BG96 Hardware Design

LPWA Module Series

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About the Document

History

Revision	Date	Author	Description
1.0	2017-08-04	Lyndon LIU/ Daryl DU	Initial
1.1	2017-08-31	Daryl DU	1. Modified GSM features in Table 2. 2. Added a note for e-I-DRX in Chapter 3.3. 3. Elaborated the description of e-I-DRX in Chapter 3.4.3. 4. Updated RF receiving sensitivity in Chapter 6.6.
1.2	2017-12-22	Lyndon LIU/ Daryl DU	1. Added the storage temperature of the module in Table 2 and Chapter 6.3. 2. Updated transmitting power values in Table 2. 3. Added the description of sleep mode in Table 5 and Chapter 3.4.4. 4. Added the description of ADC interfaces in Chapter 3.16. 5. Updated the GNSS performance in Table 21. 6. Updated the peak supply current values in Table 28. 7. Updated the current consumption values in Chapter 6.4. 8. Updated RF output power values in Table 34. 9. Updated LTE Cat NB1 RF receiving sensitivity values (without repetitions) in Table 35. 10. Updated the recommended footprint in Chapter 7.2.
1.3	2018-07-18	Lyndon LIU/ Daryl DU/ Hyman DING	1. Updated the USB interface reference design (Figure 15). 2. Added the description of GPIO interfaces (Chapter 3.17). 3. Updated GNSS performance parameters in Table 25. 4. Updated the GNSS antenna interface reference design (Figure 27). 5. Updated GNSS current consumption parameters in

			Table 35.
			6. Updated the module's baking temperature and baking hours in Chapter 8.1.
			7. Updated the recommended reflow soldering thermal profile and related parameters in Chapter 8.2.
1.4	2019-08-15	Lyndon LIU/ Rex WANG	1. Added B25 and the note thereof.
			2. Updated supported internet protocols and USB serial drivers in Table 2.
			3. Updated functional diagram in Figure 1.
			4. Enabled W_DISABLE# for airplane mode control in Chapter 3.4.1.
			5. Updated DC characteristics of PWRKEY (Table 4, Table 7).
			6. Updated DC characteristics of RESET_N (Table 4, Table 8).
			7. Updated the description of power supply reference design in Chapter 3.5.2.
			8. Updated power-on timing of the module in Figure 8.
			9. Added ADC analog-input bandwidth and ADC sampling rate in Table 22.
			10. Updated the GPIO configuration command in Chapter 3.17.
			11. Updated BG96 operating frequency in Table 27.
			12. Updated GNSS frequency in Table 29.
			13. Updated BG96 current consumption in Table 34.
			14. Updated the recommended stencil thickness and the peak reflow temperature in Chapter 8.2.
			15. Updated packaging information of the module in Chapter 8.3.

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1 Introduction

The document defines BG96 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 BG96. To facilitate application designs, it also includes some reference designs for customers' reference. The document, coupled with application notes and user guides, can help customers 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 BG96. 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.
	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

BG96 is an embedded IoT (LTE Cat M1/LTE Cat NB1/EGPRS) wireless communication module. It provides data connectivity on LTE-TDD/LTE-FDD/GPRS/EGPRS networks, and supports half-duplex operation in LTE networks. It also provides GNSS [1] and voice [2] functionality to meet customers' specific application demands. The following table shows the frequency bands of BG96 module.

Table 1: Frequency Bands of BG96 Module

Module	LTE Bands	GSM [3]	Rx-diversity	GNSS [1]
BG96	**Cat M1 & NB1:** LTE-FDD: B1/B2/B3/B4/B5/B8/B12/ B13/B18/B19/B20/B25 [4]/ B26*/B28 LTE-TDD: B39 (for Cat M1 only)	GSM850/EGSM900/ DCS1800/PCS1900	Not Supported	GPS, GLONASS, BeiDou/Compass, Galileo, QZSS

NOTES

1. [1] GNSS function is optional.
2. [2] BG96 supports VoLTE (Voice over LTE) under LTE Cat M1 network.
3. [3] BG96 GSM only supports Packet Switch.
4. [4] LTE-FDD B25 is supported on BG96 of R1.2 hardware version.
5. "*" means under development.

With a compact profile of 26.5mm × 22.5mm × 2.3mm, BG96 can meet almost all requirements for M2M applications such as smart metering, tracking system, security, wireless POS, etc.

BG96 is an SMD type module which can be embedded into applications through its 102 LGA pads. BG96 supports internet service protocols like TCP, UDP and PPP. Extended AT commands have been developed for customers to use these internet service protocols easily.

2.2. Key Features

The following table describes the detailed features of BG96 module.

Table 2: Key Features of BG96 Module

Features	Details
Power Supply	Supply voltage: 3.3V~4.3V Typical supply voltage: 3.8V
Transmitting Power	Class 3 (23dBm±2dB) for LTE-FDD bands Class 3 (23dBm±2dB) for LTE-TDD bands Class 4 (33dBm±2dB) for GSM850 Class 4 (33dBm±2dB) for EGSM900 Class 1 (30dBm±2dB) for DCS1800 Class 1 (30dBm±2dB) for PCS1900 Class E2 (27dBm±3dB) for GSM850 8-PSK Class E2 (27dBm±3dB) for EGSM900 8-PSK Class E2 (26dBm±3dB) for DCS1800 8-PSK Class E2 (26dBm±3dB) for PCS1900 8-PSK
LTE Features	Support LTE Cat M1 and LTE Cat NB1 Support 1.4MHz RF bandwidth for LTE Cat M1 Support 200KHz RF bandwidth for LTE Cat NB1 Support SISO in DL direction Cat M1: Max. 375Kbps (DL)/375Kbps (UL) Cat NB1: Max. 32Kbps (DL)/70Kbps (UL)
GSM Features	**GPRS:** Support GPRS multi-slot class 33 (33 by default) Coding scheme: CS-1, CS-2, CS-3 and CS-4 Max. 107Kbps (DL)/85.6Kbps (UL) **EDGE:** Support EDGE multi-slot class 33 (33 by default) Support GMSK and 8-PSK for different MCS (Modulation and Coding Scheme) Downlink coding schemes: CS 1-4 and MCS 1-9 Uplink coding schemes: CS 1-4 and MCS 1-9 Max. 296Kbps (DL)/236.8Kbps (UL)
Internet Protocol Features	Support PPP/TCP/UDP/SSL/TLS/FTP(S)/HTTP(S)/NITZ/PING/MQTT protocols Support PAP (Password Authentication Protocol) and CHAP (Challenge Handshake Authentication Protocol) protocols which are usually used for PPP connections

SMS	Text and PDU mode Point to point MO and MT SMS cell broadcast SMS storage: ME by default
(U)SIM Interface	Support USIM/SIM card: 1.8V, 3.0V
Audio Feature*	Support one digital audio interface: PCM interface
USB Interface	Compliant with USB 2.0 specification (slave only) and the data transfer rate can reach up to 480Mbps Used for AT command communication, data transmission, GNSS NMEA output, software debugging and firmware upgrade Support USB serial drivers for Windows 7/8/8.1/10, Linux 3.x(3.4 or later)/4.1~4.15, Android 4.x/5.x/6.x/7.x/8.x/9.x
UART Interfaces	**UART1:** ● Used for data transmission and AT command communication ● 115200bps by default ● The default frame format is 8N1 (8 data bits, no parity, 1 stop bit) ● Support RTS and CTS hardware flow control **UART2:** ● Used for module debugging and log output ● 115200bps baud rate **UART3:** ● Used for outputting GNSS data or NMEA sentences ● 115200bps baud rate
AT Commands	3GPP TS 27.007 and 3GPP TS 27.005 AT commands, as well as Quectel enhanced AT commands
Network Indication	One NETLIGHT pin for network connectivity status indication
Antenna Interfaces	Main antenna (ANT_MAIN) and GNSS antenna (ANT_GNSS) interfaces
Physical Characteristics	Dimensions: (26.5±0.15)mm × (22.5±0.15)mm × (2.3±0.2)mm Weight: approx. 3.1g
Temperature Range	Operation temperature range: -35°C ~ +75°C [1] Extended temperature range: -40°C ~ +85°C [2] Storage temperature range: -40°C ~ +90°C
Firmware Upgrade	USB interface, DFOTA
RoHS	All hardware components are fully compliant with EU RoHS directive

NOTES

1. "*" means under development.
2. [1] Within operation temperature range, the module is 3GPP compliant.

3. [2] Within extended temperature range, the module remains the ability to establish and maintain a voice, SMS, data transmission, emergency call, etc. There is no unrecoverable malfunction. There are also no effects on radio spectrum and no harm to radio network. Only one or more parameters like P_{out} might reduce in their value and exceed the specified tolerances. When the temperature returns to the normal operating temperature levels, the module will meet 3GPP specifications again.

2.3. Functional Diagram

The following figure shows a block diagram of BG96 and illustrates the major functional parts.

- Power management
- Baseband
- DDR+NAND flash
- Radio frequency
- Peripheral interfaces
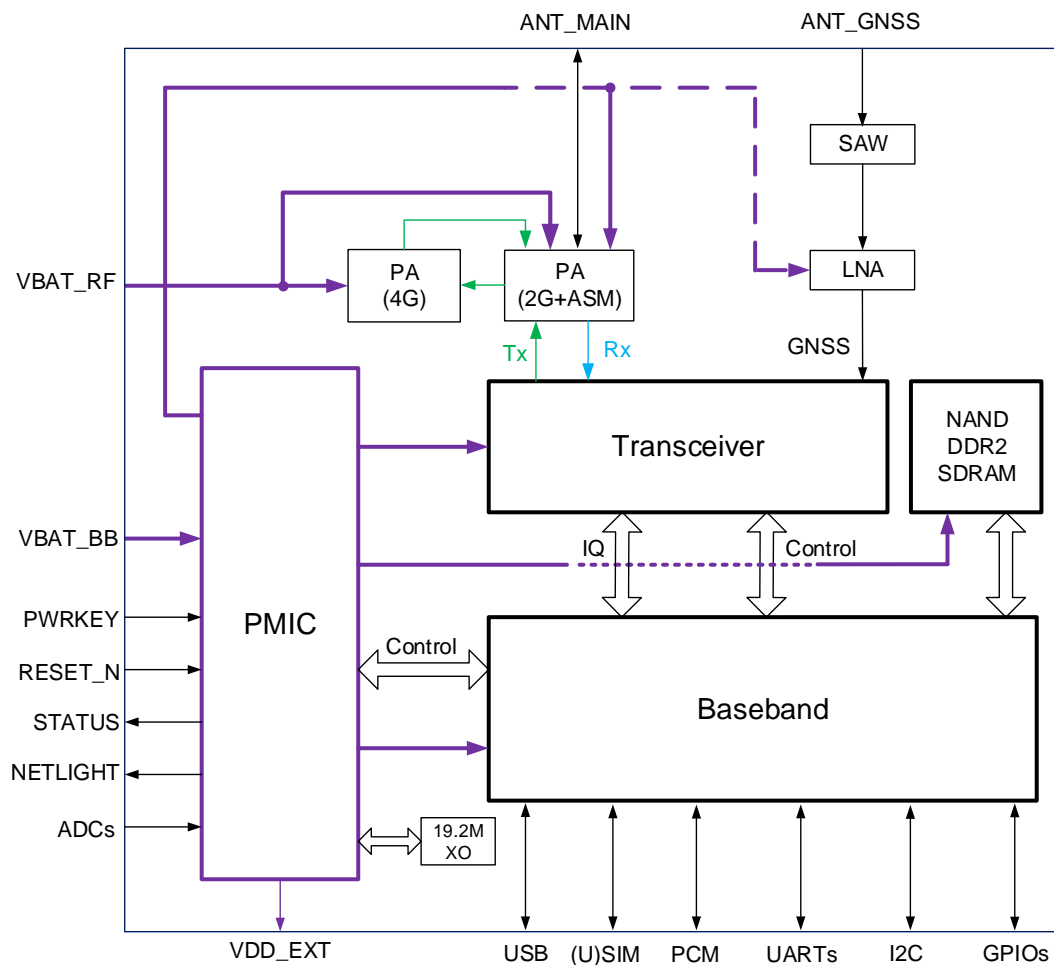
Figure 1: Functional Diagram

2.4. Evaluation Board

In order to help customers develop applications conveniently with BG96, Quectel supplies the evaluation board (EVB), USB to RS-232 converter cable, USB data cable, earphone, antenna and other peripherals to control or test the module. For more details, please refer to *document [1]*.

3 Application Interfaces

BG96 is equipped with 102 LGA pads that can be connected to customers' cellular application platforms. The following sub-chapters will provide detailed description of interfaces listed below:

- Power supply
- (U)SIM interface
- USB interface
- UART interfaces
- PCM and I2C interfaces*
- Status indication
- USB_BOOT interface
- ADC interfaces
- GPIO interfaces

NOTE

"*" means under development.

3.1. Pin Assignment

The following figure shows the pin assignment of BG96.
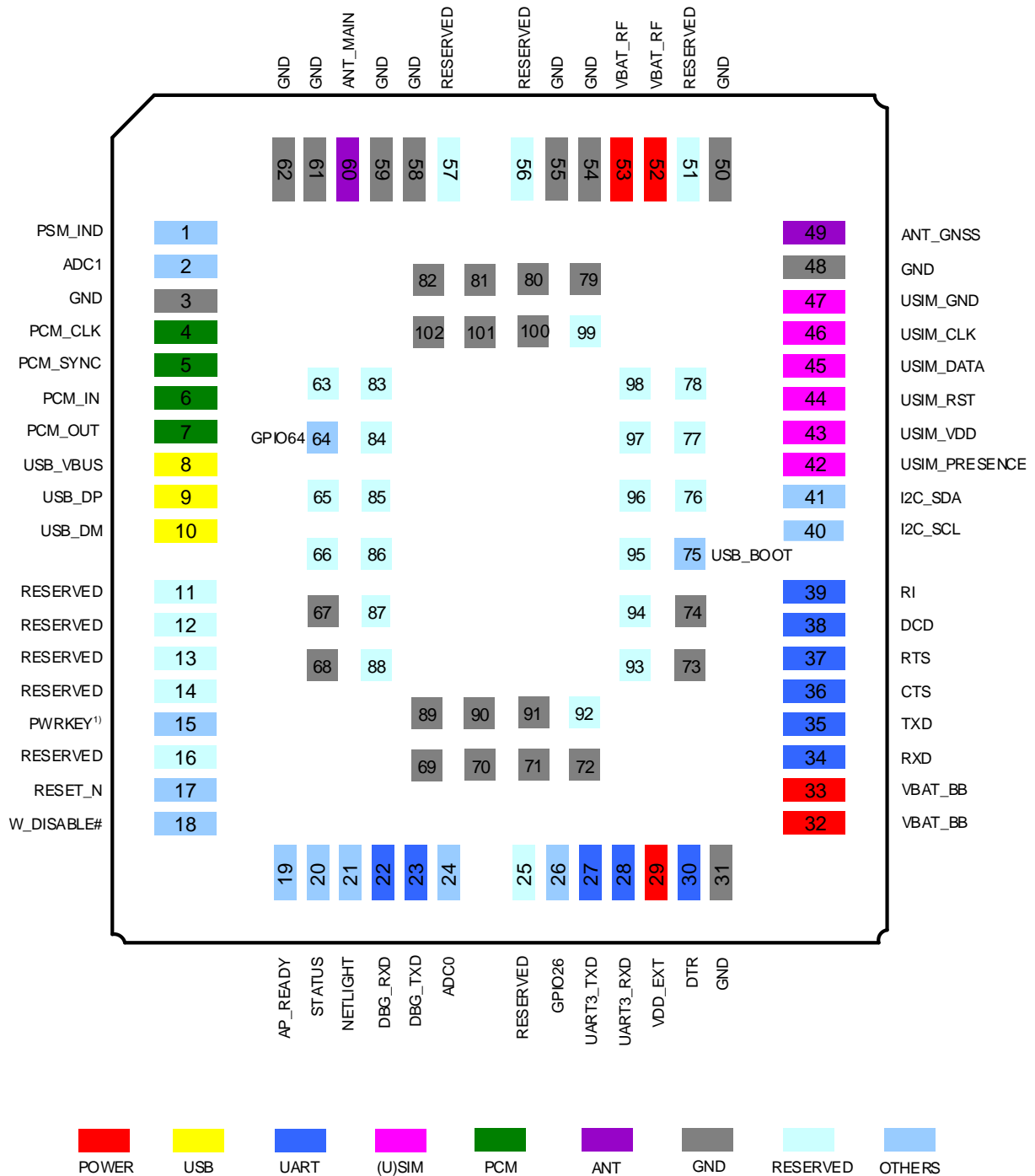
Figure 2: Pin Assignment (Top View)

NOTES

1. Keep all RESERVED pins and unused pins unconnected.
2. GND pads should be connected to ground in the design.
3. [1] PWRKEY output voltage is 0.8V because of the diode drop in the Qualcomm chipset.

