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EM12 Hardware Design

LTE-A Module Series

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About the Document

History

Revision	Date	Author	Description
1.0	2019-08-12	Oscar LIU/ Reed WANG	Initial
1.1	2019-11-18	Reed WANG/ Jim HAN	1. Deleted the CA combinations B2+B17 and B4+B17 in Table 1. 2. Updated the internet protocol features and supported USB serial drivers in Table 2. 3. Updated the EM12-G GNSS performance in Table 22 and Table 23.

Contents

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1 Introduction

This document defines EM12 module and describes its air interface and hardware interfaces which are connected with customers' applications.

This document helps customers quickly understand the interface specifications, electrical and mechanical details, as well as other related information of EM12 module. To facilitate its application in different fields, reference design is also provided for customers' reference. Associated with application notes and user guides, customers can use the module to design and set up mobile applications easily.

1.1. Safety Information

The following safety precautions must be observed during all phases of the operation, such as usage, service or repair of any cellular terminal or mobile incorporating EM12 module. Manufacturers of the cellular terminal should send the following safety information to users and operating personnel, and incorporate these guidelines into all manuals supplied with the product. If not so, Quectel assumes no liability for customers' failure to comply with these precautions.

🚚	Full attention must be given 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 the device offers an Airplane Mode, then it should be enabled prior to boarding an aircraft. Please consult the airline staff for more restrictions on the use of wireless devices on boarding the 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.
SOS	Cellular terminals or mobiles operating over radio signals and cellular network cannot be guaranteed to connect in all possible conditions (for example, with unpaid bills or with an invalid (U)SIM card). When emergent help is needed in such conditions, please remember using emergency call. 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.
♥	The cellular terminal or mobile contains a transmitter and receiver. When it is ON, it receives and transmits radio frequency signals. RF interference can occur if it is used close to TV set, radio, computer or other electric equipment.
🔥	In locations with potentially explosive atmospheres, obey all posted signs to turn off wireless devices such as your phone or other cellular terminals. Areas with potentially explosive atmospheres include fuelling areas, below decks on boats, fuel or chemical transfer or storage facilities, areas where the air contains chemicals or particles such as grain, dust or metal powders, etc.

2 Product Concept

2.1. General Description

EM12 is an LTE-A/UMTS/HSPA+ wireless communication module with receive diversity. It provides data connectivity on LTE-FDD, LTE-TDD, DC-HSDPA, HSPA+, HSDPA, HSUPA and WCDMA networks with standard PCI Express M.2 interface.

It supports embedded operating systems such as Windows, Linux and Android, and also provides GNSS1) and voice functionality2) to meet customers' specific application demands.

The following table shows the frequency bands, CA combinations3) and GNSS types of EM12 module.

Table 1: Frequency Bands, CA Combinations and GNSS Types of EM12 Module

Mode	EM12-G	
LTE-FDD	B1/B2/B3/B4/B5/B7/B8/B9/B12/B13/B14/B17 6)/B18/B19/B20/B21/B25/B26/B28 /B29 4)/B30/B32 4)/B66;	
LTE-TDD	B38/B39/B40/B41;	
2×CA (DL)	Inter-band 2×CA	B1+B3/B5/B18/B19/B20/B26; B2+B4/B5/B12/B13/B14/B29/B30/B66; B3+B5/B7/B8/B19/B20/B28; B4+B5/B12/B13/B29/B30; B5+B7/B25/B30/B66; B7+B20/B28; B12+B25/B30; B13+B66; B14+B30/B66; B19+B21; B20+B32; B25+B26/B41; B29+B30; B39+B41; B66+B12/B29/B30;
	Intra-band 2×CA	B2+B2; B3+B3; B4+B4; B7+B7; B25+B25; B38+B38; B39+B39; B40+B40; B41+B41; B66+B66;

3×CA (DL)	Inter-band 3×CA	B1+B3+B5/B7/B8/B19/B20/B28; B1+B7+B20; B2+B4+B5/B13; B2+B5+B30; B2+B12+B30; B2+B14+B66; B2+B29+B30; B3+B7+B8/B20/B28; B4+B5+B30; B4+B12+B30; B4+B29+B30; B5+B66+B2; B13+B66+B2; B66+B12+B30, B66+B29+B30; B66+B5+B30;
	Intra-band plus inter-band 3×CA	B2+B2+B5/B13; B3+B3+B1/B7/B20/B28; B3+B7+B7; B4+B4+B5/B13; B7+B7+B28; B25+B25+B26; B39+B39+B41; B41+B41+B25/B39; B66+B66+B2/B5/B13/B14;
	Intra-band 3×CA	B40+B40+B40; B41+B41+B41; B66+B66+B66;
2×CA (UL)[5]	B3+B3; B41+B41;	
WCDMA	B1/B2/B3/B4/B5/B8/B9/B19;	
GNSS[1]	GPS; GLONASS; BeiDou; Galileo; QZSS;	

NOTES

1. [1] GNSS function is optional.
2. [2] EM12 module contains **Telematics** version and **Data-only** version. **Telematics** version supports voice and data functions, while **Data-only** version only supports data function.
3. [3] For more details about CA combinations, please refer to ***document [1]***.
4. [4] LTE-FDD B29 and B32 support Rx only, and in 2×CA they are only for secondary component carrier.
5. [5] The operation temperature of UL CA is -10ºC ~ +65ºC.
6. [6] LTE-FDD B17 is supported through MFBI+B12.

EM12 can be applied in the following fields:

- Rugged Tablet PC and Laptop Computer
- Remote Monitor System
- Vehicle System
- Wireless POS System
- Smart Metering System
- Wireless Router and Switch
- Other Wireless Terminal Devices

2.2. Key Features

The following table describes the detailed features of EM12.

Table 2: Key Features of EM12

Features	Details
Function Interface	PCI Express M.2 Interface
Power Supply	Supply voltage: 3.135V~4.4V Typical supply voltage: 3.7V
Transmitting Power	Class 3 (23dBm±2dB) for LTE-FDD bands Class 3 (23dBm±2dB) for LTE-TDD bands Class 3 (24dBm+1/-3dB) for WCDMA
LTE Features	Support up to LTE Cat 12 Support 1.4MHz to 60MHz RF bandwidth Support MIMO in DL direction Support QPSK, 16-QAM, 64-QAM and 256QAM modulation FDD: Max 600Mbps (DL)/150Mbps (UL) TDD: Max 430Mbps (DL)/90Mbps (UL)
UMTS Features	Support 3GPP R9 DC-HSDPA, HSPA+, HSDPA, HSUPA and WCDMA Support QPSK, 16-QAM and 64-QAM modulation DC-HSDPA: Max 42Mbps (DL) HSUPA: Max 5.76Mbps (UL) WCDMA: Max 384Kbps (DL)/Max 384Kbps (UL)
Internet Protocol Features	Support PPP/QMI/ NTP/ TCP/ UDP/ FTP/ HTTP/ PING/ HTTPS protocols Support PAP and CHAP usually used for PPP connection
SMS	Text and PDU modes Point to point MO and MT SMS cell broadcast SMS storage: ME by default
(U)SIM Interfaces	Support (U)SIM card: 1.8V/3.0V Support Dual SIM Single Standby
Audio Feature	Support one digital audio interface: PCM interface WCDMA: AMR/AMR-WB LTE: AMR/AMR-WB Support echo cancellation and noise suppression
PCM Interface	Used for audio function with external codec Support 16-bit linear data format Support long and short frame synchronization Support master and slave modes, but must be the master in long frame synchronization

USB Interface	Compliant with USB 3.0 and USB 2.0 specifications, with maximum transmission rates up to 5Gbps on USB 3.0 and 480Mbps on USB 2.0 Used for AT command communication, data transmission, firmware upgrade, software debugging, GNSS NMEA sentence output and voice over USB* Support USB serial drivers for: Windows 7/8/8.1/10, Linux 2.6~5.4, Android 4.x/5.x/6.x/7.x/8.x/9.x
PCIe × 1 Interface*	Comply with PCI Express Specification Revision 2.1 and support 5Gbps per lane Used for data transmission
Antenna Connectors	Include Main, DIV&GNSS and GNSS antenna connectors
Rx-diversity	Support LTE/WCDMA Rx-diversity
GNSS Features	Gen9HT Lite of Qualcomm Protocol: NMEA 0183
AT Commands	Compliant with 3GPP TS 27.007, 27.005 and Quectel enhanced AT commands
Physical Characteristics	Size: (42.0±0.15)mm × (30.0±0.15)mm × (2.3±0.1)mm Weight: approx. 6.0g
Temperature Range	Operation temperature range: -30°C ~ +70°C[1)] Extended temperature range: -40°C ~ +85°C[2)] Storage temperature range: -40°C ~ +90°C
Firmware Upgrade	USB 2.0 interface and DFOTA
RoHS	All hardware components are fully compliant with EU RoHS directive

NOTES

1. [1)] Within operation temperature range, the module is 3GPP compliant. For those end devices with bad thermal dissipation condition, a thermal pad or other thermal conductive components may be required between the module and main PCB to achieve the full operation temperature range.
2. [2)] Within extended temperature range, proper mounting, heating sinks and active cooling may be required to make certain functions of the module such as voice, SMS, data transmission to be realized. Only one or more parameters like P_{out} might reduce in their values and exceed the specified tolerances. When the temperature returns to the normal operation temperature level, the module will meet 3GPP specifications again.
3. "*" means under development.

2.3. Functional Diagram

The following figure shows a block diagram of EM12.

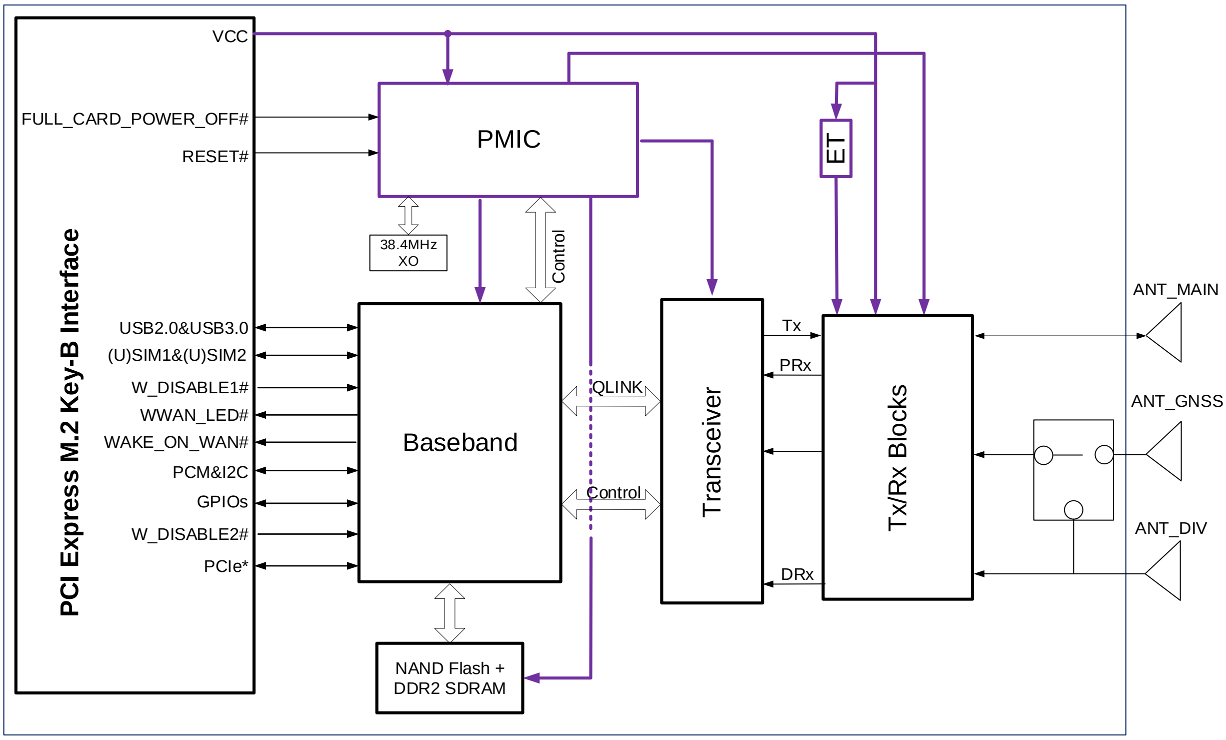


Figure 1: Functional Diagram

2.4. Evaluation Board

In order to help customers develop applications conveniently with EM12, Quectel supplies the evaluation board (M.2 EVB), a USB to RS-232 converter cable, a USB type-C cable, a pair of earphone, antennas and other peripherals to control or test the module. For more details, please refer to ***document [2]***.

3 Application Interfaces

The physical connections and signal levels of EM12 comply with PCI Express M.2 specifications. This chapter mainly describes the definition and application of the following interfaces, signals and pins of EM12:

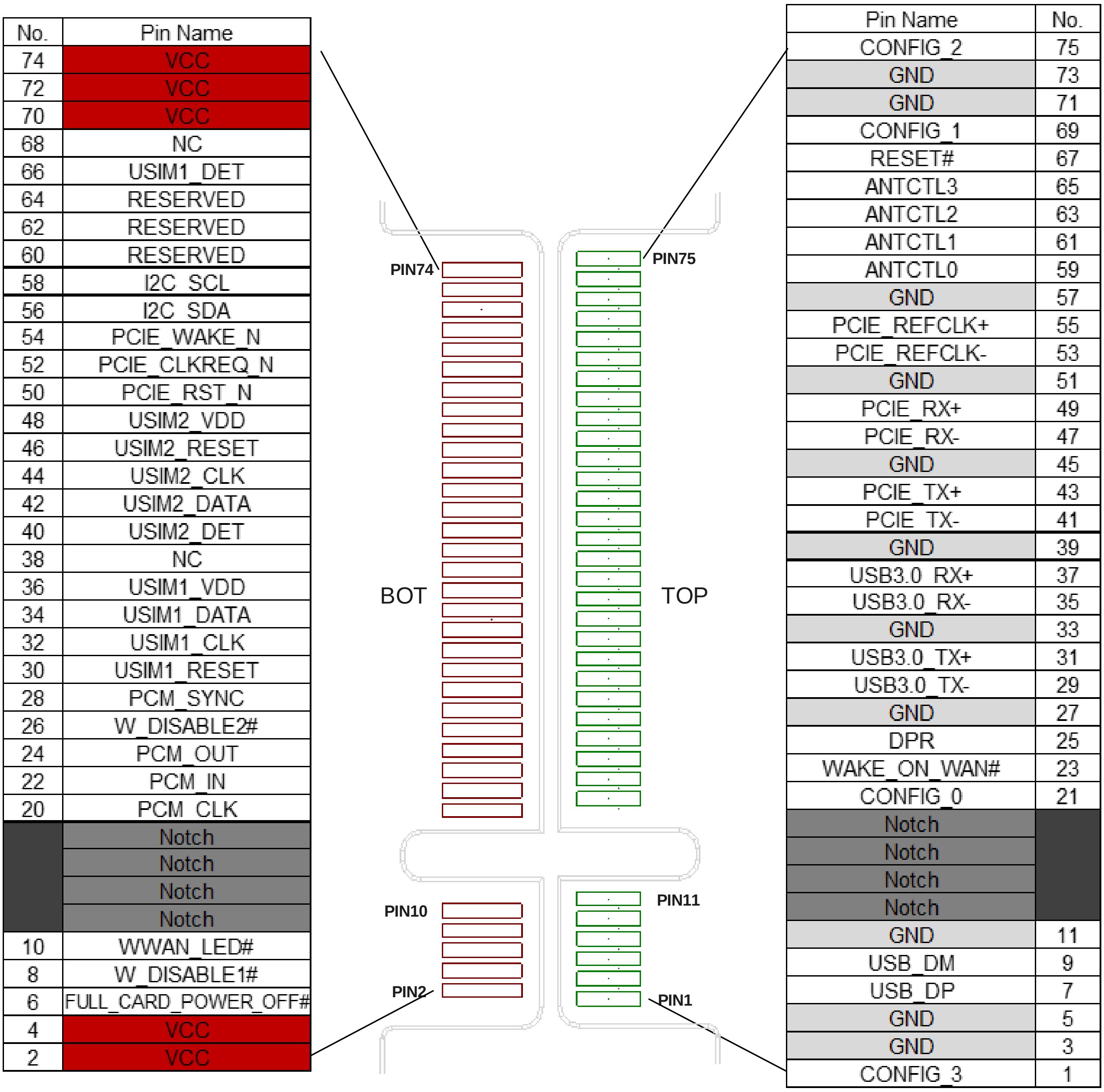
- Power supply
- (U)SIM interfaces
- USB interface
- PCIe interface*
- PCM and I2C interfaces
- Control and indication signals
- Antenna tuner control interface*
- Configuration pins

NOTE

"*" means under development.

