RF-BM-BG24B1 and RF-BM-BG24B2

EFR32BG24 Series

Bluetooth Low Energy and Bluetooth Mesh

2.4 GHz Wireless Module

with Power Amplifier

Version 1.0

Shenzhen RF-star Technology Co., Ltd.

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1 Device Overview

1.1 Description

RF-BM-BG24B1 and RF-BM-BG24B2 are IoT wireless connectivity modules based on Silicon Labs EFR32BG24 Series SoCs. They integrate a 39 MHz crystal and a 32.768 kHz crystal, up to 1024 KB programmable flash, and 128 KB RAM making it possible in many complex applications. Its 32-bit 78 MHz ARM® Cortex®-M33 core can operate at an extremely low current at flexible power modes. Its multiprotocol 2.4 GHz RF transceiver is compatible with Bluetooth® 5.3 Low Energy, Bluetooth Mesh, and 2.4 GHz Proprietary. Up to optional 10 dBm or 19.5 dBm TX power enables it in long-range requirement applications. It features a small size, robust connection distance, and rigid reliability. Those modules are pin-2-pin compatible with each other.

Table 1. Module Series of RF-BM-BG24Bx

Model	Antenna Output Mode	Chip Model	Max. CPU Speed	TX Power	FLASH	RAM
BG24B1	PCB onboard	EFR32BG24A010F1024IM48-B	78 MHz	+10 dBm	1024 KB	128 KB
BG24B2	PCB onboard	EFR32MG24A020F1024IM48-B	78 MHz	+19.5 dBm	1024 KB	128 KB

1.2 Key Features

- RF Features
  - Bluetooth® 5.3 Low Energy
  - Bluetooth Mesh
  - Proprietary 2.4 GHz
- Modulation
  - 2-(G)FSK with fully configurable shaping
  - OQPSK DSSS
  - (G)MSK
- TX power:
  - RF-BM-BG24B1: up to +10 dBm
  - RF-BM-BG24B2: up to +19.5 dBm
- RF sensitivity
  - -105.7 dBm sensitivity @ 125 kbps GFSK
  - -97.6 dBm sensitivity @ 1 Mbps GFSK
  - -94.8 dBm sensitivity @ 2 Mbps GFSK
- Microcontroller
  - Powerful 32-bit 78 MHz ARM® Cortex®-M33 with DSP instruction and floating-point unit for efficient signal processing
- Memory
  - 1024 KB programmable flash
  - 128 KB of RAM
- Support OTA upgrade
- Wide Operation Range
  - Power supply:
    - 2.2 V to 3.8 V (DC-DC mode)
    - 1.8 V to 3.8 V (Bypass mode)
  - Operating temperature: -40 °C to +85 °C
  - Storage temperature: -40 °C to +125 °C
- Wide Peripherals
  - Analog to Digital Converter (IADC)
    - 12-bit @ 1 Msps or 16-bit @ 76.9 ksps
    - Select OPNs support High Speed Mode (up to 2 Msps) and High Accuracy Mode (up to

16 bits ENOB at 3.8 ksps)
- 2 × Analog Comparator (ACMP)
- 2 × Digital to Analog Converter (VDAC)
- Up to 30 General Purpose I/O pins with output state retention and asynchronous interrupts
- 8 Channel DMA Controller (LDMA)
- 16 Channel Peripheral Reflex System (PRS)
- 3 × 16-bit Timer/Counter with 3 Compare/Capture/PWM channels (TIMER2/3/4)
- 2 × 32-bit Timer/Counter with 3 Compare/Capture/PWM channels (TIMER0/1)
- 2 × 32-bit Real Time Counter (SYSRTC/BURTC)
- 24-bit Low Energy Timer for waveform generation (LETIMER)
- 16-bit Pulse Counter with asynchronous operation (PCNT)
- 2 × Watchdog Timer (WDOG)
- 1 × Universal Synchronous/Asynchronous Receiver/Transmitter (USART), supporting UART/SPI/SmartCard (ISO7816)/IrDA/I2S
- 2 × Enhanced Universal Synchronous/Asynchronous Receiver/Transmitter (EUSART) supporting UART/SPI/DALI/IrDA
- 2 × I2C interface with SMBus support
- Low-Frequency RC Oscillator with precision mode to replace 32 kHz sleep crystal (LFRCO)
- Keypad scanner supporting up to 6x8 matrix (KEYSCAN)
- Die temperature sensor with +/-1.5 °C accuracy after singlepoint calibration

• Security Vault
- Hardware Cryptographic Acceleration for AES128/192/256, ChaCha20-Poly1305, SHA-1, SHA-2/256/384/512, ECDSA+ECDH(P-192, P-256, P-384, P-521), Ed25519 and Curve25519, J-PAKE, PBKDF2
- True Random Number Generator (TRNG)
- ARM® TrustZone®
- Secure Boot (Root of Trust Secure Loader)
- Secure Debug Unlock
- DPA Countermeasures
- Secure Key Management with PUF
- Anti-Tamper
- Secure Attestation

• Dimension: 23.35 mm × 17.0 mm × 2.2 mm

1.3 Applications

- Gateway and hubs
- Sensors
- Smark Lighting
- Switches
- Location services
- Wireless healthcare applications
- Asset tracking and management
- Electronic Shelf Label (ESL)