3.2. Pin Description

The following tables show the pin definition and description of BG96.

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

Power Supply					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
VBAT_BB	32, 33	PI	Power supply for the module's baseband part	Vmax=4.3V Vmin=3.3V Vnorm=3.8V	
VBAT_RF	52, 53	PI	Power supply for the	Vmax=4.3V Vmin=3.3V	

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
			module's RF part	Vnorm=3.8V	
VDD_EXT	29	PO	Provide 1.8V for external circuit	Vnorm=1.8V $I_O$max=50mA	Power supply for external GPIO's pull-up circuits. If unused, keep this pin open.
GND	3, 31, 48, 50, 54, 55, 58, 59, 61, 62, 67~74, 79~82, 89~91, 100~102		Ground		

Turn on/off

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
PWRKEY	15	DI	Turn on/off the module	Vnorm=0.8V V_{IL}max=0.5V	The output voltage is 0.8V because of the diode drop in the Qualcomm chipset.
RESET_N	17	DI	Reset the module	Vnorm=0.8V V_{IL}max=0.5V	If unused, keep this pin open.

Status Indication

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
STATUS	20	DO	Indicate the module's operation status	V_{OH}min=1.35V V_{OL}max=0.45V	1.8V power domain. If unused, keep this pin open.
NETLIGHT	21	DO	Indicate the module's network activity status	V_{OH}min=1.35V V_{OL}max=0.45V	1.8V power domain. If unused, keep this pin open.

USB Interface

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
USB_VBUS	8	AI	USB detection	Vmax=5.25V Vmin=3.0V Vnorm=5.0V	
USB_DP	9	IO	USB differential data bus (+)	Compliant with USB 2.0 standard	Require differential impedance of 90Ω.

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
				specification.	
USB_DM	10	IO	USB differential data bus (-)	Compliant with USB 2.0 standard specification.	Require differential impedance of 90Ω.
(U)SIM Interface					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
USIM_PRESENCE	42	DI	(U)SIM card insertion detection	V_{IL}min=-0.3V V_{IL}max=0.6V V_{IH}min=1.2V V_{IH}max=2.0V	1.8V power domain. If unused, keep this pin open.
USIM_VDD	43	PO	Power supply for (U)SIM card	**For 1.8V (U)SIM:** Vmax=1.9V Vmin=1.7V **For 3.0V (U)SIM:** Vmax=3.05V Vmin=2.7V $I_O$max=50mA	Either 1.8V or 3.0V is supported by the module automatically.
USIM_RST	44	DO	Reset signal of (U)SIM card	**For 1.8V (U)SIM:** V_{OL}max=0.45V V_{OH}min=1.35V **For 3.0V (U)SIM:** V_{OL}max=0.45V V_{OH}min=2.55V	
USIM_DATA	45	IO	Data signal of (U)SIM card	**For 1.8V (U)SIM:** V_{IL}max=0.6V V_{IH}min=1.2V V_{OL}max=0.45V V_{OH}min=1.35V **For 3.0V (U)SIM:** V_{IL}max=1.0V V_{IH}min=1.95V V_{OL}max=0.45V V_{OH}min=2.55V	
USIM_CLK	46	DO	Clock signal of (U)SIM card	**For 1.8V (U)SIM:** V_{OL}max=0.45V V_{OH}min=1.35V **For 3.0V (U)SIM:**	

				$V_{OL}max=0.45V$	
				$V_{OH}min=2.55V$	
USIM_GND	47		Specified ground for (U)SIM card		

UART1 Interface

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
DTR	30	DI	Data terminal ready (sleep mode control)	$V_{IL}min=-0.3V$ $V_{IL}max=0.6V$ $V_{IH}min=1.2V$ $V_{IH}max=2.0V$	1.8V power domain. If unused, keep this pin open.
RXD	34	DI	Receive data	$V_{IL}min=-0.3V$ $V_{IL}max=0.6V$ $V_{IH}min=1.2V$ $V_{IH}max=2.0V$	1.8V power domain. If unused, keep this pin open.
TXD	35	DO	Transmit data	$V_{OL}max=0.45V$ $V_{OH}min=1.35V$	1.8V power domain. If unused, keep this pin open.
CTS	36	DO	Clear to send	$V_{OL}max=0.45V$ $V_{OH}min=1.35V$	1.8V power domain. If unused, keep this pin open.
RTS	37	DI	Request to send	$V_{IL}min=-0.3V$ $V_{IL}max=0.6V$ $V_{IH}min=1.2V$ $V_{IH}max=2.0V$	1.8V power domain. If unused, keep this pin open.
DCD	38	DO	Data carrier detection	$V_{OL}max=0.45V$ $V_{OH}min=1.35V$	1.8V power domain. If unused, keep this pin open.
RI	39	DO	Ring indication	$V_{OL}max=0.45V$ $V_{OH}min=1.35V$	1.8V power domain. If unused, keep this pin open.

UART2 Interface

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
DBG_RXD	22	DI	Receive data	$V_{IL}min=-0.3V$ $V_{IL}max=0.6V$ $V_{IH}min=1.2V$ $V_{IH}max=2.0V$	1.8V power domain. If unused, keep this pin open.
DBG_TXD	23	DO	Transmit data	$V_{OL}max=0.45V$ $V_{OH}min=1.35V$	1.8V power domain. If unused, keep this pin open.

UART3 Interface

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
UART3_TXD	27	DO	Transmit data	$V_{OL}max=0.45V$ $V_{OH}min=1.35V$	1.8V power domain. If unused, keep this pin open.
UART3_RXD	28	DI	Receive data	$V_{IL}min=-0.3V$ $V_{IL}max=0.6V$ $V_{IH}min=1.2V$ $V_{IH}max=2.0V$	1.8V power domain. If unused, keep this pin open.

PCM Interface*

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
PCM_CLK	4	DO	PCM clock output	$V_{OL}max=0.45V$ $V_{OH}min=1.35V$	1.8V power domain. If unused, keep this pin open.
PCM_SYNC	5	DO	PCM frame synchronization output	$V_{OL}max=0.45V$ $V_{OH}min=1.35V$	1.8V power domain. If unused, keep this pin open.
PCM_IN	6	DI	PCM data input	$V_{IL}min=-0.3V$ $V_{IL}max=0.6V$ $V_{IH}min=1.2V$ $V_{IH}max=2.0V$	1.8V power domain. If unused, keep this pin open.
PCM_OUT	7	DO	PCM data output	$V_{OL}max=0.45V$ $V_{OH}min=1.35V$	1.8V power domain. If unused, keep this pin open.

I2C Interface*

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
I2C_SCL	40	OD	I2C serial clock. Used for external codec.		External pull-up resistor is required. 1.8V only. If unused, keep this pin open.
I2C_SDA	41	OD	I2C serial data. Used for external codec.		External pull-up resistor is required. 1.8V only. If unused, keep this pin open.

Antenna Interfaces

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
ANT_MAIN	60	IO	Main antenna interface		50Ω impedance.
ANT_GNSS	49	AI	GNSS antenna interface		50Ω impedance. If unused, keep this pin open.

Other Interface Pins

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
PSM_IND [1]	1	DO	Power saving mode indication	$V_{OL}max=0.45V$ $V_{OH}min=1.35V$	1.8V power domain. If unused, keep this pin open.
W_DISABLE#	18	DI	Airplane mode control	$V_{IL}min=-0.3V$ $V_{IL}max=0.6V$ $V_{IH}min=1.2V$ $V_{IH}max=2.0V$	1.8V power domain. Pull-up by default. In low voltage level, the module will enter airplane mode. If unused, keep this pin open.
AP_READY	19	DI	Application processor sleep state detection	$V_{IL}min=-0.3V$ $V_{IL}max=0.6V$ $V_{IH}min=1.2V$ $V_{IH}max=2.0V$	1.8V power domain. If unused, keep this pin open.
USB_BOOT	75	DI	Force the module to enter emergency download mode	$V_{IL}min=-0.3V$ $V_{IL}max=0.6V$ $V_{IH}min=1.2V$ $V_{IH}max=2.0V$	1.8V power domain. If unused, keep this pin open.
GPIO26	26	IO	General-purpose input/ output interface	$V_{OL}max=0.45V$ $V_{OH}min=1.35V$ $V_{IL}min=-0.3V$ $V_{IL}max=0.6V$ $V_{IH}min=1.2V$ $V_{IH}max=2.0V$	1.8V power domain. If unused, keep this pin open.
GPIO64	64	IO	General-purpose input/ output interface	$V_{OL}max=0.45V$ $V_{OH}min=1.35V$ $V_{IL}min=-0.3V$ $V_{IL}max=0.6V$ $V_{IH}min=1.2V$ $V_{IH}max=2.0V$	1.8V power domain. If unused, keep this pin open.

ADC Interfaces

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
ADC1	2	AI	General purpose analog to digital converter interface	Voltage range: 0.3V to 1.8V	If unused, keep this pin open.
ADC0	24	AI	General purpose analog to digital converter interface	Voltage range: 0.3V to 1.8V	If unused, keep this pin open.

RESERVED Pins

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
RESERVED	11~14, 16, 25, 51, 56, 57, 63, 65, 66, 76~78, 83~88, 92~99		Reserved		Keep these pins open.

NOTES

1. "*" means under development.
2. [1] When PSM is enabled and then reboot the module, the function of PSM_IND pin will be activated. This pin outputs a high voltage level when the module is in normal operation mode, and outputs a low voltage level when the module enters PSM.
3. Keep all RESERVED pins and unused pins unconnected.

3.3. Operating Modes

The table below briefly summarizes the various operating modes referred in the following chapters.

Table 5: Overview of Operating Modes

Mode	Details	
Normal Operation	Talk/Data	Network connection is ongoing. In this mode, the power consumption is decided by network setting and data transfer rate.
	Idle	Software is active. The module has registered on network, and it is ready to send and receive data.

Extended Idle Mode DRX (e-I-DRX)	BG96 module and the network may negotiate over non-access stratum signaling the use of e-I-DRX for reducing power consumption, while being available for mobile terminating data and/or network originated procedures within a certain delay dependent on the DRX cycle value.
Airplane Mode	**AT+CFUN=4** command or W_DISABLE# pin can set the module into airplane mode. In this case, RF function will be invalid.
Minimum Functionality Mode	**AT+CFUN=0** command can set the module into a minimum functionality mode without removing the power supply. In this case, both RF function and (U)SIM card will be invalid.
Sleep Mode	In this mode, the current consumption of the module will be reduced to a lower level. During this mode, the module can still receive paging message, SMS and TCP/UDP data from the network normally.
Power Saving Mode (PSM)	BG96 module may enter Power Saving Mode for reducing its power consumption. PSM is similar to power-off, but the module remains registered on the network and there is no need to re-attach or re-establish PDN connections.
Power OFF Mode	In this mode, the power management unit shuts down the power supply. Software is not active. The serial interfaces are not accessible. But operating voltage (connected to VBAT_RF and VBAT_BB) remains applied.

NOTES

During e-I-DRX, it is recommended to use UART interface for data communication, as the use of USB interface will increase power consumption.

3.4. Power Saving

3.4.1. Airplane Mode

When the module enters airplane mode, the RF function does not work and all AT commands correlative with RF function will be inaccessible. This mode can be set via the following ways.

Hardware:

W_DISABLE# is pulled up by default. Driving it to low level will let the module enter airplane mode.

Software:

AT+CFUN=<fun> command provides choice of the functionality level, through specifying **<fun>** as 0, 1 or 4.

- **AT+CFUN=0**: Minimum functionality mode. Both (U)SIM and RF functions are disabled.
- **AT+CFUN=1**: Full functionality mode (by default).

- **AT+CFUN=4**: Airplane mode. RF function is disabled.

NOTES

1. Airplane mode control via W_DISABLE# is disabled in firmware by default. It can be enabled by **AT+QCFG="airplanecontrol"** command. For more details about the command, please refer to *document [2]*.
2. The execution of **AT+CFUN** command will not affect GNSS function.

3.4.2. Power Saving Mode (PSM)

BG96 module can enter PSM for reducing its power consumption. The mode is similar to power-off, but the module remains registered on the network and there is no need to re-attach or re-establish PDN connections. So BG96 in PSM cannot immediately respond users' requests.

When the module wants to use the PSM, it shall request an Active Time value during every Attach and TAU procedures. If the network supports PSM and accepts that the module uses PSM, it will confirm the usage of PSM by allocating an Active Time value to the module. If the module wants to change the Active Time value, e.g. when the conditions are changed in the module, the module consequently requests the value it wants in the TAU procedure.

If PSM is supported by the network, then it can be enabled via **AT+CPSMS** command.

Either of the following methods will wake up the module from PSM:

- Drive PWRKEY pin to low level will wake up the module.
- When the T3412_Ext timer expires, the module will be automatically woken up.

NOTE

Please refer to *document [2]* for details about **AT+CPSMS** command.

3.4.3. Extended Idle Mode DRX (e-I-DRX)

The module (UE) and the network may negotiate over non-access stratum signalling the use of e-I-DRX for reducing its power consumption, while being available for mobile terminating data and/or network originated procedures within a certain delay dependent on the DRX cycle value.

Applications that want to use e-I-DRX need to consider specific handling of mobile terminating services or data transfers, and in particular they need to consider the delay tolerance of mobile terminated data.

In order to negotiate the use of e-I-DRX, the UE requests e-I-DRX parameters during attach procedure and RAU/TAU procedure. The EPC may reject or accept the UE request for enabling e-I-DRX. In case the EPC accepts e-I-DRX, the EPC based on operator policies and, if available, the e-I-DRX cycle length value in the subscription data from the HSS, may also provide different values of the e-I-DRX parameters than what was requested by the UE. If the EPC accepts the use of e-I-DRX, the UE applies e-I-DRX based on the received e-I-DRX parameters. If the UE does not receive e-I-DRX parameters in the relevant accept message because the EPC rejected its request or because the request was received by EPC not supporting e-I-DRX, the UE shall apply its regular discontinuous reception.

If e-I-DRX is supported by the network, then it can be enabled by **AT+CEDRXS=1** command.

NOTE

Please refer to *document [2]* for details about **AT+CEDRXS** command.

3.4.4. Sleep Mode

BG96 is able to reduce its current consumption to a lower value during the sleep mode. The following sub-chapters describe the power saving procedure of BG96 module.

3.4.4.1. UART Application

If the host communicates with the module via UART interface, the following preconditions can let the module enter sleep mode.

● Execute **AT+QSCLK=1** command to enable sleep mode.
● Drive DTR to high level.