3.1. Pin Assignment

The following figure shows the pin assignment of EM12. EM12 module and antenna connectors are on the top side.



No.	Pin Name
74	VCC
72	VCC
70	VCC
68	NC
66	USIM1_DET
64	RESERVED
62	RESERVED
60	RESERVED
58	I2C_SCL
56	I2C_SDA
54	PCIE_WAKE_N
52	PCIE_CLKREQ_N
50	PCIE_RST_N
48	USIM2_VDD
46	USIM2_RESET
44	USIM2_CLK
42	USIM2_DATA
40	USIM2_DET
38	NC
36	USIM1_VDD
34	USIM1_DATA
32	USIM1_CLK
30	USIM1_RESET
28	PCM_SYNC
26	W_DISABLE2#
24	PCM_OUT
22	PCM_IN
20	PCM_CLK
	Notch
	Notch
	Notch
	Notch
10	WWAN_LED#
8	W_DISABLE1#
6	FULL_CARD_POWER_OFF#
4	VCC
2	VCC

Pin Name	No.
CONFIG_2	75
GND	73
GND	71
CONFIG_1	69
RESET#	67
ANTCTL3	65
ANTCTL2	63
ANTCTL1	61
ANTCTL0	59
GND	57
PCIE_REFCLK+	55
PCIE_REFCLK-	53
GND	51
PCIE_RX+	49
PCIE_RX-	47
GND	45
PCIE_TX+	43
PCIE_TX-	41
GND	39
USB3.0_RX+	37
USB3.0_RX-	35
GND	33
USB3.0_TX+	31
USB3.0_TX-	29
GND	27
DPR	25
WAKE_ON_WAN#	23
CONFIG_0	21
Notch	
Notch	
Notch	
Notch	
GND	11
USB_DM	9
USB_DP	7
GND	5
GND	3
CONFIG_3	1

Figure 2: Pin Assignment

3.2. Pin Description

The following tables show the pin definition and description of EM12.

Table 3: Definition of I/O Parameters

Type	Description
AI	Analog Input
AO	Analog Output
DI	Digital Input
DO	Digital Output
IO	Bidirectional
OD	Open Drain
PI	Power Input
PO	Power Output

Table 4: Pin Description

Pin No.	M.2 Socket 2 USB 3.0-Based Pinout	EM12 Pin Name	I/O	Description	Comment
1	CONFIG_3	CONFIG_3		Not connected internally	
2	3.3V	VCC	PI	Power supply	Vmin=3.135V Vnorm=3.7V Vmax=4.4V
3	GND	GND		Ground	
4	3.3V	VCC	PI	Power supply	Vmin=3.135V Vnorm=3.7V Vmax=4.4V
5	GND	GND		Ground	
6	FULL_CARD_ POWER_OFF#	FULL_CARD_ POWER_OFF#	DI	Turn on/off the module. When it is at low level, the module is turned off.	Pulled down internally.

				When it is at high level, the module is turned on.	
7	USB_DP	USB_DP	AI/AO	USB 2.0 differential data bus (+)	
8	W_DISABLE1#	W_DISABLE1#	DI	Airplane mode control. Active low.	1.8V/3.3V power domain.
9	USB_DM	USB_DM	AI/AO	USB 2.0 differential data bus (-)	
10	GPIO_9	WWAN_LED#	OD	RF status indication. Active low.	
11	GND	GND		Ground	
12	Key	Notch		Notch	
13	Key	Notch		Notch	
14	Key	Notch		Notch	
15	Key	Notch		Notch	
16	Key	Notch		Notch	
17	Key	Notch		Notch	
18	Key	Notch		Notch	
19	Key	Notch		Notch	
20	GPIO_5 (AUDIO_0)	PCM_CLK	IO	PCM data bit clock. In master mode, it is an output signal. In slave mode, it is an input signal.	1.8V power domain. If unused, keep it open.
21	CONFIG_0	CONFIG_0		Connected to GND internally.	
22	GPIO_6 (AUDIO_1)	PCM_IN	DI	PCM data input	1.8V power domain.
23	GPIO_11 (WOWWAN#)	WAKE_ON_ WAN#	OD	Wake up the host. Active low.	1.8V/3.3V power domain.
24	GPIO_7 (AUDIO_2)	PCM_OUT	DO	PCM data output	1.8V power domain.
25	DPR	DPR	DI	Dynamic power reduction. Active low.	1.8V power domain.
26	GPIO_10 (W_DISABLE2#)	W_DISABLE2#	DI	GNSS enable control. Active low.	1.8V/3.3V power domain.

27	GND	GND		Ground	
28	GPIO_8 (AUDIO_3)	PCM_SYNC	IO	PCM data frame synchronization	1.8V power domain.
29	USB3.0-TX-	USB3.0_TX-	AO	USB 3.0 transmit data (-)	
30	UIM-RESET	USIM1_RESET	DO	(U)SIM1 card reset	1.8V/3.0V power domain.
31	USB3.0-TX+	USB3.0_TX+	AO	USB 3.0 transmit data (+)	
32	UIM-CLK	USIM1_CLK	DO	(U)SIM1 card clock	1.8V/3.0V power domain.
33	GND	GND		Ground	
34	UIM-DATA	USIM1_DATA	IO	(U)SIM1 card data	Pulled up to USIM2_VDD internally.
35	USB3.0-RX-	USB3.0_RX-	AI	USB 3.0 receive data (-)	
36	UIM-PWR	USIM1_VDD	PO	Power supply for (U)SIM1 card	1.8V/3.0V power domain.
37	USB3.0-RX+	USB3.0_RX+	AI	USB 3.0 receive data (+)	
38	N/C	NC		NC	
39	GND	GND		Ground	
40	GPIO_0 (SIM_DET2)	USIM2_DET	DI	(U)SIM2 card insertion detection	Pulled up Internally. 1.8V power domain.
41	PETn0	PCIE_TX-	AO	PCIe transmit data (-)	
42	GPIO_1 (SIM_DAT2)	USIM2_DATA	IO	(U)SIM2 card data	Pulled up to USIM2_VDD internally.
43	PETp0	PCIE_TX+	AO	PCIe transmit data (+)	
44	GPIO_2 (SIM_CLK2)	USIM2_CLK	DO	(U)SIM2 card clock	1.8V/3.0V power domain.
45	GND	GND		Ground	

46	GPIO_3 (SIM_RST2)	USIM2_RESET	DO	(U)SIM2 card reset	1.8V/3.0V power domain.
47	PERn0	PCIE_RX-	AI	PCIe receive data (-)	
48	GPIO_4 (SIM_PWR2)	USIM2_VDD	PO	Power supply for (U)SIM2 card	1.8V/3.0V power domain.
49	PERp0	PCIE_RX+	AI	PCIe receive data (+)	
50	PRST#	PCIE_RST_N	DI	PCIe reset. Active low.	3.3V power domain.
51	GND	GND		Ground	
52	CLKREQ#	PCIE_CLKREQ_N	DO	PCIe clock request. Active low.	3.3V power domain
53	REFCLKn	PCIE_REFCLK-	AI/AO	PCIe reference clock (-)	
54	PEWAKE#	PCIE_WAKE_N	DO	PCIe wakes up host. Active low.	3.3V power domain.
55	REFCLKp	PCIE_REFCLK+	AI/AO	PCIe reference clock (+)	
56	N/C	I2C_SDA	IO	I2C serial data for external codec.	Require an external pull-up to 1.8V.
57	GND	GND		Ground	
58	N/C	I2C_SCL	DO	I2C serial clock for external codec.	Require an external pull-up to 1.8V.
59	ANTCTL0	ANTCTL0	DO	Antenna tuner control	1.8V power domain.
60	COEX3	RESERVED		Reserved	
61	ANTCTL1	ANTCTL1	DO	Antenna tuner control	1.8V power domain.
62	COEX2	RESERVED		Reserved	
63	ANTCTL2	ANTCTL2	DO	Antenna tuner control	1.8V power domain.
64	COEX1	RESERVED		Reserved	
65	ANTCTL3	ANTCTL3	DO	Antenna tuner control	1.8V power

					domain.
66	SIM_DETECT	USIM1_DET	DI	(U)SIM1 card insertion detection. Active high.	Pulled up internally. 1.8V power domain.
67	RESET#	RESET#	DI	Module reset. Active low.	
68	SUSCLK (32kHz)	NC		NC	
69	CONFIG_1	CONFIG_1		Connected to GND internally	
70	3.3V	VCC	PI	Power supply	Vmin=3.135V Vnorm=3.7V Vmax=4.4V
71	GND	GND		Ground	
72	3.3V	VCC	PI	Power supply	Vmin=3.135V Vnorm=3.7V Vmax=4.4V
73	GND	GND		Ground	
74	3.3V	VCC	PI	Power supply	Vmin=3.135V Vnorm=3.7V Vmax=4.4V
75	CONFIG_2	CONFIG_2		Not connected internally	

NOTE

Please keep all NC, reserved and unused pins unconnected.

3.3. Operating Modes

The table below summarizes different operating modes of EM12.

Table 5: Overview of Operating Modes

Mode	Details	
Normal Operation mode	Idle	Software is active. The module has registered on the network, and it is ready to send and receive data.
	Talk/Data	Network connection is ongoing. In this mode, the power consumption is decided by network setting and data transfer rate.
Minimum Functionality Mode	**AT+CFUN=0** command can set the module to a minimum functionality mode without removing the power supply. In this case, both RF function and (U)SIM card will be invalid.	
Airplane Mode	**AT+CFUN=4** command or driving W_DISABLE1# pin to low level can set the module to airplane mode. In this case, RF function will be invalid.	
Sleep Mode	In this mode, the current consumption of the module will be reduced to the minimal level. In this mode, the module can still receive paging message, SMS, voice call and TCP/UDP data from the network normally.	
Power Down Mode	In this mode, the power management unit shuts down the power supply. Software is not active. The USB interface is not accessible. Operating voltage (connected to VCC) remains applied.	

NOTE

Please refer to ***document [3]*** for more details about **AT+CFUN** command.

3.4. Power Saving

3.4.1. Sleep Mode

DRX of EM12 is able to reduce the current consumption to a minimum value during the sleep mode, and DRX cycle index 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.

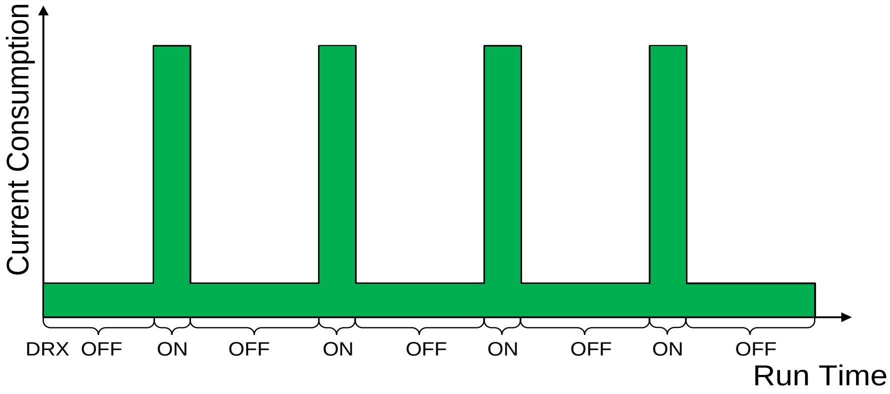


Figure 3: DRX Run Time and Current Consumption in Sleep Mode

The following section describes power saving procedure of EM12.

3.4.1.1. USB Application with USB Remote Wakeup Function

If the host supports USB suspend/resume and remote wakeup function, the following two preconditions must be met to let the module enter the sleep mode.

- Execute **AT+QSCLK=1** command to enable the sleep mode.
- The host's USB bus, which is connected with the module's USB interface, has entered suspension state.

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

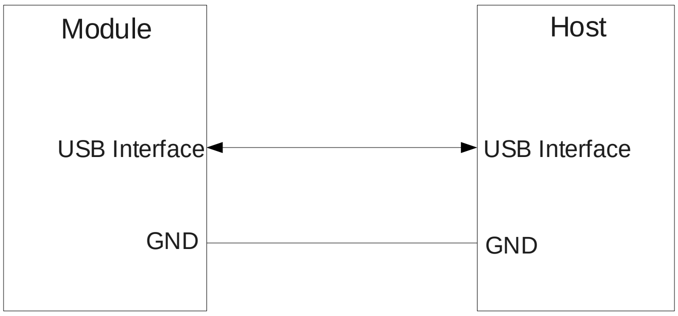


Figure 4: Sleep Mode Application with USB Remote Wakeup

- Sending data to EM12 through USB will wake up the module.
- When EM12 has a URC to report, the module will send remote wake-up signals via USB bus to wake up the host.

3.4.2. Airplane Mode

EM12 provides a W_DISABLE1# signal to disable or enable airplane mode through hardware operation. Please refer to ***Chapter 3.12.1*** for more details.

3.5. Power Supply

The following table shows pin definition of VCC pins and ground pins.

Table 6: Pin Definition of VCC and GND

Pin Name	Pin No.	I/O	Power Domain	Description
VCC	2, 4, 70, 72, 74	PI	3.135V~4.4V	3.7V typical DC supply
GND	3, 5, 11, 27, 33, 39, 45, 51, 57, 71, 73			Ground

3.5.1. Decrease Voltage Drop

The power supply range of the module is from 3.135V to 4.4V. Please make sure that the input voltage will never drop below 3.135V, otherwise the module will be turned off automatically. The following figure shows the maximum voltage drop during radio transmission in 3G and 4G networks.

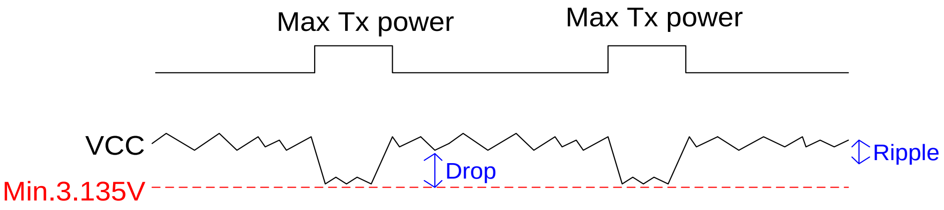


Figure 5: Power Supply Limits during Radio Transmission

To decrease voltage drop, a bypass capacitor of about 220µF with low ESR (ESR=0.7Ω) should be used, and a multi-layer ceramic chip capacitor (MLCC) array should also be reserved due to its ultra-low ESR. It is recommended to use three ceramic capacitors (100nF, 33pF, 10pF) for composing the MLCC array, and place these capacitors close to VCC pins. The main power supply from an external application has to be a single voltage source. The width of VCC trace should be no less than 2mm. In principle, the longer the VCC trace is, the wider it will be.

