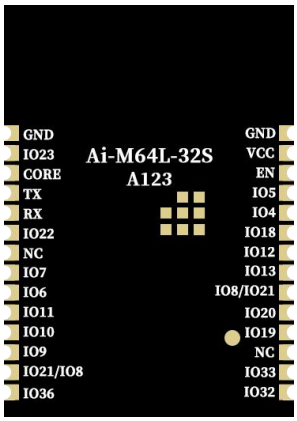
Ai-M64L-32S Specification



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Product Model: Ai-M64L-32S

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V1.0.0	2026-07-30	First edition	Qiao Rongxin	Guan Ning
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Contents

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List of Figures

List of Tables

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1 Product Overview

The Ai-M64L-32S is a standardized wireless module based on the Bouffalo Lab BL616CL RF chip, designed specifically 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 offers five core features: strong signal performance, low power consumption, high integration, security and reliability, and ultra-compact package.

Figure 1 shows the BL616CL main chip architecture.

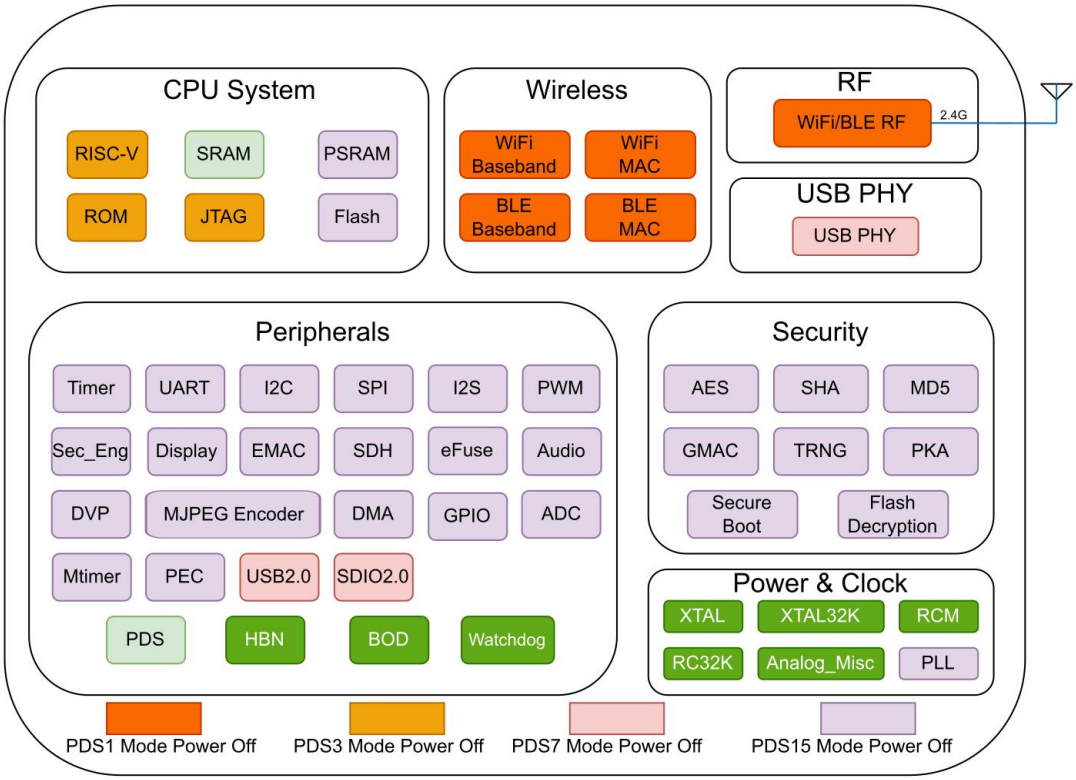

Figure 1 Main Chip Architecture Diagram

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1.1 Features

Wi-Fi

- Wi-Fi 6 (IEEE 802.11 b/g/n/ax), 20MHz bandwidth, 1T1R
- 2.4GHz operating frequency band; protocol rates from MCS0 to MCS9
- Supports OFDMA, TWT, LDPC, STBC, Beamformee, and RX diversity
- Receiver sensitivity: -99dBm@11b, 1Mbps
- Transmit power: 23dBm@11b, 1Mbps

BLE

- Bluetooth Low Energy (BLE) 5.3
- Receiver sensitivity: -99dBm@1Mbps
- High-power mode (15dBm@1Mbps)
- Supports multiple data rates: 2Mbps/1Mbps/500kbps/125kbps
- Supports multi-connection and extended advertising, suited for gateways and sensor nodes
- Wi-Fi and Bluetooth coexistence, using a shared antenna

Security

- Secure Boot (supports firmware encryption & signing)
- Supports Anti-Rollback
- XIP on-the-fly AES decryption (OTFAD)
- Supports TrustZone
- AES-ECB/CBC/CTR/GMAC/XTS modes
- MD5, SHA-1/224/256/384/512
- TRNG (True Random Number Generator)
- PKA (Public Key Accelerator) for RSA/ECC
- Total 1024 bits eFuse

Peripherals

- USB, UART, I2C, SPI, PWM, GPTimer, Watchdog, ADC, etc.

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Development Environment

- Supports secondary development, integrated with Windows and Linux development environments

Power Characteristics

- Receive current: 72.18mA
- Transmit current: TX 802.11ax, MCS9, POUT=+17dBm: 276.84mA (average, 100% duty cycle)
- PDS power consumption (DTIM10, with DC-DC, Wi-Fi connected): 59μA
- PDS power consumption (DTIM10, without DC-DC, Wi-Fi connected): 106μA
- HBN power consumption: 6μA

Physical Characteristics

- Package: SMD-28
- Module dimensions (L × W × H): 25.5 × 18.0 × 3.1mm
- Antenna type: compatible with onboard antenna and IPEX connector antenna
- Operating temperature: -40 – 105℃
- Storage conditions: -40 – 125℃, < 90% RH

Electrical Characteristics

- Supply voltage: 2.97 – 3.63V (typical value 3.3V)
- Supply current: > 500mA
- Communication interface: standard UART
- Available I/Os: 15 GPIOs exposed by default (up to 21 GPIOs)
- Protection: built-in ESD protection circuit

Note: For features not marked, please refer to the official BL616CL chip datasheet.

