MC60-OpenCPU Series
Hardware Design

GSM/GPRS/GNSS Module Series

Rev. MC60-OpenCPU_Series_Hardware_Design_V2.0

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About the Document

History

Revision	Date	Author	Description
1.0	2016-07-27	Tiger CHENG	Initial
1.1	2016-10-10	Tiger CHENG	1. Added three GPIOs which are multiplexed from the following three pins: SIM2_CLK (pin 10), SIM2_DATA (pin 11), SIM2_RST (pin 12). 2. Opened the following five GPIOs: GPIO_0 (pin 57), GPIO_1 (pin 58), GPIO_2 (pin 63), GPIO_3 (pin 64), GPIO_4 (pin 65). 3. Added the description of Periodic Mode (Chapter 3.5.2.4). 4. Added the description of AlwaysLocate™ mode (Chapter 3.5.2.5). 5. Added the description of GLP Mode (Chapter 3.5.2.6). 6. Added the description of QuecFastFix Online function (Chapter 3.20). 7. Added the description of LOCUS (Chapter 3.22). 8. Added the description of 1PPS function (Chapter 3.23). 9. Optimized the ESD performance parameter in Table 49. 10. Added the current consumption data of BT function (Table 48).
2.0	2017-05-15	Tiger CHENG	1. Added the description of SD card interface (Chapter 3.14) 2. Modified the description of Standby mode in operating modes of GNSS part (Chapter 3.7.2.2) 3. Updated the operating modes of GNSS part in All-in-one solution (Table 13) 4. Added BLE function description of MC60E module (Chapter 3.7.4)

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1 Introduction

This document defines the MC60-OpenCPU series module and describes its hardware interface which is connected with the customer application as well as its air interface.

The document can help customers quickly understand module interface specifications, as well as the electrical and mechanical details. Associated with application note and user guide, customers can use MC60-OpenCPU series module to design and set up mobile applications easily.

MC60-OpenCPU series module currently includes two variants (MC60-OpenCPU and MC60E-OpenCPU) which are only different in Bluetooth function. MC60-OpenCPU supports BT3.0 while MC60E-OpenCPU supports BT4.0 & BT3.0 functions. (Hereinafter MC60-OpenCPU series module is collectively called MC60-OpenCPU except in BT function part)

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 MC60-OpenCPU 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 the customer's 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. You must comply with laws and regulations restricting the use of wireless devices while driving.
	Switch off the cellular terminal or mobile before boarding an aircraft. Make sure it is switched off. The operation of wireless appliances in an aircraft is forbidden, so as to prevent interference with communication systems. Consult the airline staff about the use of wireless devices on boarding the aircraft, if your device offers an Airplane Mode which must be enabled prior to boarding an aircraft.
	Switch off your wireless device when in hospitals,clinics or other health care facilities. These requests are desinged to prevent possible interference with sensitive medical equipment.

	Cellular terminals or mobiles operatingover radio frequency signal and cellular network cannot be guaranteed to connect in all conditions, for example no mobile fee or with an invalid (U)SIM card. While you are in this condition and need emergent help, please remember using emergency call. In order to make or receive a call, the cellular terminal or mobile must be switched on and in a service area with adequate cellular signal strength.
	Your cellular terminal or mobile contains a transmitter and receiver. When it is ON, it receives and transmits radio frequency energy. 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

OpenCPU is a method in which the module acts as the main processor. With the development of communication technology and the ever-changing market demands, more and more customers have realized the advantages of OpenCPU solution. Especially, its advantage in reducing the product cost is greatly valued by customers. With the help of OpenCPU solution, development flow for wireless application and hardware design will be simplified. Main features of OpenCPU solution are as below:

1. Reduce product development time.
2. Simplify circuit design and reduce cost & power consumption.
3. Decrease product size.
4. Upgrade firmware remotely via OpenCPU FOTA.
5. Decrease the total cost and enhance the competitive advantages.

MC60-OpenCPU is a multi-purpose module which integrates a high performance GNSS engine and a quad-band GSM/GPRS engine. The quad-band GSM/GPRS engine can work at frequencies of GSM850MHz, EGSM900MHz, DCS1800MHz and PCS1900MHz. MC60-OpenCPU features GPRS multi-slot class 12 and supports the GPRS coding schemes CS-1, CS-2, CS-3 and CS-4. For more details about GPRS multi-slot classes and coding schemes, please refer to the ***Appendix B & C.***

The GNSS engine is a single receiver integrating GLONASS and GPS systems. It supports multiple positioning and navigation systems including autonomous GPS, GLONASS, SBAS (including WAAS, EGNOS, MSAS and GAGAN), and QZSS. It is able to achieve the industry's highest level of sensitivity, accuracy and TTFF with the lowest power consumption. The embedded flash memory provides capacity for storing user-specific configurations and allows for future updates.

MC60-OpenCPU is an SMD type module with 54 LCC pads and 14 LGA pads which can be easily embedded into applications. With a compact profile of 18.7mm × 16.0mm × 2.1mm, the module can meet almost all the requirements for M2M applications, including vehicle and personal tracking, wearable devices, security systems, wireless POS, industrial PDA, smart metering, remote maintenance & control, etc.

Designed with power saving technique, the current consumption of MC60-OpenCPU's GSM part is as low as 1.2mA in Sleep mode when DRX is 5 and the GNSS part is powered off. The GNSS engine also has many advanced power saving modes including standby and backup modes which can fit the requirement of low-power consumption in different scenes.

GSM part of MC60-OpenCPU is integrated with Internet service protocols, such as TCP/UDP, PPP, HTTP and FTP. Extended AT commands have been developed for customers to use these Internet service protocols easily.

EASY technology as a key feature of GNSS part of MC60-OpenCPU is one kind of AGPS. Capable of collecting and processing all internal aiding information like GNSS time, ephemeris, last position, etc., the GNSS part will have a fast TTFF in either Hot or Warm start.

The module fully complies with the RoHS directive of the European Union.

2.2. Key Features

The following table describes the detailed features of MC60-OpenCPU.

Table 1: Key Features (GMS/GPRS Part of MC60-OpenCPU)

Features	Implementation
Power Supply	Single supply voltage: 3.3V~4.6V Typical supply voltage: 4V
Power Saving	Typical power consumption in Sleep mode (GNSS is powered off): 1.2mA @DRX=5 0.8mA @DRX=9
Frequency Bands	● Quad-band: GSM850, EGSM900, DCS1800, PCS1900 ● The module can search these frequency bands automatically ● The frequency bands can be set by AT commands ● Compliant to GSM Phase 2/2+
GSM Class	Small MS
Transmitting Power	● Class 4 (2W) at GSM850 and EGSM900 ● Class 1 (1W) at DCS1800 and PCS1900
GPRS Connectivity	● GPRS multi-slot class 12 (default) ● GPRS multi-slot class 1~12 (configurable) ● GPRS mobile station class B
DATA GPRS	● GPRS data downlink transfer: max 85.6kbps ● GPRS data uplink transfer: max 85.6kbps ● Coding scheme: CS-1, CS-2, CS-3 and CS-4 ● Support the protocol PAP (Password Authentication Protocol) usually used for PPP connection

	● Internet service protocols TCP/UDP, FTP, PPP, HTTP, NTP, PING, etc. ● Support Packet Broadcast Control Channel (PBCCH) ● Support Unstructured Supplementary Service Data (USSD)
Temperature Range	● Operation temperature range: -35°C ~ +75°C [1)] ● Extended temperature range: -40°C ~ +85°C [2)]
(U)SIM Card Interface	● Support (U)SIM: 1.8V, 3.0V ● Support Dual (U)SIM Single Standby
SMS	● Text and PDU mode ● SMS storage: (U)SIM card
Audio Features	Speech codec modes: ● Half Rate (ETS 06.20) ● Full Rate (ETS 06.10) ● Enhanced Full Rate (ETS 06.50/06.60/06.80) ● Adaptive Multi-Rate (AMR) ● Echo Suppression ● Noise Reduction ● Embedded one amplifier of class AB with maximum driving power up to 800mW
UART Interfaces	UART Port: ● Seven lines on UART port interface ● Used for AT command communication and GPRS data transmission ● Used for PMTK command and NMEA output ● Multiplexing function ● Support autobauding from 4800bps to 115200bps Debug Port: ● Two lines on debug port interface DBG_TXD and DBG_RXD ● Debug port only used for firmware debugging Auxiliary Port: ● Two lines on auxiliary port interface: TXD_AUX and RXD_AUX ● Used for communication with the GNSS part
Phonebook Management	Support phonebook types: SM, ME, ON, MC, RC, DC, LD, LA
(U)SIM Application Toolkit	Support SAT class 3, GSM 11.14 Release 99
Physical Characteristics	Size: (18.7±0.15) × (16±0.15) × (2.1±0.2)mm Weight: Approx. 1.3g
Firmware Upgrade	● Via UART Port ● Via OpenCPU FOTA
Antenna Interface	Connected to antenna pad with 50Ω impedance control

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.

Table 2: Coding Schemes and Maximum Net Data Rates over Air Interface

Coding Scheme	1 Timeslot	2 Timeslot	4 Timeslot
CS-1	9.05kbps	18.1kbps	36.2kbps
CS-2	13.4kbps	26.8kbps	53.6kbps
CS-3	15.6kbps	31.2kbps	62.4kbps
CS-4	21.4kbps	42.8kbps	85.6kbps

Table 3: Key Features (GNSS Part of MC60-OpenCPU)

Features	Implementation
GNSS	● GPS+GLONASS
Power Supply	● Supply voltage: 2.8V~4.3V ● Typical Supply voltage: 3.3V
Power Consumption	● Acquisition: 25mA @-130dBm (GPS) ● Tracking: 19mA @-130dBm (GPS) ● Acquisition: 29mA @-130dBm (GPS+GLONASS) ● Tracking: 22mA @-130dBm (GPS+GLONASS) ● Standby: 300uA @VCC=3.3V ● Backup: 14uA @V_BCKP=3.3V
Receiver Type	● GPS L1 1575.42MHz C/A Code ● GLONASS L1 1598.0625~1605.375MHz C/A Code
Sensitivity GPS+GLONASS	● Acquisition: -149dBm ● Reacquisition: -161dBm ● Tracking: -167dBm
Time-to-First-Fix (EASY Enabled) [1]	● Cold Start: <15s average @-130dBm ● Warm Start: <5s average @-130dBm ● Hot Start: 1s @-130dBm

Time-to-First-Fix (EASY Disabled)	● Cold Start (Autonomous): <35s average @-130dBm ● Warm Start (Autonomous): <30s average @-130dBm ● Hot Start (Autonomous): 1s @-130dBm
Horizontal Position Accuracy (Autonomous)	● <2.5m CEP @-130dBm
Update Rate	● Up to 10Hz, 1Hz by default
Accuracy of 1PPS Signal	● Typical accuracy <10ns ● Time pulse width: 100ms
Velocity Accuracy	● Without aid: 0.1m/s
Acceleration Accuracy	● Without aid: 0.1m/s²
Dynamic Performance	● Maximum Altitude: 18000m ● Maximum Velocity: 515m/s ● Acceleration: 4G
GNSS UART Port	● GNSS UART port: GNSS_TXD and GNSS_ RXD ● Support baud rates from 4800bps to 115200bps; 115200bps by default ● Used for communication with the GSM Part

NOTE

[1)] In this mode, GNSS part's backup domain should be valid.

Table 4: Protocols Supported by the Module

Protocol	Type
NMEA	output, ASCII, 0183, 3.01
PMTK	Input/output, MTK proprietary protocol

NOTE

Please refer to ***document [17]*** for details of NMEA standard protocol and MTK proprietary protocol.

2.3. Functional Diagram

The following figure shows a block diagram of MC60-OpenCPU and illustrates the major functional parts.

- Memory
- Radio frequency part
- Power management
- Peripheral interfaces
  - Power supply
  - Turn-on/off interface
  - UART interface
  - Audio interfaces
  - PCM interface
  - SPI interface
  - I2C interface
  - (U)SIM interface
  - ADC interface
  - RF interface
  - BT interface
  - SD interface

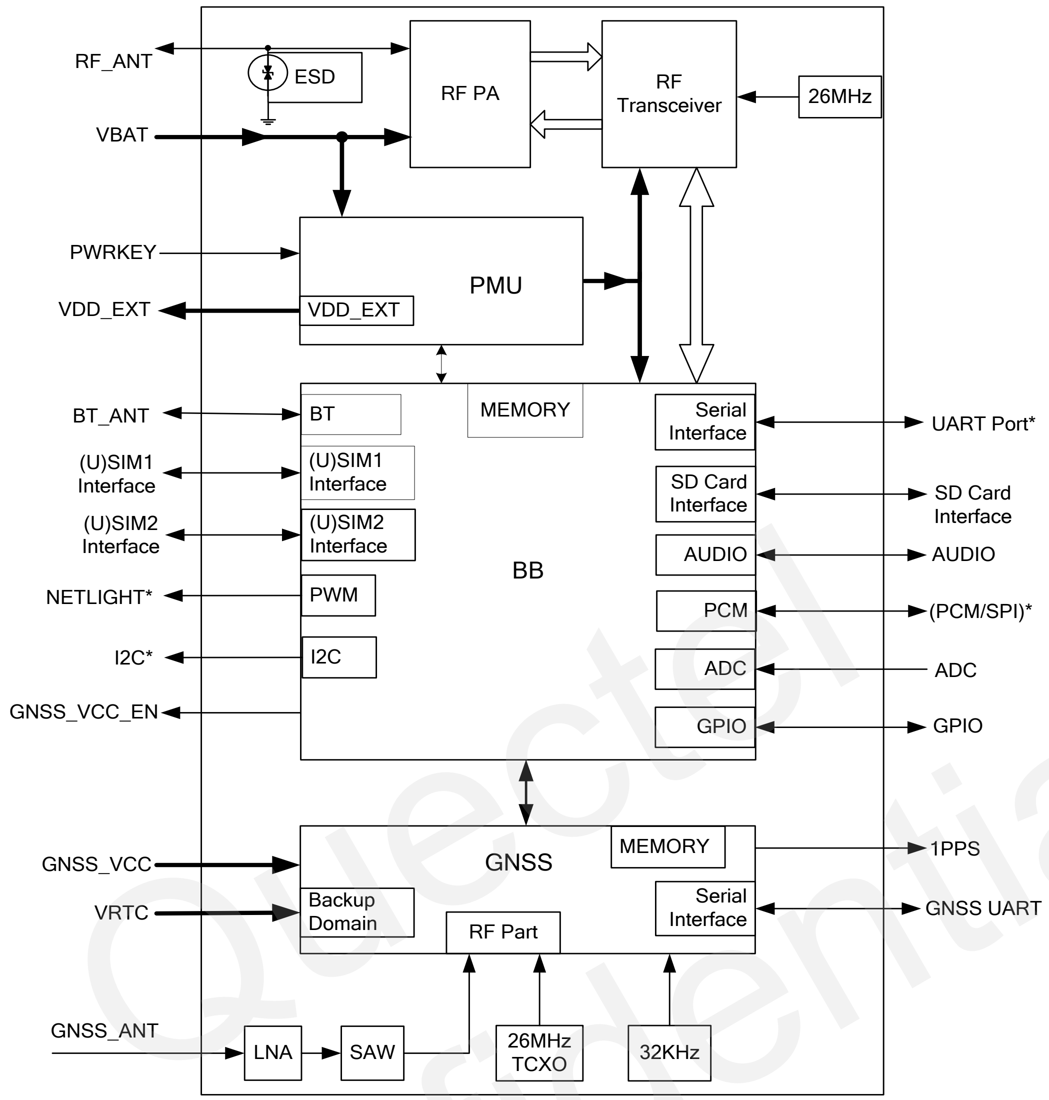


Figure 1: Module Functional Diagram

NOTE

About alternate functions of the interfaces marked with "*", please refer to ***Table 7***.

2.4. Evaluation Board

In order to help customers develop applications with MC60-OpenCPU, Quectel supplies the evaluation board (EVB), TE-A board, RS-232 to USB cable, power adapter, earphone, GSM antenna, GNSS antenna and other peripherals to control or test the module. For more details, please refer to ***document [11]*** and ***document [18]***.

3 Application Functions

3.1. General Description

MC60-OpenCPU is an SMD type module with 54 LCC pads and 14 LGA pads. The following chapters provide detailed descriptions about these pins.

- Pin of module
- Power supply
- Backup domain of GNSS
- Operating modes
- Power on/down
- Power saving
- Serial interfaces
- Audio interfaces
- PCM interface
- (U)SIM card interface
- SD card interface
- ADC
- Behaviors of the RI
- Network status indication
- EASY autonomous AGPS technology
- EPO offline AGPS technology
- QuecFastFix Online technology
- Multi-tone AIC
- LOCUS
- PPS VS. NMEA

3.2. Pin Assignment

The following figure shows the pin assignment of the MC60-OpenCPU.

