RM500U-CN

Hardware Design

5G Module Series

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Safety Information

The following safety precautions must be observed during all phases of operation, such as usage, service or repair of any cellular terminal or mobile incorporating the module. Manufacturers of the cellular terminal should notify users and operating personnel of the following safety information by incorporating these guidelines into all manuals of the product. Otherwise, Quectel assumes no liability for customers' failure to comply with these precautions.

	Full attention must be paid to driving at all times in order to reduce the risk of an accident. Using a mobile while driving (even with a handsfree kit) causes distraction and can lead to an accident. Please comply with laws and regulations restricting the use of wireless devices while driving.
	Switch off the cellular terminal or mobile before boarding an aircraft. The operation of wireless appliances in an aircraft is forbidden to prevent interference with communication systems. If there is an Airplane Mode, it should be enabled prior to boarding an aircraft. Please consult the airline staff for more restrictions on the use of wireless devices on an aircraft.
	Wireless devices may cause interference on sensitive medical equipment, so please be aware of the restrictions on the use of wireless devices when in hospitals, clinics or other healthcare facilities.
	Cellular terminals or mobiles operating over radio signal and cellular network cannot be guaranteed to connect in certain conditions, such as when the mobile bill is unpaid or the (U)SIM card is invalid. When emergency help is needed in such conditions, use emergency call if the device supports it. In order to make or receive a call, the cellular terminal or mobile must be switched on in a service area with adequate cellular signal strength. In an emergency, the device with emergency call function cannot be used as the only contact method considering network connection cannot be guaranteed under all circumstances.
	The cellular terminal or mobile contains a transceiver. When it is ON, it receives and transmits radio frequency signals. RF interference can occur if it is used close to TV sets, radios, computers or other electric equipment.
	In locations with explosive or potentially explosive atmospheres, obey all posted signs and turn off wireless devices such as mobile phone or other cellular terminals. Areas with explosive or potentially explosive atmospheres include fueling areas, below decks on boats, fuel or chemical transfer or storage facilities, and areas where the air contains chemicals or particles such as grain, dust or metal powders.

About the Document

Revision History

Version	Date	Author	Description
-	2022-12-08	Len CHEN/ Dominic GONG	Creation of the document
1.0	2023-01-06	Len CHEN/ Cavan ZHU	First official release

Contents

Safety Information **3**
About the Document **4**
Contents **5**
Table Index **7**
Figure Index **8**

1 Introduction **10**
1.1. Reference Standard 10
1.2. Special Marks 10

2 Product Overview **11**
2.1. Frequency Bands and Functions 11
2.2. Key Features 12
2.3. Functional Diagram 14
2.4. Pin Assignment 16
2.5. Pin Description 17
2.6. EVB Kit 21

3 Operating Characteristics **22**
3.1. Operating Modes 22
3.1.1. Sleep Mode 22
3.1.2. Airplane Mode 24
3.2. Power Supply 24
3.2.1. Voltage Stability Requirements 24
3.2.2. Reference Design for Power Supply 25
3.3. Turn On/Off 26
3.3.1. Turn On 26
3.3.2. Turn Off 28
3.4. Reset 28

4 Application Interfaces **31**
4.1. (U)SIM Interfaces 31
4.1.1. Pin Definition of (U)SIM Interfaces 31
4.1.2. (U)SIM Hot-plug 32
4.1.3. Normally Closed (U)SIM Card Connector 33
4.1.4. Normally Opened (U)SIM Card Connector 34
4.1.5. (U)SIM Card Connector Without Hot-plug 34
4.1.6. (U)SIM Design Notice 35
4.2. USB Interface 35
4.3. PCIe Interface 37
4.4. PCM Interface & SPI 39
4.5. I2C Interfaces 41
4.6. UART Interface 41

4.7. B_CODE_OUT 42
4.8. Control and Indication Interfaces 43
4.8.1. W_DISABLE1# 43
4.8.2. WWAN_LED# 44
4.8.3. WAKE_ON_WAN#* 45
4.9. Configuration Pins 46

5 RF Characteristic 48
5.1. Antenna Interfaces 48
5.1.1. Cellular Antenna Interfaces 48
5.1.2. Cellular Antenna Mapping 49
5.1.3. Operating Frequencies 50
5.1.4. Rx Sensitivity 51
5.1.5. Tx Power 52
5.2. Antenna Connectors 52
5.2.1. Antenna Connector Location 52
5.2.2. Antenna Connector Specifications 53
5.2.3. Antenna Connector Installation 54
5.2.4. Recommended RF Connector for Installation 55
5.2.4.1. Assemble Coaxial Cable Plug Manually 55
5.2.4.2. Assemble Coaxial Cable Plug with Jig 57
5.2.5. Recommended Manufacturers of RF Connector and Cable 57
5.3. Antenna Design Requirements 57

6 Reliability, Radio and Electrical Characteristics 59
6.1. Power Supply Requirements 59
6.2. Power Consumption 59
6.3. Digital I/O Characteristic 61
6.4. ESD Protection 62
6.5. Absolute Maximum Ratings 63
6.6. Operating and Storage Temperatures 63
6.7. Thermal Dissipation 64
6.8. Notification 65
6.8.1. Coating 65
6.8.2. Cleaning 65
6.8.3. Installing 65

7 Mechanical Information 66
7.1. Mechanical Dimensions 66
7.2. Top and Bottom Views 67
7.3. M.2 Connector 67
7.4. Packaging 67
7.4.1. Blister Tray 68
7.4.2. Packaging Process 69

8 Appendix References 70

Table Index

Table 1: Special Marks 10
Table 2: Frequency Bands 11
Table 3: Key Features 12
Table 4: Definition of I/O Parameters 17
Table 5: Pin Description 17
Table 6: Overview of Operating Modes 22
Table 7: Definition of VCC and GND Pins 24
Table 8: Definition of FULL_CARD_POWER_OFF# 26
Table 9: Pin Definition of RESET# 29
Table 10: Pin Definition of (U)SIM Interfaces 31
Table 11: Pin Definition of USB Interface 36
Table 12: Pin Definition of PCIe Interface 37
Table 13: Pin Definition of PCM Interface 40
Table 14: Pin Definition of SPI 40
Table 15: Pin Definition of I2C Interface 41
Table 16: Pin Definition of UART Interface 41
Table 17: Pin Definition of B_CODE_OUT 42
Table 18: Pin Definition of Control and Indication Interfaces 43
Table 19: RF Function Status 44
Table 20: RF Status Indications of WWAN_LED# 45
Table 21: State of WAKE_ON_WAN# 45
Table 22: Configuration Pins List of M.2 Specification 46
Table 23: Configuration Pins of the Module 46
Table 24: Pin Definition of Antenna Interfaces 48
Table 25: Cellular Antennas Mapping 49
Table 26: Operating Frequencies 50
Table 27: Receiving Sensitivity 51
Table 28: RF Output Power 52
Table 29: Major Specifications of the RF Connector 54
Table 30: Antenna Requirements 57
Table 31: Power Supply Requirements 59
Table 32: Power Consumption 59
Table 33: Logic Levels of Digital I/O 61
Table 34: (U)SIM 1.8 V I/O Requirements 62
Table 35: (U)SIM 3.0 V I/O Requirements 62
Table 36: Electrostatic Discharge Characteristics (Temperature: 25 ºC, Humidity: 40 %) 62
Table 37: Absolute Maximum Ratings 63
Table 38: Operating and Storage Temperatures 63
Table 39: Related Documents 70
Table 40: Terms and Abbreviations 70

Figure Index

Figure 1: Functional Diagram 15
Figure 2: Pin Assignment 16
Figure 3: DRX Run Time and Current Consumption in Sleep Mode 23
Figure 4: Sleep Mode Application 23
Figure 5: Wakeup Mode Application 24
Figure 6: Power Supply Limits during Radio Transmission 25
Figure 7: Reference Circuit for VCC Pins 25
Figure 8: Reference Design for Power Supply 26
Figure 9: Turn on the Module with a Host GPIO 27
Figure 10: Turn-on Timing 27
Figure 11: Turn off the Module with a Host GPIO 28
Figure 12: Turn-off Timing of the Module 28
Figure 13: Reference Circuit of RESET# with NPN Driver Circuit 29
Figure 14: Reference Circuit of RESET# with NMOS Driver Circuit 29
Figure 15: Reference Circuit of RESET# with a Button 30
Figure 16: Reset Timing 30
Figure 17: Reference Circuit for Normally Closed (U)SIM Card Connector 33
Figure 18: Reference Circuit for Normally Opened (U)SIM Card Connector 34
Figure 19: Reference Circuit for a 6-pin (U)SIM Card Connector 35
Figure 20: Reference Circuit for USB 3.0 and USB 2.0 Interface 36
Figure 21: PCIe Interface Reference Circuit (RC Mode) 38
Figure 22: PCIe Interface Reference Circuit (EP Mode) 39
Figure 23: Reference Design for PCM Interface and SPI 40
Figure 24: Reference Design for I2C Interface 41
Figure 25: Reference Circuit with Translator Chip 42
Figure 26: Reference Design of B_CODE_OUT 43
Figure 27: Reference Circuit for W_DISABLE1# 44
Figure 28: Reference Circuit for WWAN_LED# 45
Figure 29: Reference Circuit for WAKE_ON_WAN# 46
Figure 30: Recommended Circuit for Configuration Pins 47
Figure 31: Antenna Connectors on the Module 53
Figure 32: Dimensions of the Receptacle (Unit: mm) 53
Figure 33: Dimensions of Mated Plugs (Ø 0.81 mm Coaxial Cables) 54
Figure 34: Space Factor of Mated Connectors (Ø0.81 mm Coaxial Cables) (Unit: mm) 55
Figure 35: Space Factor of Mated Connectors (Ø 1.13 mm Coaxial Cables) (Unit: mm) 55
Figure 36: Plug in a Coaxial Cable Plug 56
Figure 37: Pull out a Coaxial Cable Plug 56
Figure 38: Install the Coaxial Cable Plug with Jig 57
Figure 39: Distribution of Heat Source Chips Inside the Module 64
Figure 40: Placement and Fixing of the Heatsink 65
Figure 41: Mechanical Dimensions (Unit: mm) 66

Figure 42: Top and Bottom View of the Module 67
Figure 43: Tray Size (Unit: mm) 68
Figure 44: Package Process 69

1 Introduction

This document introduces RM500U-CN module and describes its air interface and hardware interfaces which are connected with your applications.

With this document, you can quickly understand module interface specifications, electrical and mechanical details, as well as other related information of the module. The document, coupled with application notes and user guides, makes it easy to design and set up mobile applications with the module.

1.1. Reference Standard

The module complies with the following standards:

- *PCI Express M.2 Specification Revision 3.0, Version 1.2*
- *PCI Express Base Specification Revision 2.0*
- *Universal Serial Bus Specification, Revision 3.0*
- *ISO/IEC 7816-3*
- *3GPP TS 27.007* and *3GPP TS 27.005*

1.2. Special Marks

Table 1: Special Marks

Mark	Definition
*	Unless otherwise specified, when an asterisk (*) is used after a function, feature, interface, pin name, AT command, or argument, it indicates that the function, feature, interface, pin, AT command, or argument is under development and currently not supported; and the asterisk (*) after a model indicates that the sample of the model is currently unavailable.

2 Product Overview

2.1. Frequency Bands and Functions

RM500U-CN is a 5G NR/LTE/UMTS/HSPA+ wireless communication module with receiving diversity. It provides data connectivity on 5G NR SA/NSA, LTE-FDD, LTE-TDD, DC-HSDPA, HSPA+, HSDPA, HSUPA, WCDMA and other network systems. The module is a standard M.2 Key-B WWAN module. For more details, see *PCI Express M.2 Specification Revision 3.0, Version 1.2*.

RM500U-CN supports embedded operating systems such as Windows, Linux and Android, and also provides voice functionality to meet specific application demands.

RM500U-CN is an industrial-grade module for industrial and commercial applications only.

Table 2: Frequency Bands

Mode	RM500U-CN
5G NR SA	n1/n28/n41/n77/n78/n79
5G NR NSA	n41/n78/n79
LTE-FDD	B1/B2/B3/B5/B7/B8/B20/B28
LTE-TDD	B34/B38/B39/B40/B41
WCDMA	B1/B2/B5/B8

RM500U-CN can be applied in the following fields:

- Remote monitor system
- Smart metering system
- Wireless CPE
- Smart TV
- Outdoor live devices
- Wireless router and switch
- Other wireless terminal devices

2.2. Key Features

Table 3: Key Features

Feature	Details
Functional Interface	PCI Express M.2 Interface
Power Supply	● Supply voltage: 3.3–4.4 V ● Typical value: 3.7 V
(U)SIM Interfaces	● Support (U)SIM card: Class B (3.0 V) and Class C (1.8 V) ● Support Dual SIM Single Standby
USB Interface	● Compliant with USB 3.0 and USB 2.0 specifications, with maximum transmission rates up to 5 Gbps on USB 3.0 and 480 Mbps on USB 2.0 ● Used for AT command communication, data transmission, firmware upgrade, software debugging. ● Supports USB serial drivers: Windows 7/8/8.1/10/11, Linux 2.6–5.18, Android 4.x–12.x
PCIe Interface	● Complaint with PCIe Gen 2 ● One PCIe interface, supports up to 5 Gbps per lane ● Supports PCIe driver for Linux 3.10–5.18
PCM Interface	● Supports voice transmission through connecting to an external SLIC with SPI, or an external codec with I2C interface ● Supports master and slave modes, master mode by default ● Supports 8 kHz or 16 kHz sampling rate
SPI	● One SPI ● When used in combination with PCM interface for external SLIC connection, SPI is used for control signal transmission
UART Interface	● Support AT commands communication ● Support data transmission ● The baud rate is 115200 bps ● Hardware flow control is not supported
I2C Interface	● One I2C interface ● Multi-master mode is not supported
Transmitting Power	● WCDMA bands: Class 3 (23 dBm ±2 dB) ● LTE bands: Class 3 (23 dBm ±2 dB) ● LTE B41 HPUE: Class 2 (26 dBm ±2 dB) ● 5G NR n1/n41: Class 3 (23 dBm ±2 dB) ● 5G NR n28: Class 3 (23 dBm +2/-2.5 dB) ● 5G NR n77/n78/n79: Class 3 (23 dBm+2/-3 dB) ● 5G NR n41/n78/n79 HPUE: Class 2 (26 dBm +2/-3 dB)

5G NR Features	● Supports 3GPP Rel-15 ● Supports UL and DL 256QAM modulations ● Supported MIMO: - DL 4 × 4 MIMO: n1/n41/n77/n78/n79 - DL 2 × 2 MIMO: n28 - UL 2 × 2 MIMO: n41/n77/n78/n79 ● Supports SCS 15 kHz [1] and 30 kHz [1] ● Supports SA and NSA operation modes ● Supports Option 3x, 3a, 3 and Option 2 ● Maximum transmission data rates [2] - NSA: 2.2 Gbps (DL)/575 Mbps (UL) - SA: 2.0 Gbps (DL)/1 Gbps (UL)
LTE Features	● Maximum supports DL 3CC/UL 2CC DL: Cat 12/UL: Cat 13 ● Supports 1.4/3/5/10/15/20 MHz RF bandwidths ● Supported Modulations: - UL: QPSK, 16QAM and 64QAM - DL: QPSK, 16QAM, 64QAM and 256QAM ● Supports DL 2 × 2 MIMO ● Maximum transmission data rates [2]: - LTE: 600 Mbps (DL)/150 Mbps (UL)
UMTS Features	● Support 3GPP R9 DC-HSDPA, HSPA+, HSDPA, HSUPA and WCDMA ● Support QPSK, 16QAM and 64QAM modulations ● Maximum transmission data rate [2]: - DC-HSDPA: 42.2 Mbps (DL) - HSUPA: 11 Mbps (UL) - WCDMA: 384 kbps (DL)/384 kbps (UL)
Rx-diversity	Supports 5G NR/LTE/WCDMA Rx-diversity
Antenna Interfaces	ANT0, ANT1, ANT2 and ANT3
AT Commands	● Compliant with *3GPP TS 27.007* and *3GPP TS 27.005* ● Quectel enhanced AT commands
Internet Protocol Features	● Supports TCP/UDP/PPP/NTP/NITZ/FTP/HTTP/PING/CMUX*/HTTPS/FTPS/SSL/FILE*/MQTT*/MMS*/SMTP*/SMTPS* ● Supports PAP and CHAP protocols, usually used for PPP connections
Firmware Upgrade	● USB 2.0 interface ● DFOTA
SMS	● Text and PDU modes ● Point-to-point MO and MT ● SMS cell broadcast

[1] 5G NR FDD bands only support SCS 15 kHz, and 5G NR TDD bands only support SCS 30 kHz.
[2] The maximum rates are theoretical and the actual values depend on the network configuration.

	● SMS storage: (U)SIM card by default
Physical Characteristics	● M.2 Key-B ● Size: 30.0 mm × 52.0 mm × 2.3 mm ● Weight: approx. 8.9 g
Temperature Ranges	● Operating temperature range: -30 °C to +75 °C [3] ● Extended temperature range: -40 °C to +85 °C [4] ● Storage temperature range: -40°C to +90°C
RoHS	All hardware components are fully compliant with EU RoHS directive

2.3. Functional Diagram

The following figure shows the functional diagram of RM500U-CN.

- Power management
- Baseband
- NAND Flash
- RF Part
- Peripheral interfaces

[3] To meet this operating temperature range, you need to ensure effective thermal dissipation, for example, by adding passive or active heatsinks, heat pipes, vapor chambers, etc. Within this range, the module can meet 3GPP specifications.
[4] To meet this extended temperature range, you need to ensure effective thermal dissipation, for example, by adding passive or active heatsinks, heat pipes, vapor chambers, etc. Within this range, the module remains the ability to establish and maintain functions such as voice, SMS, emergency call, etc., without any unrecoverable malfunction. Radio spectrum and radio network are not influenced, while one or more specifications, such as Pout, may undergo a reduction in value, exceeding the specified tolerances of 3GPP. When the temperature returns to the normal operating temperature level, the module will meet 3GPP specifications again.