1.2 Application Scenarios

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

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2 Key Specifications

Table 1 summarizes the key electrical and physical parameters of the Ai-M64L-32S module.

Table 1 Key Specifications

Model	Ai-M64L-32S
Package	SMD-28
Dimensions	25.5 × 18.0 × 3.1mm
Antenna Type	Compatible with onboard antenna / IPEX connector antenna
Frequency Range	2400 – 2483.5MHz
Operating Temperature	-40 – 105℃
Storage Conditions	-40 – 125℃, < 90% RH
Power Supply Range	Supply voltage: 2.97 – 3.63V, typical 3.3V; supply current > 500mA
Available I/Os	15 by default (up to 21 GPIOs exposed)
UART Rate	115200bps by default
Security	WPS/WEP/WPA/WPA2/WPA3
Flash	4MByte by default (up to 16MByte supported)

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3 Electrical Characteristics

3.1 Recommended Operating Conditions

Table 2 lists the recommended operating electrical parameters of the Ai-M64L-32S module. Operating outside these ranges may cause device damage.

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 lists the I/O DC characteristics of the Ai-M64L-32S module. These parameters are mainly used for external interface level matching and GPIO circuit design.

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

Figure 2 shows the ESD protection diagram. Ai-M64L-32S is an ESD-sensitive device and requires special precautions during handling.

Figure 2 ESD Protection Diagram

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3.4 Wi-Fi RF Performance

Table 4 lists the Wi-Fi performance parameters of the Ai-M64L-32S module. The RF performance parameters are measured under typical test conditions. Actual performance may be affected by the antenna, power supply, PCB layout, test environment, and other factors.

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
2.4GHz Harmonic Suppression RBW/VBW (1MHz/3MHz)				
Mode	**Min**	**Typ**	**Max**	**Unit**
2450MHz@23dBm@2nd Harmonic	-	-48	-	dBm
2450MHz@23dBm@3rd Harmonic	-	-47.5	-	dBm

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3.5 BLE RF Performance

Table 5 lists the BLE performance parameters of the Ai-M64L-32S module. The RF performance parameters are measured under typical test conditions. Actual performance may be affected by the antenna, power supply, PCB layout, test environment, and other factors.

Table 5 BLE RF Performance

Description	Typ			Unit
Frequency Range	2400 – 2483.5			MHz
Output Power				
Rate Mode	**Min**	**Typ**	**Max**	**Unit**
1Mbps	-	10	15	dBm
2Mbps	-	10	15	dBm
Receiver Sensitivity				
Rate Mode	**Min**	**Typ**	**Max**	**Unit**
1Mbps Sensitivity @30.8% PER	-99	-	-	dBm
2Mbps Sensitivity @30.8% PER	-97	-	-	dBm
2.4GHz Harmonic Suppression RBW/VBW (1MHz/3MHz)				
Mode	**Min**	**Typ**	**Max**	**Unit**
2450MHz@15dBm@2nd Harmonic	-	-48	-	dBm
2450MHz@15dBm@3rd Harmonic	-	-47.5	-	dBm

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3.6 Power Consumption

Table 6 lists the power consumption data of the Ai-M64L-32S module in different modes. The following power consumption data are measured under a 3.3V power supply and 25℃ ambient temperature.

- The P_{OUT} 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	-	389.87	-	mA
TX 802.11g, 54Mbps, POUT = +20dBm	-	314.11	-	mA
TX 802.11n, MCS7, POUT = +19dBm	-	293.78	-	mA
TX 802.11ax, MCS9, POUT = +17dBm	-	276.84	-	mA
RX 802.11b, Packet Length 1500 bytes	-	72.18	-	mA
RX 802.11g, Packet Length 1500 bytes	-	72.18	-	mA
RX 802.11n, Packet Length 1500 bytes	-	72.18	-	mA
RX 802.11ax, Packet Length 1500 bytes	-	72.18	-	mA
PDS (DTIM10, with DC-DC, Wi-Fi disconnected)	-	24	-	μA
PDS (DTIM10, with DC-DC, Wi-Fi connected)	-	59	-	μA
PDS (DTIM10, without DC-DC, Wi-Fi disconnected)	-	42	-	μA
PDS (DTIM10, without DC-DC, Wi-Fi connected)	-	106	-	μA
HBN	-	6	-	μA

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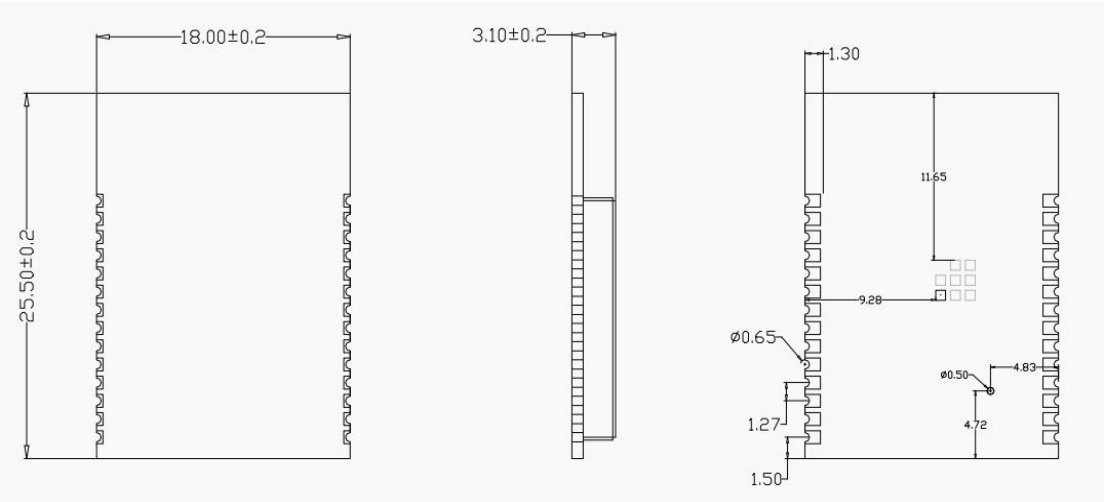
4 Mechanical Specifications

4.1 Module Dimensions

Figure 3 shows the outline dimensions of the Ai-M64L-32S module. The outline dimensions (L × W × H) are 25.50 × 18.00 × 3.10mm. The dimensional tolerance is ±0.20mm.