In addition, in order to get a stable power source, it is recommended to use a zener diode with reverse zener voltage of 5.1V and dissipation power more than 0.5W. The following figure shows a reference circuit of VCC.

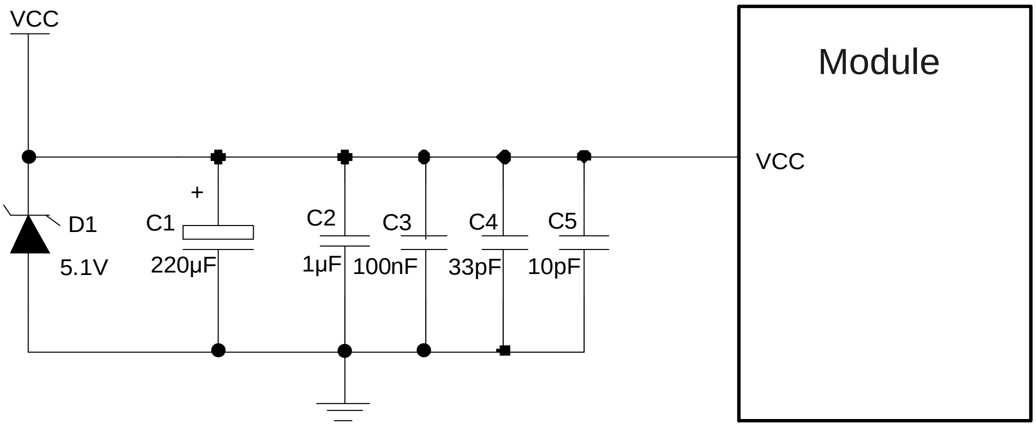


Figure 6: Reference Circuit of VCC

3.5.2. Reference Design for Power Supply

Power design for the module is very important, as the performance of the module largely depends on the power source. The power supply is capable of providing sufficient current up to 2A at least. If the voltage drop between the input and output is not too high, it is suggested that an LDO should be used to supply power for the module. If there is a big voltage difference between the input source and the desired output (VCC), a buck converter is preferred to be used as the power supply.

The following figure shows a reference design for +5V input power source. The typical output of the power supply is about 3.7V and the maximum load current is 3A.

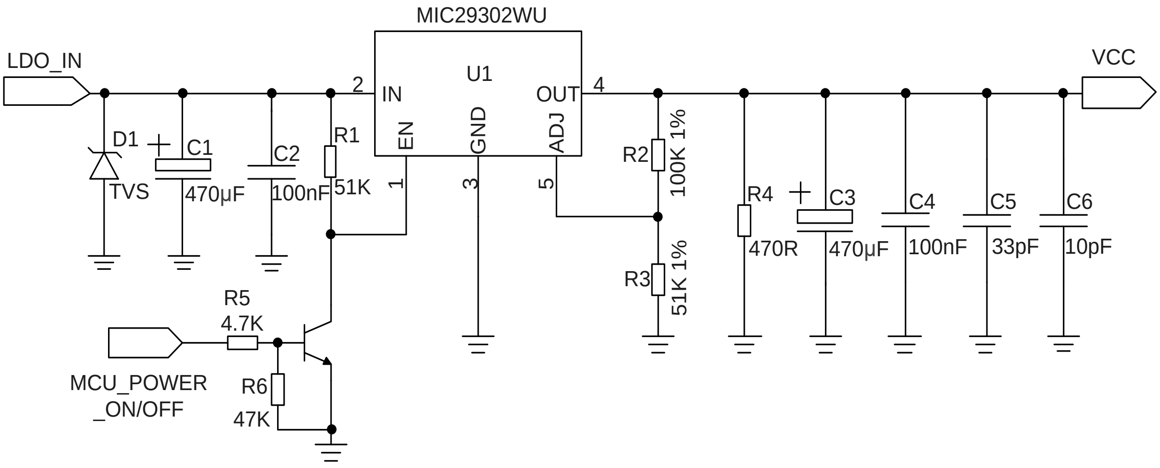


Figure 7: Reference Design of Power Supply

NOTE

In order to avoid damages to the internal flash, please do not switch off the power supply directly when the module is working. The power supply can be cut off only after the module is turned off by FULL_CARD_POWER_OFF# or AT command.

3.6. Turn on and off Scenarios

3.6.1. Turn on/off the Module through FULL_CARD_POWER_OFF#

Driving the FULL_CARD_POWER_OFF# pin to high level will turn on the module, while driving it to low level will turn off the module.

The following table shows the pin definition.

Table 7: Pin Definition of FULL_CARD_POWER_OFF#

Pin Name	Pin No.	Description	DC Characteristics	Comment
FULL_CARD_POWER_OFF#	6	Turn on/off the module. When it is at low level, the module is turned off. When it is at high level, the module is turned on.	V_{IH}max=4.4V V_{IH}min=1.19V V_{IL}max=0.2V	Pulled down internally.

3.6.1.1. Reference Circuit for GPIO Controlled FULL_CARD_POWER_OFF#

It is recommended to use a GPIO pin of the host to control FULL_CARD_POWER_OFF#. A simple reference circuit is illustrated in the following figure.

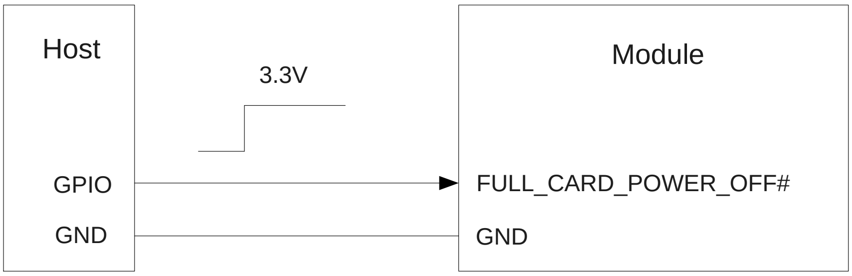


Figure 8: Turn on/off the Module through GPIO Controlled FULL_CARD_POWER_OFF#

3.6.1.2. Timing of Turn on/off the Module through FULL_CARD_POWER_OFF#

The turn-on/off scenarios are illustrated in the following figures.

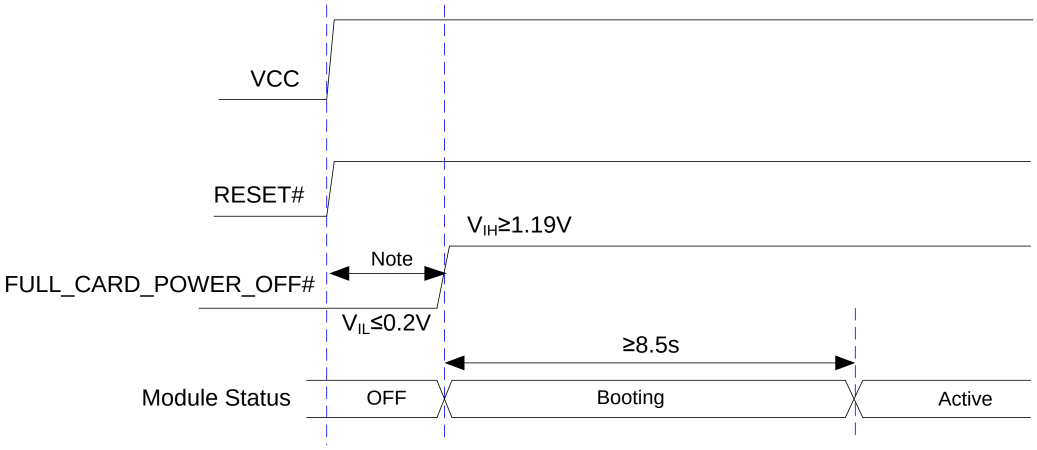


Figure 9: Timing of Turning on the Module through FULL_CARD_POWER_OFF#

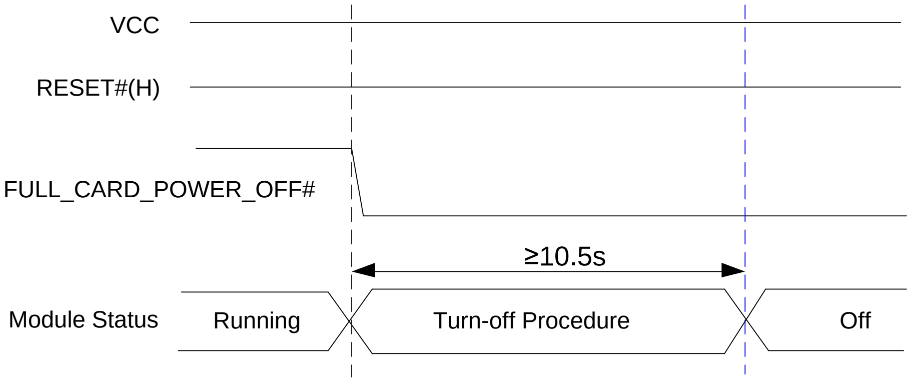


Figure 10: Timing of Turning off the Module through FULL_CARD_POWER_OFF#

NOTE

Please ensure that VCC is stable for no less than 30ms before pulling up FULL_CARD_POWER_OFF# pin.

3.6.2. Turn off the Module through AT Command

The module can also be turned off by **AT+QPOWD** command. Please refer to ***document [3]*** for more details.

The module operates as a USB peripheral, responding to requests from a host such as a PC. After executing the AT command, the USB connection will be removed within seconds, and then the module will be turned off.

NOTE

The host should be able to pull down FULL_CARD_POWER_OFF# pin, or cut off power supply of VCC immediately once the USB disconnection has been detected, otherwise the module will be powered on again.

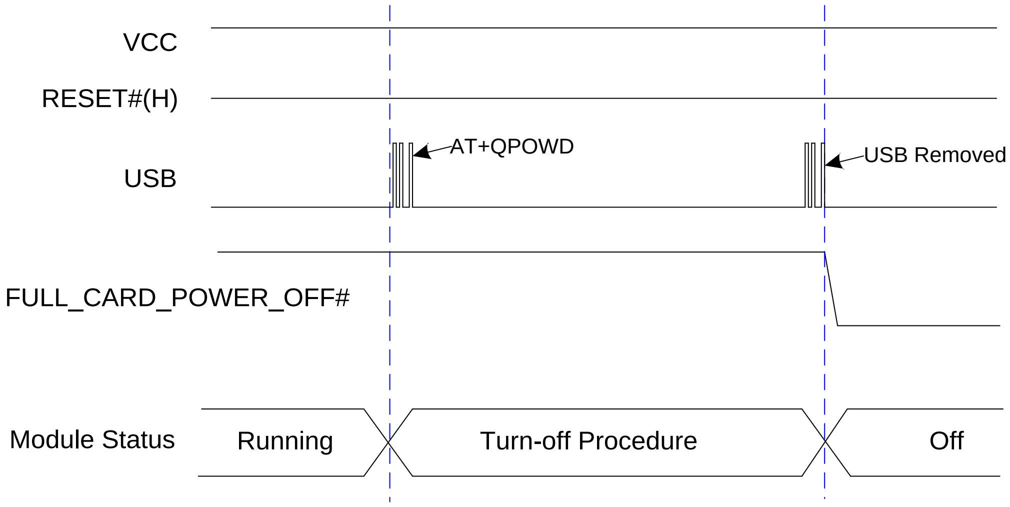


Figure 11: Timing of Turning off the Module through AT Command and FULL_CARD_POWER_OFF#

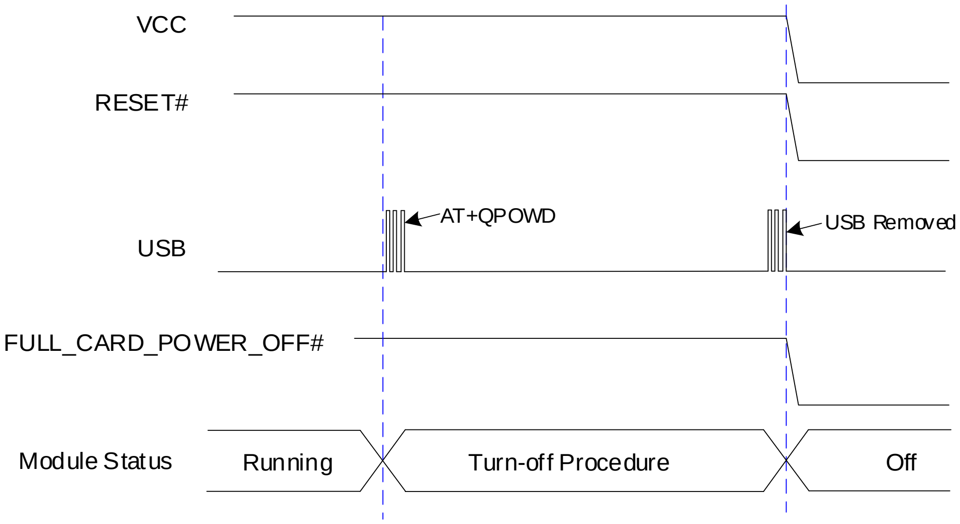


Figure 12: Timing of Turning off the Module through AT Command and Power Supply

3.7. Reset the Module

The RESET# pin is used to reset the module. The module can be reset by driving RESET# to a low level voltage for 280ms~600ms.

Table 8: Pin Definition of RESET#

Pin Name	Pin No.	Description	DC Characteristics	Comment
RESET#	67	Module reset. Active low.	V_{IH}max=2.1V V_{IH}min=1.3V V_{IL}max=0.5V	

An open collector driver or button can be used to control the RESET# pin.

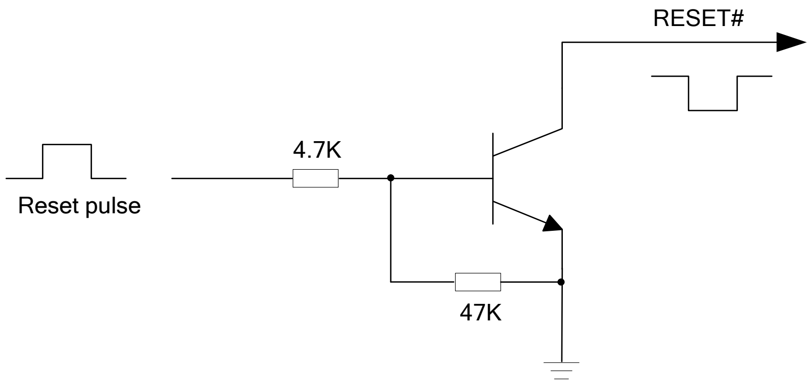


Figure 13: Reference Circuit of RESET# with a Driving Circuit

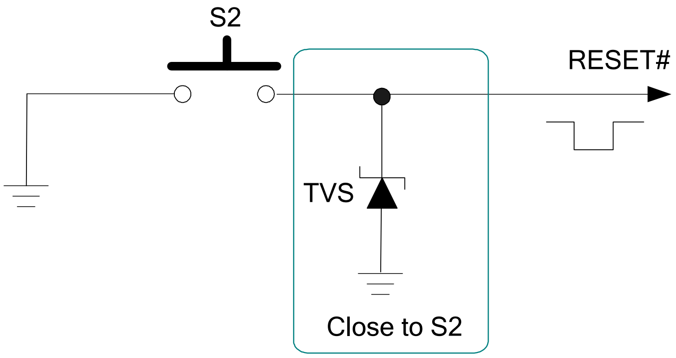


Figure 14: Reference Circuit of RESET# with a Button

The reset scenario is illustrated in the following figure.