The following figure shows the connection between the module and the host.
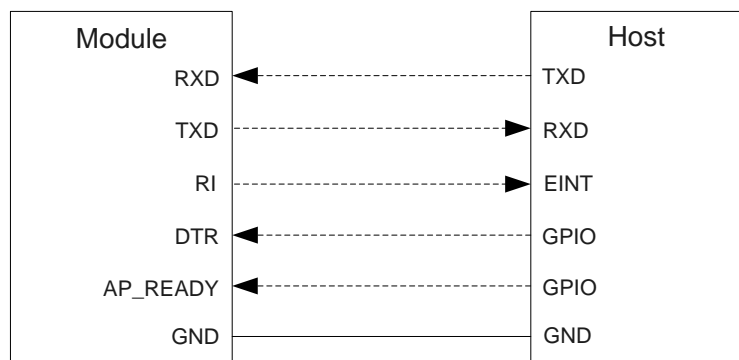
Figure 3: Sleep Mode Application via UART

- Driving the host DTR to low level will wake up the module.
- When BG96 has URC to report, RI signal will wake up the host. Please refer to *Chapter 3.14* for details about RI behavior.
- AP_READY will detect the sleep state of the host (can be configured to high level or low level detection). Please refer to **AT+QCFG="apready"** command in *document [2]* for details.

3.5. Power Supply

3.5.1. Power Supply Pins

BG96 provides the following four VBAT pins for connection with an external power supply. There are two separate voltage domains for VBAT.

- Two VBAT_RF pins for module's RF part.
- Two VBAT_BB pins for module's baseband part.

The following table shows the details of VBAT pins and ground pins.

Table 6: VBAT and GND Pins

Pin Name	Pin No.	Description	Min.	Typ.	Max.	Unit
VBAT_RF	52, 53	Power supply for the module's RF part	3.3	3.8	4.3	V
VBAT_BB	32, 33	Power supply for the module's baseband part	3.3	3.8	4.3	V
GND	3, 31, 48, 50, 54, 55, 58, 59, 61, 62, 67~74, 79~82, 89~91, 100~102	Ground	-	-	-	-

3.5.2. Decrease Voltage Drop

The power supply range of the module is from 3.3V to 4.3V. Please make sure that the input voltage will never drop below 3.3V. The following figure shows the voltage drop during burst transmission in 2G network. The voltage drop will be less in LTE Cat M1 and LTE Cat NB1 networks.
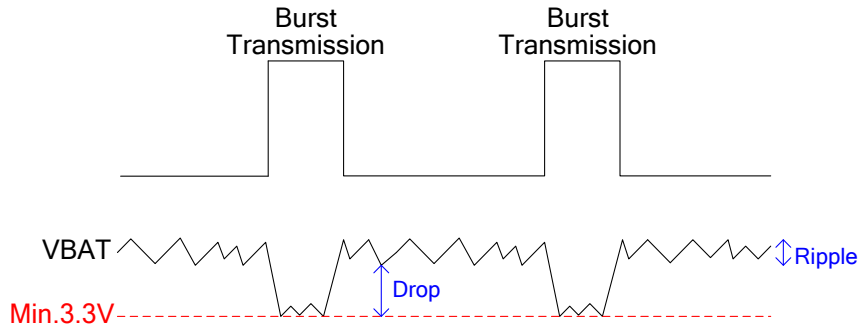
Figure 4: Power Supply Limits during Burst Transmission

To decrease voltage drop, a bypass capacitor of about 100μF with low ESR should be used, and a multi-layer ceramic chip capacitor (MLCC) array should also be reserved due to its low ESR. It is recommended to use three ceramic capacitors (100nF, 33pF, 10pF) for composing the MLCC array, and place these capacitors close to VBAT pins. The main power supply from an external application has to be a single voltage source and can be expanded to two sub paths with star structure. The width of VBAT_BB trace should be no less than 0.5mm, and the width of VBAT_RF trace should be no less than 2mm. In principle, the longer the VBAT trace is, the wider it will be.

In addition, in order to get a stable power source, it is suggested to use a TVS with low leakage current and suitable reverse stand-off voltage, and also it is recommended to place it as close to the VBAT pins as possible. The following figure shows the star structure of the power supply.
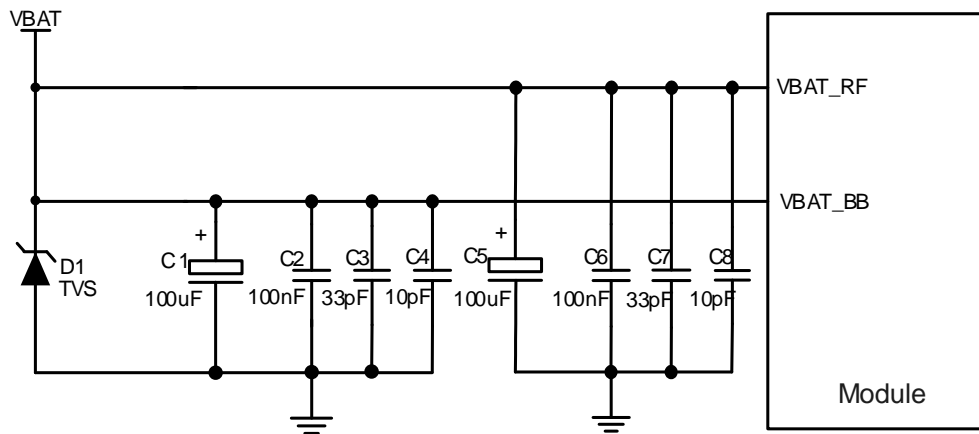
Figure 5: Star Structure of the Power Supply

3.5.3. Monitor the Power Supply

AT+CBC command can be used to monitor the VBAT_BB voltage value. For more details, please refer to *document [2]*.

3.6. Turn on and off Scenarios

3.6.1. Turn on Module Using the PWRKEY Pin

The following table shows the pin definition of PWRKEY.

Table 7: Pin Definition of PWRKEY

Pin Name	Pin No.	Description	DC Characteristics	Comment
PWRKEY	15	Turn on/off the module	Vnorm=0.8V V_{IL}max=0.5V	The output voltage is 0.8V because of the diode drop in the Qualcomm chipset.

When BG96 is in power off mode, it can be turned on by driving the PWRKEY pin to a low level for at least 500ms. It is recommended to use an open drain/collector driver to control the PWRKEY. After STATUS pin outputs a high voltage level, PWRKEY pin can be released. A simple reference circuit is illustrated in the following figure.
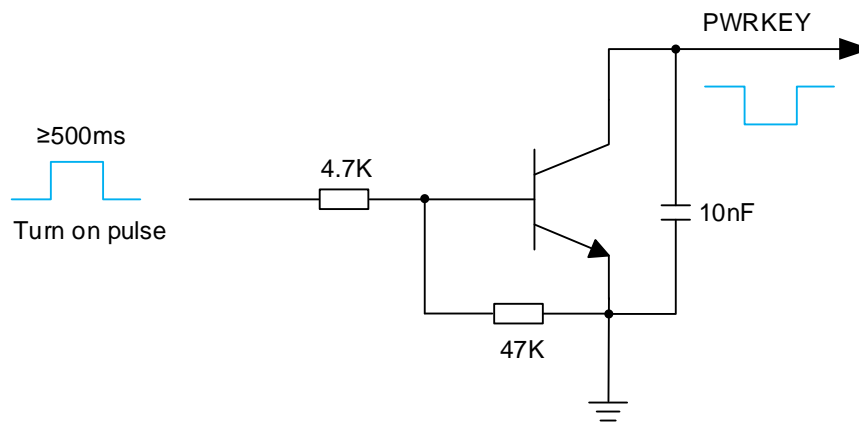
Figure 6: Turn on the Module Using Driving Circuit

Another way to control the PWRKEY is using a button directly. When pressing the key, electrostatic strike may generate from the finger. Therefore, a TVS component is indispensable to be placed nearby the button for ESD protection. A reference circuit is shown in the following figure.
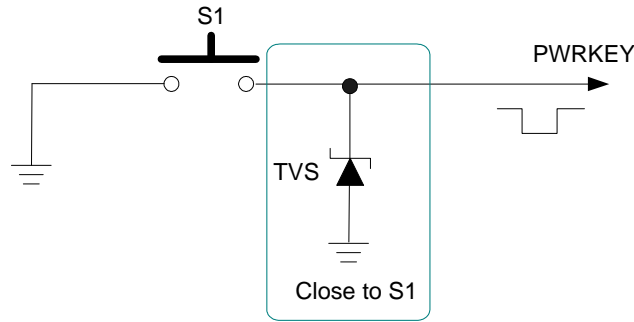
Figure 7: Turn on the Module Using Keystroke

The power on scenario is illustrated in the following figure.
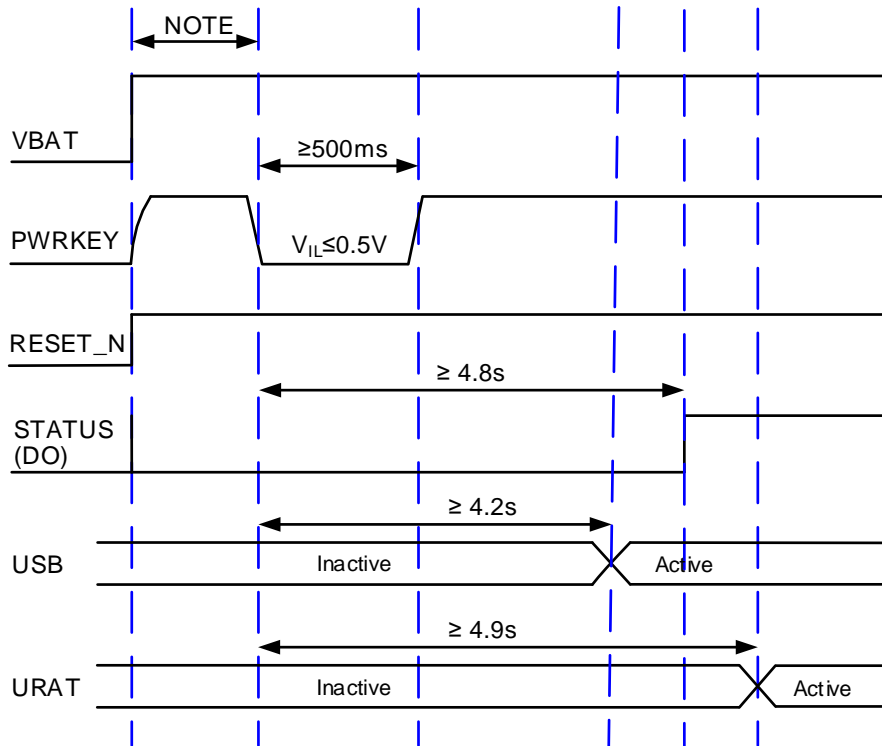
Figure 8: Power-on Timing

NOTES

1. Make sure that VBAT is stable before pulling down PWRKEY pin, and keep the interval no less than 30ms.
2. PWRKEY is internally pulled up to an internal voltage in the Qualcomm chipset, and its output voltage is the internal voltage minus a diode drop in the chipset. Therefore, the expected output voltage of PWRKEY is 0.8V.

3.6.2. Turn off Module

Either of the following methods can be used to turn off the module:

● Normal power down procedure: Turn off the module using the PWRKEY pin.
● Normal power down procedure: Turn off the module using **AT+QPOWD** command.

3.6.2.1. Turn off Module Using the PWRKEY Pin

Driving the PWRKEY pin to low level for at least 650ms, the module will execute power-off procedure after the PWRKEY is released.

The power-off scenario is illustrated in the following figure.
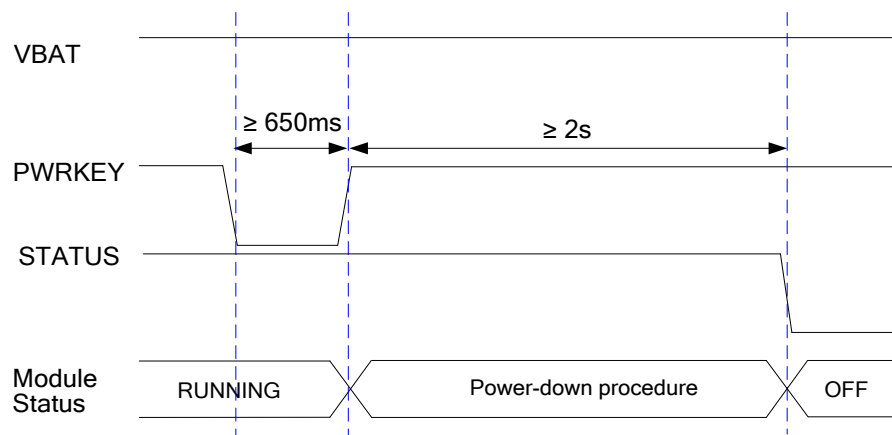
Figure 9: Power-off Timing

3.6.2.2. Turn off Module Using AT Command

It is also a safe way to use **AT+QPOWD** command to turn off the module, which is similar to turning off the module via PWRKEY pin.

Please refer to *document [2]* for details about **AT+QPOWD** command.

3.7. Reset the Module

The module can be reset by driving RESET_N to low level for a period of time between 150ms and 460ms.

Table 8: RESET_N Pin Description

Pin Name	Pin No.	Description	DC Characteristics	Comment
RESET_N	17	Reset the module	Vnorm=1.8V V_{IL}max=0.5V	

The recommended circuit is similar to the PWRKEY control circuit. An open drain/collector driver or button can be used to control the RESET_N.
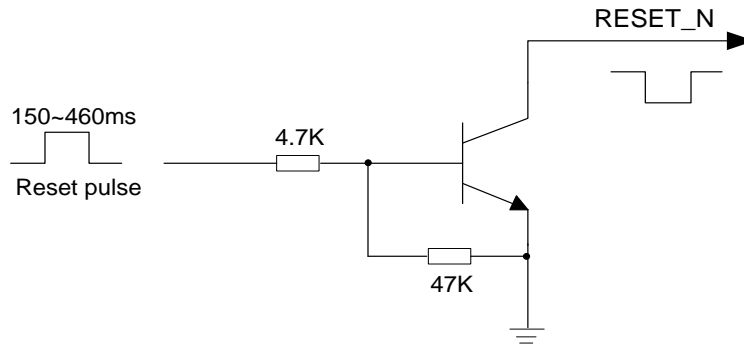
Figure 10: Reference Circuit of RESET_N by Using Driving Circuit
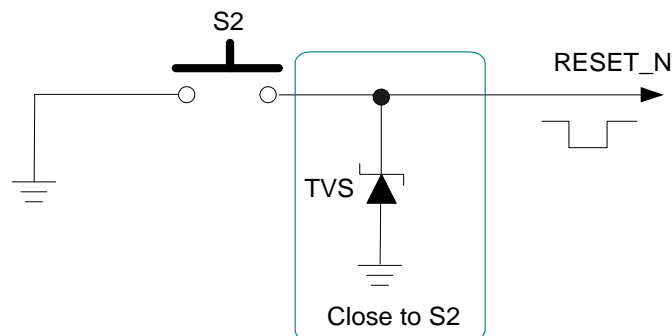
Figure 11: Reference Circuit of RESET_N by Using Button

The reset scenario is illustrated in the following figure.
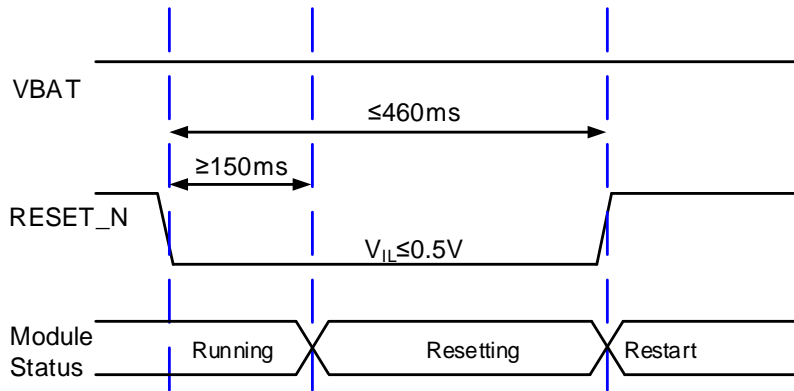
Figure 12: Timing of Resetting Module

1. Use RESET_N only when turning off the module by **AT+QPOWD** command and PWRKEY pin both failed.
2. Ensure that there is no large capacitance on PWRKEY and RESET_N pins.