Top View Side View Bottom View

Figure 3 Module Dimensions (Unit: mm)

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4.2 Shield Cover Marking Information

Figure 4 shows the shield cover marking information of the Ai-M64L-32S module. Each character corresponds to module configuration information such as chip brand, Flash size, and temperature version.

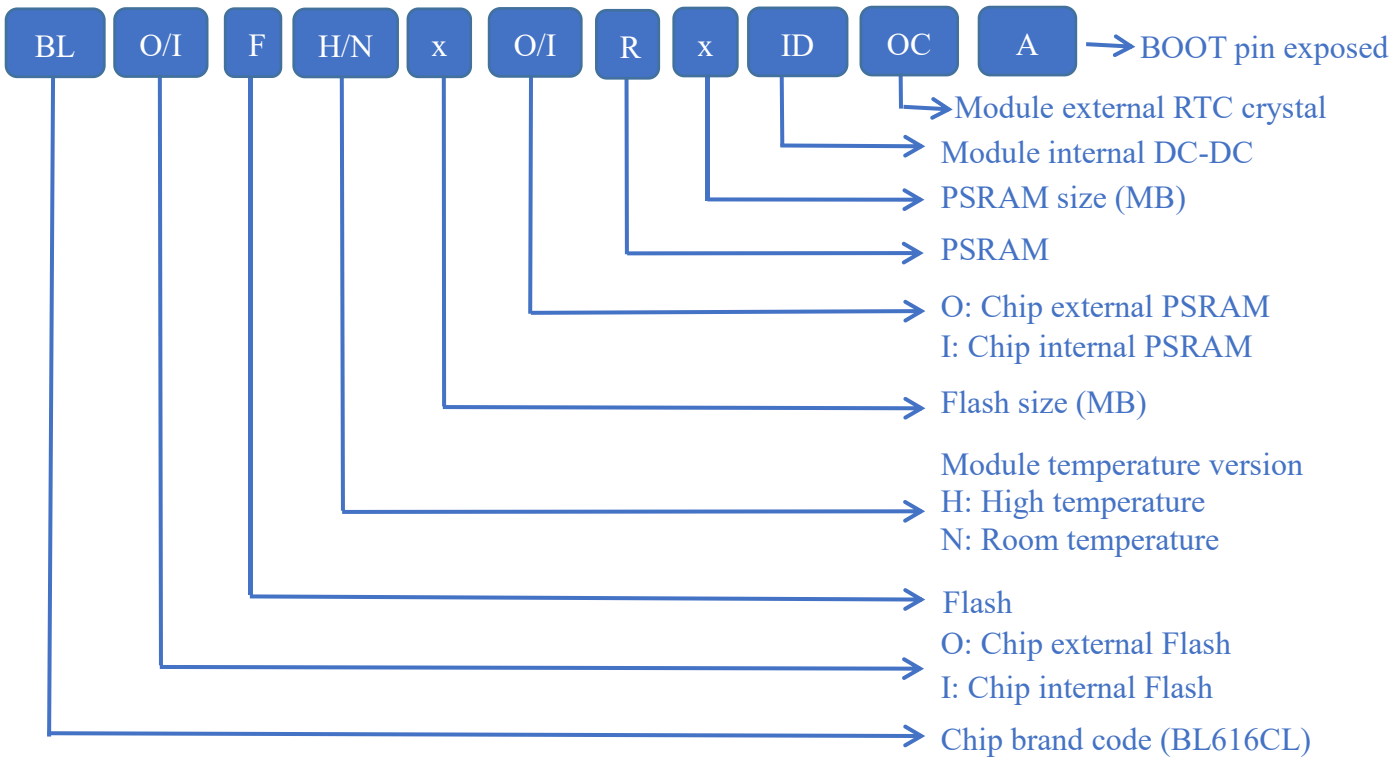

Figure 4 Shield Cover Marking Information

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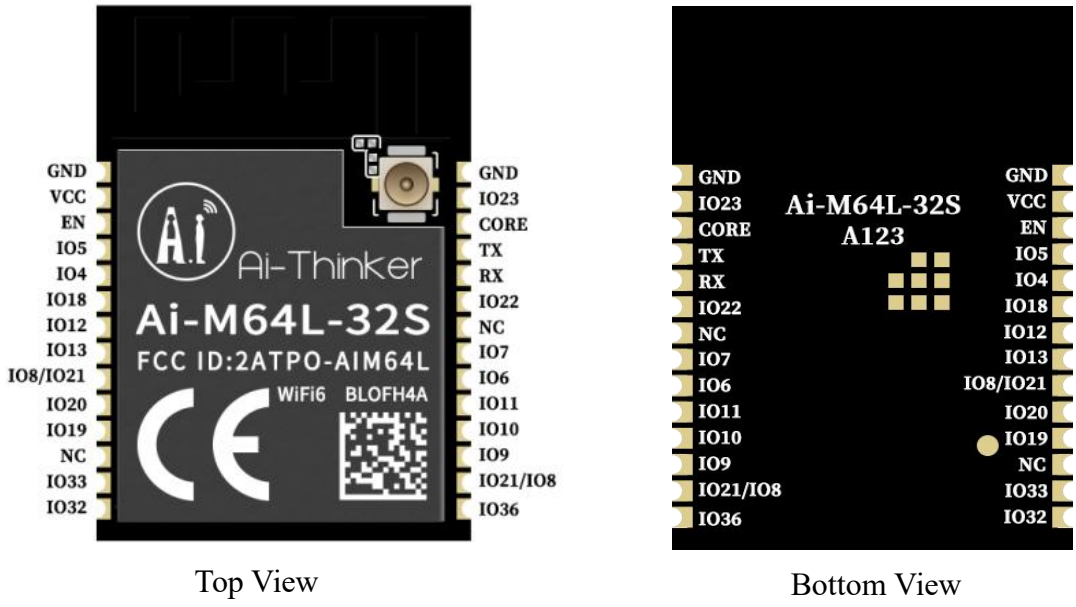
5 Pin Definition

Figure 5 shows the top and bottom views of the Ai-M64L-32S module's pin layout, with a total of 28 pins exposed.