1.4 Functional Block Diagram

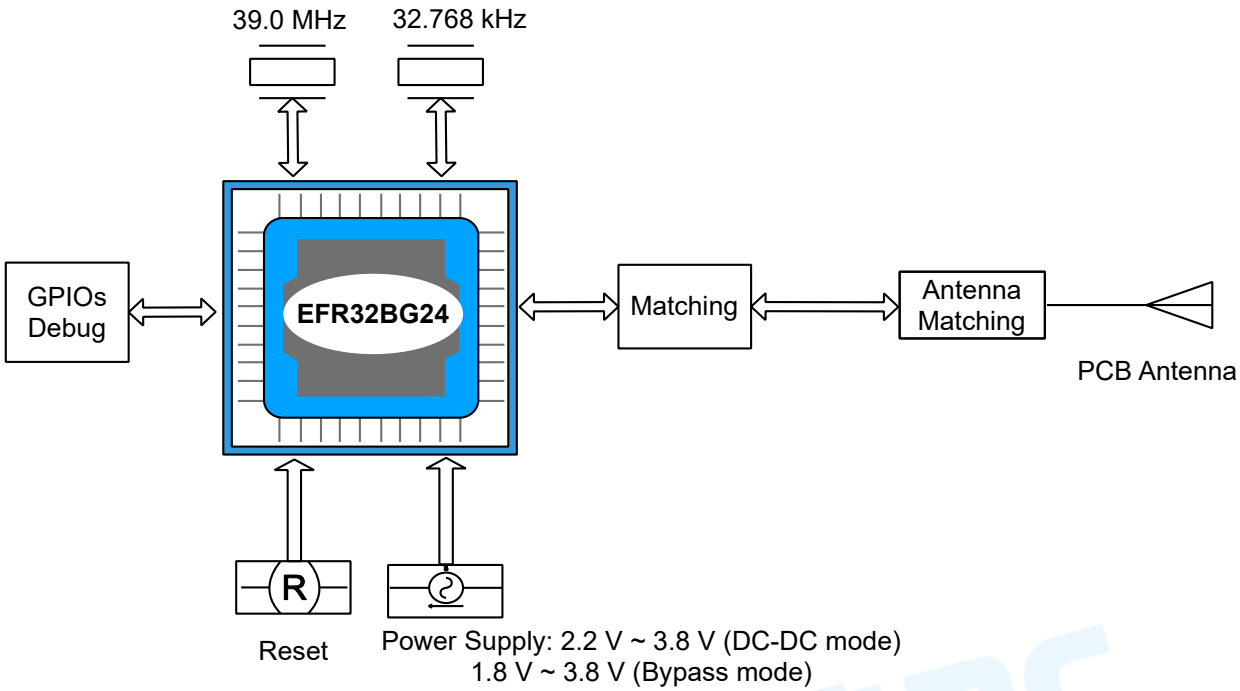


Figure 1. Functional Block Diagram of RF-BM-BG24Bx

1.6 Part Number Conventions

The part numbers are of the form of RF-BM-BG24Bx where the fields are defined as follows:

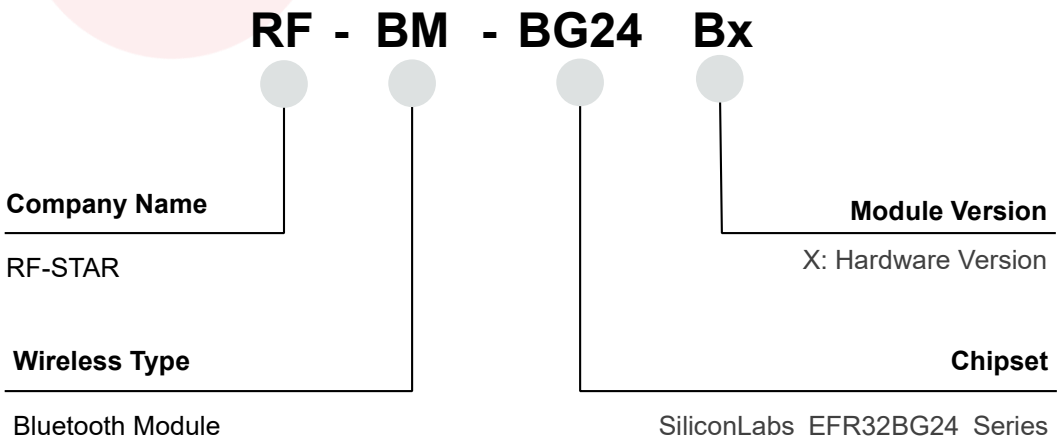


Figure 2. Part Number Conventions of RF-BM-BG24Bx

Table of Contents

2 Module Configuration and Functions

2.1 Module Parameters

Table 2. Parameters of RF-BM-BG24Bx

Chipset	RF-BM-BG24B1: EFR32BG24A010F1024IM48-B RF-BM-BG24B2: EFR32MG24A020F1024IM48-B
Supply Power Voltage	2.2 V ~ 3.8 V (DC-DC mode) 1.8 V ~ 3.8 V (Bypass mode) 3.3 V is recommended
Frequency	2402 MHz ~ 2480 MHz
Maximum Transmit Power	RF-BM-BG24B1: +10.0 dBm RF-BM-BG24B2: +19.5 dBm
Receiving Sensitivity	-105.7 dBm sensitivity @ 125 kbps GFSK -97.6 dBm sensitivity @ 1 Mbps GFSK -94.8 dBm sensitivity @ 2 Mbps GFSK
GPIO	30
Flash	1024 KB
RAM	128 KB
Power Consumption	RX current: 4.4 mA (1 Mbps GFSK) TX current: 5.0 mA @ 0 dBm 19.1 mA @ 10 dBm 156.8 mA @ 19.5 dBm Active Mode (EM0) @ 39.0 MHz: 33.4 μA/MHz EM2 DeepSleep current (16 kB RAM retention and RTC running from LFRCO): 1.3 μA
Support Protocol	Bluetooth® 5.3 Low Energy, Bluetooth Mesh, Proprietary 2.4 GHz
Crystal	39 MHz, 32.768 kHz
Package	SMT packaging (1.27-mm half-hole pitch stamp stick)
Dimension	23.35 mm × 17.0 mm × 2.2 mm
Type of Antenna	PCB antenna
Operating Temperature	-40 ℃ ~ +85 ℃
Storage Temperature	-40 ℃ ~ +125 ℃

