Ra-01S-P Specification

Version V1.0.3

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Document Revision History

Version	Date	Description of Changes	Authored by	Approved by
V1.0.0	2024.09.24	First edition	Dong Pengfei	Guan Ning
V1.0.1	2025.01.02	Added instructions that the module cannot transmit without load; added module input power limit description; added control voltage and timing descriptions for CPS and RF_EN pins; added input power limit description when matching the antenna to the module	Dong Pengfei	Guan Ning
V1.0.2	2025.07.02	Added module power consumption data	Guan Ning	Xu Hong
V1.0.3	2025.09.08	1. Updated the module dimension drawing and added a thickness illustration. 2. Changed the chip to SX126x.	Guan Ning	Xu Hong

Contents

1. Product Overview

Ra-01S-P is a LoRa series module designed and developed by Shenzhen Ai-Thinker Technology Co., Ltd. The module is designed for ultra-long-range spread spectrum communication. Its RF chip, SX126x, primarily utilizes the LoRa™ long-range modem technology, offering strong anti-interference capabilities and minimizing current consumption to the greatest extent possible. Leveraging SEMTECH's patented LoRa™ modulation technology, the module integrates a power amplifier (PA) and a low-noise amplifier (LNA), offering high sensitivity of better than -137dBm, an output power of up to +29dBm, long transmission range, and high reliability. Furthermore, compared with conventional modulation techniques, LoRa™ modulation demonstrates significant advantages in blocking immunity and selectivity, addressing the challenges of balancing range, interference resistance, and power consumption that traditional design solutions cannot simultaneously achieve.

It can be widely used in automatic meter reading, home and building automation, security systems, remote irrigation systems, and other applications.

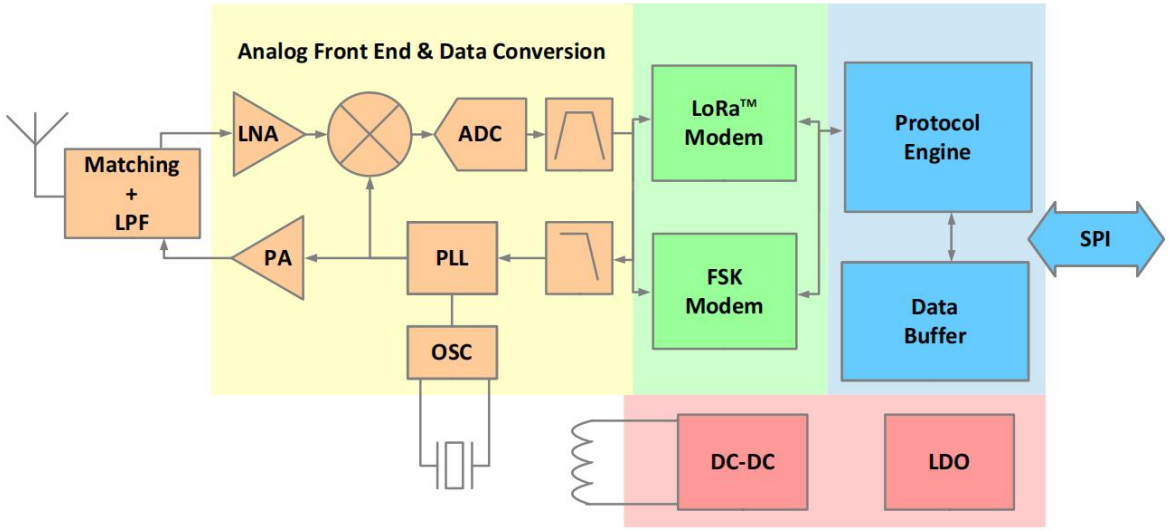


Figure 1 Main Chip Architecture Diagram

1.1. Features

- Supports FSK, GFSK, and LoRa® modulation modes
- Supports 410–525 MHz frequency band
- Maximum output power of +29dBm, with operating current of 700mA
- High sensitivity down to -137dBm@SF10, 125kHz
- Ultra-compact dimensions of 17×16×3.3 (±0.2) mm, in a dual-row castellated (stamp hole) SMT package
- Supports spreading factors SF5 / SF6 / SF7 / SF8 / SF9 / SF10 / SF11 / SF12
- Features low power consumption in receive mode, with receive current as low as 11mA
- Adopts SPI interface, half-duplex communication, with CRC and a data packet engine supporting up to 256 bytes
- Supports multiple antenna mounting methods, compatible with half-hole pads / through-hole pads / IPEX connector

