FSC-CL4040

2.4G WLAN 802.11 b/g/n and Bluetooth 4.2 dual-mode,

4G LTE-M Embedded Cellular Modem Datasheet

Version 1.0

Revision History

Version	Data	Notes	Approved By
1.0	2022/08/23	Initial Version	Devin Wan

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Contents

1. INTRODUCTION

Overview

FSC-CL4040 is a highly integrated single-chip 2.4GHz wireless LAN (WLAN) 802.11 b/g/n and Bluetooth low energy (V4.2) dual-mode and 4G embedded cellular modem with an integrated Arm Cortex-M33 CPU that includes 256 KB of RAM and 1 MB of flash. It uses a 32-bit MCU single/dual-core processor with a computing power of up to 600 MIPS, a WLAN baseband with 1T1R function, RF, Bluetooth and peripheral devices.

The FSC-CL4040 provides low-power LTE and GPS connectivity, and is compatible with most global LTE-M and NB-IoT cellular networks.

The FSC-CL4040 has many useful serial and analog peripherals integrated into the modem, including: UART, SPI, I2C, PWM and a 14-bit ADC with up to eight input channels. The modem offers 29 GPIO pins with support for flexible peripheral mapping, simplifying the development process for system designers.

If your product application stack runs on an external MCU or Processor, the FSC-CL4040 modem can act as a client and accept AT commands and provide responses over the serial UART.

FSC-CL4040 is an appropriate product for designers who want to add wireless capability to their products. Support for external antennas and increase wireless coverage.

Features

NRF9160 Features - Microcontroller:

- Up to 4x SPI master/slave with EasyDMA
- Up to 4x I2C compatible two-wire master/slave with EasyDMA
- Up to 3x UART (CTS/RTS) with EasyDMA
- I2S with EasyDMA
- Digital microphone interface (PDM) with EasyDMA
- 4x pulse width modulator (PWM) unit with EasyDMA
- 12-bit, 200 ksps ADC with EasyDMA – eight configurable channels with programmable gain
- 3x 32-bit timer with counter mode
- 2x real-time counter (RTC)
- Programmable peripheral interconnect (PPI)
- 29 general purpose I/O pins
- All necessary clock sources integrated

NRF9160 Features - LTE modem:

- Transceiver and baseband
- 3GPP LTE release 13 Cat-M1 and Cat-NB1 compliant
  ->3GPP release 13 coverage enhancement
- 3GPP LTE release 14 Cat-NB2 compliant
- GPS receiver
  ->GPS L1 C/A supported
  ->QZSS L1 C/A supported
- RF transceiver for global coverage
  ->Up to 23dBm output power
  ->-108dBm sensitivity (LTE-M) for low band, -107dBm for mid band
  ->Single 50 Ω antenna interface
- LTE band support in hardware:
  ->Cat-M1: B1, B2, B3, B4, B5, B8, B12, B13, B14, B18, B19, B20, B25, B26, B28, B66
  ->Cat-NB1/NB2: B1, B2, B3, B4, B5, B8, B12, B13, B17, B19, B20, B25, B26, B28, B66
- Supports SIM and eSIM with an ETSI TS 102 221 compatible UICC interface
- Power saving features: DRX, eDRX, PSM
- IP v4/v6 stack
- Secure socket (TLS/DTLS) API

NRF9160 Features - Current consumption @ 3.3 V:

- Power saving mode (PSM) floor current: 2.8 µA
- eDRX @ 82.91s: 19µA in Cat-M1, 38 µA in Cat-NB1 (UICC included)

ESP32 Wi-Fi Features

- 802.11 b/g/n
- 802.11 n (2.4GHz) speed up to 150 Mbps
- Wireless Multimedia (WMM)
- Frame aggregation (TX/RX A-MPDU, RX A-MSDU)
- Immediate Block ACK
- Reorganization (Defragmentation)
- Beacon automatic monitoring (hardware TSF)
- Antenna diversity

ESP32 Bluetooth Features

- Bluetooth V4.2
- Up to +9 dBm output power
- NZIF receiver has BLE reception sensitivity of -94 dBm
- Adaptive Frequency Hopping (AFH)
- Standard HCI based on SDIO/SPI/UART interface
- CVSD and SBC audio codec algorithms
- Bluetooth Piconet and Scatternet
- Multi-device connection supporting traditional Bluetooth and Bluetooth low energy
- Support simultaneous broadcast and scan
- Support SPI/I2S/I2C/UART/PWM/Ethernet MAC/ADC interface
- Low power consumption
- Support standard level 1, level 2 and level 3
- The default UART baud rate is 115.2Kbps, which can support 1200bps to 500Kbps
- Support air upgrade
- Bluetooth profile support: SPP, HID, GATT, ATT, GAP
- Support Apple MFi (iAP2), iBeacon

General Features

- Stamp module suitable for Surface Mounted Technology (SMT)
- Iron Shielding case(Optional)
- Dimension(Iron Shielding Case) : 22.9mm(L) x 21.9mm(W) x 2.0mm(H)
- Operating Voltage :
  VCC: 3.0 to 3.6V (Peak Current 1A);
  VCC_GPIO: 1.8 to 3.6V
- RoHS / REACH Compliant
- External Antenna

Application

- Sensor networks
- Logistics and asset tracking
- Smart energy
- Smart building automation
- Smart agriculture
- Industrial
- Retail and monitor devices
- Medical devices
- Wearables
- Home automation
- Automated industry
- Wi-Fi toys
- POS system

Module picture as below showing

PIN No.1

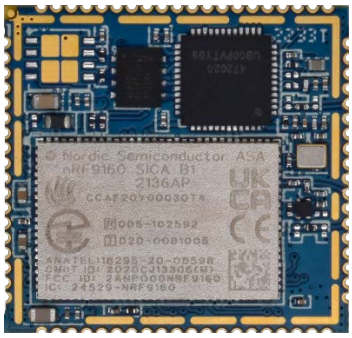


Figure 1: FSC-CL4040 Picture

2. General Specification

Table 1: General Specifications

Categories	Features	Implementation
ESP32 Bluetooth & Wi-Fi		
Wireless Specification	Bluetooth	Version : V4.2
		Frequency : 2.412 - 2.484 GHz
		Transmit Power: +9 dBm (Maximum)
	Wi-Fi	802.11 b/g/n 1x1, 2.4GHz
		Frequency : 2.412 ~ 2.484GHz
		Transmit Power(2.4GHZ): +20.5 dBm(11 b), 18 dBm(11 n)
		MCS0-7 supports 20MHz and 40MHz bandwidth
		Adjustable transmit power
Host Interface and Peripherals	UART Interface	TX, RX (Auto Flow Control)
		General Purpose I/O
		Default 115200,N,8,1
		Baudrate support from 1200 to 5000000bps
		7, 8 data bit character
	GPIO	18 (maximum – configurable) lines
		O/P drive strength (4 mA)
		Pull-up resistor (45 KΩ) control
		Read pin-level
	I2C Interface	1 (configurable from GPIO total).
		Standard mode (100Kbit/s); High-speed mode (400Kbit/s)
	SPI Interface	Support Master/Slave mode
	PWM	16-bit resolution
		Accurately capture external timed events
		Supports PWM interrupts

Profiles	Classic Bluetooth	Support
	Bluetooth Low Energy	Support
	Wi-Fi	Wi-Fi-AP(access point), Wi-Fi-Station
FW upgrade		UART
Power Consumption (VCC = 3.3V, VCC_GPIO = 3.3V, nRF9160_EN=LOW)	Bluetooth	Send BT/BLE, POUT = 0dBm, power consumption is 130mA
		Receive BT/BLE, power consumption is 95 ~ 100mA
	Wi-Fi	Send 802.11b, DSSS 1 Mbps, POUT = +19.5dBm, power consumption is 240mA
		Send 802.11g, OFDM 54 Mbps, POUT = +16dBm, power consumption is 190mA
		Send 802.11n, OFDM MCS7, POUT = +14dBm, power consumption is 180mA
		Receive 802.11b/g/n, power consumption is 95 ~ 100mA

NRF9160 Feature/Specification	
Application Processor Peripherals	**Serial Peripherals:** 4 x SPI, 3 x UART, 4 x Two Wire Interface(TWI), I^2C, I^2S **Analog Peripherals:** PDM, PWM, 8/10/12-bit ADC with 8 input channels and 200 kHz sampling rate (up to 14-bit resolution when oversampling) **Timers:** 3 x Timers, 2 x RTC Watchdog Timers
I/O Pins	**GPIO:** 29 x VCC_GPIO ref'd with flexible peripheral mapping **MAGPIO:** 3 x 1.8V ref'd GPIO for antenna tuning **COEX:** 3 x VCC_GPIO ref'd GPIO for Coexistence interface
Internet Protocols	Application Layer Protocols: HTTP/HTTPS, TLS/DTLS, MQTT Transport Layer Protocols: TCP/UDP
Cellular Capabilities	Cellular Technologies: LTE-M, LTE CAT-NB1, and LTE,CAT-NB2 Internet Protocols: IPv4, IPv6 SMS: PDU Mode Low Power Modes: PSM, eDRX Operating Frequency Range: 699 MHz to 1980 MHz Cellular Operation Mode: HD-FDD RF Output Power: -40 dBm to +23 dBm
LTE-M Specifications	LTE-M Bands: B1, B2, B3, B4, B5, B8, B12, B13, B14, B17, B18,B19, B20, B25, B26, B28, B66 Low Band RX Sensitivity: -108 dBm Middle band Rx Sensitivity: -107 dBm Uplink Speed: 300 Kbps Downlink Speed: 375 Kbps
LTE CAT-NB1 and LTE CAT-NB2 Specifications	LTE CAT-NB1 and LTE CAT-NB2 Bands: B1, B2, B3, B4, B5, B8, B12, B13, B17, B19, B20, B25, B26, B28, B66 RX Sensitivity: -114 dBm Uplink Speed: 30 Kbps