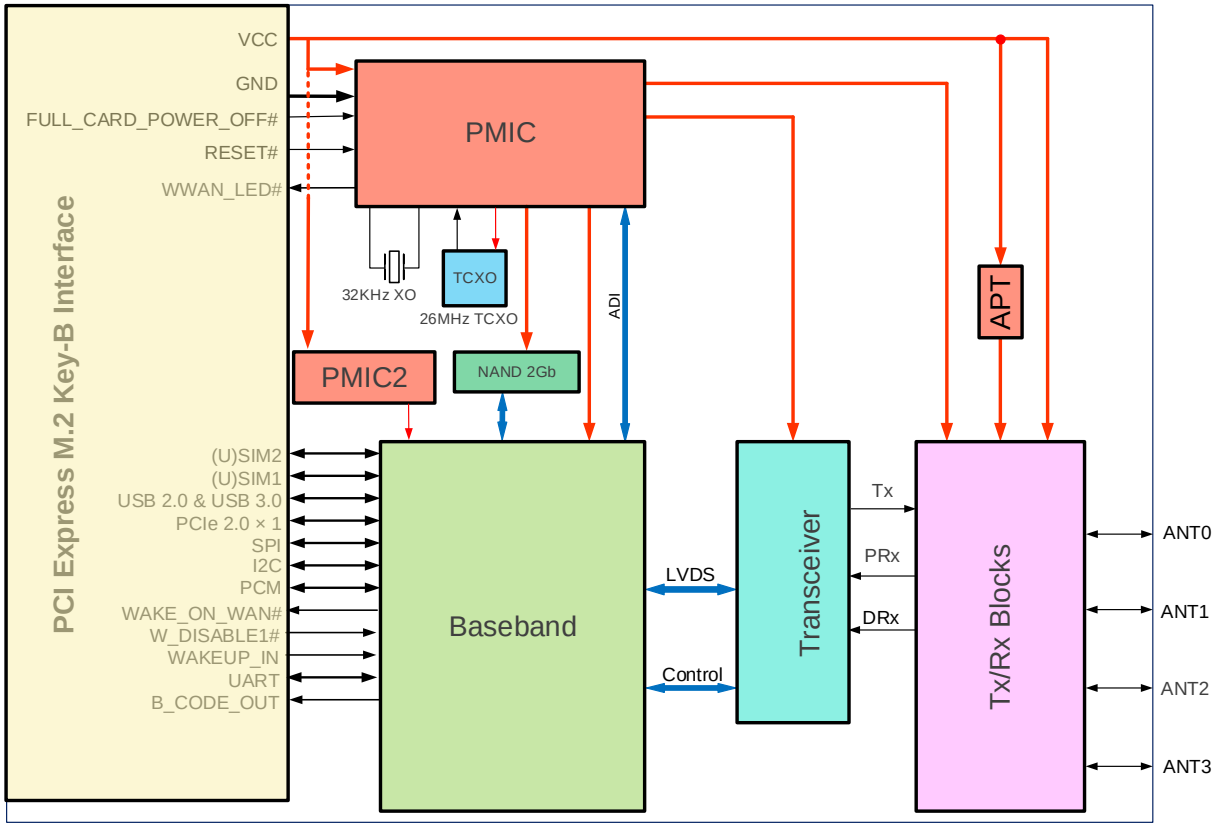


Figure 1: Functional Diagram

2.4. Pin Assignment

The following figure shows the M.2 pin assignment of RM500U-CN.

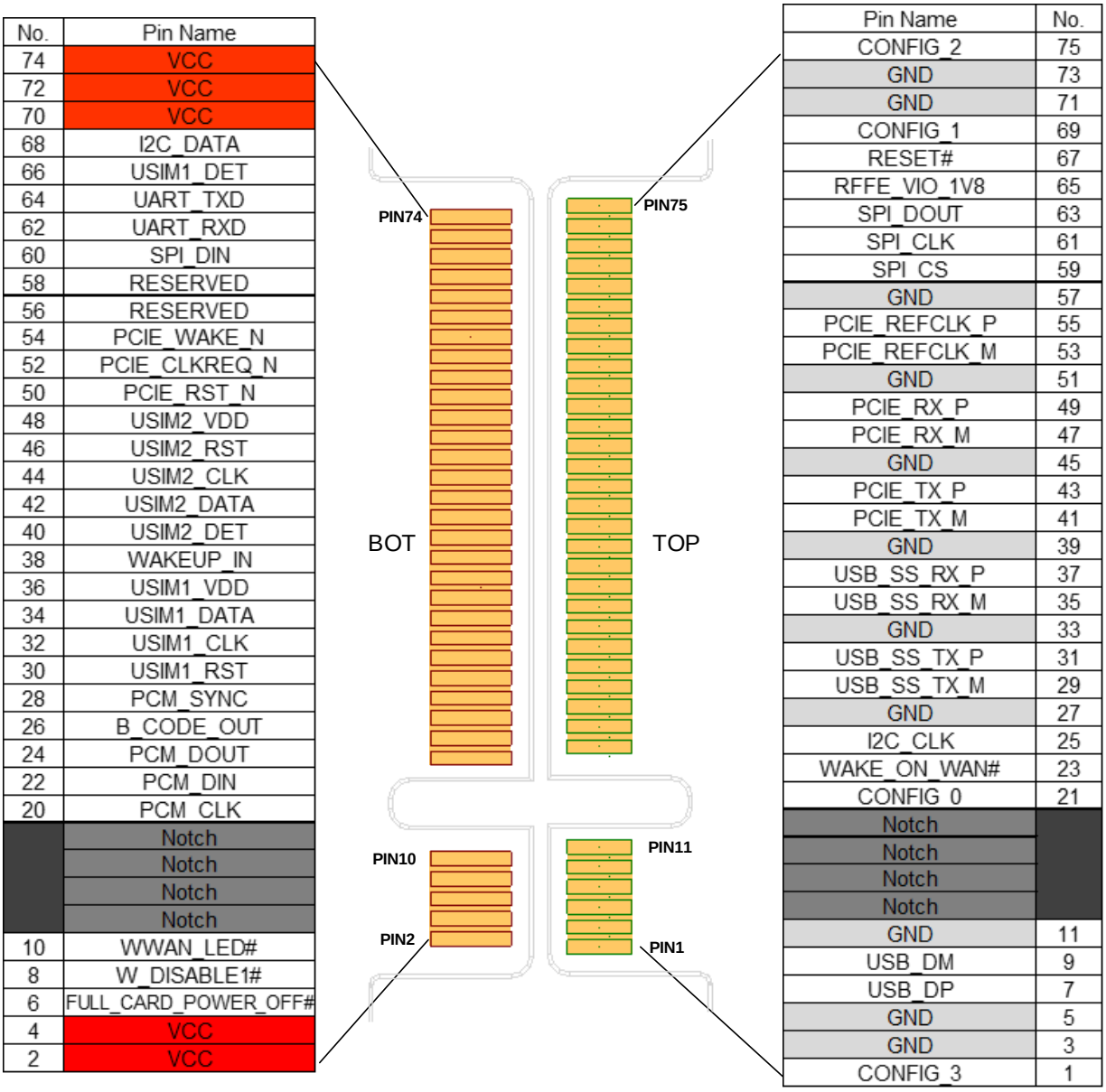


Figure 2: Pin Assignment

2.5. Pin Description

Table 4: Definition of I/O Parameters

Type	Description
AI	Analog Input
AO	Analog Output
AIO	Analog Input/Output
DI	Digital Input
DO	Digital Output
DIO	Digital Input/Output
OD	Open Drain
PI	Power Input
PO	Power Output
PU	Pull Up
PD	Pull Down

Table 5: Pin Description

Pin No.	Pin Name	I/O	Description	DC Characteristics	Comment
1	CONFIG_3	DO	Not connected internally	1.8/3.3 V	
2	VCC	PI	Power supply for the module	Vmin = 3.3 V Vnom = 3.7 V Vmax = 4.4 V	
3	GND		Ground		
4	VCC	PI	Power supply for the module	Vmin = 3.3 V Vnom = 3.7 V Vmax = 4.4 V	
5	GND		Ground		

6	FULL_CARD_ POWER_OFF#	DI, PD	Turn on/off the module	V_{IH}max = 4.4 V V_{IH}min = 1.19 V V_{IL}max = 0.2 V	High level: Turn on; Low level: Turn off. Internally pulled down with a 100 kΩ resistor.
7	USB_DP	AIO	USB 2.0 differential data (+)		Requires differential impedance of 90 Ω. A test point must be reserved.
8	W_DISABLE1#	DI, OD	Airplane mode control	1.8/3.3 V	Internally pulled up to 1.8 V. Active low.
9	USB_DM	AIO	USB 2.0 differential data (-)		Requires differential impedance of 90 Ω. A test point must be reserved.
10	WWAN_LED#	OD	RF status indication LED		
11	GND		Ground		
12	Notch		Notch		
13	Notch		Notch		
14	Notch		Notch		
15	Notch		Notch		
16	Notch		Notch		
17	Notch		Notch		
18	Notch		Notch		
19	Notch		Notch		
20	PCM_CLK	DIO	PCM clock	1.8 V	
21	CONFIG_0	DO	Not connected internally	1.8/3.3 V	
22	PCM_DIN	DI	PCM data input	1.8 V	
23	WAKE_ON_WAN#*	OD	Wake up the host		When waking up the host, it is always at low level.
24	PCM_DOUT	DO	PCM data output	1.8 V	

25	I2C_CLK	OD	I2C clock	1.8 V	
26	B_CODE_OUT	DO	B code output	1.8 V	
27	GND		Ground		
28	PCM_SYNC	DIO	PCM data frame sync	1.8 V	
29	USB_SS_TX_M	AO	USB 3.0 super-speed transmit (-)		Requires differential impedance of 90 Ω.
30	USIM1_RST	DO	(U)SIM1 card reset	USIM1_VDD 1.8/3.0 V	
31	USB_SS_TX_P	AO	USB 3.0 super-speed transmit (+)		Requires differential impedance of 90 Ω.
32	USIM1_CLK	DO	(U)SIM1 card clock	USIM1_VDD 1.8/3.0 V	
33	GND		Ground		
34	USIM1_DATA	DIO, PU	(U)SIM1 card data	USIM1_VDD 1.8/3.0 V	
35	USB_SS_RX_M	AI	USB 3.0 super-speed receive (-)		Requires differential impedance of 90 Ω.
36	USIM1_VDD	PO	Power supply for (U)SIM1 card	1.8/3.0 V	
37	USB_SS_RX_P	AI	USB 3.0 super-speed receive (+)		Requires differential impedance of 90 Ω.
38	WAKEUP_IN	DI, PU	Wake up the module	1.8 V	Internally pulled up to 1.8 V with a 100 kΩ resistor.
39	GND		Ground		
40	USIM2_DET	DI, PU	(U)SIM2 card hot-plug detect	1.8 V	Internally pulled up to 1.8 V.
41	PCIE_TX_M	AO	PCIe transmit (-)		
42	USIM2_DATA	DIO, PU	(U)SIM2 card data	USIM2_VDD 1.8/3.0 V	
43	PCIE_TX_P	AO	PCIe transmit (+)		
44	USIM2_CLK	DO	(U)SIM2 card clock	USIM2_VDD 1.8/3.0 V	

45	GND		Ground		
46	USIM2_RST	DO	(U)SIM2 card reset	USIM2_VDD 1.8/3.0 V	
47	PCIE_RX_M	AI	PCIe receive (-)		
48	USIM2_VDD	PO	Power supply for (U)SIM2 card	1.8/3.0 V	
49	PCIE_RX_P	AI	PCIe receive (+)		.
50	PCIE_RST_N	OD	PCIe reset	1.8/3.3 V	Active low.
51	GND		Ground		
52	PCIE_CLKREQ_N	OD	PCIe clock request	1.8/3.3 V	Active low.
53	PCIE_REFCLK_M	AIO	PCIe reference clock (-)	1.8/3.3 V	Active low.
54	PCIE_WAKE_N	OD	PCIe wake up	1.8/3.3 V	Active low.
55	PCIE_REFCLK_P	AIO	PCIe reference clock (+)	1.8/3.3 V	Active low.
56	RESERVED		RESERVED		
57	GND		Ground		
58	RESERVED		RESERVED		
59	SPI_CS	DO	SPI chip select	1.8 V	
60	SPI_DIN	DI	SPI data input	1.8 V	
61	SPI_CLK	DO	SPI clock	1.8 V	
62	UART_RXD	DI	Main UART receive	1.8 V	
63	SPI_DOUT	DO	SPI data output	1.8 V	
64	UART_TXD	DO	Main UART transmit	1.8 V	
65	RFFE_VIO_1V8	PO	Provide 1.8 V for external circuit	1.8 V $I_O$max = 50 mA	Power supply for external GPIO's pull-up circuits. If the signal that connects to the module needs to be pulled up to 1.8 V, you must select the

					RFFE_VIO_1V8 as the pull-up power supply.
66	USIM1_DET	DI, PU	(U)SIM1 card hot-plug detect	1.8 V	Internally pulled up to 1.8 V.
67	RESET#	DI, PU	Reset the module	V_{IL}max = 0.5 V	Internally pulled up to VCC with a 20 kΩ resistor. A test point is recommended to be reserved.
68	I2C_DATA	OD	I2C data	1.8 V	
69	CONFIG_1	DO	Connected to GND internally	1.8/3.3 V	
70	VCC	PI	Power supply for the module	Vmin = 3.3 V Vnom = 3.7 V Vmax = 4.4 V	
71	GND		Ground		
72	VCC	PI	Power supply for the module	Vmin = 3.3 V Vnom = 3.7 V Vmax = 4.4 V	
73	GND		Ground		
74	VCC	PI	Power supply for the module	Vmin = 3.3 V Vnom = 3.7 V Vmax = 4.4 V	
75	CONFIG_2	DO	Not connected internally	1.8/3.3 V	

NOTE

Keep all reserved and unused pins unconnected.

2.6. EVB Kit

To help you develop applications with the module, Quectel supplies an evaluation board (5G-M2 EVB) with accessories to control or test the module. For more details, see ***document [1]***.

3 Operating Characteristics

3.1. Operating Modes

Table 6: Overview of Operating Modes

Mode	Details	
Full functionality Mode	Idle	Software is active. The module has registered on the network, and it is ready to send and receive data.
	Voice/Data	Network is connected. In this mode, the power consumption is determined by network setting and data transfer rate.
Minimum Functionality Mode	**AT+CFUN=0** can set the module into a minimum functionality mode without removing the power supply. In this mode, both RF function and (U)SIM card are invalid.	
Airplane Mode	Execute **AT+CFUN=4** or drive W_DISABLE1# pin LOW will set the module into airplane mode. In this mode, the RF function is invalid.	
Sleep Mode	Execute **AT+QSCLK=1** and drive WAKEUP_IN pin LOW, the module will enter sleep mode. The module keeps receiving paging messages, SMS, voice calls and TCP/UDP data from the network with its current consumption reducing to the minimal level.	
Power Down Mode	In this mode, the power management unit shuts down the power supply. Software is inactive, all application interfaces are inaccessible, and the operating voltage (connected to VCC) remains applied.	

NOTE

For more details about AT command, see ***document [2]***.

3.1.1. Sleep Mode

DRX of the module is able to reduce the current consumption to a minimum value during the sleep mode, and DRX cycle values are broadcasted by the wireless network. The figure below shows the relationship between the DRX run time and the current consumption in sleep mode. The longer the DRX cycle is, the

lower the current consumption will be.

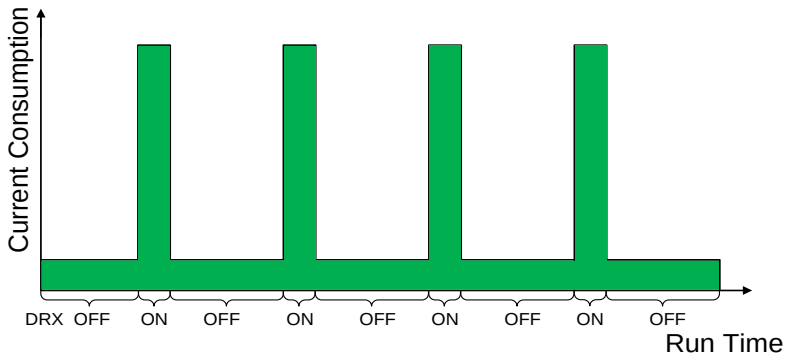


Figure 3: DRX Run Time and Current Consumption in Sleep Mode

The following two conditions must be met to make the module enter sleep mode.

- **AT+QSCLK=1** is executed to enable the sleep mode.
- The host drives WAKEUP_IN low through a GPIO and keep WAKEUP_IN low level in sleep state.

The following figure shows the connection between the module and the host.

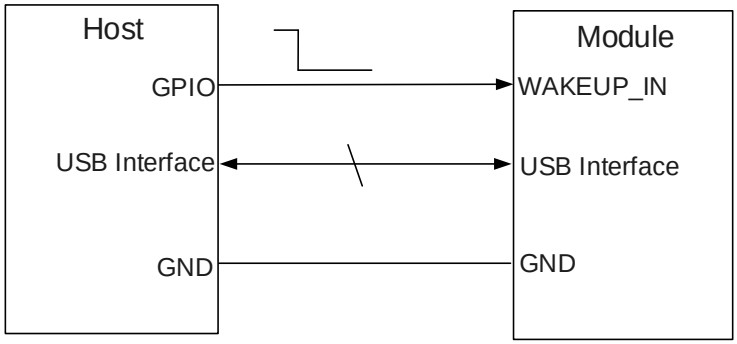


Figure 4: Sleep Mode Application

You can wake up the module by pulling up WAKEUP_IN through a host GPIO.