Top View Bottom View

Figure 5 Pin Diagram

Table 7 defines the pin functions of the Ai-M64L-32S module, including pin number, pin name, and function description.

Table 7 Pin Function Definition

No.	Name	Function
1	GND	Ground
2	VCC	3.3V power supply, current recommended to be above 500mA
3	EN	Chip enable by default; active high
4	IO5	GPIO5/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/UART_SIG5/ADC_CH5/PWM0_CH1P/PWM0_CH2N/DBI_TypeC_DCn/JTAG_TCK (Available by default. Shared with the module's internal 32.768kHz crystal pin and internal DC-DC control pin. This I/O pin is NC if an integrated 32.768kHz crystal or integrated DC-DC is customized.)
5	IO4	GPIO4/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/PWM0/ADC_CH4 (Available by default. Shared with the module's internal 32.768kHz crystal pin. This I/O pin is NC if an integrated 32.768kHz crystal is customized.)

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6	IO18	GPIO18/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/UART_SIG6/RMII_RXD[1]/CAM_DAT6/PWM0_CH2P/PWM0_CH1P/DBI_TypeB_DB6/DBI_TypeC_SCL/DISP_QSPI_SCL/AUPWM_P/JTAG_TDO
7	IO12	GPIO12/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/UART_SIG0/RMII_MDIO/CAM_DAT0/ADC_CH8/PWM0_CH0P/PWM0_CH2P/DBI_TypeB_DB0/DBI_TypeC_SDA/DISP_QSPI_SCL/AUPWM_P/JTAG_TMS
8	IO13	GPIO13/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/PWM0/ADC_CH9
9	IO8/IO21	GPIO8/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/UART_SIG8/SF2_D2/SDIO_CMD/PWM0_CH0P/DBI_TypeC_SDA/DISP_QSPI_SDA0/JTAG_TMS (Not available by default because it is shared with module's internal Flash pins. If this I/O pin is required, please contact Ai-Thinker to customize a module with on-chip Flash. IO8 and IO21 can be swapped by customization; please contact Ai-Thinker if this option is required.)
10	IO20	GPIO20/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/UART_SIG8/PDM_CLK/RMII_RX_DV/CAM_VSYNC/PWM0_CH0P/PWM0_CH2P/DBI_TypeC_SDA/DISP_QSPI_SDA0/JTAG_TMS
11	IO19	GPIO19/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/UART_SIG7/RMII_RXD[0]/CAM_DAT7/PWM0_CH3P/PWM0_CH1N/DBI_TypeB_DB7/DBI_TypeC_CSn/DISP_QSPI_CSn/AUPWM_N/JTAG_TDI
12	NC	No connection
13	IO33	USB_DM/GPIO33/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/PWM0/ADC_CH11
14	IO32	USB_DP/GPIO32/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/PWM0/ADC_CH10
15	IO36	GPIO36/SPI0_SS/SPI1_SS/I2S_BCLK/I2C_SCL/UART_SIG0/PWM0_CH0P/PWM0_CH2P/DBI_TypeB_DCn/JTAG_TMS/Bootstrap (Available on modules with the letter "A" in the shield marking suffix; NC on modules without the "A" suffix.)
16	IO21/IO8	GPIO21/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/PWM0 (Available by default. IO21 and IO8 may be swapped by customization; please contact Ai-Thinker if this option is required.)
17	IO9	GPIO9/SPI0_SCLK/SPI1_SCLK/I2S_FS/I2C_SDA/UART_SIG9/SF2_D0/SDIO_CLK/PWM0_CH1P/PWM0_CH0N/DBI_TypeC_DCn/DISP_QSPI_SDA1/JTAG_TCK (Not available by default because it is shared with module's internal Flash pins. If this I/O pin is required, please contact Ai-Thinker to customize a module with on-chip Flash.)
18	IO10	GPIO10/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/UART_SIG10/SF2_CLK/SDIO_DAT0/PWM0_CH2P/PWM0_CH1P/DBI_TypeC_SCL/DISP_QSPI_SDA2/JTAG_TDO (Not available by default because it is shared with module's internal Flash pins. If this I/O pin is required, please contact Ai-Thinker to customize a module with on-chip Flash.)

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19	IO11	GPIO11/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/UART_SIG11/SF2_D3/SDIO_DAT1/PWM0_CH3P/PWM0_CH1N/DBI_TypeC_CSn/DISP_QSPI_SDA3/JTAG_TDI (Not available by default because it is shared with module's internal Flash pins. If this I/O pin is required, please contact Ai-Thinker to customize a module with on-chip Flash.)
20	IO6	GPIO6/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/PWM0/ADC_CH6 (Not available by default because it is shared with module's internal Flash pins. If this I/O pin is required, please contact Ai-Thinker to customize a module with on-chip Flash.)
21	IO7	GPIO7/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/PWM0/ADC_CH7 (Not available by default because it is shared with module's internal Flash pins. If this I/O pin is required, please contact Ai-Thinker to customize a module with on-chip Flash.)
22	NC	No connection
23	IO22	GPIO22/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/UART_SIG10/CAM_HSYNC/PWM0_CH2P/PWM0_CH3P/DBI_TypeC_SCL/DISP_QSPI_SDA2/JTAG_TDO
24	RX	GPIO35/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/UART_SIG11/PWM0_CH3P/PWM0_CH1N/DBI_TypeC_CSn/JTAG_TDI
25	TX	GPIO34/SPI0_MISO/SPI1_MISO/I2S_DI/I2S_RCLK_O/I2C_SCL/UART_SIG10/PWM0_CH2P/PWM0_CH1P/DBI_TypeC_SCL/JTAG_TDO
26	CORE	Internal core-voltage input. (Floating by default. For an ultra-low-power module, configure an external DC-DC circuit on this pin. For detailed solutions, please contact Ai-Thinker.)
27	IO23	GPIO23/SPI0_MOSI/SPI1_MOSI/I2S_DO/I2S_RCLK_O/I2C_SDA/UART_SIG11/RMII_MDIO/CAM_VSYNC/SWGPIO[23]/PWM0_CH3P/PWM0_CH3N/DBI_TypeC_CSn/DISP_QSPI_SDA3/JTAG_TDI
28	GND	Ground
Note: Both IO36 and the test point on the back of the module can be used as the Bootstrap pin. When the voltage is high at power-up, the module enters programming mode; when the voltage is low at power-up, the module boots normally. The internal default level of the module is low.		

