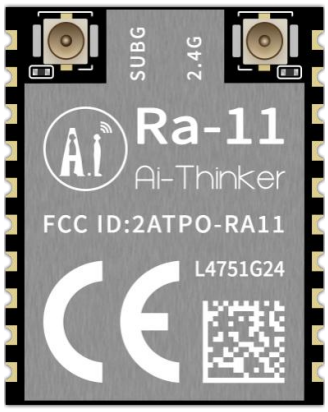
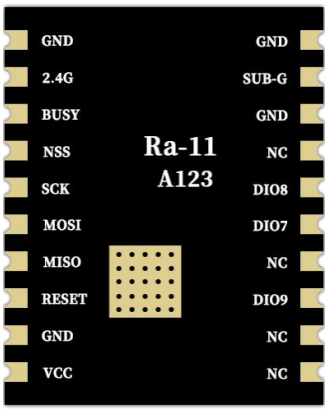
Ra-11 Specification





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V1.0.1	2026-06-17	Modified power consumption data	Chen Jun	Guan Ning
V1.0.2	2026-08-14	1. Modified power supply voltage and power consumption data; 2. Updated module renderings	Chen Jun	Guan Ning
V1.0.3	2026-09-21	1. Updated module renderings; 2. Added frequency and transmit-power regulatory limits	Chen Jun	Guan Ning

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1 Product Overview

The Ra-11 is an ultra-high-performance RF front-end module based on Semtech's third-generation LoRa transceiver LR1121 RF chip. It is designed for IoT applications, long-range wireless communications, industrial, medical, and other wireless communication applications. Its key advantage lies in an ultra-compact package and extreme RF performance. By optimizing the collaborative design of power amplifier, low-noise amplifier, filter, and external matching network, it achieves high power, low loss, low spurious emissions, and strong interference immunity.

The LR1121 RF chip supports Sub-GHz, 2.4GHz ISM band, and licensed S-band satellite communication bands, enabling both terrestrial communication and satellite communication applications. It features ultra-long-range transmission and ultra-low power consumption.

The Ra-11 module can be widely used in automatic meter reading, home and building automation, security systems, remote irrigation systems, and other scenarios.

Figure 1 shows the LR1121 main chip architecture.