2. Main Parameters

Table 1 Main Parameters Specification

Model	Ra-01S-P
Package	SMD-16
Dimensions	17*16*3.3 (mm)
Antenna Type	Compatible with half-hole pads / through-hole pads / IPEX connector
Frequency Range	410–525MHz
Operating Temperature	-40–85℃
Storage Conditions	-40–125℃, < 90% RH
Power Supply Range	Supply voltage: 3.0–3.6V, typical value: 3.3V, current > 1A
Supported Interfaces	SPI
Programmable Bit Rate	Up to 300kbps

2.1. ESD Requirements

Ra-01S-P is an ESD-sensitive device and requires special precautions during handling.

Figure 2 ESD Protection Symbol

Note:

The Ra-01S-P module is an ESD-sensitive device and requires special ESD precautions. It should normally be handled as an ESD-sensitive component. Proper ESD handling and packaging procedures must be followed throughout the entire process of handling, transportation, and operation of any application involving the Ra-01S-P module. Do not touch the module directly with bare hands or solder it using a non-ESD-safe soldering iron, as this may damage the module.

2.2. Electrical Characteristics

Table 2 Electrical Characteristics

Parameter	Min	Typ	Max	Unit
Supply Voltage 3V3	3.0	3.3	3.6	V
IO Output High Level (VOH)	0.9*VDDIO	-	VDDIO	V
IO Output Low Level (VOL)	0	-	0.1*VDDIO	V
IO Input High Level (VIH)	0.7*VDDIO	-	VDDIO+0.3	V
IO Input Low Level (VIL)	-0.3	-	0.3*VDDIO	V
(RF_EN/CPS)IO Input High Level (VIH)	1.2	-	3.6	V
(RF_EN/CPS)IO Input Low Level (VIL)	0	-	0.3	V

Table 3 SPI Interface Characteristics

Symbol	Description	Condition	Min	Typ	Max	Unit
Fsck	SCK Frequency	-	-	-	10	MHz
tch	SCK High-level Tim	-	50	-	-	ns
tcl	SCK Low-level Time	-	50	-	-	ns
trise	SCK Rise Time	-	-	5	-	ns
tfall	SCK Fall Time	-	-	5	-	ns
tsetup	MOSI Setup Time	From MOSI change to SCK rising edge	30	-	-	ns
thold	MOSI Hold Time	From SCK rising edge to MOSI change	20	-	-	ns
tnsetup	NSS Setup Time	From NSS falling edge to SCK rising edge	30	-	-	ns
tnhold	NSS Hold Time	From SCK falling edge to NSS rising edge, normal mode	100	-	-	ns
tnhigh	SPI Access Interval NSS High Time	-	20	-	-	ns
T_DATA	DATA Hold and Setup Time	-	250	-	-	ns
Fsck	SCK Frequency	-	-	-	-	ns