3.8. (U)SIM Interface

The (U)SIM interface circuitry meets ETSI and IMT-2000 requirements. Both 1.8V and 3.0V (U)SIM cards are supported.

Table 9: Pin Definition of (U)SIM Interface

Pin Name	Pin No.	I/O	Description	Comment
USIM_ PRESENCE	42	DI	(U)SIM card insertion detection	
USIM_VDD	43	PO	Power supply for (U)SIM card	Either 1.8V or 3.0V is supported by the module automatically.
USIM_RST	44	DO	Reset signal of (U)SIM card	
USIM_DATA	45	IO	Data signal of (U)SIM card	
USIM_CLK	46	DO	Clock signal of (U)SIM card	
USIM_GND	47		Specified ground for (U)SIM card	

BG96 supports (U)SIM card hot-plug via the USIM_PRESENCE pin which supports low level and high level detections. The function is disabled by default. Please refer to *document [2]* about **AT+QSIMDET** command for details.

The following figure shows a reference design of (U)SIM interface with an 8-pin (U)SIM card connector.
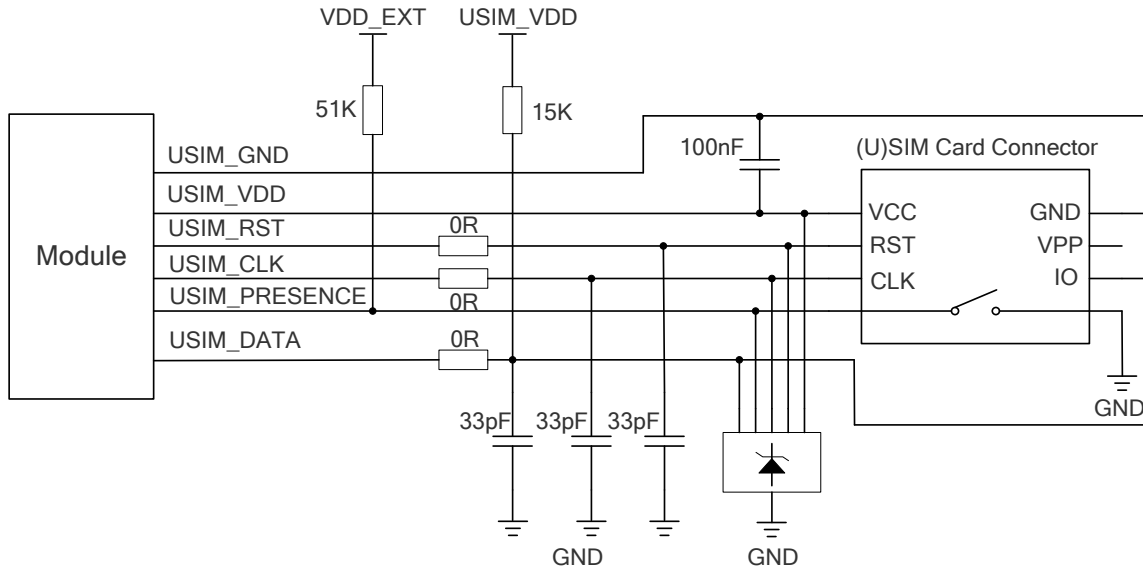
Figure 13: Reference Circuit of (U)SIM Interface with an 8-Pin (U)SIM Card Connector

If (U)SIM card detection function is not needed, please keep USIM_PRESENCE unconnected. A reference circuit for (U)SIM interface with a 6-pin (U)SIM card connector is illustrated in the following figure.
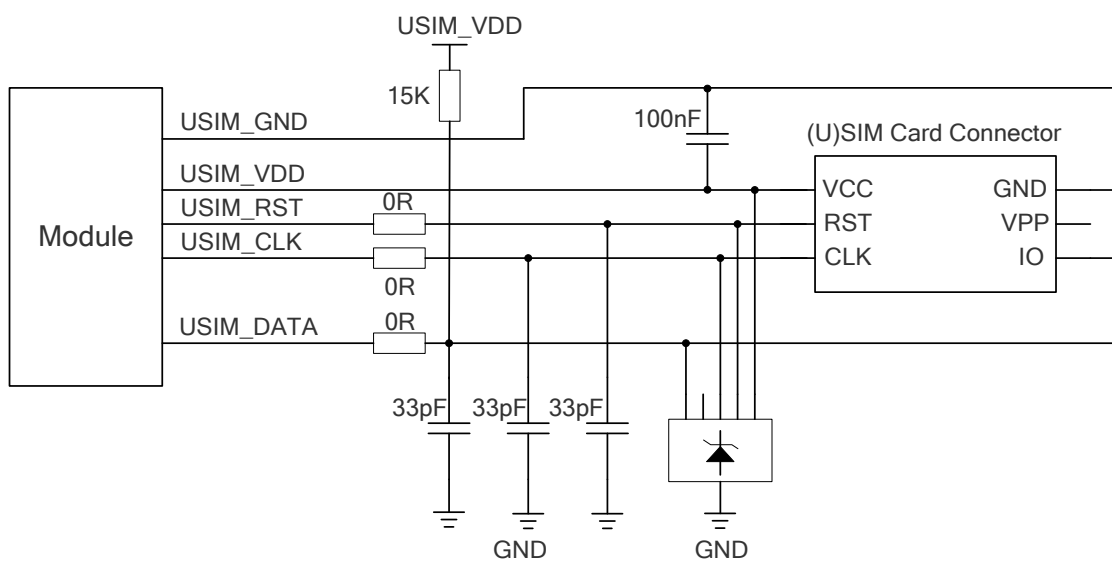
Figure 14: Reference Circuit of (U)SIM Interface with a 6-Pin (U)SIM Card Connector

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

● Keep the placement of (U)SIM card connector as close to the module as possible. Keep the trace length as less than 200mm as possible.
● Keep (U)SIM card signals away from RF and VBAT traces.
● Assure the ground 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. Make sure the bypass capacitor between USIM_VDD and USIM_GND less than 1uF, and place it as close to (U)SIM card connector as possible. If the system ground plane is complete, USIM_GND can be connected to the system ground directly.
● To avoid cross-talk between USIM_DATA and USIM_CLK, keep them away from each other and shield them with surrounded ground. USIM_RST should also be ground shielded.
● In order to offer good ESD protection, it is recommended to add a TVS diode array with parasitic capacitance not exceeding 15pF. In order to facilitate debugging, it is recommended to reserve series resistors for the (U)SIM signals of the module. The 33pF capacitors are used for filtering interference of EGSM900. Please note that the (U)SIM peripheral circuit should be close to the (U)SIM card connector.
● The pull-up resistor on USIM_DATA line can improve anti-jamming capability when long layout trace and sensitive occasion are applied, and should be placed close to the (U)SIM card connector.

3.9. USB Interface

BG96 contains one integrated Universal Serial Bus (USB) interface which complies with the USB 2.0 specification and supports high-speed (480Mbps) and full-speed (12Mbps) modes. The USB interface is used for AT command communication, data transmission, software debugging and firmware upgrade. 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_VBUS	8	AI	USB connection detection	Typically 5.0V
USB_DP	9	IO	USB differential data bus (+)	Require differential impedance of 90Ω
USB_DM	10	IO	USB differential data bus (-)	
GND	3		Ground	

For more details about USB 2.0 specification, 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 interface.
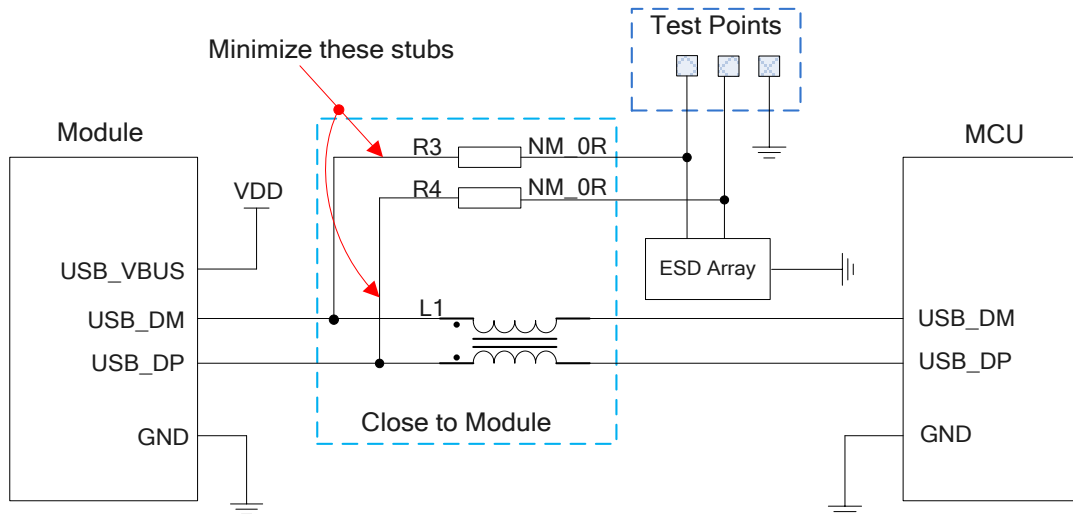
Figure 15: Reference Circuit of USB Interface

A common mode choke L1 is recommended to be added in series between the module and customer's MCU in order to suppress EMI spurious transmission. Meanwhile, the 0Ω resistors (R3 and R4) should be added in series between the module and the test points so as to facilitate debugging, and the resistors are not mounted by default. In order to ensure the integrity of USB data line signal, L1/R3/R4 components must be placed close to the module, and also these resistors should be placed close to each other. The extra stubs of trace must be as short as possible.

The following principles should be complied with while designing the USB interface, so as to meet USB 2.0 specification.

● It is important to route the USB signal traces as differential pairs with total grounding. The impedance of USB differential trace is 90Ω.
● Do not route signal traces under crystals, oscillators, magnetic devices and RF signal traces. It is important to route the USB differential traces in inner-layer with ground shielding on not only upper and lower layers but also right and left sides.
● Pay attention to the influence of junction capacitance of ESD protection devices on USB data lines. Typically, the capacitance value should be less than 2pF.
● Keep the ESD protection devices as close to the USB connector as possible.

NOTE

BG96 module can only be used as a slave device.

3.10. UART Interfaces

The module provides three UART interfaces: UART1, UART2 and UART3 interfaces. The following are their features.

- UART1 interface supports 9600bps, 19200bps, 38400bps, 57600bps, 115200bps, 230400bps, 460800bps and 921600bps baud rates, and the default is 115200bps. It is used for data transmission and AT command communication.
- UART2 interface supports 115200bps baud rate, and is used for module debugging and log output.
- UART3 interface supports 115200bps baud rate, and is used for outputting GNSS data and NMEA sentences.

The following tables show the pin definition of the three UART interfaces.

Table 11: Pin Definition of UART1 Interface

Pin Name	Pin No.	I/O	Description	Comment
DTR	30	DI	Data terminal ready. Sleep mode control.	1.8V power domain
RXD	34	DI	Receive data	1.8V power domain
TXD	35	DO	Transmit data	1.8V power domain
CTS	36	DO	Clear to send	1.8V power domain
RTS	37	DI	Request to send	1.8V power domain
DCD	38	DO	Data carrier detection	1.8V power domain
RI	39	DO	Ring indication	1.8V power domain

NOTE

AT+IPR command can be used to set the baud rate of the UART, and **AT+IFC** command can be used to set the hardware flow control (hardware flow control is disabled by default). Please refer to *document [2]* for details.

Table 12: Pin Definition of UART2 Interface

Pin Name	Pin No.	I/O	Description	Comment
DBG_RXD	22	DI	Receive data	1.8V power domain
DBG_TXD	23	DO	Transmit data	1.8V power domain

Table 13: Pin Definition of UART3 Interface

Pin Name	Pin No.	I/O	Description	Comment
UART3_TXD	27	DO	Transmit data	1.8V power domain
UART3_RXD	28	DI	Receive data	1.8V power domain

The logic levels are described in the following table.

Table 14: Logic Levels of Digital I/O

Parameter	Min.	Max.	Unit
V_{IL}	-0.3	0.6	V
V_{IH}	1.2	2.0	V
V_{OL}	0	0.45	V
V_{OH}	1.35	1.8	V

The module provides 1.8V UART interface. A voltage-level translator should be used if customers' application is equipped with a 3.3V UART interface. The voltage-level translator TXS0108EPWR provided by *Texas Instruments* is recommended. The following figure shows a reference design.
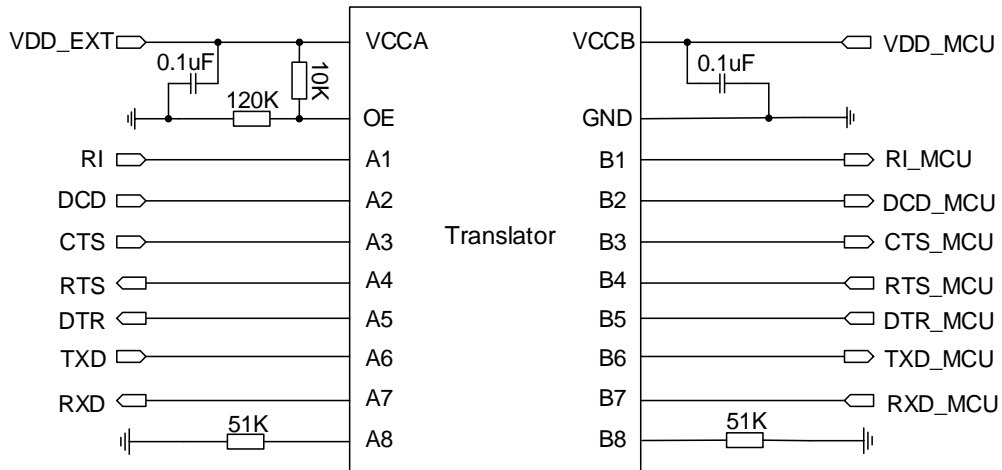
Figure 16: Reference Circuit with Translator Chip

Please visit http://www.ti.com for more information.

Another example with transistor translation circuit is shown as below. For the design of circuits in dotted lines, please refer to that of circuits in solid lines, but please pay attention to the direction of connection.
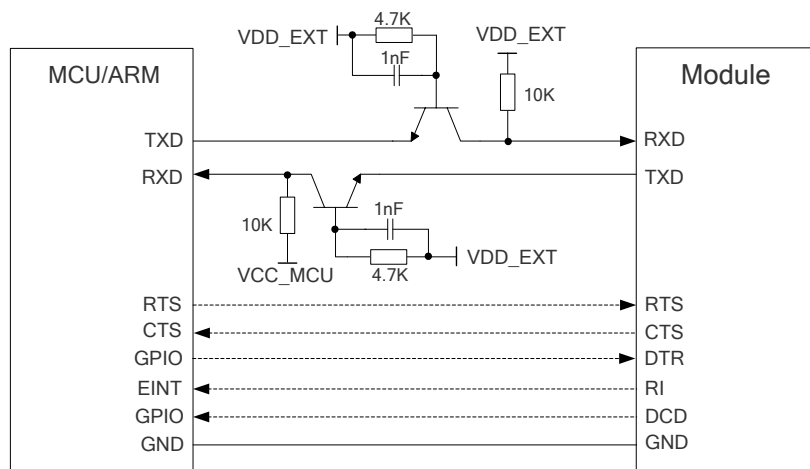
Figure 17: Reference Circuit with Transistor Circuit

NOTE

Transistor circuit solution is not suitable for applications with high baud rates exceeding 460Kbps.

3.11. PCM and I2C Interfaces*

BG96 provides one Pulse Code Modulation (PCM) digital interface and one I2C interface. The following table shows the pin definition of the two interfaces which can be applied on audio codec design.