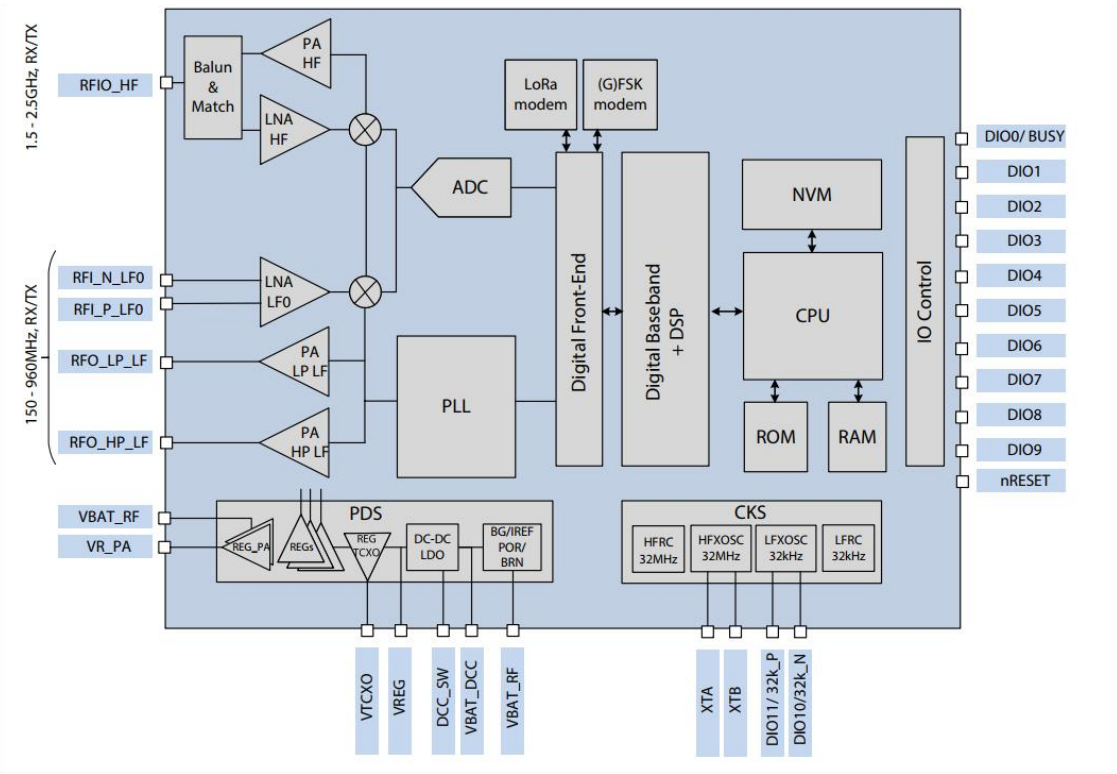


Figure 1 Main Chip Architecture Diagram

1.1 Features

RF Performance

- Transmit power: theoretical maximum transmit power of 22dBm@Sub-GHz, 13dBm@2.4GHz
- Integrated PA regulator power selector. This design simplifies the dual power supply configuration for +15/+22dBm@Sub-GHz. Users can select a low-power operating mode with a maximum output power of +15dBm
- The module requires an external MCU to adjust the transmit power and operating frequency, which must be configured by the user in strict compliance with the regulations of the relevant country or region.
- Receiver sensitivity:
  - Sub-GHz: up to -142dBm@BWLORA = 62.5kHz/SF12/CR4/5 (refer to chip datasheet)
  - 2.4GHz: up to -112dBm@BWLORA = 406kHz/SF7/CR4/5 (refer to chip datasheet)

Operating Frequency Bands

- Sub-GHz: 470 – 510MHz by default for China (433MHz can be customized)
- 2.4GHz: 2400 – 2500MHz by default for China

Power Consumption

- Sleep current: ≤ 40μA
- Receive current: ≤ 7mA
- Transmit current: Sub-GHz@22dBm 122mA; 2.4GHz@13dBm 34mA

Communication and Protocols

- Supports LoRa / (G)FSK modulation
- Supports Sub-GHz / 2.4GHz LR-FHSS modulation
- Optional factory programming of Modem-E firmware (with built-in LoRaWAN protocol stack)
- In the Sub-GHz band, compatible with the SX126X and SX127X series products
- In the 2.4GHz band, compatible with the SX128X series products
- Hardware support for AES-128 encryption / decryption algorithm

Physical Characteristics

- Package: SMD-20
- Module dimensions (L × W × H): 20.00 × 16.00 × 3.20mm
- Antenna type: IPEX Gen 1 connector / castellated antenna
- Operating temperature: -40 – 85℃
- Storage conditions: -40 – 125℃, < 90% RH

Electrical Characteristics

- Supply voltage: 2.7 – 3.6V (typical value 3.3V)
- Supply current: > 200mA
- Communication interface: standard SPI interface
- Protection: built-in ESD protection circuit

Note: For features not marked, please refer to the official Semtech LR1121 chip datasheet.

1.2 Application Scenarios

- Smart Industry
- Energy Monitoring
- Outdoor IoT
- Consumer Electronics
- Radio and Remote-controlled Drones

2 Key Specifications

Table 1 summarizes the key electrical and physical parameters of the Ra-11 module.

Table 1 Key Specifications

Model	Ra-11
Package	SMD-20
Dimensions	20.00 × 16.00 × 3.20mm
Antenna Type	IPEX Gen 1 connector / castellated antenna
Frequency Range	470 – 510MHz; 2400 – 2500MHz
Operating Temperature	-40 – 85℃
Storage Conditions	-40 – 125℃, <90% RH
Power Supply Range	Supply voltage: 2.7 – 3.6V, typical 3.3V; supply current > 200mA
Communication Interface	SPI

3 Electrical Characteristics

3.1 Recommended Operating Conditions

Table 2 lists the recommended operating electrical parameters of the Ra-11 module. Operating outside these ranges may cause device damage.

Table 2 Recommended Operating Conditions

Symbol	Parameter	Min	Typ	Max	Unit
VCC	Supply Voltage	2.7	3.3	3.6	V
I	Supply Current	200	-	-	mA

3.2 I/O DC Electrical Characteristics

Table 3 lists the I/O DC characteristics of the Ra-11 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	0.7 × VCC	-	VCC + 0.3	V
VIL	Low-level Input Voltage	-0.3	-	0.3 × VCC	V
VOH	High-level Output Voltage	-	0.9 × VCC	-	V
VOL	Low-level Output Voltage	-	-	0.1 × VCC	V
ZPUD	Pull-up/Pull-down Resistors	-	40	100	kΩ

3.3 Electrostatic Discharge

Figure 2 shows the ESD protection diagram. Ra-11 is an ESD-sensitive device and requires special precautions during handling.