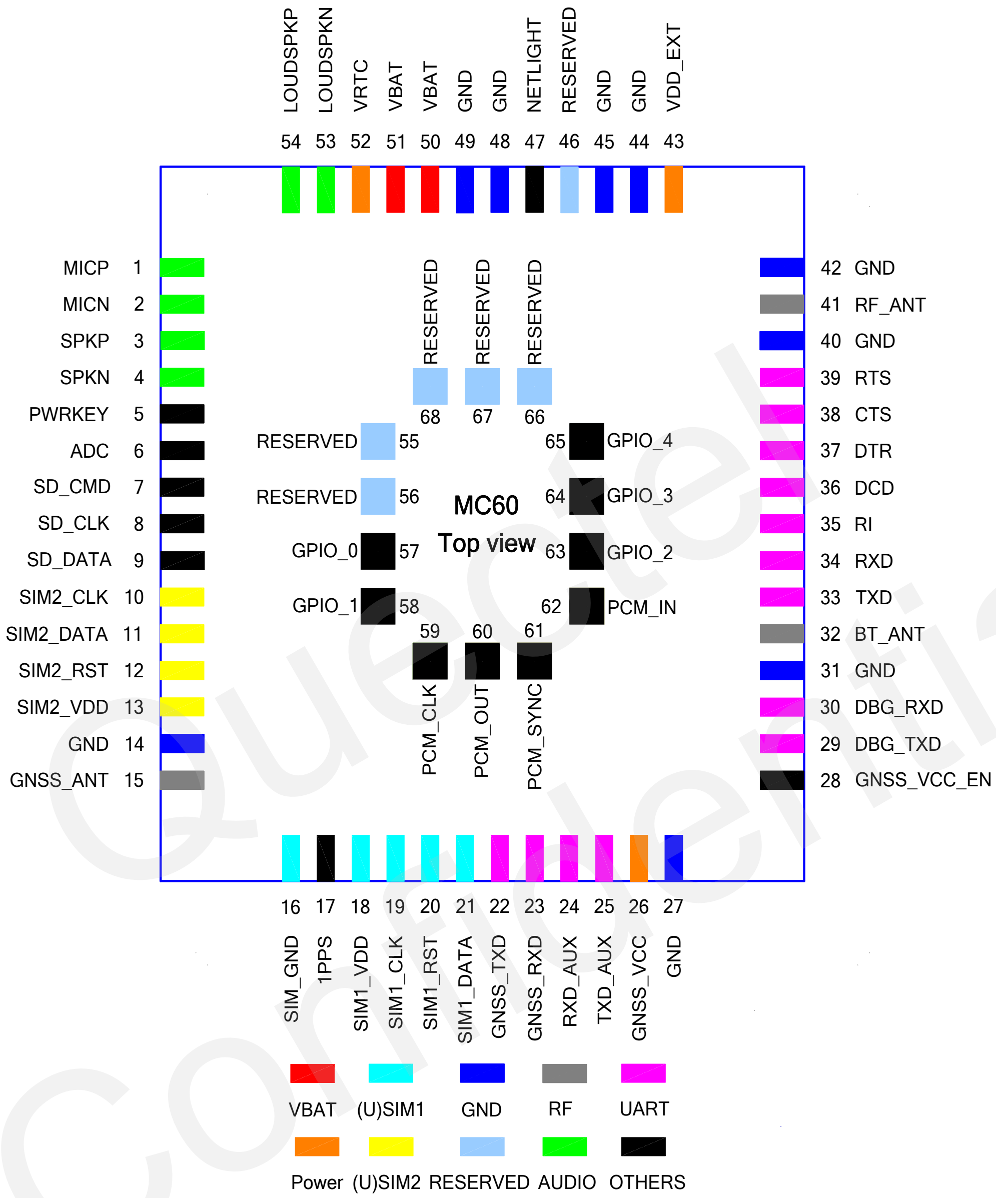


Figure 2: Pin Assignment

NOTE

Please keep all reserved pins open.

3.3. Pin Description

Table 5: I/O Parameters Definition

Type	Description
IO	Bidirectional input/output
DI	Digital input
DO	Digital output
PI	Power input
PO	Power output
AI	Analog input
AO	Analog output

Table 6: Pin Description

Power Supply					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
VBAT	50, 51	PI	Power supply of GSM/GPRS part: VBAT=3.3V~4.6V	$V_I$max=4.6V $V_I$min=3.3V $V_I$norm=4.0V	It must be able to provide sufficient current up to 1.6A in a transmitting burst.
GNSS_ VCC	26	PI	Power supply of GNSS part: GNSS_VCC=2.8V~4.3V	$V_I$max=4.3V $V_I$min=2.8V $V_I$norm=3.3V	Assure load current no less than 150mA.
VRTC	52	IO	Power supply for GNSS's backup domain. Charging for backup battery or golden capacitor when the VBAT is applied.	VImax=3.3V VImin=1.5V VInorm=2.8V VOmax=2.8V VOmin=2.1V VOnorm=2.6V IOmax=2mA Iin≈14uA	Refer to ***Chapter 3.6.5***
VDD_ EXT	43	PO	Supply 2.8V voltage for external circuit.	$V_O$max=2.9V $V_O$min=2.7V	1. If unused, keep this pin

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
				$V_O$norm=2.8V $I_O$max=20mA	open. 2. It is recommended to add a 2.2uF~4.7uF bypass capacitor, when using this pin for power supply.
GND	14, 27, 31, 40, 42, 44, 45, 48, 49		Ground		
Turn on/off					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
PWRKEY	5	DI	Power on/off key. PWRKEY should be pulled down for a moment to turn on or turn off the system.	V_{IL}max= 0.1 × VBAT V_{IH}min= 0.6 × VBAT V_{IH}max=3.1V	
Audio Interface					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
MICP MICN	1, 2	AI	Positive and negative voice input	Refer to ***Chapter 3.10.6***	If unused, keep these pins open.
SPKP SPKN	3, 4	AO	Channel 1 positive and negative voice output		If unused, keep these pins open. Support both voice and ringtone output.
LOUD SPKP LOUD SPKN	54 53	AO	Channel 2 positive and negative voice output		1. If unused, keep these pins open. 2. Integrate a Class- AB amplifier internally. 3. Support both voice and ringtone

					output.
Network Status Indicator					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
NETLIGHT	47	DO	Network status indication	V_{OH}min= 0.85 × VDD_EXT V_{OL}max= 0.15 × VDD_EXT	If unused, keep this pin open.
UART Port					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
TXD	33	DO	Transmit data	V_{IL}min=0V V_{IL}max= 0.25 × VDD_EXT V_{IH}min= 0.75 × VDD_EXT V_{IH}max= VDD_EXT+0.2 V_{OH}min= 0.85 × VDD_EXT V_{OL}max= 0.15 × VDD_EXT	If only TXD, RXD and GND are used for communication, it is recommended to keep all other pins open.
RXD	34	DI	Receive data		
DTR	37	DI	Data terminal ready		
RI	35	DO	Ring indication		
DCD	36	DO	Data carrier detection		
CTS	38	DO	Clear to send		
RTS	39	DI	Request to send		
Debug Port					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
DBG_TXD	29	DO	Transmit data	The same as UART port	If unused, keep these pins open.
DBG_RXD	30	DI	Receive data		
Auxiliary UART Port					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
TXD_AUX	25	DO	Transmit data	The same as UART port	Refer to ***Chapter 3.9.3***
RXD_AUX	24	DI	Receive data		
GNSS UART Port					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
GNSS_TXD	22	DO	Transmit data	V_{OL}max=0.42V V_{OH}min=2.4V V_{OH}nom=2.8V	Refer to ***Chapter 3.9.3***
GNSS_	23	DI	Receive data		

RXD				V_{IL}min=-0.3V V_{IL}max=0.7V V_{IH}min=2.1V V_{IH}max=3.1V	
(U)SIM Interface					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
SIM1_ VDD SIM2_ VDD	18 13	PO	Power supply for (U)SIM card	The voltage can be selected by software automatically. Either 1.8V or 3.0V.	
SIM1_ CLK SIM2_ CLK	19 10	DO	Clock signal of (U)SIM card	V_{OL}max= 0.15 × SIM_VDD V_{OH}min= 0.85 × SIM_VDD	All signals of (U)SIM interface should be protected against ESD with a TVS diode array; Maximum trace length is 200mm from the module pad to (U)SIM card connector.
SIM1_ DATA SIM2_ DATA	21 11	IO	Data signal of (U)SIM card	V_{IL}max= 0.25 × SIM_VDD V_{IH}min= 0.75 × SIM_VDD V_{OL}max= 0.15 × SIM_VDD V_{OH}min= 0.85 × SIM_VDD	
SIM1_ RST SIM2_ RST	20 12	DO	Reset signal of (U)SIM card	V_{OL}max= 0.15 × SIM_VDD V_{OH}min= 0.85 × SIM_VDD	
SIM_ GND	16		Specified ground for (U)SIM card		
SIM1_ PRESENCE	37	DI	(U)SIM1 card insertion detection	V_{IL}min=0V V_{IL}max= 0.25 × VDD_EXT V_{IH}min= 0.75 × VDD_EXT VIHmax= VDD_EXT+0.2	
ADC					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
ADC	6	AI	General purpose analog to digital converter	Voltage range: 0V to 2.8V	If unused, keep this pin open.
Digital Audio Interface (PCM)					

Pin Name	Pin No.	I/O	Description	DC Characteristics	Comment
PCM_CLK	59	DO	PCM clock	V_{IL}min= 0V V_{IL}max= 0.25 × VDD_EXT V_{IH}min= 0.75 × VDD_EXT V_{IH}max= VDD_EXT+0.2 V_{OH}min= 0.85 × VDD_EXT V_{OL}max= 0.15×VDD_EXT	If unused, keep these pins open.
PCM_OUT	60	DO	PCM data output		
PCM_SYNC	61	DO	PCM frame synchronization		
PCM_IN	62	DI	PCM data input		
SD Card Interface					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
SD_CMD	7	DO	Command signal of SD card	V_{IL}min=0V V_{IL}max= 0.25 × VDD_EXT V_{IH}min= 0.75 × VDD_EXT V_{IH}max= VDD_EXT+0.2 V_{OH}min= 0.85 × VDD_EXT V_{OL}max= 0.15 × VDD_EXT	If unused, keep these pins open.
SD_CLK	8	DO	Clock signal of SD card		
SD_DATA	9	IO	Data signal of SD card		
Antenna Interface					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
RF_ANT	41	IO	GSM antenna pad	Impedance of 50Ω	
BT_ANT	32	IO	BT antenna pad	Impedance of 50Ω	If unused, keep this pin open.
GNSS_ANT	15	AI	GNSS signal input	Impedance of 50Ω	
Other Interfaces					
Pin Name	**Pin No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
GNSS_VCC_EN	28	DO	GNSS power enabled	V_{OH}min= 0.85 × VDD_EXT V_{OL}max= 0.15 × VDD_EXT	Refer to ***Chapter 3.6.3.2***

1PPS	17	DO	One pulse per second	V_{OL}max=0.42V V_{OH}min=2.4V V_{OH}nom=2.8V	1. Synchronized at rising edge and the pulse width is 100ms. 2. If unused, keep this pin open.
GPIO	57, 58, 63, 64, 65	IO		V_{OL}max=VDD_EXT V_{OH}min=2.0V V_{IL}max=0.67V V_{IH}min=1.7V V_{IH}max= VDD_EXT+0.3V	If unused, keep these pins open.
RESERVED	46, 55, 56, 66, 67, 68,				Keep these pins open.

Table 7: Multiplexed Functions

Pin Name	Pin No.	Mode 1 (default)	Mode 2	Mode 3	Mode 4
SD_CMD	7	SD_CMD	GPIO		
SD_CLK	8	SD_CLK	GPIO		
SD_DATA	9	SD_DATA	GPIO		
SIM2_CLK	10	SIM2_CLK	GPIO		
SIM2_DATA	11	SIM2_DATA	GPIO		
SIM2_RST	12	SIM2_RST	GPIO		
RI	35	RI	GPIO	I2SCL	
DCD	36	DCD	GPIO	I2SDA	
DTR	37	DTR	GPIO	EINT	SIM_PRESENCE
CTS	38	CTS	GPIO	EINT	
RTS	39	RTS	GPIO		
NETLIGHT	47	NETLIGHT	GPIO	PWM_OUT	EINT

PCM_CLK	59	PCM_CLK	GPIO	SPI_CS
PCM_OUT	60	PCM_OUT	GPIO	SPI_MOSI
PCM_SYNC	61	PCM_SYNC	GPIO	SPI_MISO
PCM_IN	62	PCM_IN	GPIO	SPI_CLK

3.4. Application Mode Introduction

In MC60-OpenCPU, the GSM part and GNSS part work as a whole unit. The GNSS part can be regarded as a peripheral of the GSM Part. This allows for convenient communication between GSM and GNSS parts, such as AT command sending for GNSS control, GNSS part firmware upgrading, and EPO data download.

The schematic diagram is shown below.

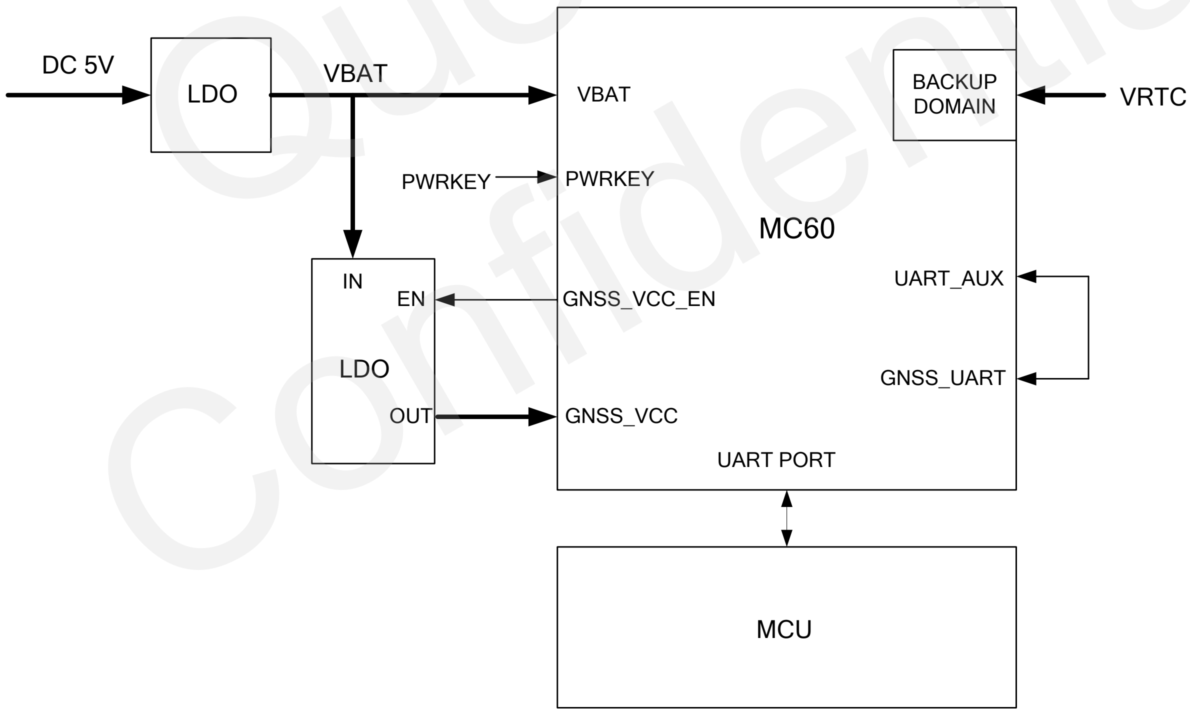


Figure 3: MC60-OpenCPU Schematic Diagram

3.5. Flash Memory Allocation

A 32M-bit flash memory is used in the module. The flash memory allocation is shown as below.

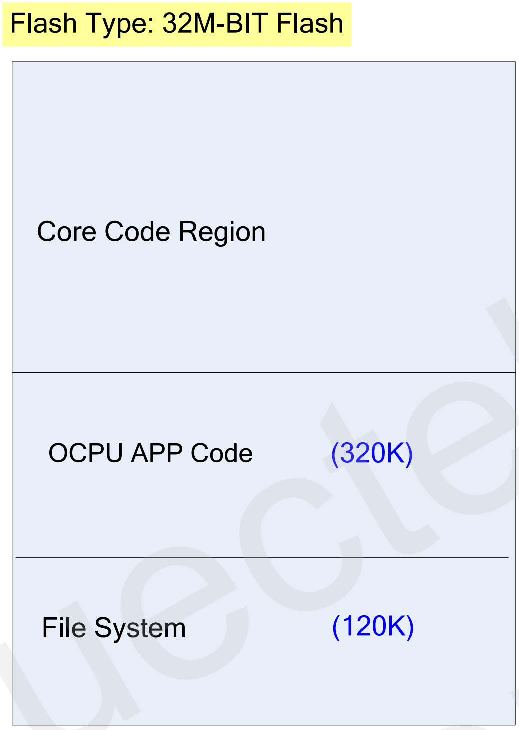


Figure 4: Flash Memory Allocation

MC60-OpenCPU allocates 320KB space for customer's code and 120KB file system space which is used to store the data (e.g. system configuration file, temporary data, image, multimedia file, etc.) related to file operation.

