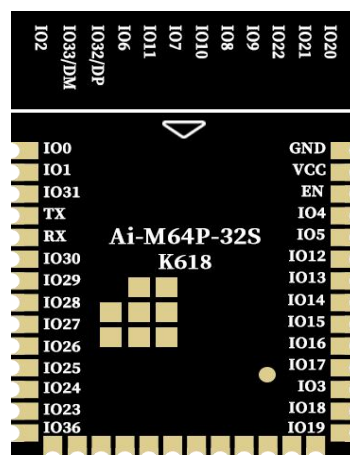


Ai-M64P-32S Specification

Version V1.0.1

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Document Revision History

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1 Product Overview

The Ai-M64P-32S is a standardized wireless module based on the Bouffalo Lab BL616CL RF chip, specifically designed for ultra-low power, high-performance, and high-security IoT scenarios. Fully retaining the chip-level RF performance and full-function peripherals, the module undergoes rigorous RF matching and reliability verification with plug-and-play capability, significantly reducing the development barriers and mass-production risks of end products. The product has five core features: strong signal performance, low power consumption, high integration, security and reliability, and ultra-compact package, while also supporting backward compatibility.

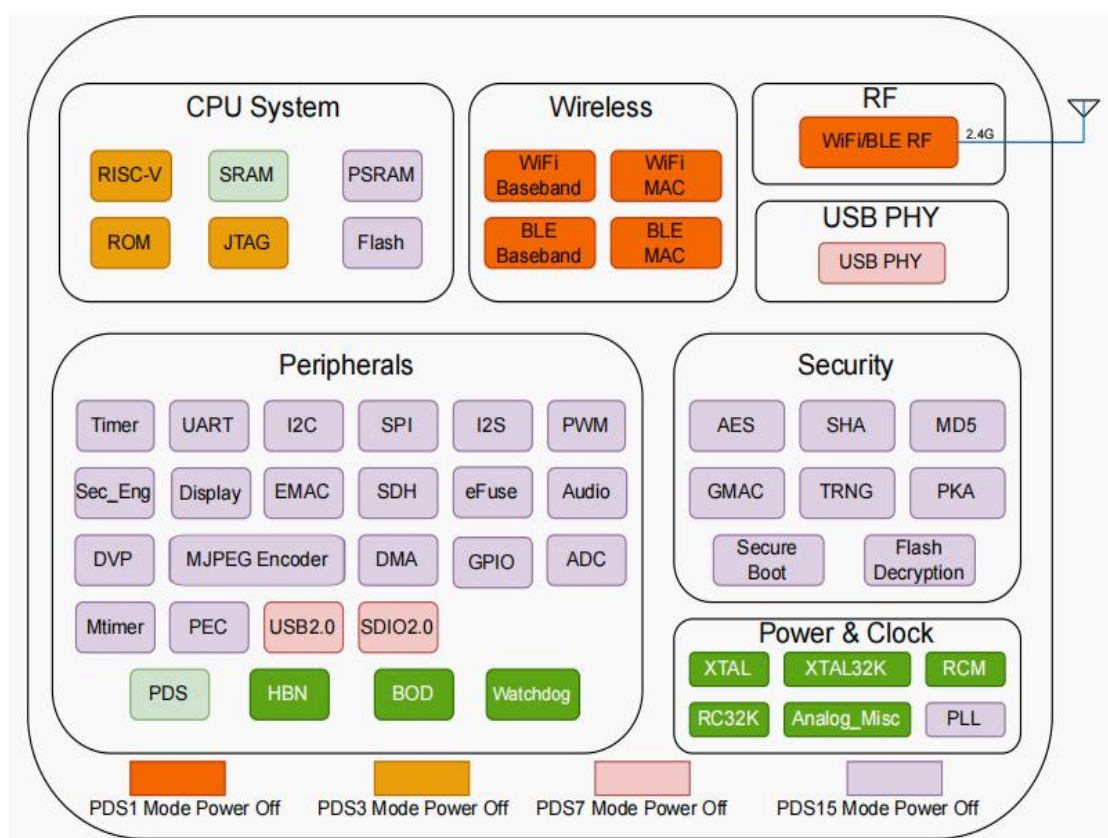


Figure 1 Main Chip Architecture Diagram

1.1 Features

● Wi-Fi 6

- ✧ Supports IEEE 802.11b/g/n/ax, 20MHz bandwidth, 1T1R
- ✧ Fully supports OFDMA, TWT, LDPC, STBC, Beamformee, and RX diversity, enabling more stable, longer-range, and more power-efficient concurrent connections for multiple devices
- ✧ Receiver sensitivity reaches -99dBm@1Mbps, providing superior wall penetration and long-range coverage compared with similar products
- ✧ Transmit power reaches 23dBm@1Mbps, providing sufficient link margin and no disconnection in weak network environments

● BLE 5.3 Long Range and Low Latency

- ✧ Supports BLE 5.3 with multiple data rates: 2Mbps, 1Mbps, 500kbps, and 125kbps
- ✧ Receiver sensitivity reaches -99dBm@125kbps
- ✧ Supports multi-connection, extended advertising, AOI/AOD, compatible with gateways and sensor nodes

