RF-BM-BG22C3 EFR32BG22C224

Bluetooth 5.2 Low Energy Module

Version 1.1

Shenzhen RF-star Technology Co., Ltd.

May 26th, 2023

1 Device Overview

1.1 Description

RF-BM-BG22C3 is an RF module based on EFR32BG22C224F512GM32-C, one of the Gecko family of SoCs from Silicon Labs, with a 32-bit ARM® Cortex®-M33 core with 76.8 MHz maximum operating frequency. It integrates a 38.4 MHz crystal, a matching, an antenna matching, a low-pass filter, and the antenna option (the one is chip antenna and a half-hole ANT pin, and the other is the IPEX connector and a half-hole ANT pin). As for the hardware, it supports Bluetooth 5.2 Low Energy, Low Power Node of Bluetooth Mesh, Direction Finding AoA/AoD and proprietary and also has a range of analog and digital interfaces such as PRS, ADC, UART, SPI, I²C, PWM, ISO 7816, IrDA, I²S, EUART and PDM. It features low power consumption, compact size, robust connection distance, and rigid reliability. An integrated PA in the chip enables the module to reach up to 6 dBm TX power. 1.27-mm pitch stamp stick package for easy assembling and cost-effective PCB design. As for the firmware, it can be preprogrammed with an RF-star BLE5.0 serial communication protocol for simple programming.

1.2 Key Features

- RF Features
  - Bluetooth 5.2 Low Energy
  - Bluetooth Mesh Low Power Node
  - Direction finding using Angle-of-Arrival (AoA) and Angle-of-Departure (AoD)
  - Proprietary
- Modulation
  - 2 (G)FSK with fully configurable shaping
  - OQPSK DSSS
  - (G)MSK
- TX power: -28 dBm ~ 6 dBm
- Sensitivity
  - -98.9 dBm @ 1 Mbit/s GFSK
  - -96.2 dBm @ 2 Mbit/s GFSK
  - -106.7 dBm @ 125 kbit/s GFSK
- 32-bit 76.8 MHz ARM® Cortex®-M33 with DSP instruction and floating-point unit for efficient signal processing
- Memory
  - Flash: 512 KB
  - RAM: 32 KB
- Wide Operation Range
  - Single power supply
    - DC-DC mode: 2.2 V to 3.8 V
    - Bypass mode: 1.8 V to 3.8 V
  - Operating temperature: -40 °C to +85 °C
  - Storage temperature: -40 °C to +125 °C
- Wide Peripherals
  - 12-bit 1 Msps SAR ADC
  - Up to 12 GPIOs with output state retention and asynchronous interrupts
  - 8 Channel DMA Controller
  - 12 Channel Peripheral Reflex System (PRS)
  - 4 × 16-bit Timer/Counter with 3 Compare/Capture/PWM channels
  - 1 × 32-bit Timer/Counter with 3 Compare/Capture/PWM channels
  - 32-bit RTC
  - 24-bit Low Energy Timer for waveform generation
  - 1×Watchdog Timer
  - 2 × Universal Synchronous/Asynchronous Receiver/Transmitter
    - UART
    - SPI
    - SmartCard (ISO 7816)
    - IrDA
    - I²S
  - 1×Enhanced Universal Asynchronous Receiver /

Transmitter (EUART)
- 2×I²C interface with SMBus support
- Digital microphone interface (PDM)
- Precision Low-Frequency RC Oscillator enabling single-crystal operation
- RFSENSE with selective OOK mode
- Die temperature sensor with +/-2 degree C accuracy across temperature range

• Security Features
- Secure Boot with Root of Trust and Secure Loader (RTSL)
- Hardware Cryptographic Acceleration for AES128/256, SHA-1, SHA-2 (up to 256-bit), ECC (up to 256-bit), ECDSA, and ECDH
- True Random Number Generator (TRNG) compliant with NIST SP800-90 and AIS-31
- ARM® TrustZone®
- Secure Debug with lock / unlock

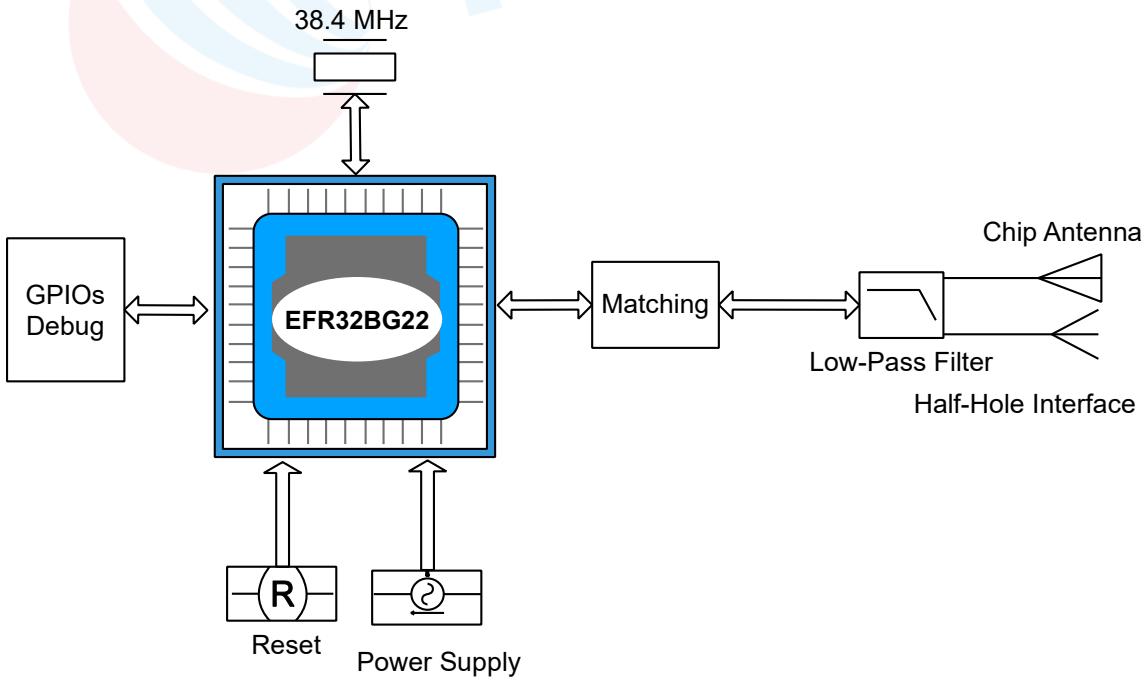
• Transmission range:
- RF-BM-BG22C3: 110 m (@ PCB antenna, 1 Mbps/s); 135 m (@ PCB antenna, 125 kbps/s)