- RAM

MC60-OpenCPU reserves 100KB RAM space for the embedded application and provides about 500KB dynamic memory at most.

3.6. Power Supply

3.6.1. Power Features

3.6.1.1. Power Features of GSM Part

The power supply of the GSM part is one of the key issues in MC60-OpenCPU design. Due to the 577us radio burst in GSM part every 4.615ms, the power supply must be able to deliver high current peaks in a burst period. During these peaks, drops on the supply voltage must not exceed the minimum working voltage of the GSM part.

The maximum current consumption of GSM part could reach 1.6A during a burst transmission. It will cause a large voltage drop on the VBAT. In order to ensure stable operation of the part, it is recommended that the maximum voltage drop during the burst transmission does not exceed 400mV.

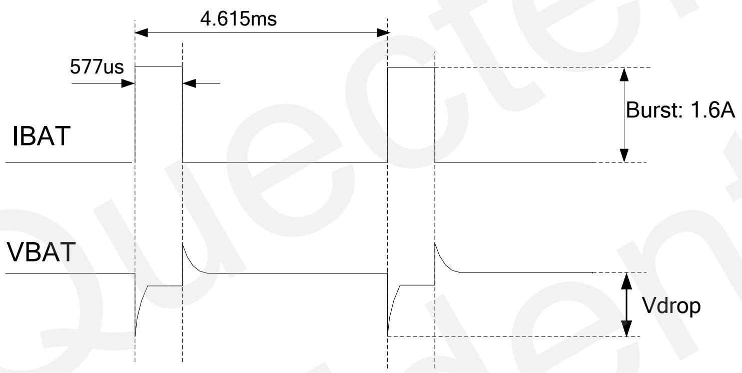


Figure 5: Voltage Ripple during Transmitting (GSM Part)

3.6.1.2. Power Features of GNSS Part

The power supply of GNSS part is controlled by the GSM part through the GNSS_VCC_EN pin.

3.6.2. Decrease Supply Voltage Drop

3.6.2.1. Decrease Supply Voltage Drop for GSM Part

Power supply range of the GSM part is from 3.3V to 4.6V. Make sure that the input voltage will never drop below 3.3V even in a burst transmission. If the power voltage drops below 3.3V, the module will be turned off automatically. For better power performance, it is recommended to place a 100uF tantalum capacitor with low ESR (ESR=0.7Ω) and ceramic capacitors 100nF, 33pF and 10pF near the VBAT pin. A reference circuit is illustrated in the following figure.

The VBAT trace should be wide enough to ensure that there is not too much voltage drop during burst transmission. The width of trace should be no less than 2mm; and in principle, the longer the VBAT trace, the wider it will be.

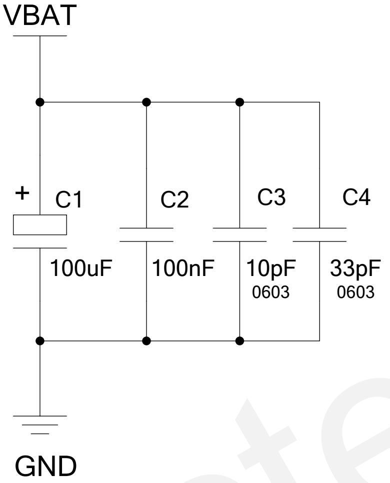


Figure 6: Reference Circuit for the VBAT Input (GSM Part)

3.6.2.2. Decrease Supply Voltage Drop for GNSS Part

Power supply range of GNSS part is from 2.8 to 4.3V. GNSS_VCC's maximum average current is 40mA during GNSS acquisition after power up. So it is important to supply sufficient current and make the power clean and stable. The decouple combination of 10uF and 100nF capacitor is recommended nearby GNSS_VCC pin. A reference circuit is illustrated in the following figure.

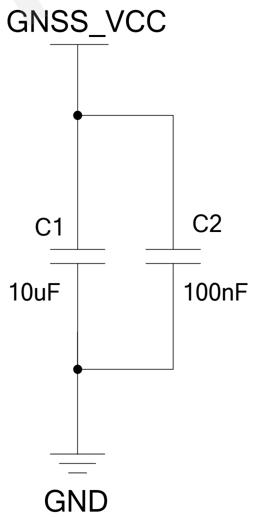


Figure 7: Reference Circuit for the GNSS_VCC Input

3.6.3. Reference Design for Power Supply

3.6.3.1. Reference Design for Power Supply of GSM Part

The power supply of GSM part 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 to use a LDO as the GSM part's power supply. If there is a big voltage difference between the input source and the desired output (VBAT), a switcher power converter is recommended to be used as the power supply.

The following figure shows a reference design for +5V input power source for GSM part. The designed output for the power supply is 4.0V and the maximum load current is 3A. In addition, in order to get a stable output voltage, a zener diode is placed close to the pins of VBAT. As to the zener diode, it is suggested to use a zener diode whose reverse zener voltage is 5.1V and dissipation power is more than 1W.

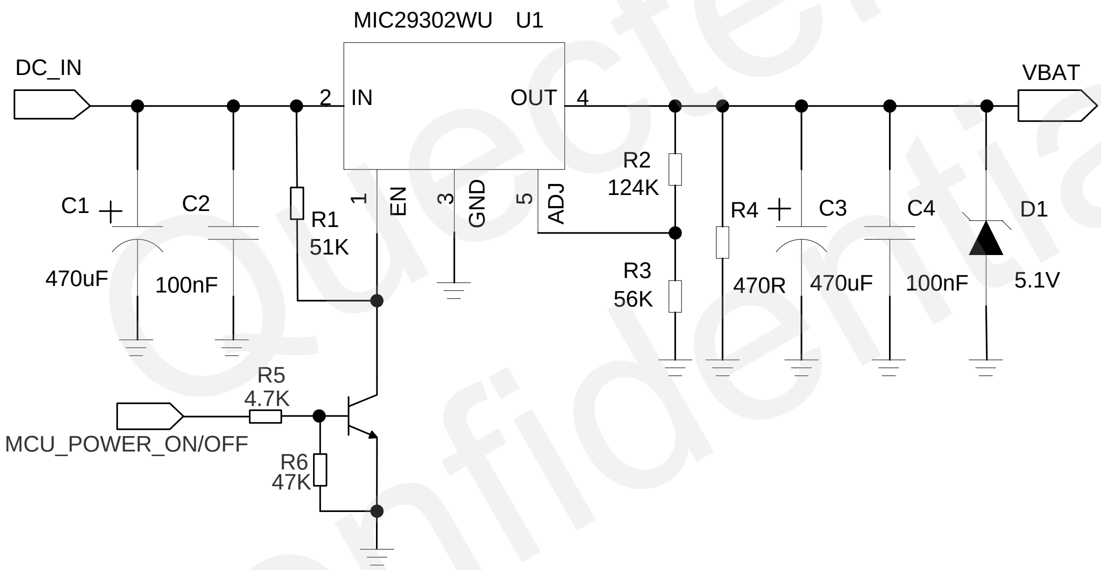


Figure 8: Reference Circuit for Power Supply of the GSM Part

NOTE

It is suggested to control the module's main power supply (VBAT) via LDO enable pin to restart the module when the module becomes abnormal. Power switch circuit like P-channel MOSFET switch circuit can also be used to control VBAT.

3.6.3.2. Reference Design for Power Supply of GNSS Part

The power supply of GNSS part is controlled by the GSM part through the GNSS_VCC_EN pin. A reference circuit for the GNSS part power supply is given below. Please pay attention to the electrical characteristics of GNSS_VCC_EN to match LDO's EN pin. Please refer to ***document [16]*** for details about the AT commands for GNSS control.

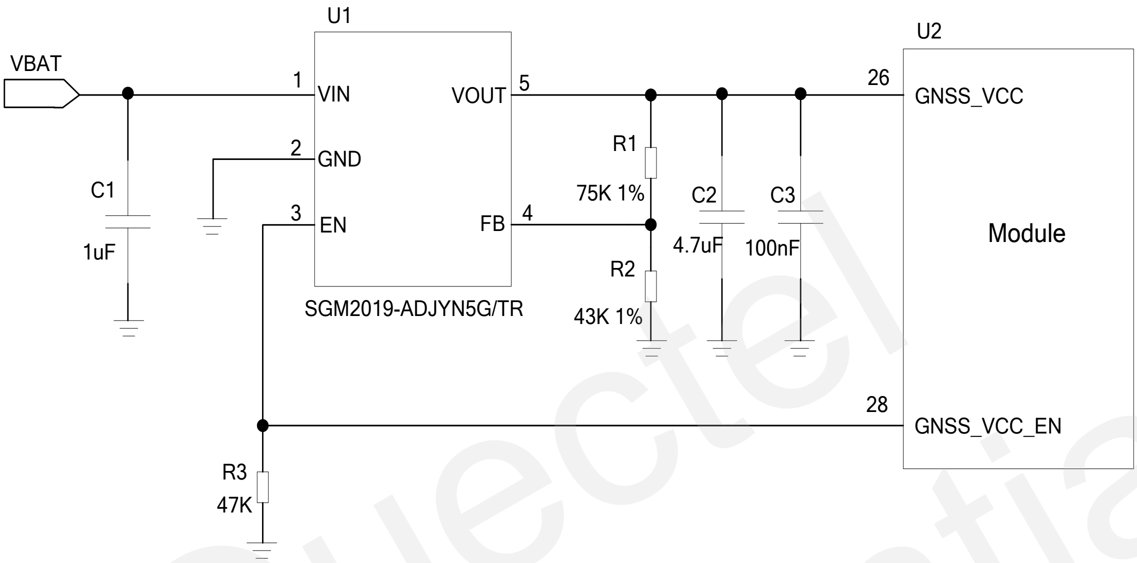


Figure 9: Reference Circuit Design for GNSS Part

3.6.4. Monitor Power Supply

The command **AT+CBC** can be used to monitor the supply voltage of the GSM part. The unit of the displayed voltage is mV. For details, please refer to ***document [1]***.

3.6.5. Backup Domain of GNSS

The GNSS part of MC60-OpenCPU features a backup domain which contains all the necessary GNSS information for quick start-up and a small amount of user configuration variables. In GNSS's backup mode, the backup domain is still alive. As long as the backup domain is alive, EASY technology will be available.

3.6.5.1. Use VBAT as the Backup Power Source of GNSS

In MC60-OpenCPU, GNSS's backup mode will be active as long as the main power supply (VBAT) is remained, even when the module is turned off and GNSS_VCC is powered off; as the GNSS's backup domain is powered by VBAT. In this case, the VRTC pin can be kept floating, and the current consumption is only about 220uA.

When powered by VBAT, a reference schematic diagram is shown below.

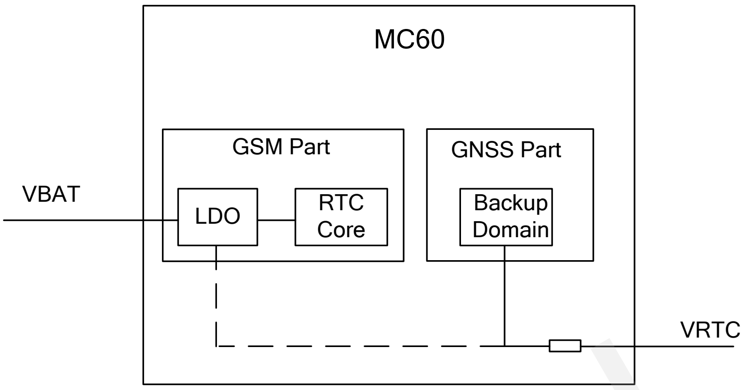


Figure 10: Internal GNSS's Backup Domain Power Construction

3.6.5.2. Use VRTC as Backup Power of GNSS

In MC60-OpenCPU, when the main power supply (VBAT) is removed after the module is turned off, and GNSS_VCC is also powered off, a backup supply such as a coin-cell battery (rechargeable or non-chargeable) or a super capacitor can be used to power the VRTC pin to keep GNSS in backup mode. In this case, the current consumption is as low as 14uA approximately.

When powered by VRTC, a reference schematic diagram is shown below.

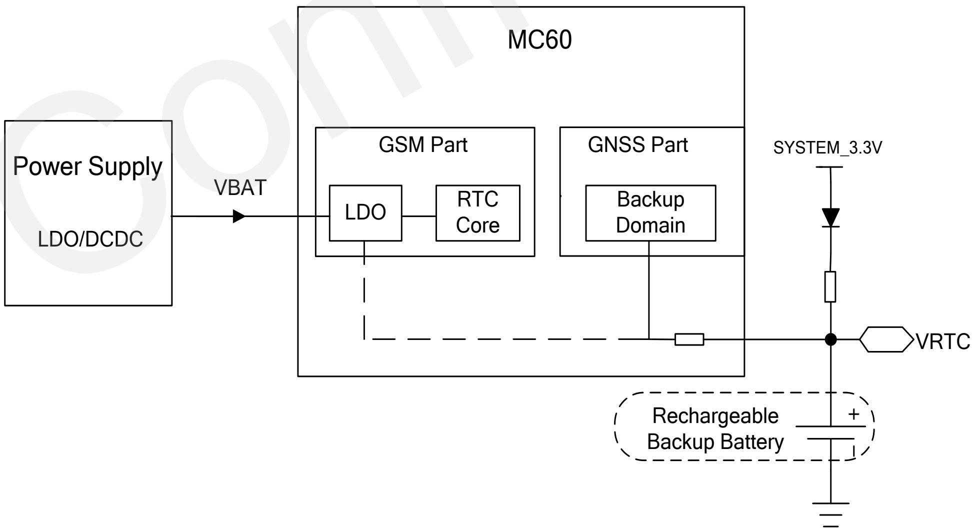


Figure 11: VRTC Powered by a Rechargeable Battery

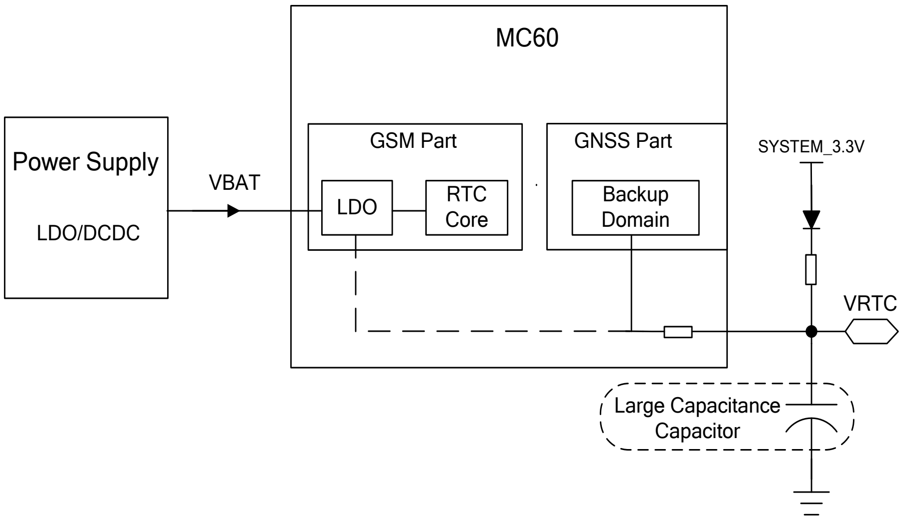


Figure 12: VRTC Powered by a Capacitor

A rechargeable or non-chargeable coin-cell battery can also be used here. For more information, please visit http://www.sii.co.jp/en.

NOTE

As SYSTEM_3.3V is used for battery charging, it is recommended to keep it powered for the longest time in all system power supplies.

3.7. Operating Modes

3.7.1. Operating Modes of GSM Part

The table below briefly summarizes the various operating modes of GSM part mentioned in the following chapters.

Table 8: Operating Modes Overview of GSM Part

Modes	Function	
GSM Normal Operation	GSM/GPRS Sleep	After enabling Sleep mode by calling **Ql_SleepEnable()**, the module will automatically enter into Sleep mode when CPU is in idle state. In this case, the current consumption of module's GSM part will reduce to the minimal level. During Sleep mode, the GSM part can still receive paging message and SMS from the network normally.

	GSM IDLE	Software is active. The GSM part has registered on GSM network, and it is ready to send and receive GSM data.
	GSM TALK	GSM connection is ongoing. In this mode, the power consumption is decided by the configuration of Power Control Level (PCL), dynamic DTX control and the working RF band.
	GPRS IDLE	The GSM part is not registered on GPRS network. It is not reachable through GPRS channel.
	GPRS STANDBY	The GSM part is registered on GPRS network, but no GPRS PDP context is active. The SGSN knows the Routing Area where the module is located at.
	GPRS READY	The PDP context is active, but no data transfer is ongoing. The GSM part is ready to receive or send GPRS data. The SGSN knows the cell where the module is located at.
	GPRS DATA	There is GPRS data in transfer. In this mode, power consumption is decided by the PCL, working RF band and GPRS multi-slot configuration.
POWER DOWN	Normal shutdown calling **Ql_PowerDown()** or using the PWRKEY pin.	
Minimum Functionality Mode (without removing power supply)	**AT+CFUN** command can set the GSM part to a minimum functionality mode without removing the power supply. In this case, the RF part of the GSM part will not work or the (U)SIM card will not be accessible, or both RF part and (U)SIM card will be disabled; but the UART port is still accessible. The power consumption in this case is very low.	