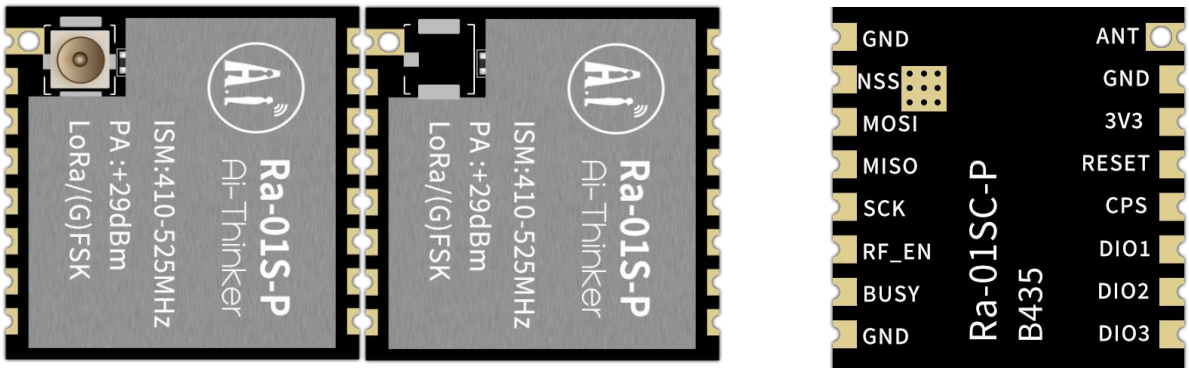
2.3. Power Consumption

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

Table 4 Power Consumption

Mode	Min	Avg	Max	Unit
TX	-	570	-	mA
TX (PA Bypass)	-	70	-	mA
RX	-	11	-	mA
Deep Sleep (RF_EN/CPS pulled up with 10kΩ, pulled down)	-	710	-	μA
STANDBY (RF_EN/CPS pulled up with 10kΩ, pulled down)	-	1.5	-	μA
Deep Sleep (RF_EN/CPS not pulled up, 10kΩ pulled down)	-	6	-	μA
STANDBY (RF_EN/CPS not pulled up, 10kΩ pulled down)		590		μA

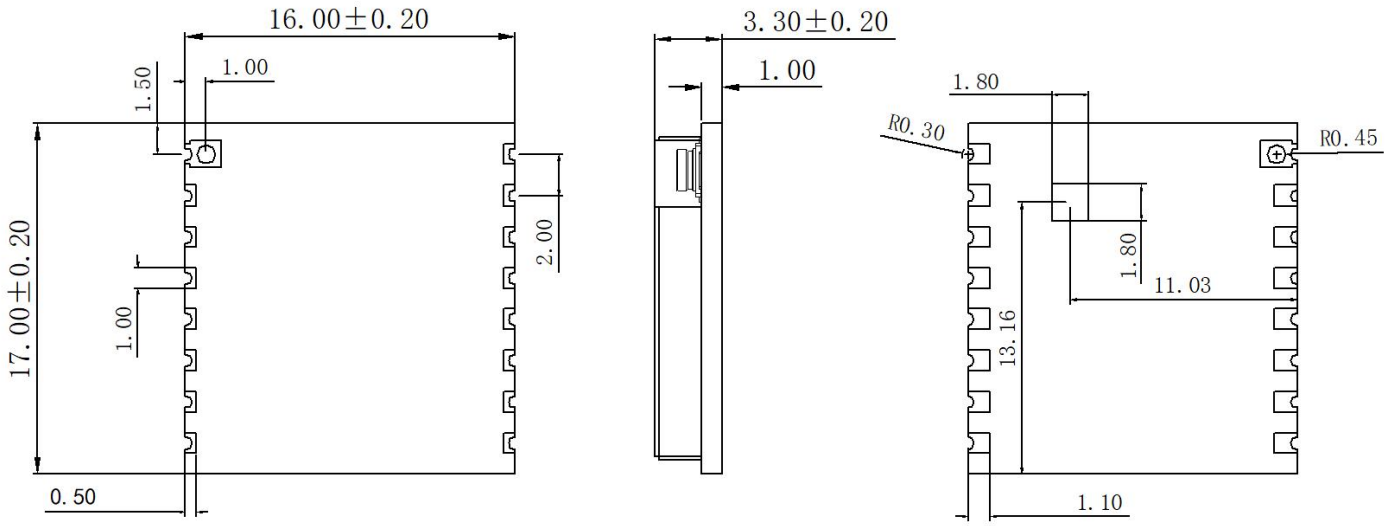
3. Appearance and Dimensions



Top View Bottom View

Figure 3 Appearance Diagram

(Rendering for reference only; actual product shall prevail)

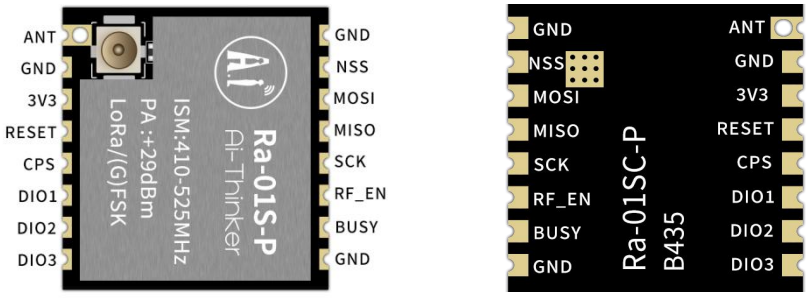


Top View Side View Bottom View

Figure 4 Dimension Diagram (Unit: mm)

4. Pin Definition

Ra-01S-P module exposes a total of 16 pins, as shown in the pin diagram. The pin function definition table provides the detailed interface specifications.