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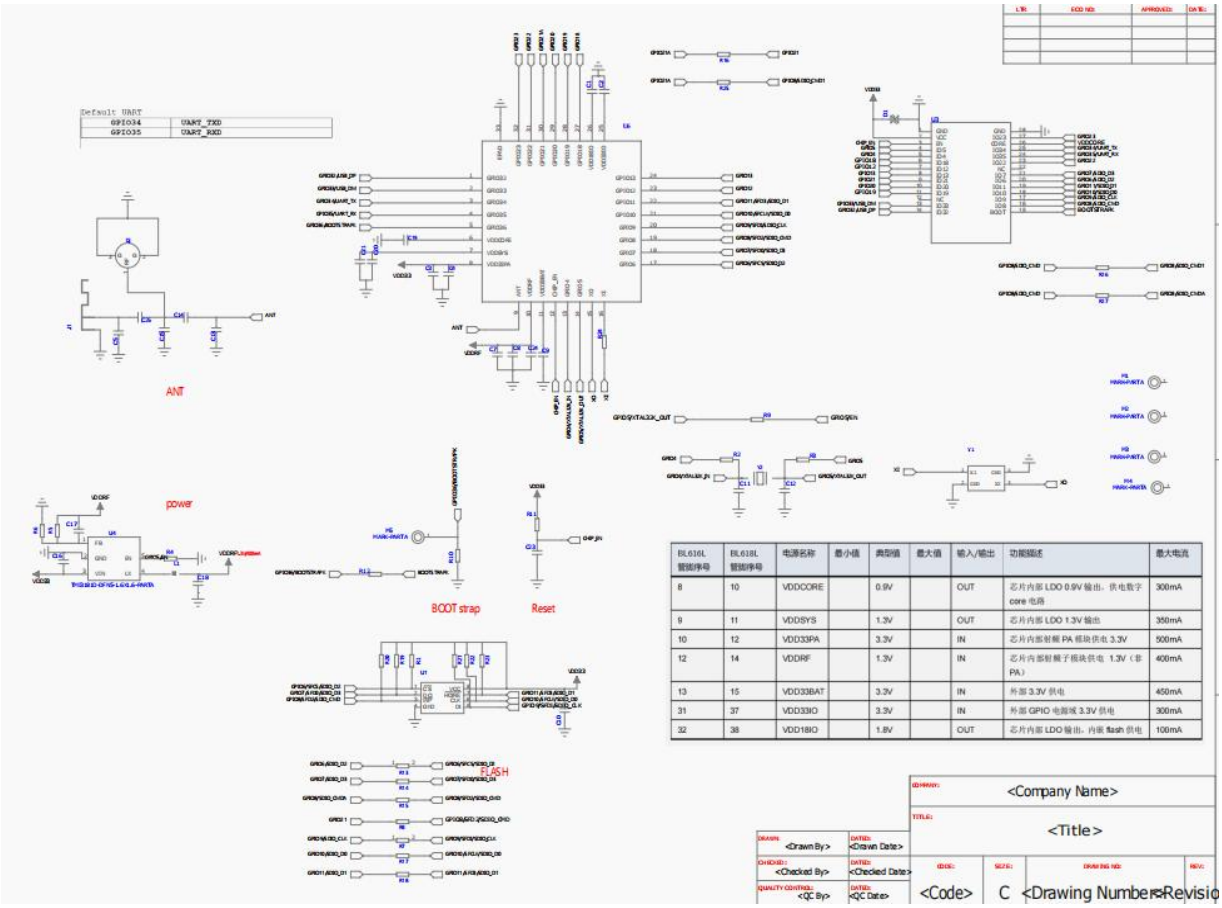
6 Schematic

Figure 6 shows the schematic of the Ai-M64L-32S module.



BL616L 管脚序号	BL618L 管脚序号	电源名称	最小值	典型值	最大值	输入/输出	功能描述	最大电流
8	10	VDDCORE		0.9V		OUT	芯片内部 LDO 0.9V 输出，供电数字 core 电路	300mA
9	11	VDDSYS		1.3V		OUT	芯片内部 LDO 1.3V 输出	350mA
10	12	VDD33PA		3.3V		IN	芯片内部射频 PA 模块供电 3.3V	500mA
12	14	VDDRF		1.3V		IN	芯片内部射频子模块供电 1.3V（非 PA）	400mA
13	15	VDD33BAT		3.3V		IN	外部 3.3V 供电	450mA
31	37	VDD33IO		3.3V		IN	外部 GPIO 电源域 3.3V 供电	300mA
32	38	VDD18IO		1.8V		OUT	芯片内部 LDO 输出，内部 flash 供电	100mA

Figure 6 Schematic

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7 Antenna Parameters

7.1 Antenna Test Prototype

Figure 7 shows the antenna test prototype of the Ai-M64L-32S module.

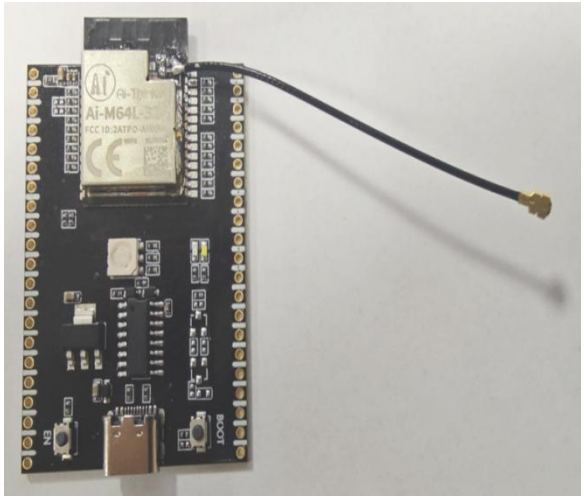

Figure 7 Antenna Test Prototype

7.2 Antenna S-Parameters

Figure 8 shows the antenna S-parameter results of the Ai-M64L-32S module measured by a network analyzer, including three RF characteristic curves: Smith chart, S11 return loss and VSWR.