3.7.1.1. Minimum Functionality Mode

Minimum Functionality Mode reduces the functionality of the GSM part to a minimum level in order to minimize the current consumption. The GSM part can enter into Minimum Functionality Mode through using **AT+CFUN=0** command. When executing **AT+CFUN?** command and the returned value is not equal to 1, it can enter into Full Functionality Mode through using **AT+CFUN=1** command. For detailed information about the AT commands, please refer to the ***document [1]***.

3.7.1.2. Sleep Mode

After entering into Sleep mode, the GSM part can still receive calls, SMS and GPRS data, but the serial interfaces do not work. The Sleep mode is disabled by default. The GSM part can enter into Sleep mode when it is idle through calling the API function **Ql_SleepEnable()**.

When the GSM part is in Sleep mode, the following methods can wake it up.

- Incoming call

- SMS or MMS
- GPRS data
- External interrupts
- System timer timeout

The following method can make the GSM part exit from Sleep mode.

- Call the API function **Ql_SleepDisable()** when the application program is executed.

For detailed information about API functions, please refer to the ***document [19]***.

3.7.2. Operating Modes of GNSS Part

3.7.2.1. Full on Mode

Full on mode includes tracking mode and acquisition mode. Acquisition mode is defined as that the GNSS part starts to search satellites, and to determine the visible satellites, coarse carrier frequency & code phase of satellite signals. When the acquisition is completed, it switches to tracking mode automatically. Tracking mode is defined as that the GNSS part tracks satellites and demodulates the navigation data from specific satellites.

When the GNSS_VCC is valid, the GNSS part will enter into full on mode automatically. The following table describes the default configuration of full on mode.

Table 9: Default Configuration of Full on Mode (GNSS Part)

Item	Configuration	Comment
Baud Rate	115200bps	
Protocol	NMEA	RMC, VTG, GGA, GSA, GSV and GLL
Update Rate	1Hz	
SBAS	Enable	
AIC	Enable	
LOCUS	Disable	
EASY Technology	Enable	EASY will be disabled automatically when update rate exceeds 1Hz.
GNSS	GPS+GLONASS	

In full on mode, the consumption complies with the following regulations:

When the GNSS part is powered on, the average current will rush to 40mA and last for a few seconds; then the consumption will be decreased to the acquisition current marked in ***Table 3*** and Quectel defined this state as acquisition state, and also it will last for several minutes until it switches to tracking state automatically. The consumption in tracking state is less than that in acquisition state. The value is also listed in ***Table 3***.

Sending PMTK commands allows for switching among multiple positioning systems:

- $PMTK353,0,1,0,0,0*2A: search GLONASS satellites only
- $PMTK353,1,0,0,0,0*2A: search GPS satellites only
- $PMTK353,1,1*37: search GLONASS and GPS satellites

NOTE

Make sure the GNSS part is powered on before sending these PMTK commands.

3.7.2.2. Standby Mode

Standby mode is a low-power consumption mode. In standby mode, the internal core and I/O power domain are still active; but RF and TCXO are powered off, and the GNSS part stops satellites search and navigation. The way to enter into standby mode is using PMTK commands.

When the GNSS part exits from standby mode, it will use all internal aiding information like GNSS time, ephemeris, last position, etc., to ensure the fastest possible TTFF in either Hot or Warm start. The typical current consumption is about 300uA @GNSS_VCC=3.3V in standby mode.

Sending the following PMTK command can make GNSS part enter into standby mode:

- $PMTK161,0*28: send this command in **Stand-alone** solution.

The following methods will make GNSS part exit from standby mode:

- Sending any data via GNSS_UART will make GNSS part exit from standby mode in **Stand-alone** solution.

NOTE

Standby mode takes effect only in **Stand-alone** solution.

3.7.2.3. Backup Mode

Backup mode requires lower power consumption than standby mode. In this mode, the GNSS part stops acquiring and tracking satellites, but the backed-up memory in backup domain which contains all the necessary GNSS information for quick start-up and a small amount of user configuration variables is alive. Due to the backed-up memory, EASY technology is available. The current consumption in this mode is about 14uA.

The following method will make GNSS part enter into backup mode:

- Cutting off GNSS_VCC and keeping VBAT/VRTC powered will make GNSS part enter into back mode from full on mode.

The following method will make GNSS part exit from backup mode:

- As long as the GNSS_VCC is powered, the GNSS part will exit from backup mode and enter full on mode immediately.

3.7.2.4. Periodic Mode

Periodic mode can control the full on mode and standby/backup mode periodically to reduce power consumption. It contains periodic standby mode and periodic backup mode.

The format of the command, which enables the module's GNSS part to enter into periodic mode, is shown below:

Table 10: Format of the PMTK Command Enabling Periodic Mode

Format: $PMTK225,<Type>,<Run_time>,<Sleep_time>,<2nd_run_time>,<2nd_sleep_time>*<checksum><CR><LF>			
Parameter	**Format**	**Description**	**Range (ms)**
Type	Decimal	**Type=1**: Periodic backup mode **Type=2**: Periodic standby mode	/
Run_time	Decimal	**Run_time**=Full on mode period (ms)	1000~518400000
Sleep_time	Decimal	**Sleep_time**=Standby/Backup mode period (ms)	1000~518400000
2nd_run_time	Decimal	**2nd_run_time**=Full on mode period (ms) for extended acquisition in case module's acquisition fails during the	0 or 1000~518400000

		Run_time	
2nd_sleep_time	Decimal	**2nd_sleep_time**=Standby/Backup mode period (ms) for extended sleep in case module's acquisition fails during the **Run_time**	0 or 1000~518400000
Checksum	Hexadecimal	Hexadecimal checksum	

Example

```
$PMTK225,2,3000,12000,18000,72000*15<CR><LF>
$PMTK225,1,3000,12000,18000,72000*16<CR><LF>
```

In periodic standby mode, sending "$PMTK225,0*2B" in any time can make the GNSS part enter into full on mode.

In periodic backup mode, sending "$PMTK225,0*2B" during the **Run_time** or **2nd_run_time** period can also make the GNSS part enter into full on mode. But this is hard to operate and thus is not recommended.

The following figure has shown the operation mechanism of periodic mode. When customers send PMTK command, the GNSS part will be in full on mode first. Several minutes later, it will enter into periodic mode according to the parameters set. When the GNSS part fails to fix the position during **Run_time**, it will switch to **2nd_run_time** and **2nd_sleep_time** automatically. As long as it fixes the position again successfully, it will return to **Run_time** and **Sleep_time**.

Before entering into periodic mode, please make sure the GNSS part is in tracking mode; otherwise it may have a risk of failure in satellite tracking. If the module is located in weak signal areas, it is better to set a longer **2nd_run_time** to ensure the success of reacquisition.

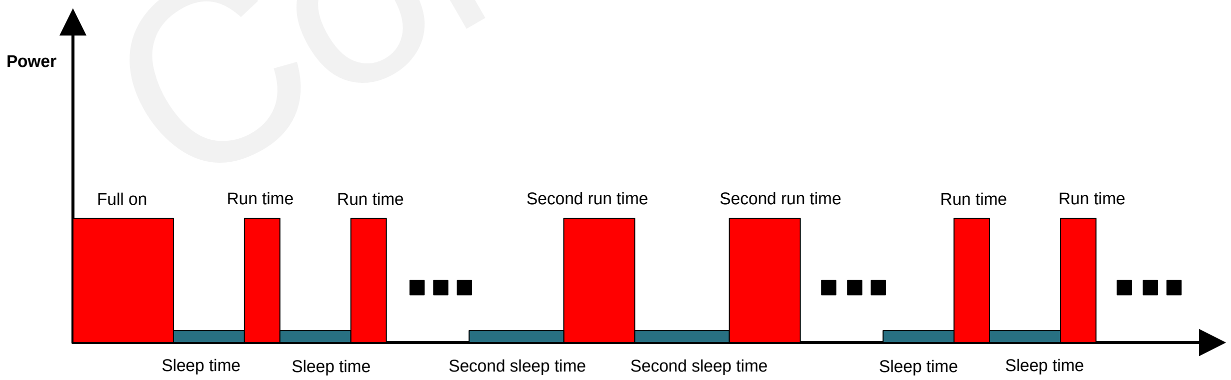


Figure 13: Operation Mechanism of Periodic Mode

The average current consumption in periodic mode can be calculated based on the following formula:

$I_{periodic}$= ($I_{tracking}$*T1+$I_{standby/backup}$*T2)/(T1+T2)   T1: Run_time, T2: Sleep_time

Example

PMTK225,2,3000,12000,18000,72000*15 for periodic mode means 3s in tracking mode and 12s in standby mode based on GPS&GLONASS. The average current consumption is calculated below:
$I_{periodic}$ = ($I_{tracking}$*T1+$I_{standby}$*T2)/(T1+T2) = (22mA*3s+0.5mA*12s)/(3s+12s) ≈ 4.8(mA)

PMTK225,1,3000,12000,18000,72000*15 for periodic mode means 3s in tracking mode and 12s in backup mode based on GPS&GLONASS. The average current consumption is calculated below:
$I_{periodic}$ = ($I_{tracking}$*T1+I_{backup}*T2)/(T1+T2) = (22mA*3s+0.007mA*12s)/(3s+12s) ≈ 4.4(mA)

3.7.2.5. AlwaysLocate™ Mode

AlwaysLocate™ is an intelligent power saving mode. It contains AlwaysLocate™ backup mode and AlwaysLocate™ standby mode.

AlwaysLocate™ standby mode allows the GNSS part to switch automatically between full on mode and standby mode. According to the environmental and motion conditions, the GNSS part can adaptively adjust the full on time and standby time to achieve the balance between positioning accuracy and power consumption. Sending “$PMTK225,8*23” and the module returning “$PMTK001,225,3*35” mean that the GNSS part has entered AlwaysLocate™ standby mode successfully, which greatly saves power consumption. Sending “$PMTK225,0*2B” in any time will make the GNSS part back to full on mode.

AlwaysLocate™ backup mode is similar to AlwaysLocate™ standby mode. The difference is that the AlwaysLocate™ backup mode allows the GNSS part to switch automatically between full on mode and backup mode. Sending “$PMTK225,9*22” command will make the part enter into AlwaysLocate™ backup mode. During the “Full on mode” period in AlwaysLocate™ backup mode, sending “$PMTK225,0*2B” will make the GNSS part back to full on mode.

The positioning accuracy in AlwaysLocate™ mode may be decreased, especially in high speed movement. The following figure shows the power consumption of module in different scenarios.

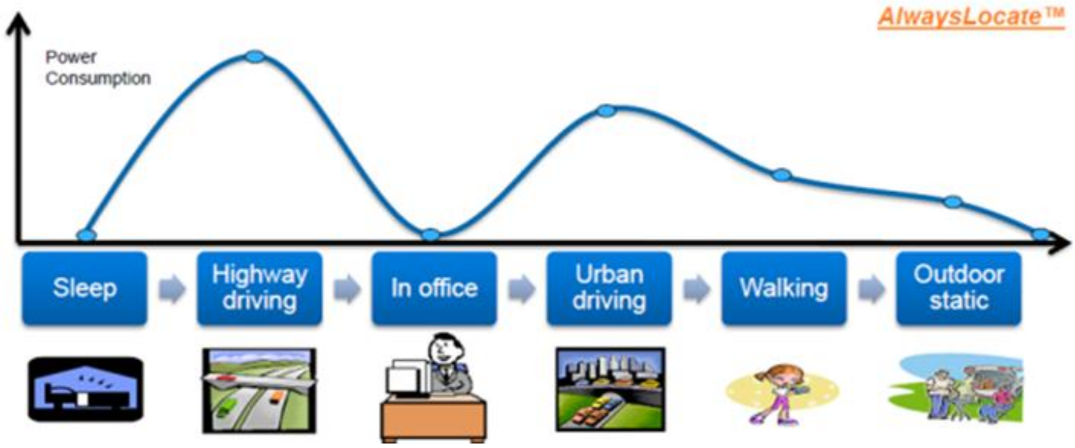


Figure 14: Power Consumption in Different Scenarios (AlwaysLocate™ Mode)

When located in outdoors in static and equipped with an active antenna, the GNSS part has an average current consumption of approx. 2.7mA after tracking satellites in AlwaysLocate™ standby mode and 2.6mA in AlwaysLocate™ backup mode based on GPS&GLONASS.

3.7.2.6. GLP Mode

GLP (GNSS low power) mode is an optimized solution for wearable fitness and tracking devices. It can reduce power consumption by closing high accuracy positioning.

In GLP mode, the GNSS part can also provide good positioning performance in walking and running scenarios, and supports automatic dynamic duty operation switch for balance on performance and power consumption. It will come back to normal mode in difficult environments to keep good accuracy, thus realizing maximum performance with the lowest power consumption.

The average current consumption in GLP mode is down to 8.9mA in static scenario, which is only 40% of that in normal mode. It may increase a little bit in dynamic scenario. The average current consumption in different outdoor scenarios in GLP mode and normal mode is shown in the table below.

Table 11: Average Current Consumption in GLP Mode and Normal Mode

Scenario	In GLP Mode (mA)	In Normal Mode (mA)
Static	8.9	22
Walking	11.2	22
Running	11.5	22

Driving	21.5	22

Customers can use the following commands to make the GNSS part enter into or exit from the GLP mode:

- $PQGLP,W,1,1*21: The command is used to set the GNSS part into GLP mode. When "$PQGLP,W,OK*09" is returned, it means the part has entered into GLP mode successfully.
- $PQGLP,W,0,1*20: The command is used to make the GNSS part exit from GLP mode. When "$PQGLP,W,OK*09" is returned, it means the part has exited from GLP mode successfully.

NOTES

1. It is recommended to set all the necessary commands before the GNSS part enters into GLP mode. If customers need to send commands, please exit from GLP mode first.
2. When the GNSS part enters into GLP mode, 1PPS function will be disabled.
3. When the GLP mode is enabled, the SBAS will be affected.
4. In high dynamic scenario, the module will have slightly decreased positioning accuracy in GLP mode.
5. The GNSS part will automatically come back to the normal mode in complex environments to keep good positioning accuracy.

3.7.3. Summary of GSM and GNSS Parts' States

Table 12: Combination States of GSM and GNSS Parts

GNSS Part Modes	GSM Part Modes		
	Normal	Sleep	Minimum Functionality
Full on	✓	✓	✓
Backup	✓	✓	✓
Periodic	✓	✓	✓
AlwaysLocate	✓	✓	✓
GLP	✓	✓	✓

NOTES

1. The mark ✓ means that the part supports this mode.
2. All PMTK commands used for the GNSS part should be sent through GSM UART after the GNSS

part is powered on. Make sure the GSM UART Port is accessible.

3. When the GSM part is in Sleep mode, the GNSS part can work in either standby or full on mode. However, if NMEA GPS data is needed, the GSM part should be woken up first and then send the corresponding AT command to get. For detailed AT command information, please refer to the ***document [1]***.

3.7.4. BT Function

MC60-OpenCPU series module supports Bluetooth function. Bluetooth is a wireless technology that allows devices to communicate, or transmit data/voice, wirelessly over a short distance. It is described as a short-range communication technology intended to replace the cables connecting portable and/or fixed devices while maintaining a high level of security. Bluetooth is standardized as IEEE802.15 and operates in the 2.4 GHz range using RF technology. Its data rate is up to 3Mbps.

MC60-OpenCPU module is fully compliant with Bluetooth specification 3.0, and supports profiles including SPP and HFP-AG. For more details, please refer to ***document [15]***.

MC60E-OpenCPU module adopts dual-mode chip, and supports BT3.0&BT4.0 specifications. BT4.0 supports Bluetooth low power (BLE) technology, which is low cost, short-range and interoperable wireless technology, and uses intelligent means to minimize power consumption, thus extends the applicability of the technology to a wide range of extended applications, such as watch, anti-theft key ring, sports and fitness sensor, health care sensor and remote control.

3.8. Power on and down Scenarios

GNSS function is turned on or off by the AT command sent from GSM part.

3.8.1. Power on

The module can be turned on by driving the pin PWRKEY to a low level voltage. An open collector driver circuit is suggested to control the PWRKEY. A simple reference circuit is illustrated as below.

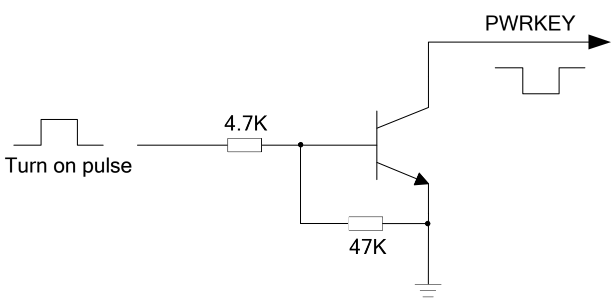


Figure 15: Turn on the Module with an Open-collector Driver

NOTES

1. MC60-OpenCPU is set to autobauding mode (**AT+IPR=0**) by default. In autobauding mode, URC **RDY** is not reported to the host controller after the module is powered on. When the module is powered on after a delay of 4s~5s, it can receive AT commands. Host controller should first send an **AT** string in order that the module can detect baud rate of host controller, and it should continue to send the next **AT** string until receiving **OK** string from the module. Then enter **AT+IPR=x;&W** to set a fixed baud rate for the module and save the configuration to flash memory of the module. After these configurations, the URC **RDY** would be received from the UART Port of the module every time when the module is powered on. For more details, refer to the section **AT+IPR** in ***document [1]***.
2. When AT command is responded, it indicates the module is turned on successfully; or else the module fails to be turned on.