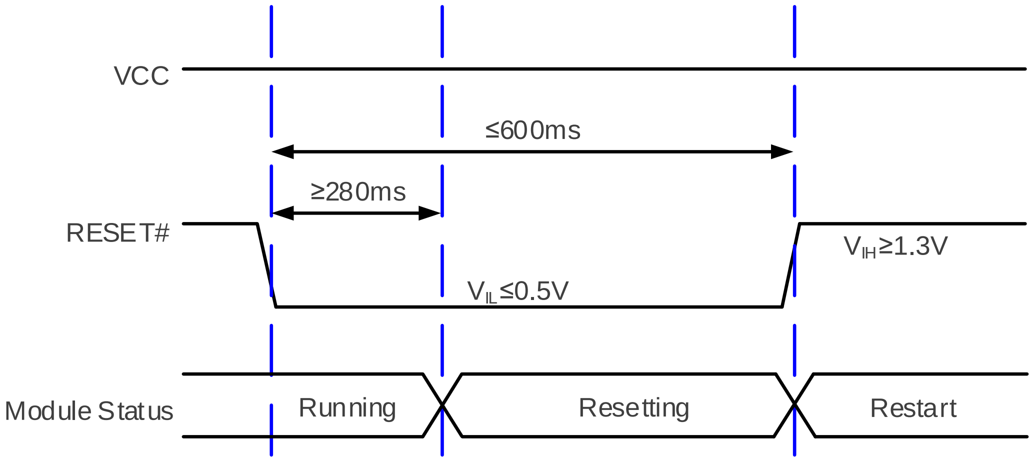


Figure 15: Timing of Resetting the Module

NOTE

Please ensure that there is no capacitance on RESET# pin.

3.8. (U)SIM Interfaces

The (U)SIM interface circuitry meets ETSI and IMT-2000 requirements. Both 1.8V and 3.0V (U)SIM cards are supported, and Dual SIM Single Standby function is supported.

Table 9: Pin Definition of (U)SIM Interfaces

Pin Name	Pin No.	I/O	Description	Comment
USIM1_VDD	36	PO	Power supply for (U)SIM1 card	Either 1.8V or 3.0V is supported by the module automatically.
USIM1_DATA	34	IO	(U)SIM1 card data	
USIM1_CLK	32	DO	(U)SIM1 card clock	
USIM1_RESET	30	DO	(U)SIM1 card reset	
USIM1_DET	66	DI	(U)SIM1 card insertion detection. Active high.	Pulled up internally. 1.8V power domain.
USIM2_VDD	48	PO	Power supply for (U)SIM2 card	Either 1.8V or 3.0V is supported by the module automatically.

USIM2_DATA	42	IO	(U)SIM2 card data	
USIM2_CLK	44	DO	(U)SIM2 card clock	
USIM2_RESET	46	DO	(U)SIM2 card reset	
USIM2_DET	40	DI	(U)SIM2 card insertion detection. Active high.	Pulled up internally. 1.8V power domain.

EM12 supports (U)SIM card hot-plug via the USIM_DET pin, which is a level trigger pin. The USIM_DET is normally short-circuited to ground when (U)SIM card is not inserted. When the (U)SIM card is inserted, the USIM_DET will change from low to high level. The rising edge will indicate insertion of the (U)SIM card. When the (U)SIM card is removed, the USIM_DET will change from high to low level. This falling edge will indicate the absence of the (U)SIM card.

The following figure shows a reference design of (U)SIM interface, with a normally closed card detection switch.

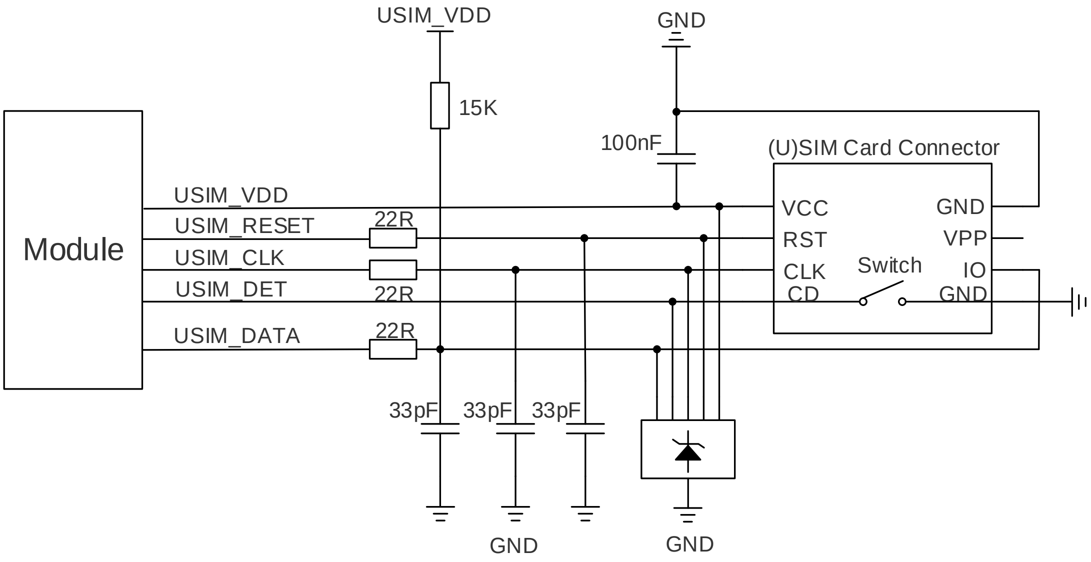


Figure 16: Reference Circuit for (U)SIM Card Connector Connection (Normally Closed Switch)

(U)SIM card connector with normally closed card detection switch:

- When the (U)SIM card is absent, the switch is closed and USIM_DET is at low level.
- When the (U)SIM card is inserted, the switch is open and USIM_DET is at high level.

The following figure shows a reference design of (U)SIM interface, with a normally open card detection switch.

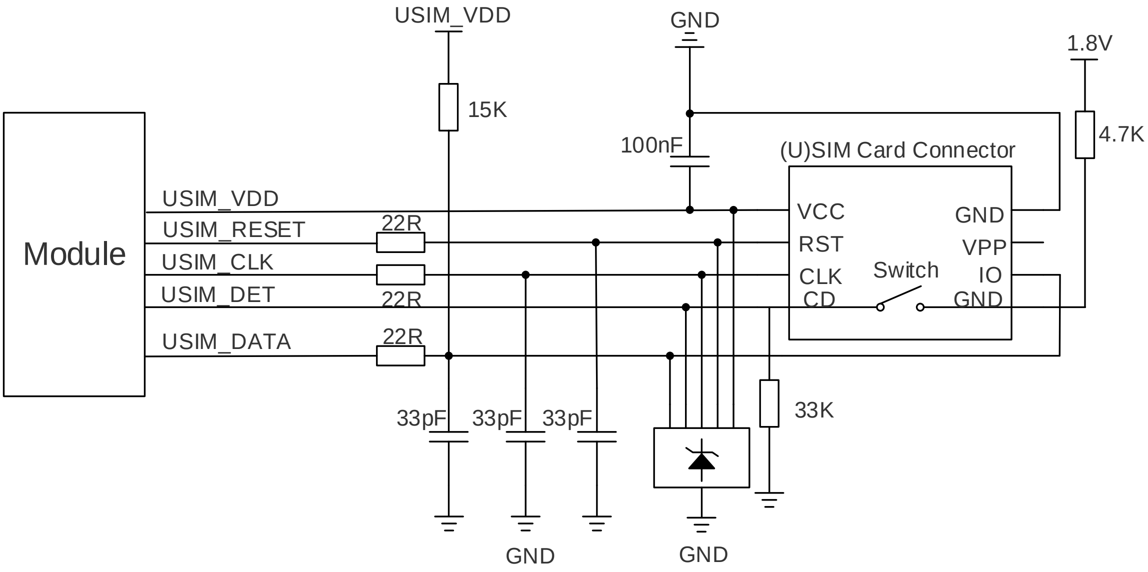


Figure 17: Reference Circuit for (U)SIM Card Connector Connection (Normally Open Switch)

(U)SIM card connector with normally open card detection switch:

- When the (U)SIM card is absent, the switch is open and USIM_DET is at low level.
- When the (U)SIM card is inserted, the switch is closed and USIM_DET is at high level.

If (U)SIM card detection function 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 in the following figure.

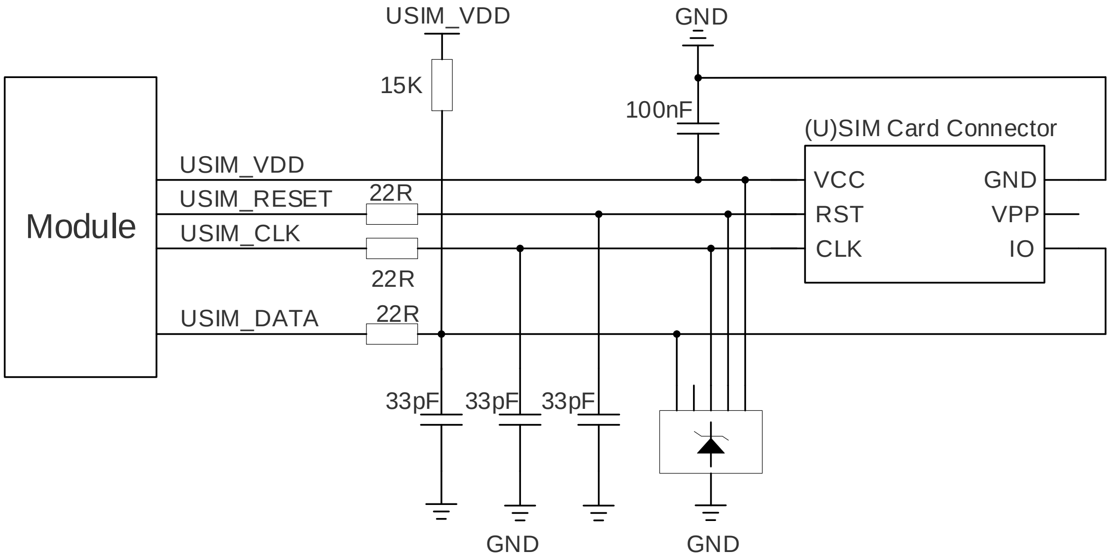


Figure 18: Reference Circuit of a 6-Pin (U)SIM Card Connector

In order to enhance the reliability and availability of the (U)SIM card in customers' applications, please follow the criteria below in (U)SIM circuit design:

- Keep (U)SIM card connector as close as possible to the module. Keep the trace length less than 200mm.
- Keep (U)SIM card signals away from RF and VCC traces.
- Keep the ground traces between the module and the (U)SIM card connector short and wide. Keep the trace width of ground and USIM_VDD no less than 0.5mm to maintain the same electric potential.
- To avoid cross-talk between USIM_DATA and USIM_CLK, keep them away from each other and shield them with surrounded ground.
- To offer good ESD protection, it is recommended to add a TVS diode array with parasitic capacitance not exceeding 10pF. The 22Ω resistors should be added in series between the module and the (U)SIM card connector so as to suppress EMI spurious transmission and enhance ESD protection. The 33pF capacitors are used to filter out RF interference. Please note that the (U)SIM peripheral circuit should be close to the (U)SIM card connector.
- The pull-up resistor on the USIM_DATA line can improve anti-jamming capability and should be placed close to the (U)SIM card connector.

3.9. USB Interface

EM12 provides one integrated Universal Serial Bus (USB) interface which complies with USB 3.0 and USB 2.0 specifications. It supports super speed (5 Gbps) on USB 3.0, 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, GNSS NMEA output, software debugging, firmware upgrade and voice over USB*.

The following table shows the pin definition of USB interface.

Table 10: Pin Definition of USB Interface

Pin Name	Pin No.	I/O	Description	Comment
USB_DP	7	AI/AO	USB 2.0 differential data bus (+)	Require differential impedance of 90Ω
USB_DM	9	AI/AO	USB 2.0 differential data bus (-)	
USB3.0_TX-	29	AO	USB 3.0 transmit data (-)	Require differential impedance of 90Ω
USB3.0_TX+	31	AO	USB 3.0 transmit data (+)	
USB3.0_RX-	35	AI	USB 3.0 receive data (-)	Require differential impedance of 90Ω
USB3.0_RX+	37	AI	USB 3.0 receive data (+)	

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

The USB interface is recommended to be reserved for firmware upgrade in customers' designs. The following figure shows a reference circuit of USB 2.0 & USB 3.0 interface.

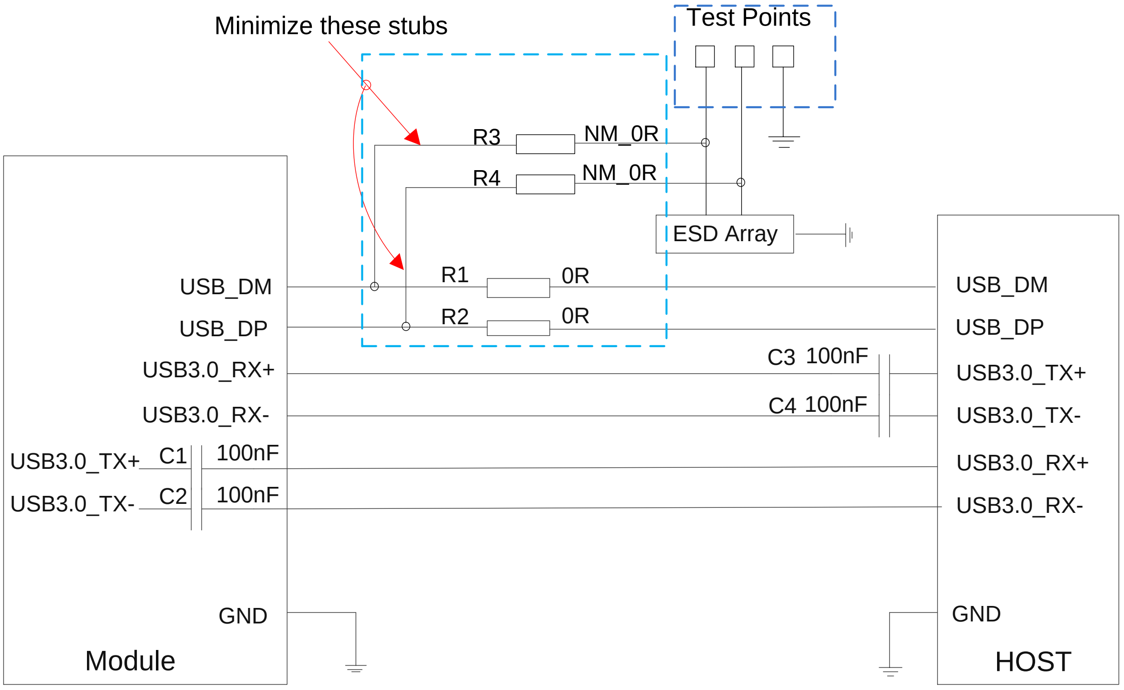


Figure 19: Reference Circuit of USB 2.0 & 3.0 Interface

In order to ensure the signal integrity of USB data lines, C1 and C2 have been placed inside the module, C3 and C4 should be placed close to the host, and R1, R2, R3 and R4 should be placed close to the module and also close to each other. The extra stubs of traces must be as short as possible.