Table 15: Pin Definition of PCM and I2C Interfaces

Pin Name	Pin No.	I/O	Description	Comment
PCM_CLK	4	DO	PCM clock output	1.8V power domain
PCM_SYNC	5	DO	PCM frame synchronization output	1.8V power domain
PCM_IN	6	DI	PCM data input	1.8V power domain
PCM_OUT	7	DO	PCM data output	1.8V power domain
I2C_SCL	40	OD	I2C serial clock	Require external pull-up to 1.8V
I2C_SDA	41	OD	I2C serial data	Require external pull-up to 1.8V

The following figure shows a reference design of PCM and I2C interfaces with an external codec IC.
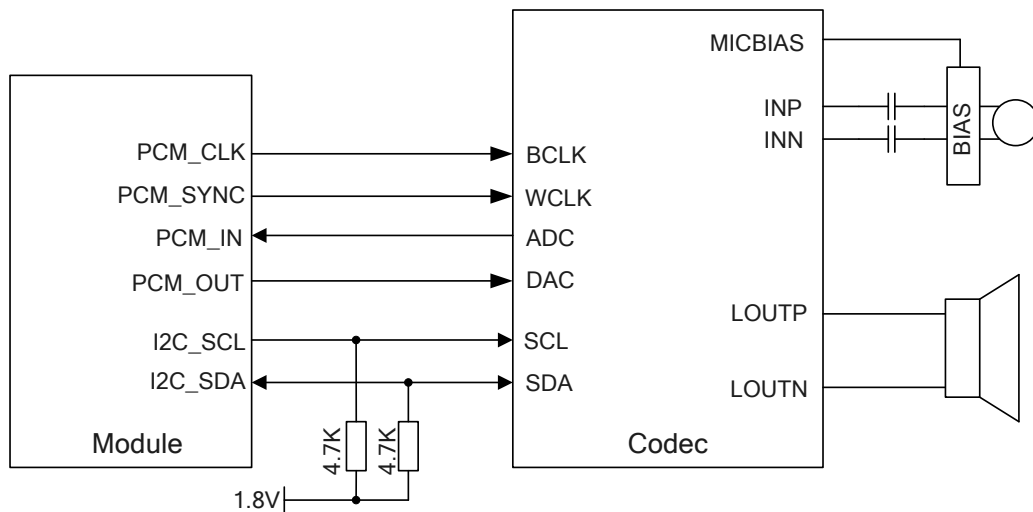
Figure 18: Reference Circuit of PCM Application with Audio Codec

---

NOTE

"*" means under development.

3.12. Network Status Indication

BG96 provides one network status indication pin: NETLIGHT. The pin is used to drive a network status indication LED. The following tables describe the pin definition and logic level changes of NETLIGHT in different network activity status.

Table 16: Pin Definition of NETLIGHT

Pin Name	Pin No.	I/O	Description	Comment
NETLIGHT	21	DO	Indicate the module's network activity status	1.8V power domain

Table 17: Working State of NETLIGHT

Pin Name	Logic Level Changes	Network Status
NETLIGHT	Flicker slowly (200ms High/1800ms Low)	Network searching
	Flicker slowly (1800ms High/200ms Low)	Idle
	Flicker quickly (125ms High/125ms Low)	Data transfer is ongoing
	Always high	Voice calling

A reference circuit is shown in the following figure.
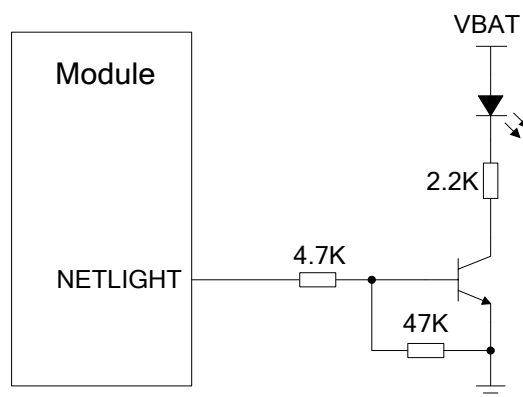
Figure 19: Reference Circuit of NETLIGHT

3.13. STATUS

The STATUS pin is used to indicate the operation status of BG96 module. It will output high level when the module is powered on.

The following table describes the pin definition of STATUS.

Table 18: Pin Definition of STATUS

Pin Name	Pin No.	I/O	Description	Comment
STATUS	20	DO	Indicate the module's operation status	1.8V power domain

The following figure shows a reference circuit of STATUS.
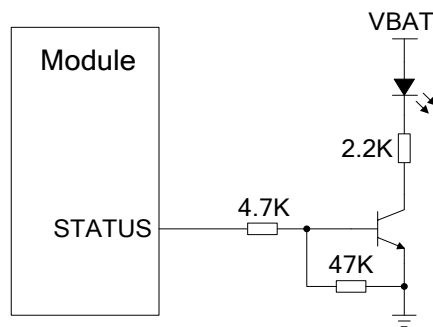
Figure 20: Reference Circuit of STATUS

3.14. Behaviors of RI

AT+QCFG="risignaltype","physical" command can be used to configure RI behavior.

No matter on which port URC is presented, URC will trigger the behavior of RI pin.

NOTE

URC can be outputted from UART port, USB AT port and USB modem port, through configuration via **AT+QURCCFG** command. The default port is USB AT port.

The default behaviors of RI are shown as below.

Table 19: Default Behaviors of RI

State	Response
Idle	RI keeps in high level.
URC	RI outputs 120ms low pulse when a new URC is reported.

The default RI behaviors can be configured flexibly by **AT+QCFG="urc/ri/ring"** command. For more details, please refer to *document [2]*.

3.15. USB_BOOT Interface

BG96 provides a USB_BOOT pin. During development or factory production, USB_BOOT can force the module to boot from USB port for firmware upgrade.

Table 20: Pin Definition of USB_BOOT Interface

Pin Name	Pin No.	I/O	Description	Comment
USB_BOOT	75	DI	Force the module to enter emergency download mode	1.8V power domain. Active high. If unused, keep it open.

The following figure shows a reference circuit of USB_BOOT interface.
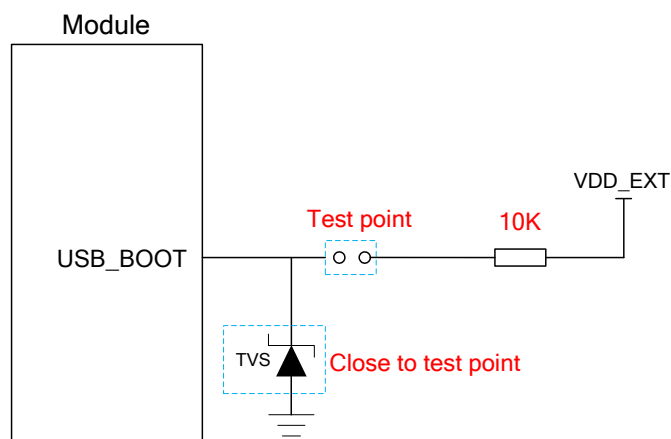
Figure 21: Reference Circuit of USB_BOOT Interface

> **NOTE**

It is recommended to reserve the above circuit design during application design.

3.16. ADC Interfaces

The module provides two analog-to-digital converter (ADC) interfaces. **AT+QADC=0** command can be used to read the voltage value on ADC0 pin. **AT+QADC=1** command can be used to read the voltage value on ADC1 pin. For more details about these AT commands, please refer to *document [2]*.

In order to improve the accuracy of ADC voltage values, the trace of ADC should be surrounded by ground.

Table 21: Pin Definition of ADC Interfaces

Pin Name	Pin No.	Description
ADC0	24	General purpose analog to digital converter interface
ADC1	2	General purpose analog to digital converter interface

The following table describes the characteristics of ADC interfaces.

Table 22: Characteristics of ADC Interfaces

Parameter	Min.	Typ.	Max.	Unit
ADC0 Voltage Range	0.3		1.8	V
ADC1 Voltage Range	0.3		1.8	V
ADC Resolution			15	bits
ADC Analog-input Bandwidth		100		kHz
ADC Sampling Rate		2.4		MHz

> **NOTES**
>
> 1. ADC input voltage must not exceed 1.8V.
> 2. It is prohibited to supply any voltage to ADC pins when VBAT is removed.
> 3. It is recommended to use resistor divider circuit for ADC application, and the divider resistor accuracy should be no less than 1%.

3.17. GPIO Interfaces

The module provides two general-purpose input and output (GPIO) interfaces. **AT+QCFG="GPIO"** command can be used to configure corresponding GPIO pin's status. For more details about the AT command, please refer to *document [2]*.

Table 23: Pin Definition of GPIO Interfaces

Pin Name	Pin No.	Description
GPIO26	26	General purpose input and output interface
GPIO64	64	General purpose input and output interface

The following table describes the characteristics of GPIO interfaces.

Table 24: Logic Levels of GPIO interfaces

Parameter	Min.	Max.	Unit
V_{IL}	-0.3	0.6	V
V_{IH}	1.2	2.0	V
V_{OL}	0	0.45	V
V_{OH}	1.35	1.8	V

> **NOTE**
>
> "*" means under development.

4 GNSS Receiver

4.1. General Description

BG96 includes a fully integrated global navigation satellite system solution that supports Gen8C-Lite of Qualcomm (GPS, GLONASS, BeiDou/Compass, Galileo and QZSS).

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

By default, BG96 GNSS engine is switched off. It has to be switched on via AT command. For more details about GNSS engine technology and configurations, please refer to *document [3]*.

4.2. GNSS Performance

The following table shows the GNSS performance of BG96.

Table 25: GNSS Performance

Parameter	Description	Conditions	Typ.	Unit
Sensitivity (GNSS)	Cold start	Autonomous	-146	dBm
	Reacquisition	Autonomous	-157	dBm
	Tracking	Autonomous	-157	dBm
TTFF (GNSS)	Cold start @open sky	Autonomous	31	s
		XTRA enabled	11.54	s
	Warm start @open sky	Autonomous	21	s
		XTRA enabled	2.52	s

		Autonomous	2.7	s
	Hot start @open sky	XTRA enabled	1.82	s
Accuracy (GNSS)	CEP-50	Autonomous @open sky	< 2.5	m

NOTES

1. Tracking sensitivity: the lowest GNSS signal value at the antenna port on which the module can keep on positioning for 3 minutes.
2. Reacquisition sensitivity: the lowest GNSS signal value at the antenna port on which the module can fix position again within 3 minutes after loss of lock.
3. Cold start sensitivity: the lowest GNSS signal value at the antenna port on which the module fixes position within 3 minutes after executing cold start command.

4.3. Layout Guidelines

The following layout guidelines should be taken into account in customers' designs.

- Maximize the distance between the GNSS antenna and the main antenna.
- Digital circuits such as (U)SIM card, USB interface, camera module, display connector and SD card should be kept away from the antennas.
- Use ground vias around the GNSS trace and sensitive analog signal traces to provide coplanar isolation and protection.
- Keep 50Ω characteristic impedance for the ANT_GNSS trace.

Please refer to *Chapter 5* for GNSS antenna reference design and antenna installation information.

5 Antenna Interfaces

BG96 includes a main antenna interface and a GNSS antenna interface. The antenna ports have an impedance of 50Ω.

5.1. Main Antenna Interface

5.1.1. Pin Definition

The pin definition of main antenna interface is shown below.

Table 26: Pin Definition of Main Antenna Interface

Pin Name	Pin No.	I/O	Description	Comment
ANT_MAIN	60	IO	Main antenna interface	50Ω characteristic impedance

5.1.2. Operating Frequency

Table 27: BG96 Operating Frequency

3GPP Band	Transmit	Receive	Unit
LTE-FDD B1	1920~1980	2110~2170	MHz
LTE-FDD B2, PCS1900	1850~1910	1930~1990	MHz
LTE-FDD B3, DCS1800	1710~1785	1805~1880	MHz
LTE-FDD B4	1710~1755	2110~2155	MHz
LTE-FDD B5, GSM850	824~849	869~894	MHz
LTE-FDD B8, EGSM900	880~915	925~960	MHz
LTE-FDD B12	699~716	729~746	MHz

LTE-FDD B13	777~787	746~756	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 B25 [1]	1850~1915	1930~1995	MHz
LTE-FDD B26*	814~849	859~894	MHz
LTE-FDD B28	703~748	758~803	MHz
LTE-TDD B39	1880~1920	1880~1920	MHz

NOTES

1. [1] LTE-FDD B25 is supported on BG96 of R1.2 hardware version.
2. "*" means under development.

5.1.3. Reference Design of RF Antenna Interface

A reference design of main antenna pad is shown as below. A π-type matching circuit should be reserved for better RF performance, and the π-type matching components (R1/C1/C2) should be placed as close to the antenna as possible. The capacitors are not mounted by default.
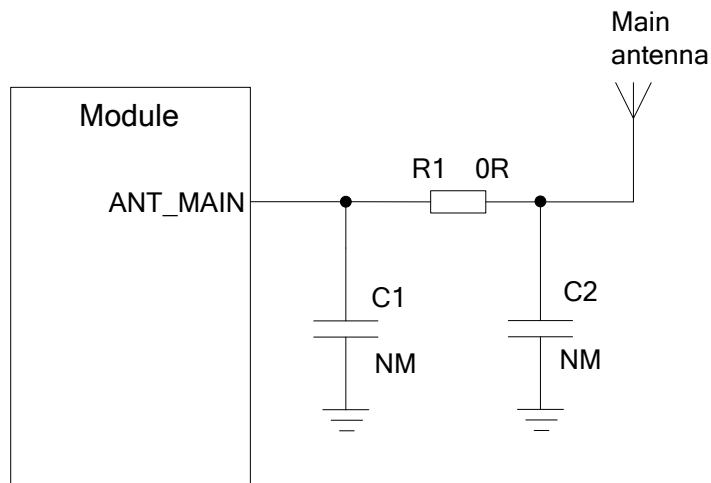
Figure 22: Reference Circuit of RF Antenna Interface

5.1.4. Reference Design of RF Layout

For user's PCB, the characteristic impedance of all RF traces should be controlled to 50Ω. The impedance of the RF traces is usually determined by the trace width (W), the materials' dielectric constant, height from the reference ground to the signal layer (H), and the clearance between RF traces and grounds (S). Microstrip or coplanar waveguide is typically used in RF layout to control characteristic impedance. The following are reference designs of microstrip or coplanar waveguide with different PCB structures.
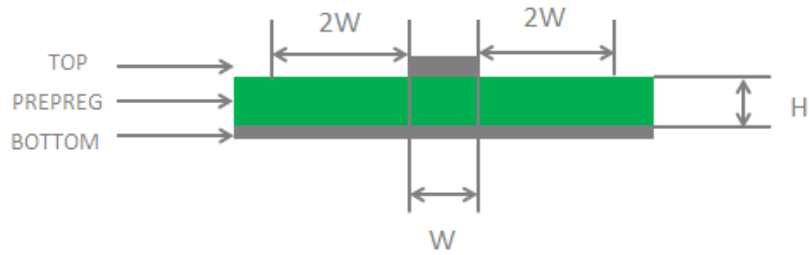
Figure 23: Microstrip Design on a 2-layer PCB
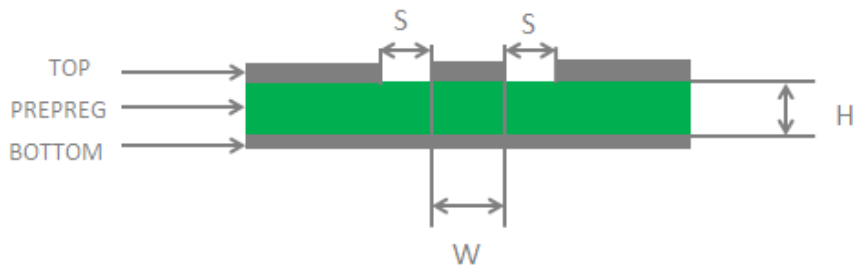
Figure 24: Coplanar Waveguide Design on a 2-layer PCB
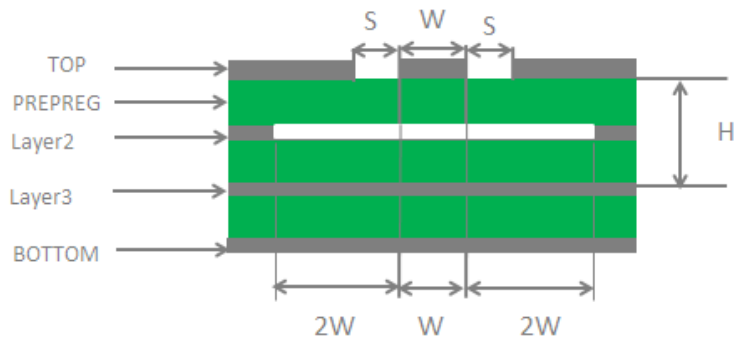
Figure 25: Coplanar Waveguide Design on a 4-layer PCB (Layer 3 as Reference Ground)
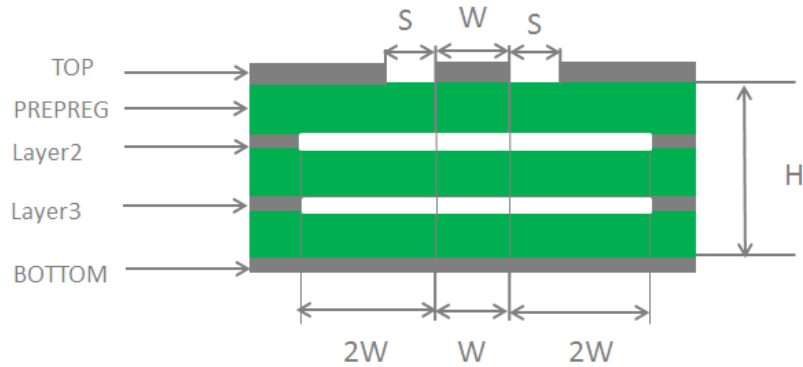
Figure 26: Coplanar Waveguide Design on a 4-layer PCB (Layer 4 as Reference Ground)