The other way to control the PWRKEY is through a button directly. While pressing the key, electrostatic strike may generate from the finger, and thus, a TVS component is indispensable to be placed nearby the button for ESD protection. For the best performance, the TVS component must be placed nearby the button. A reference circuit is shown in the following figure.

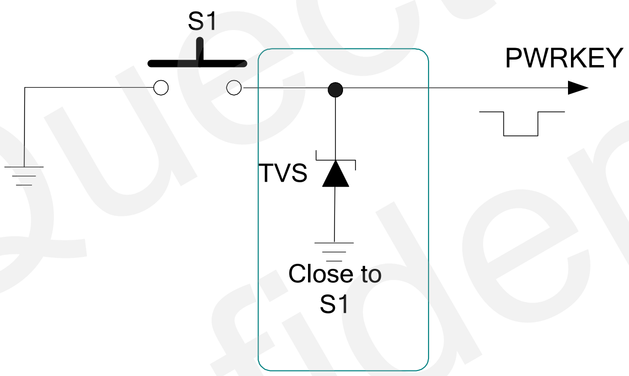


Figure 16: Turn on the Module with a Button

Command **AT+QGNSSC=1** should be sent to enable the GNSS power supply after the GSM part is running. When the GNSS_VCC is valid, the GNSS will enter into full on mode automatically. The turn-on timing is illustrated in the following figure.

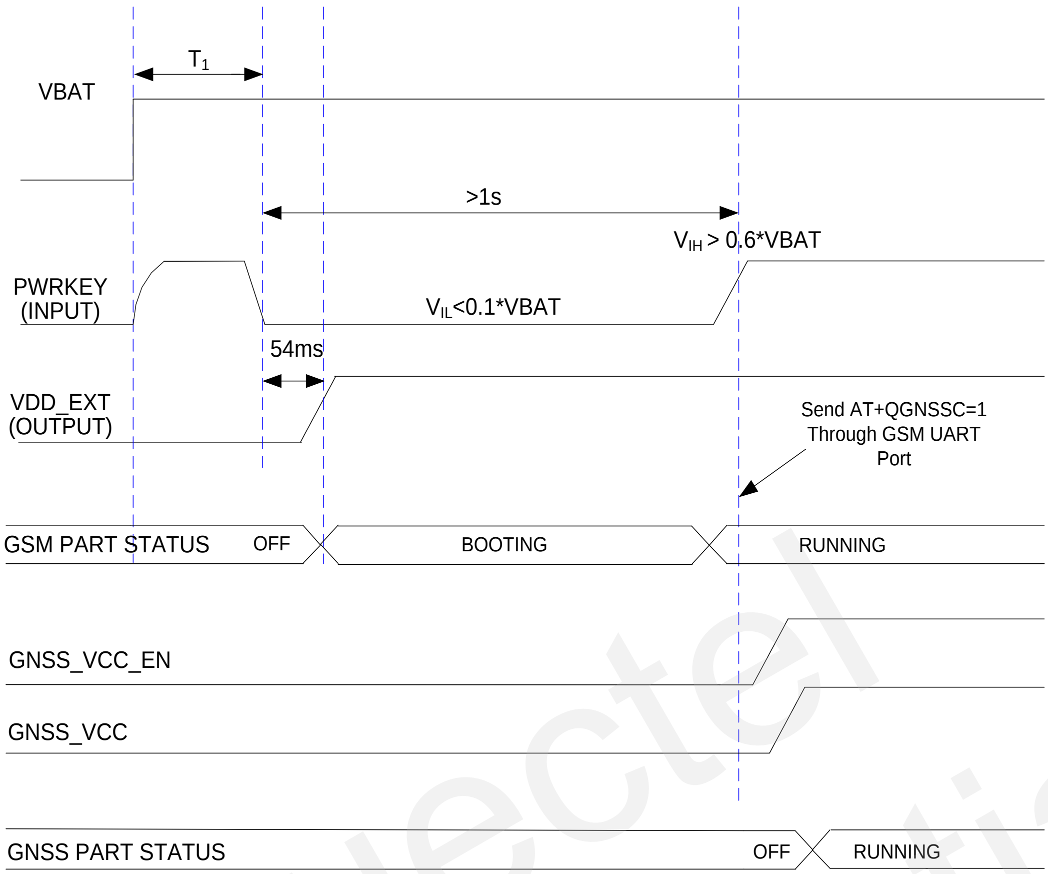


Figure 17: Turn-on Timing

NOTE

Make sure that VBAT is stable before pulling down PWRKEY pin. The time of T_1 is recommended to be 100ms.

3.8.2. Power down

The following procedures can be used to turn off the module:

- Normal power down procedure: Turn off module using the PWRKEY pin.
- Normal power down procedure: Turn off module by executing command **AT+QPOWD** or calling API **Ql_PowerDown()**.
- Under-voltage automatic shutdown: Take effect when under-voltage is detected.

3.8.2.1. Power down Module Using the PWRKEY Pin

It is a safe way to turn off the module by driving the PWRKEY to a low level voltage for a certain time. The power down scenario is illustrated in the following figure.

The power down procedure causes the module to log off from the network and allows the firmware to save important data before completely disconnecting the power supply.

Before the completion of the power down procedure, the module sends out the result code shown below:

NORMAL POWER DOWN

NOTES

1. When unsolicited result codes do not appear when autobauding is active and DTE & DCE are not correctly synchronized after start-up, the module is recommended to be set to a fixed baud rate.
2. As network logout time is related to the local mobile network, it is recommended to delay about 12 seconds before disconnecting the power supply or restarting the module.

After that moment, no further AT commands can be executed. Then the module enters the power-down mode.

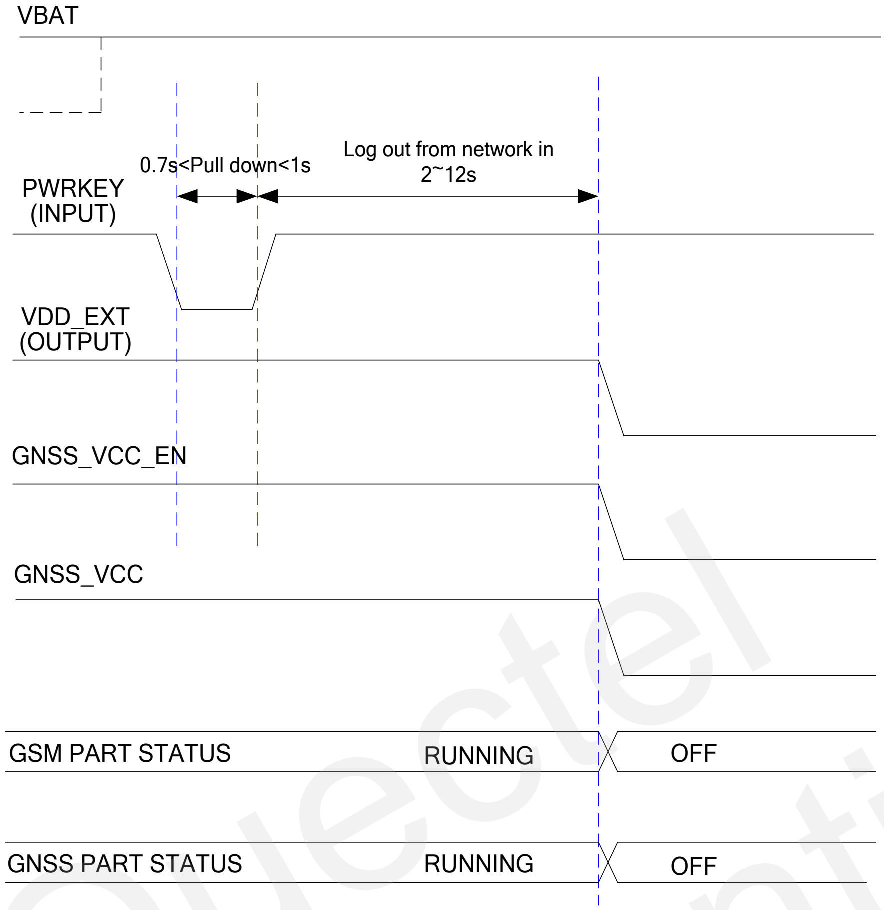


Figure 18: Turn-off Timing by Using the PWRKEY Pin

3.8.2.2. Power down Module Using AT Command

It is also a safe way to turn off the module via **AT+QPOWD=1** command. This command will let the module log off from the network and allow the firmware to save important data before completely disconnecting the power supply.

Before the completion of the power down procedure, the module sends out the result code shown below:

NORMAL POWER DOWN

After that moment, no further AT commands can be executed. And then the module enters into the power down mode.

Please refer to ***document [1]*** for details about **AT+QPOWD** command.

3.8.2.3. Power down Module Using the API Function

The module can achieve normal turn-off through calling an API function **Ql_PowerDown()**.

For detailed information about the API function, please refer to the ***document [19]***.

3.8.2.4. Power down GNSS Part Alone Using AT Command

It is a safe way to turn off the GNSS part alone via **AT+QGNSSC=0** command. The power down scenario for GNSS part is illustrated in the following figure.

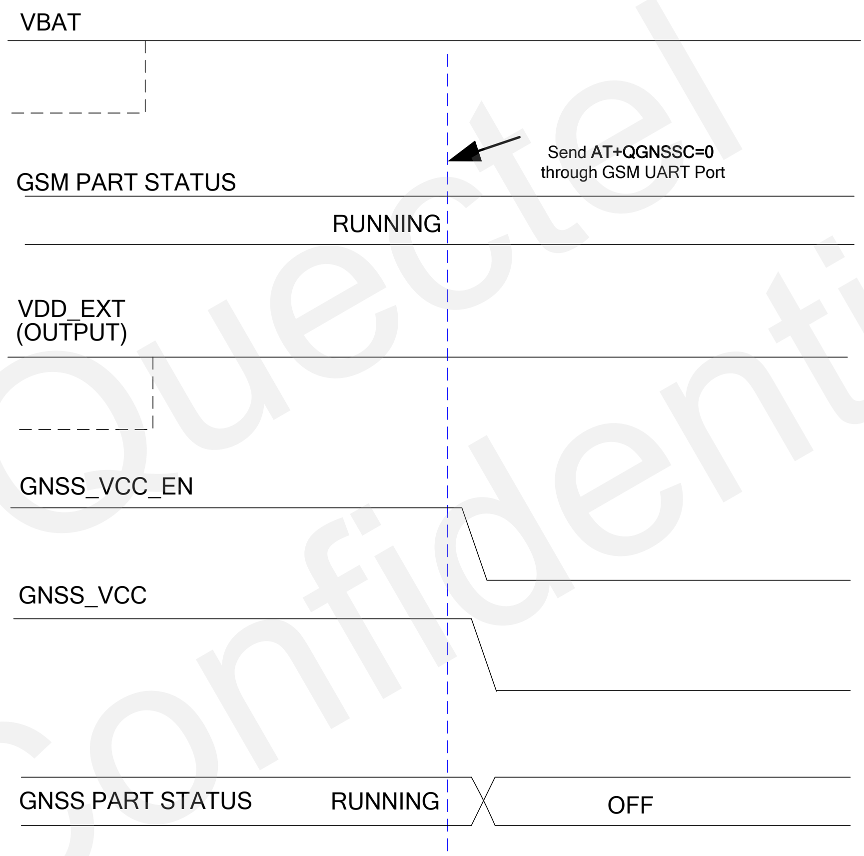


Figure 19: Turn-off Timing of GNSS Part by Using AT Command

3.8.2.5. Under-voltage Automatic Shutdown

The module will constantly monitor the voltage applied on the VBAT. If the voltage is ≤3.5V, the following URC will be presented:

UNDER_VOLTAGE WARNING

The normal input voltage range is from 3.3V to 4.6V. If the voltage is <3.3V, the module will automatically shut down.

If the voltage is <3.3V, the following URC will be presented:

UNDER_VOLTAGE POWER DOWN

After that moment, no further AT commands can be executed. The module logs off from network and enters into power down mode.

NOTE

When unsolicited result codes do not appear when autobauding is active and DTE & DCE are not correctly synchronized after start-up, the module is recommended to be set to a fixed baud rate.

3.8.3. Recommended Turn-on Structure for OpenCPU System

In order to ensure the stability of OpenCPU system, it is suggested to use a low-power MCU to monitor the status of the module. The MCU should possess several GPIOs and one ADC interface. The system structure is shown in the figure below. This structure possesses two advantages:

- When the VBAT voltage detected by ADC is too low, the MCU will turn off the module by controlling PWRKEY pin and switch off power supply by controlling the PMOS transistor.
- Normally, the module outputs periodic pulse to the MCU. If the MCU does not detect the pulse within the stipulated time, the MCU will switch off VBAT and then turn on the module again.

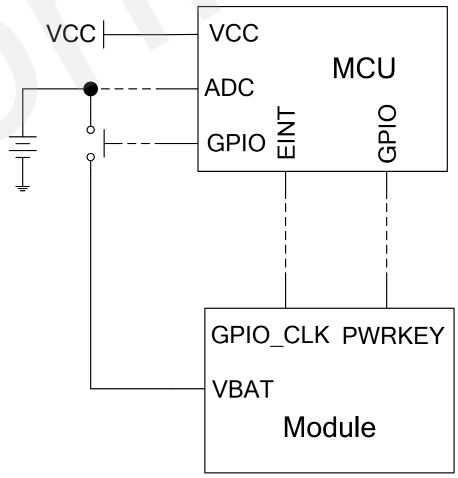


Figure 20: Recommended Turn-on Structure for OpenCPU System

Furthermore, a watchdog component can also be used to control the power of module. A watchdog component with timeout of 1.6s at least should be used, for instance, TI's TPS3823-33DBVR. One GPIO of module should be connected to the WDI pin of the watchdog and change the electrical level of the WDI pin timely. If timeout occurs, the watchdog will switch off the power of module. The sketch map for watchdog is shown as below.

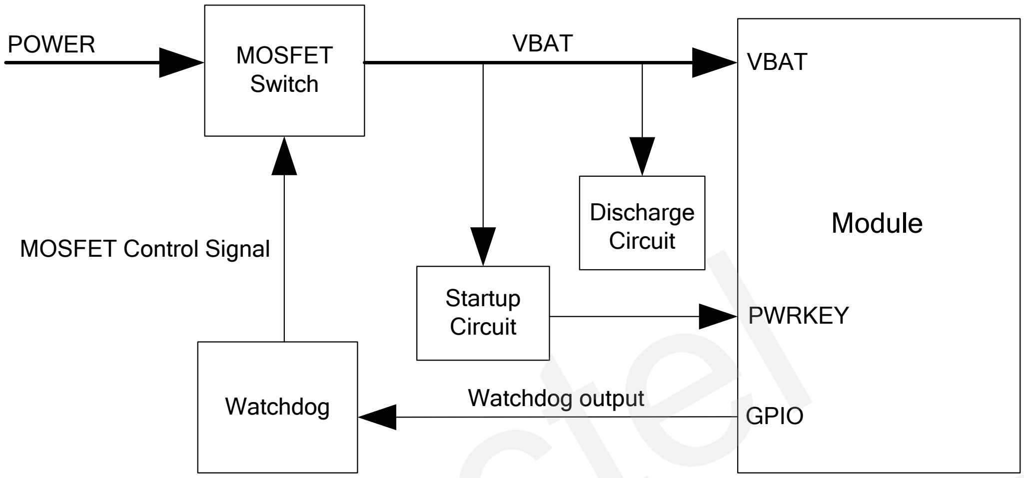


Figure 21: Sketch Map for Watchdog

3.9. Serial Interfaces

The module provides four serial ports: UART Port, Debug Port, Auxiliary UART Port and GNSS UART Port. The module is designed as DCE (Data Communication Equipment), following the traditional DCE-DTE (Data Terminal Equipment) connection. Autobauding function supports baud rate from 4800bps to 115200bps.

The UART Port:

- TXD: Send data to RXD of DTE.
- RXD: Receive data from TXD of DTE.
- RTS: Request to send.
- CTS: Clear to send.
- DTR: DTE is ready and inform DCE (this pin can wake the module up).
- RI: Ring indicator (when there is a call, SMS or URC output, the module will inform DTE with the RI pin).
- DCD: Data carrier detection (the validity of this pin demonstrates successful set-up of the communication link).

The Debug Port:

- DBG_TXD: Send data to the COM port of peripheral.
- DBG_RXD: Receive data from the COM port of peripheral.