• Dimension: 8 mm x 8 mm x 1.82 mm

1.3 Applications

• Asset tags and beacons
• Consumer electronics remote controls
• Portable medical
• Sports, fitness and wellness devices
• Connected home
• Building automation and security

1.4 Functional Block Diagram



DC-DC mode: 2.2 V to 3.8 V

Bypass mode: 1.8 V to 3.8 V

Figure 1. Functional Block Diagram of RF-BM-BG22C3

1.5 Part Number Conventions

The part numbers are of the form of RF-BM-BG22C3 where the fields are defined as follows:

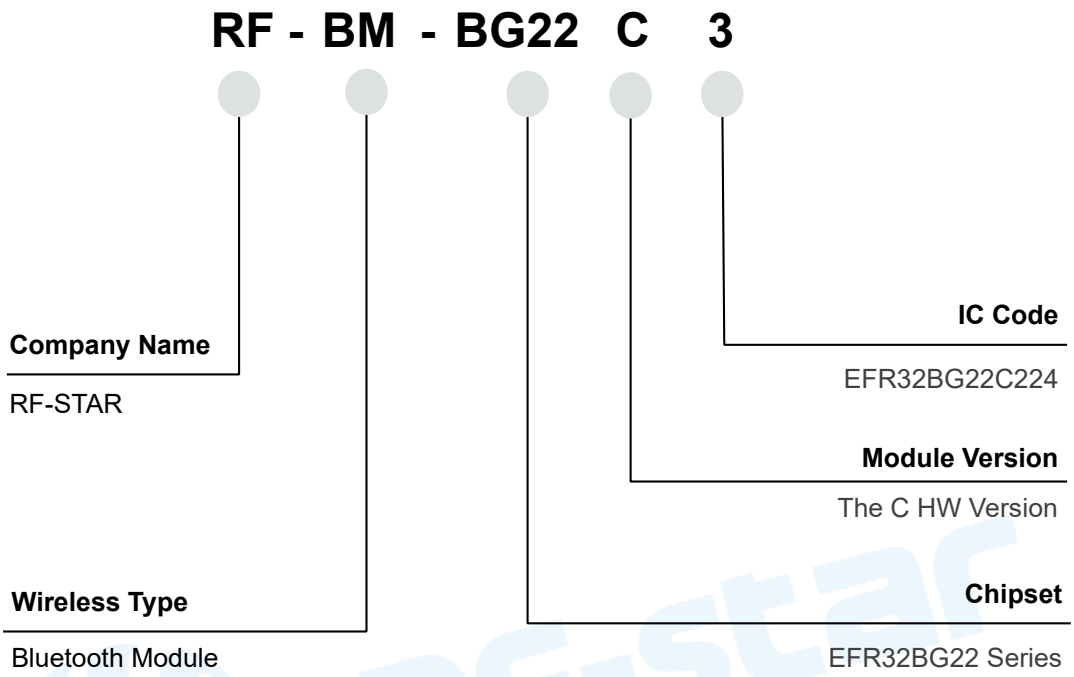


Figure 2. Part Number Conventions of RF-BM-BG22C3

Table of Contents

2 Module Configuration and Functions

2.1 Module Parameters

Table 1. Parameters of RF-BM-BG22C3

Chipset	EFR32BG22C224F512GM32-C
Supply Power Voltage	DC-DC mode: 2.2 V ~ 3.8 V, recommended to 3.3 V Bypass mode: 1.8 V ~ 3.8 V, recommended to 3.3 V
Frequency	2402 MHz ~ 2480 MHz
Transmit Power	-28.0 dBm ~ 6 dBm (typical: 0 dBm)
Receiving Sensitivity	-98.9 dBm sensitivity @ 1 Mbit/s GFSK -96.2 dBm sensitivity @ 2 Mbit/s GFSK -106.7 dBm sensitivity @ 125 kbps GFSK
GPIO	12
Crystal	38.4 MHz
RAM	32 KB
Flash	512 KB
Package	SMT Packaging (1.27-mm half-hole pitch stamp stick)
Frequency Error	±24 kHz
Dimension	8 mm x 8 mm x 1.82 mm
Type of Antenna	Chip antenna, half-hole ANT pin
Operating Temperature	-40 ℃ ~ +85 ℃
Storage Temperature	-40 ℃ ~ +125 ℃