Top View Bottom View

Figure 5 Pin Diagram

Table 5 Pin Function Definition

No.	Name	Function Description
1	ANT	Antenna interface
2	GND	Ground
3	3V3	3.3V power supply, typical
4	RESET	Reset pin
5	CPS	FEM chip TX bypass enable pin. Low level in TX mode: RF signal bypasses PA and outputs directly; internal pull-up by default
6	DIO1	Digital IO1 software configurable
7	DIO2	Digital IO2 software configurable
8	DIO3	Digital IO3 software configurable
9	GND	Ground
10	BUSY	Status indicator pin
11	RF_EN	FEM enable pin, active high; internal pull-up by default; High level: active mode; Low level: sleep mode
12	SCK	SPI clock input
13	MISO	SPI data output
14	MOSI	SPI data input
15	NSS	SPI chip select input
16	GND	Ground
EPAD	GND	Ground, solidly grounded for better heat dissipation

All general-purpose I/O pins of the SX126x are available in LoRa™ mode. Their function mapping is determined by the configuration of the RegDioMapping1 and RegDioMapping2 registers.

Table 6 I/O Function Mapping

Operating Mode	DIOx Mapping	DIO3	DIO2	DIO1
All	00	CadDone	Fhss Change Channel	RxRimeout
	01	Valid Header	Fhss Change Channel	Fhss Change Channel
	10	PayloadCrc Error	Fhss Change Channel	CadDetected
	11	-	-	-

5. Schematic Diagram

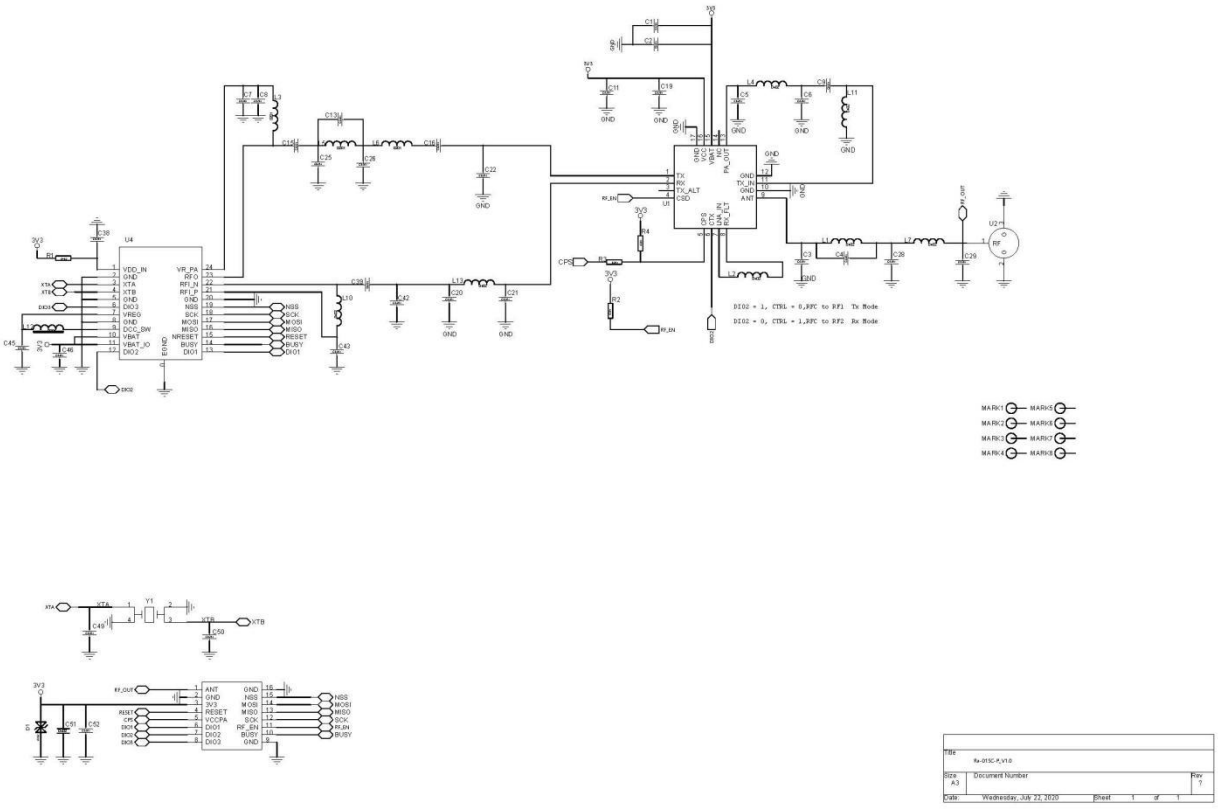


Figure 6 Schematic Diagram

6. Design Guide

6.1. Application Circuit

(1) Special Pin Description

■ CPS Pin

CPS is the TX bypass control pin for the module's internal PA chip, with an internal 10kΩ pull-up resistor (the RF is amplified by PA by default in TX mode). In TX mode:

✓ When this pin is at a high level, the module's RF signal is amplified by PA and output;

✓ When this pin is at a low level, the module's RF signal bypasses PA and outputs directly;

✓ This logic is invalid in receive mode. For low-power operation, this pin should be set low.

■ RF_EN Pin

The RF_EN pin is the enable pin for the module's internal PA chip. When this pin is at a high level, the module operates in the normal transmit/receive state. When this pin is at a low level, the RF function of the module is disabled, thereby reducing power consumption.

Table 7 RF Switch Truth Table

Mode	RF_EN
FEM Power Down	0
FEM Active	1

The module's default BOM includes an internal 10kΩ pull-up resistor, which means the module is in the normal transmit/receive state by default. If a low-power operating mode is required, please use an external MCU to control this pin low. When the pin is at a low level, the default pull-up resistor on this pin may cause leakage current. If the internal pull-up resistor is not needed, please contact Ai-Thinker to modify the BOM.

In summary, the module provides two BOM configurations:

Configuration 1: CPS and RF_EN with internal 10kΩ pull-up resistors (default BOM configuration).

Configuration 2: CPS and RF_EN without internal pull-up resistors; requires control by the IO ports of an external MCU

(2) Application Circuit

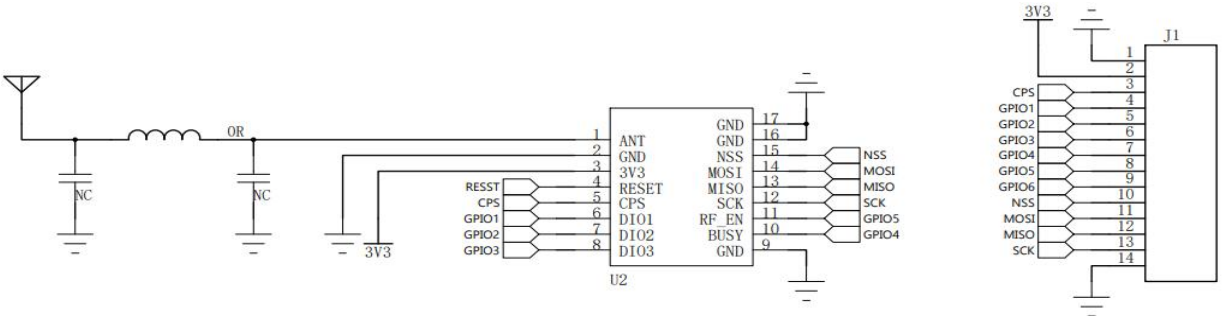


Figure 7 Application Circuit

- It is recommended to use the external MCU I/O to control the module's RF_EN pin to enable low-power operating scenarios.
- The transmit power level configured for SX126x in the module shall not exceed +3dBm; otherwise, excessive power may damage the PA.
- Do not leave the antenna port floating during TX transmission. High VSWR under no-load transmission poses a high risk of damaging the FEM chip. If the ANT port must be left floating, the TX input power shall not exceed 0dBm to prevent chip damage.
- The voltage on CPS and RF_EN pins must comply with the recommended value (1.2–3.6V) and shall not exceed the module's 3V3 supply voltage. Ensure that the module's 3V3 power is applied before or at the same time as CPS and RF_EN during power-up.
- During antenna matching and tuning, impedance mismatch may occur, resulting in very high VSWR. In this process, it is recommended not to transmit packets or apply power directly, in order to avoid chip damage caused by excessive VSWR. After antenna tuning is completed, re-transmit packets and adjust power.
- The power supply current must meet the specification requirements. Insufficient current supply may prevent the power and current from reaching the expected level.

(3) Other Notes

- Besides the SPI interface, connect BUSY/DIO1 to the I/O pins of the host MCU.