The following principles of USB interface design should be complied with, so as to meet USB 2.0 & USB 3.0 specifications.

- It is important to route the USB 2.0 & 3.0 signal traces as differential pairs with total grounding. The differential impedance of USB differential pairs should be controlled to 90Ω.
- For USB 2.0 signal traces, the trace lengths must be less than 120mm, the differential data pair matching is less than 2mm (15ps).
- For USB 3.0 signal traces, the maximum length of TX and RX differential data pair is recommended to be less than 100mm, the TX and RX differential data pair matching is less than 0.7mm (5ps).
- Do not route signal traces under crystals, oscillators, magnetic devices or RF signal traces. It is important to route the USB 2.0 & 3.0 differential traces in inner-layer of the PCB, and surround the traces with ground on that layer and with ground planes above and below.
- If a USB connector is used, please keep the ESD protection components as close as possible to the USB connector. Pay attention to the influence of junction capacitance of ESD protection components

on USB 2.0 & 3.0 data traces. The capacitance value of ESD protection components should be less than 2.0pF for USB 2.0, and less than 0.4pF for USB 3.0.

- If possible, reserve a 0Ω resistor on USB_DP and USB_DM lines respectively.

NOTE

"*" means under development.

3.10. PCIe Interface*

EM12 provides one integrated PCIe (Peripheral Component Interconnect Express) interface which complies with the *PCI Express Specification, Revision 2.1* and supports 5Gbps per lane. The PCIe interface of EM12 is only used for data transmission.

- *PCI Express Specification, Revision 2.1* compliance
- Data rate at 5Gbps per lane
- Can be used to connect to an external Ethernet IC (MAC and PHY) or WLAN IC

The following table shows the pin definition of PCIe interface.

Table 11: Pin Definition of PCIe Interface

Pin Name	Pin No.	I/O	Description	Comment
PCIE_REFCLK+	55	AI/AO	PCIe reference clock (+)	If unused, keep them open.
PCIE_REFCLK-	53	AI/AO	PCIe reference clock (-)	
PCIE_RX+	49	AI	PCIe receive data (+)	If unused, keep them open.
PCIE_RX-	47	AI	PCIe receive data (-)	
PCIE_TX+	43	AO	PCIe transmit data (+)	If unused, keep them open.
PCIE_TX-	41	AO	PCIe transmit data (-)	
PCIE_RST_N	50	DI	PCIe reset. Active low.	If unused, keep it open.
PCIE_CLKREQ_N	52	DO	PCIe clock request. Active low.	If unused, keep it open.
PCIE_WAKE_N	54	DO	PCIe wakes up host. Active low.	If unused, keep it open.

The following figure shows a reference circuit of PCIe endpoint mode.

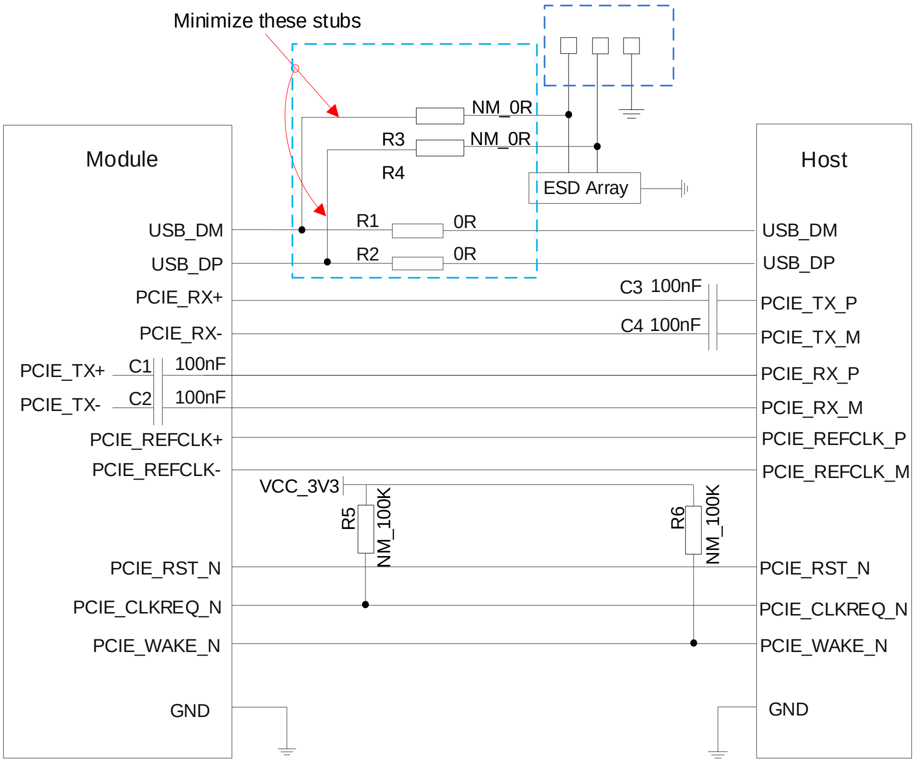


Figure 20: PCIe Interface Reference Circuit (EP Mode)

To ensure the signal integrity of PCIe interface, C1 and C2 have been placed inside the module. C3 and C4 should be placed close to the host, and R1, R2, R3 and R4 should be placed close to the module and also close to each other. The extra stubs of traces must be as short as possible.

The following principles of PCIe interface design should be complied with, so as to meet PCIe V2.1 specifications.

- It is important to route the USB 2.0 & PCIe signal traces as differential pairs with total grounding.
- For USB 2.0 signal traces, the trace lengths must be less than 120mm, the differential data pair matching is less than 2mm (15ps).
- For PCIe signal traces, the TX and RX differential data pair maximum length is recommended to be less than 250mm, the TX and RX differential data pair matching are less than 0.7mm (5ps).
- Do not route signal traces under crystals, oscillators, magnetic devices or RF signal traces. It is important to route the PCIe differential traces in inner-layer of the PCB, and surround the traces with ground on that layer and with ground planes above and below.
- If possible, reserve a 0Ω resistor on USB_DP and USB_DM lines respectively.

NOTES

1. USB is required because PCIe does not support features such as firmware upgrade, GNSS NMEA output and software debugging. Firmware upgrade must be over USB 2.0, while GNSS NMEA output and software debugging can be over USB 2.0/3.0 (USB 2.0 is recommended).
2. "*" means under development.

3.11. PCM and I2C Interfaces

EM12 supports audio communication via Pulse Code Modulation (PCM) digital interface and I2C interface.

The PCM interface supports the following modes:

- Primary mode (short frame synchronization, works as both master and slave)
- Auxiliary mode (long frame synchronization, works as master only)

In primary mode, the data is sampled on the falling edge of the PCM_CLK and transmitted on the rising edge. The PCM_SYNC falling edge represents the MSB. In this mode, the PCM interface supports 256kHz, 512kHz, 1024kHz or 2048kHz PCM_CLK at 8kHz PCM_SYNC, and also supports 4096kHz PCM_CLK at 16kHz PCM_SYNC.

In auxiliary mode, the data is sampled on the falling edge of the PCM_CLK and transmitted on the rising edge. The PCM_SYNC rising edge represents the MSB. In this mode, PCM interface operates with a 256kHz PCM_CLK and an 8kHz, 50% duty cycle PCM_SYNC only.

EM12 supports 16-bit linear data format. The following figures show the primary mode's timing relationship with 8kHz PCM_SYNC and 2048kHz PCM_CLK, as well as the auxiliary mode's timing relationship with 8kHz PCM_SYNC and 256kHz PCM_CLK.

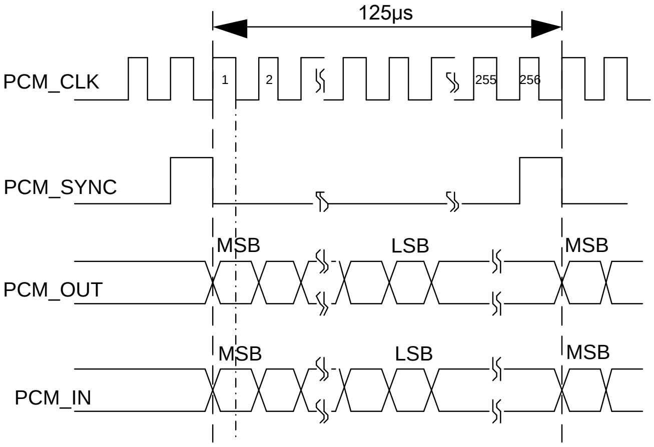


Figure 21: Primary Mode Timing

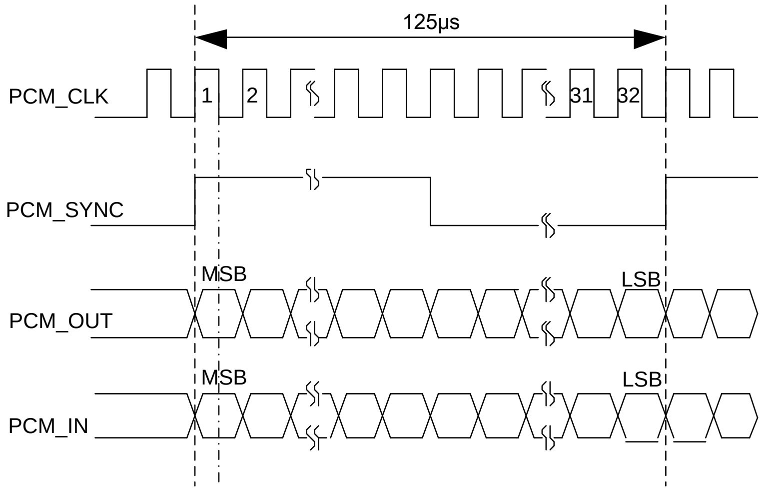


Figure 22: Auxiliary Mode Timing

The following table shows the pin definition of PCM and I2C interfaces which can be applied on audio codec design.

Table 12: Pin Definition of PCM and I2C Interfaces

Pin Name	Pin No.	I/O	Description	Comment
PCM_IN	22	DI	PCM data input	1.8V power domain.
PCM_OUT	24	DO	PCM data output	1.8V power domain.
PCM_SYNC	28	IO	PCM data frame synchronization	1.8V power domain.
PCM_CLK	20	IO	PCM data bit clock. In master mode, it is an output signal. In slave mode, it is an input signal.	1.8V power domain. If unused, keep it open.
I2C_SCL	58	DO	I2C serial clock for external codec.	Require an external pull-up to 1.8V.
I2C_SDA	56	IO	I2C serial data for external codec.	

The clock and mode can be configured by AT command, and the default configuration is master mode using short frame synchronization format with 2048kHz PCM_CLK and 8kHz PCM_SYNC. Please refer to ***document [3]*** for details about **AT+QDAI** command.

The following figure shows a reference design of PCM interface with an external codec IC.

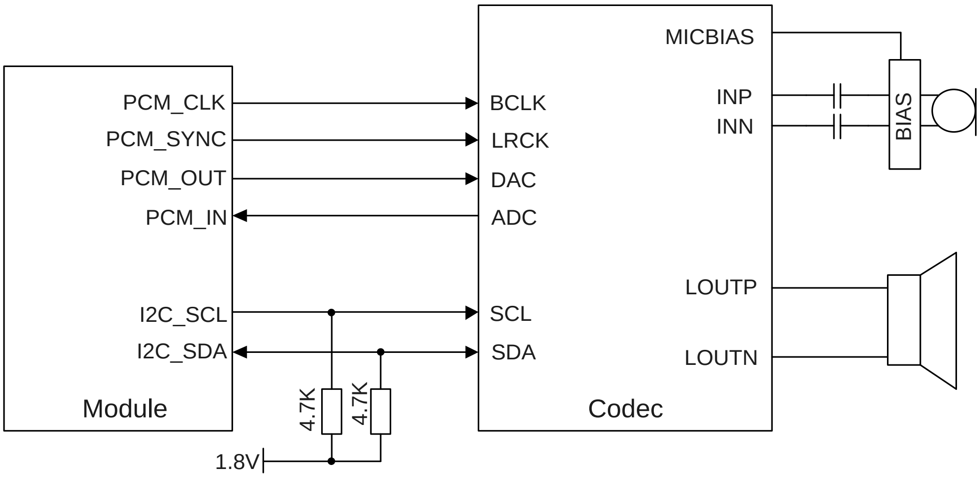


Figure 23: Reference Circuit of PCM Application with Audio Codec

NOTES

1. It is recommended to reserve an RC (R=22Ω, C=22pF) circuit on the PCM lines, especially for PCM_CLK.
2. EM12 works as a master device pertaining to I2C interface.

3.12. Control and Indication Signals

The following table shows the pin definition of control and indication signals.

Table 13: Pin Definition of Control and Indication Signals

Pin Name	Pin No.	I/O	Power Domain	Description
W_DISABLE1#	8	DI	1.8V/3.3V	Airplane mode control. Active low.
W_DISABLE2#	26	DI	1.8V/3.3V	GNSS enable control. Active low.
WWAN_LED#	10	OD	3.3V	RF status indication. Active low.
WAKE_ON_WAN#	23	OD	1.8V/3.3V	Wake up the host. Active low.
DPR	25	DI	1.8V	Dynamic power reduction. Active low.

3.12.1. W_DISABLE1# Signal

EM12 provides a W_DISABLE1# pin to disable or enable the RF function (excluding GNSS). The W_DISABLE1# pin is pulled up by default. When **AT+CFUN=1**, driving W_DISABLE1# low will make the module enter airplane mode. In airplane mode, the RF function will be disabled.

Table 14: Airplane Mode Controlled by Hardware

W_DISABLE1#	RF Function Status	Module Operating Mode
High level	RF enabled	Full functionality mode
Low level	RF disabled	Airplane mode

The RF function can also be enabled or disabled through AT commands, and the details are as follows.

Table 15: Airplane Mode Controlled by Software

AT+CFUN=?	RF Function Status	Module Operating Mode
0	RF and (U)SIM disabled	Minimum functionality mode
1	RF enabled	Full functionality mode
4	RF disabled	Airplane mode

3.12.2. W_DISABLE2# Signal

EM12 provides a W_DISABLE2# signal to disable or enable the GNSS function. The W_DISABLE2# pin is pulled up by default. Driving it to low level will disable the GNSS function.

By default, GNSS engine of the module is switched off. It has to be switched on by AT commands. The following table shows the GNSS function status of the module.

Table 16: GNSS Function Status

W_DISABLE2# Level	AT Commands	GNSS Function
High Level	**AT+QGPS=1**	Enabled
	AT+QGPSEND	Disabled
Low Level	**AT+QGPS=1**	Disabled
	AT+QGPSEND	

NOTE

Please refer to ***document [4]*** for more details about **AT+QGPS** command.

3.12.3. WWAN_LED# Signal

The WWAN_LED# signal is used to indicate the RF status of the module, and its typical current consumption is up to 10mA.

In order to reduce the current consumption of the LED, a resistor must be placed in series with the LED, as illustrated in the figure below. The LED is ON when the WWAN_LED# signal is at a low voltage level.

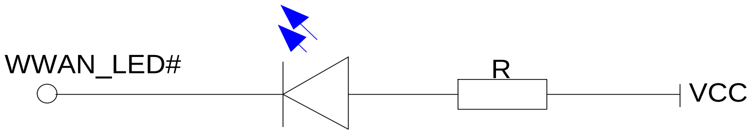


Figure 24: WWAN_LED# Signal Reference Circuit

The following table shows the RF status indicated by WWAN_LED# signal and the AT commands used to control WWAN_LED#.