2.2 Module Pin Diagram

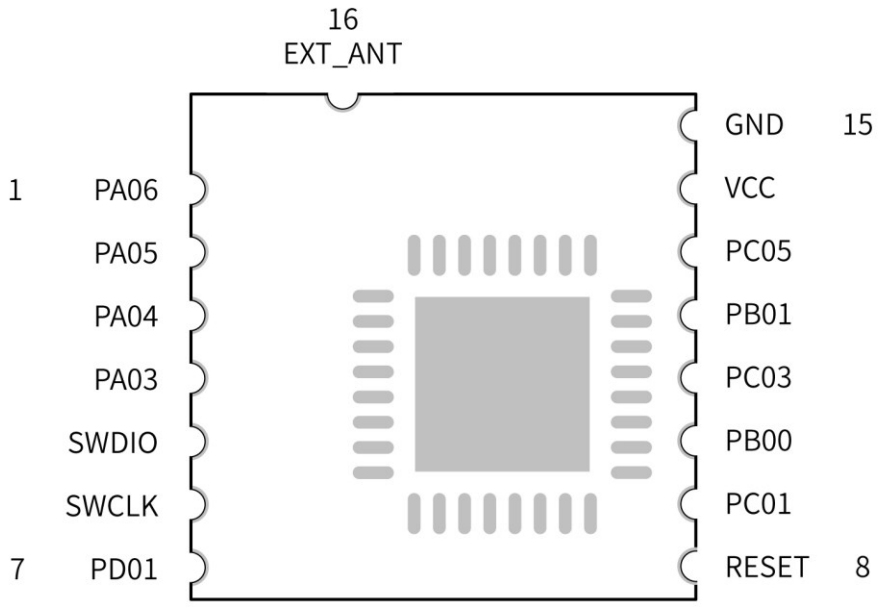


Figure 3. Pin Diagram of RF-BM-BG22C3

2.3 Pin Functions

Table 2. Pin Functions of RF-BM-BG22C3

Pin	Name	Chip Pin	Pin Type	Description
1	PA06	PA06	GPIO	
2	PA05	PA05	GPIO	
3	PA04	PA04	GPIO	
4	PA03	PA03	GPIO	
5	SWDIO	PA02	GPIO	
6	SWCLK	PA01	GPIO	
7	PD01	PD01	GPIO	
8	RESET	RESET	-	Reset, active low, internal pull-up. The max. power supply of this pin is 1.8 V under DC-DC mode.
9	PC01	PC01	GPIO	
10	PB00	PB00	GPIO	
11	PC03	PC03	GPIO	

12	PB01	PB01	GPIO	
13	PC05	PC05	GPIO	
14	VCC	VCC	VCC	2.2 V ~ 3.8 V, recommended to 3.3 V
15	GND	GND	-	Ground
16	EXT_ANT	EXT_ANT	-	External antenna pin.

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 3. Recommended Operating Conditions of RF-BM-BG22C3

Items	Condition	Min.	Typ.	Max.	Unit
Operating Supply Voltage	DC-DC mode	2.2	3.3	3.8	V
	Bypass mode	1.8	3.3	3.8	V
Frequency Range		2402		2480	MHz
Operating Temperature	/	-40	+25	+85	℃
Environmental Hot Pendulum	/	-20		+20	℃/min

3.2 Handling Ratings

Table 4. Handling Ratings of RF-BM-BG22C3

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

3.3 Current Consumption

Table 5. Current Consumption of RF-BM-BG22C3

Hardware Version: 1.0a			
Test Condition	FLUKE15B+ multimeter, load connects to DSA1030 spectrum analyzer, offset: 0.2, RBW = 100 KHz		
Stand-by	1 μA		
Transmitting Current	Set Tx Power	Actual Tx Power	Actual Current
	0 dBm	-0.5 dBm	4.0 mA
Receiving Current	2.5 mA		

Note: The test method is closely related to the current. For example, the output load antenna is different from the standard 50 Ω test data.

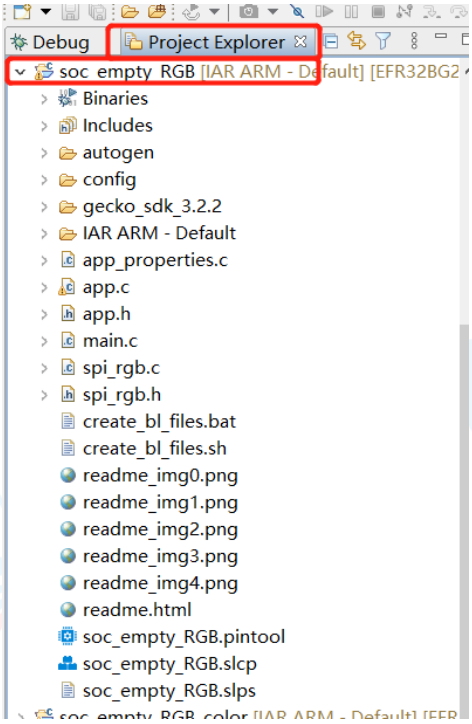
4 Setting of Frequency Offset Register

The setting of the frequency offset register can be regarded as the auxiliary setting of modifying the frequency offset for the hardware RF part.

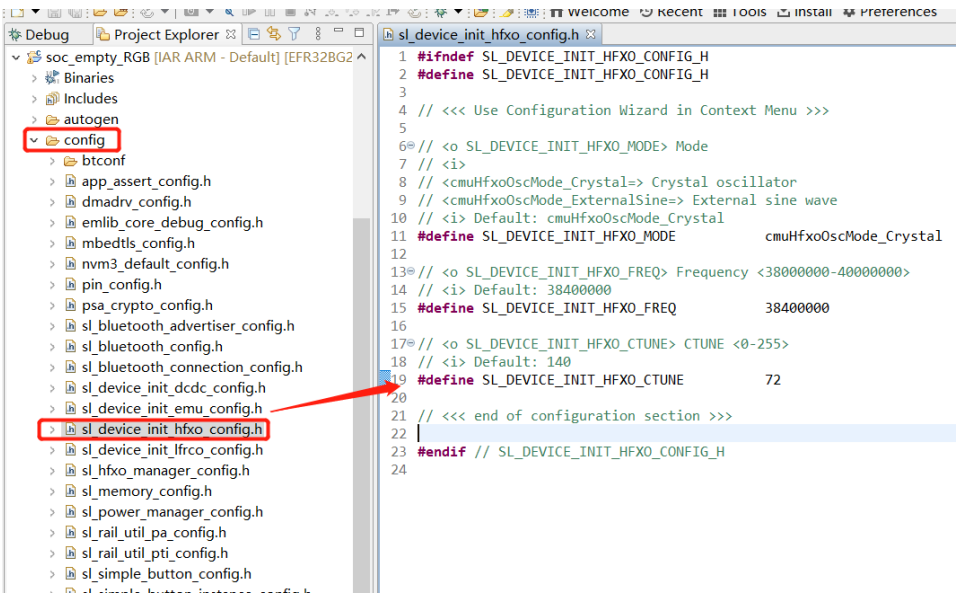
If the frequency offset is needed to be modified, you can find the ***sl_device_init_hfxo_config.h*** file in the corresponding project and modify the ***CTUNE*** value.