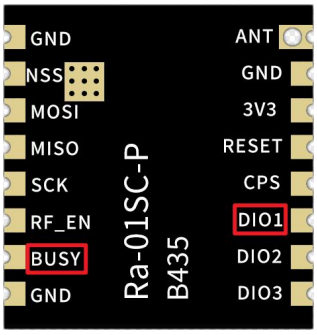


Figure 8 BUSY/DIO1 Application Notes

- The antenna is soldered on the mainboard. It is recommended to reserve a π-type matching circuit at the antenna interface.

6.2. Recommended PCB Footprint Dimensions

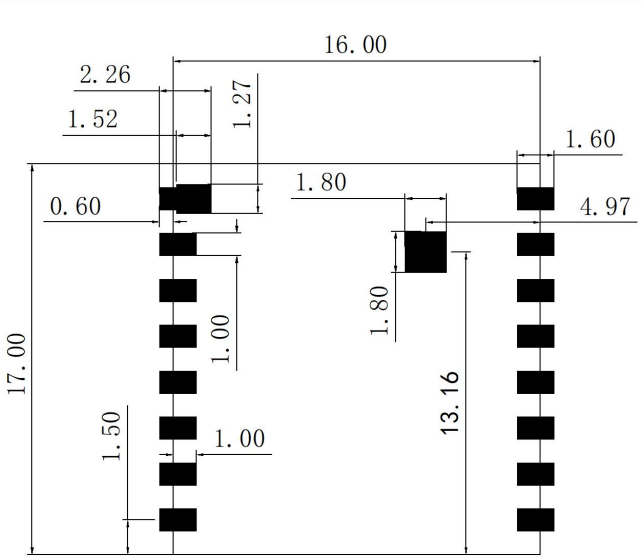


Figure 9 Recommended PCB Footprint Dimensions (Unit: mm)

6.3. Antenna Installation

- The Ra-01S-P requires an external antenna for operation. The module is equipped with half-hole pads can be routed to the mainboard.
- To achieve optimal antenna performance, the antenna assembly should be kept away from any metal objects.
- Antenna mounting structure has a significant impact on module performance. Make sure the antenna is exposed as much as possible and oriented vertically. If the module is installed inside the host enclosure, use a high-quality antenna extension cable to route the antenna outside the enclosure.
- The antenna must not be installed inside a metal enclosure, as this will greatly reduce the transmission range.

6.4. Power Supply

- A 3.3V voltage is recommended, with a peak current above 1A.
- If using DC-DC, the ripple should be controlled within 100mV.
- 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 3.3V power interface.
- For the power supply circuit designed for the module, it is recommended to keep at least 30% current margin to ensure stable and reliable long-term operation.
- Ensure correct polarity of the power supply. Reverse connection may cause permanent damage to the module.

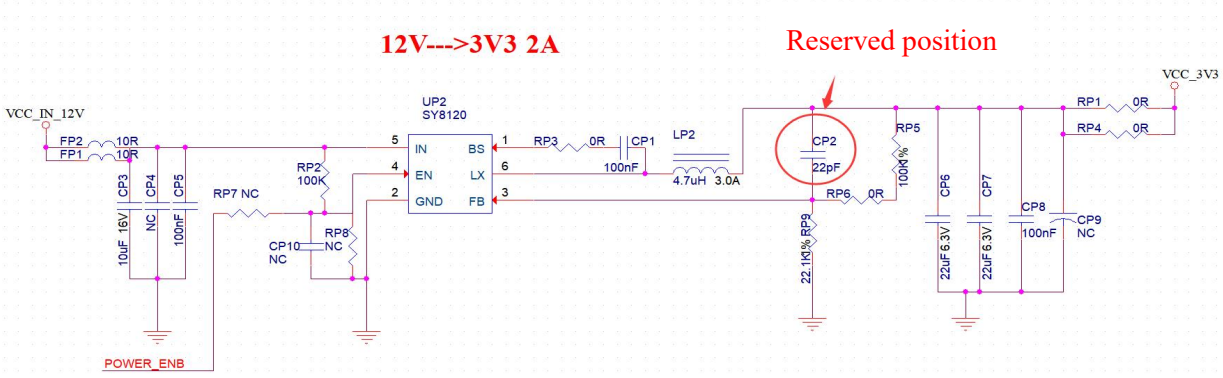


Figure 10 DC-DC Buck Circuit

6.5. GPIO Level Shifting

- 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 IO 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.