		Downlink Speed: 60 Kbps
SIM Specification		Soldered-Down SIM: No Support External Sim Interface: Support for an external SIM interface
Cellular Certifications		Verizon ODI: TBD PTCRB: TBD AT&T: TBD GCF: TBD
GPS Specifications		GPS Band: GPS L1 C/A GPS Center Frequency: 1575.42 MHz Sensitivity, Cold Start: -142dBm Sensitivity, Hot Start: -145dBm Sensitivity, Tracking: -151dBm Cold Start TTFF: 40 seconds Hot Start TTFF: 1.5 seconds
Typical Power Consumption (VCC = 3.3V, VCC_GPIO = 3.3V, ESP32_EN=LOW)		Socket Dial, Good Signal Strength: Avg: 24 mA, Max: 46 mA Socket Dial, Fair Signal Strength: Avg: 25 mA, Max: 108 mA Socket Dial, Poor Signal Strength: Avg: 27 mA, Max: 344 mA Registered Idle: Average: 3.58 mA, Max: 36 mA Unregistered Idle: Average: 533 uA, Max: 7.5mA Powered Off: Average: 2.4 uA, Max: 71 uA GPS: Average: 43 mA, Max: 59 mA PSM and eDRX: TBD eDRX: TBD
General		
Size		22.9mm(L) x 21.9mm(W) x 2.0mm(H)
Power Supply Inputs		Supply Voltage (VCC): 3.0V to 3.6V GPIO Reference Voltage (VCC_GPIO): 1.8V to 3.6V
Antenna		External (BT/Wi-Fi 2.4GHz, GPS 1575.42MHz, LTE CAT 699MHz~1980MHz)
Operating temperature		-40°C ~+85°C
Storage temperature		-40°C ~+85°C
Miscellaneous	Lead Free	Lead-free and RoHS compliant
	Warranty	One Year
Humidity		20% ~ 90% non-condensing
MSL grade:		MSL 3
ESD grade:		Human Body Model: ±1500 V Human Body Model Class: 1C Charge device model: ±250 V

3. HARDWARE SPECIFICATION

3.1 Block Diagram and PIN Diagram

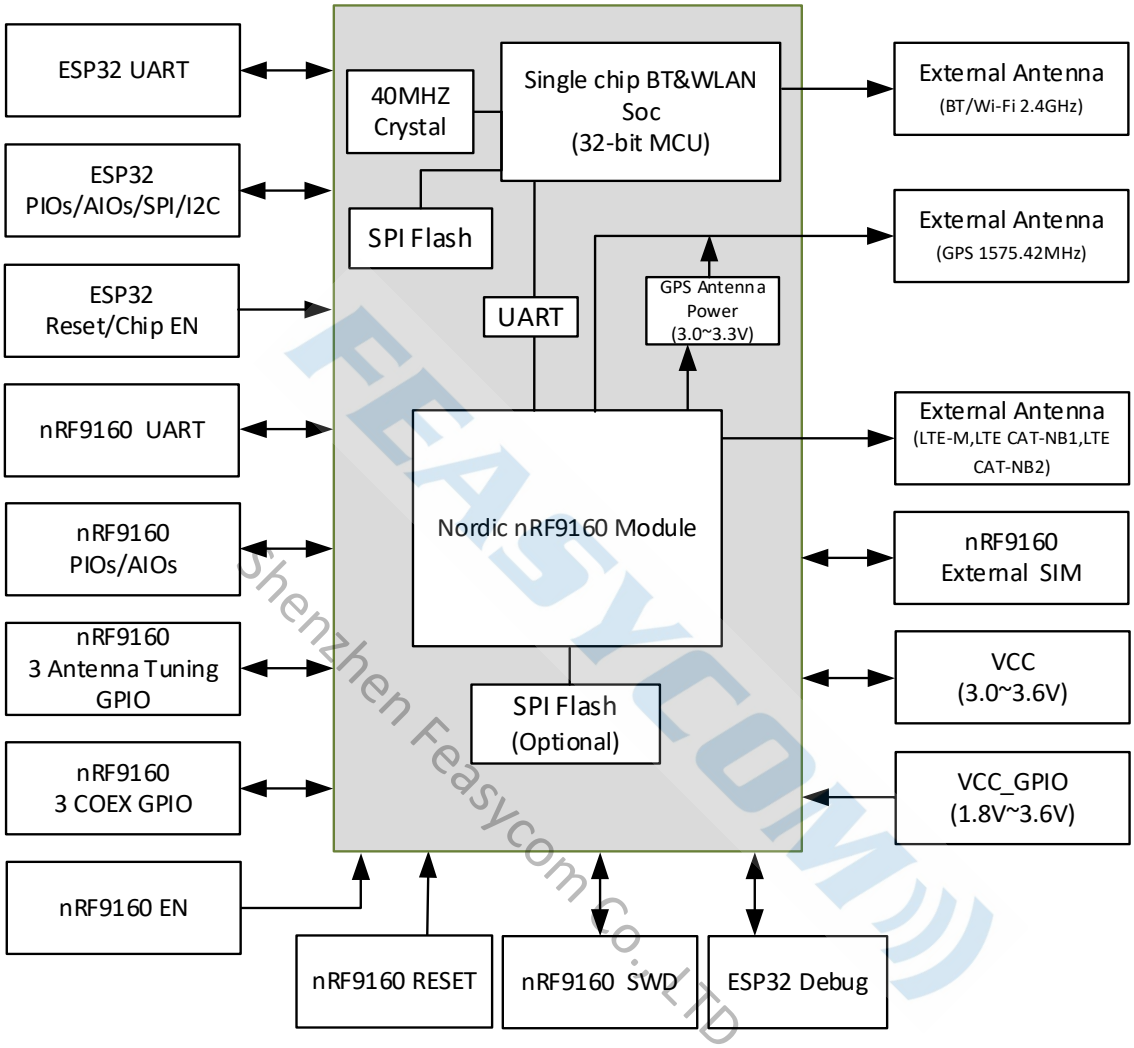


Figure 2: Block Diagram

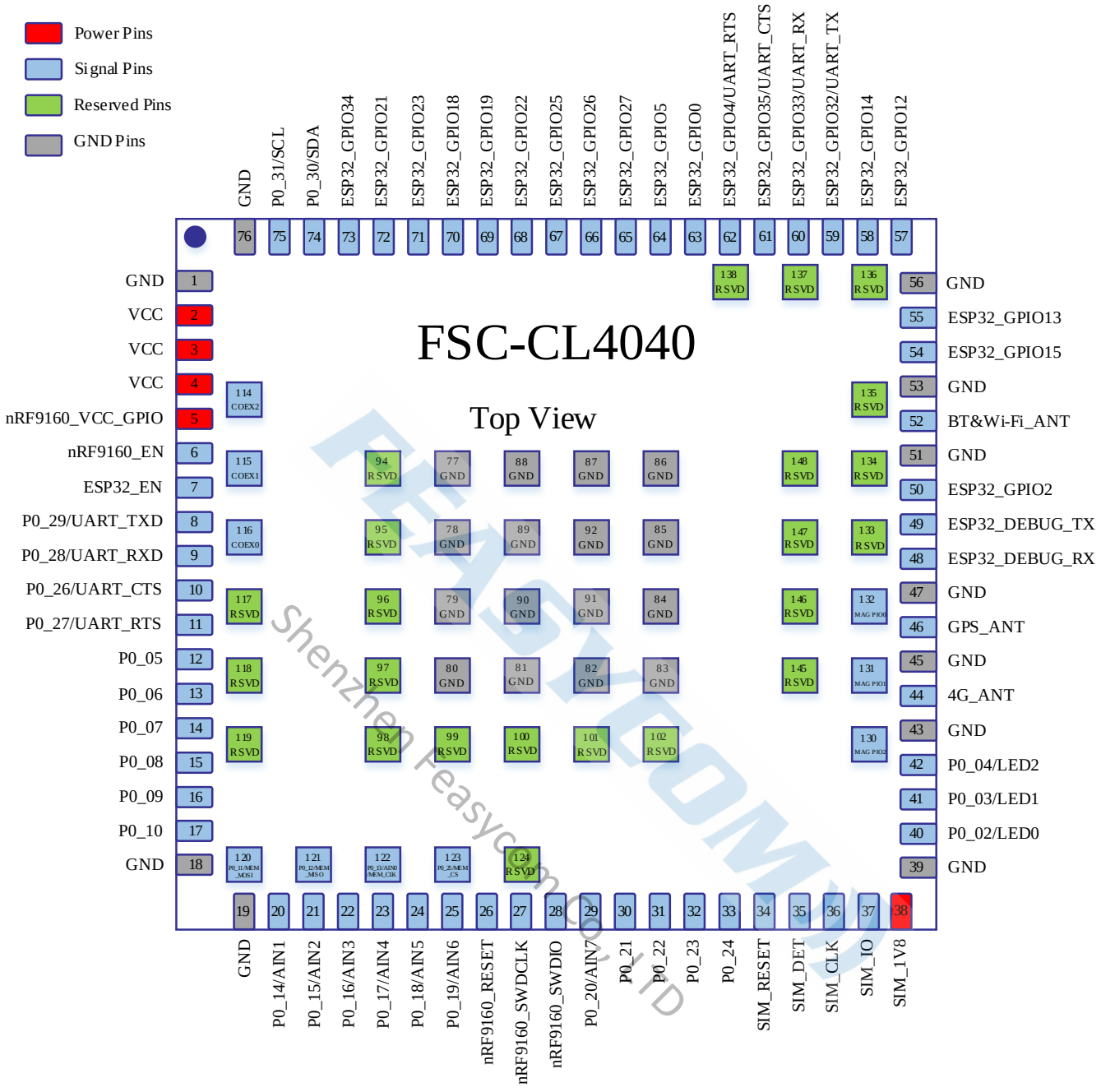


Figure 3: FSC-CL4040 PIN Diagram (Top View)