In order to ensure RF performance and reliability, the following principles should be complied with in RF layout design:

● Use an impedance simulation tool to accurately control the characteristic impedance of RF traces to 50Ω.
● The GND pins adjacent to RF pins should not be designed as thermal relief pads, and should be fully connected to ground.
● The distance between the RF pins and the RF connector should be as short as possible, and all the right-angle traces should be changed to curved ones.
● There should be clearance under the signal pin of the antenna connector or solder joint.
● The reference ground of RF traces should be complete. Meanwhile, adding some ground vias around RF traces and the reference ground could help to improve RF performance. The distance between the ground vias and RF traces should be no less than two times as wide as RF signal traces (2*W).

For more details about RF layout, please refer to **document [4].**

5.2. GNSS Antenna Interface

The following tables show the pin definition and frequency specification of GNSS antenna interface.

Table 28: Pin Definition of GNSS Antenna Interface

Pin Name	Pin No.	I/O	Description	Comment
ANT_GNSS	49	AI	GNSS antenna interface	50Ω impedance

Table 29: 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

A reference design of GNSS antenna interface is shown as below.
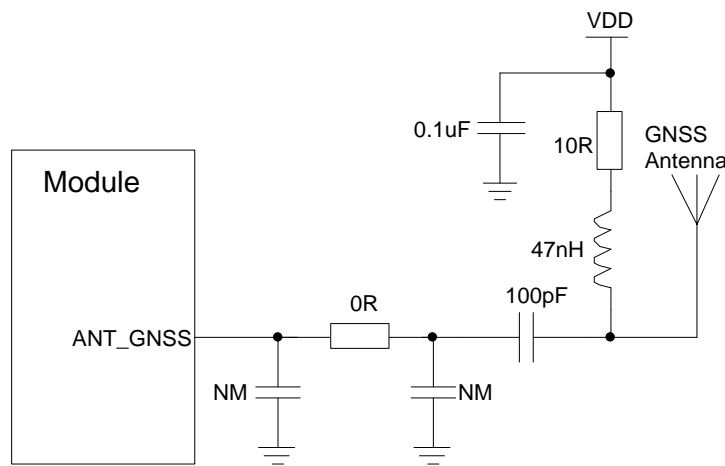
Figure 27: Reference Circuit of GNSS Antenna Interface

> **NOTES**
>
> 1. An external LDO can be selected to supply power according to the active antenna requirement.
> 2. If the module is designed with a passive antenna, then the VDD circuit is not needed.

5.3. Antenna Installation

5.3.1. Antenna Requirements

The following table shows the requirements on main antenna and GNSS antenna.

Table 30: Antenna Requirements

Antenna Type	Requirements	
GNSS [1]	Frequency range: 1559MHz ~1609MHz Polarization: RHCP or linear VSWR: < 2 (Typ.) Passive antenna gain: > 0dBi Active antenna noise figure: < 1.5dB Active antenna gain: > 0dBi Active antenna embedded LNA gain: < 17dB	
LTE/GSM	VSWR: ≤ 2 Efficiency: > 30% Max Input Power (W): 50 Input Impedance (Ω): 50 Cable Insertion Loss: < 1dB (LTE B5/B8/B12/B13/B18/B19/B20/B26/B28, GSM850/EGSM900) Cable Insertion Loss: < 1.5dB (LTE B1/B2/B3/B4/B25/B39, DCS1800/PCS1900)	

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.

5.3.2. Recommended RF Connector for Antenna Installation

If RF connector is used for antenna connection, it is recommended to use the U.FL-R-SMT connector provided by *HIROSE.*
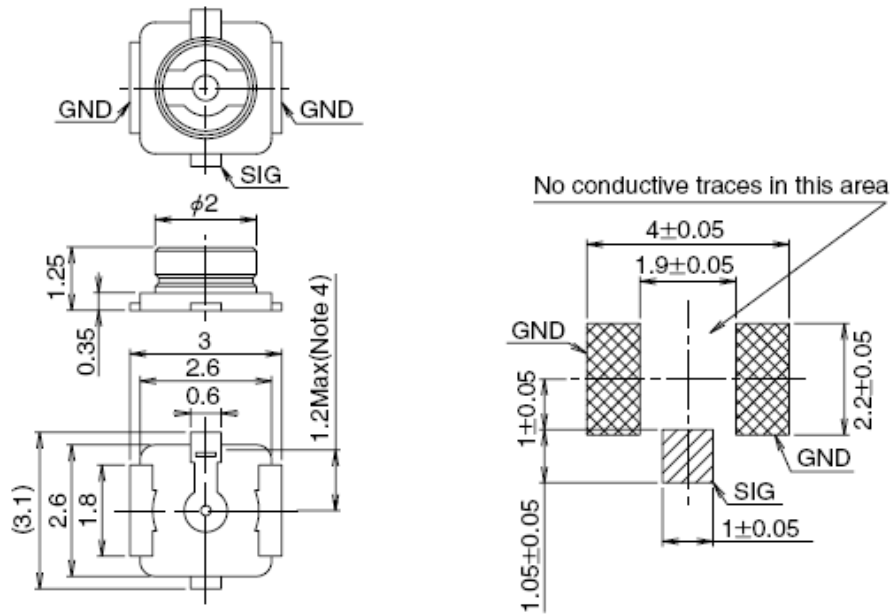
Figure 28: Dimensions of the U.FL-R-SMT Connector (Unit: mm)

U.FL-LP serial connectors listed in the following figure can be used to match the U.FL-R-SMT.

	U.FL-LP-040	U.FL-LP-066	U.FL-LP(V)-040	U.FL-LP-062	U.FL-LP-088
Part No.					
Mated Height	2.5mm Max. (2.4mm Nom.)	2.5mm Max. (2.4mm Nom.)	2.0mm Max. (1.9mm Nom.)	2.4mm Max. (2.3mm Nom.)	2.4mm Max. (2.3mm Nom.)
Applicable cable	Dia. 0.81mm Coaxial cable	Dia. 1.13mm and Dia. 1.32mm Coaxial cable	Dia. 0.81mm Coaxial cable	Dia. 1mm Coaxial cable	Dia. 1.37mm Coaxial cable
Weight (mg)	53.7	59.1	34.8	45.5	71.7
RoHS	YES				

Figure 29: Mechanicals of U.FL-LP Connectors

The following figure describes the space factor of mated connector.
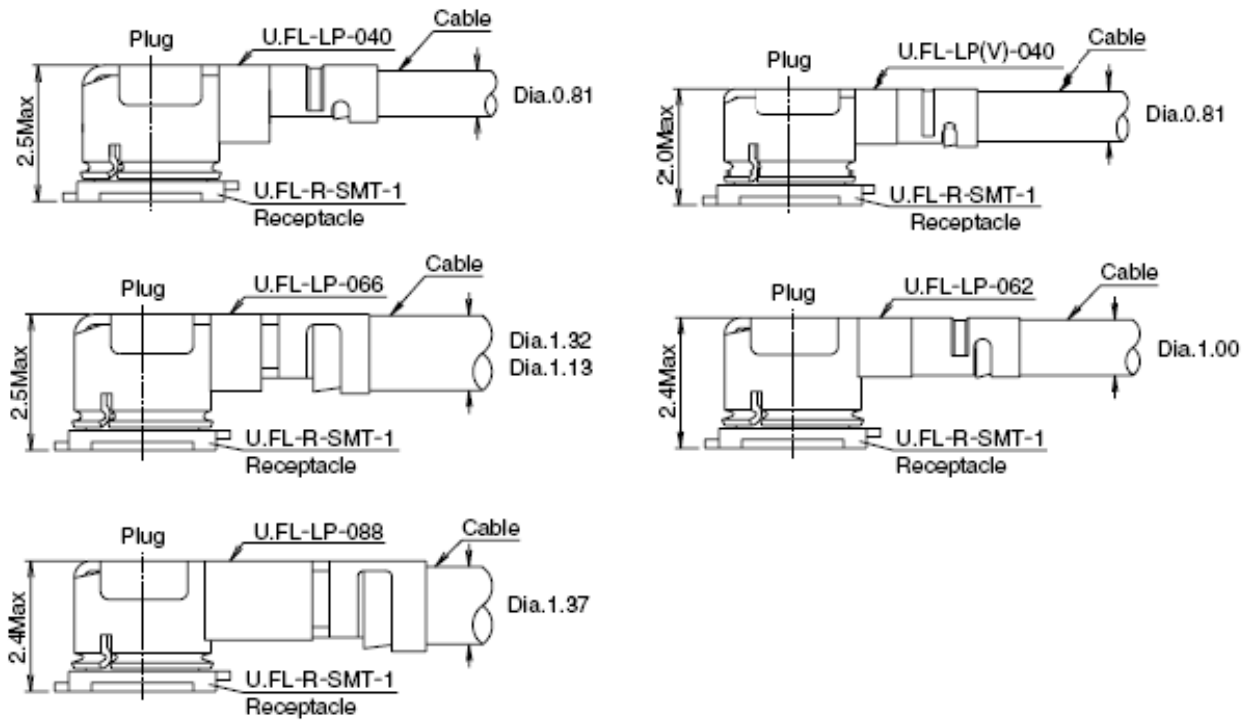
Figure 30: Space Factor of Mated Connector (Unit: mm)

For more details, please visit http://www.hirose.com.

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 31: Absolute Maximum Ratings

Parameter	Min.	Max.	Unit
VBAT_BB	-0.5	6	V
VBAT_RF	-1.2	6	V
USB_VBUS	-0.3	5.5	V
Voltage at Digital Pins	-0.3	2.3	V

6.2. Power Supply Ratings

Table 32: Power Supply Ratings

Parameter	Description	Conditions	Min.	Typ.	Max.	Unit
VBAT	VBAT_BB and VBAT_RF	The actual input voltages must stay between the minimum and maximum values.	3.3	3.8	4.3	V
I_{VBAT}	Peak supply current (during transmission slot)	Maximum power control level on EGSM900		1.8	2.0	A

USB_VBUS	USB detection		3.0	5.0	5.25	V

6.3. Operation and Storage Temperatures

The operation and storage temperatures of the module are listed in the following table.

Table 33: Operation and Storage Temperatures

Parameter	Min.	Typ.	Max.	Unit
Operation Temperature Range [1]	-35	+25	+75	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.
2. [2] Within extended temperature range, the module remains the ability to establish and maintain a voice, SMS, data transmission, emergency call, etc. There is no unrecoverable malfunction. There are also no effects on radio spectrum and no harm to radio network. Only one or more parameters like P_{out} might reduce in their value and exceed the specified tolerances. When the temperature returns to the normal operating temperature levels, the module will meet 3GPP specifications again.

6.4. Current Consumption

The following table shows current consumption of BG96 module.

Table 34: BG96 Current Consumption

Parameter	Description	Conditions	Typ. [1]	Unit
I_{VBAT}	Leakage Current	Power off mode	8	uA
	PSM	Power Saving Mode @Real Network	10	uA

Rock Bottom Sleep [2]	**AT+CFUN=0** @Sleep State	0.8	mA
Sleep State [3]	DRX=1.28s @ Instrument	1.5	mA
	DRX=1.28s @ Instrument	1.96	mA
	e-I-DRX=20.48s @ Instrument	1.2	mA
	e-I-DRX=20.48s @ Instrument	1.1	mA
	@Real 2G Network	2.0	mA
Idle State	DRX=1.28s @ Instrument	15	mA
	DRX=1.28s @ Instrument	15	mA
	e-I-DRX=20.48s @ Instrument	15	mA
	e-I-DRX=20.48s @ Instrument	15	mA
	@Real 2G Network	15	mA
LTE Cat M1 Data Transfer (GNSS OFF)	LTE-FDD B1 @23.31dBm	220	mA
	LTE-FDD B2 @23.05dBm	208	mA
	LTE-FDD B3 @23.09dBm	214	mA
	LTE-FDD B4 @23.19dBm	214	mA
	LTE-FDD B5 @23.22dBm	210	mA
	LTE-FDD B8 @21.83dBm	203	mA
	LTE-FDD B12 @21.88dBm	215	mA
	LTE-FDD B13 @21.96dBm	197	mA
	LTE-FDD B18 @23.04dBm	212	mA
	LTE-FDD B19 @23.13dBm	211	mA
	LTE-FDD B20 @23.07dBm	209	mA
	LTE-FDD B25 @23.01dBm	211	mA
	LTE-FDD B26 @TBD	TBD	mA
	LTE-FDD B28 @22.52dBm	215	mA

	LTE-TDD B39 @TBD	TBD	mA
LTE Cat NB1 Data Transfer (GNSS OFF)	LTE-FDD B1 @22.8dBm	170	mA
	LTE-FDD B2 @22.6dBm	171	mA
	LTE-FDD B3 @22.6dBm	161	mA
	LTE-FDD B4 @22.6dBm	161	mA
	LTE-FDD B5 @22.9dBm	156	mA
	LTE-FDD B8 @22.7dBm	170	mA
	LTE-FDD B12 @23dBm	170	mA
	LTE-FDD B13 @22.9dBm	167	mA
	LTE-FDD B18 @23.1dBm	159	mA
	LTE-FDD B19 @22.9dBm	155	mA
	LTE-FDD B20 @22.7dBm	157	mA
	LTE-FDD B25 @23dBm	165	mA
	LTE-FDD B26 @TBD	TBD	mA
	LTE-FDD B28 @22.5dBm	163	mA
GPRS Data Transfer (GNSS OFF)	GSM850 4UL 1DL @30.17dBm	575	mA
	GSM850 3UL 2DL @32dBm	533	mA
	GSM850 2UL 3DL @32.74dBm	402	mA
	GSM850 1UL 4DL @32.52dBm	220	mA
	EGSM900 4UL 1DL @30.54dBm	586	mA
	EGSM900 3UL2DL @31.36dBm	556	mA
	EGSM900 2UL 3DL @32.62dBm	399	mA
	EGSM900 1UL 4DL @32.75dBm	228	mA
	DCS1800 4UL 1DL @29.81dBm	543	mA
	DCS1800 3UL 2DL @30.09dBm	426	mA

	DCS1800 2UL 3DL @30.1dBm	301	mA
	DCS1800 1UL4DL @30.34dBm	182	mA
	PCS1900 4UL 1DL @29.64dBm	516	mA
	PCS1900 3UL 2DL @29.86dBm	404	mA
	PCS1900 2UL 3DL @29.7dBm	281	mA
	PCS1900 1UL 4DL @29.94dBm	171	mA
	GSM850 4UL1DL @26.02dBm	403	mA
	GSM850 3UL 2DL @26.11dBm	312	mA
	GSM850 2UL 3DL @26.57dBm	224	mA
	GSM850 1UL 4DL @26.92dBm	136	mA
	EGSM900 4UL 1DL @25.92dBm	391	mA
	EGSM900 3UL 2DL @26.11dBm	301	mA
	EGSM900 2UL 3DL @26.16dBm	217	mA
EDGE Data Transfer (GNSS OFF)	EGSM900 1UL 4DL @26.88dBm	133	mA
	DCS1800 4UL 1DL @24.7dBm	373	mA
	DCS1800 3UL 2DL @25.97dBm	286	mA
	DCS1800 2UL 3DL @25.03dBm	208	mA
	DCS1800 1UL 4DL @25.03dBm	127	mA
	PCS1900 4UL1DL @24.92dBm	375	mA
	PCS1900 3UL 2DL @24.86dBm	288	mA
	PCS1900 2UL 3DL @25.17dBm	207	mA
	PCS1900 1UL 4DL @25.31dBm	127	mA
LTE Voice (GNSS OFF)	Voice @LTE Cat M1 network	108	mA

Table 35: GNSS Current Consumption

Description	Conditions	Typ.	Unit
Searching (AT+CFUN=0)	Cold Start @Passive Antenna	41.7	mA
	Lost State @Passive Antenna	42	mA
Tracking (AT+CFUN=0)	Instrument Environment	21.7	mA
	Open Sky @Passive Antenna	36	mA
	Open Sky @Active Antenna	35	mA

6.5. RF Output Power

The following table shows the RF output power of BG96 module.