● Wi-Fi/BLE Coexistence

- ✧ Built-in coexistence engine at chip level. No external switch is required, and dual-mode TDD operation is supported without interference
- ✧ Supports BLE-assisted Wi-Fi fast connection, with over 50% faster provisioning speed

● High Computing Performance and Large Memory

- ✧ 32-bit RISC-V CPU, up to 320MHz with FPU, supporting edge computing
- ✧ Built-in 388KB SRAM, 224KB OCRAM, 160KB WRAM, 4KB HBN RAM, optional 2/4/8MB Flash and 4/8MB PSRAM

● Full-Function Interfaces, One Module Replacing Multiple Chips

- ✧ Integrated USB2.0 HS, EMAC 10/100M, DVP camera, DBI display, MJPEG codec
- ✧ Rich peripherals: 3*UART, 2*I2C, 2*SPI, 1*I2S, 1*PWM (4 channels), 1*16-bit GPADC (12 channels), and 1*Touch interface

● Industrial-grade Low Power Consumption and Security

- ✧ Supports PDS (Power Down Sleep) and HBN (Hibernate) modes. Sleep current is at the μ A level, helping extend battery life
- ✧ Secure boot, firmware encryption and signature, TrustZone, and full hardware encryption with AES/SHA/PKA/TRNG, protecting against cracking and tampering

● High Reliability and Easy Mass Production

- ✧ Normal operating temperature: -40–85°C (customizable to -40–105°C)
- ✧ Pre-certified RF parameters shorten the certification cycle, plug-and-play

Note: For features not listed, please refer to the Bouffalo Lab BL616CL chip datasheet.

1.2 Application Scenarios

- Audio and Video Multimedia
- Internet of Things (IoT)
- Mobile Devices
- Smart Home
- Central Control Devices

2 Key Specifications

Table 1 Key Specifications

Model	Ai-M64P-32S
Package	SMD-40
Dimensions	25.5*18.0*3.1 (mm)
Antenna Type	On-board antenna/I-PEX connector antenna
Frequency Range	2400–2483.5MHz
Operating Temperature	-40–85°C
Storage Conditions	-40–125°C, <90% RH
Power Supply Range	Supply voltage: 2.97–3.63V, typical value 3.3V; supply current >500mA
Available I/Os	37 by default
UART Baud Rate	115200bps by default
Security	WPS/WEP/WPA/WPA2/WPA3
Flash	4MB by default, up to 16MB

3 Electrical Characteristics

3.1 Recommended Operating Conditions

Table 2 Recommended Operating Conditions

Symbol	Parameter	Min	Typ	Max	Unit
VCC	Supply Voltage	2.97	3.3	3.63	V
I	Supply Current	500	-	-	mA

3.2 I/O DC Electrical Characteristics

Table 3 I/O DC Electrical Characteristics

Symbol	Parameter	Min	Typ	Max	Unit
VIH	High-level Input Voltage	2	-	-	V
VIL	Low-level Input Voltage	-	-	0.8	V
VOH	High-level Output Voltage	-	0.9*VCC	-	V
VOL	Low-level Output Voltage	-	0.1*VCC	-	V

3.3 Electrostatic Discharge

The Ai-M64P-32S is an ESD-sensitive device and requires special precautions during handling.



Figure 2 ESD Protection Symbol

3.4 Wi-Fi RF Performance

Table 4 Wi-Fi RF Performance

Description	Typ			Unit
Frequency Range	2400–2483.5			MHz
Output Power				
Mode	Min	Typ	Max	Unit
802.11b, 11Mbps	-	19	23	dBm
802.11g, 54Mbps	-	18	20	dBm
802.11n, HT20 (MCS7)	-	18	19	dBm
802.11ax, HE20 (MCS9)	-	16	17	dBm
Receiver Sensitivity				
Mode	Min	Typ	Max	Unit
802.11b, 1Mbps	-99	-	-	dBm
802.11b, 11Mbps	-90	-	-	dBm
802.11g, 6Mbps	-93	-	-	dBm
802.11g, 54Mbps	-78	-	-	dBm
802.11n, HT20 (MCS7)	-76	-	-	dBm
802.11ax, HE20 (MCS9)	-69	-	-	dBm

3.5 BLE RF Performance

Table 5 BLE RF Performance

Description	Typ			Unit
Frequency Range	2400–2483.5			MHz
Output Power				
Data Rate Mode	Min	Typ	Max	Unit
1Mbps	-	10	15	dBm
2Mbps	-	10	15	dBm
Receiver Sensitivity				
Data Rate Mode	Min	Typ	Max	Unit
1Mbps Sensitivity @ 30.8% PER	-99	-	-	dBm
2Mbps Sensitivity @ 30.8% PER	-97	-	-	dBm

3.6 Power Consumption

The following power consumption data are measured based on a 3.3V power supply and an ambient temperature of 25°C.

- The POUT power for all transmit modes is measured at the antenna interface.
- All transmission data are measured at 100% duty cycle in continuous transmit mode.

