	F = F0 - 3 MHz	-	-45	-	dB
Anti-out-of-band blocking	30 MHz - 2000 MHz	-10	-	-	dBm

performance	2000 MHz - 2400 MHz	-27	-	-	dBm
	2500 MHz - 3000 MHz	-27	-	-	dBm
	3000 MHz - 12.5 GHz	-10	-	-	dBm
Intermodulation performance	-	-36	-	-	dBm

4.5.2 Transmitter

Table 12 BLE Emitter Characteristics

Parameters	Condition	Min	Classical	Max	Unite
Radio Frequency Transmitting Power	-	-	+7.5	+10	dBm
Radio Frequency Power Control Range	-	-	25	-	dB
Neighborhood 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 - > 3 MHz	-	-50	-	dBm
Δf1avg	-	-	-	265	kHz
Δf2max	-	247	-	-	kHz
Δf2avg/Δf1avg	-	-	-0.92	-	-
ICFT	-	-	-10	-	kHz
Frequency drift rate	-	-	0.7	-	kHz/50us
Frequency drift	-	-	2	-	kHz

4.6 Reflow Profile

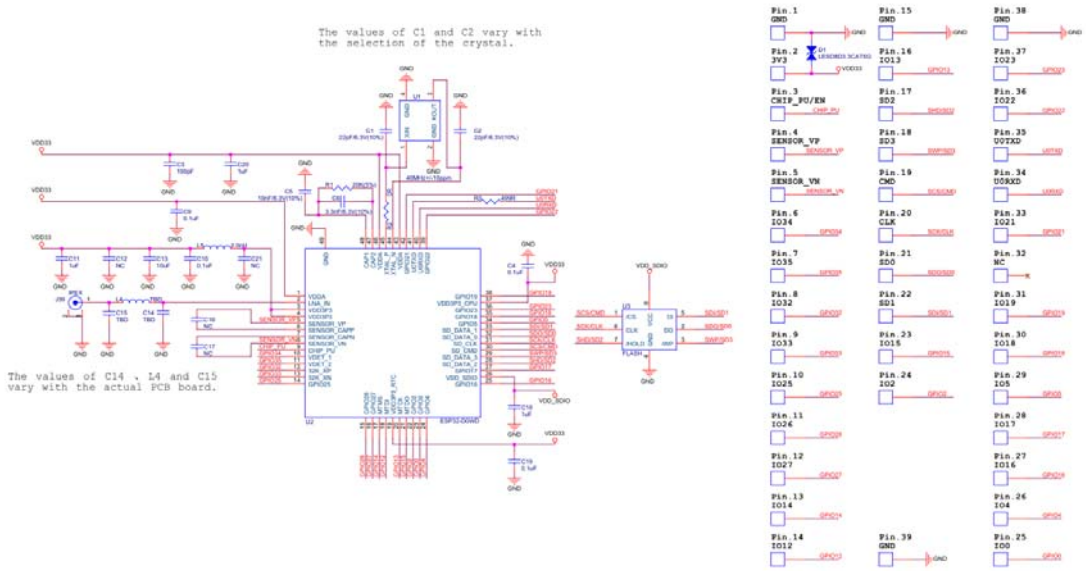
Table 13 Temperature Curve of Reflow Welding

Item	value
Temperature rise rate TS Max to TL	Max 3°C/s
Preheat	
Minimum Temperature Value (TS Min.)	150°C
Typical Temperature Value (TSTyp.)	175°C
Maximum temperature (TS Max.)	200°C

Time (TS)	60-180s
Heating rate (TL to TP)	Max 3°C/s
Duration: Temperature (TL)/Time (TL)	217°C/60~150s
Peak Temperature (TP)	Max temperature 260°C, duration 10s
Target Temperature Peak (TP Target Value)	260°C +0/-5°C
Duration of actual peak temperature (tP) 5°C	20~40s
Cooling rate TS Max to TL	Max 6°C/s
Time required to adjust from 25°C to peak temperature (t)	Longest 8minutes

Description: 32 kHz board crystal oscillator connects GPIO32 and GPIO33 of ESP32. In order to use the ADC, Touch or GPIO functions of IO32 and IO33, 32 kHz crystal oscillators and their capacitors C13 and C17 need to be removed, and 0 ohm resistors R5 and R6 need to be welded.