Table 36: BG96 RF Output Power

Frequency	Max.	Min.
LTE-FDD B1/B2/B3/B4/B5/B8/B12/B13/B18/B19/B20/B25/B26/B28	23dBm±2dB	<-39dBm
LTE-TDD B39	23dBm±2dB	<-39dBm
GSM850/EGSM900	33dBm±2dB	5dBm±5dB
DCS1800/PCS1900	30dBm±2dB	0dBm±5dB
GSM850/EGSM900 (8-PSK)	27dBm±3dB	5dBm±5dB

DCS1800/PCS1900 (8-PSK)	26dBm±3dB	0dBm±5dB

6.6. RF Receiving Sensitivity

The following table shows the conducted RF receiving sensitivity of BG96 module.

Table 37: BG96 Conducted RF Receiving Sensitivity

Network	Band	Primary	Diversity	Sensitivity (dBm)	
				Cat M1/3GPP	Cat NB1[1)]/3GPP
LTE	LTE-FDD B1	Supported	Not Supported	-107.0/-102.7	-112.5/-107.5
	LTE-FDD B2			-106.7/-100.3	-112.5/-107.5
	LTE-FDD B3			-106.8/-99.3	-113/-107.5
	LTE-FDD B4			-106.9/-102.3	-112.5/-107.5
	LTE-FDD B5			-107.0/-100.8	-114/-107.5
	LTE-FDD B8			-107.3/-99.8	-113/-107.5
	LTE-FDD B12			-107.7/-99.3	-113.5/-107.5
	LTE-FDD B13			-106.5/-99.3	-112/-107.5
	LTE-FDD B18			-107.5/-102.3	-113.5/-107.5
	LTE-FDD B19			-107.1/-102.3	-114/-107.5
	LTE-FDD B20			-107.2/-99.8	-114/-107.5
	LTE-FDD B25 [2)]			-106/-100.3	-112/-107.5
	LTE-FDD B26			TBD/-100.3	TBD/-107.5
	LTE-FDD B28			-107.2/-100.8	-113/-107.5
	LTE-TDD B39			TBD /-103	Not Supported
Network	Band	Primary	Diversity	Sensitivity (dBm)	
				GSM/3GPP	

GSM	GSM850/EGSM900	Supported	Not Supported	-109/-102
	DCS1800/PCS1900			-108.5/-102

NOTES

1. [1] LTE Cat NB1 receiving sensitivity without repetitions.
2. [2] LTE-FDD B25 is supported on BG96 of R1.2 hardware version.

6.7. Electrostatic Discharge

The module is not protected against electrostatics 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 electrostatic discharge characteristics of BG96 module.

Table 38: Electrostatic Discharge Characteristics

Tested Interfaces	Contact Discharge	Air Discharge	Unit
VBAT, GND	±10	±15	kV
Main/GNSS Antenna Interfaces	±10	±15	kV

7 Mechanical Dimensions

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

7.1. Mechanical Dimensions of the Module
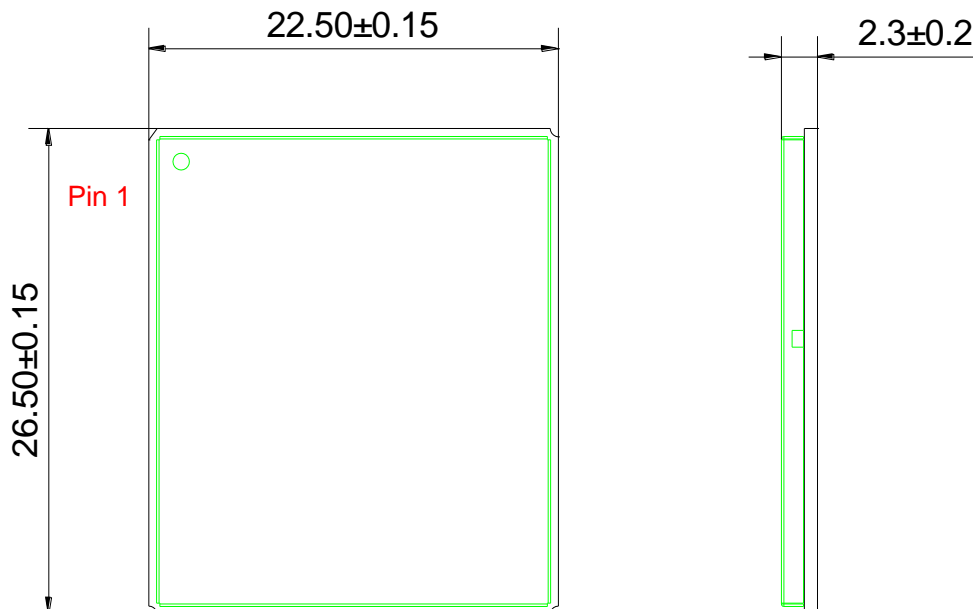
Figure 31: Module Top and Side Dimensions
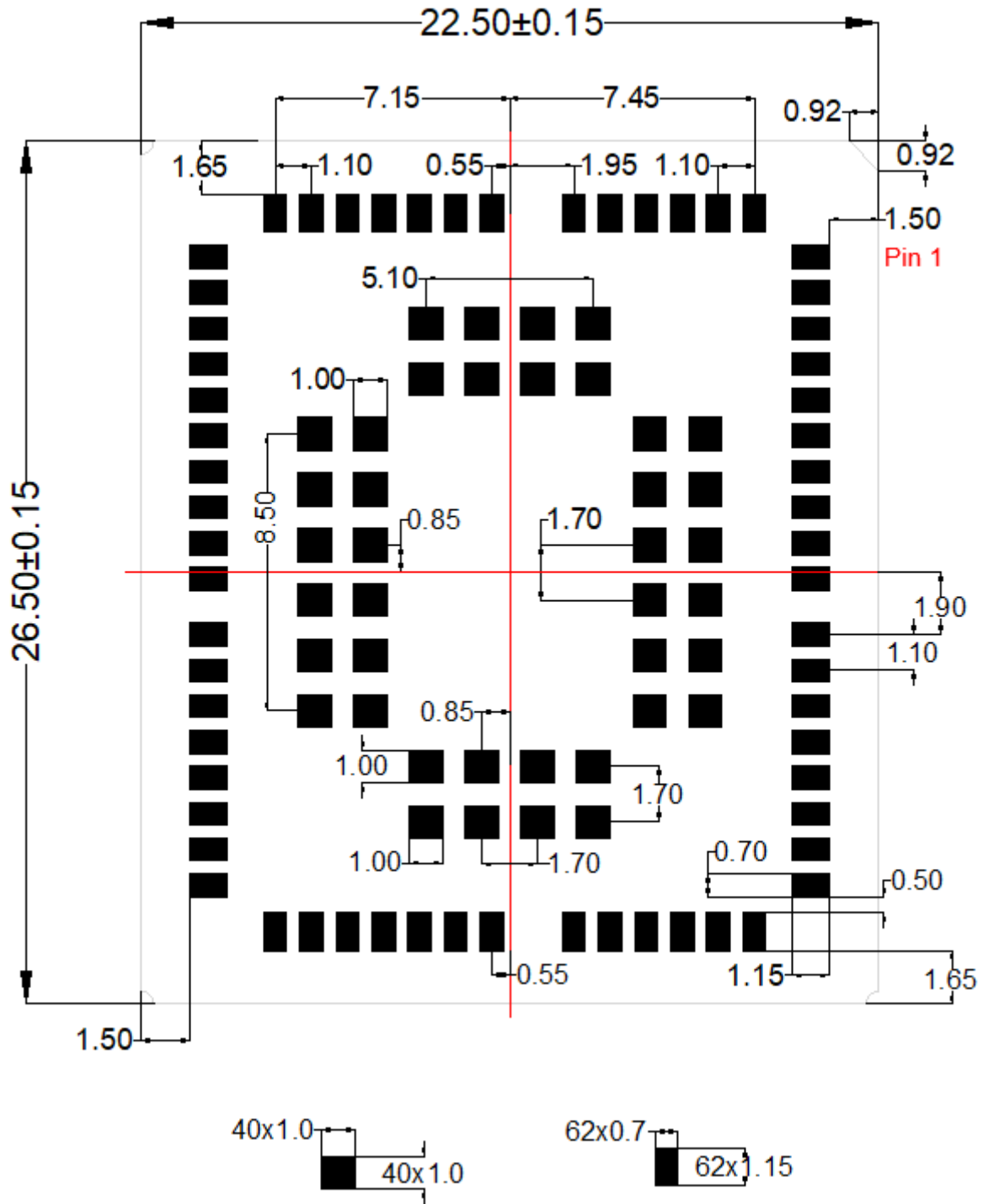
Figure 32: Module Bottom Dimensions (Bottom View)

7.2. Recommended Footprint
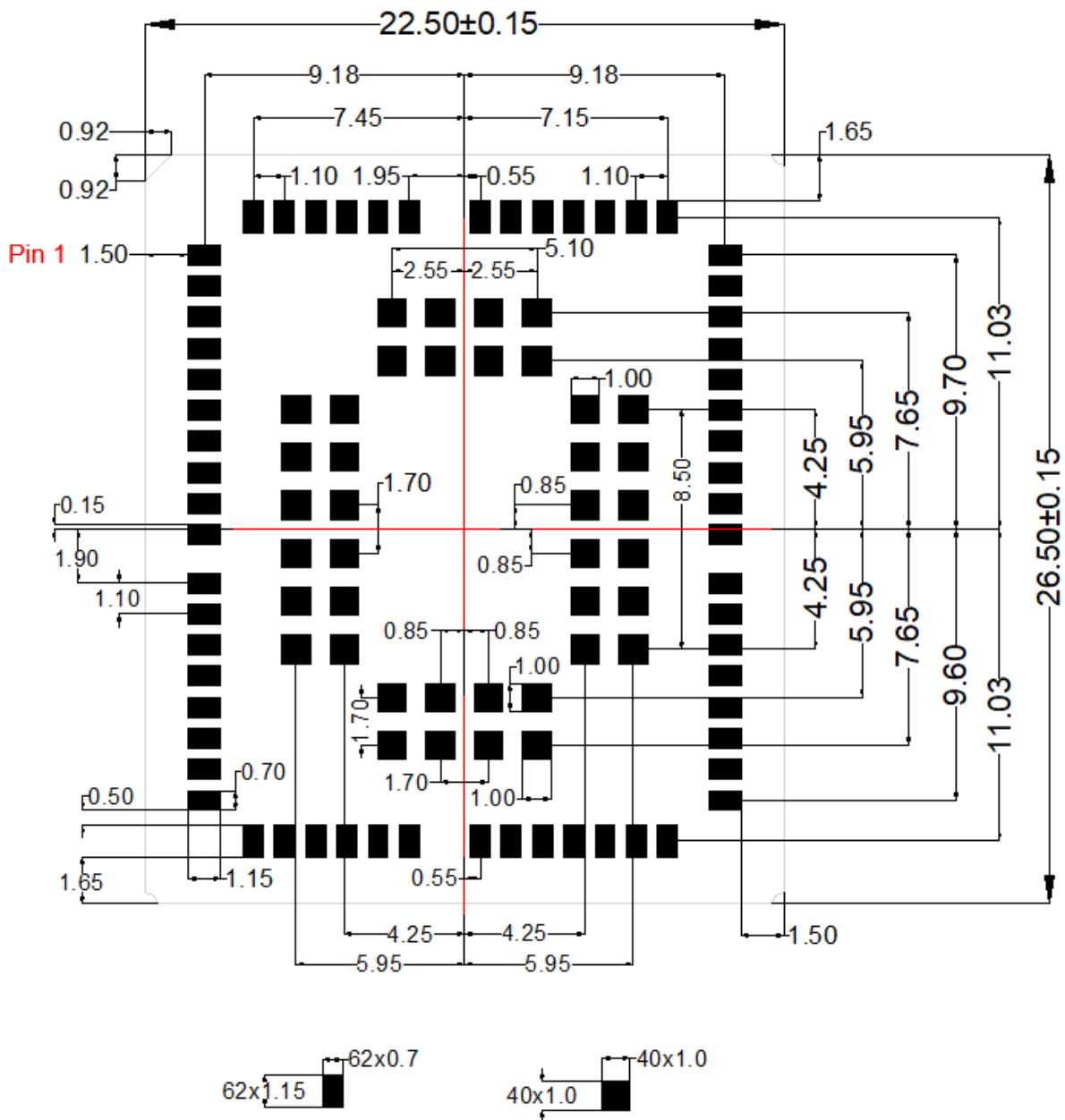
Figure 33: Recommended Footprint (Top View)

NOTES

1. For easy maintenance of the module, please keep about 3mm between the module and other components on the host PCB.
2. All reserved pins must be kept open.
3. For stencil design requirements of the module, please refer to *document [5]*.

7.3. Top/Bottom View of the Module

Figure 34: Top View of the Module
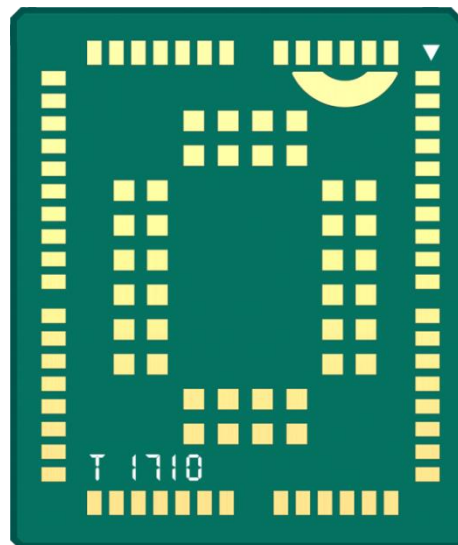
Figure 35: Bottom View of the Module

NOTE

These are renderings of BG96 module. For authentic appearance, please refer to the module that you receive from Quectel.

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8 Storage, Manufacturing and Packaging

8.1. Storage

BG96 is stored in a vacuum-sealed bag. It is rated at MSL 3, and its storage restrictions are listed below.