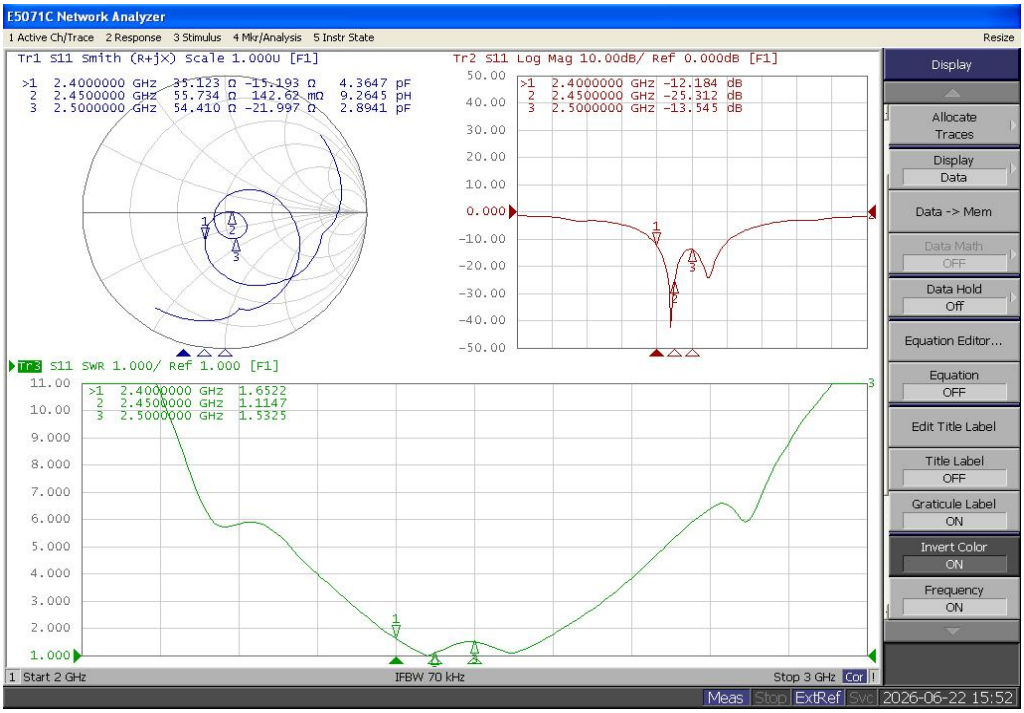

Figure 8 Antenna S-Parameters

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7.3 Antenna Gain and Efficiency

Table 8 shows the measured gain and radiation efficiency parameters of the Ai-M64L-32S module's antenna at each frequency point within the 2400 – 2500MHz operating band.

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	54.35	57.00

7.4 Antenna Radiation Pattern

Figure 9 shows the 3D radiation pattern and planar cut patterns of the Ai-M64L-32S module's antenna at a typical 2.4GHz frequency point.

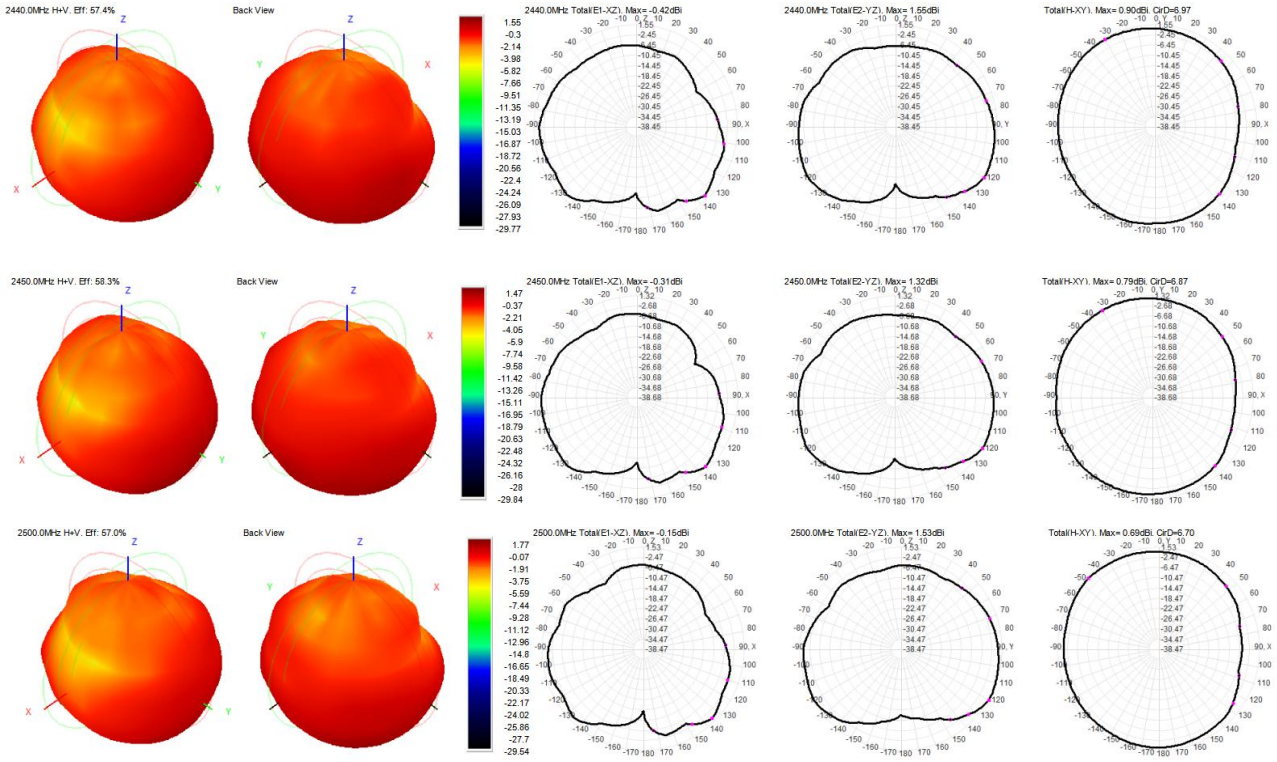

Figure 9 Antenna Radiation Pattern

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8 Design Guide

8.1 Application Reference Circuit

Figure 10 shows the hardware application reference circuit for the Ai-M64L-32S module, illustrating the serial communication, power supply, enable, and program download interface connections.