Figure 2 ESD Protection Diagram

3.4 LoRa RF Performance

Table 4 lists the LoRa RF performance parameters of the Ra-11 module. 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 LoRa RF Performance

Description	Typ			Unit
Frequency Range	2400 – 2500			MHz
2.4GHz Output Power (Software Setting 13)				
Mode	**Min**	**Typ**	**Max**	**Unit**
2400MHz	-	12.8	-	dBm
2450MHz	-	12.8	-	dBm
2500MHz	-	11.8	-	dBm
2.4GHz Receiver Sensitivity (BW=406kHz, SF7, CR4/5)				
Mode	**Min**	**Typ**	**Max**	**Unit**
2400MHz	-	-112	-	dBm
2450MHz	-	-112	-	dBm
2500MHz	-	-112	-	dBm
2.4GHz Harmonic Suppression RBW/VBW (1MHz / 3MHz)				
Mode	**Min**	**Typ**	**Max**	**Unit**
2450MHz@12dBm@2nd Harmonic	-	-45	-	dBm
2450MHz@12dBm@3rd Harmonic	-	-45	-	dBm
Description	**Typ**			**Unit**
Frequency Range	470 – 510			MHz
Sub-GHz Output Power (Software Setting 15)				
Mode	**Min**	**Typ**	**Max**	**Unit**
470MHz	-	14.8	-	dBm

490MHz	-	14.6	-	dBm
510MHz	-	14	-	dBm
Sub-GHz Output Power (Software Setting 22)				
Mode	**Min**	**Typ**	**Max**	**Unit**
470MHz	-	20.8	-	dBm
490MHz	-	20.6	-	dBm
510MHz	-	20.4	-	dBm
Sub-GHz Receiver Sensitivity (BW = 125kHz，SF7，CR4/5)				
Mode	**Min**	**Typ**	**Max**	**Unit**
470MHz	-	-127	-	dBm
490MHz	-	-127	-	dBm
510MHz	-	-127	-	dBm
Sub-GHz Harmonic Suppression RBW/VBW (1MHz / 3MHz)				
Mode	**Min**	**Typ**	**Max**	**Unit**
490MHz@22dBm@2nd Harmonic	-	-37	-	dBm
490MHz@22dBm@3rd Harmonic	-	-37	-	dBm

Table 5 lists the regulatory requirements for common countries and regions. The module requires an external MCU to adjust the transmit power and operating frequency, which must be configured by the user in strict compliance with the regulations of the relevant country or region. The configurable Sub-GHz transmit power range is -9 to +22dBm, while the configurable 2.4GHz transmit power range is -18 to +13dBm.

Table 5 RF Regulatory Limits by Country / Region

Country / Region	Regulation	Operating Band	Power Limit
Mainland China	Document No. 52 (2019)	470 – 510MHz	ERP ≤ 17dBm
Mainland China	Document No. 129 (2021)	2400 – 2483.5MHz	EIRP ≤ 20dBm
European Union	CE	433.05 – 434.79MHz	ERP ≤ 10dBm
European Union	CE	863 – 870MHz	ERP ≤ 14dBm

European Union	CE	2400 – 2483.5MHz	EIRP ≤ 20dBm
North America	FCC	902 – 928MHz	EIRP ≤ 30dBm
North America	FCC	2400 – 2483.5MHz	EIRP ≤ 30dBm

Notes:

- ERP (dBm) = Pt (dBm) − Cable Loss (dB) + Antenna Gain (dBd)
- EIRP (dBm) = Pt (dBm) − Cable Loss (dB) + Antenna Gain (dBi)

According to the sample code on Ai-Thinker's official website, the procedures for configuring transmit power and operating frequency are as follows:

* @param [in] radio Pointer to radio data structure

* @param [in] output_pwr_in_dbm Output power - in dBm

* @param [in] rf_freq_in_hz RF frequency - in Hertz

static inline ral_status_t ral_set_tx_cfg(const ral_t* radio, const int8_t output_pwr_in_dbm,

const uint32_t rf_freq_in_hz);

For questions regarding the above configuration, please contact Ai-Thinker.

3.5 Power Consumption

Table 6 lists the power consumption data of the Ra-11 module in different modes. The following power consumption data are measured under a 3.3V power supply and 25°C 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.

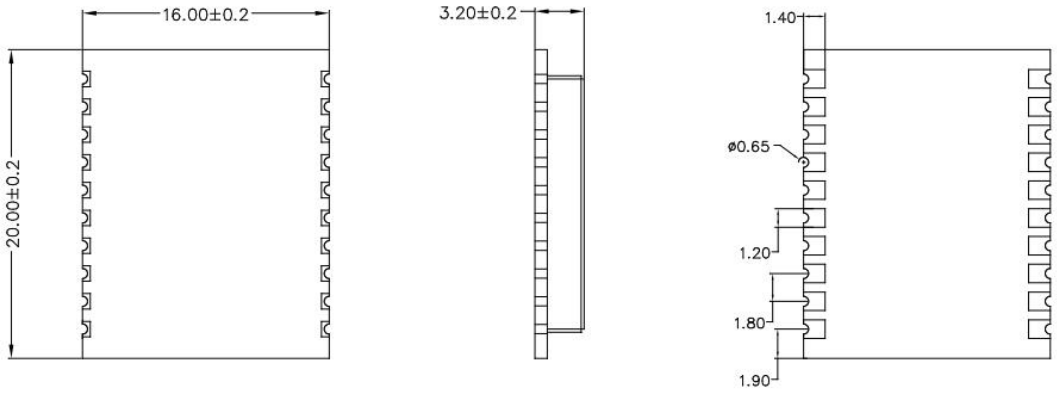
Table 6 Instantaneous Power Consumption

Mode	Min	Avg	Max	Unit
2.4GHz@TX (13dBm)	-	34	-	mA
Sub-GHz@TX (22dBm)	-	122	-	mA
2.4GHz@RX	-	6	-	mA
Sub-GHz@RX	-	7	-	mA
Sleep Current	-	40	-	μA