Table 17: RF Status Indication and LED Control Commands

WWAN_LED# Level	LED	RF Status	AT Commands Used to Control WWAN_LED#
Low Level	On	On	**AT+QPMUGPIO=1,3**
High Level	Off	Off	**AT+QPMUGPIO=0,3**

NOTES

1. RF function is turned off if any of the following circumstances occurs:
   - The (U)SIM card is not working.
   - W_DISABLE1# signal is at low level (airplane mode enabled).
2. Please refer to ***document [3]*** for more details about **AT+QPMUGPIO** command.

3.12.4. WAKE_ON_WAN# Signal*

The WAKE_ON_WAN# signal is an open collector signal, which requires a pull-up resistor on the host. When a URC returns, a 1s low level pulse signal will be outputted to wake up the host. The module operation status indicated by WAKE_ON_WAN# is shown as below.

Table 18: States of the WAKE_ON_WAN# Signal

WAKE_ON_WAN# States	Module Operation Status
Output a 1s low level pulse signal	Incoming call/SMS/data received (to wake up the host)
Always at high level	Idle/Sleep

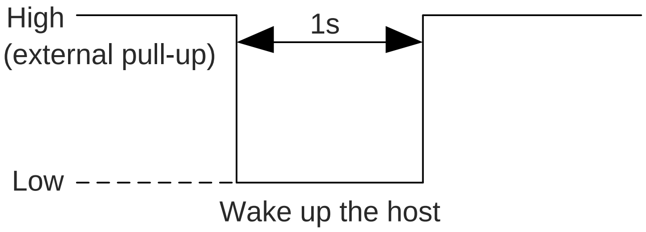


Figure 25: WAKE_ON_WAN# Behavior

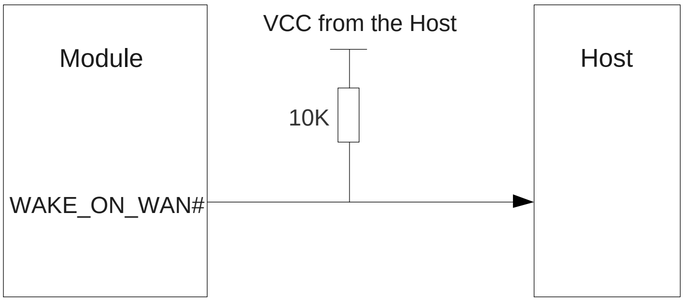


Figure 26: Reference Circuit of WAKE_ON_WAN#

NOTE

"*" means under development.

3.12.5. DPR Signal

EM12 provides a DPR (Dynamic Power Reduction) signal for body SAR (Specific Absorption Rate) detection. The signal is provided by a host proximity sensor to trigger the reduction of radio transmit output power.

Table 19: Function of the DPR Signal

DPR Level	Function
High/Floating	Max transmitting power will NOT be backed off
Low	Max transmitting power will be backed off by executing **AT+QCFG="sarcfg"** command

NOTE

Please refer to ***document [3]*** for more details about **AT+QCFG="sarcfg"** command.

3.13. Antenna Tuner Control Interface*

ANTCTL[0:3] signals are used for antenna tuner control and should be routed to an appropriate antenna control circuitry.

More details about the interface will be added in a future version of the document.

Table 20: Pin Definition of Antenna Tuner Control Interface

Pin Name	Pin No.	I/O	Description	Comment
ANTCTL0	59	DO	Antenna tuner control	1.8V power domain
ANTCTL1	61	DO	Antenna tuner control	1.8V power domain

ANTCTL2	63	DO	Antenna tuner control	1.8V power domain
ANTCTL3	65	DO	Antenna tuner control	1.8V power domain

NOTE

"*" means under development.

3.14. Configuration Pins

EM12 provides 4 configuration pins and is configured as WWAN-USB 3.0.

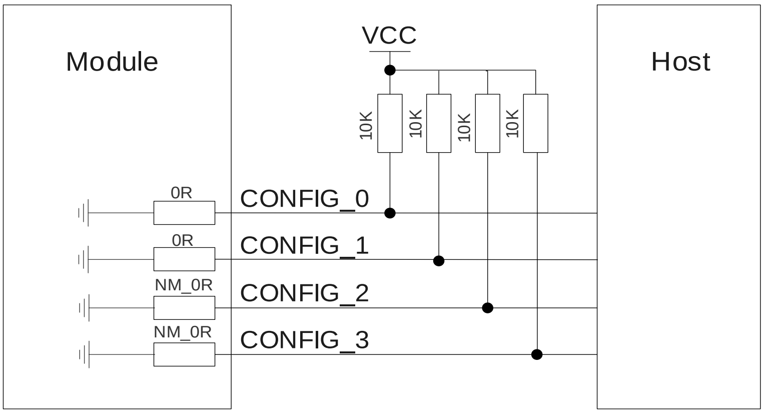


Figure 27: Reference Circuit of Configuration Pins

Table 21: Pin Definition of Configuration Pins

Pin Name	Pin No.	Description
CONFIG_0	21	Connected to GND internally.
CONFIG_1	69	
CONFIG_2	75	Not connected internally.
CONFIG_3	1	

The 4 pins on EM12 module are defined as below:

Table 22: List of Configuration Pins

Config_0 (Pin 21)	Config_1 (Pin 69)	Config_2 (Pin 75)	Config_3 (Pin 1)	Module Type and Main Host Interface	Port Configuration
GND	GND	NC	NC	WWAN-USB 3.0	2

4 GNSS Receiver

4.1. General Description

EM12 includes a fully integrated global navigation satellite system solution that supports Gen9HT-Lite of Qualcomm (GPS, GLONASS, BeiDou, Galileo and QZSS).

The module supports standard NMEA-0183 protocol, and outputs NMEA sentences at 1Hz data update rate via USB interface by default.

The GNSS receive path uses either the dedicated GNSS connector or the DIV&GNSS connector. And the GNSS antenna connection can be configured by the following AT command.

AT+QCFG	**Configure GNSS Antenna Connection Mode**
Write Command **AT+QCFG="gpsdrx"**	Response **+QCFG: "gpsdrx", <mode>** **OK**
Write Command **AT+QCFG="gpsdrx",<mode>**	Response **OK** or **ERROR**

Parameter

<mode>	GNSS antenna connection mode. 0 GNSS antenna uses the dedicated GNSS connector. 1 GNSS antenna and DIV antenna share the DIV&GNSS connector.

For more details about GNSS engine technology and configurations, please refer to ***document [4]***.

4.2. GNSS Performance

The following table shows the GNSS performance of EM12.

Table 23: EM12-G GNSS Performance (DIV&GNSS Connector is Used)

Parameter	Description	Conditions	Typ.	Unit
Sensitivity (GNSS)	Cold start	Autonomous	-144	dBm
	Reacquisition	Autonomous	-158	dBm
	Tracking	Autonomous	-158	dBm
TTFF (GNSS)	Cold start @open sky	Autonomous	34.53	s
		XTRA enabled	19.05	s
	Warm start @open sky	Autonomous	30.49	s
		XTRA enabled	3.06	s
	Hot start @open sky	Autonomous	2.43	s
		XTRA enabled	3.71	s
Accuracy (GNSS)	CEP-50	Autonomous @open sky	<2.5	m

Table 24: EM12-G GNSS Performance (GNSS Connector is Used)

Parameter	Description	Conditions	Typ.	Unit
Sensitivity (GNSS)	Cold start	Autonomous	-144	dBm
	Reacquisition	Autonomous	-158	dBm
	Tracking	Autonomous	-157	dBm
TTFF (GNSS)	Cold start @open sky	Autonomous	35.93	s
		XTRA enabled	19.59	s
	Warm start @open sky	Autonomous	32.98	s
		XTRA enabled	2.84	s

	Hot start @open sky	Autonomous	3.23	s
		XTRA enabled	2.96	s
Accuracy (GNSS)	CEP-50	Autonomous @open sky	<2.5	m

NOTES

1. Tracking sensitivity: the minimum GNSS signal power at which the module can maintain lock (keep positioning for at least 3 minutes continuously).
2. Reacquisition sensitivity: the minimum GNSS signal power required for the module to maintain lock within 3 minutes after loss of lock.
3. Cold start sensitivity: the minimum GNSS signal power at which the module can fix positon successfully within 3 minutes after executing cold start command.

5 Antenna Connection

EM12 is mounted with three 2mm × 2mm antenna connectors (receptacles) for external antenna connection: a main antenna connector, a DIV&GNSS antenna connector, and a GNSS antenna connector. The impedance of the antenna connectors is 50Ω.

5.1. Main/DIV&GNSS/GNSS Antenna Connectors

5.1.1. Antenna Connectors

The main/DIV&GNSS/GNSS antenna connectors are shown as below.

Figure 28: Antenna Connectors on the Module

5.1.2. Operating Frequency

Table 25: EM12-G Operating Frequencies

3GPP Band	Transmit	Receive	Unit
WCDMA B1	1920~1980	2110~2170	MHz
WCDMA B2	1850~1910	1930~1990	MHz
WCDMA B3	1710~1785	1805~1880	MHz
WCDMA B4	1710~1755	2110~2155	MHz
WCDMA B5	824~849	869~894	MHz
WCDMA B8	880~915	925~960	MHz
WCDMA B9	1750~1785	1845~1880	MHz
WCDMA B19	830~845	875~890	MHz
LTE-FDD B1	1920~1980	2110~2170	MHz
LTE-FDD B2	1850~1910	1930~1990	MHz
LTE-FDD B3	1710~1785	1805~1880	MHz
LTE-FDD B4	1710~1755	2110~2155	MHz
LTE-FDD B5	824~849	869~894	MHz
LTE-FDD B7	2500~2570	2620~2690	MHz
LTE-FDD B8	880~915	925~960	MHz
LTE-FDD B9	1749.9~1784.9	1844.9~1879.9	MHz
LTE-FDD B12	699~716	729~746	MHz
LTE-FDD B13	777~787	746~756	MHz
LTE-FDD B14	788~798	758~768	MHz
LTE-FDD B17	704~716	734~746	MHz
LTE-FDD B18	815~830	860~875	MHz
LTE-FDD B19	830~845	875~890	MHz

LTE-FDD B20	832~862	791~821	MHz
LTE-FDD B21	1447.9~1462.9	1495.9~1510.9	MHz
LTE-FDD B25	1850~1915	1930~1995	MHz
LTE-FDD B26	814~849	859~894	MHz
LTE-FDD B28	703~748	758~803	MHz
LTE-FDD B29	/	717~728	MHz
LTE-FDD B30	2305~2315	2350~2360	MHz
LTE-FDD B32	/	1452~1496	MHz
LTE-TDD B38	2570~2620	2570~2620	MHz
LTE-TDD B39	1880~1920	1880~1920	MHz
LTE-TDD B40	2300~2400	2300~2400	MHz
LTE-TDD B41	2496~2690	2496~2690	MHz
LTE-FDD B66	1710~1780	2110~2200	MHz

5.1.3. GNSS Frequency

Table 26: GNSS Frequency

Type	Frequency	Unit
GPS	1575.42±1.023	MHz
GLONASS	1597.5~1605.8	MHz
Galileo	1575.42±2.046	MHz
BeiDou	1561.098±2.046	MHz
QZSS	1575.42	MHz

5.2. Receptacles and Mating Plugs

The receptacle dimensions are illustrated as below.

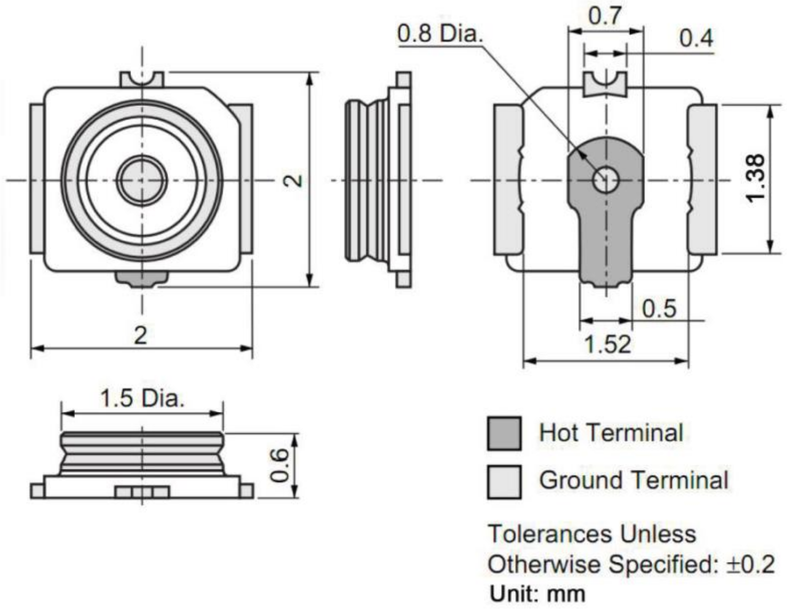


Figure 29: Dimensions of the Receptacles (Unit: mm)

Table 27: Major Specifications of the Antenna Connectors

Item	Specification
Nominal Frequency Range	DC to 6GHz
Nominal Impedance	50Ω
Temperature Rating	-40°C to +85°C
Voltage Standing Wave Ratio (VSWR)	Meet the requirements of: Max 1.3 (DC~3GHz) Max 1.45 (3GHz~6GHz)

The receptacle accepts two types of mating plugs to meet two maximum mated heights: 1.20mm (using a Ø0.81mm coaxial cable) and 1.45mm (using a Ø1.13mm coaxial cable).

The following figure shows the specifications of mating plugs using Ø0.81mm coaxial cables.

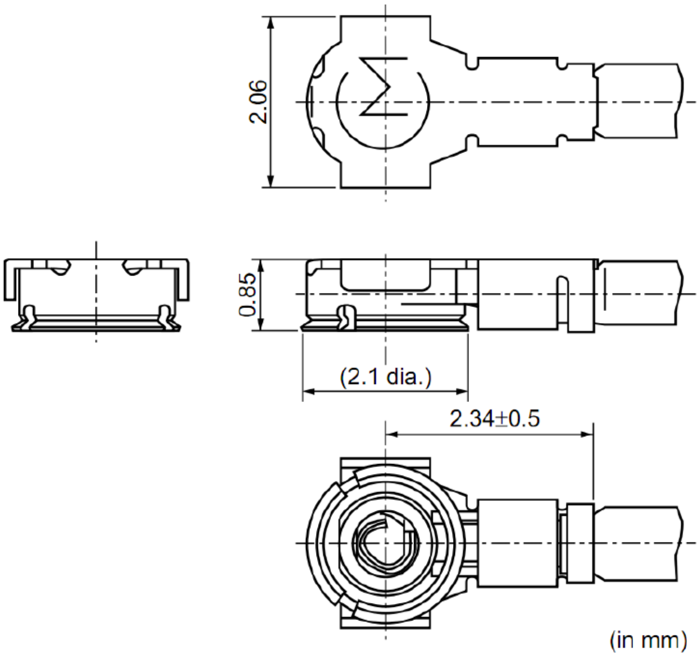


Figure 30: Specifications of Mating Plugs Using Ø0.81mm Coaxial Cables

The following figure illustrates the connection between the receptacle antenna connector on EM12 and the mating plug using a Ø0.81mm coaxial cable.