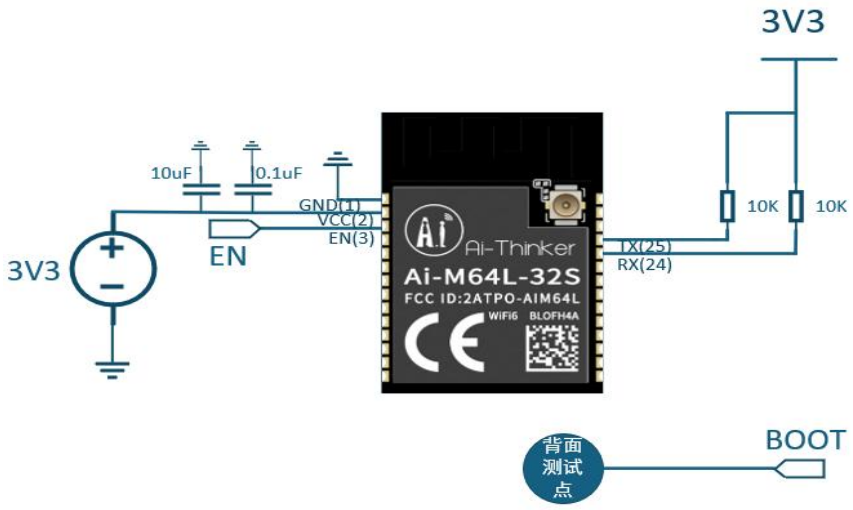

Figure 10 Application Reference Circuit

Notes on the Application Reference Circuit:

- VCC supply voltage: 2.97 – 3.63V. The external power supply output current is recommended to be above 500mA.
- The Boot pin for all modules in this series is located on the test point on the back of the module. For module versions with marking suffix “A”, the chip’s Boot configuration pin is exposed to the edge castellated pad, corresponding to module pin IO36. Module versions without the “A” suffix do not have this pin exposed.
- For module versions with marking suffix “A”, both IO36 (castellated pad) and the back test point pad can be used as the download Boot pin. It is recommended to prioritize IO36 (castellated pad) as the download interface configuration pin, and it is not recommended to use this IO as a regular GPIO. If this IO must be used, the external circuit’s power-on startup timing must meet the timing requirements of the Boot pin.

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8.2 Recommended PCB Footprint Dimensions

Figure 11 shows the recommended PCB footprint dimensions of the Ai-M64L-32S module. The pad dimensions (L × W) are 2.20 × 0.90mm. The center-to-center spacing between adjacent pads is 1.27mm.

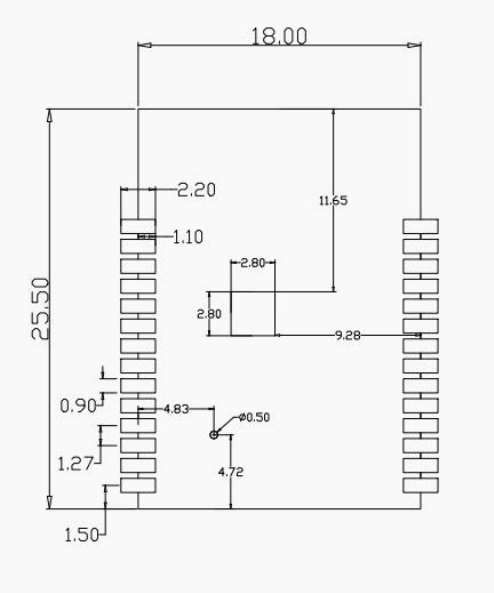

Figure 11 Recommended PCB Footprint Dimensions (Unit: mm)

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8.3 Power Supply

Figure 12 shows a DC-DC buck power supply circuit converting 12V to 3.3V, with a maximum output current of 2A.

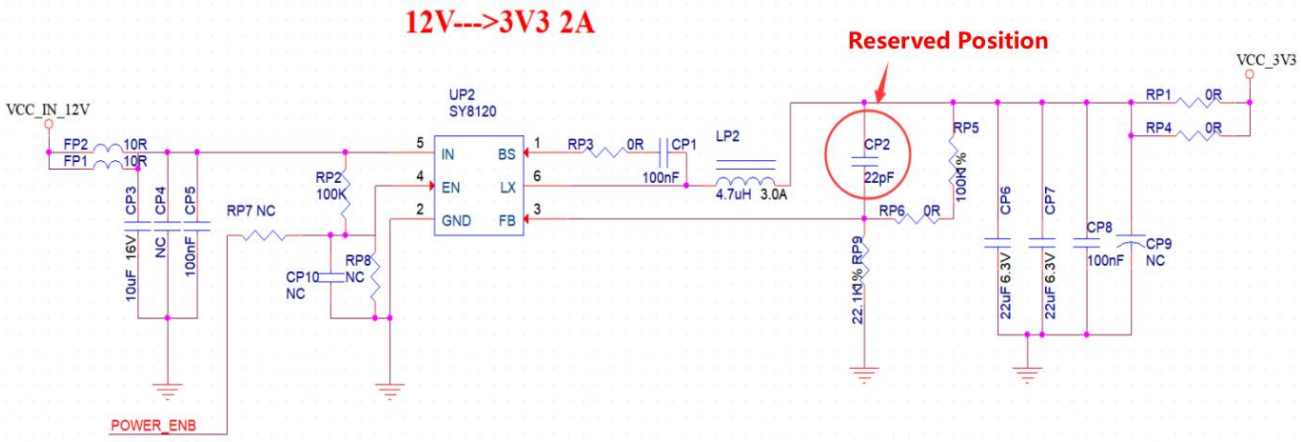

Figure 12 DC-DC Buck Circuit

Notes on the DC-DC Buck Circuit:

- Recommended VCC voltage: 3.3V; recommended current ≥ 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.

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8.4 GPIO

Figure 13 shows a 3.3V and 5V bidirectional UART level-shifting circuit, which supports bidirectional serial communication across different voltage levels.