3.2 PIN Definition Descriptions

Table 2: Pin definition

Pin	Pin Name	Type	Pin Descriptions	Notes
1	GND	VSS	Ground	
2	VCC	PWR	Main Power Supply Input Pin	
3	VCC	PWR	Main Power Supply Input Pin	
4	VCC	PWR	Main Power Supply Input Pin	

5	nRF9160_VCC_GPIO	PWR	nRF9160 GPIO Power Supply Input and Reference Voltage (1.8V ~ 3.6V)
6	nRF9160_EN	I	nRF9160 Enable Pin Tie to VCC to boot the modem. Can be pulled-up to VCC with a 10k resistor to enable auto power on whenever power is applied.
7	ESP32_EN	I	External reset input: Active LOW, Set this pin low reset the module.
8	P0_29/UART_TXD	O	nRF9160 UART TX Output Pin
9	P0_28/UART_RXD	I	nRF9160 UART RX Input Pin
10	P0_26/UART_CTS	I	nRF9160 UART0 CTS Input Pin, Active-Low flow control input for nRF9160 UART.
11	P0_27/UART_RTS	O	nRF9160 UART0 RTS Output Pin, Active-Low flow control output for nRF9160 UART.
12	P0_05	I/O	nRF9160 Digital I/O Pin #5
13	P0_06	I/O	nRF9160 Digital I/O Pin #6
14	P0_07	I/O	nRF9160 Digital I/O Pin #7
15	P0_08	I/O	nRF9160 Digital I/O Pin #8
16	P0_09	I/O	nRF9160 Digital I/O Pin #9
17	P0_10	I/O	nRF9160 Digital I/O Pin #10
18	GND	VSS	Ground
19	GND	VSS	Ground
20	P0_14/AIN1	I/O AIN	nRF9160 Digital I/O Pin #14. Analog input 1.
21	P0_15/AIN2	I/O AIN	nRF9160 Digital I/O Pin #15. Analog input 2.
22	P0_16/AIN3	I/O AIN	nRF9160 Digital I/O Pin #16. Analog input 3.
23	P0_17/AIN4	I/O AIN	nRF9160 Digital I/O Pin #17. Analog input 4.
24	P0_18/AIN5	I/O AIN	nRF9160 Digital I/O Pin #18. Analog input 5.
25	P0_19/AIN6	I/O AIN	nRF9160 Digital I/O Pin #19. Analog input 6.
26	nRF9160_RESET	I	nRF9160 Reset Pin Note: External pull-up not allowed.不允许外部上拉.
27	nRF9160_SWDCLK	I	nRF9160 Serial wire debug clock input for debug and programming
28	nRF9160_SWDIO	I/O	nRF9160 Serial wire debug I/O for debug and programming
29	P0_20/AIN7	I/O AIN	nRF9160 Digital I/O Pin #20. Analog input 7.
30	P0_21	I/O	nRF9160 Digital I/O Pin #21
31	P0_22	I/O	nRF9160 Digital I/O Pin #22
32	P0_23	I/O	nRF9160 Digital I/O Pin #23
33	P0_24	I/O	nRF9160 Digital I/O Pin #24

34	SIM_RESET	I/O	SIM reset
35	SIM_DET	I/O	SIM detect. Not used. Needs to be left floating.
36	SIM_CLK	I/O	SIM clock
37	SIM_IO	I/O	SIM data
38	SIM_1V8	PWR	SIM 1.8V power supply output
39	GND	VSS	Ground
40	P0_02/LED0	I/O	nRF9160 Digital I/O Pin #2. Alternative Function: LED0
41	P0_03/LED1	I/O	nRF9160 Digital I/O Pin #3. Alternative Function: LED1
42	P0_04/LED2	I/O	nRF9160 Digital I/O Pin #4. Alternative Function: LED2
43	GND	VSS	Ground
44	4G_ANT	RF	LTE CAT RF input/output
45	GND	VSS	Ground
46	GPS_ANT	RF	GPS RF input/output
47	GND	VSS	Ground
48	ESP32_DEBUG_RX	I/O	Debug Interface (Data IN)
49	ESP32_DEBUG_TX	I/O	Debug Interface (Data OUT)
50	ESP32_GPIO2	I	ESP32 Input pin
51	GND	VSS	Ground
52	BT&Wi-Fi_ANT	RF	BT&WLAN 2.4GHz RF input/output
53	GND	VSS	Ground
54	ESP32_GPIO15	I/O	ESP32 Programmable input/output line Alternative Function: SPI_CLK
55	ESP32_GPIO13	I/O	ESP32 Programmable input/output line Alternative Function: SPI_MOSI
56	GND	VSS	Ground
57	ESP32_GPIO12	I/O	ESP32 Programmable input/output line Alternative Function: SPI_MISO
58	ESP32_GPIO14	I/O	ESP32 Programmable input/output line Alternative Function: SPI_CS
59	ESP32_GPIO32/UART_TX	I/O	ESP32 UART Data output
60	ESP32_GPIO33/UART_RX	I/O	ESP32 UART Data input
61	ESP32_GPIO35/UART_CTS	I/O	ESP32 Programmable input/output line Alternative Function: UART Clear to Send (active low)
62	ESP32_GPIO4/UART_RTS	I/O	ESP32 Programmable input/output line Alternative Function: UART Request to Send (active low)
63	ESP32_GPIO0	I/O	ESP32 Programmable input/output line, Default pull down
64	ESP32_GPIO5	I/O	ESP32 Programmable input/output line, Default pull up
65	ESP32_GPIO27	I/O	ESP32 Programmable input/output line, Default pull down
66	ESP32_GPIO26	I/O	ESP32 Programmable input/output line, Default pull up
67	ESP32_GPIO25	I/O	ESP32 Programmable input/output line, Default pull up
68	ESP32_GPIO22	I/O	ESP32 Programmable input/output line

69	ESP32_GPIO19	I/O	ESP32 Programmable input/output line, Alternative Function: I2C_SCL
70	ESP32_GPIO18	I/O	ESP32 Programmable input/output line, Alternative Function: I2C_SDA
71	ESP32_GPIO23	I/O	ESP32 Programmable input/output line
72	ESP32_GPIO21	I/O	ESP32 Programmable input/output line
73	ESP32_GPIO34	I	ESP32 Input pin
74	P0_30/SDA	I/O	nRF9160 Digital I/O Pin #30. Alternative Function: I2C_SDA
75	P0_31/SCL	I/O	nRF9160 Digital I/O Pin #31. Alternative Function: I2C_SCLK
76	GND	VSS	Ground
77-92	GND	VSS	Ground
94-102	NC		Reserved Pins
114	COEX2	I/O	Coexistence interface. Not used. Needs to be left floating.
115	COEX1	I/O	Coexistence interface. Not used. Needs to be left floating.
116	COEX0	I/O	Coexistence interface. Not used. Needs to be left floating. ***Note:*** *This port is used to control the power supply of GPS.*
117-119	NC		Reserved Pins
120	P0_11/MEM_MOSI	I/O	nRF9160 Digital I/O Pin #11. ***Alternative Function (optional):*** *Internal Flash chip interface, SPI_FLASH MOSI*
121	P0_12/MEM_MISO	I/O	nRF9160 Digital I/O Pin #12. ***Alternative Function (optional):*** *Internal Flash chip interface, SPI_FLASH MISO*
122	P0_13/AIN0/MEM_CLK	I/O	nRF9160 Digital I/O Pin #13. ***Alternative Function (optional):*** *Internal Flash chip interface, SPI_FLASH CLK*
123	P0_25/MEM_CS	I/O	nRF9160 Digital I/O Pin #25. ***Alternative Function (optional):*** *Internal Flash chip interface, SPI_FLASH CS*
124	NC		Reserved Pins
130	MAGPIO2	I/O	Antenna Tuning GPIO pin #2, **Fixed 1.8V**
131	MAGPIO1	I/O	Antenna Tuning GPIO pin #1, **Fixed 1.8V**
132	MAGPIO0	I/O	Antenna Tuning GPIO pin #0, **Fixed 1.8V**
133-138	NC		Reserved Pins
145-148	NC		Reserved Pins

4. PHYSICAL INTERFACE

4.1 UART Interface Characteristics

Table 3: nRF9160 UART Specifications

Parameter	Symbol	Min	Type	Max	Unit
Baud rate		0.3	115.2	1000	Kbps
Data Bits			8		
Parity Bit			N		
Stop Bit(s)			1		

Table 4: ESP32 UART Specifications

Parameter	Possible Values	
Baudrate	Minimum	110 bps (≤2%Error)
	Standard	115200bps(≤1%Error)
	Maximum	5000000bps(≤1%Error)
Flow control		RTS/CTS
Parity		None, Odd or Even
Number of stop bits		1 /2
Bits per channel		7/8

When connecting the module to a host, please make sure to follow.