Table 6 Power Consumption

Mode	Min	Avg	Max	Unit
TX 802.11b, 11Mbps, POUT = +23dBm	-	435	-	mA
TX 802.11g, 54Mbps, POUT = +20dBm	-	352	-	mA
TX 802.11n, MCS7, POUT = +19dBm	-	338	-	mA
TX 802.11ax, MCS9, POUT = +17dBm	-	290	-	mA
RX 802.11b, Packet Length 1500 bytes	-	84.5	-	mA
RX 802.11g, Packet Length 1500 bytes	-	84.5	-	mA
RX 802.11n, Packet Length 1500 bytes	-	84.5	-	mA
RX 802.11ax, Packet Length 1500 bytes	-	84.5	-	mA
PDS (Tickless 3), Wi-Fi Disconnected	-	45	-	μA
PDS (Tickless 3), Wi-Fi Connected	-	256	-	μA
PDS (Tickless 10), Wi-Fi Disconnected	-	45	-	μA
PDS (Tickless 10), Wi-Fi Connected	-	90	-	μA
HBN Mode	-	5	-	μA

4.1 Module Dimensions

4.2 Shield Cover Marking Information

4.3 External Antenna Connector Dimensions

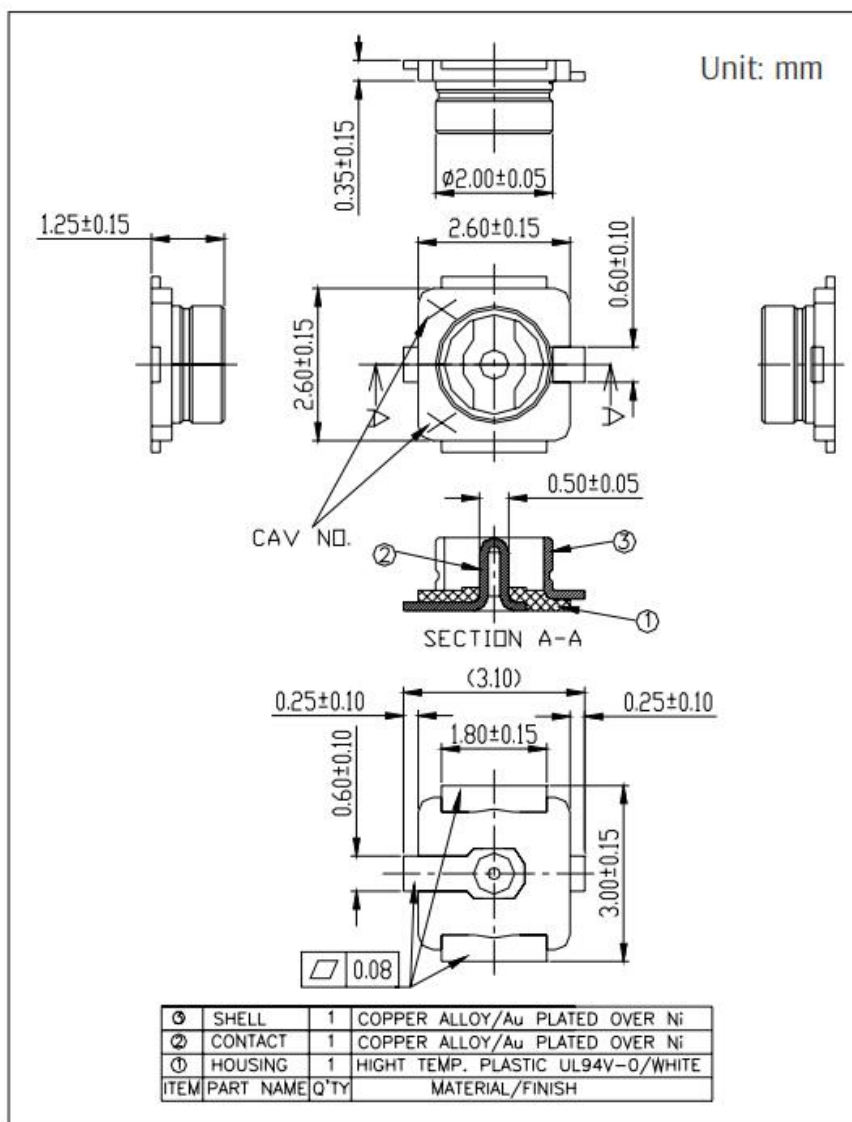
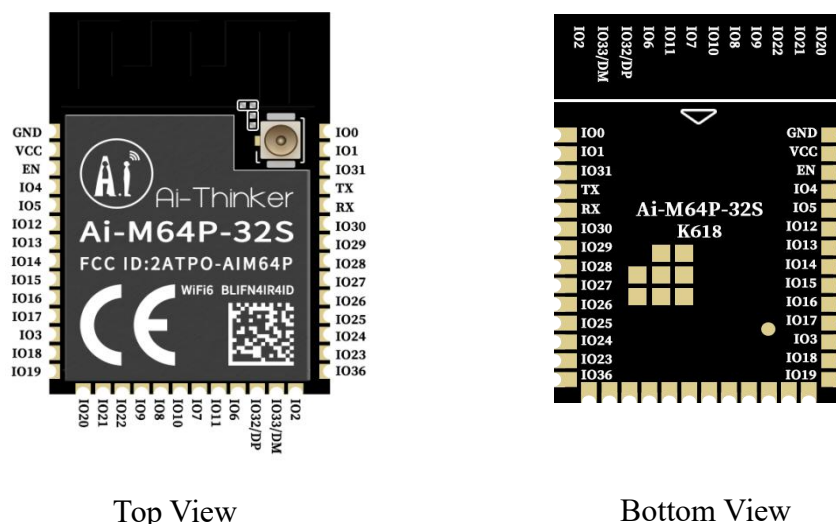


Figure 5 External Antenna Connector Dimensions (Unit: mm)

5 Pin Definition

The Ai-M64P-32S module exposes a total of 40 pins, as shown in the pin diagram. The pin function definition table provides the detailed interface specifications.