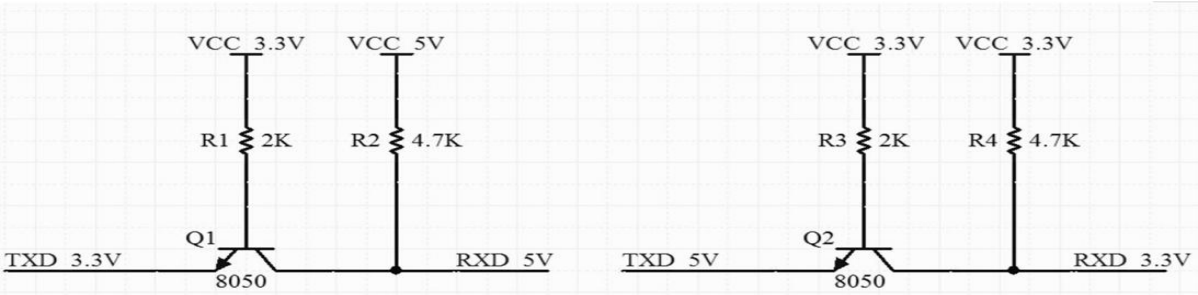


Figure 11 Level-shifting Circuit

6.6. Software Programming

- The maximum input power of the FEM chip shall not exceed +3dBm, otherwise the FEM chip may be damaged. Users must strictly configure the output power of SX126x; 0dBm to 3dBm is recommended.
- This module is a peripheral circuit based on SX126x. Users may operate it fully according to the SX126x chip datasheet.
- DIO1/DIO2 are general-purpose I/O pins that can be configured for multiple functions.
- Among them, the TX/RX control of the RF switch can be controlled either by an external MCU alone, or jointly by the external MCU and SX126x DIO2.
- Differences Between LLCC68 and SX126x:

(1) SX126x

Supports spreading factors SF5, SF6, SF7, SF8, SF9, SF10, SF11, SF12;

SX126x configurable spreading factor and receiver bandwidth:

LoRa@Rx/Tx, BW = 7.8–500 kHz,

SF5 to SF12, BR = 0.018–62.5kbps.

(2) LLCC68

Supports spreading factors SF5, SF6, SF7, SF8, SF9, SF10, SF11;

LLCC68 configurable spreading factor and receiver bandwidth:

LoRa@ Rx/Tx, BW = 125 / 250 / 500kHz,

LoRa@ , SF = 5/6/7/8/9 for BW = 125kHz,

LoRa@ , SF = 5/6/7/8/9/10 for BW = 250kHz,

LoRa@ , SF = 5/6/7/8/9/10/11 for BW = 500kHz.

7. FAQ

7.1. Factors Affecting Transmission Range

- Communication range will be attenuated accordingly when direct line-of-sight obstructions exist.
- Temperature, humidity, and co-channel interference will increase the packet loss rate.
- The ground absorbs and reflects radio waves, resulting in poor performance when testing near the ground.
- Seawater has a strong ability to absorb radio waves, resulting in poor performance in coastal testing.
- Metal objects near the antenna or placing it in a metal enclosure will cause severe signal attenuation.
- Incorrect power register settings or setting the over-the-air (OTA) data rate too high (higher OTA rates correspond to shorter transmission ranges).
- Power supply voltage is below the recommended voltage at room temperature; the lower the voltage, the less the transmit power.
- The matching between the antenna and the module is poor, or there are quality issues with the antenna itself.

7.2. Module Usage Precautions

- Check the power supply to ensure the voltage is within the recommended range. Exceeding the maximum rating may cause permanent damage to the module.
- Check the stability of the power supply, ensuring that the voltage does not fluctuate significantly and frequently.
- Ensure electrostatic discharge (ESD) precautions are followed during installation and use, as high-frequency components are electrostatic sensitive.
- Ensure the humidity is not excessively high during installation and use, as some components are moisture-sensitive.
- Unless there are special requirements, it is not recommended to use the product at excessively high or low temperatures.

7.3. Factors Causing Interference to the Module

- Co-channel signal interference nearby. Move away from the interference source, or change the frequency/channel to avoid interference.
- Non-standard SPI clock waveform. Check for interference on the SPI lines, and ensure the SPI bus traces are not excessively long.
- Non-ideal power supply may also cause garbled data; ensure the power supply is highly reliable.
- Poor quality or excessively long extension cables/feeder lines can also result in a high bit error rate.