5 Schematic diagram



ESP32-WROOM-32U Schematic diagram

6 The recommended PCB design

ESP32-WROOM-32U module can be welded directly to PCB board. For the ESP-32 version of the external antenna, due to the external antenna, the module placement requirements are not high, please adjust as appropriate. The specification of the external antenna connector is shown in the figure below.

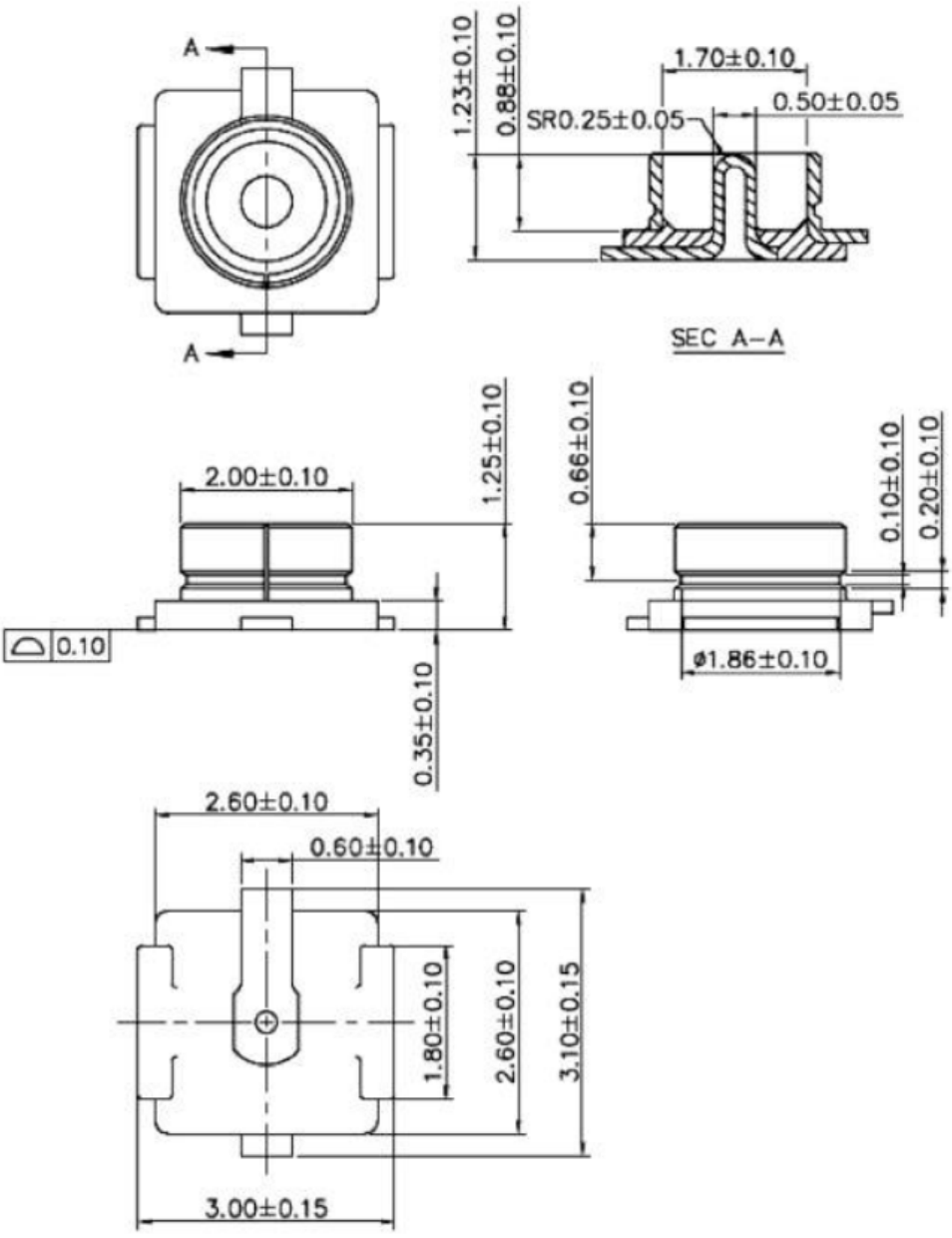
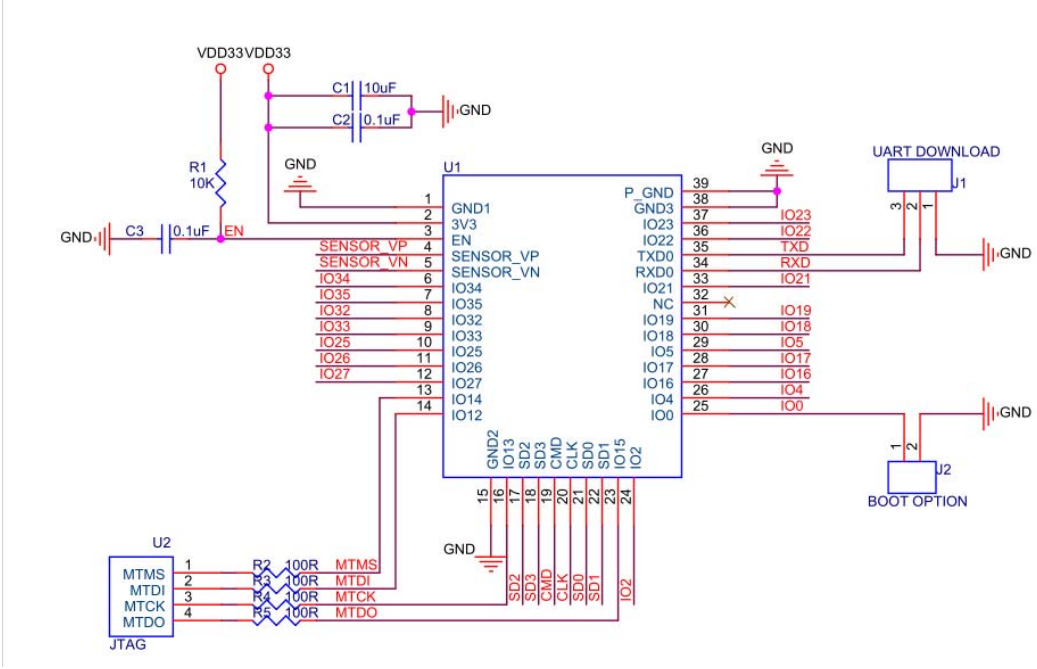