4 Mechanical Specifications

4.1 Module Dimensions

Figure 3 shows the outline dimensions of the Ra-11 module. The outline dimensions (L × W × H) are 20.00 × 16.00 × 3.20mm. The dimensional tolerance is ±0.20mm.



Top View Side View Bottom View

Figure 3 Module Dimensions (Unit: mm)

4.2 External Antenna Connector Dimensions

Figure 4 shows the engineering drawing of the IPEX antenna connector used with Ra-11. This connector is used to connect an external 50Ω RF antenna.

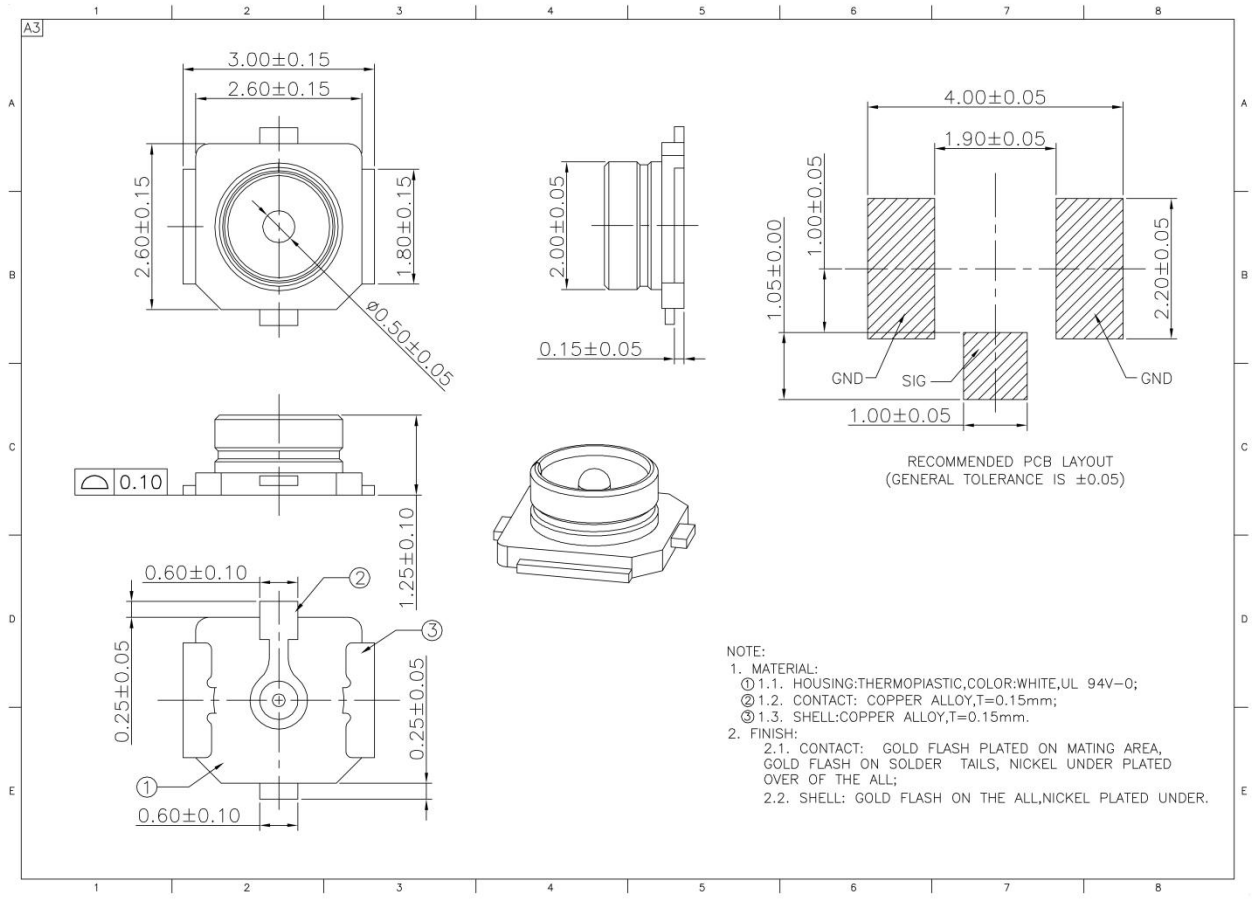
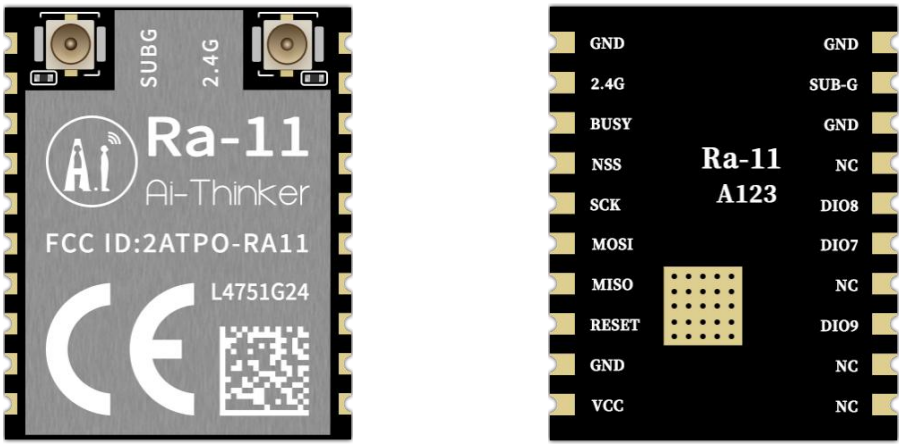