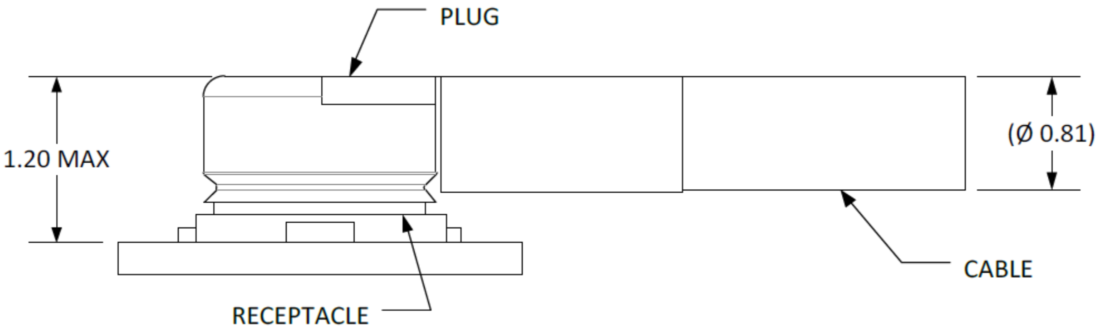


Figure 31: Connection between Receptacle and Mating Plug Using Ø0.81mm Coaxial Cable

The following figure illustrates the connection between the receptacle antenna connector on EM12 and the mating plug using a Ø1.13mm coaxial cable.

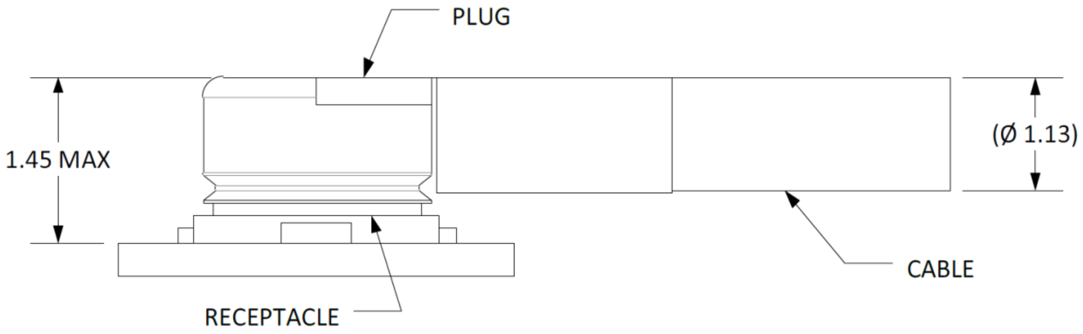


Figure 32: Connection between Receptacle and Mating Plug Using Ø1.13mm Coaxial Cable

5.3. Antenna Requirements

The following table shows the requirements on main antenna, Rx-diversity antenna and GNSS antenna.

Table 28: Antenna Requirements

Type	Requirements
GNSS[1]	Frequency Range: 1559MHz~1609MHz Polarization: RHCP or linear VSWR: <2 (Typ.) Passive Antenna Gain: >0dBi
WCDMA/LTE	VSWR: ≤2 Efficiency: >30% Max Input Power: 50W Input Impedance: 50Ω Cable Insertion Loss: <1dB (WCDMA B5/B8/B19, LTE B5/B8/B12/B13/B14/B17/B18/B19/B20/B26/B28/B29) Cable Insertion Loss: <1.5dB (WCDMA B1/B2/B3/B4/B9, LTE B1/B2/B3/B4/B9/B21/B25/B32/B39/B66) Cable Insertion Loss: <2dB (LTE B7/B30/B38/B40/B41)

NOTE

1) It is recommended to use a passive GNSS antenna when LTE B13 or B14 is supported, as the use of active antenna may generate harmonics which will affect the GNSS performance.

6 Electrical, Reliability and Radio Characteristics

6.1. Absolute Maximum Ratings

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

Table 29: Absolute Maximum Ratings

Parameter	Min.	Max.	Unit
VCC	-0.3	4.7	V
Voltage at Digital Pins	-0.3	2.3	V

6.2. Power Supply Requirements

The typical input voltage of EM12 is 3.7V, as specified by *PCIe M.2 Electromechanical Spec Rev1.0*. The following table shows the power supply requirements of EM12.

Table 30: Power Supply Requirements

Parameter	Description	Min.	Typ.	Max.	Unit
VCC	Power Supply	3.135	3.7	4.4	V

6.3. I/O Requirements

Table 31: I/O Requirements

Parameter	Description	Min.	Max.	Unit
V_{IH}	Input high voltage	$0.7 \times V_{DD18}$ 1)	$V_{DD18}+0.3$	V
V_{IL}	Input low voltage	-0.3	$0.3 \times V_{DD18}$	V
V_{OH}	Output high voltage	$V_{DD18}-0.5$	V_{DD18}	V
V_{OL}	Output low voltage	0	0.4	V

NOTE

1) V_{DD18} refers to I/O power domain.

6.4. Operation and Storage Temperatures

Table 32: Operation and Storage Temperatures

Parameter	Min.	Typ.	Max.	Unit
Operation Temperature Range 1)	-30	+25	+70	ºC
Extended Temperature Range 2)	-40		+85	ºC
Storage temperature Range	-40		+90	ºC

NOTES

1. 1) Within operation temperature range, the module is 3GPP compliant. For those end devices with bad thermal dissipation condition, a thermal pad or other thermal conductive components may be required between the module and main PCB to achieve the full operation temperature range.
2. 2) Within extended temperature range, proper mounting, heating sinks and active cooling may be required to make certain functions of the module such as voice, SMS, data transmission, emergency call to be realized. Only one or more parameters like P_{out} might reduce in their values and exceed the specified tolerances. When the temperature returns to normal operation temperature level, the module will meet 3GPP specifications again.

6.5. Current Consumption

Table 33: EM12-G Current Consumption

Parameter	Description	Conditions	Typ.	Unit
I_{VCC}	OFF State	Power down	56	μA
I_{VCC}	Sleep State	**AT+CFUN=0** (USB disconnected)	2.53	mA
		WCDMA PF=64 (USB disconnected)	3.37	mA
		WCDMA PF=128 (USB disconnected)	3.08	mA
		WCDMA PF=256 (USB disconnected)	2.82	mA
		LTE-FDD PF=64 (USB disconnected)	3.89	mA
		LTE-FDD PF=128 (USB disconnected)	3.19	mA
		LTE-FDD PF=256 (USB disconnected)	2.87	mA
		LTE-TDD PF=64 (USB disconnected)	3.92	mA
		LTE-TDD PF=128 (USB disconnected)	3.31	mA
		LTE-TDD PF=256 (USB disconnected)	2.91	mA
I_{VCC}	Idle State	WCDMA PF=64 (USB disconnected, band 1)	9.37	mA
		WCDMA PF=64 (USB active, band 1)	18.31	mA
		LTE-FDD PF=64 (USB disconnected, band 1)	10.13	mA
		LTE-FDD PF=64 (USB active, band 1)	19.11	mA
		LTE-TDD PF=64 (USB disconnected, band 38)	10.21	mA
		LTE-TDD PF=64 (USB active, band 38)	19.32	mA
		WCDMA B1 HSDPA CH10700 @21.1dBm	440	mA
		WCDMA B1 HSUPA CH10700 @22.6dBm	520	mA
		WCDMA B2 HSDPA CH9800 @21.2dBm	430	mA
		WCDMA B2 HSUPA CH9800 @22.7dBm	506	mA

I_{VCC}	WCDMA Data Transfer (GNSS Off)	WCDMA B3 HSDPA CH1338 @21.1dBm	423	mA
		WCDMA B3 HSUPA CH1338 @22.6Bm	482	mA
		WCDMA B4 HSDPA CH1638 @21.1dBm	421	mA
		WCDMA B4 HSUPA CH1638 @22.6dBm	487	mA
		WCDMA B5 HSDPA CH4407 @21.8dBm	345	mA
		WCDMA B5 HSUPA CH4407 @22.2dBm	400	mA
		WCDMA B8 HSDPA CH3012 @20.8dBm	367	mA
		WCDMA B8 HSUPA CH3012 @22.2dBm	427	mA
		WCDMA B9 HSDPA CH9312 @21.3dBm	427	mA
		WCDMA B9 HSUPA CH9312 @22.8dBm	490	mA
		WCDMA B19 HSDPA CH738 @21.0dBm	351	mA
		WCDMA B19 HSUPA CH738 @22.3dBm	400	mA
I_{VCC}	LTE Data Transfer (GNSS Off)	LTE-FDD B1 CH300 @23.0dBm	575	mA
		LTE-FDD B2 CH900 @22.8dBm	576	mA
		LTE-FDD B3 CH1575 @23.0dBm	559	mA
		LTE-FDD B4 CH2175 @23.0dBm	540	mA
		LTE-FDD B5 CH2525 @22.6dBm	450	mA
		LTE-FDD B7 CH3100 @22.3dBm	566	mA
		LTE-FDD B8 CH3625 @22.6dBm	463	mA
		LTE-FDD B9 CH3975 @23.0dBm	524	mA
		LTE-FDD B12 CH5095 @22.6dBm	442	mA
		LTE-FDD B13 CH5230 @22.4dBm	473	mA
		LTE-FDD B14 CH5330 @22.4dBm	453	mA
		LTE-FDD B17 CH5790 @22.5dBm	458	mA
		LTE-FDD B18 CH5925 @23.0dBm	521	mA

I_{VCC}	LTE Data Transfer (GNSS Off)	LTE-FDD B19 CH6075 @22.6dBm	472	mA
		LTE-FDD B20 CH6300 @23.2dBm	500	mA
		LTE-FDD B21 CH6525 @22.3dBm	556	mA
		LTE-FDD B25 CH8365 @22.5dBm	540	mA
		LTE-FDD B26 CH8865 @23.0dBm	490	mA
		LTE-FDD B28 CH9410 @23.3dBm	533	mA
		LTE-FDD B30 CH9820 @23.1dBm	680	mA
		LTE-FDD B66 CH132322 @23.1dBm	570	mA
		LTE-TDD B38 CH38000 @22.7dBm	357	mA
		LTE-TDD B39 CH38450 @22.8dBm	282	mA
		LTE-TDD B40 CH39150 @22.5dBm	330	mA
		LTE-TDD B41 CH40620 @22.7dBm	357	mA
	WCDMA Voice Call (GNSS Off)	WCDMA B1 CH10700 @22.7dBm	480	mA
		WCDMA B2 CH9800 @22.7dBm	480	mA
		WCDMA B3 CH1338 @22.7dBm	470	mA
		WCDMA B4 CH1638 @22.7dBm	465	mA
		WCDMA B5 CH4407 @22.3dBm	390	mA
		WCDMA B8 CH3012 @22.3dBm	392	mA
		WCDMA B9 CH9312 @22.8dBm	465	mA
		WCDMA B19 CH738 @22.4dBm	370	mA

NOTE

For detailed power consumption data of EM12 CA combinations, please refer to ***document [1]***.

6.6. RF Output Power

The following table shows the RF output power of EM12 module.

Table 34: RF Output Power

Frequency	(3GPP Standard) Max.	EM12 Max.	EM12 Min.
WCDMA bands	24dBm+1.7/-3.7dB	24dBm+1/-3dB	<-50dBm
LTE-FDD bands	23dBm±2.7dB	23dBm±2dB	<-40dBm
LTE-TDD bands	23dBm±2.7dB	23dBm±2dB	<-40dBm

6.7. RF Receiving Sensitivity

The following table shows conducted RF min. receiving sensitivity of EM12 module.

Table 35: EM12-G Conducted RF Min. Receiving Sensitivity

Frequency	Primary	Diversity	SIMO1)	SIMO2) (Worst Case)
WCDMA B1	-109.0	-108.0	-111.0	-106.7dBm
WCDMA B2	-109.0	-108.5	-111.0	-104.7dbm
WCDMA B3	-109.0	-108.5	-111.0	-103.7dbm
WCDMA B4	-109.0	-108.0	-111.0	-106.7dBm
WCDMA B5	-110.5	-109.5	-112.5	-104.7dbm
WCDMA B8	-110.5	-109.5	-112.5	-103.7dBm
WCDMA B9	-109.0	-108.5	111.0	-105.7dBm
WCDMA B19	-110.5	-109.5	-112.5	-106.7dBm
LTE-FDD B1 (10MHz)	-96.5	-96.5	-99.0dbm	-96.3dBm
LTE-FDD B2 (10MHz)	-97.0	-97.5	-99.5dbm	-94.3dBm

LTE-FDD B3 (10MHz)	-97.0	-97.0	-99.5dbm	-93.3dBm
LTE-FDD B4 (10MHz)	-97.0	-96.0	-99.5dBm	-96.3dBm
LTE-FDD B5 (10MHz)	-99.0	-98.5	-101.0dBm	-94.3dBm
LTE-FDD B7 (10MHz)	-97.0	-96.5	-99.0dBm	-94.3dBm
LTE-FDD B8 (10MHz)	-99.0	-98.5	-101.0dBm	-93.3dBm
LTE-FDD B9 (10MHz)	-97.0	-97.5	-100.0dBm	-95.3dBm
LTE-FDD B12 (10MHz)	-99.0	-98.5	-101.5dBm	-93.3dBm
LTE-FDD B13 (10MHz)	-99.0	-98.5	-101.5dBm	-93.3dBm
LTE-FDD B14 (10MHz)	-97.5	-98.0	-100.5dbm	-93.3dBm
LTE-FDD B17 (10MHz)	-99.0	-99.0	-102.0dBm	-93.3dBm
LTE-FDD B18 (10MHz)	-99.5	-98.5	-101.5dBm	-96.3dBm
LTE-FDD B19 (10MHz)	-98.5	-98.0	-101.0dBm	-96.3dBm
LTE-FDD B20 (10MHz)	-98.5	-98.5	-101.0dBm	-93.3dBm
LTE-FDD B21 (10MHz)	-96.5	-96.5	-98.5dBm	-96.3dBm
LTE-FDD B25 (10MHz)	-97.0	-97.0	-99.5dBm	-92.8dBm
LTE-FDD B26 (10MHz)	-98.5	-98.0	-100.5dBm	-93.8dBm
LTE-FDD B28 (10MHz)	-98.0	-98.5	-100.5dBm	-94.8dBm
LTE-FDD B30 (10MHz)	-97.0	-96.0	-98.5dBm	-95.3dBm
LTE-TDD B38 (10MHz)	-96.5	-96.5	-98.5dBm	-96.3dBm
LTE-TDD B39 (10MHz)	-97.5	-98.0	-100.0dBm	-96.3dBm
LTE-TDD B40 (10MHz)	-96.5	-96.0	-98.5dBm	-96.3dBm
LTE-TDD B41 (10MHz)	-96.0	-96.0	-98.5dBm	-94.3dBm
LTE-FDD B66 (10MHz)	-97.0	-96.0	-99.0dBm	-95.8dBm

NOTES

1. [1] SIMO is a smart antenna technology that uses a single antenna at the transmitter side and multiple (two for EM12) antennas at the receiver side, which can improve Rx performance.
2. [2] As per 3GPP specification.

6.8. ESD Characteristics

The module is not protected against electrostatic discharge (ESD) in general. Consequently, it is subject to ESD handling precautions that typically apply to ESD sensitive components. Proper ESD handling and packaging procedures must be applied throughout the processing, handling and operation of any application that incorporates the module.

The following table shows the module electrostatic discharge characteristics.

Table 36: Electrostatic Discharge Characteristics (Temperature: 25ºC, Humidity: 40%)

Interfaces	Contact Discharge	Air Discharge	Unit
VCC, GND	±5	±10	kV
Antenna Interfaces	±4	±8	kV
Other Interfaces	±0.5	±1	kV

6.9. Thermal Dissipation

EM12 is designed to work over an extended temperature range. In order to achieve a maximum performance while working under extended temperatures or extreme conditions (such as with maximum power or data rate, etc.) for a long time, it is strongly recommended to add a thermal pad or other thermally conductive compounds between the module and the main PCB for thermal dissipation.