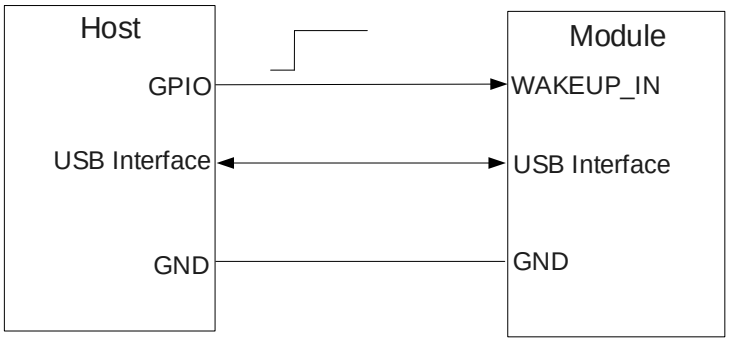


Figure 5: Wakeup Mode Application

3.1.2. Airplane Mode

Executing **AT+CFUN=4** or driving W_DISABLE1# pin low will set the module into airplane mode. See ***Chapter 4.8.1*** for more details.

3.2. Power Supply

Table 7: Definition of VCC and GND Pins

Pin No.	Pin Name	I/O	DC Characteristics	Description
2, 4, 70, 72, 74	VCC	PI	3.3–4.4 V 3.7 V typical DC supply	Power Supply for the module
3, 5, 11, 27, 33, 39, 45, 51, 57, 71, 73	GND	-	-	Ground

3.2.1. Voltage Stability Requirements

The power supply range of the module is from 3.3 V to 4.4 V. Ensure that the input voltage will never drop below 3.3 V, otherwise the module will be powered off automatically. The figure below shows the maximum voltage drop during radio frequency transmission in 3G/4G/5G networks.

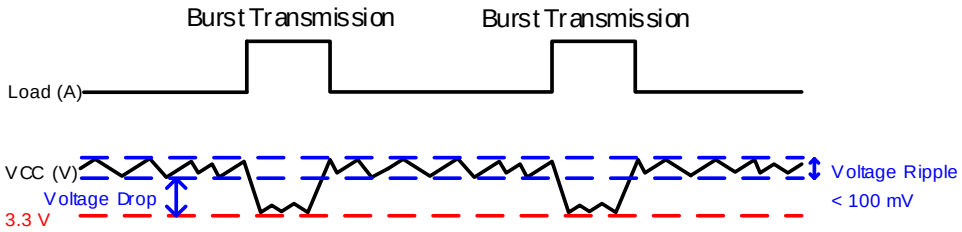


Figure 6: Power Supply Limits during Radio Transmission

To decrease the voltage drop, 1 filter capacitor of about 220 µF with low ESR (ESR ≤ 0.7 Ω) should be placed close to VCC pin. It is recommended to use a tantalum capacitor. Meanwhile, 4 multi-layer ceramic chip capacitors (MLCC: 1 µF, 100 nF, 33 pF, 10 pF) are recommended to be placed close to VCC pin for power supply filtering due to their ultra-low ESR. The width of VCC trace should be not less than 3 mm. In principle, the longer the VCC trace is, the wider it should be.

In addition, to ensure the stability of the power supply, it is recommended to use a TVS with a reverse zener voltage of 5.1 V and a dissipation power higher than 0.5 W. The following figure shows a reference circuit for the VCC.

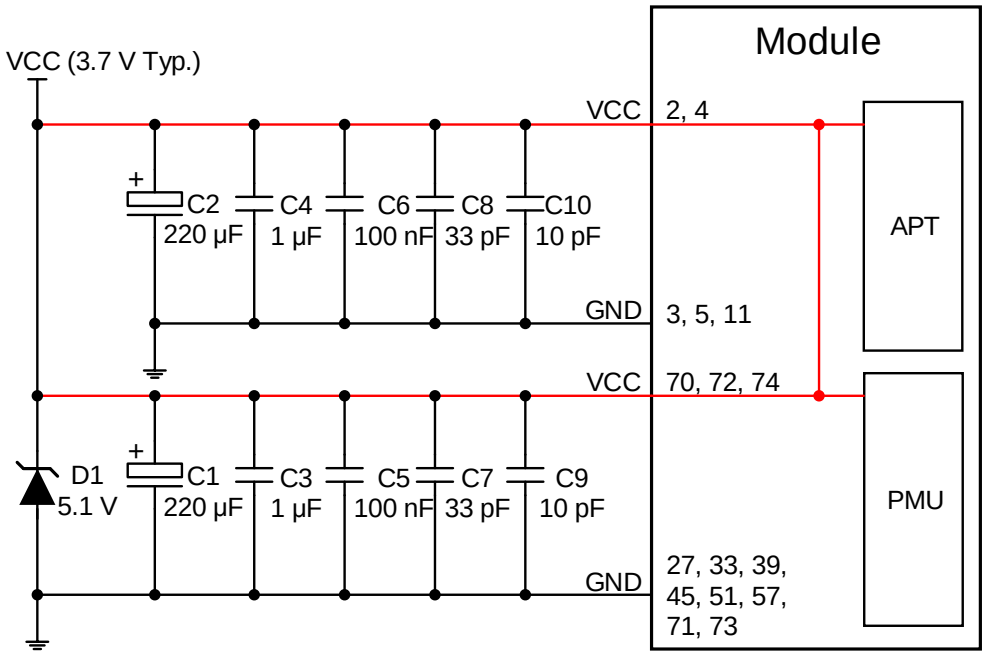


Figure 7: Reference Circuit for VCC Pins

3.2.2. Reference Design for Power Supply

The power source is critical to the module's performance. The continuous current of the power supply should be 3 A at least and the peak current should be 4 A at least.

The following figure shows a reference design for +5.0 V input power source based on the DC-DC converter. The typical output of the power supply is 3.7 V.

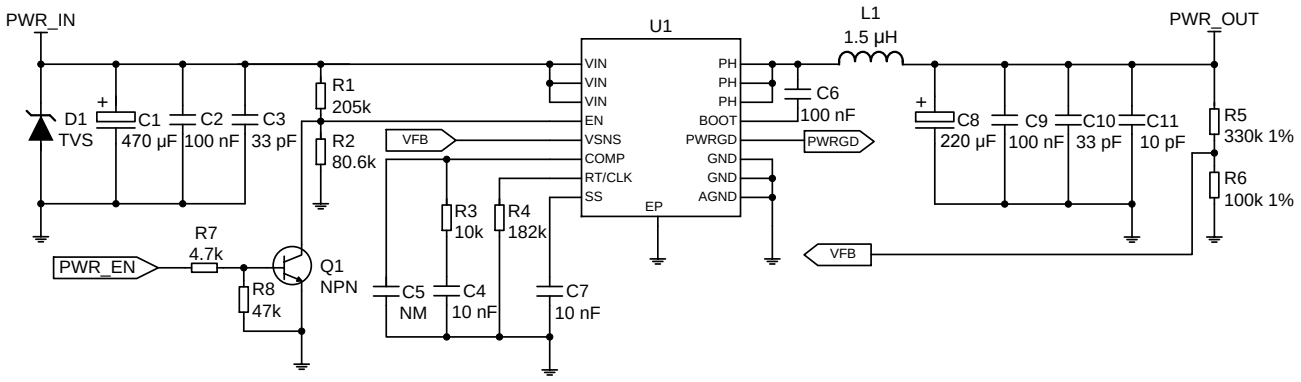


Figure 8: Reference Design for Power Supply

NOTE

To avoid corrupting the data in the internal flash, do not switch off the power supply when the module works normally. It is recommended to turn off the module by cutting off the power supply after driving FULL_CARD_POWER_OFF# pin low through the host GPIO.

3.3. Turn On/Off

3.3.1. Turn On

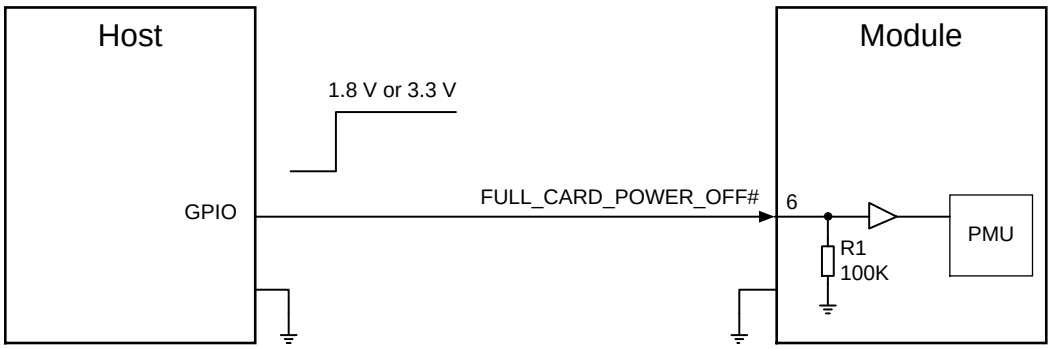
FULL_CARD_POWER_OFF# is used to turn on/off the module. When the input signal is asserted HIGH (≥ 1.19 V), the module will be turned on. This input signal can be driven by either 1.8 V or 3.3 V GPIO. And this pin has been internally pulled down to GND with a 100 kΩ resistor, that is, it is at low level, so the module is in shutdown state by default.

Table 8: Definition of FULL_CARD_POWER_OFF#

Pin No.	Pin Name	I/O	Description	DC Characteristics	Comment
6	FULL_CARD_ POWER_OFF#	DI, PD	Turn on/off the module	V_{IH}max = 4.4 V V_{IH}min = 1.19 V V_{IL}max = 0.2 V	High level: Turn on; Low level: Turn off. Internally pulled down with a 100 kΩ resistor.

You can use a host GPIO to turn on the module by pulling up FULL_CARD_POWER_OFF#. A simple

reference circuit is illustrated by the following figure.



NOTE:
The voltage of pin 6 should be not less than 1.19 V when it is at high level.

Figure 9: Turn on the Module with a Host GPIO

The turn-on timing is illustrated by the following figure.

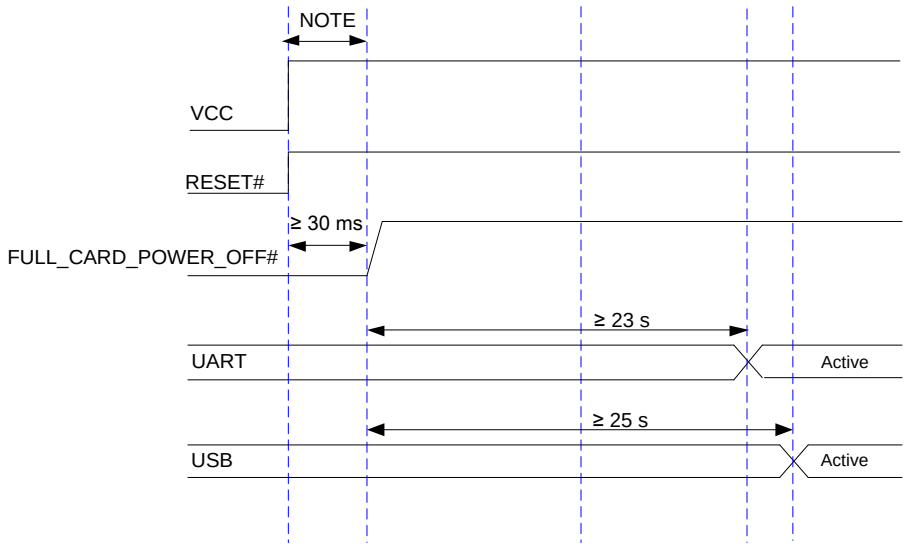


Figure 10: Turn-on Timing

NOTE

Ensure that VCC voltage is stable before pulling up FULL_CARD_POWER_OFF# pin. It is recommended that the time difference between VCC power-up and pulling up FULL_CARD_POWER_OFF# pin is not less than 30 ms.

3.3.2. Turn Off

It is recommended to turn off the module by drive FULL_CARD_POWER_OFF# low with a host GPIO. A simple reference circuit is illustrated by the following figure.

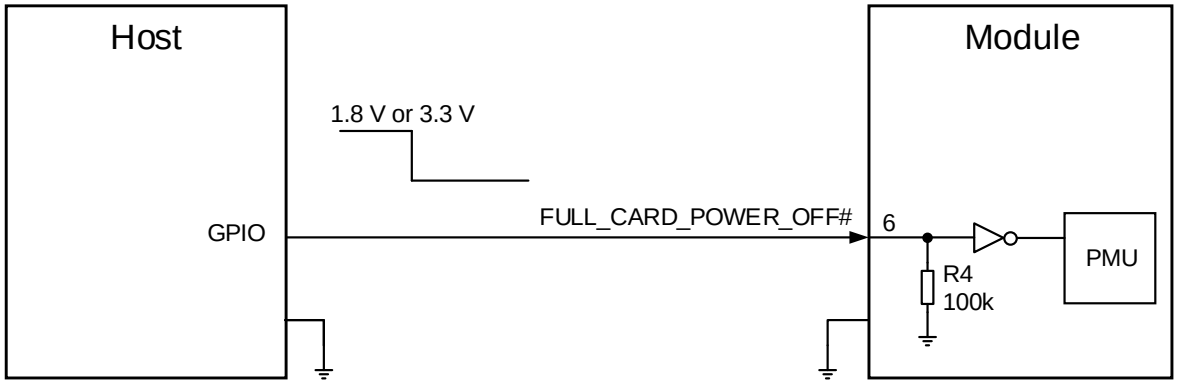


Figure 11: Turn off the Module with a Host GPIO

The turn-off timing is illustrated by the following figure.

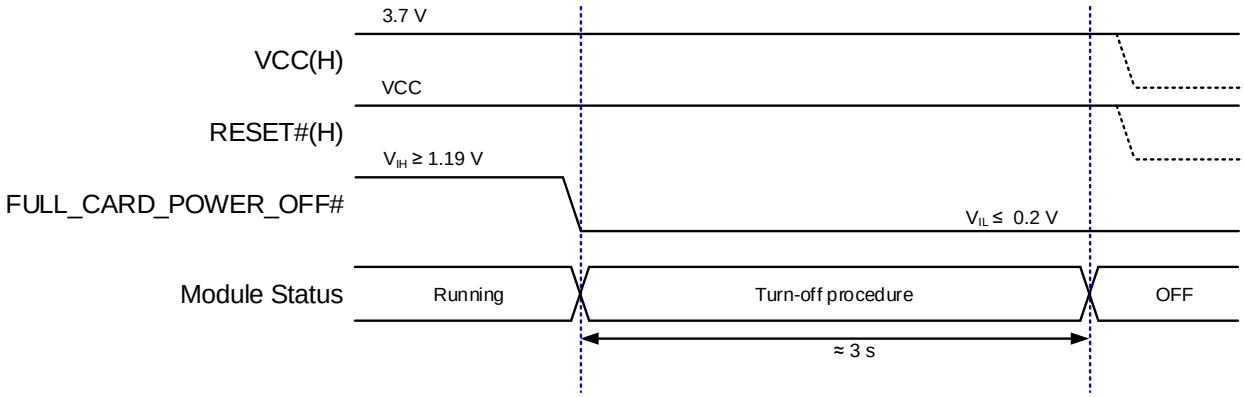


Figure 12: Turn-off Timing of the Module

3.4. Reset

RESET# is an asynchronous and active LOW signal. When this pin is active, the module will immediately enter Power-On Reset (PoR) condition.

Please note that triggering the RESET# signal will lead to loss of all temporary data in the module and removal of system drivers. It will also disconnect the module from the network.

Table 9: Pin Definition of RESET#

Pin No.	Pin Name	I/O	Description	DC Characteristic	Comment
67	RESET#	DI, PU	Reset the module	V_{IL}max = 0.5 V	Active low; Internally pulled up to VCC with a 20 kΩ resistor. A test point is recommended to be reserved.

The module can be reset by driving RESET# pin low for 250–600 ms. A NPN driver circuit, NMOS driver circuit or button can be used to control the RESET# pin.