2.2 Module Pin Diagram

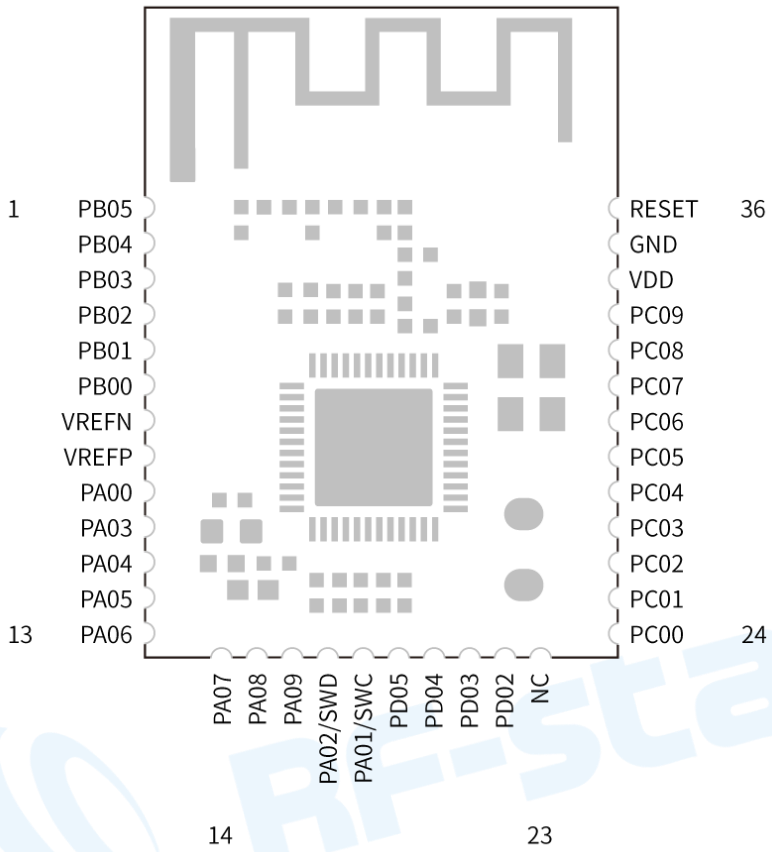


Figure 3. Pin Diagram of RF-BM-BG24Bx

2.3 Pin Functions

Table 3. Pin Functions of RF-BM-BG24Bx

Pin	Name	Chip Pin	Description
1	PB05	PB05	GPIO
2	PB04	PB04	GPIO
3	PB03	PB03	GPIO
4	PB02	PB02	GPIO
5	PB01	PB01	GPIO
6	PB00	PB00	GPIO
7	VREFN	VREFN	Dedicated ADC VREF Negative Input
8	VREFP	VREFP	Dedicated ADC VREF Positive Input
9	PA00	PA00	GPIO
10	PA03	PA03	GPIO
11	PA04	PA04	GPIO

12	PA05	PA05	GPIO
13	PA06	PA06	GPIO
14	PA07	PA07	GPIO
15	PA08	PA08	GPIO
16	PA09	PA09	GPIO
17	PA02/SWD	PA02/SWD	GPIO/SWD
18	PA01/SWC	PA01/SWC	GPIO/SWC
19	PD05	PD05	GPIO
20	PD04	PD04	GPIO
21	PD03	PD03	GPIO
22	PD02	PD02	GPIO
23	NC	NC	None connect
24	PC00	PC00	GPIO
25	PC01	PC01	GPIO
26	PC02	PC02	GPIO
27	PC03	PC03	GPIO
28	PC04	PC04	GPIO
29	PC05	PC05	GPIO
30	PC06	PC06	GPIO
31	PC07	PC07	GPIO
32	PC08	PC08	GPIO
33	PC09	PC09	GPIO
34	VDD	VDD	Power Supply: 2.2 V ~ 3.8 V (DC-DC mode), 1.8 V ~ 3.8 V (Bypass mode), recommend to 3.3 V
35	GND	GND	Ground
36	RESET	RESET_N	Reset pin. Active low. Internal pull-up. **In DC-DC mode, the max. pull-low voltage is 1.8 V.**

3 Specifications

3.1 Recommended Operating Conditions

The functional operation does not guarantee performance beyond the limits of the conditional parameter values in the table below. Long-term work beyond this limit will affect the reliability of the module more or less.

Table 4. Recommended Operating Conditions of RF-BM-BG24Bx

Items	Condition	Min.	Typ.	Max.	Unit
Operating Supply Voltage	DC-DC mode	2.2	3.3	3.8	V
	Bypass mode	1.8		3.8	V
Operating Temperature	/	-40	+25	+85	℃

3.2 Handling Ratings

Table 5. Handling Ratings of RF-BM-BG24Bx

Items	Condition	Min.	Typ.	Max.	Unit
Storage Temperature	Tstg	-40	+25	+125	℃
Human Body Model	HBM		±2000		V
Moisture Sensitivity Level			3		
Charged Device Model			±500		V

4 Setting of Frequency Offset Register

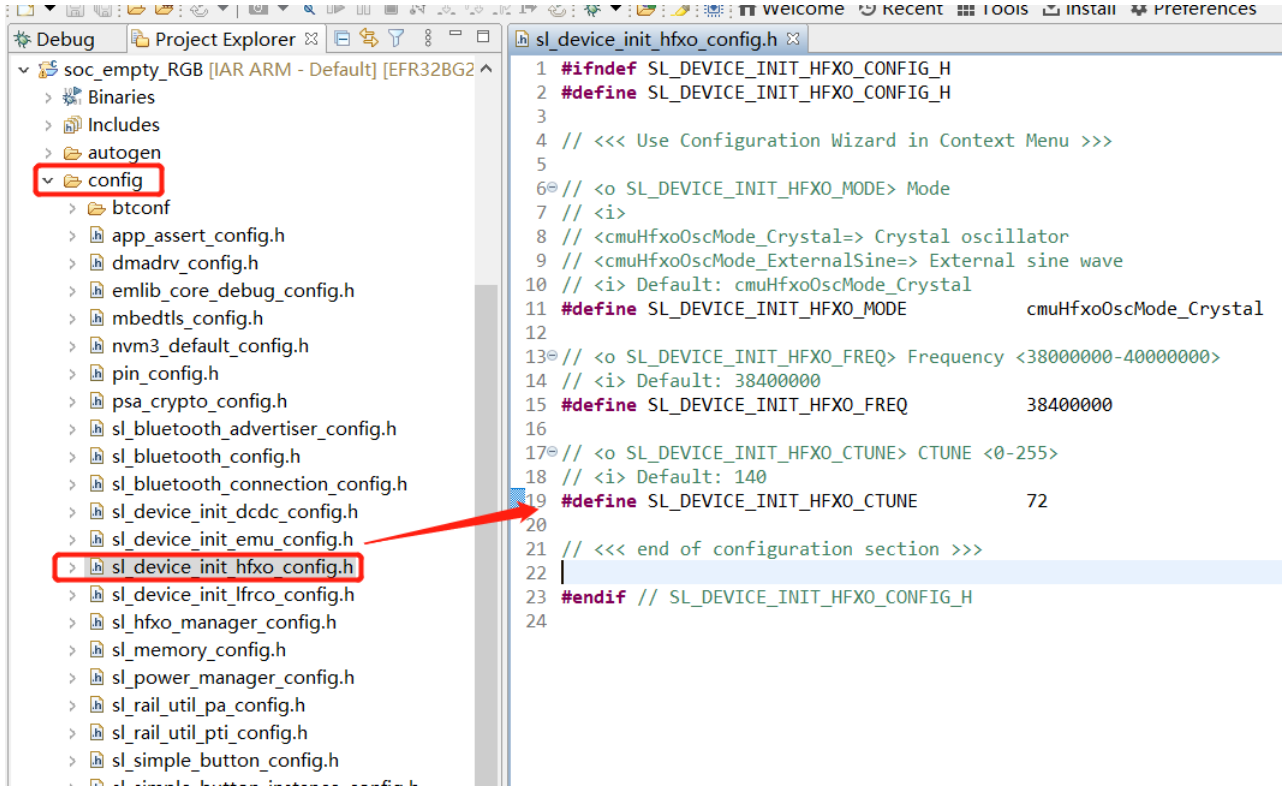
Because there is no matching capacitance circuit of the IC's crystal part, we need to set the frequency offset register through the software to do the assistant frequency offset adjustment of the hardware RF part.