The thermal dissipation area (i.e. the area for adding thermal pad) is show as below. The dimensions are measured in mm.

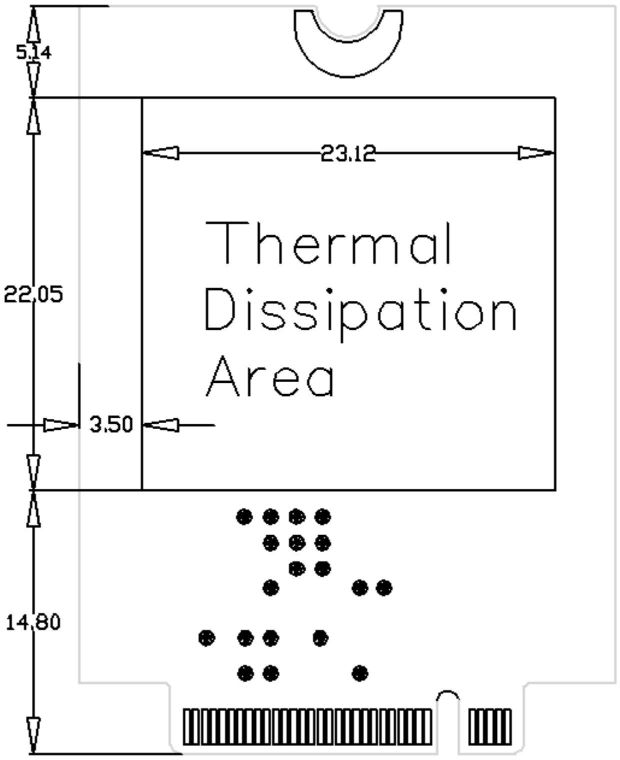


Figure 33: Thermal Dissipation Area on Bottom Side of Module (Top View)

There are some other measures to enhance heat dissipation performance:

- Add ground vias as many as possible on PCB.
- Maximize airflow over/around the module.
- Place the module away from other heating sources.
- Module mounting holes must be used to attach (ground) the device to the main PCB ground.
- It is NOT recommended to apply solder mask on the main PCB where the module's thermal dissipation area is located.
- Select an appropriate material, thickness and surface for the outer housing (i.e. the mechanical enclosure) of the application device that integrates the module so that it provides good thermal dissipation.
- Customers may also need active cooling to pull heat away from the module.
- If possible, add a heatsink on the top of the module. A thermal pad should be used between the heatsink and the module, and the heatsink should be designed with as many fins as possible to increase heat dissipation area.

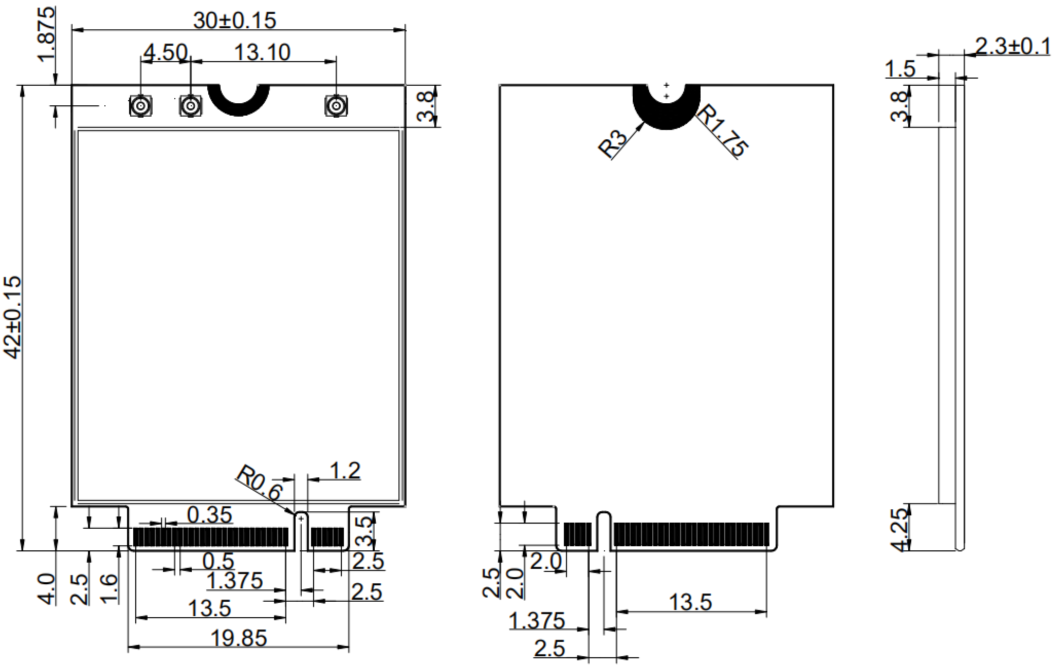
NOTE

For more detailed guidelines on thermal design, please refer to ***document [5]***.

7 Mechanical Dimensions and Packaging

This chapter mainly describes mechanical dimensions and packaging specifications of EM12 module. All dimensions are measured in mm, and the dimensional tolerances are ±0.05mm unless otherwise specified.

7.1. Mechanical Dimensions of the Module



Top View

Bottom View

Side View

Figure 34: Mechanical Dimensions of EM12 (Unit: mm)

7.2. Standard Dimensions of M.2 PCI Express

The following figure shows the standard dimensions of M.2 PCI Express. Please refer to ***document [5]*** for detailed A and B.

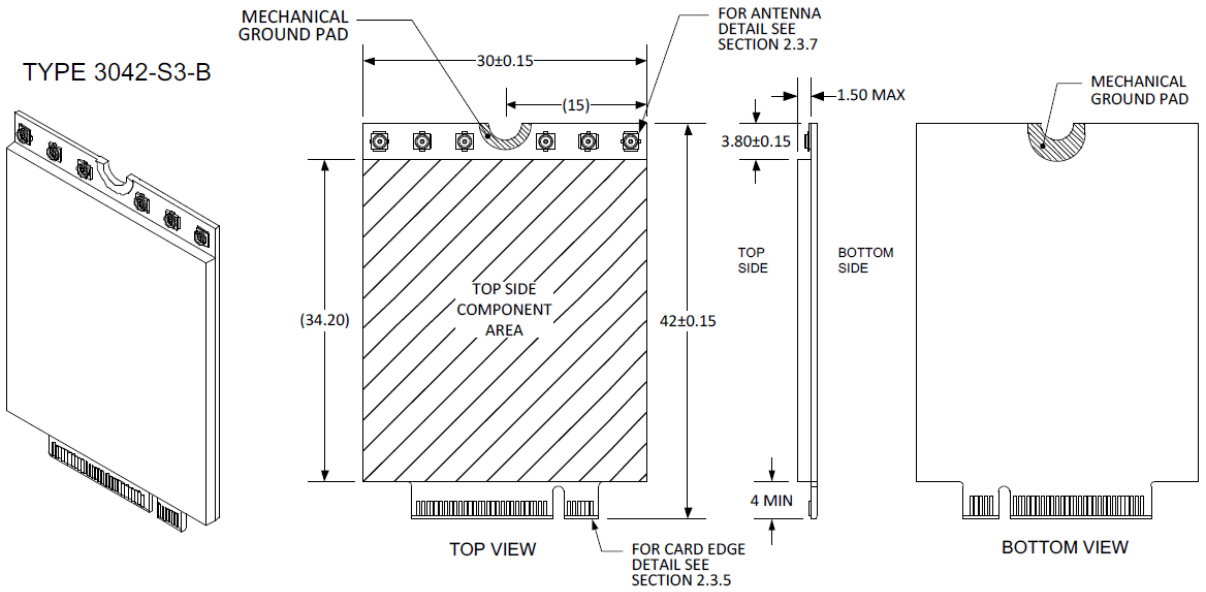
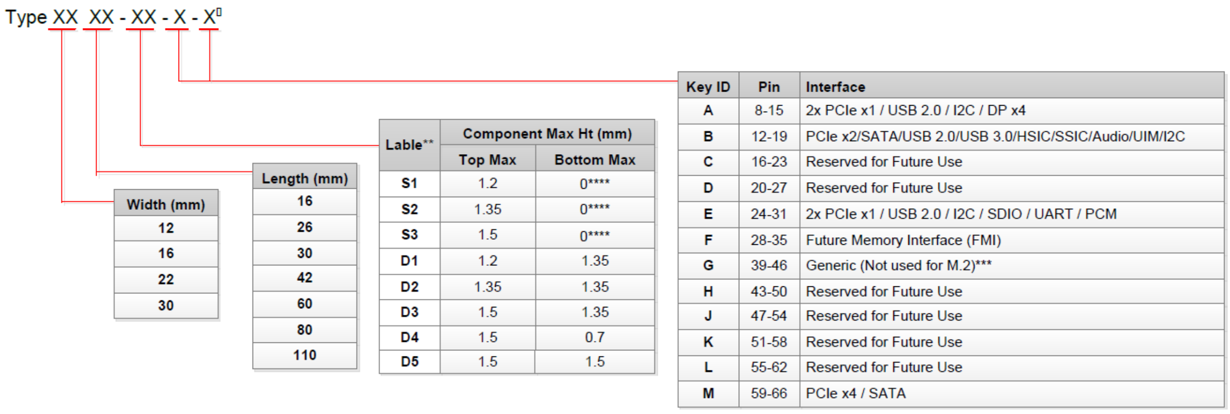


Figure 35: Standard Dimensions of M.2 Type 3042-S3 (Unit: mm)

According to M.2 nomenclature, EM12 is Type 3042-S3-B (30.0mm × 42.0mm, max component height on the top is 1.5mm and single-sided, key ID is B).



Width (mm)
12
16
22
30

Length (mm)
16
26
30
42
60
80
110

Lable**	Component Max Ht (mm)	
	Top Max	Bottom Max
S1	1.2	0****
S2	1.35	0****
S3	1.5	0****
D1	1.2	1.35
D2	1.35	1.35
D3	1.5	1.35
D4	1.5	0.7
D5	1.5	1.5

Key ID	Pin	Interface
A	8-15	2x PCIe x1 / USB 2.0 / I2C / DP x4
B	12-19	PCIe x2/SATA/USB 2.0/USB 3.0/HSIC/SSIC/Audio/UIM/I2C
C	16-23	Reserved for Future Use
D	20-27	Reserved for Future Use
E	24-31	2x PCIe x1 / USB 2.0 / I2C / SDIO / UART / PCM
F	28-35	Future Memory Interface (FMI)
G	39-46	Generic (Not used for M.2)***
H	43-50	Reserved for Future Use
J	47-54	Reserved for Future Use
K	51-58	Reserved for Future Use
L	55-62	Reserved for Future Use
M	59-66	PCIe x4 / SATA

✱ Use ONLY when a double slot is being specified
✱✱ Label included in height dimension
✱✱✱ Key G is intended for custom use. Devices with this key will not be M.2-compliant. Use at your own risk!
✱✱✱✱ Insulating label allowed on connector-based designs

Figure 36: M.2 Nomenclature

7.3. Top and Bottom Views of the Module

Figure 37: Top View of the Module

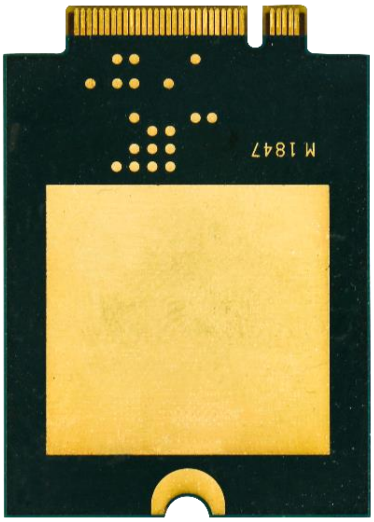


Figure 38: Bottom View of the Module

NOTE

These are renderings of EM12 module. For authentic appearance, please refer to the module that you receive from Quectel.

7.4. M.2 Connector

EM12 adopts a standard PCI Express M.2 connector which compiles with the directives and standards listed in the ***document [6]***.

7.5. Packaging

EM12 modules are packaged in trays. The following figure shows the tray size.

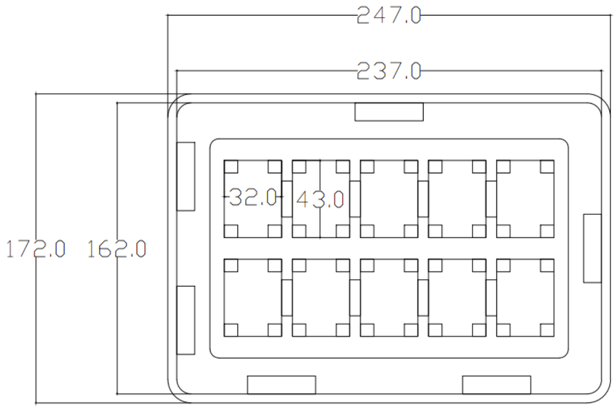


Figure 39: Tray Size (Unit: mm)

Each tray contains 10 modules. The smallest package contains 100 modules. Tray packaging procedures are as below.

1. Use 10 trays to package 100 modules at a time (tray size: 247.0mm × 172.0mm).
2. Place an empty tray on the top of the 10-tray stack.
3. Fix the stack with masking tape in “#” shape as shown in the following figure.
4. Pack the stack with conductive bag, and then fix the bag with masking tape.
5. Place the list of IMEI No. into a small carton.
6. Seal the carton and then label the seal with sealing sticker (small carton size: 250.0mm × 175.0mm × 128.0mm).

Figure 40: Tray Packaging Procedure

8 Appendix References

Table 37: Related Documents

SN	Document Name	Remark
[1]	Quectel_EM12_CA_Feature	EM12 CA Feature
[2]	Quectel_M.2_EVB_User_Guide	M.2 EVB User Guide
[3]	Quectel_EM12&EG12&EG18_AT_Commands_Manual	EM12, EG12 and EG18 AT Commands Manual
[4]	Quectel_EM12&EG12&EG18_GNSS_AT_Commands_Manual	EM12, EG12 and EG18 GNSS AT Commands Manual
[5]	Quectel_LTE_Module_Thermal_Design_Guide	Thermal Design Guide for LTE modules
[6]	PCI Express M.2 Specification	PCI Express Specification

Table 38: Terms and Abbreviations

Abbreviation	Description
bps	bits per second
CA	Carrier Aggregation
DC-HSPA+	Dual Carrier High Speed Packet Access +
DFOTA	Delta Firmware upgrade Over-The-Air
DL	Downlink
ESD	Electrostatic Discharge
FDD	Frequency Division Duplexing
GLONASS	Global Navigation Satellite System (Russia)
GNSS	Global Navigation Satellite System

GPS	Global Positioning System
GSM	Global System for Mobile Communications
HR	Half Rate
HSPA	High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
kbps	kilobits per second
LED	Light Emitting Diode
LTE	Long Term Evolution
Mbps	Megabits per second
ME	Mobile Equipment
MFBI	Multi-frequency Band Indicator
MIMO	Multiple Input Multiple Output
MLCC	Multi-layer Ceramic Capacitor
MMS	Multimedia Messaging Service
MO	Mobile Origination
MT	Mobile Termination
PDU	Protocol Data Unit
PPP	Point-to-Point Protocol
RF	Radio Frequency
Rx	Receive
SAR	Specific Absorption Rate
SMS	Short Message Service
Tx	Transmit
UART	Universal Asynchronous Receiver/Transmitter
UL	Uplink

URC	Unsolicited Result Code
(U)SIM	(Universal) Subscriber Identity Module
WCDMA	Wideband Code Division Multiple Access