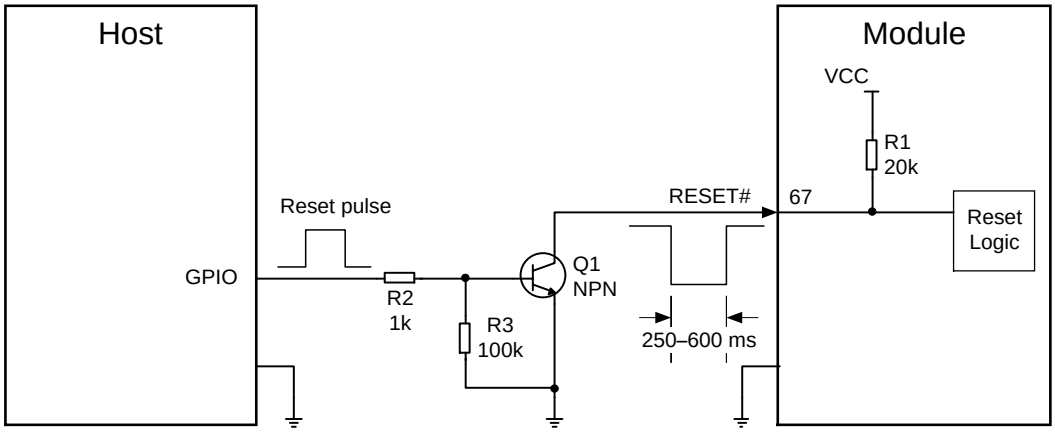


Figure 13: Reference Circuit of RESET# with NPN Driver Circuit

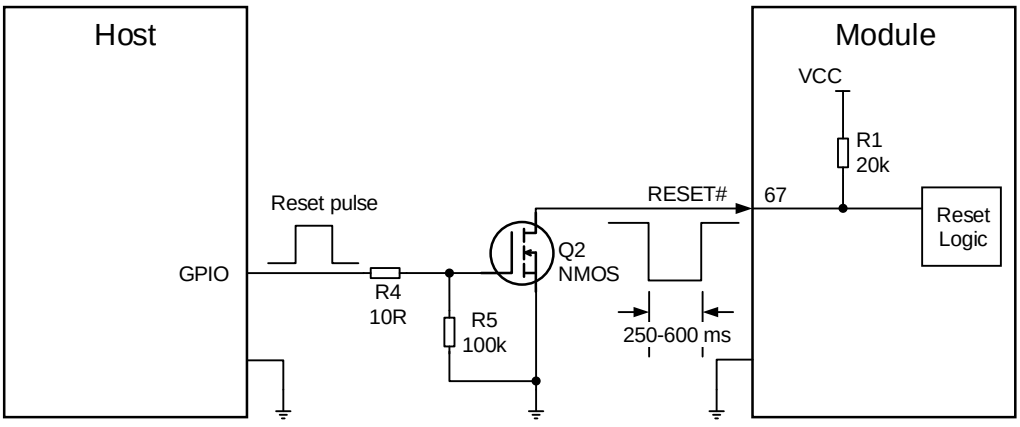
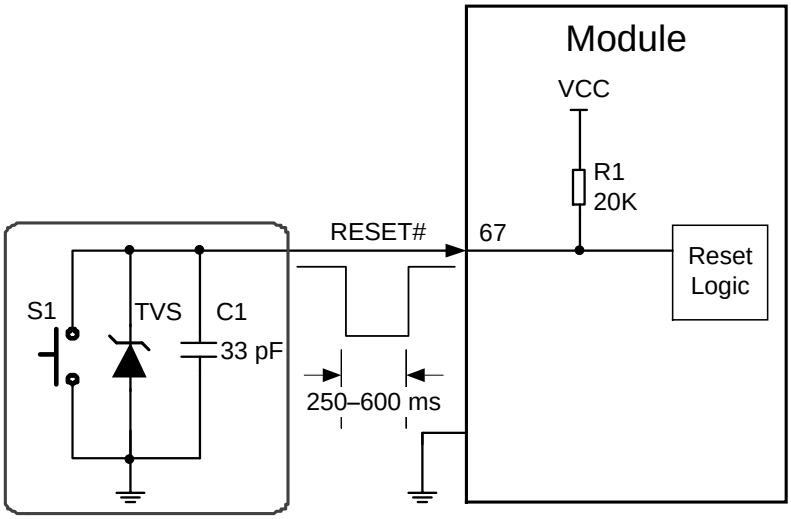


Figure 14: Reference Circuit of RESET# with NMOS Driver Circuit



NOTE: The capacitor C1 is recommended to be less than 47 pF.

Figure 15: Reference Circuit of RESET# with a Button

The reset timing is illustrated by the following figure.

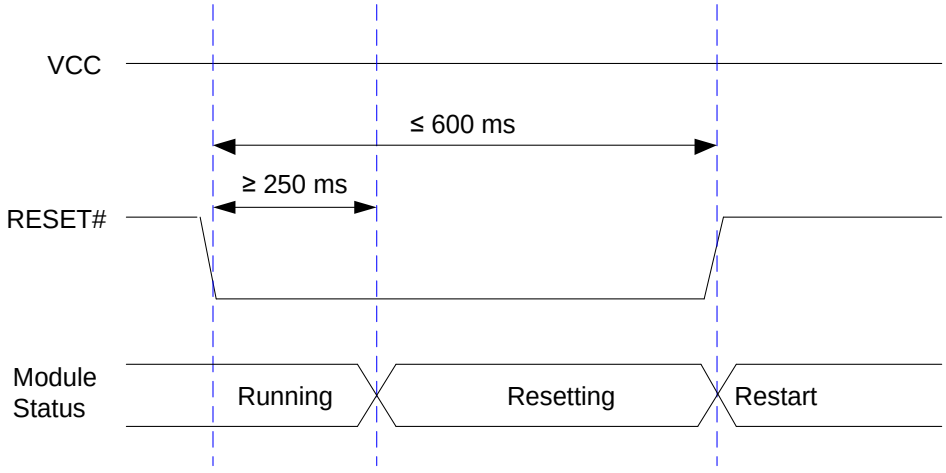


Figure 16: Reset Timing

4 Application Interfaces

The physical connections and signal levels of RM500U-CN comply with PCI Express M.2 specification. This chapter mainly describes the definition and application of the following interfaces/pins of the module:

- (U)SIM interfaces
- USB interface
- PCIe interface
- PCM interface
- SPI
- I2C interface
- UART interface
- B_CODE_OUT
- Control and indication interfaces
- Configuration pins

4.1. (U)SIM Interfaces

RM500U-CN provides two (U)SIM interfaces, and supports dual SIM single standby. The (U)SIM interfaces circuitry meets ETSI and IMT-2000 requirements. Both Class B (3.0 V) and Class C (1.8 V) (U)SIM cards are supported.

4.1.1. Pin Definition of (U)SIM Interfaces

Table 10: Pin Definition of (U)SIM Interfaces

Pin No.	Pin Name	I/O	Description	DC Characteristics	Comment
36	USIM1_VDD	PO	Power supply for (U)SIM1 card	1.8/3.0 V	
34	USIM1_DATA	DIO, PU	(U)SIM1 card data	USIM1_VDD 1.8/3.0 V	
32	USIM1_CLK	DO	(U)SIM1 card clock	USIM1_VDD 1.8/3.0 V	
30	USIM1_RST	DO	(U)SIM1 card reset	USIM1_VDD 1.8/3.0 V	

66	USIM1_DET	DI, PU	(U)SIM1 card hot-plug detect	1.8 V	Internally pulled up to 1.8 V.
48	USIM2_VDD	PO	Power supply for (U)SIM2 card	USIM2_VDD 1.8/3.0 V	
42	USIM2_DATA	DIO, PU	(U)SIM2 card data	USIM2_VDD 1.8/3.0 V	
44	USIM2_CLK	DO	(U)SIM2 card clock	USIM2_VDD 1.8/3.0 V	
46	USIM2_RST	DO	(U)SIM2 card reset	USIM2_VDD 1.8/3.0 V	
40	USIM2_DET	DI, PU	(U)SIM2 card hot-plug detect	1.8 V	Internally pulled up to 1.8 V.

4.1.2. (U)SIM Hot-plug

The module supports (U)SIM card hot-plug via (U)SIM card hot-plug detect pins (USIM1_DET and USIM2_DET). (U)SIM card insertion is detected by high/low level. (U)SIM card hot-plug is disabled by default.

The following command configures (U)SIM card hot-plug detection .

AT+QSIMDET Configure (U)SIM Card Hot-Plug Detection	
Test Command **AT+QSIMDET=?**	Response **+QSIMDET: (**list of supported **<enable>**s**),(**list of supported **<insert_level>**s**)** **OK**
Read Command **AT+QSIMDET?**	Response **+QSIMDET: <enable>,<insert_level>** **OK**
Write Command **AT+QSIMDET=<enable>,<insert_level>**	Response **OK** If there is any error: **ERROR**
Maximum Response Time	3s
Characteristics	The command takes effect after the module is rebooted. The configuration will be saved automatically.

Parameter

<enable>	Integer type. Enable or disable (U)SIM card detection. 0 Disable 1 Enable
<insert_level>	Integer type. The level of (U)SIM detection pin when a (U)SIM card is inserted. 0 Low level 1 High level

NOTE

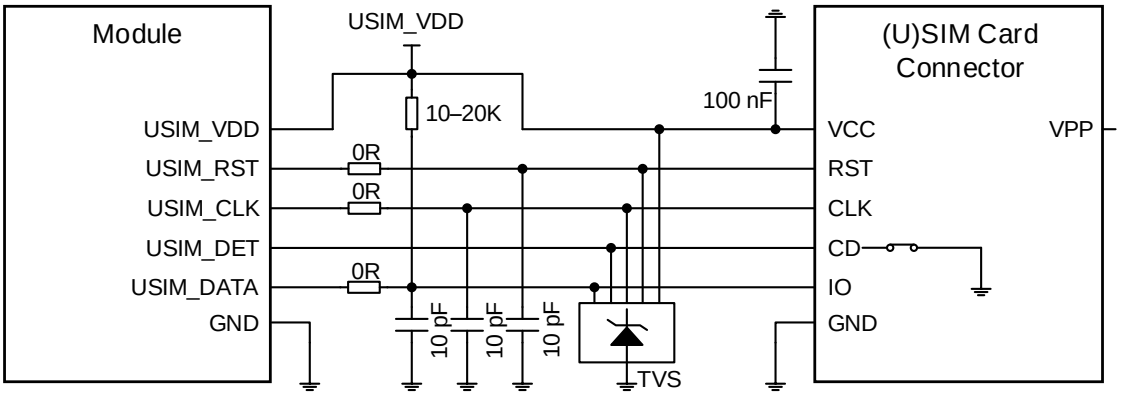
1. Hot-plug function is invalid if the configured value of **<insert_level>** is inconsistent with hardware design.
2. The underlined value is the default parameter value.
3. Only when the module fails to detect the (U)SIM card or is in the Minimum Functionality Mode (**AT+CFUN=0**), the (U)SIM card detection function can be controlled by this command.

4.1.3. Normally Closed (U)SIM Card Connector

With a normally closed (U)SIM card connector, USIM_DET pin is shorted to ground when there is no (U)SIM card inserted. (U)SIM card detection by high level is applicable to this type of connector. After executing **AT+QSIMDET=1,1** to enable the (U)SIM hot-plug: when a (U)SIM card is inserted, USIM_DET will change from low to high level; when the (U)SIM card is removed, USIM_DET will change from high to low level.

- When the (U)SIM card is absent, CD is shorted to ground and USIM_DET is at low level.
- When the (U)SIM card is presented, CD is open from ground and USIM_DET is at high level.

The following figure shows a reference design for (U)SIM interface with a normally closed (U)SIM card connector.



NOTE:
All these resistors, capacitors and TVS should be close to (U)SIM card connector in PCB layout.

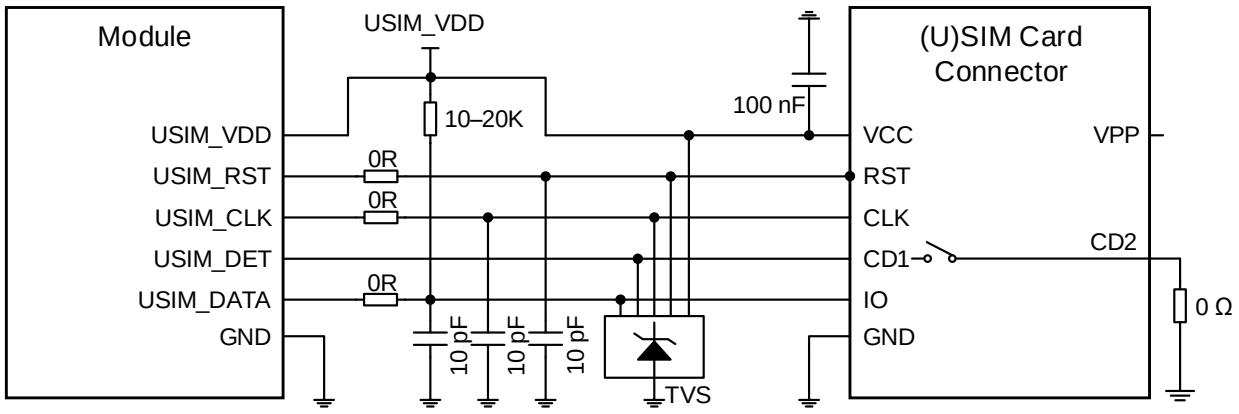
Figure 17: Reference Circuit for Normally Closed (U)SIM Card Connector

4.1.4. Normally Opened (U)SIM Card Connector

With a normally opened (U)SIM card connector, CD1 and CD2 of the connector are disconnected when there is no (U)SIM card inserted. (U)SIM card detection by low level is applicable to this type of connector. After executing **AT+QSIMDET=1,0** to enable the (U)SIM hot-plug: when a (U)SIM card is inserted, USIM_DET will change from high to low level; when the (U)SIM card is removed, USIM_DET will change from low to high level.

- When the (U)SIM card is absent, CD1 is open from CD2 and USIM_DET is at high level.
- When the (U)SIM card is presented, CD1 is pull down to ground and USIM_DET is at low level.

The following figure shows a reference design for (U)SIM interface with a normally opened (U)SIM card connector.

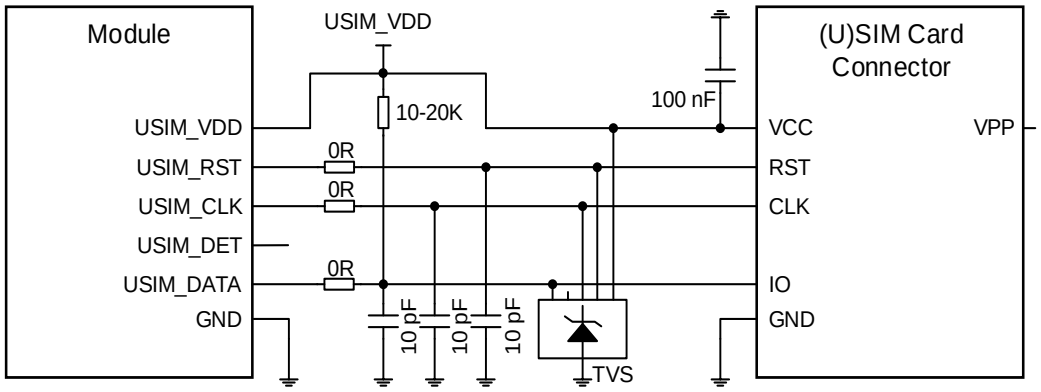


NOTE:
All these resistors, capacitors and TVS should be close to (U)SIM card connector in PCB layout.

Figure 18: Reference Circuit for Normally Opened (U)SIM Card Connector

4.1.5. (U)SIM Card Connector Without Hot-plug

If (U)SIM card hot-plug is not needed, please keep USIM_DET unconnected. A reference circuit for (U)SIM card interface with a 6-pin (U)SIM card connector is illustrated by the following figure.



NOTE:
All these resistors, capacitors and TVS should be close to (U)SIM card connector in PCB layout.

Figure 19: Reference Circuit for a 6-pin (U)SIM Card Connector

4.1.6. (U)SIM Design Notice

To enhance the reliability and availability of the (U)SIM card in applications, please follow the criteria below in (U)SIM circuit design.

- Place the (U)SIM card connector as close to the module as possible. Keep the trace length less than 200 mm. The USIM_VDD trace width should be not less than 0.5 mm.
- Keep (U)SIM card signals away from RF and VCC traces.
- To avoid cross-talk between USIM_CLK and USIM_DATA, keep them away from each other and shield them with surrounded ground.
- Pull up USIM_DATA to USIM_VDD with a 10–20 kΩ resistor, and place the resistor near the (U)SIM card connector.
- To offer better ESD protection, add a TVS diode array of which the parasitic capacitance should be not higher than 10 pF. Add 0 Ω resistors in series between the module and the (U)SIM card connector to suppress EMI such as spurious transmission, and to enhance ESD protection. The 10 pF capacitors are used to filter out RF interference.

4.2. USB Interface

RM500U-CN provides one integrated Universal Serial Bus (USB) interface which complies with the USB 3.0 and USB 2.0 specifications, and supports SuperSpeed (5 Gbps) on USB 3.0 and high-speed (480 Mbps) and full-speed (12 Mbps) modes on USB 2.0. The USB interface is used for AT command communication, data transmission, software debugging and firmware upgrade [5].

[5] Only USB 2.0 supports firmware upgrade.

Table 11: Pin Definition of USB Interface

Pin No.	Pin Name	I/O	Description	Comment
7	USB_DP	AIO	USB 2.0 differential data (+)	Requires differential impedance of 90 Ω. Test points must be reserved.
9	USB_DM	AIO	USB 2.0 differential data (-)	
29	USB_SS_TX_M	AO	USB 3.0 super-speed transmit (-)	Requires differential impedance of 90 Ω.
31	USB_SS_TX_P	AO	USB 3.0 super-speed transmit (+)	
35	USB_SS_RX_M	AI	USB 3.0 super-speed receive (-)	
37	USB_SS_RX_P	AI	USB 3.0 super-speed receive (+)	

For more details about the USB 3.0 and USB 2.0 specifications, please visit http://www.usb.org/home.

The test points must be reserved for USB 2.0 interface in designs. The following figure shows a reference circuit for USB 2.0 and USB 3.0 interface.

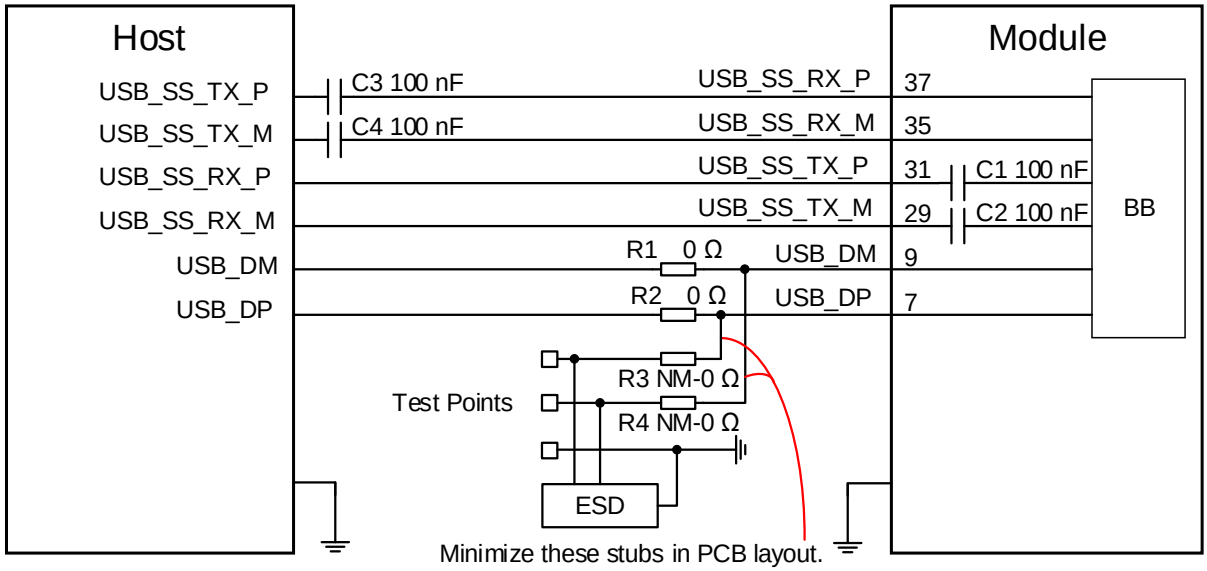


Figure 20: Reference Circuit for USB 3.0 and USB 2.0 Interface

AC coupling capacitors C3 and C4 must be placed close to the Tx side of the host USB 3.0 and must be placed close to each other. C1 and C2 have been integrated inside the module, so do not place these two capacitors on your schematic and PCB. To ensure the signal integrity of USB 2.0 data traces, R1, R2, R3 and R4 must be placed close to the module, and the stubs must be minimized in PCB layout.