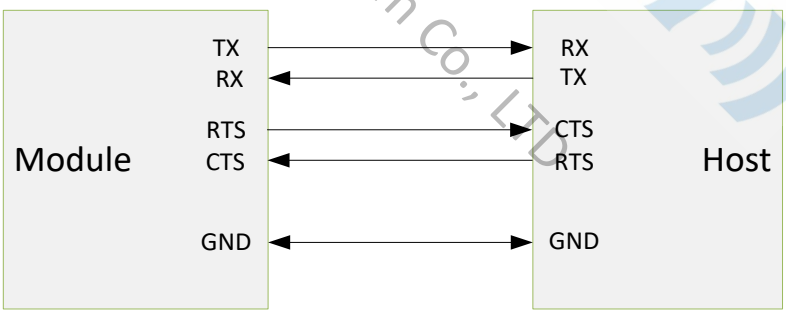


Figure 4: UART Connection

4.2 General Purpose Digital IO

1, nRF9160

NRF9160 provides a total of 31 I/O ports, of which 25 I/O ports can be used independently, 4 I/O ports are multiplexed as SPI communication interfaces to connect with Flash chip and lead out to module pins (the Flash chip inside the modu le is optional), and 2 I/O ports are multiplexed as UART interfaces to communicate with ESP32.

2, ESP32

The module has a total of 19 GPIO pins. By configuring the corresponding registers, these pins can be assigned different functions, including the following types of GPIO: Only GPIO with digital function, GPIO with analog function, GPIO with capacitive touch function, etc. GPIO with analog function and GPIO with capacitive touch function can be configured as digital GPIO.

Most GPIOs with digital functions can be configured as internal pull-up/pull-down or set to high impedance. When configured as an input, the input value can be obtained by reading the register. Input pins can also be set to generate CPU interrupts by edge triggering or level triggering.

4.3 ESP32 Ethernet MAC interface

FSC-CL4040 provides a media access controller (MAC) interface that complies with the IEEE-802.3-2008 standard for Ethernet communications. FSC-CL4040 requires an external physical layer interface chip (PHY) to connect the physical LAN bus (twisted pair, optical fiber, etc.). The physical layer interface chip is connected to the chip through 17 MII signals or 9 RMII signals. The Ethernet MAC interface (EMAC) supports the following features:

- To 10 Mbps and 100 Mbps
- Dedicated DMA controller realizes high-speed transmission between Ethernet MAC interface and dedicated SRAM
- Tagged MAC frame (support VLAN)
- Half-duplex (CSMA/CD) and full-duplex operation
- MAC control sublayer (control frame)
- 32-bit CRC automatic generation and elimination
- Multiple address filtering modes for unicast and multicast addresses (broadcast and group addresses)
- Record the 32-bit status code of each frame sent and received
- The internal FIFO is used to buffer transmitted and received frames.
- Both transmit FIFO and receive FIFO are 512 words (32-bit)
- Hardware PTP (Precision Time Protocol) compliant with IEEE 1588 2008 (PTP V2) standard
- 25 MHz/50 MHz clock output

4.4 nRF9160 SIM Interfaces

The traces connecting the external SIM interface pins should be as short as possible, and proper high-speed PCB design principles should be followed in order to ensure the highest possible signal integrity.

It is also recommended to add an ESD/EMI protection IC on the baseboard, especially in situations that are prone to EMI and ESD, like users inserting SIM cards into SIM connectors. The design files can be referenced for an ideal implementation of the modem's external SIM Interface with an ESD/EMI protection IC.

4.5 nRF9160 Cellular Interfaces

4.5.1 Supported LTE Bands

Table 5: Supported LTE Bands

Band	Notes	Uplink	Downlink	Unit
B1		1920 – 1980	2110 – 2170	MHz
B2		1850 – 1910	1930 – 1990	MHz
B3		1710 – 1785	1805 – 1880	MHz
B4		1710 – 1755	2110 – 2155	MHz
B5		824 – 849	869 – 894	MHz
B8		880 – 915	925 – 960	MHz
B12		698 – 716	728 – 746	MHz
B13		777 – 787	746 – 756	MHz
B14	LTE-M Only	788 – 798	758 – 768	MHz
B17		704 – 716	734 – 746	MHz
B18	LTE-M Only	815 – 830	860 – 875	MHz
B19		830 – 845	875 – 890	MHz
B20		832 – 862	791 – 821	MHz
B25		1850 – 1915	1930 – 1995	MHz
B26		814 – 849	859 – 894	MHz
B28		703 – 748	758 – 803	MHz
B66		1710 – 1780	2110 – 2200	MHz

4.5.2 Cellular Antenna Requirements

nRF9160 modems have a Single-Input Single-Output (SISO) cellular interface that supports LTE CAT-M1, LTE CAT-NB1, and LTE CAT-NB2.

Table 6: The chosen cellular antenna must meet or exceed the following specifications

Parameter	Min	Type	Max	Unit
Characteristic Impedance		50		Ω
VSWR	<3:1	<2:1		V
Return Loss	>6.0	>9.5		dB
Efficiency		>50		%
Maximum Input Power			1	W

4.6 nRF9160 GPS Interfaces

FSC-CL4040 features an integrated GPS receiver that supports L1 C/A reception at 1575MHz. The operation of the GPS receiver is time-multiplexed with the LTE radio, meaning the GPS position can only be taken when the LTE radio is in RRC Idle mode, Power Save Mode (PSM), or when the LTE radio is deactivated.

4.6.1 GPS Antenna Requirements

It is strongly recommended to use an active GPS antenna for optimal performance, but a passive antenna may also be used.

Note: When employing a passive GPS antenna, additional matching and/or an LNA on the baseboard may be required in order to achieve acceptable performance.

The modem has an on-board LDO that can be used to supply power to an active antenna. When enabled, the LDO biases the GPS antenna at 3.3V in order to power the LNA inside of the active antenna. A DC blocking capacitor is included on the modem to isolate the GPS receiver from the 3.3V DC bias.

Table 7: The chosen active antenna must meet or exceed the following specifications

Parameter	Min	Type	Max	Unit
Characteristic Impedance		50		Ω
Antenna Type	Active Antenna (strongly recommended) or Passive Antenna			
Center Frequency		1575.42		MHz
VSWR	< 3:1	< 2:1		
Return Loss	> 6.0	> 9.5		dB
Efficiency		>50		%
Active Antenna Supply Voltage	3.0		3.3	V
Active Antenna LNA Gain		> 15		dB
Maximum LNA Noise Factor			1.5	dB

4.6.2 GPS Antenna Placement Guidelines

- The antenna must be installed according to the antenna manufacturer's instructions in order to obtain the maximum performance of the GPS receiver.
- The antenna location must be evaluated carefully if operating in conjunction with any other antenna or transmitter.
- The antenna must not be installed inside metal cases or near any obstacle that may degrade features like antenna lobes and gain.
- Keep the antenna and the antenna cabling away from any power supply lines, noisy EM devices, and wireless RF lines.

5. ELECTRICAL CHARACTERISTICS

5.1 Recommended Operating Conditions

Table 8: Recommended Operating Conditions

Parameter	Min	Type	Max	Unit
VCC	3.0	3.3	3.6	V
VCC_GPIO	1.7	1.8/3.3	3.6	V
Operating temperature (T_A)	-40	25	+85	°C
Storage temperature (T_{stg})	-40	25	+85	°C
ENABLE Signal	**VIL:** 0V to 0.4V	VCC	**VIH:** 1.2V to VCC	V

5.2 nRF9160 SIM Interface Pins

Table 9: nRF9160 SIM interface pins

Name	Notes	Min	Type	Max
SIM_RESET	External SIM reset signal. 1.8V referenced.	**VIL:** 0V to 0.27V		**VIH:** 1.26V to 1.8V
SIM_DET	SIM detect. Not used. Needs to be left floating.	**VIL:** 0V to 0.27V		**VIH:** 1.26V to 1.8V
SIM_CLK	External SIM clock output. 1.8V ref'd.	**VIL:** 0V to 0.27V		**VIH:** 1.26V to 1.8V
SIM_IO	External SIM interface IO signal. 1.8V referenced.	**VIL:** 0V to 0.27V		**VIH:** 1.26V to 1.8V
SIM_1V8	External SIM Supply Voltage Pin	1.65V	1.8V	1.95V

5.3 nRF9160 Antenna Tuning GPIO Pins

FSC-CL4040 has three 1.8V referenced pins that can be used to drive external antenna tuning circuitry such as RF switches.