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

Oen the project, find the Project Explorer window, and open the project folder, as shown in the following figure.



Then choose the config folder, find the ***sl_device_init_hfxo_config.h*** file, and double-click to open it, as shown in the figure below.



Find ***SL_DEVICE_INIT_HFXO_CTUNE***, the official default value of SiliconLabs is 140, RF-star changes it to 72 according to the requirements of the development board hardware RF part.

Remark: This is the value for RF-star's standard EFR32BG22 series modules, the value of the other customized products needs to be confirmed.

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

sl_device_init_hfxo_config.h

```
#ifndef SL_DEVICE_INIT_HFXO_CONFIG_H
#define SL_DEVICE_INIT_HFXO_CONFIG_H

// <<< Use Configuration Wizard in Context Menu >>>

// <o SL_DEVICE_INIT_HFXO_MODE> Mode
// <i>
// <cmuHfxoOscMode_Crystal=> Crystal oscillator
// <cmuHfxoOscMode_ExternalSine=> External sine wave
// <i> Default: cmuHfxoOscMode_Crystal
#define SL_DEVICE_INIT_HFXO_MODE           cmuHfxoOscMode_Crystal

// <o SL_DEVICE_INIT_HFXO_FREQ> Frequency <38000000-40000000>
// <i> Default: 38400000
#define SL_DEVICE_INIT_HFXO_FREQ           38400000

// <o SL_DEVICE_INIT_HFXO_CTUNE> CTUNE <0-255>
// <i> Default: 140
#define SL_DEVICE_INIT_HFXO_CTUNE          72

// <<< end of configuration section >>>

#endif // SL_DEVICE_INIT_HFXO_CONFIG_H