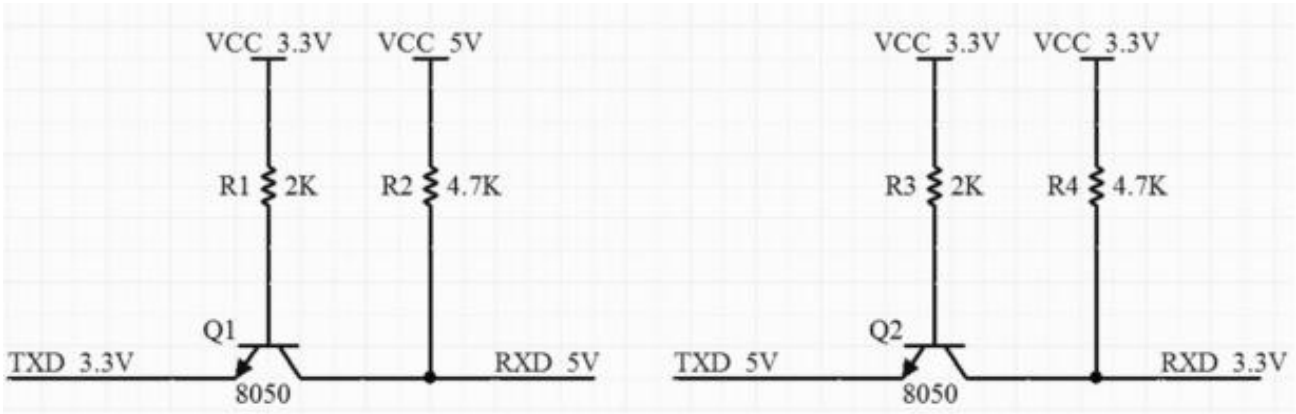

Figure 13 Level-Shifting Circuit

Notes on the Level-Shifting Circuit:

- Some I/O pins are brought out from the module. 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 refer to the instructions in the specification, as it affects the module boot configuration.
- The module I/O pins level is 3.3V. If the host controller I/O voltage level does not match the module, a level-shifting circuit should 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.

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9 Storage Conditions

Products sealed in moisture barrier bags should be stored in a non-condensing atmosphere at < 40℃ 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±5℃ and 60% RH. Otherwise, the module requires baking before being returned to production.

10 Reflow Soldering Profile

Figure 14 shows the module reflow soldering process profile. The process is divided into four stages: ramp-up zone, preheat/soak zone, reflow soldering zone and cooling zone.

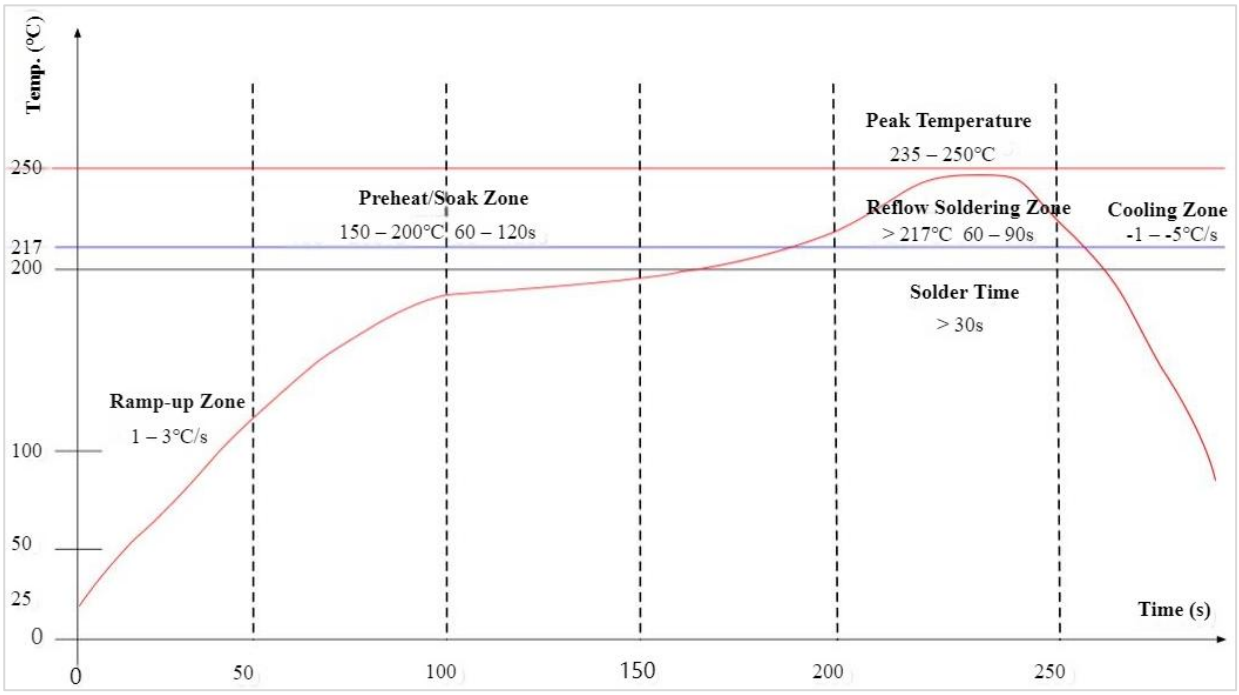

Figure 14 Reflow Soldering Profile

Reflow Soldering Profile Description:

- Ramp-up zone – Temperature: 25 – 150℃, Time: 60 – 90s, Ramp rate: 1 – 3℃/s
- Preheat/soak zone – Temperature: 150 – 200℃, Time: 60 – 120s
- Reflow soldering zone – Temperature: > 217℃, Time: 60 – 90s, Peak temperature: 235 – 250℃, Time: 30 – 70s
- Cooling zone – Temperature: peak temperature to 180℃, Cooling rate: -1 – -5℃/s
- Solder – Sn-Ag-Cu lead-free solder alloy (SAC305)

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11 Packaging Information

Figure 15 shows the packaging of the Ai-M64L-32S module. The module is packed in tape-and-reel, 800 pcs/reel.

Figure 15 Tape and Reel Packaging Diagram

12 Contact Us

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