You can find the ***sl_device_init_hfxo_config.h*** file in the corresponding project and modify the ***CTUNE*** value.

Take the ***empty_RGB*** project as an example:

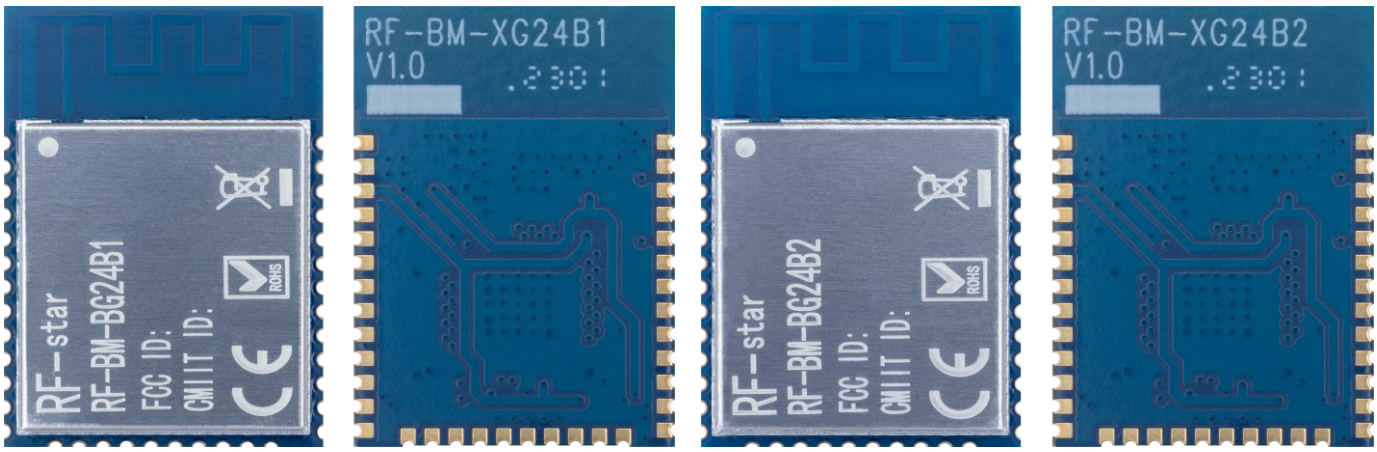
Find ***SL_DEVICE_INIT_HFXO_CTUNE***, the official default value of SiliconLabs is 140, the value is needed to be changed to **72** for RF-star's **RF-BM-BG24Bx**.

If the user needs to change to other values, you can directly modify it (Value range: 0 ~ 255). As shown below.