The Auxiliary UART Port:

- TXD_AUX: Send data to the GNSS part.
- RXD_AUX: Receive data from the GNSS part.

The GNSS UART Port

- GNSS_TXD: Send data to the GSM part.
- GNSS_RXD: Receive data from the GSM part.

The logic levels are described in the following table.

Table 13: Logic Levels of the UART Interface

Parameter	Min.	Max.	Unit
V_{IL}	0	0.25 × VDD_EXT	V
V_{IH}	0.75 × VDD_EXT	VDD_EXT+0.2	V
V_{OL}	0	0.15 × VDD_EXT	V
V_{OH}	0.85 × VDD_EXT	VDD_EXT	V

Table 14: Pin Definition of the UART Interfaces

Interface	Pin Name	Pin No.	I/O	Description
UART Port	TXD	33	DO	Transmit data
	RXD	34	DI	Receive data
	DTR	37	DI	Data terminal ready
	RI	35	DO	Ring indication
	DCD	36	DO	Data carrier detection
	CTS	38	DO	Clear to send

	RTS	39	DI	Request to send
Debug Port	DBG_RXD	30	DI	Receive data
	DBG_TXD	29	DO	Transmit data
Auxiliary UART Port	RXD_AUX	24	DI	Receive data
	TXD_AUX	25	DO	Transmit data
GNSS UART Port	GNSS_RXD	23	DI	Receive data
	GNSS_TXD	22	DO	Transmit data

NOTE

If DCD, RI, DTR, CTS and RTS are not used, they can be multiplexed as GPIOs. As to GPIO, please refer to ***Chapter 3.18***.

Functions and events related to serial interfaces are as below:

- **Ql_UART_Register**: register a callback for the specified serial port
- **Ql_UART_Open**: open the specified serial port
- **Ql_UART_Write**: send data to the specified serial port
- **Ql_UART_Read**: read data from the specified serial port
- **Ql_UART_SetDCBConfig**: set DCB of serial port
- **EVENT_UART_READY_TO_READ**: read indication when data comes

For more details about the software design, please refer to the ***document [19]***.

3.9.1. UART Port

3.9.1.1. Features of UART Port

- 8 data bits, no parity bit, one stop bit.
- Firmware upgrade and data communication.
- Supported baud rates are as below: 300bps, 600bps, 2400bps, 4800bps, 9600bps, 14400bps, 19200bps, 28800bps, 38400bps, 57600bps, 115200bps, 230400bps, 460800bps.
- The module supports autobauding by default, and its default baud rate is 115200bps.
- Support hardware flow control, but it is disabled by default.

NOTES

1. The API function **Ql_UART_SetDCBConfig** can be used to set different baud rates.
2. The API function **Ql_UART_Open** can be used to set hardware flow control.

3.9.1.2. The Connection of UART

A reference design for UART Port is shown as below.

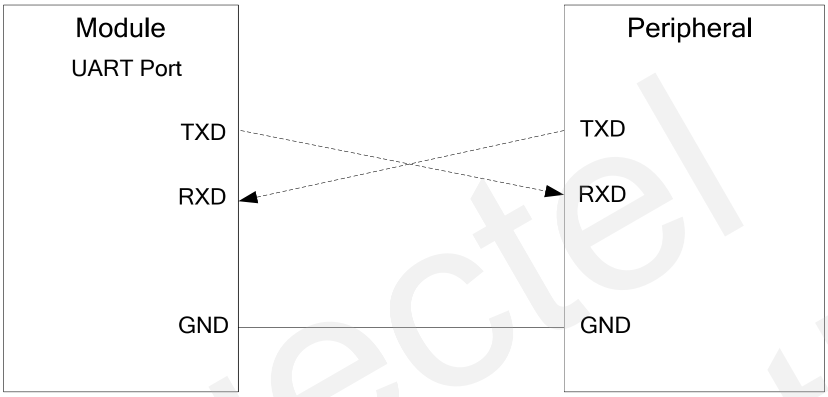


Figure 22: Reference Design for UART Port

3.9.1.3. Firmware Upgrade

The UART Port can be used to upgrade firmware. The PWRKEY pin must be pulled down before firmware upgrade. The following cautions must be taken into account.

- VBAT voltage must be stable
- PWRKEY pin must be set to low

The following figure shows a reference design for firmware upgrade

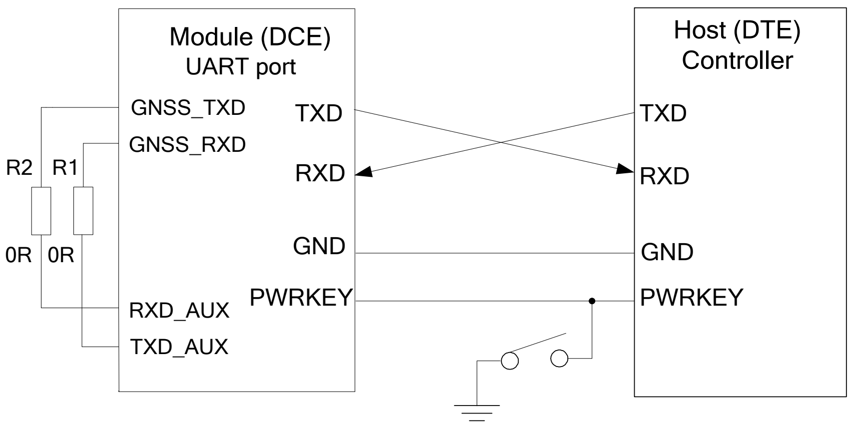


Figure 23: Reference Design for Firmware Upgrade

NOTE

The firmware of module might need to be upgraded due to a certain reasons. It is thus recommended to reserve these pins in the host board for firmware upgrade.

3.9.2. Debug Port

As to Debug Port, there are two working modes (Basic Mode and Advanced Mode) which can be switched through configuring APP software.

- Under Basic Mode, the port can be used to execute software debugging and it can also be connected to a peripheral device. Its default baud rate is 115200bps.
- Under Advanced Mode, the port can only be used to execute software debugging, capture the system's log with Cather tool and call **Ql_Debug_Trace()** to output the application log. In this mode, its baud rate is 460800bps.

A reference design for the Debug Port is shown as below.

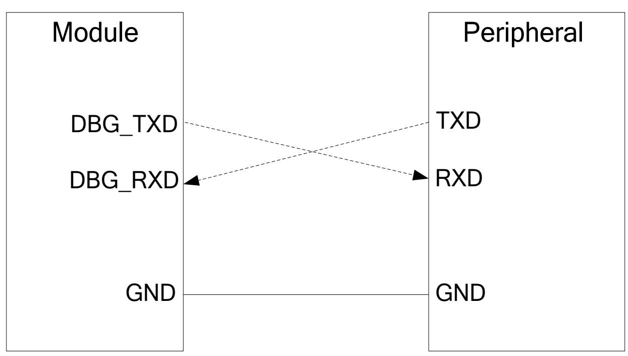


Figure 24: Reference Design for Debug Port

3.9.3. Auxiliary UART Port and GNSS UART Port

The Auxiliary UART Port and GNSS UART Port should be connected together, thus allowing for communication between GSM and GNSS parts. A reference design is shown below.

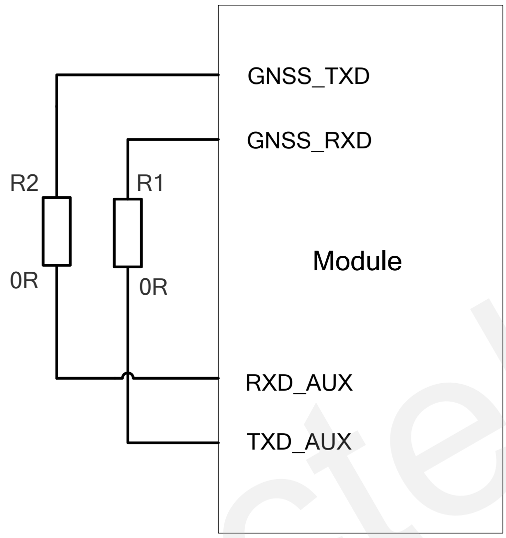


Figure 25: Auxiliary and GNSS UART Port Connection

NOTE

As the GNSS part of MC60-OpenCPU outputs more data than a single GNSS system, the default output NMEA types running in 4800bps baud rate and 1Hz update rate will lose some data. The solution to avoid losing data in 4800bps baud rate and 1Hz update rate is to decrease the output NMEA types. 115200bps baud rate is enough to transmit GNSS NMEA in default settings and it is thus recommended.

3.9.4. UART Application

A reference design of 3.3V level match is shown as below. If the host is a 3V system, please change the 5.6K resistors to 10K ones.

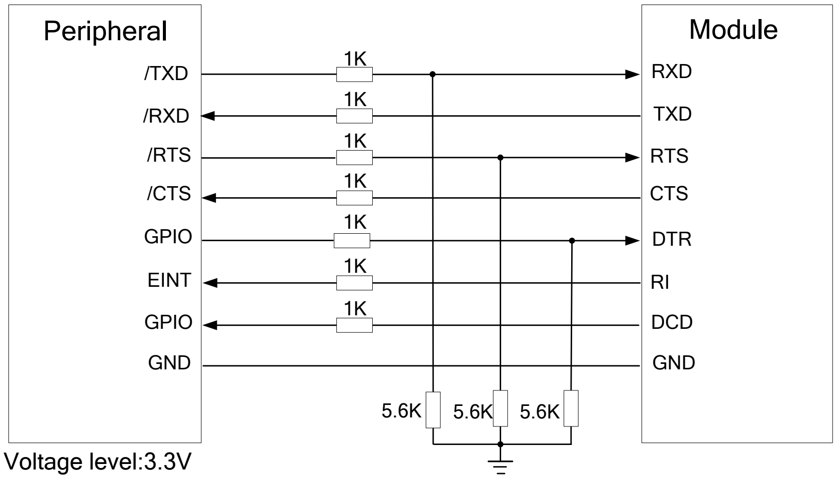


Figure 26: Level Match Design for 3.3V System

NOTE

It is highly recommended to add the resistor divider circuit on the UART signal lines when the host's level is 3V or 3.3V. For a higher voltage level system, a level shifter IC could be used between the host and the module. For more details about UART circuit design, please refer to ***document [10]***.

The following figure shows a sketch map between the module and the standard RS-232 interface. As the electrical level of module is 2.8V, a RS-232 level shifter must be used. Note that customers should assure the I/O voltage of level shifter which connects to module is 2.8V.

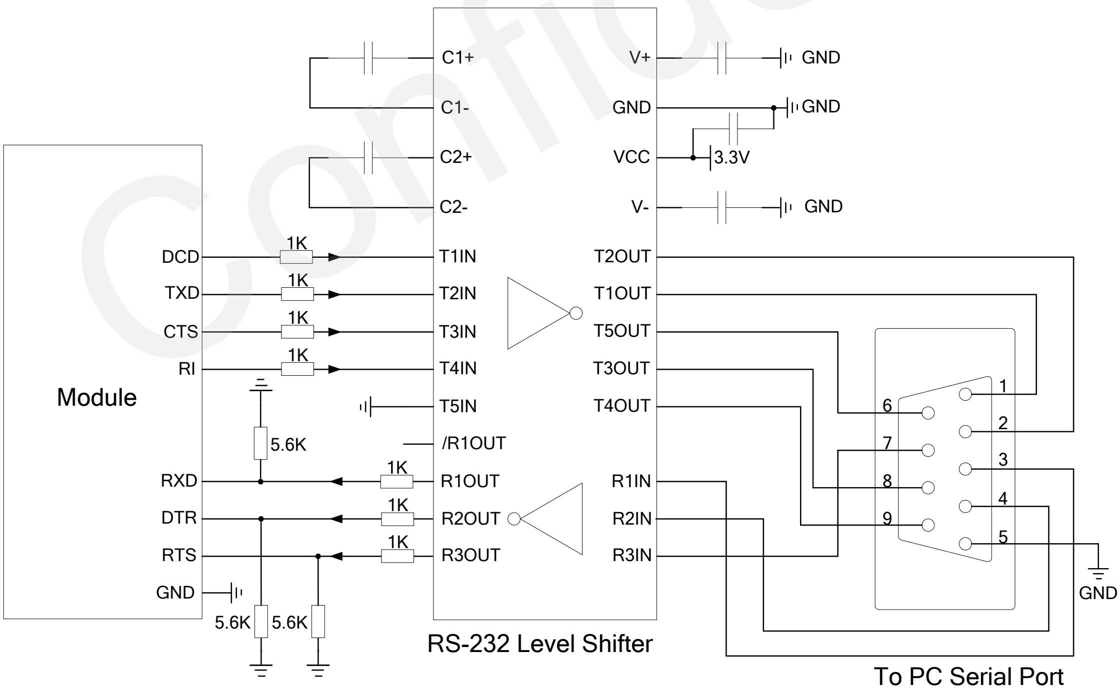


Figure 27: Sketch Map for RS-232 Interface Match

Please visit vendors' websites to select a suitable IC, such as: http://www.maximintegrated.com and http://www.exar.com.

3.10. Audio Interfaces

The module provides one analog input channel and two analog output channels.

Table 15: Pin Definition of Audio Interface

Interface	Pin Name	Pin No.	I/O	Description
AIN/AOUT1	MICP	1	AI	Microphone positive input
	MICN	2		Microphone negative input
	SPKP	3	AO	Channel 1 Audio positive output
	SPKN	4		Channel 1 Audio negative output
AIN/AOUT2	MICP	1	AI	Microphone positive input
	MICN	2		Microphone negative input
	LOUDSPKP	54	AO	Channel 2 Audio positive output
	LOUDSPKN	53		Channel 2 Audio negative output

AIN can be used for input of microphone and line. An electret microphone is usually used. AIN are differential input channels.

AOUT1 is used for output of receiver. The channel is typically used for building a receiver into a handset. AOUT1 channel is a differential channel.

AOUT2 is used for loudspeaker output as it is embedded with an amplifier of class AB whose maximum drive power is 800mW. AOUT2 is a differential channel.

AOUT2 also can be used for output of earphone, and can be used as a single-ended channel.

All these audio channels support voice and ringtone output, and so on, and can be switched by **AT+QAUDCH** command. For more details, please refer to ***document [1]***.

Use AT command **AT+QAUDCH** to select audio channel:

- **AT+QAUDCH=0**: AIN/AOUT1, the default value is 0.
- **AT+QAUDCH=1**: AIN/AOUT2, this channel is always used for earphone.
- **AT+QAUDCH=2**: AIN/AOUT2, this channel is always used for loudspeaker.

For each channel, customers can use **AT+QMIC** to adjust the input gain level of microphone. Customers can also use **AT+CLVL** to adjust the output gain level of receiver and speaker. **AT+QSIDET** is used to set the side-tone gain level. For more details, please refer to ***document [1]***.

Table 16: AOUT2 Output Characteristics

Item	Condition	Min.	Typ.	Max.	Unit
RMS Power	8Ω load VBAT=3.7v THD+N=1%		800		mW

3.10.1. Decrease TDD Noise and Other Noises

It is recommended to use the electret microphone with dual built-in capacitors (e.g. 10pF and 33pF) for filtering out RF interference, thus reducing TDD noise. The 33pF capacitor is applied for filtering out 900MHz RF interference when the module is transmitting at EGSM900MHz. Without placing this capacitor, TDD noise could be heard. The 10pF capacitor is used for filtering out 1800MHz RF interference. Please note that the resonant frequency point of a capacitor largely depends on the material and production technique. Therefore, customers would have to discuss with their capacitor vendors to choose most suitable capacitors for filtering out GSM850MHz, EGSM900MHz, DCS1800MHz and PCS1900MHz separately.

The severity degree of the RF interference in the voice channel during GSM transmitting period largely depends on the application design. In some cases, EGSM900 TDD noise is more severe; while in other cases, DCS1800 TDD noise is more obvious. Therefore, customers can choose a suitable capacitor based on the test results. Sometimes, even no RF filtering capacitor is required.

The capacitor which is used for filtering out RF noise should be close to the audio interfaces, and the audio trace should be as short as possible.

In order to decrease radio or other signal interference, the position of RF antenna should be kept away from audio interface and audio trace. The power trace could not be parallel with the audio trace, and should be far away from it.

The differential audio traces must be routed according to the differential signal layout rule.

3.10.2. Microphone Interfaces Design

AIN channels come with internal bias supply for external electret microphone. A reference circuit is shown in the following figure.