```

5 Application, Implementation, and Layout

5.1 Module Photos

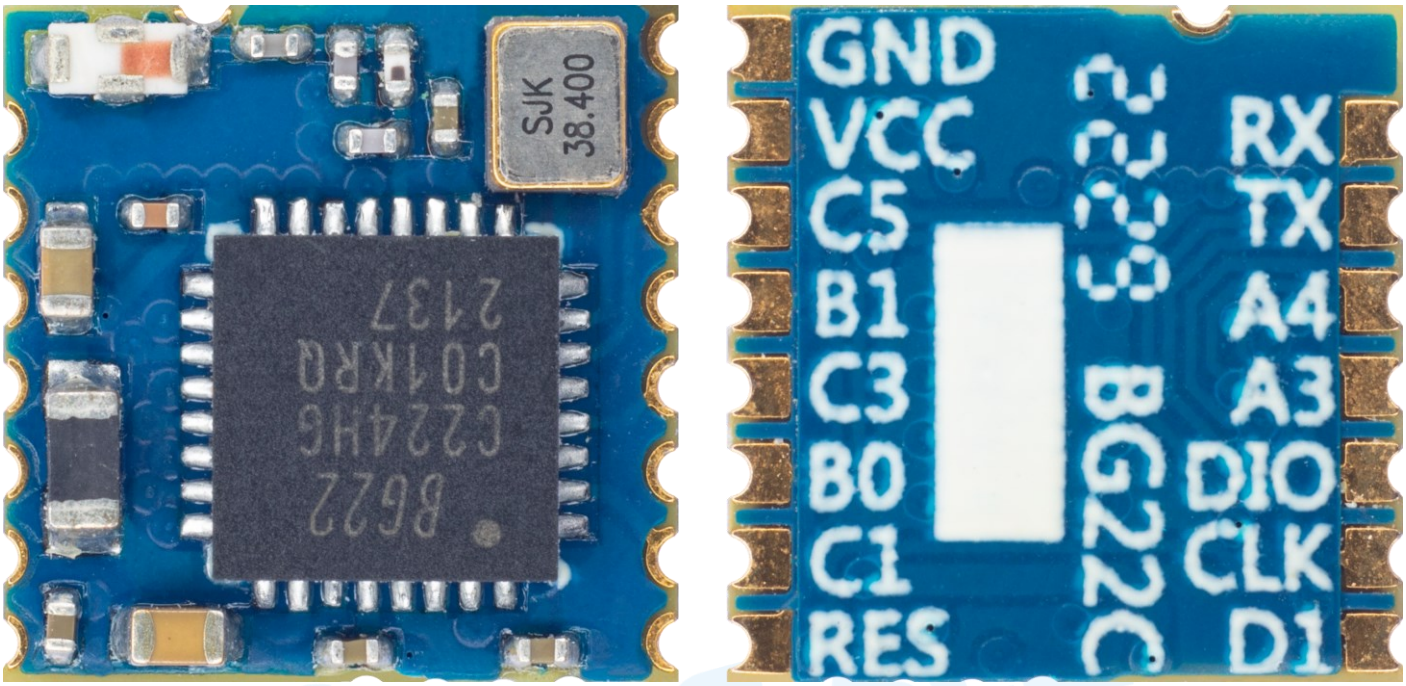


Figure 4. Photos of RF-BM-BG22C3

5.2 Recommended PCB Footprint

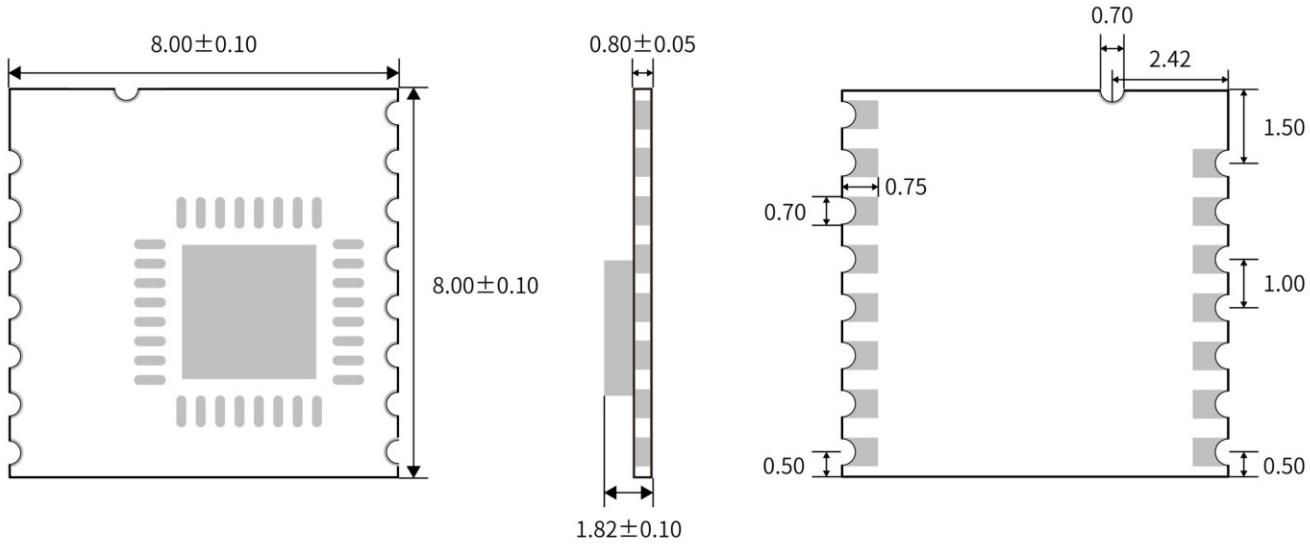


Figure 5. Recommended PCB Footprint of RF-BM-BG22C3 (mm)

5.3 Schematic Diagram

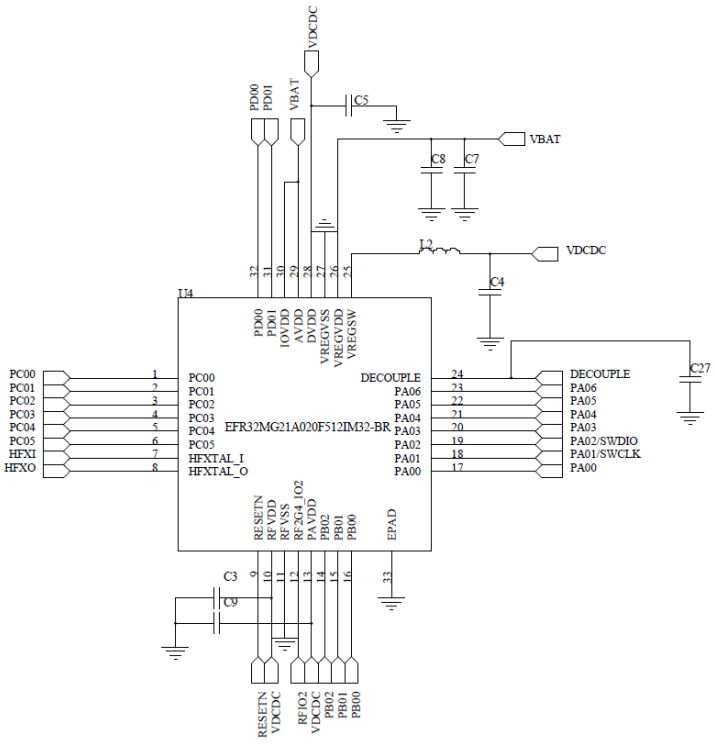


Figure 6. Schematic Diagram of RF-BM-BG22C3

5.4 Reference Design

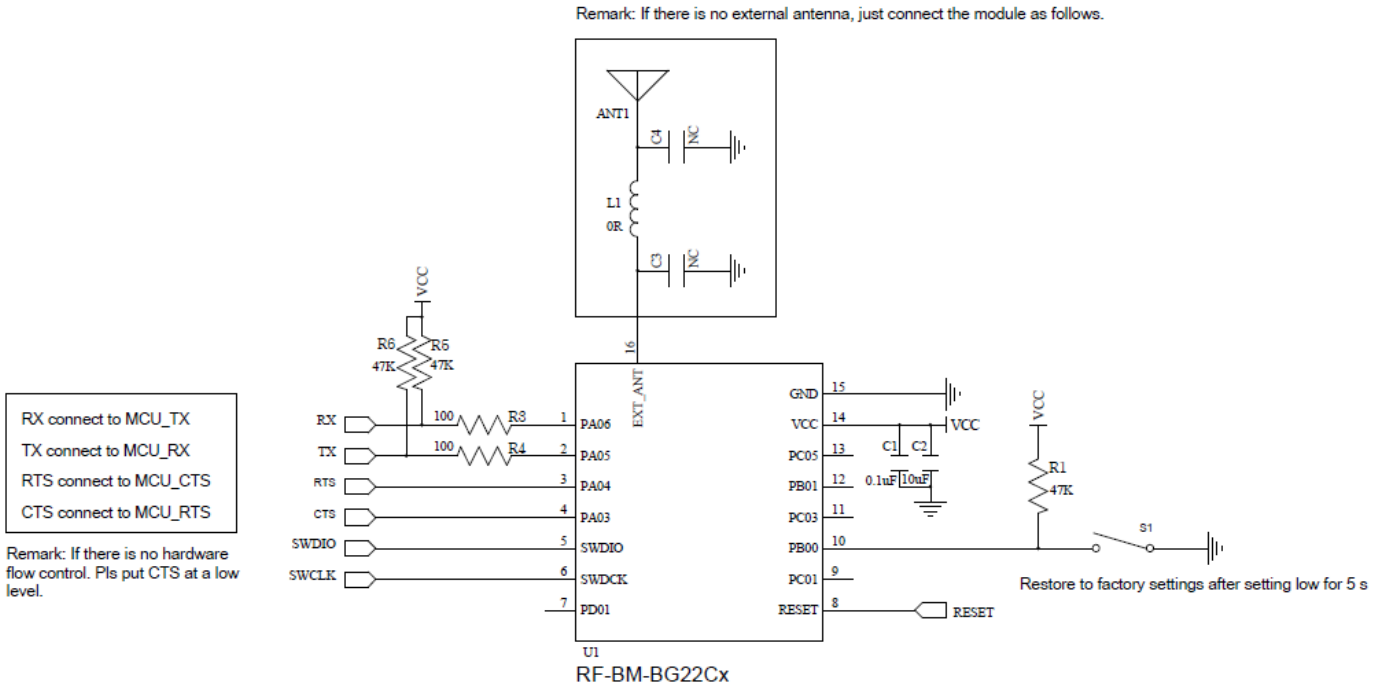


Figure 7. Reference Design of RF-BM-BG22Cx

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.