Top View

Bottom View

Figure 6 Pin Diagram

Table 7 Pin Function Definition

No.	Name	Function
1	GND	Ground
2	VCC	3.3V power supply; supply current recommended >500mA
3	EN	Default chip enable pin, active-high
4	IO4	GPIO4/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/PWM0/ADC_CH4 (Default available. This IO is shared with the module's internal 32.768kHz crystal input pin. If the module is customized with an internal mounted 32.768kHz crystal, this IO is NC.)
5	IO5	GPIO5/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/PWM0/ADC_CH5 (Default available. This IO is shared with the module's internal 32.768kHz crystal output pin. If the module is customized with an internal mounted 32.768kHz crystal, this IO is NC.)
6	IO12	GPIO12/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/PWM0/ADC_CH8
7	IO13	GPIO13/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/PWM0/ADC_CH9
8	IO14	GPIO14/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/PWM 0

9	IO15	GPIO15/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/PWM0
10	IO16	GPIO16/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/PWM0
11	IO17	GPIO17/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/PWM0
12	IO3	GPIO3/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/PWM0/ADC_CH3 (Default unavailable. This IO is internally connected to the module DC-DC for low-power use. If low power is not required and this IO needs to be used, please contact Ai-Thinker for customization.)
13	IO18	GPIO18/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/PWM0
14	IO19	GPIO19/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/PWM0
15	IO20	GPIO20/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/PWM0
16	IO21	GPIO21/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/PWM0
17	IO22	GPIO22/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/PWM0
18	IO9	GPIO9/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/PWM0 (Default available. This IO is shared with the module's internal Flash pin. If the module is customized with internal mounted Flash, this IO is NC.)
19	IO8	GPIO8/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/PWM0. (Default available. This IO is shared with the module's internal Flash pin. If the module is customized with internal mounted Flash, this IO is NC.)
20	IO10	GPIO10/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/PWM0 (Default available. This IO is shared with the module's internal Flash pin. If the module is customized with internal mounted Flash, this IO is NC.)
21	IO7	GPIO7/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/PWM0/ADC_CH7 (Default available. This IO is shared with the module's internal Flash pin. If the module is customized with internal mounted Flash, this IO is NC.)
22	IO11	GPIO11/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/PWM0 (Default available. This IO is shared with the module's internal Flash pin. If the module is customized with internal mounted Flash, this IO is NC.)
23	IO6	GPIO6/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/PWM0/ADC_CH6 (Default available. This IO is shared with the module's internal Flash pin.

		If the module is customized with internal mounted Flash, this IO is NC.)
24	IO32/DP	USB_DP/GPIO32/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/PWM0/ADC_CH10
25	IO33/DM	USB_DM/GPIO33/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/PWM0/ADC_CH11
26	IO2	GPIO2/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/PWM0/ADC_CH2 (Default unavailable. This IO is internally connected to the module DC-DC for low-power use. If low power is not required and this IO needs to be used, please contact Ai-Thinker for customization.)
27	IO36	NC by default and unavailable. Please contact Ai-Thinker if required. GPIO36/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/PWM0
28	IO23	GPIO23/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/PWM0
29	IO24	GPIO24/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/PWM0
30	IO25	GPIO25/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/PWM0
31	IO26	GPIO26/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/PWM0
32	IO27	GPIO27/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/PWM0
33	IO28	GPIO28/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/PWM0
34	IO29	GPIO29/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/PWM0
35	IO30	GPIO30/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/PWM0
36	RX	GPIO35/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/PWM0
37	TX	GPIO34/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/PWM0
38	IO31	GPIO31/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/PWM0
39	IO1	GPIO1/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/PWM0/ADC_CH1
40	IO0	GPIO0/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/PWM0/ADC_CH0
Note: 1. IO36 and the test point on the module's bottom side can both be used as Bootstrap pins. If it is high at the moment of power-on, the module enters flashing mode. If it is low at the moment of power-on, the module boots normally. The module is internally pulled low by default.		