Table 10: nRF9160 Antenna Tuning GPIO Pins

Name	Notes	Min	Type	Max
MAGPIO2	Antenna tuning GPIO2. Fixed 1.8V reference.	**VIL:** 0V to 0.54V		**VIH:** 1.26V to 1.8V
MAGPIO1	Antenna tuning GPIO1. Fixed 1.8V reference.			
MAGPIO0	Antenna tuning GPIO0. Fixed 1.8V reference.			
		VOL: 0V to 0.4V		**VOH:** 1.7V to 1.9V

5.4 nRF9160 LTE modem coexistence interface

The LTE modem uses a dedicated three-pin interface for RF interference avoidance towards a companion radio device such as an external positioning device or Bluetooth Low Energy device.

The inputs and outputs for this interface are the following:

- COEX0 – Input to the LTE modem from the external device. When active high, indicates that the external device transceiver is turned on. When internal GPS is used, COEX0 can be used as active high control for the external LNA component.
- COEX1 – Output from the LTE modem to the external device. Active high time mark pulse, which is synchronous to LTE system time. When internal GPS is used, COEX1 delivers the GPS 1PPS (one pulse per second) time mark pulse.
- COEX2 – Output from the LTE modem to the external device. When active high, indicates that the LTE modem transceiver is turned on. COEX2 can also be treated as active low grant from LTE modem to the external device, indicating grant to transmit and receive.

Note: Using the COEX2 pin requires an external pull-down resistor in the 100 kΩ size range.

The COEX interface timing in relation to modem state is shown in the following figure.

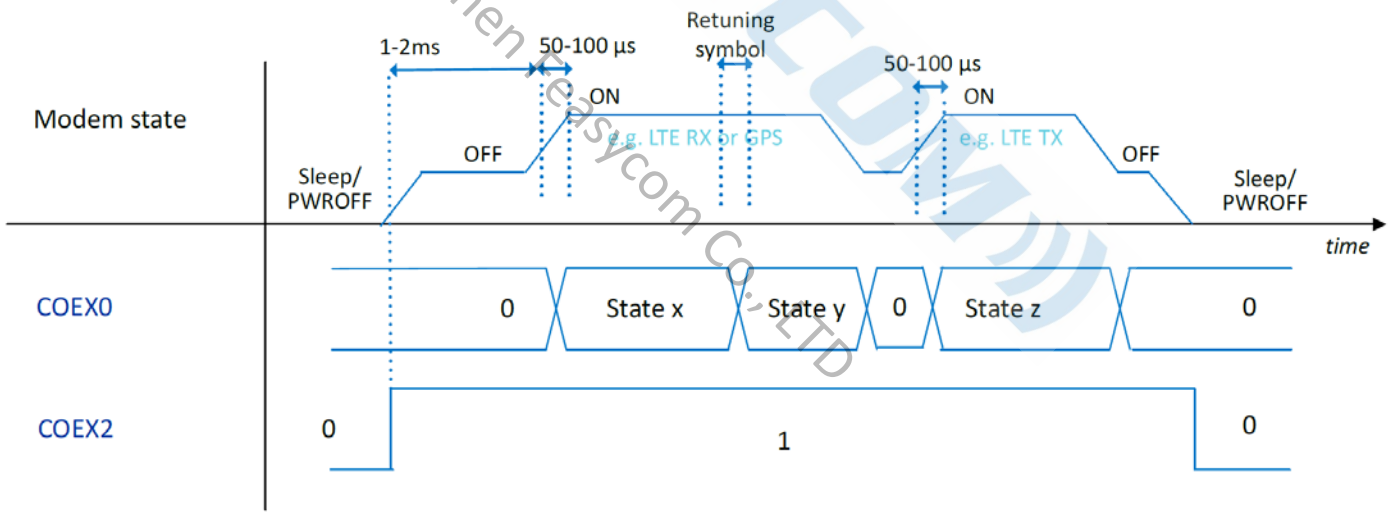


Figure 5: COEX interface timing

5.5 nRF9160 Cellular and GPS Specifications

5.5.1 Available Technologies and Bands

Table 11: Available Technologies and Bands

Cellular Technology	Bands
LTE CAT-M1	B1, B2, B3, B4, B5, B8, B12, B13, B14, B17, B18,B19, B20, B25, B26, B28, B66
LTE CAT-NB1, LTE CAT-NB2	B1, B2, B3, B4, B5, B8, B12, B13, B17, B19, B20,B25, B26, B28, B66
GPS	L1 C/A (1575.42 MHz)

5.5.2 LTE CAT-M1 Specifications

Table 12: LTE CAT-M1 Specifications

Parameter	Description	Min	Type	Max
Operating Frequency	Modem operating frequency range	699MHz		1980MHz
Output Power	RF output power.	-40dBm	23dBm	23dBm
Output Power Accuracy	Accuracy of reported output power.			±2dBm
Low Band RX Sensitivity	CAT-M1 RX sensitivity at low band.		-108dBm	
Midband Rx Sensitivity	CAT-M1 RX sensitivity at midband.		-107dBm	
Uplink Speed	CAT-M1 upload speed.			300 Kbps
Downlink Speed	CAT-M1 download speed.			375 Kbps

5.5.3 LTE CAT-NB1 and LTE CAT-NB2 Specifications

Table 13: LTE CAT-NB1 and LTE CAT-NB2 Specifications

Parameter	Description	Min	Type	Max
Operating Frequency	Modem operating frequency range	699MHz		1980MHz
Output Power	RF output power.	-40dBm	23dBm	23dBm
Output Power Accuracy	Accuracy of reported output power.			±2dBm
RX Sensitivity	CAT-NB1 / CAT-NB2 RX sensitivity.		-114dBm	
Uplink Speed	CAT-M1 upload speed.			30 Kbps
Downlink Speed	CAT-M1 download speed.			60 Kbps

5.5.4 GPS Specifications

Table 14: GPS Specifications

Parameter	Description	Min	Type	Max
Operating Frequency	GPS L1 C/A center frequency.		1575.42MHz	
Sensitivity, Cold Start	RX sensitivity for cold start.		-147 dBm	
Sensitivity, Hot Start	RX sensitivity for hot start.		-147 dBm	
Sensitivity, Tracking	RX sensitivity while tracking.		-155 dBm	
TTFF, cold	Cold start, clear LOS to sky, typical conditions		43 s	
TTFF, hot	Hot start, clear LOS to sky, typical conditions		1.5 s	
Periodic Accuracy	Periodic tracking position accuracy		5 m	
Continuous Accuracy	Continuous tracking position accuracy		3 m	

5.6 ESP32 RF Characteristic

5.6.1 ESP32 Wi-Fi RF

Table 15: Wi-Fi radio frequency characteristics

Parameter	Mode	Min	Type	Max	Unit
Working frequency	-	2412	-	2484	MHz
Output impedance	-	-	30+j10 Ω	-	Ω
Output Power	11n, MCS7	12	13	14	dBm
	11b Mode	18.5	19.5	20.5	dBm
Sensitivity	11b, 1 Mbps	-	-98	-	dBm
	11b, 11 Mbps	-	-88	-	dBm
	11g, 6 Mbps	-	-93	-	dBm
	11g, 54 Mbps	-	-75	-	dBm
	11n, HT20, MCS0	-	-93	-	dBm
	11n, HT20, MCS7	-	-73	-	dBm
	11n, HT40, MCS0	-	-90	-	dBm
	11n, HT40, MCS7	-	-70	-	dBm
Adjacent channel suppression	11g, 6 Mbps	-	27	-	dB
	11g, 54 Mbps	-	13	-	dB
	11n, HT20, MCS0	-	27	-	dB
	11n, HT20, MCS7	-	12	-	dB

5.6.2 ESP32 Classic Bluetooth RF -- Receiver-Basic Data Rate (BR)

Table 16: Receiver characteristics – basic data rate (BR)

Parameter	Condition	Min	Type	Max	Unit
Sensitivity@0.1% BER	-	-90	-89	-88	dBm
Maximum received signal@0.1% BER	-	0	-	-	dBm
Co-channel rejection ratio C/I	-	-	+7	-	dB
Adjacent channel selective suppression ratio C/I	F = F0 + 1 MHz	-	-	-6	dB
	F = F0 – 1 MHz	-	-	-6	dB
	F = F0 + 2 MHz	-	-	-25	dB
	F = F0 – 2 MHz	-	-	-33	dB
	F = F0 + 3 MHz	-	-	-25	dB
	F = F0 – 3 MHz	-	-	-45	dB
Out-of-band blocking	30 MHz ~ 2000 MHz	-10	-	-	dBm
	2000 MHz ~ 2400 MHz	-27	-	-	dBm
	2500 MHz ~ 3000 MHz	-27	-	-	dBm
	3000 MHz ~ 12.5 GHz	-10	-	-	dBm
Intermodulation	-	36			dBm

5.6.3 ESP32 Classic Bluetooth RF -- Transmitter-Basic Data Rate (BR)

Table 17: Transmitter characteristics – basic data rate (BR)