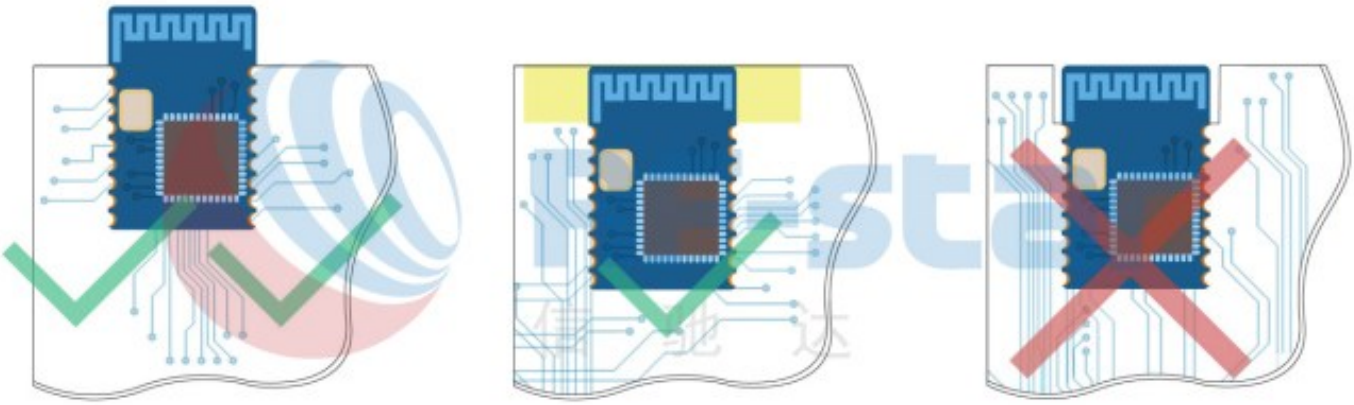


Figure 8. Recommendation of Antenna Layout

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

5.5.2 Antenna Output Mode Modification

1. RF-BM-BG22C3 has two antenna output modes. The one is an onboard chip antenna and the other is a stamp half-hole output (ANT pin, see pin function table for details).

The default delivery is the ***chip antenna***. If you want to use the external antenna by the ANT pin, pls disassembly the chip antenna. The location of the chip antenna is shown in the figure below.

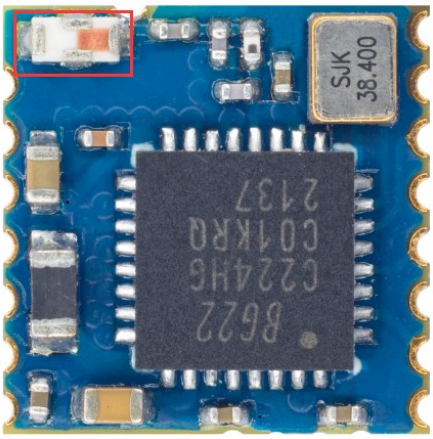


Figure 9. Antenna Output Mode Change of RF-BM-BG22C3

5.5.3 External Antenna Design Recommendation of the Half-Hole ANT Pin

1. A Π-type matching circuit is reserved for the antenna, and 50 Ω impedance control is performed on the RF traces. The traces are as short as possible, and 135° or arc traces are used as much as possible. No vias are used to change layers. More GND vias are placed around the RF traces.

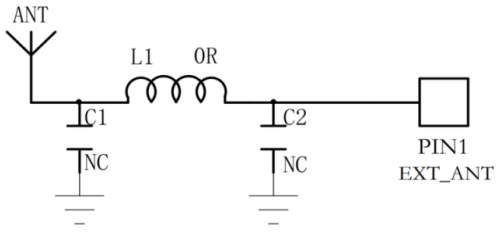


Figure 10. Reference Design of the External Antenna

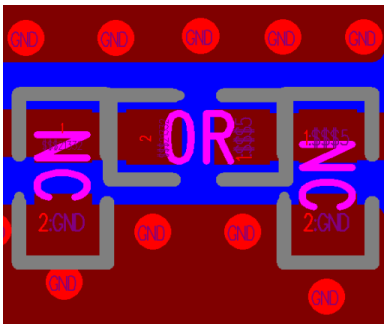


Figure 11. Reference Design of the External Antenna Traces

2. The RF trace width and copper-clad spacing can be calculated by SI9000 software, and the impedance is controlled to 50 Ω according to the actual board thickness, number of layers, plate, dielectric thickness, dielectric constant, copper thickness, line width, line spacing, and solder mask thickness.

Example: FR4 is a double-layer board with a thickness of 1.0 mm. Through calculation, the width of the trace is 0.8254 mm, and the spacing between traces and copper is 0.22 mm.