6 Schematic

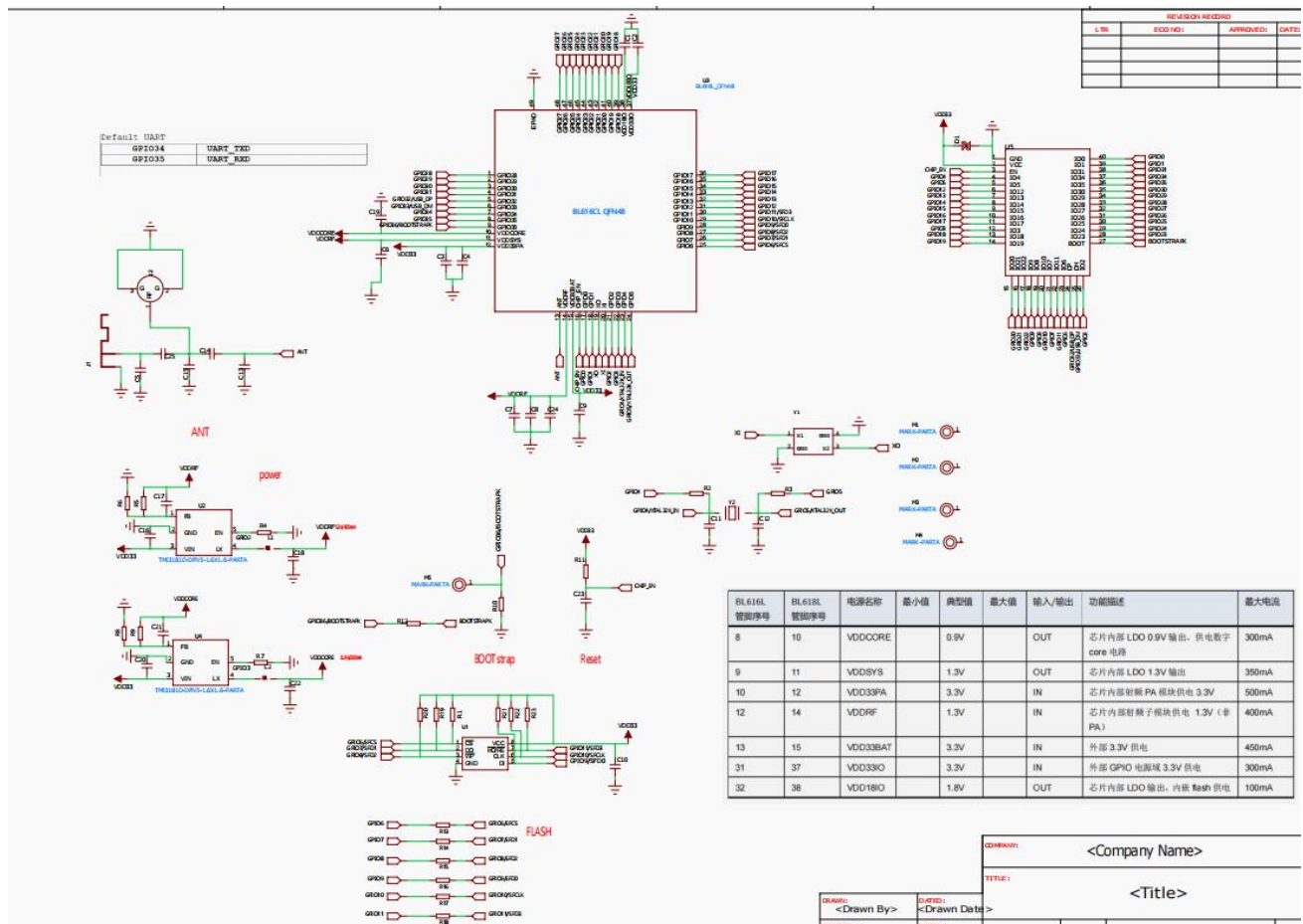


Figure 7 Schematic

7 Antenna Parameters

7.1 Antenna Gain and Efficiency

Table 8 Antenna Gain and Efficiency

No.	1	2	3	4	5	6	7	8	9	10	11
Frequency (MHz)	2400	2410	2420	2430	2440	2450	2460	2470	2480	2490	2500
Gain (dBi)	0.99	1.21	1.39	1.31	1.55	1.47	1.54	1.60	1.69	1.35	1.77
Efficiency (%)	51.24	53.39	56.41	57.07	57.38	58.33	57.25	55.55	55.26	55.35	57.00