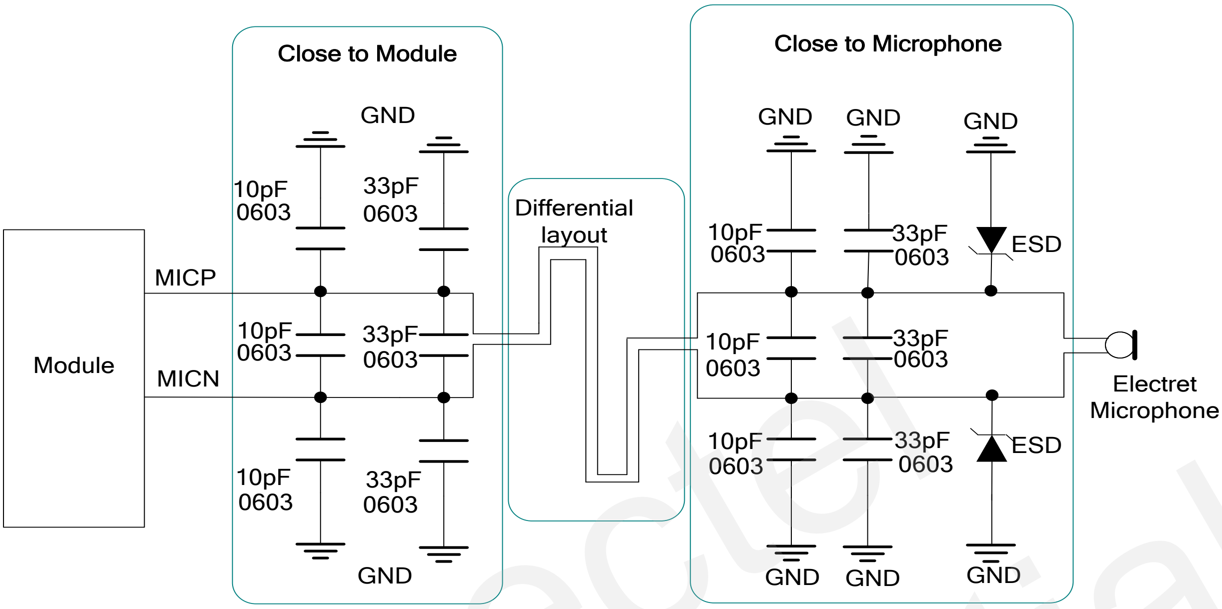


Figure 28: Reference Design for AIN

3.10.3. Receiver and Speaker Interface Design

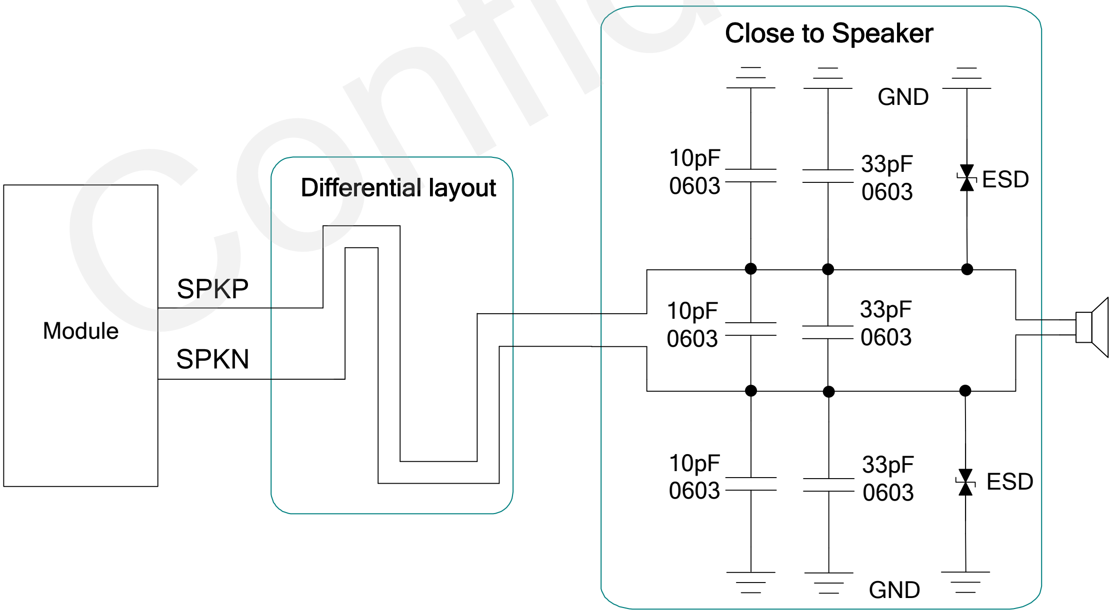


Figure 29: Handset Interface Design for AOUT1

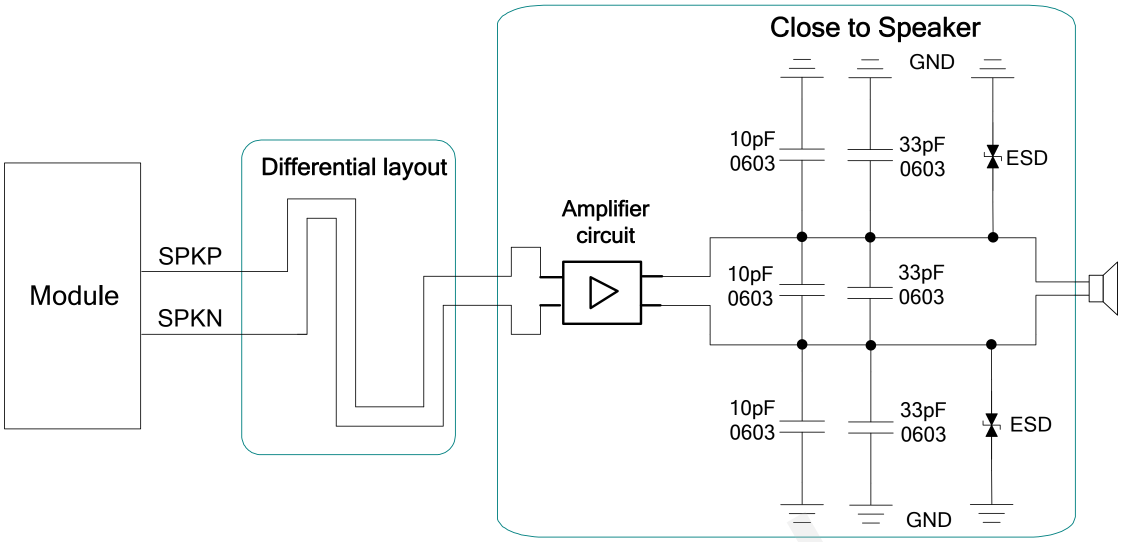


Figure 30: Speaker Interface Design with an Amplifier for AOUT1

A suitable differential audio amplifier can be chosen from the Texas Instrument's website (http://www.ti.com). There are also other excellent audio amplifier vendors in the market.

3.10.4. Earphone Interface Design

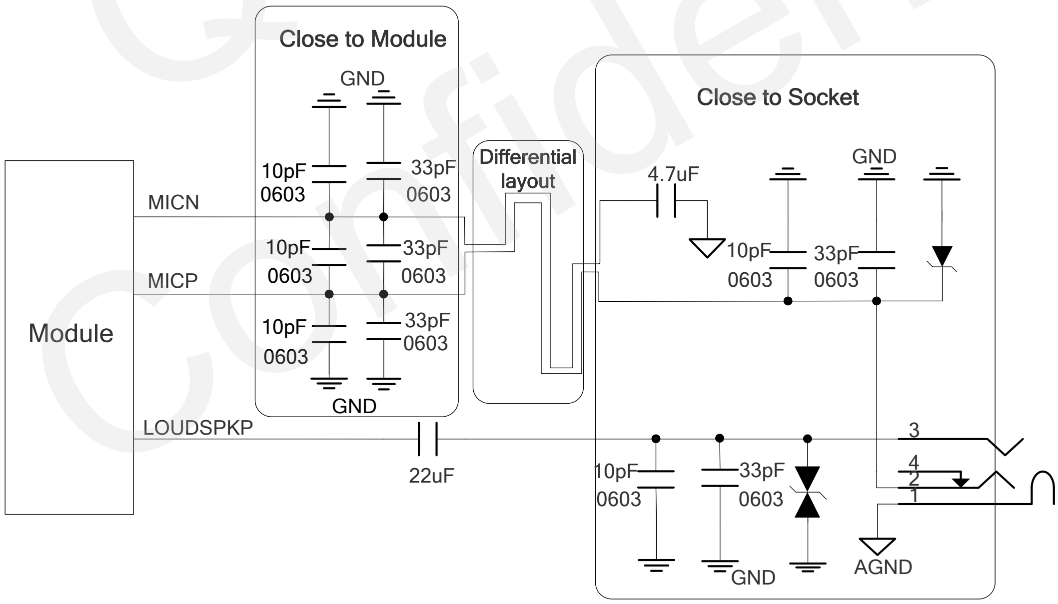


Figure 31: Earphone Interface Design

3.10.5. Loud Speaker Interface Design

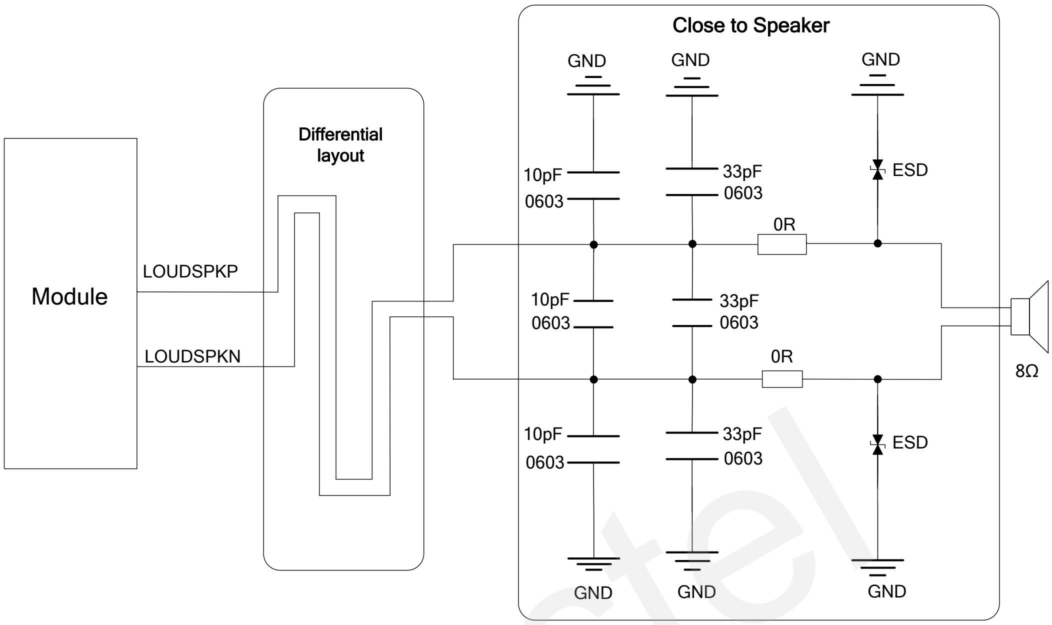


Figure 32: Loud Speaker Interface Design

3.10.6. Audio Characteristics

Table 17: Typical Electret Microphone Characteristics

Parameter	Min.	Typ.	Max.	Unit
Working Voltage	1.2	1.5	2.0	V
Working Current	200		500	uA
External Microphone Load Resistance		2.2		Kohm

Table 18: Typical Speaker Characteristics

Parameter			Min.	Typ.	Max.	Unit
AOUT1 Output	Single-ended	Load resistance		32		Ohm
		Reference level	0		2.4	Vpp
	Differential	Load resistance		32		Ohm

		Reference level	0		4.8	Vpp
AOUT2 Output	Differential	Load resistance		8		Ohm
		Reference level	0		2 × VBAT	Vpp
	Single-ended	Load resistance		8		Ohm
		Reference level	0		VBAT	Vpp

3.11. PCM Interface

MC60-OpenCPU provides a PCM interface. The interface is used for digital audio transmission between the module and the device. It is composed of PCM_CLK, PCM_SYNC, PCM_IN and PCM_OUT signal lines.

Pulse Code Modulation (PCM) is a converter that changes the consecutive analog audio signals to discrete digital signals. The whole process of Pulse Code Modulation includes sampling, quantizing and encoding.

Table 19: Pin Definition of PCM Interface

Pin Name	Pin No.	I/O	Description	Comment
PCM_OUT	60	DO	PCM data output	2.8V power domain
PCM_IN	62	DI	PCM data input	
PCM_CLK	59	DO	PCM clock output	
PCM_SYNC	61	DO	PCM frame synchronization output	

3.11.1. Parameter Configuration

MC60-OpenCPU supports 16-bit linear code PCM format through software configuration. The sample rate is 8KHz and the clock source rate is 256KHz. The module can only act in master mode. The PCM interface supports both long and short frame synchronization, and it only supports MSB first. For more detailed information, please refer to the table below.

Table 20: PCM Parameter Configuration

Parameter	Description
Interface Format	Linear
Data Length	Linear: 16bits
Sample Rate	8KHz
PCM Clock/Synchronization Source	Module acts in master mode: clock and synchronization sources are generated by module
PCM Synchronization Rate	8KHz
PCM Clock Rate	Module acts in master mode: 256KHz (linear)
PCM Synchronization Format	Long/short frame synchronization
PCM Data Ordering	MSB first
Zero Padding	Not supported
Sign Extension	Not supported

3.11.2. Timing Diagram

The sample rate of the PCM interface is 8KHz and the clock source rate is 256KHz. Every frame contains 32-bit data. The left 16 bits are valid, and the data of the left 16 bits and the right 16 bits are the same. The following are the timing diagrams of different frame synchronization formats.

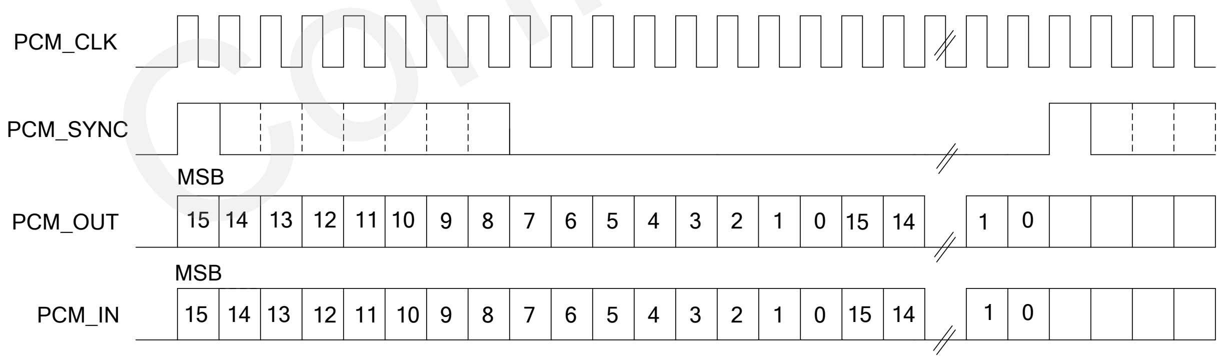


Figure 33: Timing Diagram for Long Frame Synchronization

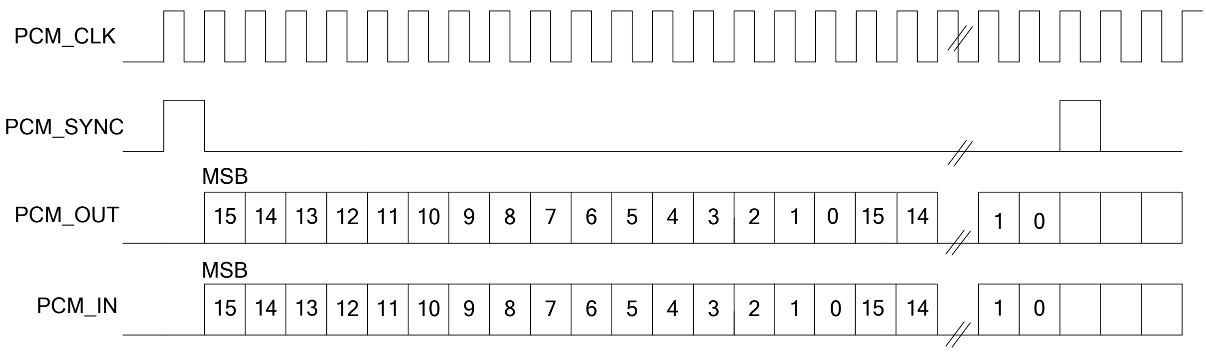


Figure 34: Timing Diagram for Short Frame Synchronization

3.11.3. Reference Design

MC60-OpenCPU can only work as a master, providing clock and synchronization source for PCM bus. A reference design for PCM is shown below.

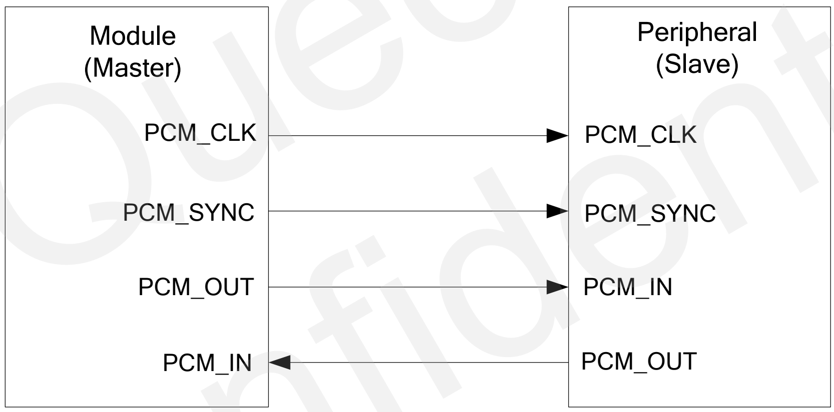


Figure 35: Reference Design for PCM

3.11.4. AT Command

There are two AT commands for the configuration of PCM: **AT+QPCMON** and **AT+QPCMVOL**. Details are illustrated below.