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

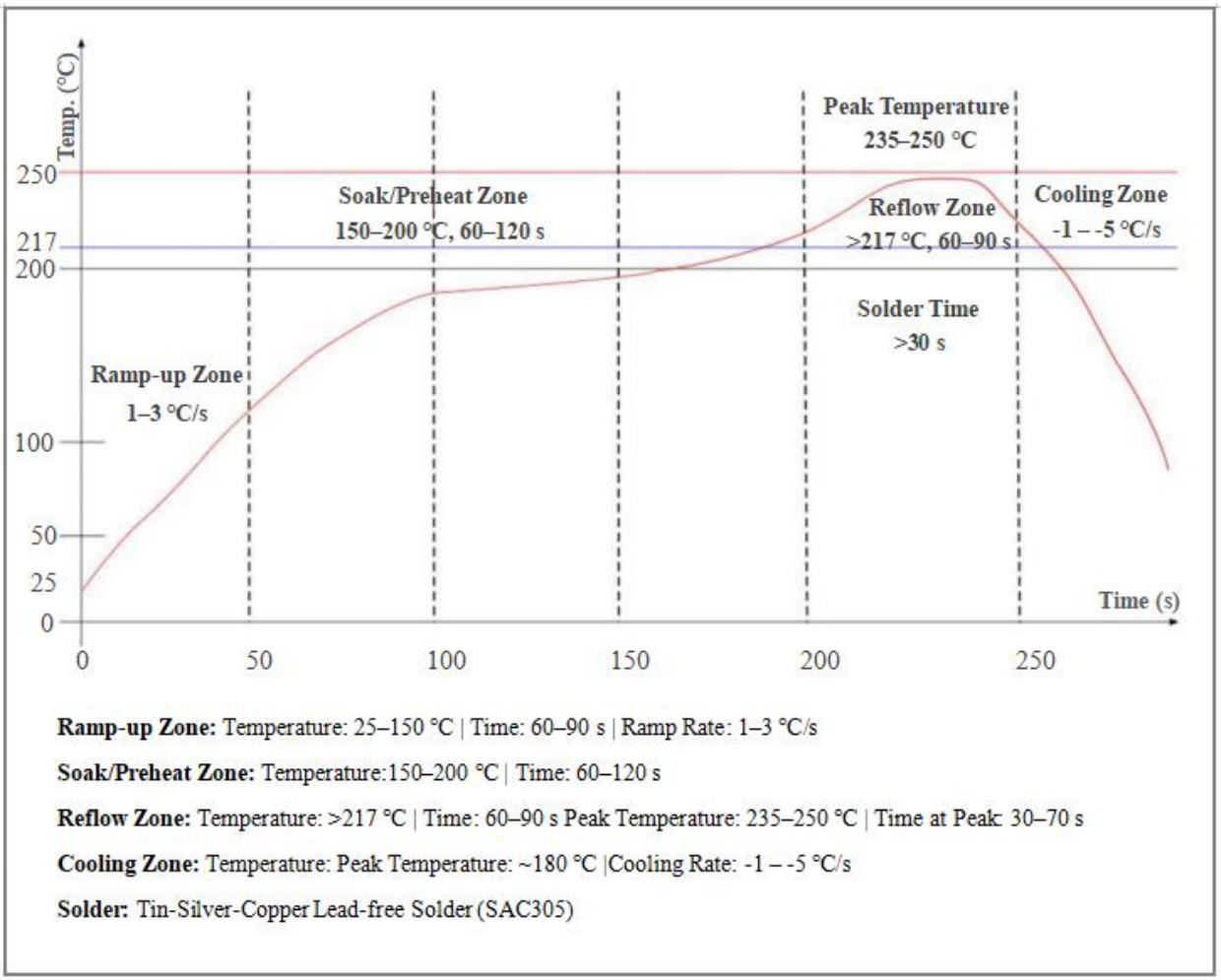


Figure 12 Reflow Soldering Profile

10. Packaging Information

As shown below, the Ra-01S-P module is packaged in tape and reel, with 800pcs/reel.

Figure 13 Tape and Reel Packaging Diagram

11. Contact Information

Official Website Official Forum Development DOCS LinkedIn

Tmall Store Taobao Store Alibaba Store

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Domestic Business Cooperation: sales@aithinker.com

Overseas Business Cooperation: overseas@aithinker.com

Company Address: Room 403–405, 408–410, Building C, Huafeng Smart Innovation Port, Gushu, Xixiang, Bao'an District, Shenzhen, Guangdong, China

Contact Hotline: 0755-29162996

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