Figure 4 External Antenna Connector Dimensions (Unit: mm)

5 Pin Definition

Figure 5 shows the top and bottom views of the Ra-11 module's pin layout, with a total of 20 pins exposed.



Top View Bottom View

Figure 5 Pin Diagram

Table 7 defines the pin functions of the Ra-11 module, including pin number, pin name, and function description.

Table 7 Pin Function Definition

No.	Name	Function
1	GND	Module ground
2	SUB-G	Sub-GHz antenna interface, external 50Ω antenna
3	GND	Module ground
4	NC	NC
5	DIO8	Unavailable by default; officially used for RFSW3 RF switch control
6	DIO7	Unavailable by default; officially used for RFSW2 RF switch control
7	NC	NC
8	DIO9	Module interrupt interface; refer to the chip datasheet for details
9	NC	NC
10	NC	NC
11	VCC	Connect to power supply positive terminal

12	GND	Module ground
13	RESET	Reset trigger input, active low; refer to the chip datasheet for details
14	MISO	SPI data output
15	MOSI	SPI data input
16	SCK	SPI clock input
17	NSS	SPI chip select input
18	BUSY	Used for status indication; refer to the chip datasheet for details
19	2.4G	2.4GHz antenna interface, external 50Ω antenna
20	GND	Module ground

Notes:
1. The “IO11” and “IO10” pins of the LR1121 chip are internally connected to a 32.768kHz crystal inside the module.
2. The “IO5” and “IO6” pins of the LR1121 chip are internally connected to the RF switch inside the module. They control the Sub-GHz transmit (TX: +22dBm high power and +15dBm low power) and receive (RX) operations, and are consistent with the control states in the official SDK.

6 Schematic

Figure 6 shows the schematic of the Ra-11 module, integrating RF antennas, power supply, clock, and reserved peripheral interfaces.