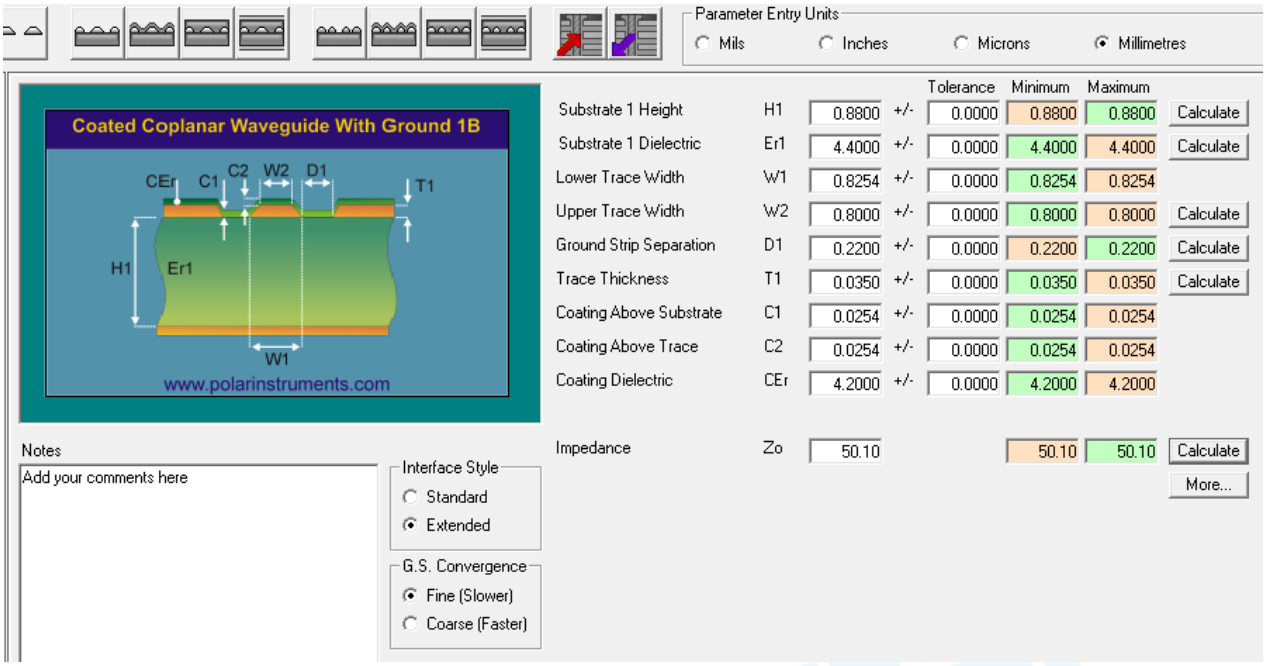


Figure 12. SI9000 Impedance Calculation Diagram

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 the 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 performances 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

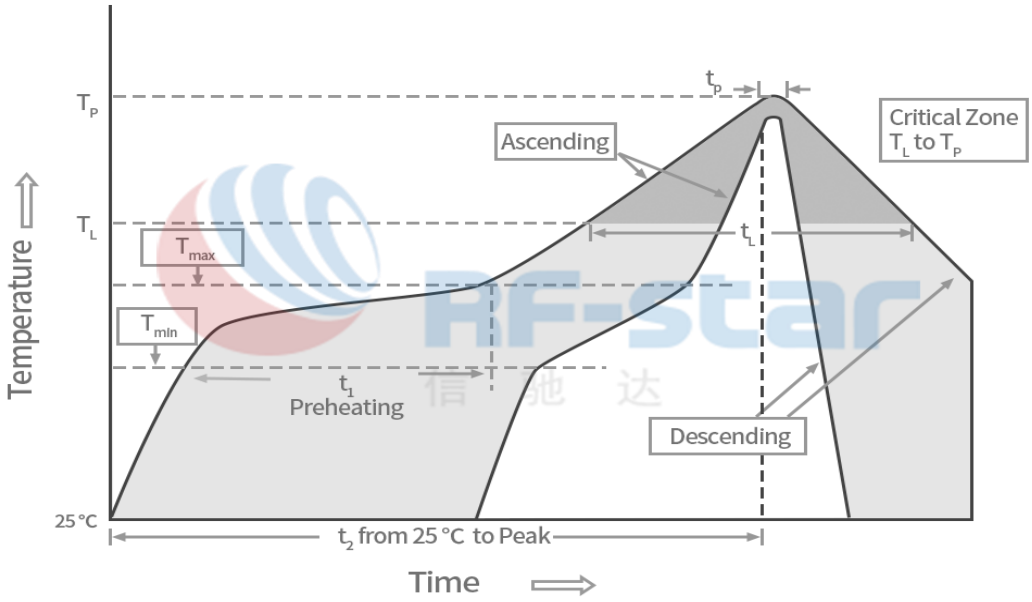


Figure 13. Recommended Reflow for Lead-Free Solder

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.