When designing the USB interface, you should follow the following principles to meet USB 2.0 & USB 3.0 specifications.

- Route the USB signal traces as differential pairs with ground surrounded. The impedance of differential trace of USB 2.0 and USB 3.0 is 90 Ω.
- For USB 2.0 signal traces, the total trace length should be less than 120 mm, and the length matching of each differential data pair (DP/DM) should be less than 2 mm. For USB 3.0 signal traces, the length matching of each differential data pair (Tx/Rx) should be less than 0.15 mm, while the matching between Tx and Rx should be less than 10 mm.
- Do not route signal traces under crystals, oscillators, magnetic devices, PCIe and RF signal traces. Route the USB differential traces in inner-layer of the PCB, and surround the traces with ground on that layer and with ground planes above and below.
- Junction capacitance of the ESD protection components might cause influences on USB data lines, so you should pay attention to the selection of the components. Typically, the stray capacitance should be less than 1.0 pF for USB 2.0, and less than 0.15 pF for USB 3.0. Keep the ESD protection components as close to the USB connector as possible.
- If possible, reserve 0 Ω resistors on USB_DP and USB_DM lines in series respectively.

4.3. PCIe Interface

RM500U-CN provides one PCIe interface that is compliant with *PCI Express Base Specification Revision 2.0*. It could configure PCIe operation mode through **AT+QCFG="pcie/mode"**, and the module supports RC mode by default. For more details about the AT command, see ***document [2]***. The main features of PCIe interface are as follows:

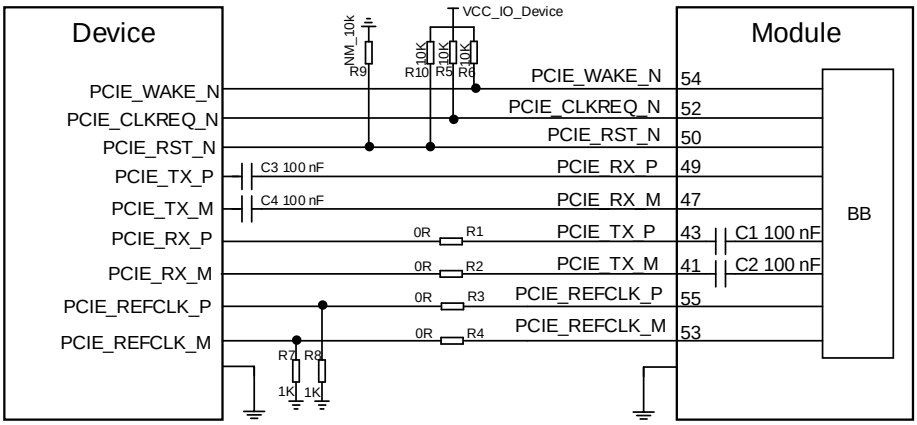
- Support PCIe Gen 2, backward compatible
- Data rates up to 5 Gbps per lane
- Support PCIe to Ethernet
- PCIe supports RC and EP modes

Table 12: Pin Definition of PCIe Interface

Pin No.	Pin Name	I/O	Description	Comment
55	PCIE_REFCLK_P	AIO	PCIe reference clock (+)	Active low. 1.8/3.3 V power domain. In RC mode, it is an output signal. In EP mode, it is an input signal.
53	PCIE_REFCLK_M	AIO	PCIe reference clock (-)	
41	PCIE_TX_M	AO	PCIe transmit (-)	Requires differential impedance of 100 Ω.
43	PCIE_TX_P	AO	PCIe transmit (+)	
47	PCIE_RX_M	AI	PCIe receive (-)	

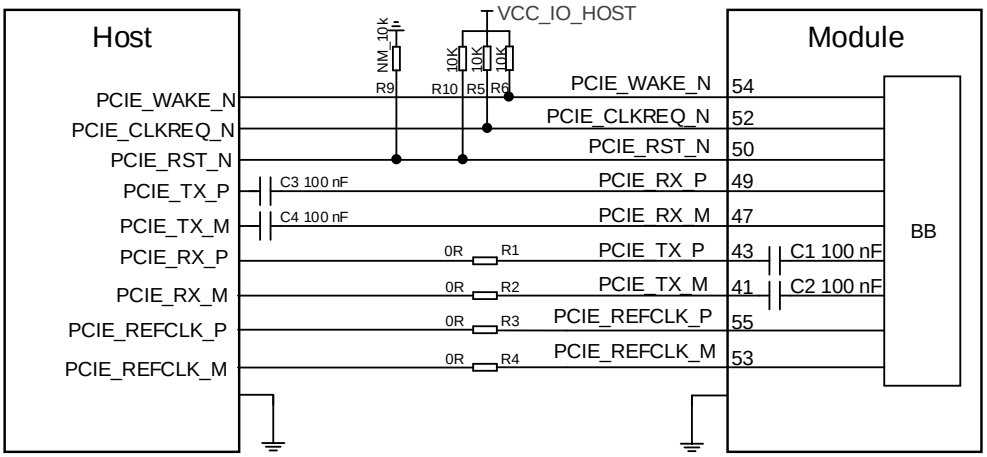
49	PCIE_RX_P	AI	PCIe receive (+)	
52	PCIE_CLKREQ_N	OD	PCIe clock request	Active low. 1.8/3.3 V power domain. In RC mode, it is an input signal. In EP mode, it is an output signal.
50	PCIE_RST_N	OD	PCIe reset	Active low. 1.8/3.3 V power domain. In RC mode, it is an output signal. In EP mode, it is an input signal.
54	PCIE_WAKE_N	OD	PCIe wake up	Active low. 1.8/3.3 V power domain. In RC mode, it is an input signal. In EP mode, it is an output signal.

The following figure shows a reference circuit for the PCIe interface.



NOTE: When connected to the device of 1.8 V power domain, pins 50, 52 and 54 need to be pulled up to RFFE_VIO_1V8. When connected to the device of 3.3 V power domain, VCC_IO_Device needs to be controlled by RFFE_VIO_1V8.

Figure 21: PCIe Interface Reference Circuit (RC Mode)



NOTE: When connected to the host of 1.8 V power domain, pins 50, 52 and 54 need to be pulled up to RFFE_VIO_1V8. When connected to the host of 3.3 V power domain, VCC_IO_HOST needs to be controlled by RFFE_VIO_1V8.

Figure 22: PCIe Interface Reference Circuit (EP Mode)

To ensure the signal integrity of PCIe interface, AC coupling capacitors C3 and C4 should be placed close to the device (RC mode)/host (EP mode) on PCB. C1 and C2 have been integrated inside the module, so do not place these two capacitors on your schematic and PCB.

The following principles of PCIe interface design should be complied with to meet the PCIe specification.

- Keep the PCIe data and control signals away from sensitive circuits and signals, such as RF, audio, crystal and oscillator signals.
- Don't route PCIe data traces under components or cross them with other traces.
- Keep the maximum total trace length less than 300 mm.
- Keep the length matching of each differential data pair (Tx/Rx/REFCLK) less than 0.15 mm for PCIe routing traces.
- Keep the differential impedance of PCIe data trace (Tx/Rx/REFCLK) as 100 Ω ±10 %.

4.4. PCM Interface & SPI

RM500U-CN supports to connect to SLIC via PCM interface and SPI.

Table 13: Pin Definition of PCM Interface

Pin No.	Pin Name	I/O	Description	Comment
20	PCM_CLK	DIO	PCM clock	In master mode, it is an output signal. In slave mode, it is an input signal.
22	PCM_DIN	DI	PCM data input	
24	PCM_DOUT	DO	PCM data output	
28	PCM_SYNC	DIO	PCM data frame sync	In master mode, it is an output signal. In slave mode, it is an input signal.

Table 14: Pin Definition of SPI

Pin No.	Pin Name	I/O	Description	DC Characteristics
59	SPI_CS	DO	SPI chip select	1.8 V
60	SPI_DIN	DI	SPI data input	
61	SPI_CLK	DO	SPI clock	
63	SPI_DOUT	DO	SPI data output	

The figure below shows a reference design for PCM interface and SPI with an external SLIC. For more details, see ***document [3]***.



Figure 23: Reference Design for PCM Interface and SPI

4.5. I2C Interfaces

The module provides one I2C interface with a maximum rate of 3.4 Mbps.

Table 15: Pin Definition of I2C Interface

Pin No.	Pin Name	I/O	Description	DC Characteristics	Comment
25	I2C_CLK	OD	I2C clock	1.8 V	External pull-up is required. If unused, keep them unconnected.
68	I2C_DATA	OD	I2C data	1.8 V	

The figure below shows a reference design for I2C interface.

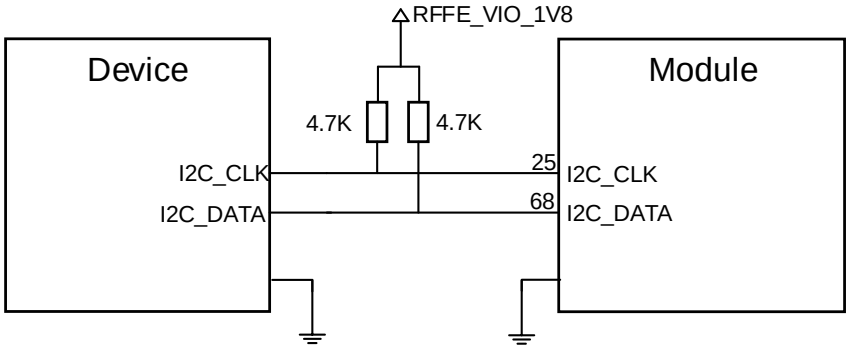


Figure 24: Reference Design for I2C Interface

4.6. UART Interface

RM500U-CN provides a UART interface, which can be used for data transmission and AT commands communication, and it supports a baud rate of 115200 bps by default.

Table 16: Pin Definition of UART Interface

Pin No.	Pin Name	I/O	Description	DC Characteristics
62	UART_RXD	DI	Main UART receive	1.8 V
64	UART_TXD	DO	Main UART transmit	1.8 V

The module provides a 1.8 V UART interface. Use a voltage-level translator if the application is equipped with a 3.3 V UART interface. A voltage-level translator TXS0108EPWR provided by Texas Instruments is recommended.

The following figure shows a reference design for UART Interface.

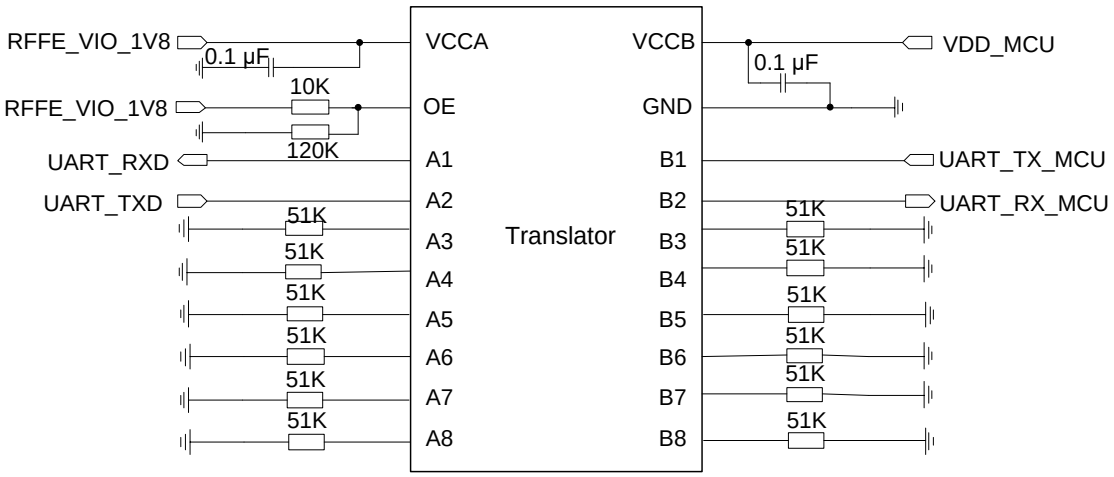


Figure 25: Reference Circuit with Translator Chip

4.7. B_CODE_OUT

RM500U-CN provides a B_CODE_OUT interface for external devices timing.

Table 17: Pin Definition of B_CODE_OUT

Pin No.	Pin Name	I/O	Description	DC Characteristics
26	B_CODE_OUT	DO	B code output	1.8 V

The following figure shows a reference design for B_CODE_OUT.

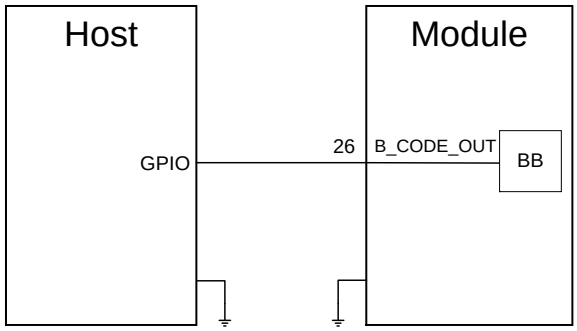


Figure 26: Reference Design of B_CODE_OUT

NOTE

B code timing function is optional.

4.8. Control and Indication Interfaces

Table 18: Pin Definition of Control and Indication Interfaces

Pin No.	Pin Name	I/O	Description	DC Characteristics
8	W_DISABLE1#	DI, OD	Airplane mode control	1.8/3.3 V
10	WWAN_LED#	OD	RF status indication LED	
23	WAKE_ON_WAN#*	OD	Wake up the host	
38	WAKEUP_IN	DI, PU	Wake up the module	1.8 V

4.8.1. W_DISABLE1#

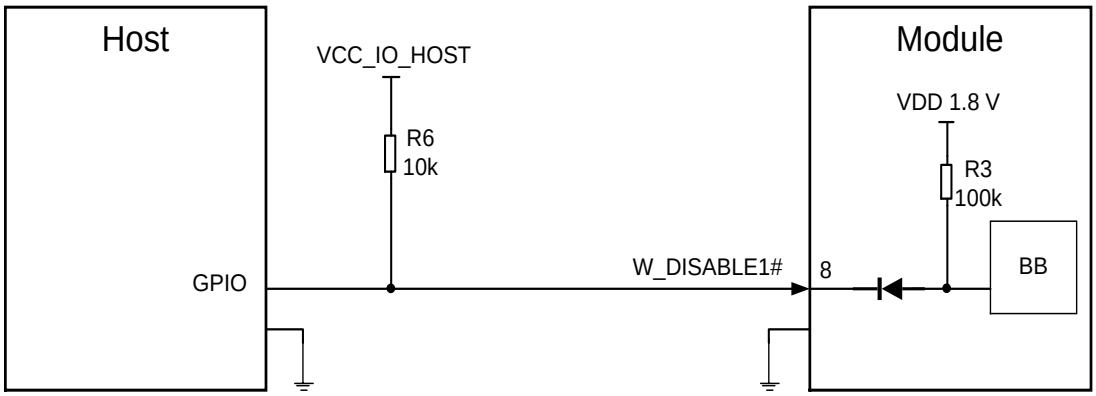
RM500U-CN provides a W_DISABLE1# pin to enable or disable airplane mode. This pin is pulled up by default inside the module and is compatible with both 1.8 V and 3.3 V power domains. Driving it low will set the module to airplane mode. In airplane mode, the RF function will be disabled.

The RF function can also be enabled or disabled through **AT+CFUN**. For more details, see ***document [2]***.

Table 19: RF Function Status

Logic Level	AT Command	RF Function Status	Operating Mode
High	**AT+CFUN=1**	Enabled	Full functionality mode
	AT+CFUN=0	Disabled	Minimum functionality mode
	AT+CFUN=4	Disabled	Airplane mode
Low	**AT+CFUN=0** **AT+CFUN=1** **AT+CFUN=4**	Disabled	Airplane mode

The reference design for the W_DISABLE1# pin is shown in the figure below. This pin is pulled up to 1.8 V internally. Therefore, the control signal (GPIO) of the host can be 1.8 V or 3.3 V. W_DISABLE1# is active low.



NOTE: The typical voltage level of VCC_IO_HOST could be 1.8 V or 3.3 V.

Figure 27: Reference Circuit for W_DISABLE1#

4.8.2. WWAN_LED#

WWAN_LED# is used to indicate the RF status of the module, and its sink current is up to 27 mA.

To reduce current consumption of the LED, a current limiting resistor must be placed in series with the LED, as illustrated by the figure below.