Parameter	Condition	Min	Type	Max	Unit
RF transmit power	-	-	0	-	dBm
Gain control step	-	-	3	-	dB
RF power control range	-	-12	-	+9	dBm
20 dB bandwidth		-	0.9	-	MHz
Adjacent channel transmit power	F = F0 ± 2 MHz	-	-47	-	dBm
	F = F0 ± 3 MHz	-	-55	-	dBm
	F = F0 ± > 3 MHz	-	-60	-	dBm
Δ f1avg	–	-	-	-155	kHz
Δ f2max		133.7	-	-	kHz
Δ f2avg/Δ f1avg		-	0.92	-	
ICFT		-	-7	-	kHz
Drift rate		-	0.7	-	kHz/50_s
Offset (DH1)		-	6	-	kHz
Offset (DH5)		-	6	-	kHz

5.6.4 ESP32 Classic Bluetooth RF -- Receiver-Enhanced Data Rate (EDR)

Table 18: Receiver characteristics-enhanced data rate (EDR)

Parameter	Condition	Min	Type	Max	Unit
π/4 DQPSK					
Sensitivity@0.01% BER	-	-90	-9+	-99	dBm
Maximum received signal @0.01% BER	-	-	0	-	dBm
Co-channel rejection ratio C/I		-	11	-	dB
Adjacent channel selective suppression ratio C/I	F = F0 + 1 MHz	-	-7	-	dB
	F = F0 – 1 MHz	-	-7	-	dB
	F = F0 + 2 MHz	-	-25	-	dB
	F = F0 – 2 MHz	-	-35	-	dB
	F = F0 + 3 MHz	-	-25	-	dB
	F = F0 – 3 MHz	-	-45	-	dB
8DPSK					
Sensitivity@0.01% BER	-	-84	-83	-82	dBm
Maximum received signal @0.01% BER	-	-	-5	-	dBm
Co-channel rejection ratio C/I	-	-	18	-	dB
Adjacent channel selective suppression ratio C/I	F = F0 + 1 MHz	-	2	-	dB
	F = F0 – 1 MHz	-	2	-	dB
	F = F0 + 2 MHz	-	-25	-	dB
	F = F0 – 2 MHz	-	-25	-	dB
	F = F0 + 3 MHz	-	-25	-	dB
	F = F0 – 3 MHz	-	-38	-	dB

5.6.5 ESP32 Classic Bluetooth RF -- Transmitter-Enhanced Data Rate (EDR)

Table 19: Transmitter characteristics-enhanced data rate (EDR)

Parameter	Condition	Min	Type	Max	Unit
RF transmit power	-	-	0	-	dBm
Gain control step	-	-	3	-	dBm
RF power control range	-	-12	-	+9	dB
π/4 DQPSK max w0	-	-	-0.72	-	kHz
π/4 DQPSK max wi	-	-	-6	-	kHz
π/4 DQPSK max |wi + w0|	-	-	-7.42	-	kHz
8DPSK max w0	-	-	0.7	-	kHz
8DPSK max wi	-	-	-9.6	-	kHz
8DPSK max |wi + w0|	-	-	-10	-	kHz
π/4 DQPSK modulation accuracy	RMS DEVM	-	4.28	-	%
	99% DEVM	-	100	-	%
	Peak DEVM	-	13.3	-	%
	RMS DEVM	-	5.8	-	%

8 DPSK modulation accuracy	99% DEVM	-	100	-	%
	Peak DEVM	-	14	-	%
In-band spurious emissions	F = F0 ± 1 MHz	-	-46	-	dBm
	F = F0 ± 2 MHz	-	-40	-	dBm
	F = F0 ± 3 MHz	-	-46	-	dBm
	F = F0 +/- > 3 MHz	-	-	-53	dBm
EDR differential phase encoding		-	-100	-	%

5.6.6 ESP32 Receiver-Bluetooth Low Energy RF

Table 20: Low-power Bluetooth receiver features

Parameter	Condition	Min	Type	Max	Unit
Sensitivity@30.8% PER	-	-94	-93	-92	dBm
Maximum received signal @30.8% PER	-	0	-	-	dBm
Co-channel rejection ratio C/I	-	-	+10	-	dB
Adjacent channel suppression ratio C/I	F = F0 + 1 MHz	-	-5	-	dB
	F = F0 – 1 MHz	-	-5	-	dB
	F = F0 + 2 MHz	-	-25	-	dB
	F = F0 – 2 MHz	-	-35	-	dB
	F = F0 + 3 MHz	-	-25	-	dB
	F = F0 – 3 MHz	-	-45	-	dB
Out-of-band blocking	30 MHz ~ 2000 MHz	-10	-	-	dBm
	2000 MHz ~ 2400 MHz	-27	-	-	dBm
	2500 MHz ~ 3000 MHz	-27	-	-	dBm
	3000 MHz ~ 12.5 GHz	-10	-	-	dBm
Intermodulation		-36	-	-	dBm

5.6.7 ESP32 Transmitter-Bluetooth Low Energy RF

Table 21: Low-power Bluetooth transmitter features

Parameter	Condition	Min	Type	Max	Unit
RF transmit power	-	-	0	-	dBm
Gain control step	-	-	3	-	dB
RF power control range	-	-10	-	+9	dBm
Adjacent channel transmit power	F = F0 ± 2 MHz	-	-52	-	dBm
	F = F0 ± 3 MHz	-	-58	-	dBm
	F = F0 ± > 3 MHz	-	-60	-	dBm
Δ f1avg	-	-	-	265	kHz
Δ f2max	-	247	-	-	kHz
Δ f2avg/Δ f1avg	-	-	0.92	-	
ICFT	-	-	-10	-	kHz

Drift speed	-	-	0.7	-	kHz/50 _s
Offset	-	-	2	-	kHz

6. MSL & ESD

Table 22: MSL and ESD

Parameter	Value
MSL grade:	MSL 3
ESD grade	**Electrostatic discharge**
ESD – Human Body Model (HBM) Rating JESD22-A114-B	±1500 V , Class 1C
ESD – Charged Device Model (CDM) Rating JESD22-C101-D	±250 V

7. RECOMMENDED TEMPERATURE REFLOW PROFILE

Prior to any reflow, it is important to ensure the modules were packaged to prevent moisture absorption. New packages contain desiccate (to absorb moisture) and a humidity indicator card to display the level maintained during storage and shipment. If directed to bake units on the card, please check the below and follow instructions specified by IPC/JEDEC J-STD-033.

Note: The shipping tray cannot be heated above 65°C. If baking is required at the higher temperatures displayed in the below , the modules must be removed from the shipping tray.

Any modules not manufactured before exceeding their floor life should be re-packaged with fresh desiccate and a new humidity indicator card. Floor life for MSL (Moisture Sensitivity Level) 3 devices is 168 hours in ambient environment 30°C/60%RH.

Notice (注意) :

Feasycom module must use Step-Stencil, suggestion using the stencil thickness about 0.16-0.2mm,

it could be modify with the product.

使用我司模块，须使用阶梯钢网，建议阶梯钢网厚度0.16-0.20mm，可根据自己产品适应性，进行相应调整.

Table 23: Recommended baking times and temperatures

MSL	125°C Baking Temp.		90°C/≤ 5%RH Baking Temp.		40°C/ ≤ 5%RH Baking Temp.	
	Saturated @ 30°C/85%	Floor Life Limit + 72 hours @ 30°C/60%	Saturated @ 30°C/85%	Floor Life Limit + 72 hours @ 30°C/60%	Saturated @ 30°C/85%	Floor Life Limit + 72 hours @ 30°C/60%
3	9 hours	7 hours	33 hours	23 hours	13 days	9 days

Feasycom surface mount modules are designed to be easily manufactured, including reflow soldering to a PCB. Ultimately it is the responsibility of the customer to choose the appropriate solder paste and to ensure oven temperatures during reflow meet the requirements of the solder paste. Feasycom surface mount modules conform to J-STD-020D1 standards for reflow temperatures.

The soldering profile depends on various parameters necessitating a set up for each application. The data here is given only for guidance on solder reflow.

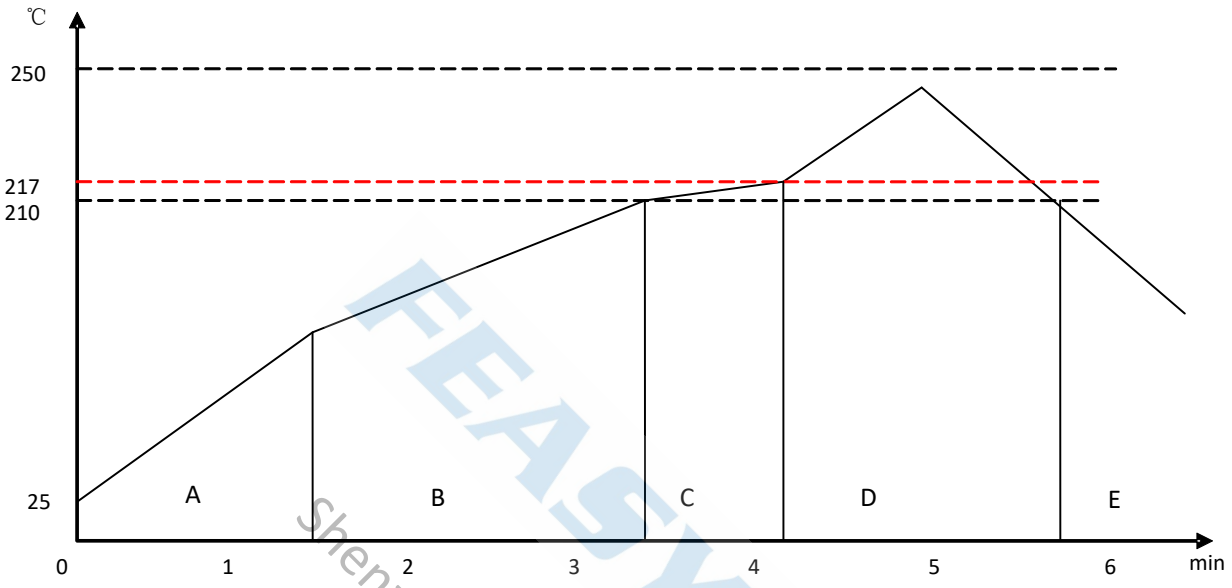


Figure 6: Typical Lead-free Re-flow

Pre-heat zone (A) — This zone raises the temperature at a controlled rate, **typically 0.5 – 2 °C/s**. The purpose of this zone is to preheat the PCB board and components to 120 ~ 150 °C. This stage is required to distribute the heat uniformly to the PCB board and completely remove solvent to reduce the heat shock to components.