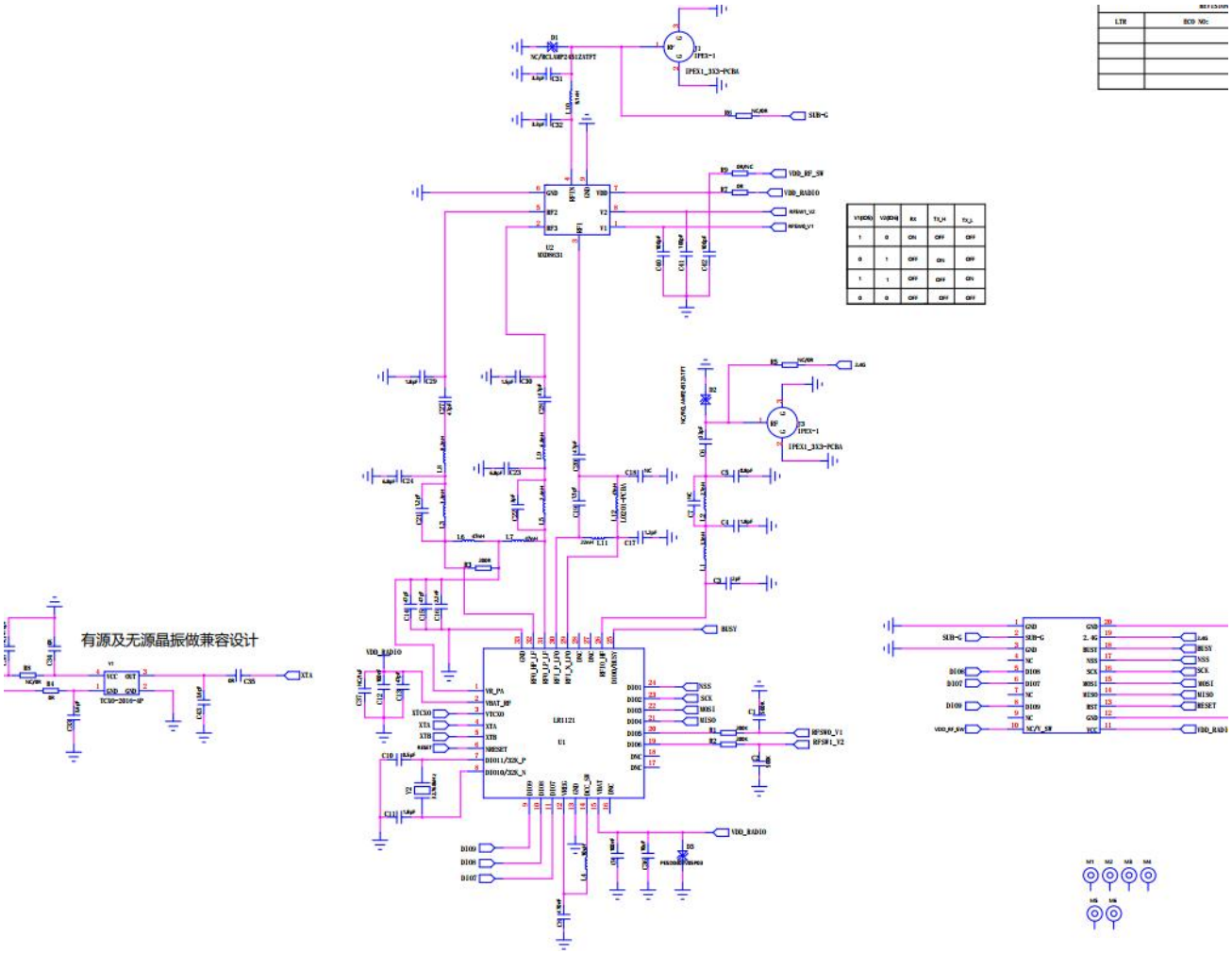


Figure 6 Schematic

7 Design Guide

7.1 Application Reference Circuit

Figure 7 shows the hardware application reference circuit of the Ra-11 module.

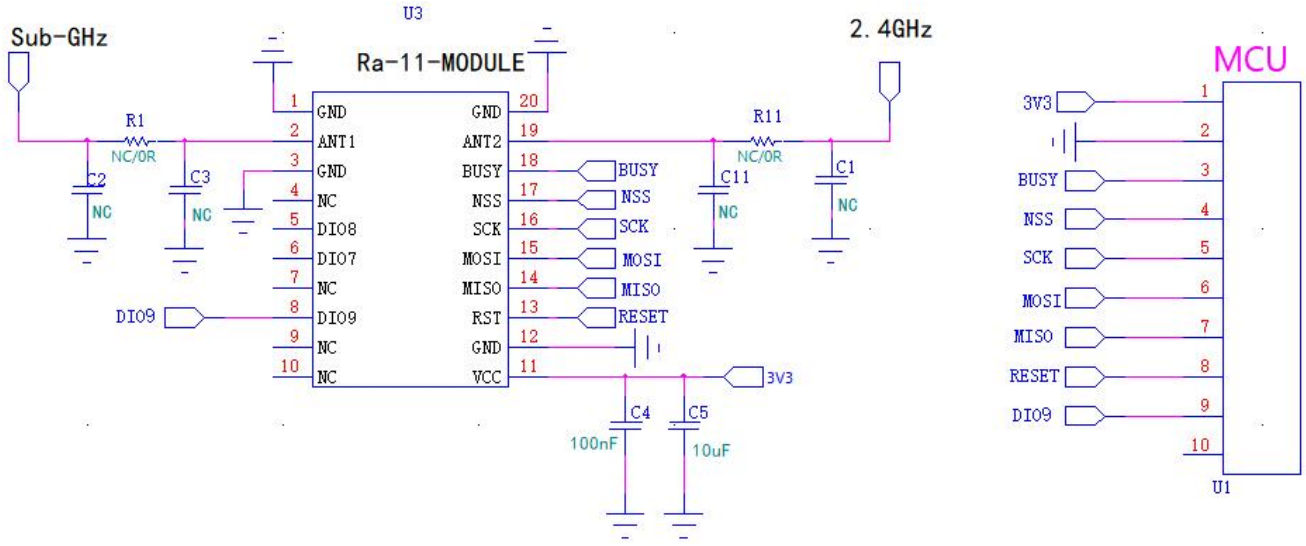


Figure 7 Application Reference Circuit

Notes on the Application Reference Circuit:

- VCC supply voltage: 2.7 – 3.6V. The external power supply output current is recommended to be above 200mA.
- RF specifications: LoRa ISM 470 – 510MHz; 2.4GHz wireless band.
- If the antenna is soldered onto the mainboard, it is recommended to reserve a π-type matching circuit at the antenna port.
- DIO9 is the communication interrupt pin and must be connected to an I/O pin of the main MCU.
- Communication interface: standard SPI communication (NSS/SCK/MOSI/MISO), compatible with host MCU SPI peripherals.
- Ra-11 is a LoRa Sub-GHz + 2.4GHz dual-mode wireless module. The Sub-GHz and 2.4GHz antennas operate independently for transmission and reception and must not be shared.

7.2 Recommended PCB Footprint Dimensions

Figure 8 shows the recommended PCB footprint dimensions of the Ra-11 module. The pad dimensions (L × W) are 2.60 × 1.20mm. The center-to-center spacing between adjacent pads is 1.80mm.

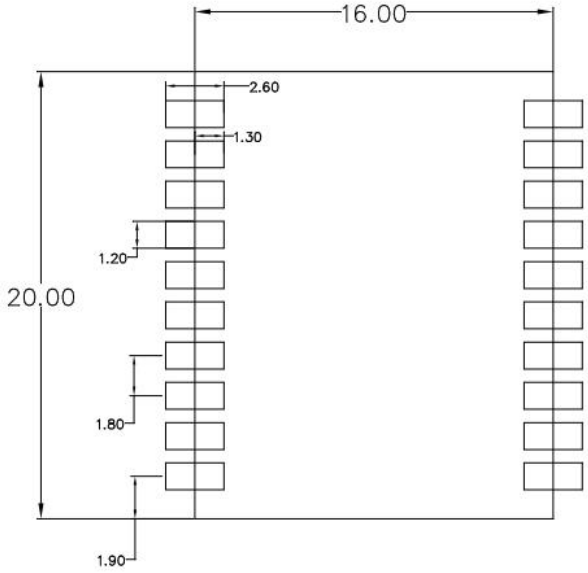


Figure 8 Recommended PCB Footprint Dimensions (Unit: mm)

7.3 Power Supply

Figure 9 shows a DC-DC buck power supply circuit converting 12V to 3.3V, with a maximum output current of 2A.

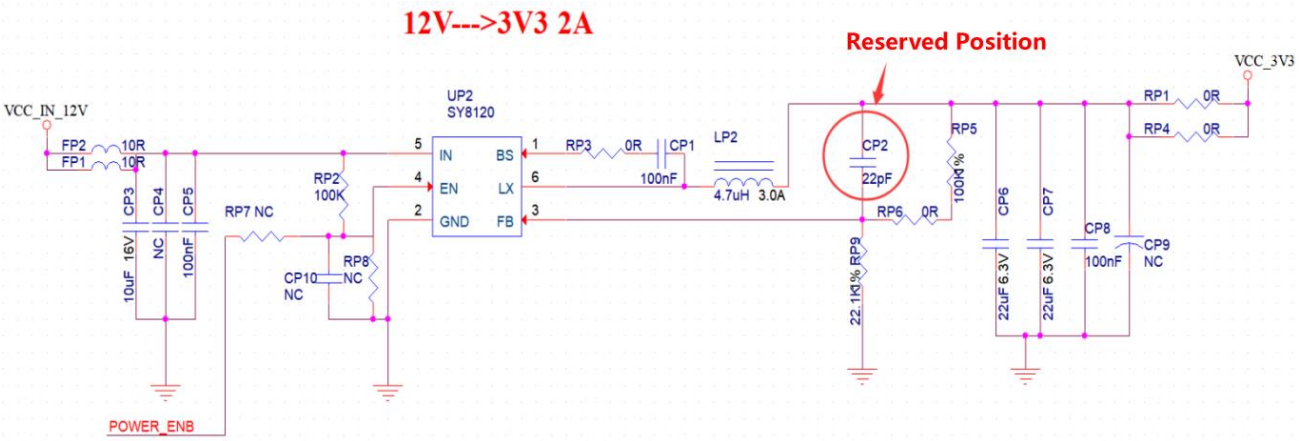


Figure 9 DC-DC Buck Circuit

Notes on the DC-DC Buck Circuit:

- Recommended VCC voltage: 3.3V; recommended current > 200mA.
- 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.

7.4 GPIO

Figure 10 shows a 3.3V and 5V bidirectional UART level-shifting circuit, which supports bidirectional serial communication across different voltage levels.