5 Application, Implementation, and Layout

5.1 Module Photos



RF-BM-BG24B1 RF-BM-BG24B2

Figure 4. Photos of RF-BM-BG24Bx

5.2 Recommended PCB Footprint

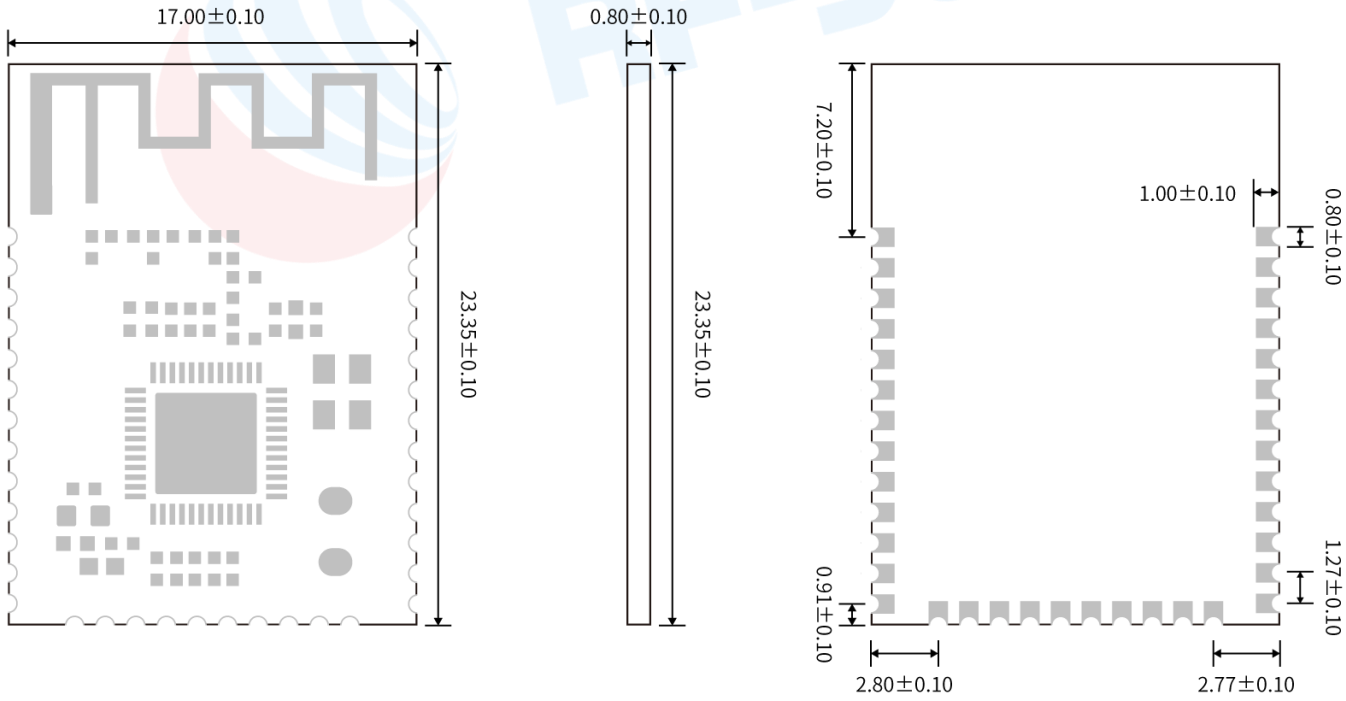


Figure 5. Recommended PCB Footprint of RF-BM-BG24Bx (mm)

5.3 Schematic Diagram

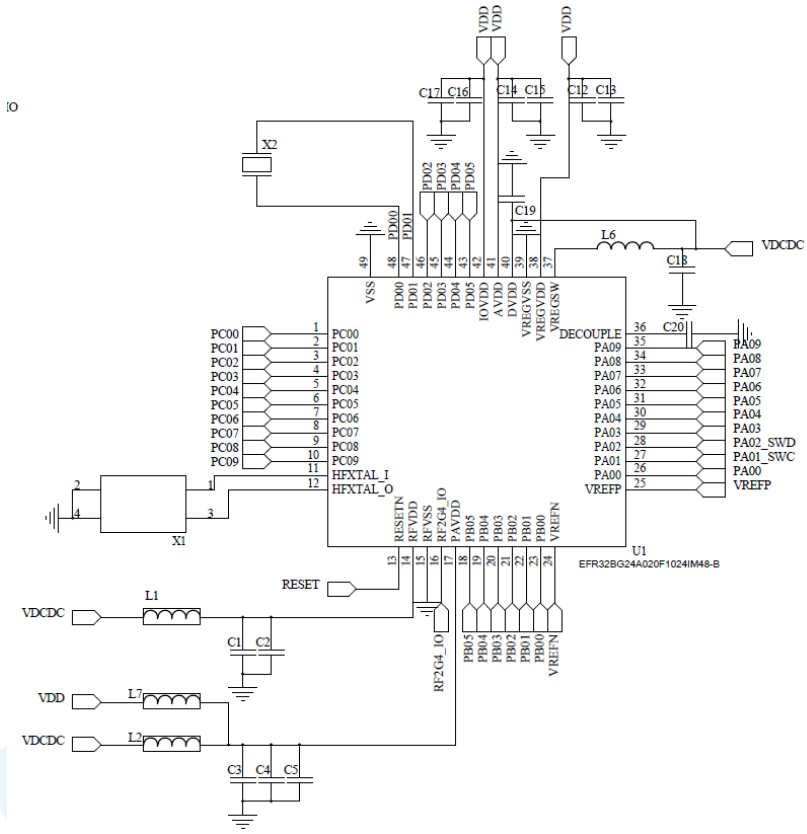


Figure 6. Schematic Diagram of RF-BM-BG24Bx

5.4 Reference Design

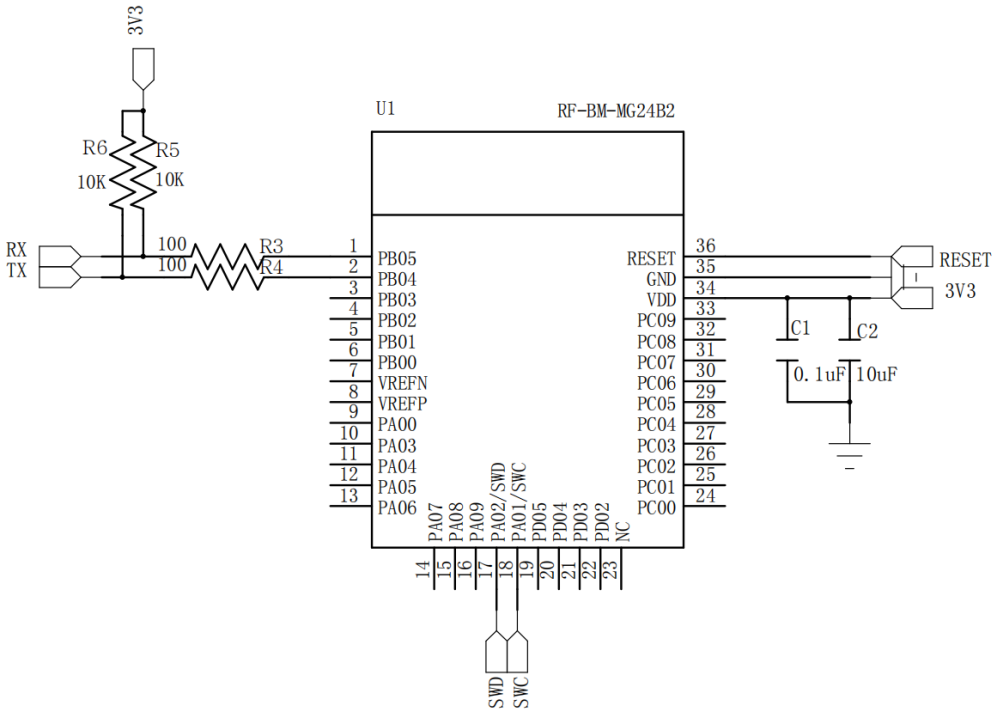


Figure 7. Reference Design of RF-BM-BG24Bx

5.5 Antenna

5.5.1 Antenna Design Recommendation

1. The antenna installation structure has a great influence on the module performance. It is necessary to ensure the antenna is exposed and preferably vertically upward. When the module is installed inside of the case, a high-quality antenna extension wire can be used to extend the antenna to the outside of the case.
2. The antenna must not be installed inside the metal case, which will cause the transmission distance to be greatly weakened.
3. The recommendation of antenna layout.