Equilibrium Zone 1 (B) — In this stage the flux becomes soft and uniformly encapsulates solder particles and spread over PCB board, preventing them from being re-oxidized. Also with elevation of temperature and liquefaction of flux, each activator and rosin get activated and start eliminating oxide film formed on the surface of each solder particle and PCB board. **The temperature is recommended to be 150° to 210° for 60 to 120 second for this zone.**

Equilibrium Zone 2 (C) (optional) — In order to resolve the upright component issue, it is recommended to keep the temperature in 210 – 217 ° for about 20 to 30 second.

Reflow Zone (D) — The profile in the figure is designed for Sn/Ag3.0/Cu0.5. It can be a reference for other lead-free solder. The peak temperature should be high enough to achieve good wetting but not so high as to cause component discoloration or damage. Excessive soldering time can lead to intermetallic growth which can result in a brittle joint. The recommended peak temperature (Tp) is 230 ~ 250 °C. The soldering time should be 30 to 90 second when the temperature is above 217 °C.

Cooling Zone (E) — The cooling ate should be fast, to keep the solder grains small which will give a longer-lasting joint. **Typical cooling rate should be 4 °C.**

8. MECHANICAL DETAILS

8.1 Mechanical Details

- Dimension: 22.9mm(L) x 21.9mm(W) x 2.0mm(H) Tolerance: ±0.2mm
- Module size: 22.9mm x 21.9mm Tolerance: ±0.2mm

(分板后边角残留板边误差：不大于0.5mm)

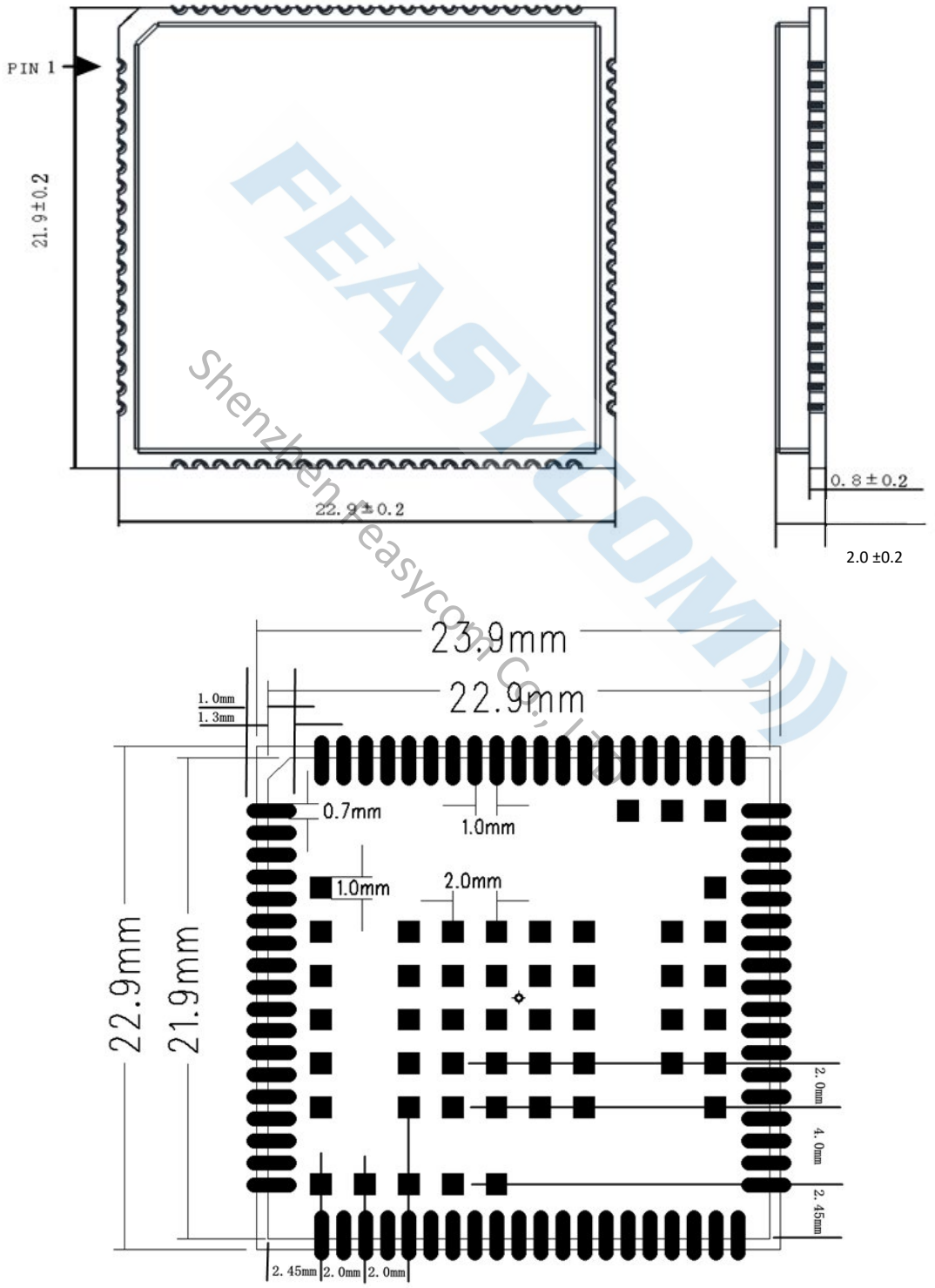


Figure 7: FSC-CL4040 footprint Layout Guide (Top View)

9. HARDWARE INTEGRATION SUGGESTIONS

9.1 Requirement for the 3.3V power supply

- To use a dedicated power supply circuit for FSC-CL4040.
- <0.05% line regulation and <0.5%/A load regulation are required for ripple frequency below 100KHz.
- Transient-response: 1, the ripple raised from 100/800mA step-response test should be small than 200mVpp.

  2, The ripple swing shall settle down within 1~2 cycles, 2 cycles for the worst case.
- Power supply spur: make sure the spurs from switching mode power supply or other noisy circuits are reasonably small. Once issue concerned with such a power supply spur, alternative power supply filtering might be needed.
- VCC: 3.0 to 3.6V (Peak Current 1A); VCC_GPIO: 1.8 to 3.6V

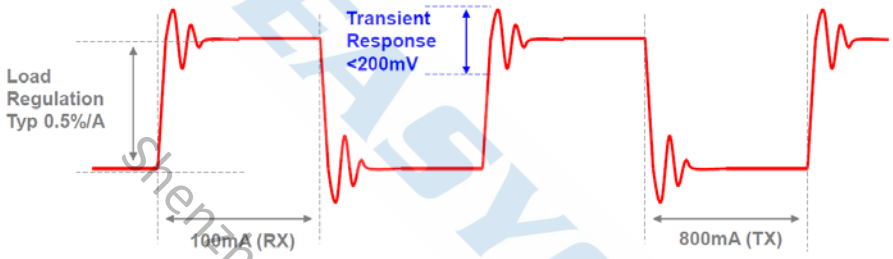


Figure 8: Requirement for the 3.3V power supply

9.2 RF Circuit- RF pads

- Some RF components such as 0402-packaged RLC, connectors, or module pins are with large soldering pad, those pads have higher parasitic capacitance which can impact the characteristic impedance of RF traces.
- The GND under those pads shall be dug out, shown as below, for keeping good 50Ω matching.
- The dig-out layers and area should be calculated carefully, we recommend digging the area a little higher than the simulation results.

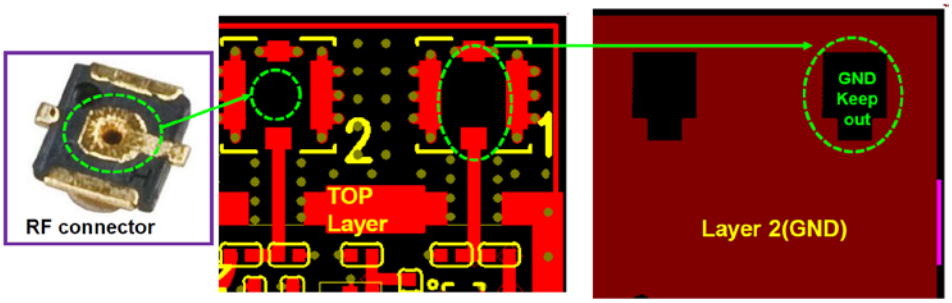


Figure 9: RF Circuit- RF pads

9.3 Soldering Recommendations

FSC-CL4040 is compatible with industrial standard reflow profile for Pb-free solders. The reflow profile used is dependent on the thermal mass of the entire populated PCB, heat transfer efficiency of the oven and particular type of solder paste used. Consult the datasheet of particular solder paste for profile configurations.