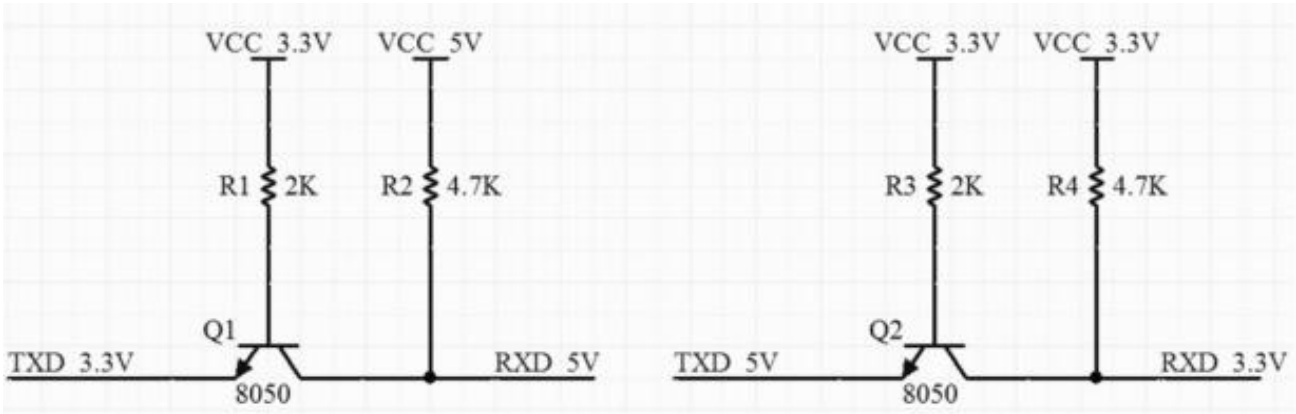


Figure 10 Level-Shifting Circuit

Notes on the Level-Shifting Circuit:

- Some I/O pins are exposed on 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.

8 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.

9 Reflow Soldering Profile

Figure 11 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.

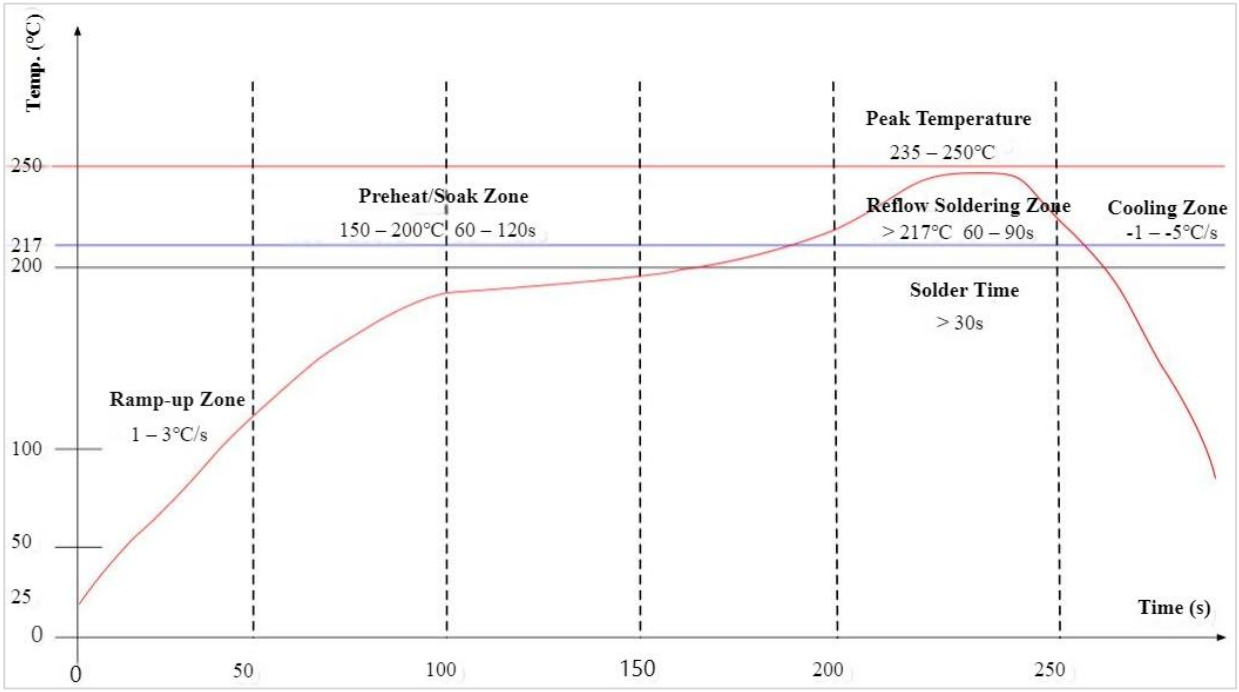


Figure 11 Reflow Soldering Profile

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)

10 Packaging Information

Figure 12 shows the packaging of the Ra-11 module. The module is packed in tape-and-reel, 800 pcs/reel.

Figure 12 Tape and Reel Packaging Diagram

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