   The inverted-F antenna position on PCB is free-space electromagnetic radiation. The location and layout of the antenna are key factors to increase the data rate and transmission range.

   Therefore, the layout of the module antenna location and routing is recommended as follows:

   （1） Place the antenna on the edge (corner) of the PCB.

   （2） Make sure that there is no signal line or copper foil in each layer below the antenna.

   （3） It is best to hollow out the antenna position in the following figure to ensure that the S11 of the module is minimally affected.

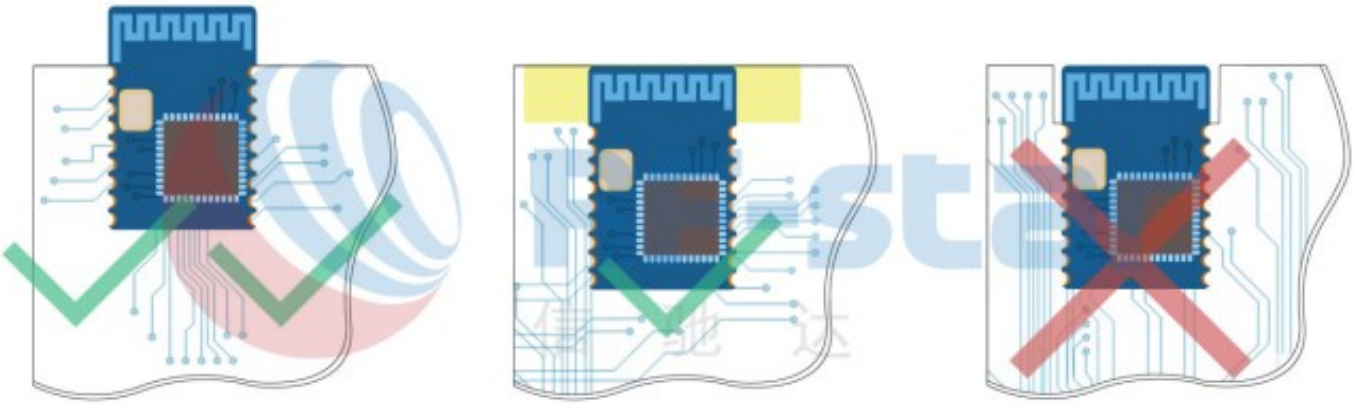


Figure 8. Recommendation of Antenna Layout

Note: The hollow-out position is based on the antenna used.

5.6 Basic Operation of Hardware Design

1. It is recommended to offer the module a DC stabilized power supply, a tiny power supply ripple coefficient, and reliable ground. Please pay attention to the correct connection between the positive and negative poles of the power supply. Otherwise, the reverse connection may cause permanent damage to the module.
2. Please ensure the supply voltage is between the recommended values. The module will be permanently damaged if the voltage exceeds the maximum value. Please ensure a stable power supply and no frequently fluctuating voltage.

3. When designing the power supply circuit for the module, it is recommended to reserve more than 30% of the margin, which is beneficial to the long-term stable operation of the whole machine. The module should be far away from the power electromagnetic, transformer, high-frequency wiring, and other parts with large electromagnetic interference.
4. The bottom of the module should avoid high-frequency digital routing, high-frequency analog routing, and power routing. If it has to route the wire on the bottom of the module, for example, it is assumed that the module is soldered to the Top Layer, the copper must be spread on the connection part of the top layer and the module, and be close to the digital part of the module and routed in the Bottom Layer (all copper is well-grounded).
5. Assuming that the module is soldered or placed in the Top Layer, it is also wrong to randomly route the Bottom Layer or other layers, which will affect the spurs and receiving sensitivity of the module to some degree.
6. Assuming that there are devices with large electromagnetic interference around the module, which will greatly affect the module performance. It is recommended to stay away from the module according to the strength of the interference. If circumstances permit, appropriate isolation and shielding can be done.
7. Assuming that there are routings of large electromagnetic interference around the module (high-frequency digital, high-frequency analog, power routings), which will also greatly affect the module performance. It is recommended to stay away from the module according to the strength of the interference. If circumstances permit, appropriate isolation and shielding can be done.
8. It is recommended to stay away from devices whose TTL protocol is the same 2.4 GHz physical layer, for example, USB 3.0.

5.7 Trouble Shooting

5.7.1 Unsatisfactory Transmission Distance

1. When there is a linear communication obstacle, the communication distance will be correspondingly weakened. Temperature, humidity, and co-channel interference will lead to an increase in the communication packet loss rate. The performance of ground absorption and reflection of radio waves will be poor when the module is tested close to the ground.
2. Seawater has a strong ability to absorb radio waves, so the test results by the seaside are poor.
3. The signal attenuation will be very obvious if there is metal near the antenna or if the module is placed inside the metal shell.
4. The incorrect power register set or the high data rate in the open air may shorten the communication distance. The higher the data rate, the closer the distance.
5. The low voltage of the power supply is lower than the recommended value at ambient temperature, and the lower the voltage, the smaller the power is.
6. The unmatchable antennas and modules or the poor quality of antenna will affect the communication distance.

5.7.2 Vulnerable Module

1. Please ensure the supply voltage is between the recommended values. The module will be permanently damaged if the voltage exceeds the maximum value. Please ensure a stable power supply and no frequently fluctuating voltage.
2. Please ensure the anti-static installation and the electrostatic sensitivity of high-frequency devices.
3. Due to some humidity-sensitive components, please ensure the suitable humidity during installation and application. If there is no special demand, it is not recommended to use at too high or too low temperature.

5.7.3 High Bit Error Rate

1. There are co-channel signal interferences nearby. It is recommended to be away from the interference sources or modify the frequency and channel to avoid interferences.
2. The unsatisfactory power supply may also cause garbled. It is necessary to ensure the power supply's reliability.
3. If the extension wire or feeder wire is of poor quality or too long, the bit error rate will be high.

5.8 Electrostatics Discharge Warnings

The module will be damaged by the discharge of static. RF-star suggests that all modules should follow the 3 precautions below:

1. According to the anti-static measures, bare hands are not allowed to touch modules.
2. Modules must be placed in anti-static areas.
3. Take the anti-static circuitry (when inputting HV or VHF) into consideration in product design.
   Static may result in the degradation in performance of the module, even causing failure.