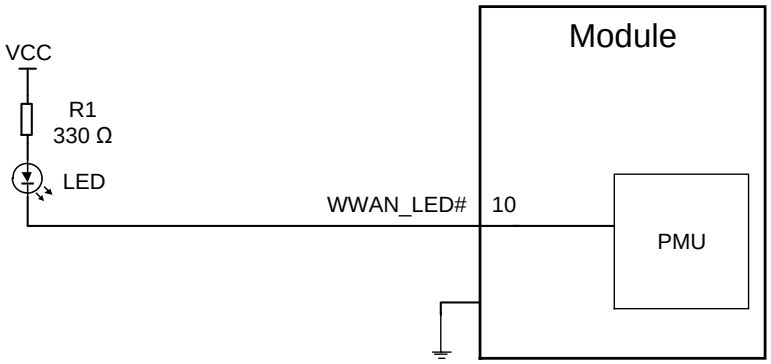


Figure 28: Reference Circuit for WWAN_LED#

Table 20: RF Status Indications of WWAN_LED#

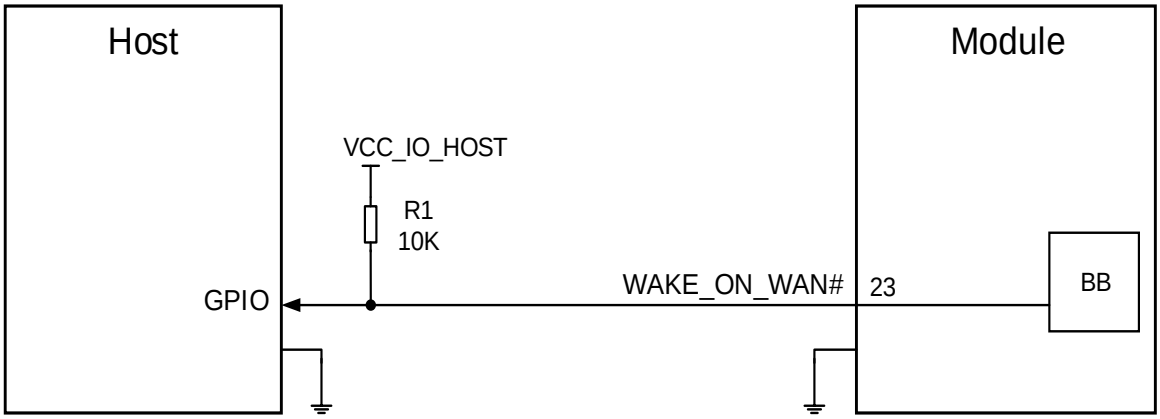
WWAN_LED# Logic Level	Description
Low (LED on)	RF function is enabled.
High (LED off)	RF function is disabled if any of the following occurs: ● The (U)SIM card is not powered or absent. ● W_DISABLE1# is at low level or **AT+CFUN=4** (airplane mode enabled). ● **AT+CFUN=0** (RF function disabled).

4.8.3. WAKE_ON_WAN#*

The WAKE_ON_WAN# is an open drain pin, which requires a pull-up resistor on the host.

Table 21: State of WAKE_ON_WAN#

WAKE_ON_WAN# State	Module Operation Status
Always at low level	Call/SMS/Data is incoming/Idle (to wake up the host)
Always at high level	Sleep



NOTE: The voltage level on VCC_IO_HOST depends on the host side due to the open drain in pin 23.

Figure 29: Reference Circuit for WAKE_ON_WAN#

4.9. Configuration Pins

RM500U-CN provides four configuration pins, which are defined as below.

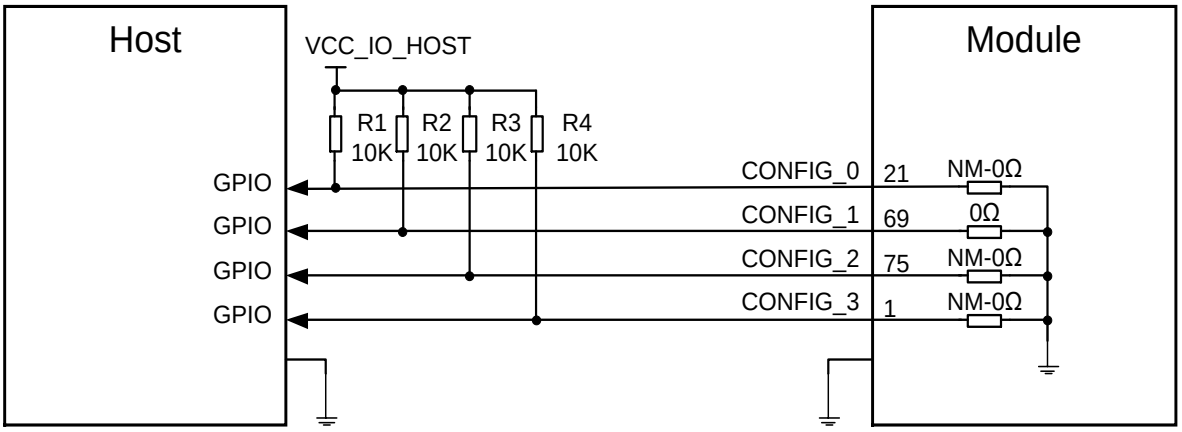
Table 22: Configuration Pins List of M.2 Specification

CONFIG_0 (Pin 21)	CONFIG_1 (Pin 69)	CONFIG_2 (Pin 75)	CONFIG_3 (Pin 1)	Module Type and Main Host Interface	Port Configuration
NC	GND	NC	NC	WWAN-PCIe USB 3.0	2 (Quectel defined)

Table 23: Configuration Pins of the Module

Pin No.	Pin Name	I/O	DC Characteristics	Description
21	CONFIG_0	DO	1.8/3.3 V	Not connected internally
69	CONFIG_1	DO	1.8/3.3 V	Connected to GND internally
75	CONFIG_2	DO	1.8/3.3 V	Not connected internally
1	CONFIG_3	DO	1.8/3.3 V	Not connected internally

The following figure shows a reference circuit for these four pins.



NOTE: The voltage level of VCC_IO_HOST depends on the host side and could be 1.8 V or 3.3 V.

Figure 30: Recommended Circuit for Configuration Pins

5 RF Characteristic

RM500U-CN provides four antenna interfaces, ANT0, ANT1, ANT2 and ANT3 and the impedance is 50 Ω.

5.1. Antenna Interfaces

5.1.1. Cellular Antenna Interfaces

Table 24: Pin Definition of Antenna Interfaces

Pin Name	I/O	Description	Comment
ANT0	AIO	Antenna 0 interface: - **5G NR:** n1/n28 TRX & n41/n77/n78/n79 TRX1 - **LTE & WCDMA:** LMHB TRX	50 Ω impedance.
ANT1	AIO	Antenna 1 interface: - **5G NR：** n1 DRX MIMO & n41 DRX0 & n77/n78/n79 DRX1	
ANT2	AIO	Antenna 2 interface: - **5G NR：** n1 PRX MIMO & n41/n77/n78/n79 TRX0	
ANT3	AIO	Antenna 3 interface: - **5G NR:** n1/n28 DRX & n41 DRX1 & n77/n78/n79 DRX0 - **LTE & WCDMA:** LMHB DRX	

5.1.2. Cellular Antenna Mapping

Table 25: Cellular Antenna Mapping

Antenna	WCDMA & LTE	5G NR				LB (MHz)	MHB (MHz)	n77/n78 (MHz)	n79 (MHz)
		n1	n28	n41	n77/ n78/ n79				
ANT0	LMHB TRX	TRX	TRX	TRX1	TRX1	703–960	1710–2690	3300–4200	4400–5000
ANT1	-	DRX MIMO	-	DRX0	DRX1	-	2110–2690	3300–4200	4400–5000
ANT2	-	PRX MIMO	-	TRX0	TRX0	-	2110–2690	3300–4200	4400–5000
ANT3	LMHB DRX	DRX	DRX	DRX1	DRX0	758–960	1805–2690	3300–4200	4400–5000

5.1.3. Operating Frequencies

Table 26: Operating Frequencies

Band Name	Transmit (MHz)	Receive (MHz)	LTE-FDD	LTE-TDD	WCDMA	5G NR
B1	1920–1980	2110–2170	B1	-	B1	n1
B2	1850–1910	1930–1990	B2	-	B2	-
B3	1710–1785	1805–1880	B3	-	-	-
B5	824–849	869–894	B5	-	B5	-
B7	2500–2570	2620–2690	B7	-	-	-
B8	880–915	925–960	B8	-	B8	-
B20	832–862	791–821	B20	-	-	-
B28	703–748	758–803	B28	-	-	n28
B34	2010–2025	2010–2025	-	B34	-	-
B38	2570–2620	2570–2620	-	B38	-	-
B39	1880–1920	1880–1920	-	B39	-	-
B40	2300–2400	2300–2400	-	B40	-	-
B41	2496–2690	2496–2690	-	B41	-	n41
n77	3300–4200	3300–4200	-	-	-	n77
n78	3300–3800	3300–3800	-	-	-	n78
n79	4400–5000	4400–5000	-	-	-	n79

5.1.4. Rx Sensitivity

Table 27: Receiving Sensitivity

Frequency Bands	Receiving Sensitivity (Typical)			3GPP (SIMO)
	Primary	Diversity	SIMO [6]	
WCDMA B1	-108.0 dBm	-110.4 dBm	-112.8 dBm	-106.7 dBm
WCDMA B2	-108.9 dBm	-109.8 dBm	-112.5 dBm	-104.7 dBm
WCDMA B5	-108.5 dBm	-110.0 dBm	-113 dBm	-104.7 dBm
WCDMA B8	-108 dBm	-111.3 dBm	-113.2 dBm	-103.7 dBm
LTE-FDD B1 (10 MHz)	-98.5 dBm	-99.7 dBm	-101.5 dBm	-96.3 dBm
LTE-FDD B2 (10 MHz)	-96.5 dBm	-99.7 dBm	-100.0 dBm	-94.3 dBm
LTE-FDD B3 (10 MHz)	-97.3 dBm	-98.9 dBm	-100.5 dBm	-93.3 dBm
LTE-FDD B5 (10 MHz)	-97.6 dBm	-99.2 dBm	-100.6 dBm	-94.3 dBm
LTE-FDD B7 (10 MHz)	-94.2 dBm	-97.8 dBm	-97.5 dBm	-94.3 dBm
LTE-FDD B8 (10 MHz)	-98.0 dBm	-100.3 dBm	-101.0 dBm	-93.3 dBm
LTE-FDD B20 (10 MHz)	-98.5 dBm	-98.5 dBm	-101.5 dBm	-93.3 dBm
LTE-FDD B28 (10 MHz)	-98.0 dBm	-97.0 dBm	-101.0 dBm	-94.8 dBm
LTE-TDD B34 (10 MHz)	-96.3 dBm	-98.5 dBm	-99.5 dBm	-96.3 dBm
LTE-TDD B38 (10 MHz)	-96.3 dBm	-98.0 dBm	-99.3 dBm	-96.3 dBm
LTE-TDD B39 (10 MHz)	-97.3 dBm	-98.5 dBm	-100.3 dBm	-96.3 dBm
LTE-TDD B40 (10 MHz)	-96.0 dBm	-97.0 dBm	-98.5 dBm	-96.3 dBm
LTE-TDD B41 (10 MHz)	-96.3 dBm	-98.0 dBm	-99.3 dBm	-94.3 dBm
5G NR FDD n1 (5 MHz)	TBD	TBD	-106.5 dBm	-102.0 dBm
5G NR FDD n28 (5 MHz)	TBD	TBD	-101.0 dBm	-97.8 dBm
5G NR TDD n41 (100 MHz)	TBD	TBD	-92.5 dBm	-86.7 dBm

[6] For the SIMO receiving sensitivity, WCDMA, LTE and 5G n28 bands are tested with 2 Rx antennas while 5G n1/n41/n77/n78/n79 bands are tested with 4 Rx antennas.

5G NR TDD n77 (100 MHz)	TBD	TBD	-92.5 dBm	-86.8 dBm
5G NR TDD n78 (100 MHz)	TBD	TBD	-93.0 dBm	-87.3 dBm
5G NR TDD n79 (100 MHz)	TBD	TBD	-92.5 dBm	-86.8 dBm

5.1.5. Tx Power

Table 28: RF Output Power

Frequency Bands	Max. Tx Power	Min. Tx Power
WCDMA B1/B2/B5/B8	23 dBm ±2 dB (Class 3)	< -49 dBm
LTE-FDD B1/B2/B3/B5/B7/B8/B20/B28	23 dBm ±2 dB (Class 3)	< -39 dBm
LTE-TDD B34/B38/B39/B40/B41 LTE-TDD B41 HPUE	23 dBm ±2 dB (Class 3) 26 dBm ±2 dB (Class 2)	< -39 dBm
5G NR n1/n41 5G NR n28 5G NR n77/n78/n79 5G NR n41/n78/n79 HPUE	23 dBm ±2 dB (Class 3) 23 dBm +2/-2.5 dB (Class 3) 23 dBm +2/-3 dB (Class 3) 26 dBm +2/-3 dB (Class 2)	< -40 dBm [7]

5.2. Antenna Connectors

5.2.1. Antenna Connector Location

RM500U-CN has four antenna connectors: ANT0, ANT1, ANT2 and ANT3, which are shown below.

[7] For 5G NR TDD bands, they have different standards for different channel bandwidths. See the specifications as described in *Clause 6.3.1* of *TS 38.101-1 [2].*



Figure 31: Antenna Connectors on the Module

5.2.2. Antenna Connector Specifications

RM500U-CN is mounted with standard 2 mm × 2 mm receptacle antenna connectors for convenient antenna connection and the connector dimensions are illustrated as below:

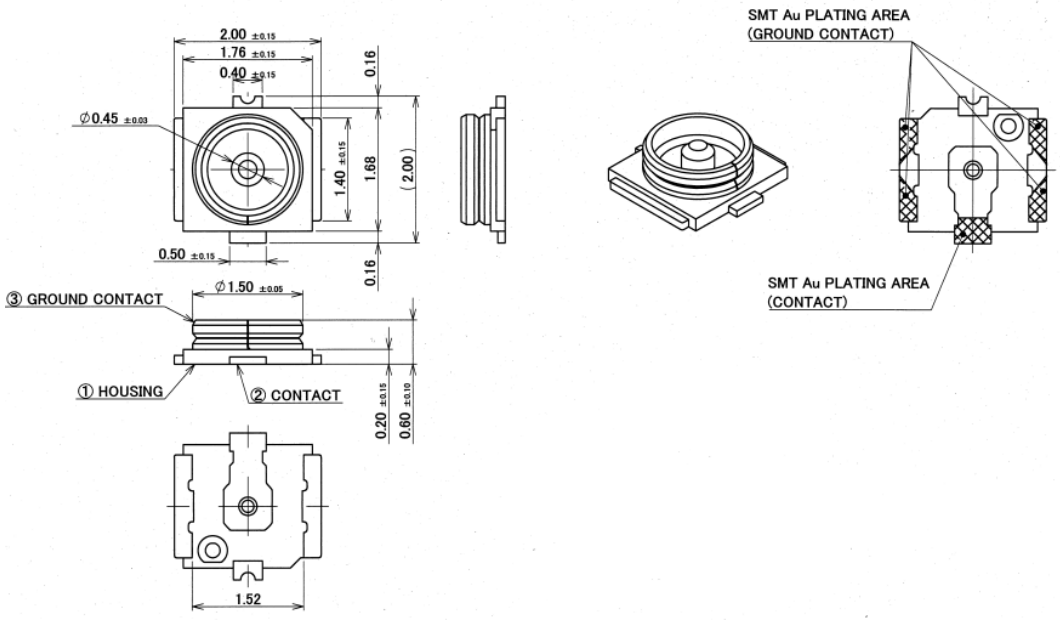


Figure 32: Dimensions of the Receptacle (Unit: mm)

Table 29: Major Specifications of the RF Connector

Item	Specification
Nominal Frequency Range	DC–6 GHz
Nominal Impedance	50 Ω
Temperature Rating	-40 °C to +85 °C
Voltage Standing Wave Ratio (VSWR)	Max. 1.3 (DC–3 GHz) Max. 1.45 (3–6 GHz)

5.2.3. Antenna Connector Installation

The receptacle RF connector used in conjunction with RM500U-CN will accept two types of mating plugs that will meet a maximum height of 1.2 mm using a Ø 0.81 mm coaxial cable or a maximum height of 1.45 mm utilizing a Ø 1.13 mm coaxial cable.

The following figure shows the dimensions of mated plugs using Ø 0.81 mm coaxial cables.

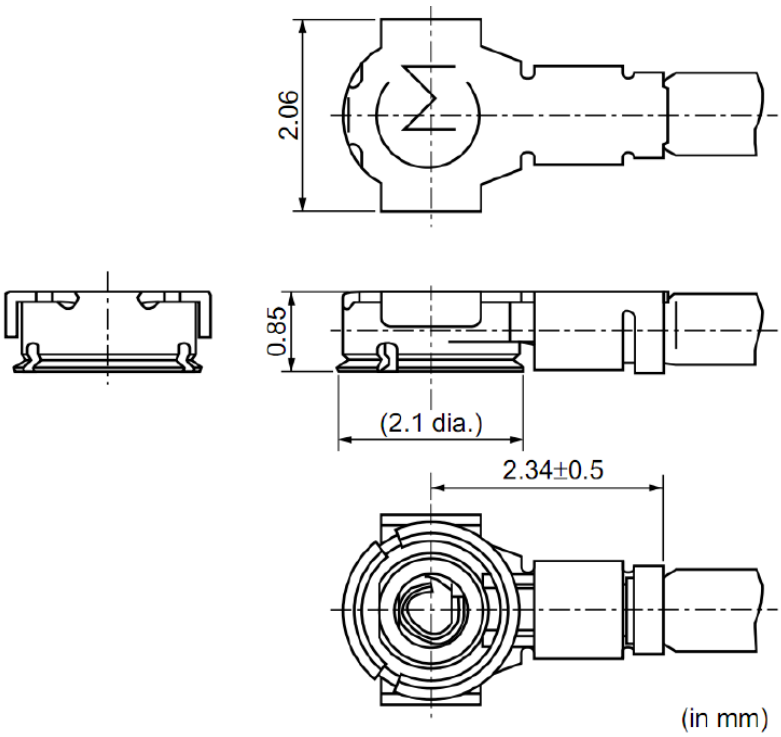


Figure 33: Dimensions of Mated Plugs (Ø 0.81 mm Coaxial Cables)

The following figure illustrates the connection between the receptacle RF connector on RM500U-CN and the mated plug using a Ø 0.81 mm coaxial cable.