Figure 9.1 External antenna connector

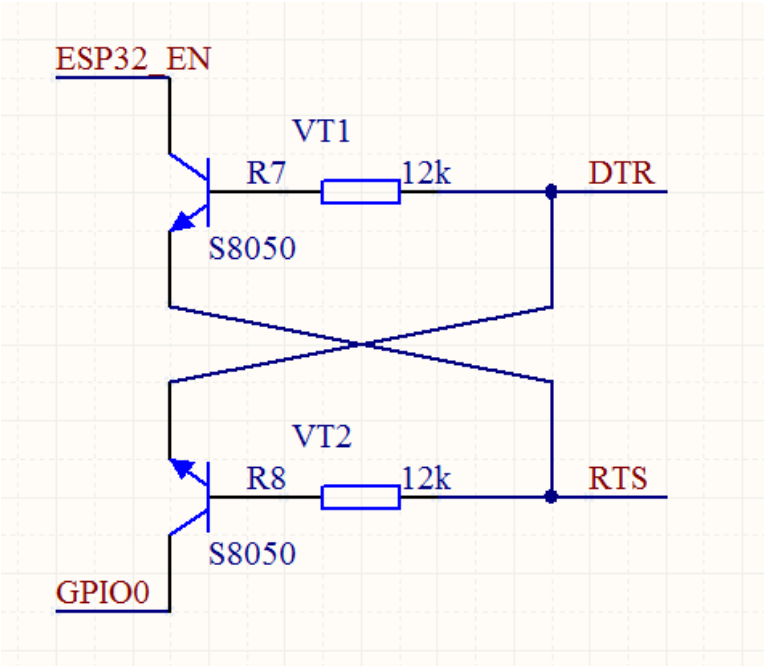
Appendix 1. Minimum system



Note: The power consumption of ESP-32 module is relatively large. It is recommended to supply power independently.

Appendix 2. Automatic Burning Circuit

Connecting EN and GPIO pins of module with DTR and RTS of serial chip can realize software control operation mode.



Appendix.

From DOIT	
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IoT Application	*智能建筑云*
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