5.9 Soldering and Reflow Condition

1. Heating method: Conventional Convection or IR/convection.
2. Solder paste composition: Sn96.5/Ag3.0/Cu0.5
3. Allowable reflow soldering times: 2 times based on the following reflow soldering profile.
4. Temperature profile: Reflow soldering shall be done according to the following temperature profile.
5. Peak temperature: 245 ℃.

Table 6. Temperature Table of Soldering and Reflow

Profile Feature	Sn-Pb Assembly	Pb-Free Assembly
Solder Paste	Sn63 / Pb37	Sn96.5 / Ag3.0 / Cu0.5
Min. Preheating Temperature (T_{min})	100 ℃	150 ℃
Max. Preheating Temperature (T_{max})	150 ℃	200 ℃
Preheating Time (T_{min} to T_{max}) (t_1)	60 s ~ 120 s	60 s ~ 120 s

Average Ascend Rate (T_{max} to T_p)	Max. 3 ℃/s	Max. 3 ℃/s
Liquid Temperature (T_L)	183 ℃	217 ℃
Time above Liquidus (t_L)	60 s ~ 90 s	30 s ~ 90 s
Peak Temperature (T_p)	220 ℃ ~ 235 ℃	230 ℃ ~ 250 ℃
Average Descend Rate (T_p to T_{max})	Max. 6 ℃/s	Max. 6 ℃/s
Time from 25 ℃ to Peak Temperature (t_2)	Max. 6 minutes	Max. 8 minutes
Time of Soldering Zone (t_P)	20±10 s	20±10 s

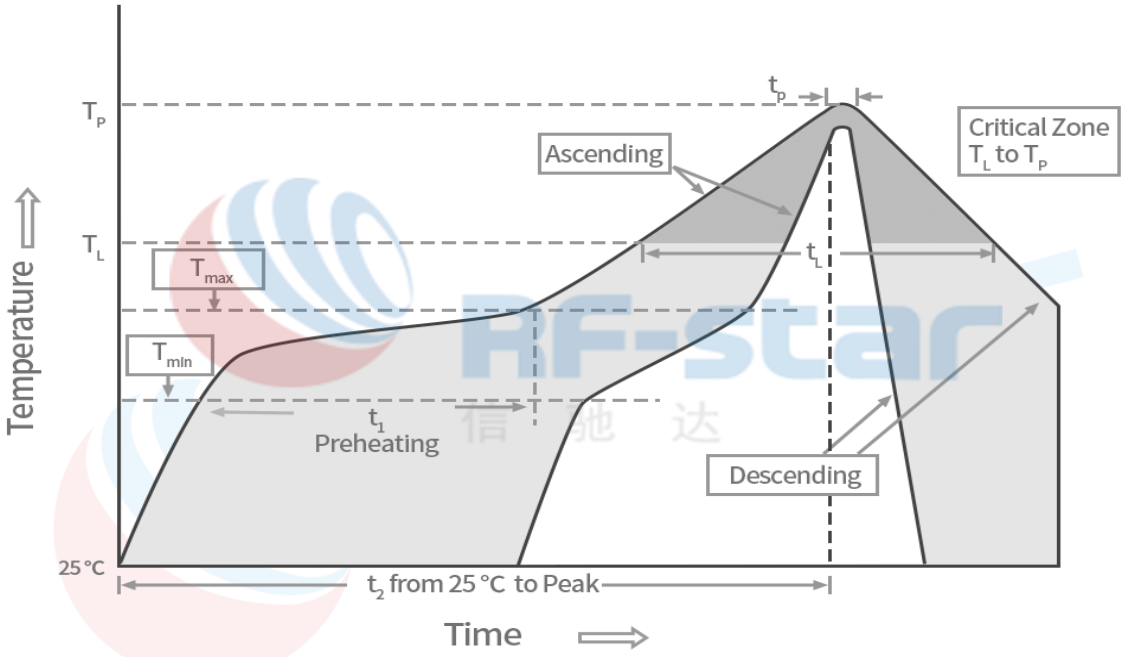


Figure 9. Recommended Reflow for Lead-Free Solder

6 Optional Package Specification

The default package method is ***by tray***. If you need the modules to be shipped by tape & reel, pls contact us in advance.