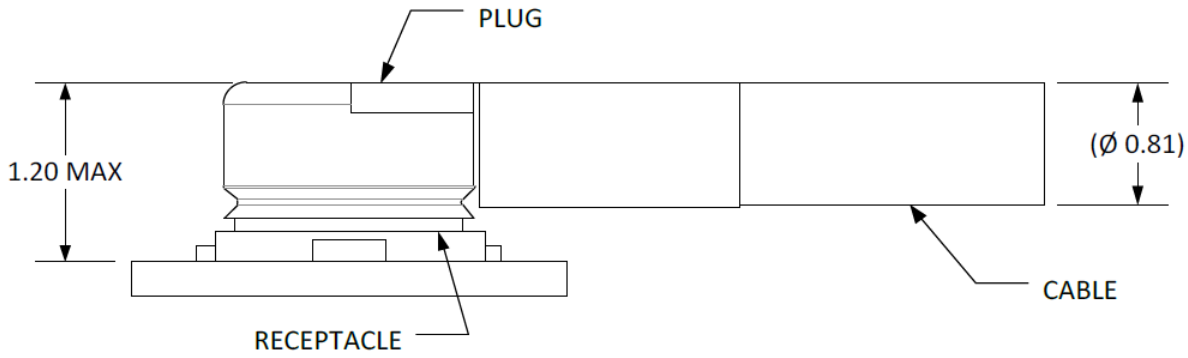


Figure 34: Space Factor of Mated Connectors (Ø0.81 mm Coaxial Cables) (Unit: mm)

The following figure illustrates the connection between the receptacle RF connector on RM500U-CN and the mated plug using a Ø 1.13 mm coaxial cable.

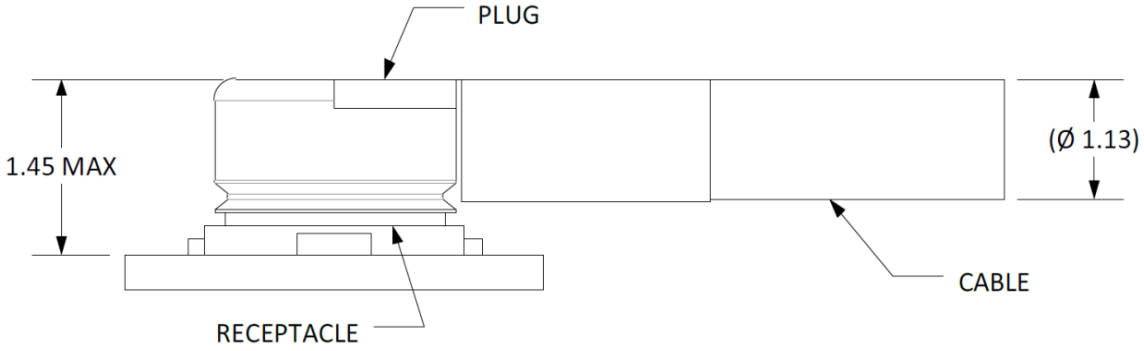


Figure 35: Space Factor of Mated Connectors (Ø 1.13 mm Coaxial Cables) (Unit: mm)

5.2.4. Recommended RF Connector for Installation

5.2.4.1. Assemble Coaxial Cable Plug Manually

The illustration for plugging in a coaxial cable plug is shown below, θ = 90° is acceptable, while θ ≠ 90° is not.

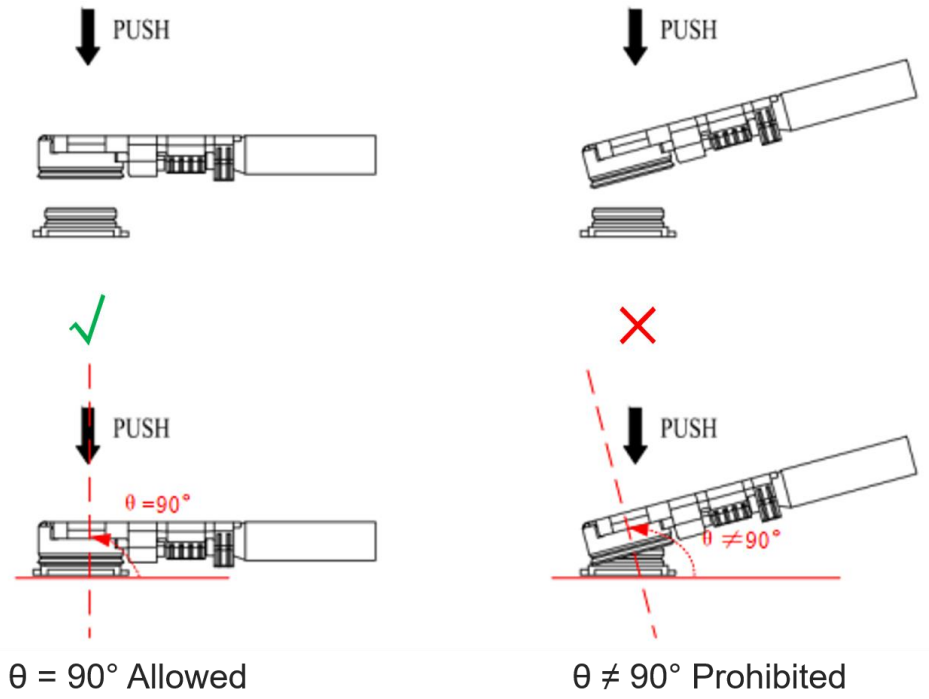


Figure 36: Plug in a Coaxial Cable Plug

The illustration of pulling out the coaxial cable plug is shown below, θ = 90° is acceptable, while θ ≠ 90° is not.

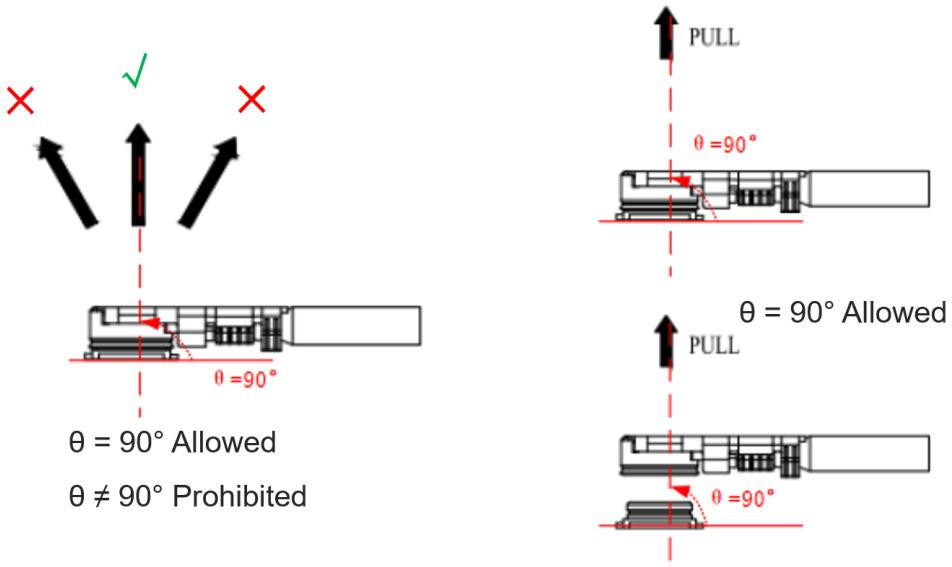


Figure 37: Pull out a Coaxial Cable Plug

5.2.4.2. Assemble Coaxial Cable Plug with Jig

The pictures of installing the coaxial cable plug with a jig is shown below, θ = 90° is acceptable, while θ ≠ 90° is not.

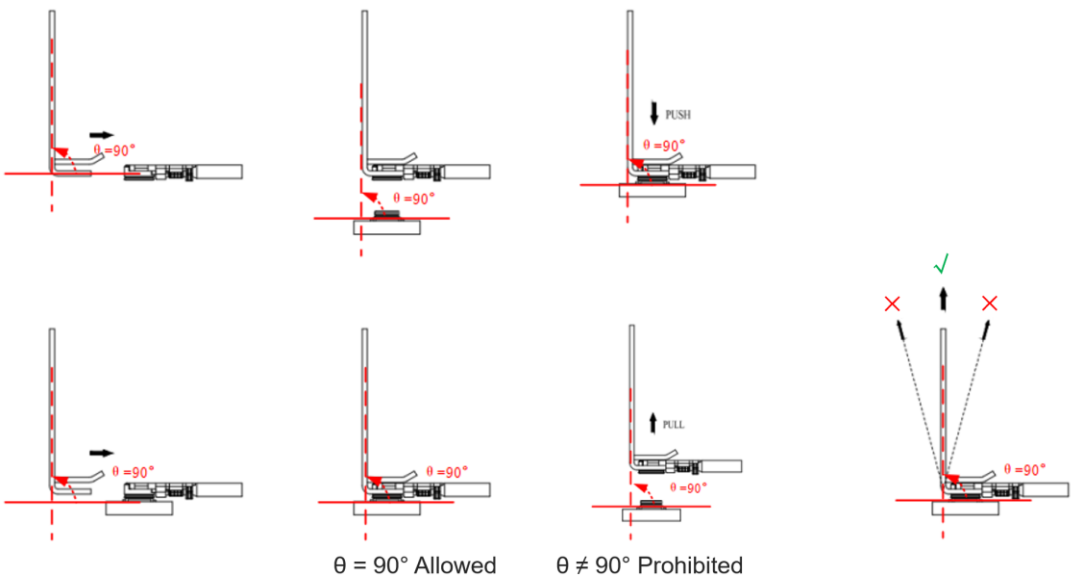


Figure 38: Install the Coaxial Cable Plug with Jig

5.2.5. Recommended Manufacturers of RF Connector and Cable

It is recommended to use I-PEX MHF® 4 series RF plugs and coaxial cables. For more details, visit https://www.i-pex.com.

5.3. Antenna Design Requirements

Table 30: Antenna Design Requirements

Type	Requirements
WCDMA/LTE/5G NR	● VSWR: ≤ 2 ● Efficiency: > 30 % ● Maximum input power: 50 W ● Input Impedance: 50 Ω ● Cable insertion loss: **< 1 dB:** LB (<1 GHz) **< 1.5 dB:** MB (1–2.3 GHz)

	< 2 dB: HB (> 2.3 GHz)

6 Reliability, Radio and Electrical Characteristics

6.1. Power Supply Requirements

The typical input voltage of RM500U-CN is 3.7 V. The following table shows the power supply requirements.

Table 31: Power Supply Requirements

Parameter	Description	Min.	Typ.	Max.	Unit
VCC	Power supply for the module	3.3	3.7	4.4	V
Voltage Ripple		-	30	100	mV

6.2. Power Consumption

Table 32: Power Consumption

Description	Conditions	Typ.	Unit
OFF state	Power down	90	μA
Sleep state	**AT+CFUN=0** (USB disconnected)	3.7	mA
Idle state	SA PF = 64 (USB disconnected)	39	mA
WCDMA maximum transmitting power	WCDMA B1 HSDPA CH10700 @ 22.7 dBm	759	mA
	WCDMA B1 HSUPA CH10700 @ 20.7 dBm	670	mA
	WCDMA B2 HSDPA CH9800 @ 22.6 dBm	680	mA

	WCDMA B2 HSUPA CH9800 @ 20.57 dBm	600	mA
	WCDMA B5 HSDPA CH4408 @ 23.39 dBm	620	mA
	WCDMA B5 HSUPA CH4408 @ 21.07 dBm	557	mA
	WCDMA B8 HSDPA CH3012 @ 22.64 dBm	624	mA
	WCDMA B8 HSUPA CH3012 @ 20.08 dBm	546	mA
LTE maximum transmitting power	LTE-FDD B1 CH300 @ 22.7 dBm	756	mA
	LTE-FDD B2 CH900 @ 22.66 dBm	716	mA
	LTE-FDD B3 CH1575 @ 22.85 dBm	610	mA
	LTE-FDD B5 CH2525 @ 22.99 dBm	667	mA
	LTE-FDD B7 CH3100 @ 22.91 dBm	691	mA
	LTE-FDD B8 CH3625 @ 23.06 dBm	649	mA
	LTE-FDD B20 CH6300 @ 22.94 dBm	623	mA
	LTE-FDD B28 CH9435 @ 22.17 dBm	628	mA
	LTE-TDD B34 CH36275 @ 23.3 dBm	367	mA
	LTE-TDD B38 CH38000 @ 22.93 dBm	411	mA
	LTE-TDD B39 CH38450 @ 23.08 dBm	305	mA
	LTE-TDD B40 CH39150 @ 23.03 dBm	384	mA
	LTE-TDD B41 CH40620 @ 22.68 dBm	369	mA
5G NR maximum transmitting power	5G NR-FDD n1 CH424000 @ 21.96dBm	1130	mA
	5G NR-FDD n1 CH428000 @ 21.96 dBm	1126	mA
	5G NR-FDD n1 CH432000 @ 22.27dBm	1123	mA
	5G NR-FDD n28 CH153600 @ 22.0 dBm	937	mA
	5G NR-FDD n28 CH156600 @ 22.0 dBm	894	mA
	5G NR-FDD n28 CH158600 @ 22.3 dBm	931	mA
	5G NR-TDD n41 CH501204 @ 25.5 dBm	639	mA
	5G NR-TDD n41 CH518598 @ 25.15 dBm	642	mA

	5G NR-TDD n41 CH535998 @ 25.13 dBm	674	mA
	5G NR-TDD n77 CH623334@ 23.83 dBm	724	mA
	5G NR-TDD n77 CH650000 @ 24.51 dBm	699	mA
	5G NR-TDD n77 CH676666 @ 24.14 dBm	724	mA
	5G NR-TDD n78 CH623334 @ 26.54dBm	787	mA
	5G NR-TDD n78 CH636666 @ 26.80 dBm	758	mA
	5G NR-TDD n78 CH650000 @ 26.46 dBm	801	mA
	5G NR-TDD n79 CH695090 @ 25.29 dBm	732	mA
	5G NR-TDD n79 CH713522 @ 25.16 dBm	730	mA
	5G NR-TDD n79 CH731976 @ 25.09 dBm	741	mA
WCDMA voice call	WCDMA B1 CH10700 @ 22.82 dBm	782	mA
	WCDMA B2 CH9800 @ 22.83 dBm	719	mA
	WCDMA B5 CH4407 @ 23.4 dBm	635	mA
	WCDMA B8 CH3012 @ 22.87 dBm	641	mA

6.3. Digital I/O Characteristic

Table 33: Logic Levels of Digital I/O

Parameter	Description	Min.	Max.	Unit
V_{IH}	Input high voltage	0.7 × V_{pad}	V_{pad}	V
V_{IL}	Input low voltage	0	0.3 × V_{pad}	V
V_{OH}	Output high voltage	0.9 × V_{pad}	V_{pad}	V
V_{OL}	Output low voltage	0	0.1 × V_{pad}	V

NOTE

V_{pad} is the module I/O voltage domain.

Table 34: (U)SIM 1.8 V I/O Requirements

Parameter	Description	Min.	Max.	Unit
USIM_VDD	Power supply	1.65	1.95	V
V_{IH}	Input high voltage	0.7 × USIM_VDD	USIM_VDD + 0.3	V
V_{IL}	Input low voltage	-0.3	0.2 × USIM_VDD	V
V_{OH}	Output high voltage	0.8 × USIM_VDD	USIM_VDD	V
V_{OL}	Output low voltage	0	0.4	V

Table 35: (U)SIM 3.0 V I/O Requirements

Parameter	Description	Min.	Max.	Unit
USIM_VDD	Power supply	2.7	3.3	V
V_{IH}	Input high voltage	0.7 × USIM_VDD	USIM_VDD + 0.3	V
V_{IL}	Input low voltage	-0.3	0.2 × USIM_VDD	V
V_{OH}	Output high voltage	0.8 × USIM_VDD	USIM_VDD	V
V_{OL}	Output low voltage	0	0.4	V

6.4. ESD Protection

Static electricity occurs naturally and it may damage the module. Therefore, applying proper ESD countermeasures and handling methods is imperative. For example, wear anti-static gloves during the development, production, assembly and testing of the module; add ESD protection components to the ESD sensitive interfaces and points in the product design.

Table 36: Electrostatic Discharge Characteristics (Temperature: 25–30 ºC, Humidity: 40 ±5 %)

Tested Interfaces	Contact Discharge	Air Discharge	Unit
VCC, GND	±5	±10	kV
Antenna Interfaces	±4	±8	kV

Other Interfaces	±0.5	±1	kV

6.5. Absolute Maximum Ratings

Absolute maximum ratings for power supply and voltage on digital pins of the module are listed in the following table.

Table 37: Absolute Maximum Ratings

Parameter	Min.	Max.	Unit
VCC	-0.3	6	V
Voltage at digital pins	-0.3	1.98	V

6.6. Operating and Storage Temperatures

Table 38: Operating and Storage Temperatures

Parameter	Min.	Typ.	Max.	Unit
Operating Temperature Range [8]	-30	+25	+75	ºC
Extended Temperature Range [9]	-40	-	+85	ºC
Storage Temperature Range	-40	-	+90	ºC

[8] To meet this operating temperature range, you need to ensure effective thermal dissipation, for example, by adding passive or active heatsinks, heat pipes, vapor chambers, etc. Within this range, the module can meet 3GPP specifications.
[9] To meet this extended temperature range, you need to ensure effective thermal dissipation, for example, by adding passive or active heatsinks, heat pipes, vapor chambers, etc. Within this range, the module remains the ability to establish and maintain functions such as voice, SMS, emergency call, etc., without any unrecoverable malfunction. Radio spectrum and radio network are not influenced, while one or more specifications, such as Pout, may undergo a reduction in value, exceeding the specified tolerances of 3GPP. When the temperature returns to the normal operating temperature level, the module will meet 3GPP specifications again.