Feasycom will give following recommendations for soldering the module to ensure reliable solder joint and operation of the module after soldering. Since the profile used is process and layout dependent, the optimum profile should be studied case by case. Thus following recommendation should be taken as a starting point guide.

9.4 Layout Guidelines(External Antenna)

Placement and PCB layout are critical to optimize the performances of a module without on-board antenna designs. The trace from the antenna port of the module to an external antenna should be 50Ω and must be as short as possible to avoid any interference into the transceiver of the module. The location of the external antenna and RF-IN port of the module should be kept away from any noise sources and digital traces. A matching network might be needed in between the external antenna and RF-IN port to better match the impedance to minimize the return loss.

As indicated in below, RF critical circuits of the module should be clearly separated from any digital circuits on the system board. All RF circuits in the module are close to the antenna port. The module, then, should be placed in this way that module digital part towards your digital section of the system PCB.

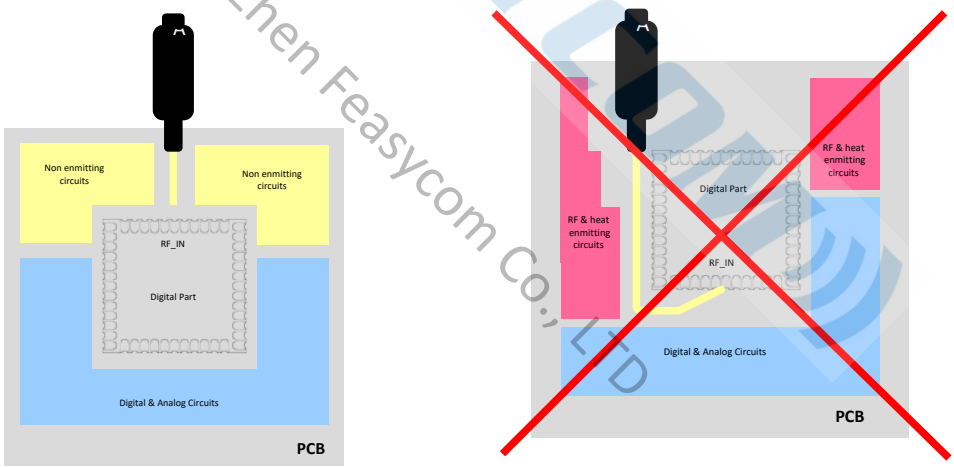


Figure 10: Placement the Module on a System Board

9.4.1 Antenna Connection and Grounding Plane Design

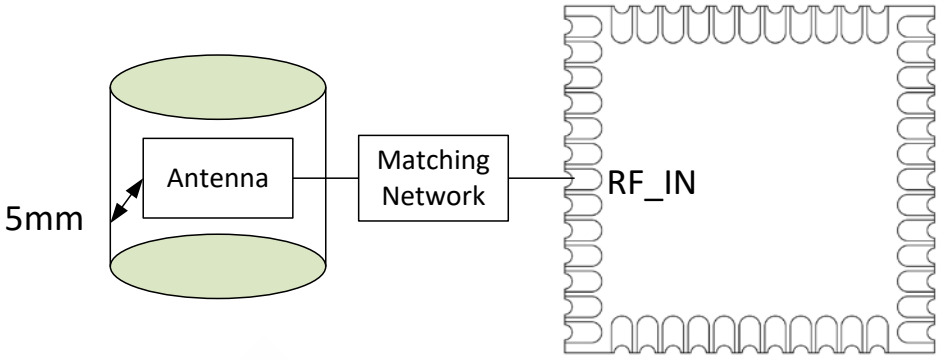


Figure 11: Leave 5mm Clearance Space from the Antenna

General design recommendations are:

- The length of the trace or connection line should be kept as short as possible.
- Distance between connection and ground area on the top layer should at least be as large as the dielectric thickness.
- Routing the RF close to digital sections of the system board should be avoided.
- To reduce signal reflections, sharp angles in the routing of the micro strip line should be avoided. Chamfers or fillets are preferred for rectangular routing; 45-degree routing is preferred over Manhattan style 90-degree routing.

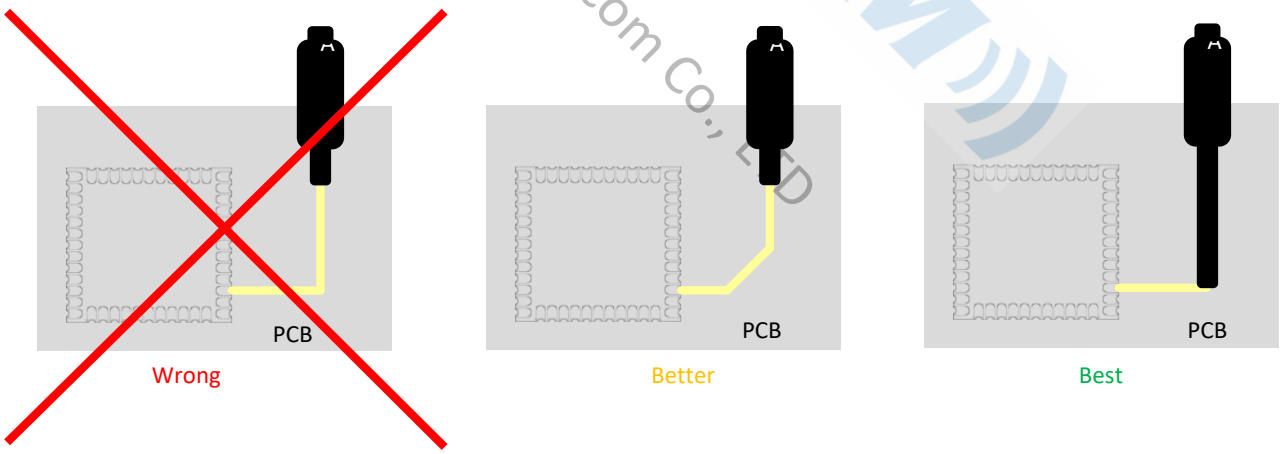


Figure 12: Recommended Trace Connects Antenna and the Module

- Routing of the RF-connection underneath the module should be avoided. The distance of the micro strip line to the ground plane on the bottom side of the receiver is very small and has huge tolerances. Therefore, the impedance of this part of the trace cannot be controlled.
- Use as many vias as possible to connect the ground planes.

10. PRODUCT PACKAGING INFORMATION

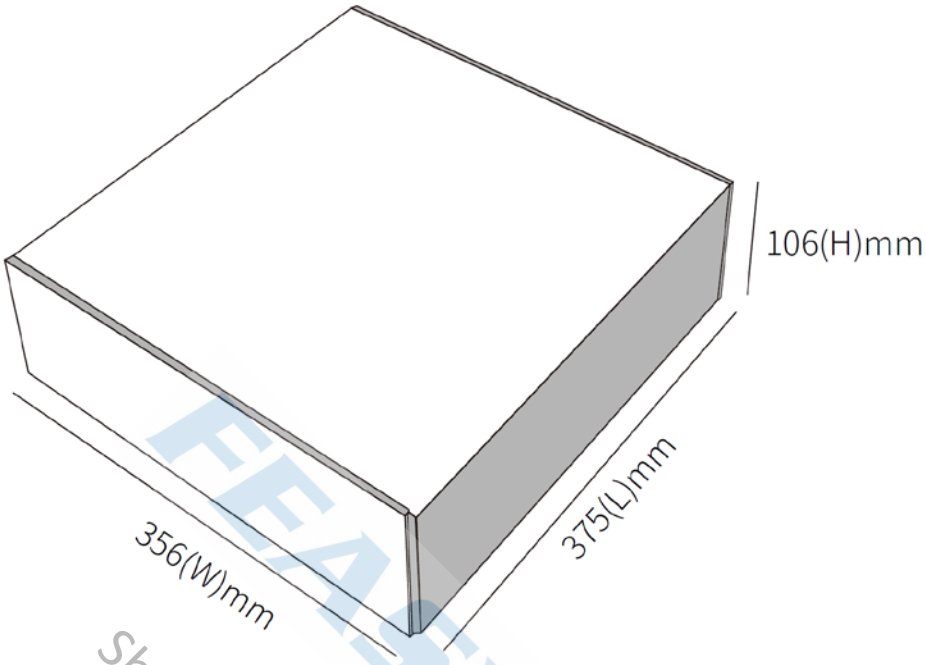
10.1 Default Packing

a, Tray vacuum

b, Tray Dimension: 160mm * 290mm

Figure 13: Tray vacuum

10.2 Packing box (Optional)



* If other packing is required, please confirm with the customer

* Packing: 500pcs per carton (Minimum packing quantity)

* **The outer packing size is for reference only, please refer to the actual size**

Figure 14: Packing Box

11. APPLICATION SCHEMATIC