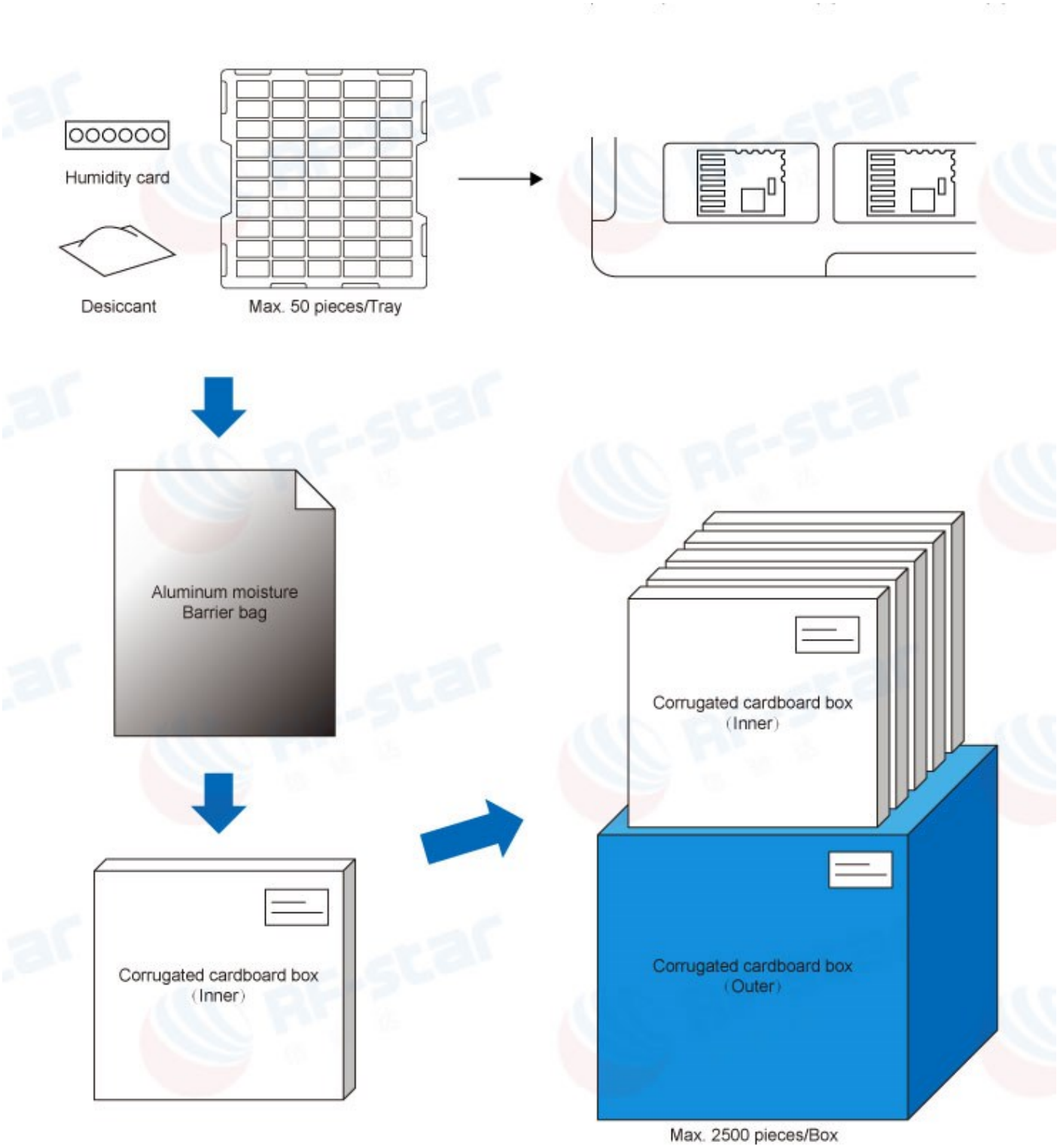


Figure 10. Default Package by Tray

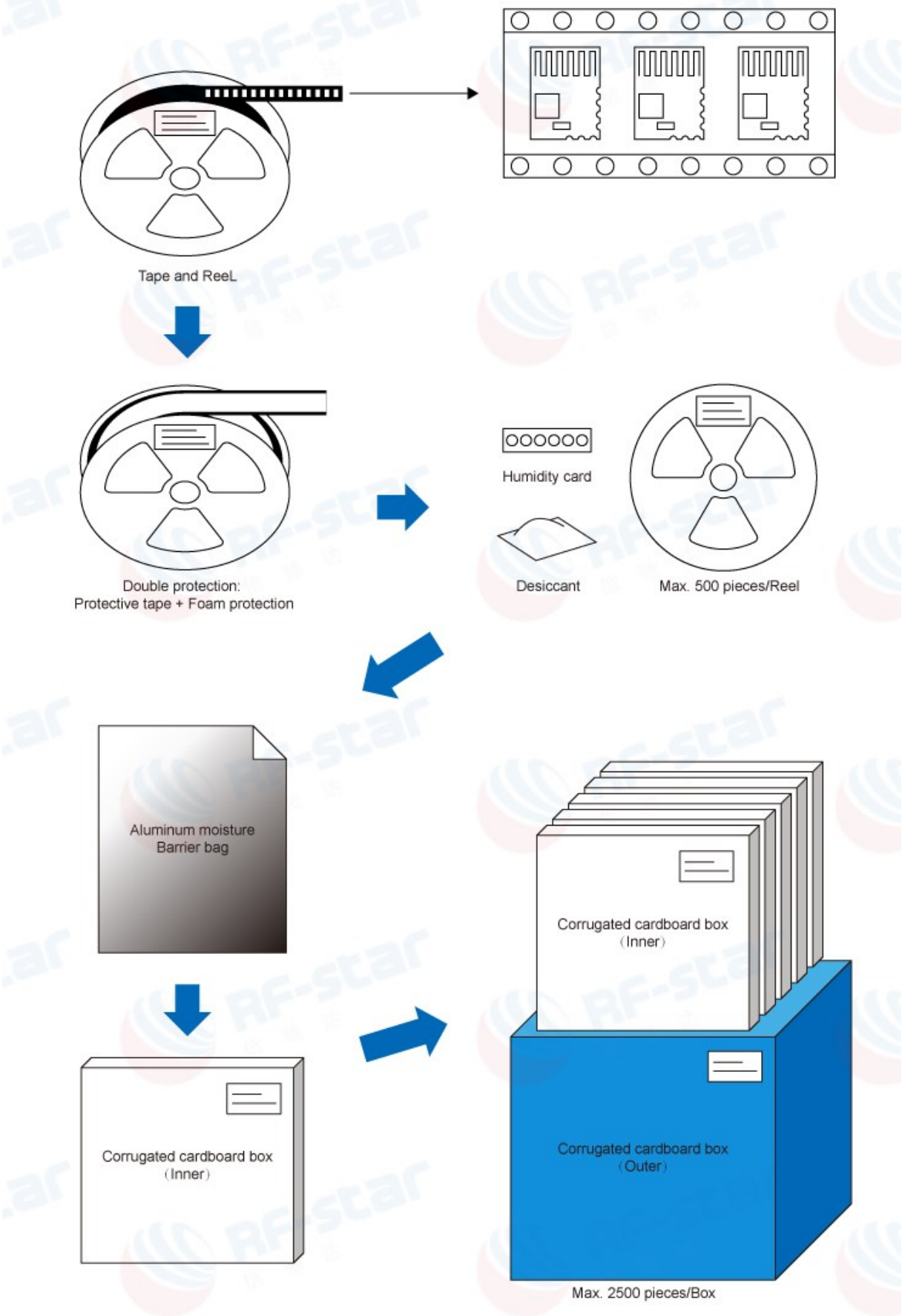


Figure 11. Package by Tape & Reel

7 Revision History

Date	Version No.	Description
2023.03.22	V1.0	The initial version is released.
2023.05.26	V1.0	Update MSL level. Update the Shenzhen office address.

Note:

1. The document will be optimized and updated from time to time. Before using this document, please make sure it is the latest version.
2. To obtain the latest document, please download it from the official website: www.rfstariot.com and www.szrfstar.com.

8 Contact Us

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