6.7. Thermal Dissipation

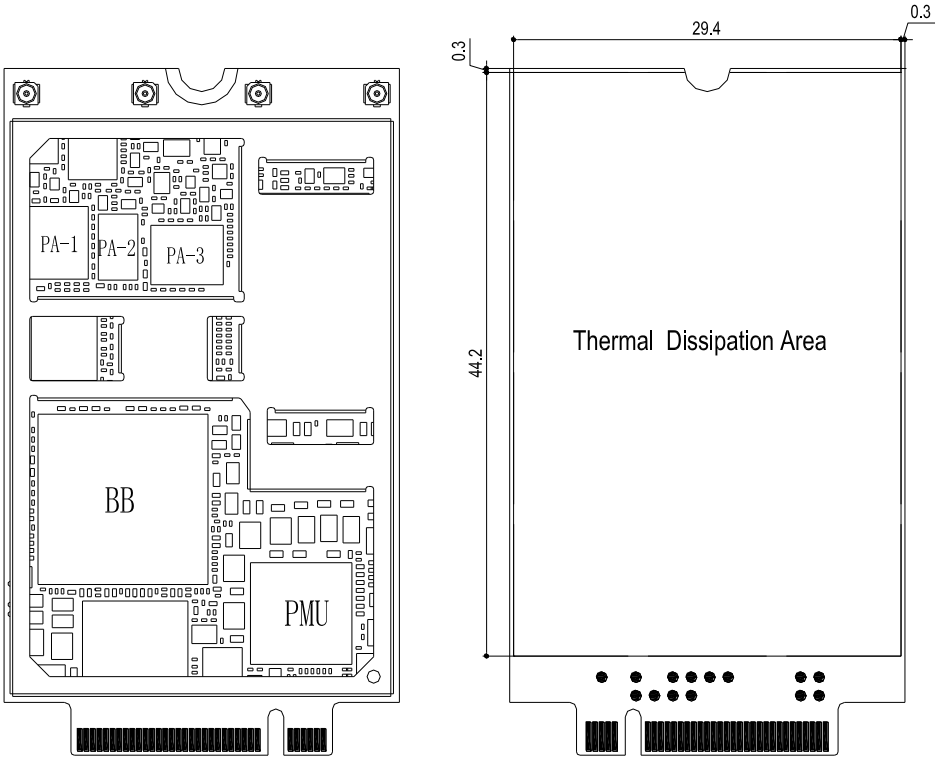


Figure 39: Distribution of Heat Source Chips Inside and on Bottom Side of the Module

The module offers the best performance when all internal IC chips are working within their operating temperatures. When the IC chip reaches or exceeds the maximum junction temperature, the module may still work but the performance and function (such as RF output power, data rate, etc.) will be affected to a certain extent. Therefore, the thermal design should be maximally optimized to ensure all internal IC chips always work within the recommended operating temperature range.

The following principles for thermal consideration are provided for reference:

- Keep the module away from heat sources on your PCB, especially high-power components such as processor, power amplifier, and power supply.
- Maintain the integrity of the PCB copper layer and drill as many thermal vias as possible.
- Expose the copper in the PCB area where module is mounted.
- Apply a soft thermal pad with appropriate thickness and high thermal conductivity between the module and the PCB to conduct heat.
- Follow the principles below when the heatsink is necessary:
  - Do not place large size components in the area where the module is mounted on your PCB to reserve enough place for heatsink installation.
  - Attach the heatsink to the shielding cover of the module; In general, the base plate area of the

heatsink should be larger than the module area to cover the module completely;
- Choose the heatsink with adequate fins to dissipate heat;
- Choose a TIM (Thermal Interface Material) with high thermal conductivity, good softness and good wettability and place it between the heatsink and the module;
- Fasten the heatsink with four screws to ensure that it is in close contact with the module to prevent the heatsink from falling off during the drop, vibration test, or transportation.

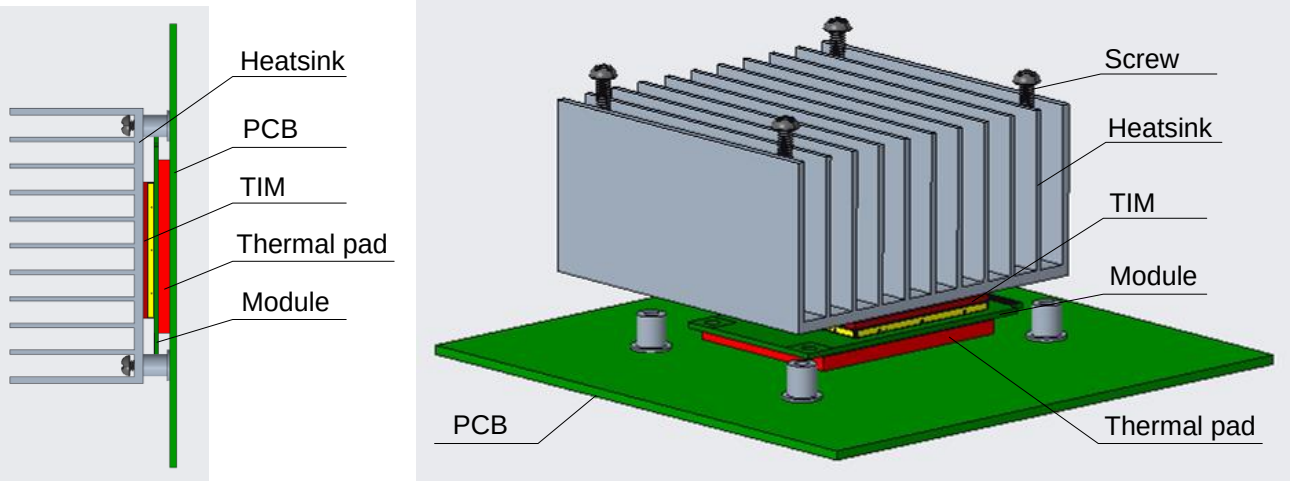


Figure 40: Placement and Fixing of the Heatsink

6.8. Notification

Please follow the principles below in the module application.

6.8.1. Coating

If a conformal coating is necessary for the module, do NOT use any coating material that may chemically react with the PCB or shielding cover, and prevent the coating material from flowing into the module.

6.8.2. Cleaning

Avoid using ultrasonic technology for module cleaning since it can damage crystals inside the module.

6.8.3. Installing

It is recommended to fix the module firmly when the module is inserted into a socket.

7 Mechanical Information

This chapter describes the mechanical dimensions of the module. All dimensions are measured in millimeter (mm), and the dimensional tolerances are ±0.15 mm unless otherwise specified.

7.1. Mechanical Dimensions

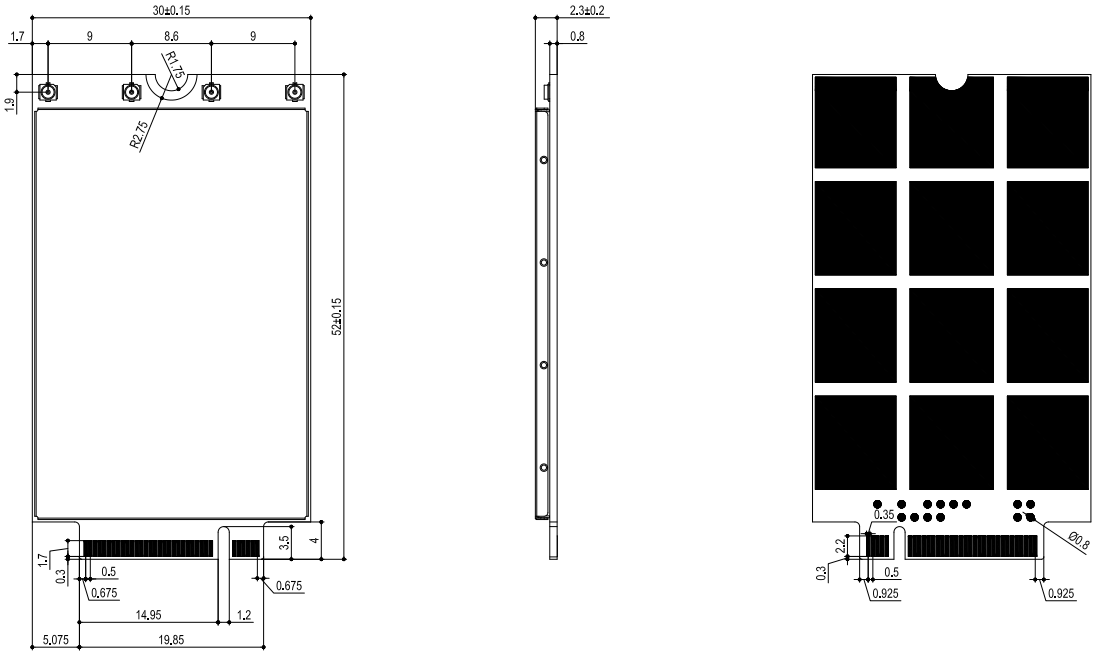


Figure 41: Mechanical Dimensions (Unit: mm)

7.2. Top and Bottom Views



Figure 42: Top and Bottom View of the Module

NOTE

Images above are for illustration purpose only and may differ from the actual module. For authentic appearance and label, please refer to the module received from Quectel.

7.3. M.2 Connector

RM500U-CN adopts a standard PCI Express M.2 connector which compiles with the directives and standards listed in *PCI Express M.2 Specification Revision 3.0, Version 1.2.*

7.4. Packaging

This chapter describes only the key parameters and process of packaging. All figures below are for

reference only. The appearance and structure of the packaging materials are subject to the actual delivery.

The module adopts blister tray packaging and details are as follow.

7.4.1. Blister Tray

Dimension details are as follow:

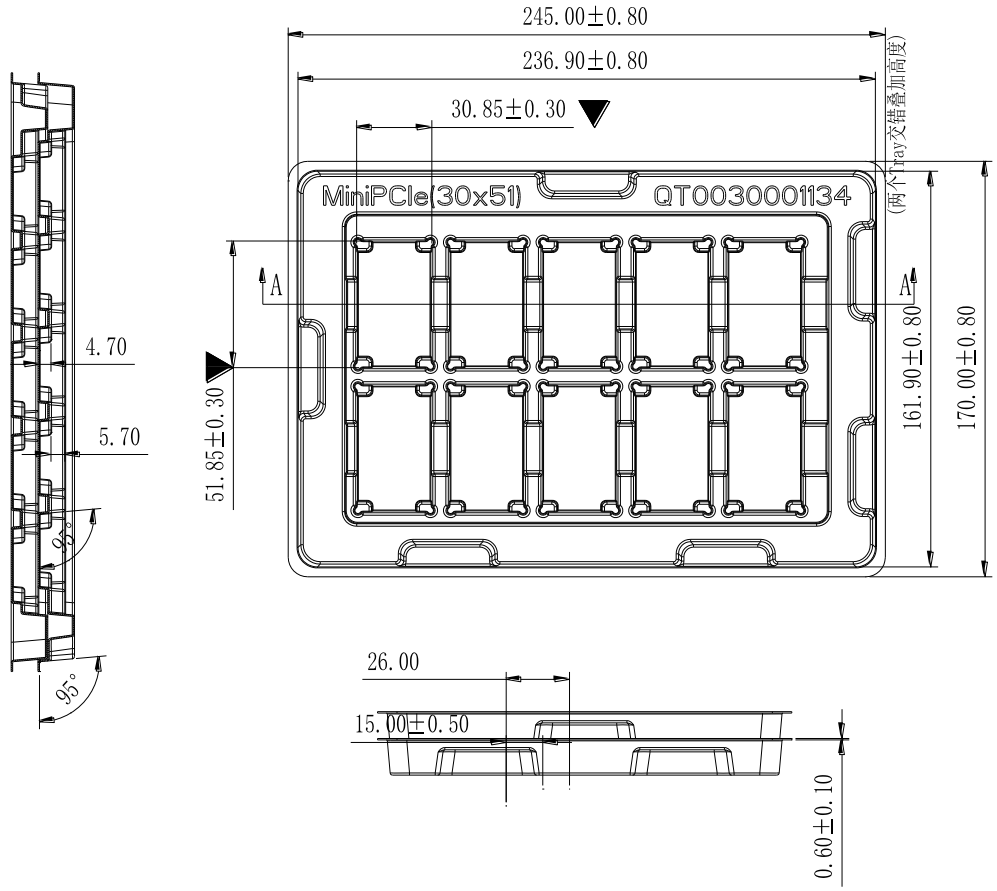
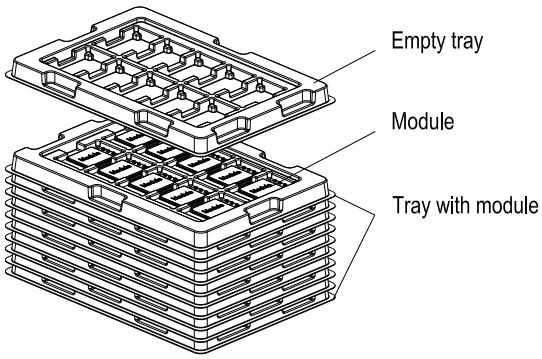
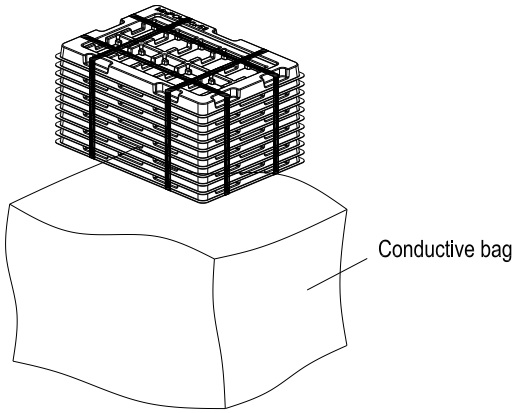


Figure 43: Tray Size (Unit: mm)

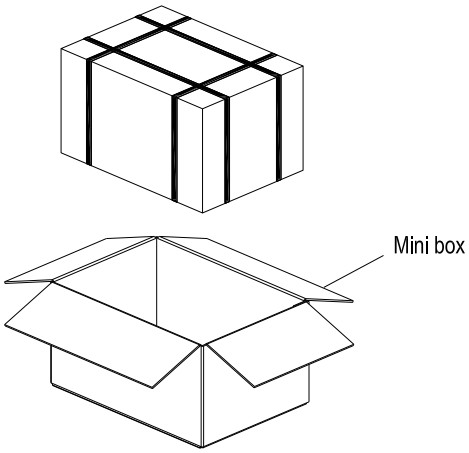
7.4.2. Packaging Process



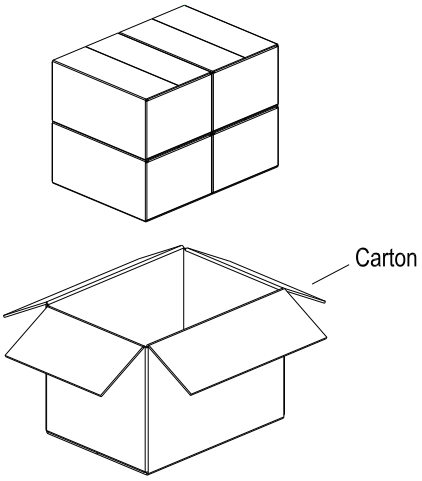
Pack 10 modules in each blister tray. Stack 10 blister trays with modules together, and put 1 empty blister tray on the top.



Pack 11 blister trays together and then put these blister trays into a conductive bag, seal and pack the conductive bag.



Put seal-packed blister trays into a mini box. One mini box contains 100 modules.



Put 4 mini boxes into 1 carton and then seal it. One carton contains 400 modules.

Figure 44: Package Process

8 Appendix References

Table 39: Related Documents

Document Name
[1] Quectel_5G-M2_EVB_User_Guide
[2] Quectel_RGx00U&RM500U_Series_AT_Commands_Manual
[3] Quectel_RM500U-CN_Reference_Design

Table 40: Terms and Abbreviations

Abbreviation	Description
3GPP	3rd Generation Partnership Project
AP	Application Processor
APT	Average Power Tracking
CPE	Customer-Premise Equipment
ESD	Electrostatic Discharge
HSUPA	High Speed Uplink Packet Access
$I_O$max	Maximum Output Load Current
kbps	Kilo Bits Per Second
LED	Light Emitting Diode
LTE	Long Term Evolution
LVDS	Low Voltage Differential Signaling
Mbps	Mega Bits Per Second

MIMO	Multiple-Input Multiple-Output
MLCC	Multiplayer Ceramic Chip Capacitor
MMS	Multimedia Messaging Service
NMOS	Negative-channel MOS (Metal-Oxide-Semiconductor)
NPN	Negative-Positive-Negative
PAP	Password Authentication Protocol
PCB	Printed Circuit Board
PCIe	Peripheral Component Interconnect Express
PCM	Pulse Code Modulation
PDU	Protocol Data Unit
PPP	Point-to-Point Protocol
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RC	Root Complex
RF	Radio Frequency
RFFE	RF Front-End
Rx	Receive
SCS	Subcarrier Spacing
SIMO	Single Input Multiple Output
SMS	Short Message Service
Tx	Transmit
UART	Universal Asynchronous Receiver & Transmitter
URC	Unsolicited Result Code
USB	Universal Serial Bus
(U)SIM	(Universal) Subscriber Identity Module

V_{IH}	Input High Voltage Level
V_{IH}max	Maximum High-level Input Voltage
V_{IH}min	Minimum High-level Input Voltage
V_{IL}	Input Low Voltage Level
V_{IL}max	Maximum Low-level Input Voltage
Vmax	Maximum Voltage
Vmin	Minimum Voltage
Vnom	Nominal Voltage
V_{OH}	Output High Voltage Level
V_{OL}	Output Low Voltage Level
VSWR	Voltage Standing Wave Ratio
WCDMA	Wideband Code Division Multiple Access
WLAN	Wireless Local Area Network