7.2 Antenna Radiation Pattern

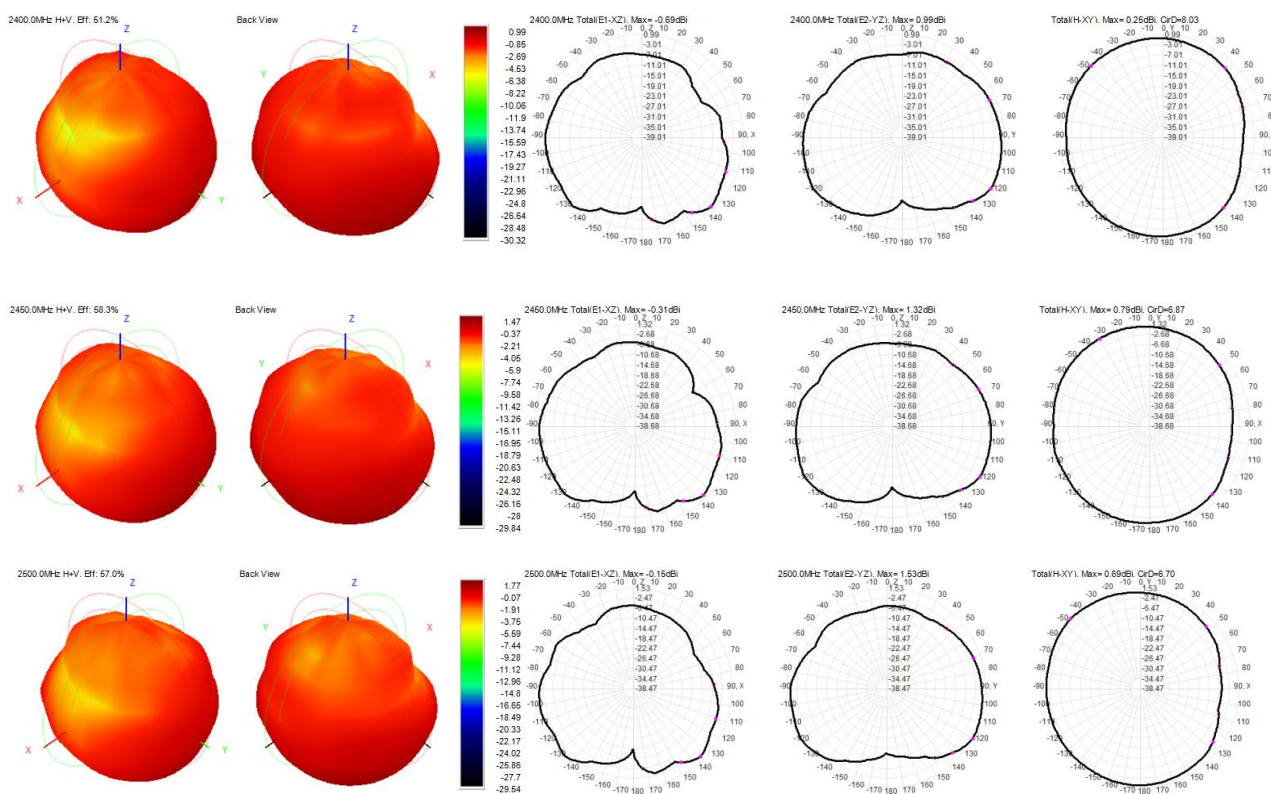


Figure 8 Antenna Radiation Pattern

8 Design Guide

8.1 Application Reference Circuit

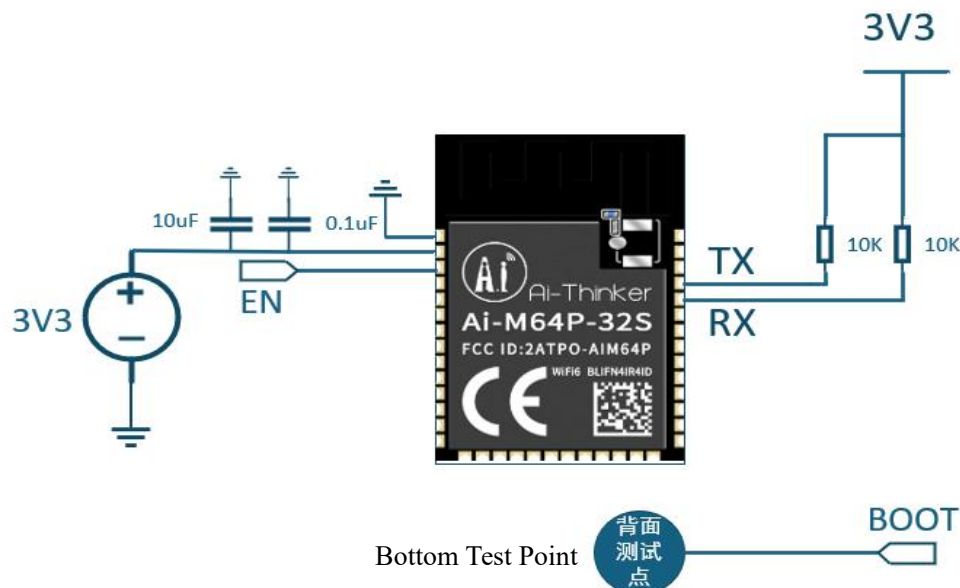


Figure 9 Application Reference Circuit

- VCC supply voltage: 2.97–3.63V. The external power supply output current is recommended to be above 500mA.
- IO36 and the test point on the bottom side can both be used as Bootstrap pins. If the level is high at the moment of power-on, the module enters flashing mode. If the level is low at the moment of power-on, the module boots normally. The module is internally pulled low by default.
- IO36 is NC by default; contact Ai-Thinker if this pin needs to be externally led out.

8.2 Recommended PCB Footprint Dimensions

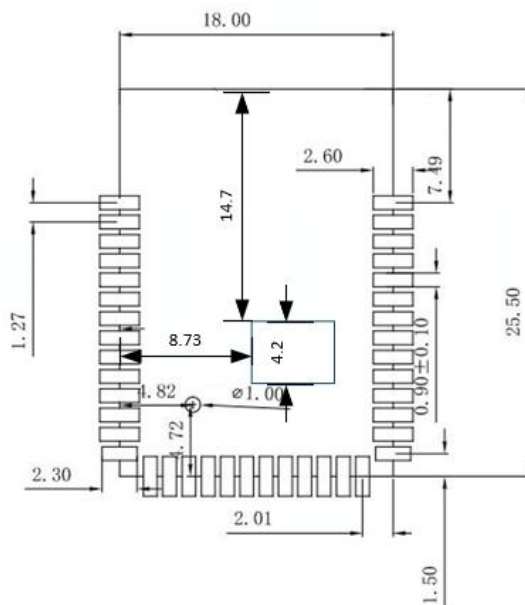


Figure 10 Recommended PCB Footprint Dimensions (Unit: mm)

8.3 Antenna Layout Requirements

- For the installation position on the mainboard, the following 2 options are recommended.
Option 1: Place the module at the mainboard edge, with the antenna area extending beyond it.
Option 2: Place the module at the mainboard edge, with a clearance cutout at the antenna position.
- To ensure optimal antenna performance, metal components should be kept away from the antenna area, and the antenna should be placed as far as possible from high-frequency devices.