1. Shelf life in the vacuum-sealed bag: 12 months at <40ºC/90%RH.

2. After the vacuum-sealed bag is opened, devices that will be subjected to reflow soldering or other high temperature processes must be:

    ● Mounted within 168 hours at the factory environment of ≤30ºC/60%RH.
    ● Stored at <10%RH.

3. Devices require baking before mounting, if any circumstance below occurs.

    ● When the ambient temperature is 23ºC±5ºC and the humidity indication card shows the humidity is >10% before opening the vacuum-sealed bag.
    ● Device mounting cannot be finished within 168 hours at factory conditions of ≤30ºC/60% RH.

4. If baking is required, devices may be baked for 8 hours at 120ºC±5ºC.

> **NOTE**
>
> As the plastic package cannot be subjected to high temperature, it should be removed from devices before high temperature (120ºC) baking. If shorter baking time is desired, please refer to *IPC/JEDECJ-STD-033* for baking procedure.

8.2. Manufacturing and Soldering

Push the squeegee to apply the solder paste on the surface of stencil, thus making the paste fill the stencil openings and then penetrate to the PCB. The force on the squeegee should be adjusted properly so as to produce a clean stencil surface on a single pass. To ensure the module soldering quality, the thickness of stencil for the module is recommended to be 0.13mm~0.15mm. For more details, please refer to **document [5]**.

It is suggested that the peak reflow temperature is 238~245°C, and the absolute maximum reflow temperature is 245°C. To avoid damage to the module caused by repeated heating, it is strongly recommended that the module should be mounted after reflow soldering for the other side of PCB has been completed. The recommended reflow soldering thermal profile (lead-free reflow soldering) and related parameters are shown below.
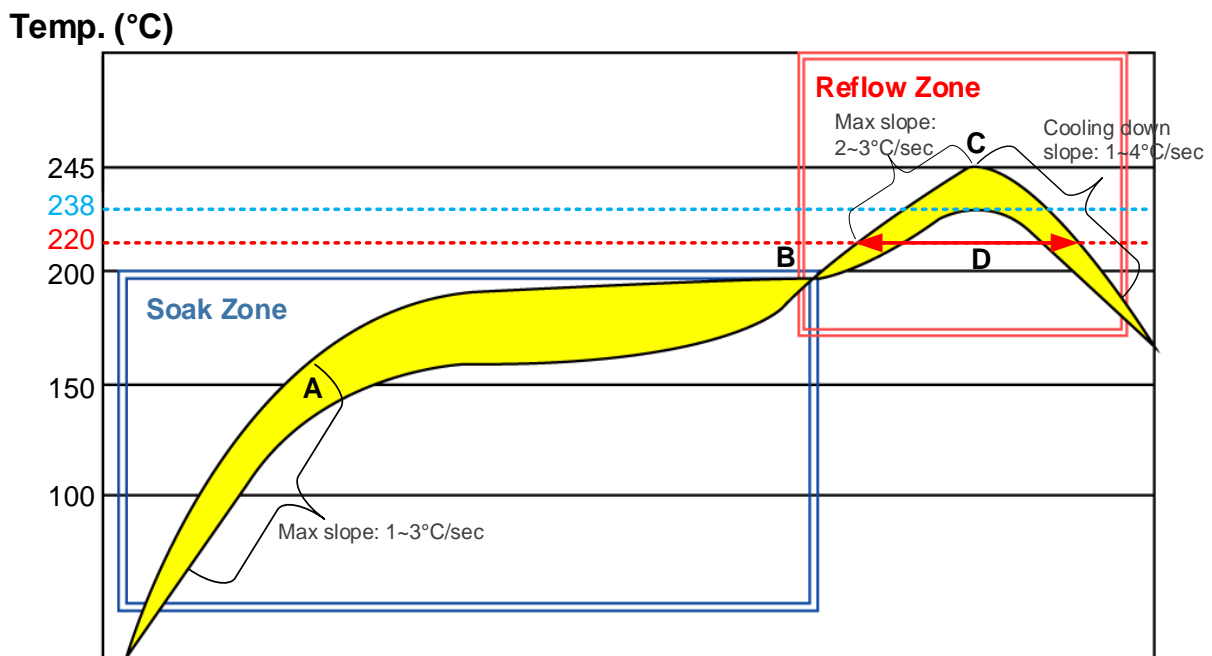
Figure 36: Recommended Reflow Soldering Thermal Profile

Table 39: Recommended Thermal Profile Parameters

Factor	Recommendation
Soak Zone	
Max slope	1 to 3°C/sec
Soak time (between A and B: 150°C and 200°C)	60 to 120 sec

Reflow Zone	
Max slope	2 to 3°C/sec
Reflow time (D: over 220°C)	40 to 60 sec
Max temperature	238°C ~ 245°C
Cooling down slope	1 to 4°C/sec
Reflow Cycle	
Max reflow cycle	1

8.3. Packaging

BG96 is packaged in a vacuum-sealed bag which is ESD protected. The bag should not be opened until the devices are ready to be soldered onto the application.

The reel is 330mm in diameter and each reel contains 250 modules. The following figures show the packaging details, measured in mm.
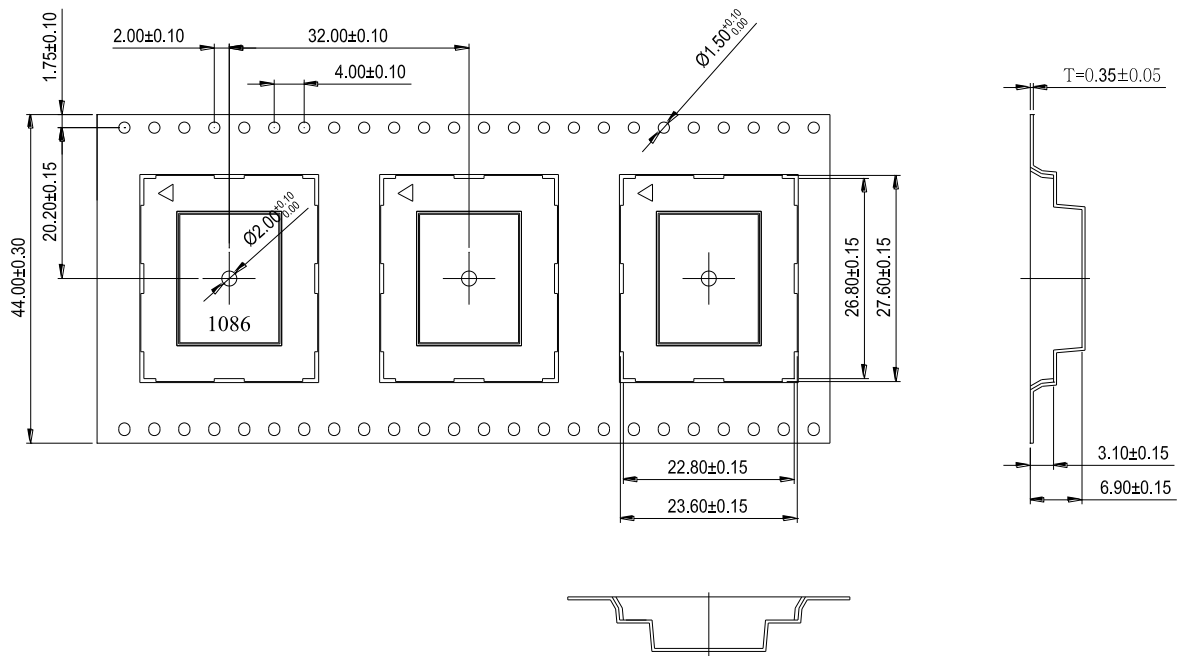
Figure 37: Tape Dimensions
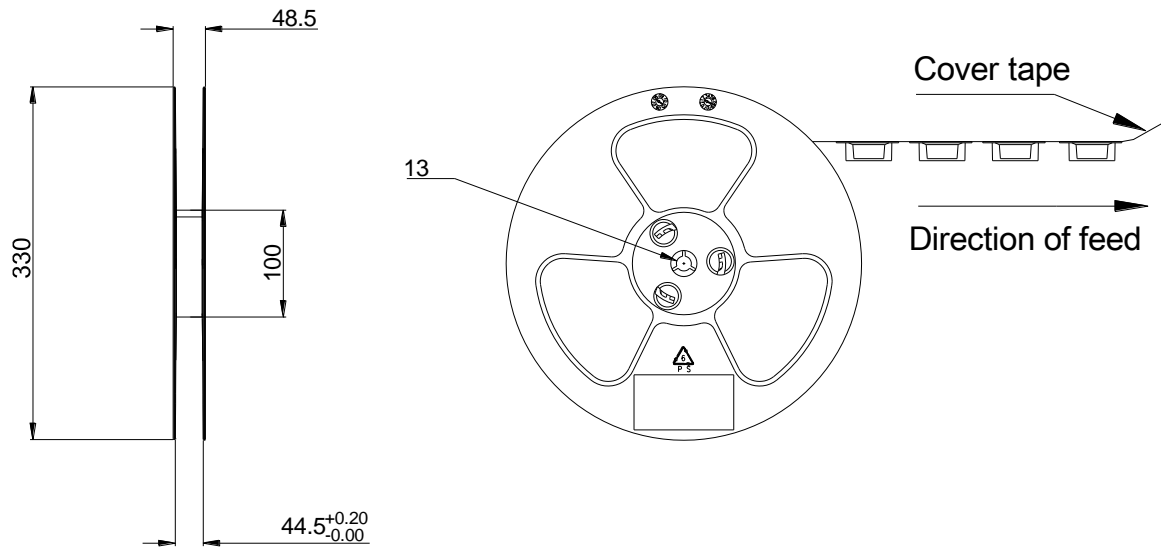
Figure 38: Reel Dimensions

Table 40: Reel Packaging

Model Name	MOQ for MP	Minimum Package: 250pcs	Minimum Package x 4=1000pcs
BG96	250pcs	Size: 370mm × 350mm × 56mm N.W: 1.0kg G.W: 1.71kg	Size: 380mm × 250mm × 365mm N.W: 4.0kg G.W: 7.16kg

9 Appendix A References

Table 41: Related Documents

SN	Document Name	Remark
[1]	Quectel_UMTS&LTE_EVB_User_Guide	UMTS&LTE EVB User Guide
[2]	Quectel_BG96_AT_Commands_Manual	BG96 AT Commands Manual
[3]	Quectel_BG96_GNSS_AT_Commands_Manual	BG96 GNSS AT Commands Manual
[4]	Quectel_RF_Layout_Application_Note	RF Layout Application Note
[5]	Quectel_Module_Secondary_SMT_User_Guide	Module Secondary SMT User Guide

Table 42: Terms and Abbreviations

Abbreviation	Description
AMR	Adaptive Multi-rate
bps	Bits Per Second
CHAP	Challenge Handshake Authentication Protocol
CS	Coding Scheme
CTS	Clear To Send
DFOTA	Delta Firmware Upgrade Over The Air
DL	Downlink
DTR	Data Terminal Ready
DTX	Discontinuous Transmission
e-I-DRX	Extended Idle Mode Discontinuous Reception
EPC	Evolved Packet Core

ESD	Electrostatic Discharge
FDD	Frequency Division Duplex
FR	Full Rate
GMSK	Gaussian Minimum Shift Keying
GSM	Global System for Mobile Communications
HSS	Home Subscriber Server
I/O	Input/Output
Inorm	Normal Current
LED	Light Emitting Diode
LNA	Low Noise Amplifier
LTE	Long Term Evolution
MO	Mobile Originated
MS	Mobile Station (GSM engine)
MT	Mobile Terminated
PAP	Password Authentication Protocol
PCB	Printed Circuit Board
PDU	Protocol Data Unit
PPP	Point-to-Point Protocol
PSM	Power Saving Mode
RF	Radio Frequency
RHCP	Right Hand Circularly Polarized
Rx	Receive
SISO	Single Input Single Output
SMS	Short Message Service
TDD	Time Division Duplexing

TX	Transmitting Direction
UL	Uplink
UE	User Equipment
URC	Unsolicited Result Code
(U)SIM	(Universal) Subscriber Identity Module
Vmax	Maximum Voltage Value
Vnorm	Normal Voltage Value
Vmin	Minimum Voltage Value
$V_{IH}max$	Maximum Input High Level Voltage Value
$V_{IH}min$	Minimum Input High Level Voltage Value
$V_{IL}max$	Maximum Input Low Level Voltage Value
$V_{IL}min$	Minimum Input Low Level Voltage Value
$V_{I}max$	Absolute Maximum Input Voltage Value
$V_{I}min$	Absolute Minimum Input Voltage Value
$V_{OH}max$	Maximum Output High Level Voltage Value
$V_{OH}min$	Minimum Output High Level Voltage Value
$V_{OL}max$	Maximum Output Low Level Voltage Value
$V_{OL}min$	Minimum Output Low Level Voltage Value
VSWR	Voltage Standing Wave Ratio

10 Appendix B GPRS Coding Schemes

Table 43: Description of Different Coding Schemes

Scheme	CS-1	CS-2	CS-3	CS-4
Code Rate	1/2	2/3	3/4	1
USF	3	3	3	3
Pre-coded USF	3	6	6	12
Radio Block excl.USF and BCS	181	268	312	428
BCS	40	16	16	16
Tail	4	4	4	-
Coded Bits	456	588	676	456
Punctured Bits	0	132	220	-
Data Rate Kb/s	9.05	13.4	15.6	21.4

11 Appendix C GPRS Multi-slot Classes

Twenty-nine classes of GPRS multi-slot modes are defined for MS in GPRS specification. Multi-slot classes are product dependent, and determine the maximum achievable data rates in both the uplink and downlink directions. Written as 3+1 or 2+2, the first number indicates the amount of downlink timeslots, while the second number indicates the amount of uplink timeslots. The active slots determine the total number of slots the GPRS device can use simultaneously for both uplink and downlink communications.

The description of different multi-slot classes is shown in the following table.

Table 44: GPRS Multi-slot Classes

Multislot Class	Downlink Slots	Uplink Slots	Active Slots
1	1	1	2
2	2	1	3
3	2	2	3
4	3	1	4
5	2	2	4
6	3	2	4
7	3	3	4
8	4	1	5
9	3	2	5
10	4	2	5
11	4	3	5
12	4	4	5
13	3	3	NA
14	4	4	NA

15	5	5	NA
16	6	6	NA
17	7	7	NA
18	8	8	NA
19	6	2	NA
20	6	3	NA
21	6	4	NA
22	6	4	NA
23	6	6	NA
24	8	2	NA
25	8	3	NA
26	8	4	NA
27	8	4	NA
28	8	6	NA
29	8	8	NA
30	5	1	6
31	5	2	6
32	5	3	6
33	5	4	6

12 Appendix D EDGE Modulation and Coding Schemes

Table 45: EDGE Modulation and Coding Schemes

Coding Schemes	Modulation	Coding Family	1 Timeslot	2 Timeslot	4 Timeslot
CS-1:	GMSK	/	9.05kbps	18.1kbps	36.2kbps
CS-2:	GMSK	/	13.4kbps	26.8kbps	53.6kbps
CS-3:	GMSK	/	15.6kbps	31.2kbps	62.4kbps
CS-4:	GMSK	/	21.4kbps	42.8kbps	85.6kbps
MCS-1	GMSK	C	8.80kbps	17.60kbps	35.20kbps
MCS-2	GMSK	B	11.2kbps	22.4kbps	44.8kbps
MCS-3	GMSK	A	14.8kbps	29.6kbps	59.2kbps
MCS-4	GMSK	C	17.6kbps	35.2kbps	70.4kbps
MCS-5	8-PSK	B	22.4kbps	44.8kbps	89.6kbps
MCS-6	8-PSK	A	29.6kbps	59.2kbps	118.4kbps
MCS-7	8-PSK	B	44.8kbps	89.6kbps	179.2kbps
MCS-8	8-PSK	A	54.4kbps	108.8kbps	217.6kbps
MCS-9	8-PSK	A	59.2kbps	118.4kbps	236.8kbps