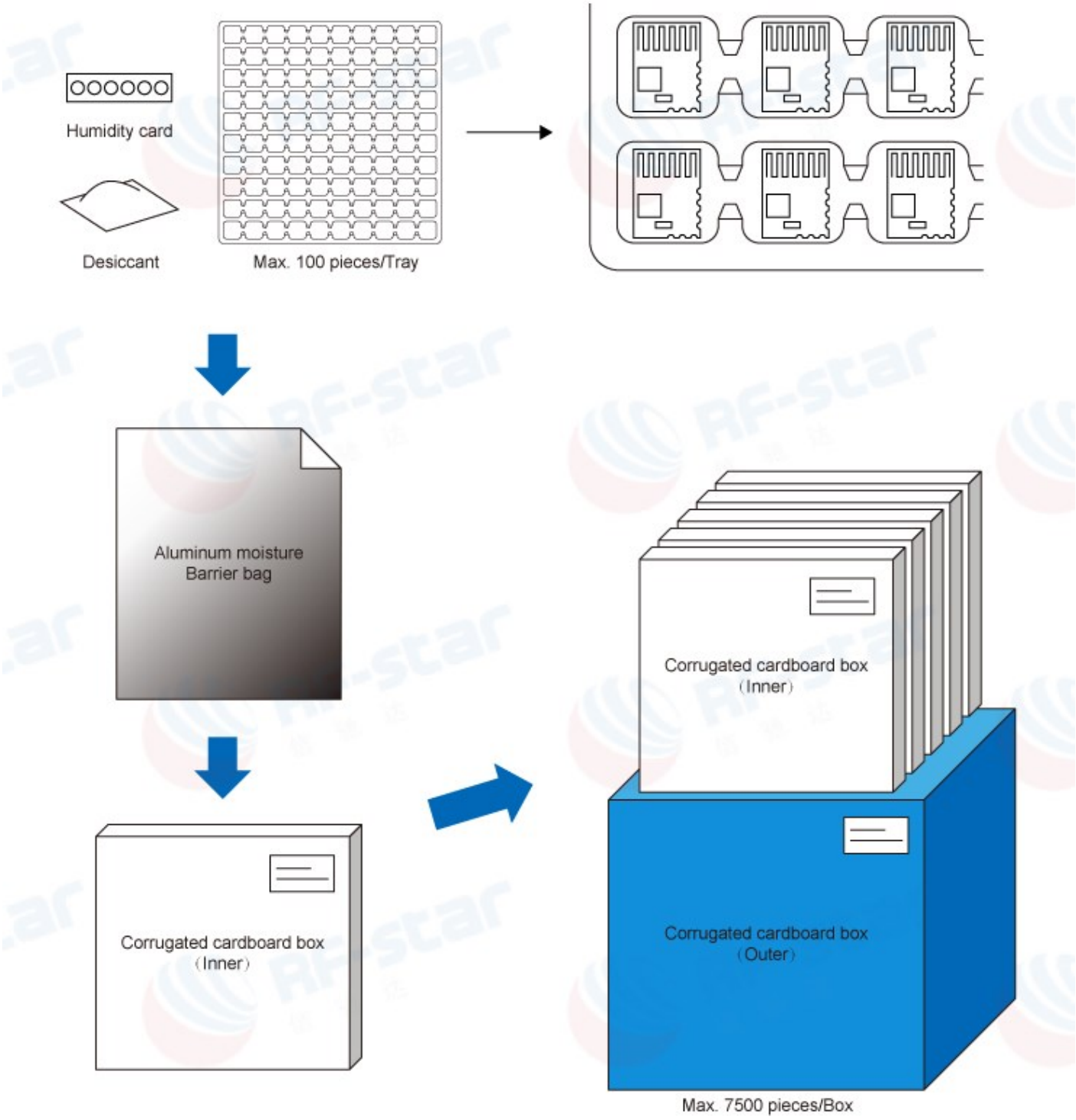


Figure 14. Default Package by Tray

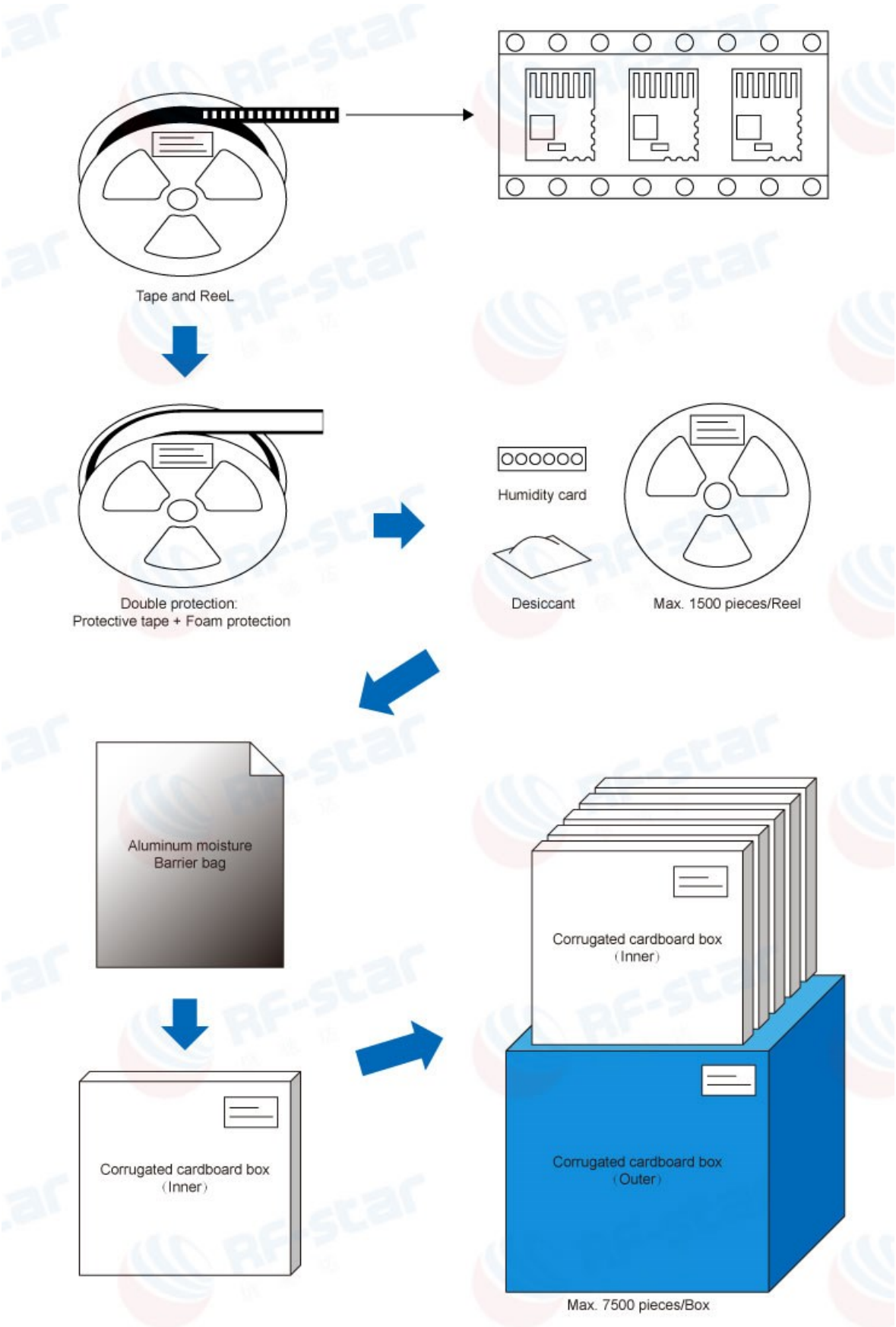


Figure 15. Package by Tape & Reel

7 Revision History

Date	Version No.	Description
2022.08.03	V1.0	The initial version is released.
2022.08.12	V1.1	Add the setting of frequency offset register. Add the max. power supply of the RESET pin.
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.

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Email: sunny@szrfstar.com, sales@szrfstar.com

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