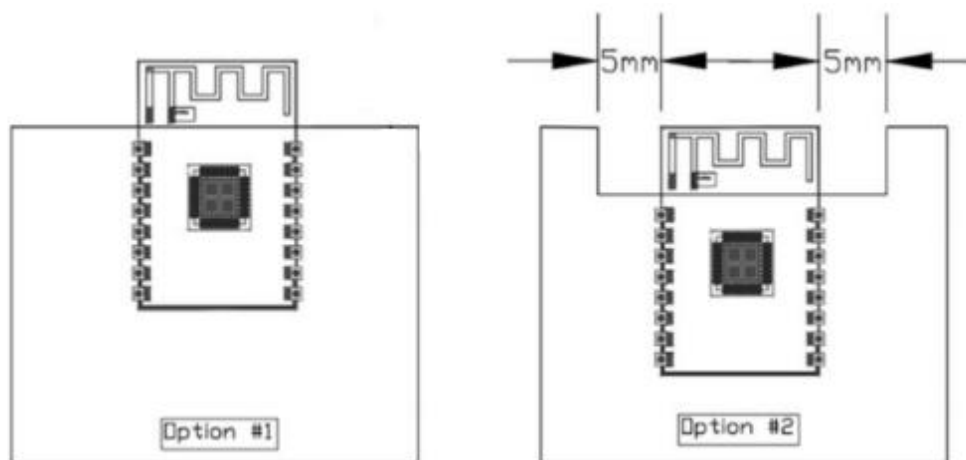


Figure 11 Antenna Layout Diagram

8.4 Power Supply

- VCC is recommended as 3.3V, with a peak current above 500mA.
- An LDO is recommended for power supply; if using DC-DC, the ripple should be controlled within 30mV.
- For the DC-DC power supply circuit, it is recommended to reserve space for dynamic response capacitors to optimize output ripple under large load transients.
- It is recommended to add ESD protection devices to the power interface.

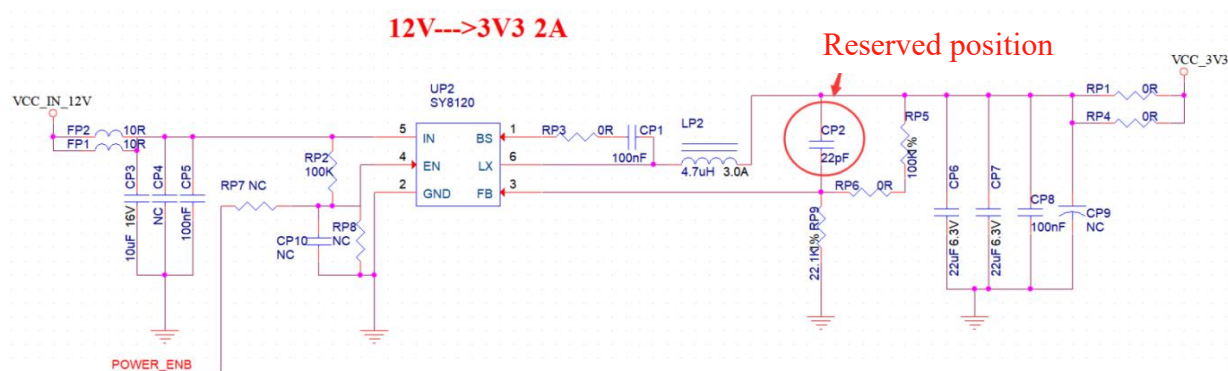


Figure 12 DC-DC Buck Circuit

8.5 GPIO

- Some I/O pins are exposed on the module periphery. To use these I/O pins, it is recommended to connect a 10-100Ω resistor in series with each I/O pin. This helps suppress overshoot, stabilize signal levels, and benefits both EMI and ESD protection.
- The pull-up or pull-down configuration for special I/O pins must follow the guidelines in the specification, as it affects the module's boot configuration.
- The module's I/O pins operate at 3.3V. If the I/O voltage level of the main controller and the module do not match, a level-shifting circuit must be added.
- If an I/O pin is directly connected to a peripheral interface or pin headers, it is recommended to reserve space for an ESD protection device near the connector on the I/O trace.

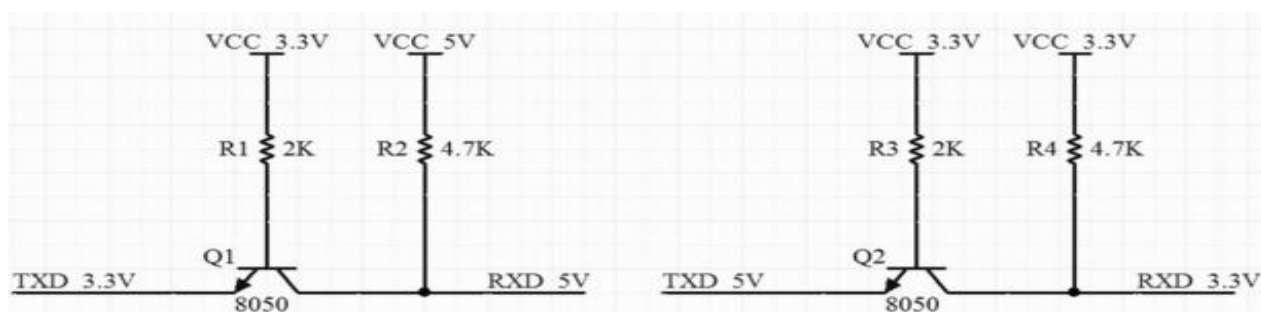


Figure 13 Level-shifting Circuit

9 Storage Conditions

Products sealed in moisture barrier bags should be stored in a non-condensing atmosphere at $< 40^{\circ}\text{C}$ and $< 90\%$ RH.

The moisture sensitivity level (MSL) of the module is level 3.

The module must be used within 168 hours after vacuum bag removal under conditions of $25\pm 5^{\circ}\text{C}$ and 60% RH. Otherwise, the module requires baking before being returned to production.

10 Reflow Soldering Profile

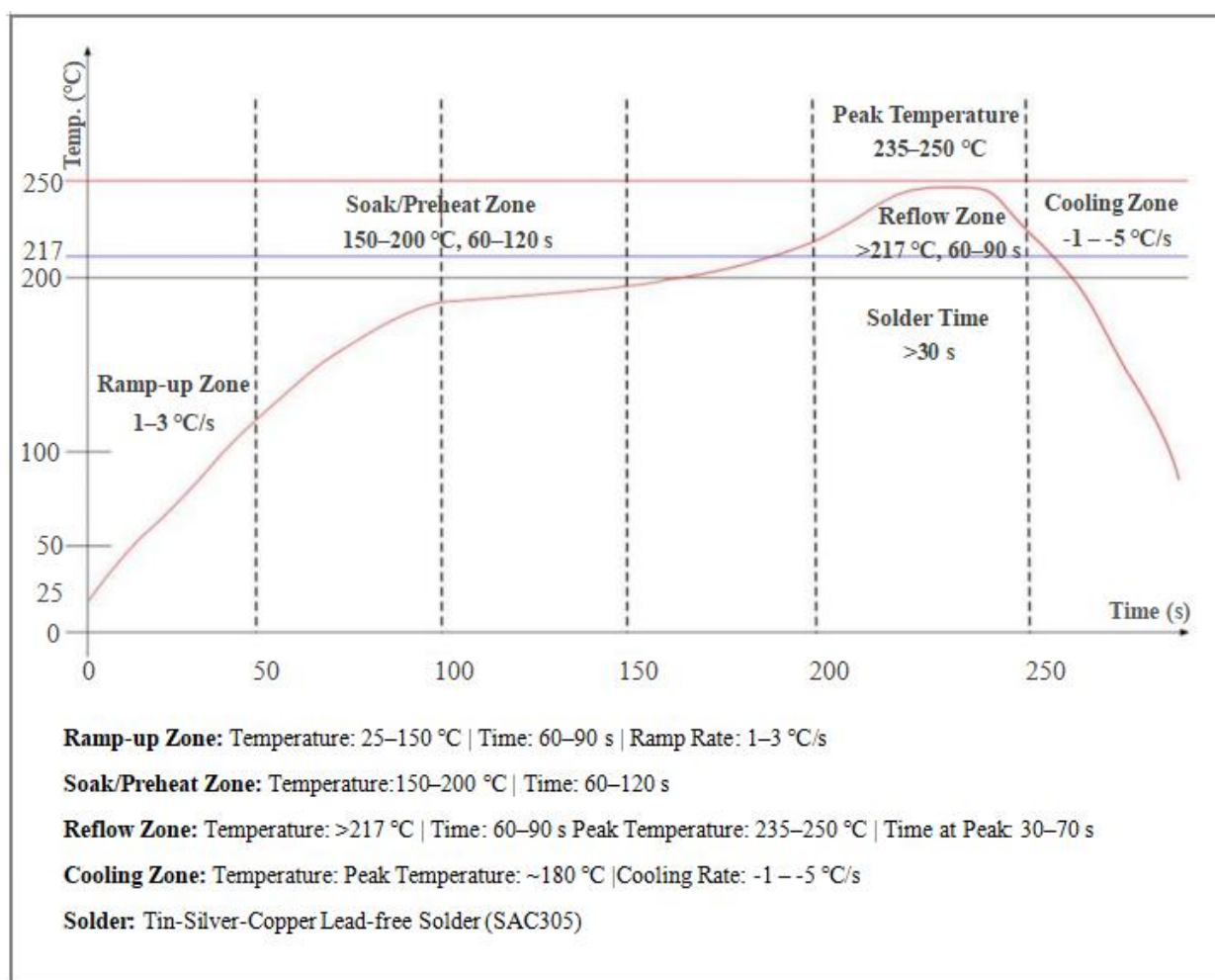


Figure 14 Reflow Soldering Profile

11 Packaging Information

The Ai-M64P-32S module is packaged in tape and reel, 800 pcs/reel.



Figure 15 Tape and Reel Packaging Diagram

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