- **AT+QPCMON** is used to configure the operating mode of PCM

Command format: **AT+QPCMON=mode, Sync_Type, Sync_Length, SignExtension, MSBFirst**

Table 21: AT+QPCMON Command Parameter Configuration

Parameter	Value Range	Description
Mode	0; 2	0: Close PCM 2: Open PCM when audio talk is set up
Sync_Type	0~1	0: Short frame synchronization 1: Long frame synchronization
Sync_Length	1~8	Programmable from 1bit to 8bits via software configuration in long frame synchronization format
Sign Extension	0~1	Not supported
MSB First	0~1	0: MSB first 1: Not supported

- **AT+QPCMVOL** is used to configure the input and output volume of PCM.

Command format: **AT+QPCMVOL=vol_pcm_in, vol_pcm_out**

Table 22: AT+QPCMVOL Command Parameter Configuration

Parameter	Value Range	Description
vol_pcm_in	0~32767	Set the input volume
vol_pcm_out	0~32767	Set the output volume The voice may be distorted when this value exceeds 16384.

3.12. SPI and I2C Interface

MC60-OpenCPU supports SPI and I2C interfaces.

3.12.1. SPI Interface

The SPI interface is multiplexed by PCM interface. SPI interface of MC60-OpenCPU acts as the master only. It provides a duplex, synchronous and serial communication link with the peripheral devices. Its operation voltage is 2.8V, with clock rates up to 10MHz. Main features of the SPI interface are listed below.

- Support master mode operation
- Adjustable clock speed
- Serial clock with programmable polarity and phase

The logic levels of SPI interfaces are described in the following table.

Table 23: Logic Levels of the SPI Interface

Parameter	Min.	Max.	Unit
V_{IL}	0	0.25 × VDD_EXT	V
V_{IH}	0.75 × VDD_EXT	VDD_EXT+0.2	V
V_{OL}	0	0.15 × VDD_EXT	V
V_{OH}	0.85 × VDD_EXT	VDD_EXT	V

Table 24: Pin Definition of the SPI Interface

Pin No.	Pin Name	I/O	Description	Alternate Function [1)]
60	SPI_MOSI	DO	Master output, Slave input of SPI interface	PCM_OUT
62	SPI_CLK	DI	Clock signal of SPI interface	PCM_IN
61	SPI_MISO	DO	Master input, Slave output of SPI interface	PCM_SYNC
59	SPI_CS	DO	Chip select of SPI interface	PCM_CLK

NOTE

[1)] If several interfaces share the same I/O pin, to avoid conflict between these alternate functions, only one peripheral should be enabled at a time.

The MC60-OpenCPU SPI must be configured as the master. The API functions of the file system can be used to read/write SPI. For detailed information about the software design, please refer to the ***document [19]***.

3.12.2. I2C Interface

I2C is a two-wire serial interface which is multiplexed by RI and DCD pins. The two signals are SCL and SDA. Main features of the I2C interface are listed below.

- Support master mode operation
- Adjustable clock speed for LS/FS mode operation

- Support 7-bit addressing
- Support high speed mode

Table 25: Logic Levels of the I2C Interface

Parameter	Min.	Max.	Unit
V_{IL}	0	0.25 × VDD_EXT	V
V_{IH}	0.75 × VDD_EXT	VDD_EXT+0.2	V
V_{OL}	0	0.15 × VDD_EXT	V
V_{OH}	0.85 × VDD_EXT	VDD_EXT	V

Table 26: Pin Definition of the I2C Interface

<table>
<tr><th>Pin No.</th><th>Pin Name</th><th>I/O</th><th>Description</th><th>Comment</th><th>Alternate Function [1)]</th></tr>
<tr><td>35</td><td>I2C_SCL</td><td>DO</td><td>I2C serial clock</td><td rowspan="2">Require external pull-up resistor</td><td>RI</td></tr>
<tr><td>36</td><td>I2C_SDA</td><td>DO</td><td>I2C serial data</td><td>DCD</td></tr>
</table>

NOTE

[1)] If several interfaces share the same I/O pin, to avoid conflict between these alternate functions, only one peripheral should be enabled at a time.

The API functions of the file system can be used to read/write I2C. For detailed information about the software design, please refer to the ***document [19]***.

3.13. (U)SIM Card Interface

The (U)SIM card interface circuitry meets GSM Phase 1 and GSM Phase 2+ specifications, and supports FAST 64kbps (U)SIM card (intended for use with a (U)SIM application tool-kit).

The (U)SIM card is powered by an internal regulator in the module. Both 1.8V/3.0V (U)SIM cards and Dual (U)SIM Single Standby function are supported.

Table 27: Pin Definition of the (U)SIM Interface

Pin Name	Pin No.	I/O	Description	Alternate Function [1]
SIM1_VDD	18	PO	Supply power for (U)SIM1 card. Automatic detection of (U)SIM1 card voltage. Voltage accuracy: 3.0V±5% and 1.8V±5%. Maximum supply current is around 10mA.	
SIM1_CLK	19	DO	Clock signal of (U)SIM1 card	
SIM1_DATA	21	IO	Data signal of (U)SIM1 card	
SIM1_RST	20	DO	Reset signal of (U)SIM1 card	
SIM1_PRESENCE	37	DI	(U)SIM1 card insertion detection	DTR
SIM_GND	16		Specified ground for (U)SIM card	
SIM2_VDD	13	PO	Supply power for (U)SIM2 card. Automatic detection of (U)SIM2 card voltage. Voltage accuracy: 3.0V±5% and 1.8V±5%. Maximum supply current is around 10mA.	
SIM2_CLK	10	DO	Clock signal of (U)SIM2 card	
SIM2_DATA	11	IO	Data signal of (U)SIM2 card	
SIM2_RST	12	DO	Reset signal of (U)SIM2 card	

NOTE

[1] If several interfaces share the same I/O pin, to avoid conflict between these alternate functions, only one peripheral should be enabled at a time.

The following figure shows a reference design for (U)SIM1 card interface with an 8-pin (U)SIM card connector.

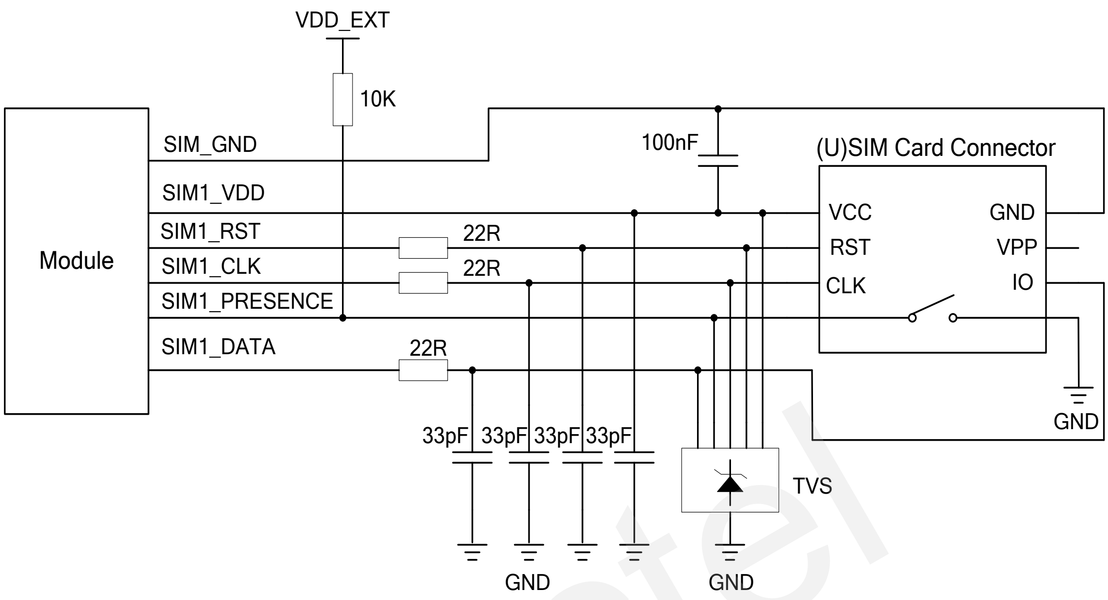


Figure 36: Reference Circuit for (U)SIM1 Card Interface with an 8-Pin (U)SIM Card Connector

If (U)SIM1 card insertion detection function is not used, keep pin SIM1_PRESENCE unconnected. A reference circuit for (U)SIM1 card interface with a 6-pin (U)SIM card connector is illustrated in the following figure.

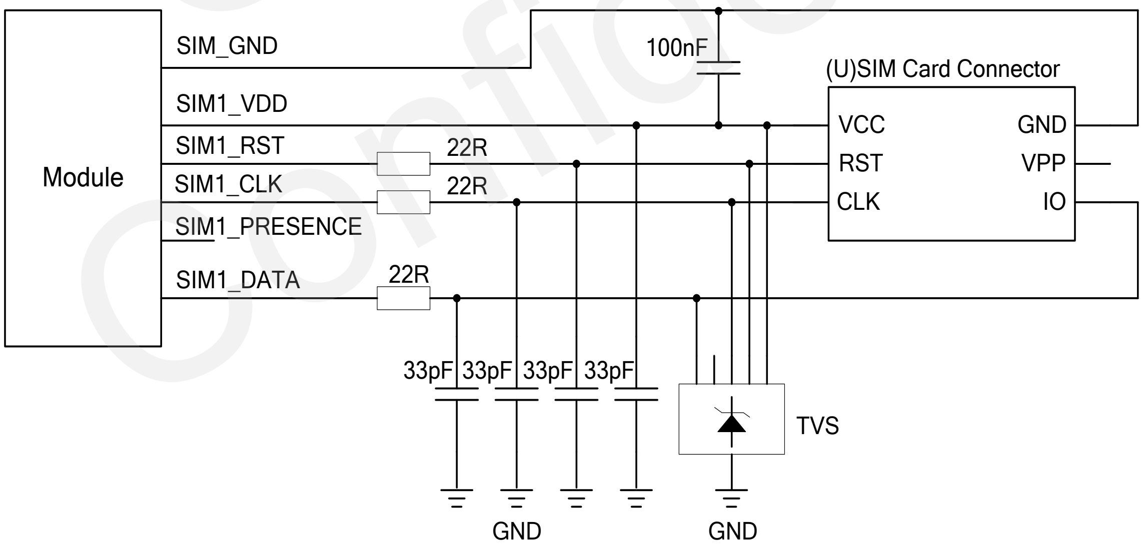


Figure 37: Reference Circuit for (U)SIM1 Card Interface with a 6-Pin (U)SIM Card Connector

The following figure shows a reference design for (U)SIM2 card interface with a 6-pin (U)SIM card connector.

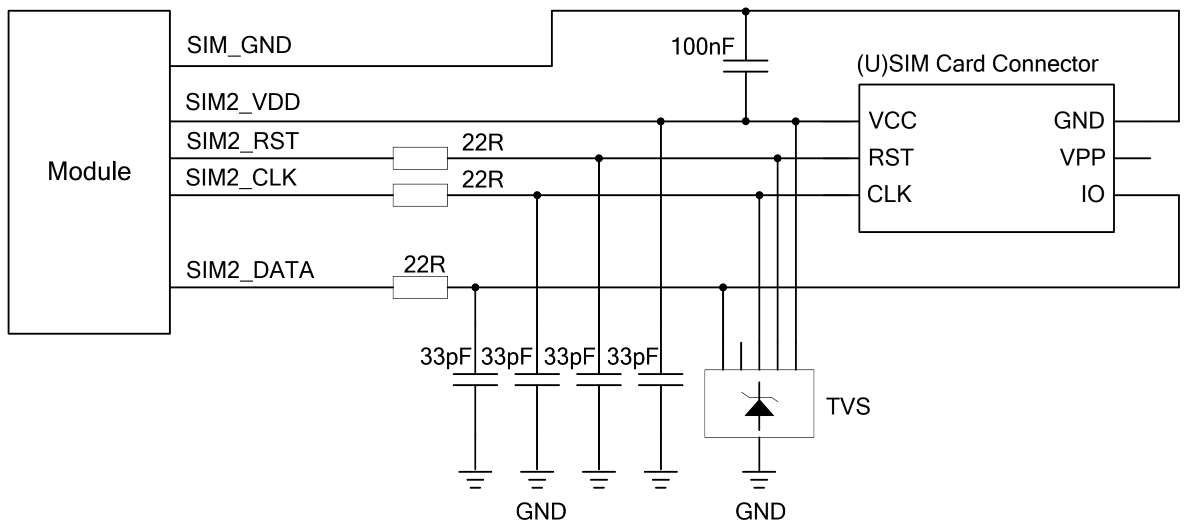


Figure 38: Reference Circuit for (U)SIM2 Card Interface with a 6-Pin (U)SIM Card Connector

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 layout of (U)SIM card 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 module and (U)SIM card connector short and wide. Keep the width of ground no less than 0.5mm to maintain the same electric potential. The decouple capacitor between SIM_VDD and GND should be not more than 1μF and be placed close to the (U)SIM card connector.
- To avoid cross talk between SIM_DATA and SIM_CLK, keep them away from each other and shield them with surrounded ground.
- In order to offer good ESD protection, it is recommended to add a TVS diode array whose parasitic capacitance should be not more than 50pF. Place the ESD protection device as close as possible to the (U)SIM card connector, and make sure the (U)SIM card signal lines go through the ESD protection device first from (U)SIM card connector and then connect to the module. The 22Ω resistors should be connected in series between the module and the (U)SIM card so as to suppress EMI spurious transmission and enhance ESD protection. Please note that the (U)SIM peripheral circuit should be close to the (U)SIM card connector.
- The pull-up resistor on SIM_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.

3.14. SD Card Interface

The module provides an SD card interface that supports many types of memory such as Memory Stick, SD/MCC card, and T-Flash (or Micro SD) card. The following are the main features of SD card interface.

- Only support 1bit serial mode
- Not support the SPI mode for SD memory card
- Not support multiple SD memory cards
- Not support hot plug
- The data rate up to 48MHz in serial mode
- Support memory cards with maximum capacity up to 32GB

With the SD card interface features and reference circuit shown as below, customers can easily design the SD card application circuit to enhance the memory capacity of the module. Users can store some high-capacity files such as automobile application systems to SD card. The module can record and store the audio files to the SD card, and also can play the audio files in SD card.

Table 28: Pin Definition of SD Card Interface

Pin Name	Pin No.	I/O	Description
SD_CMD	7	DO	Command signal of SD card
SD_CLK	8	DO	Clock signal of SD card
SD_DATA	9	IO	Data signal of SD card

A reference design for SD card interface is shown below.

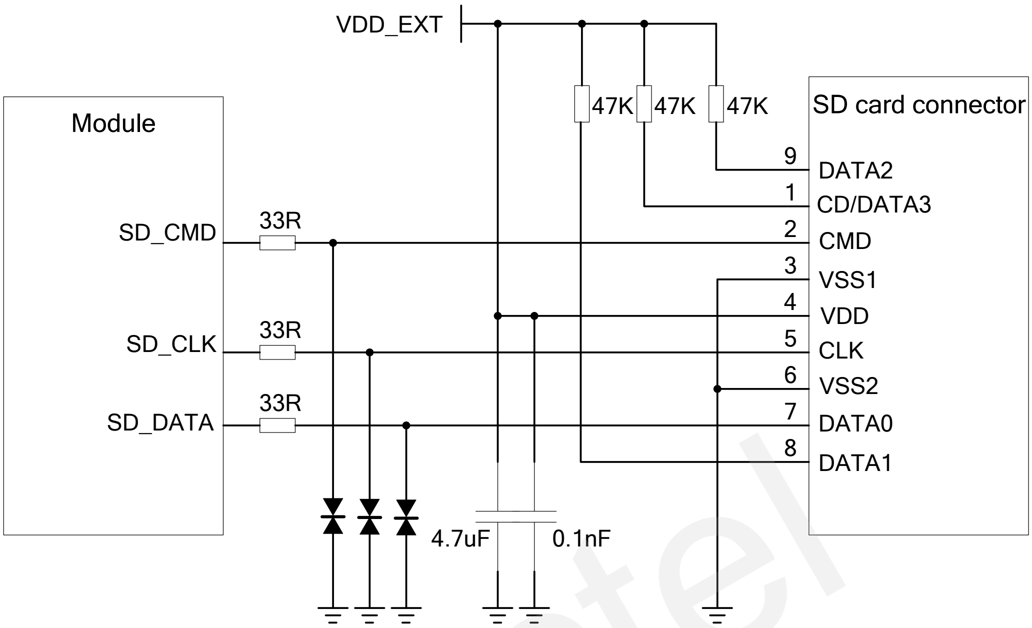


Figure 39: Reference Circuit for SD Card Interface

Table 29: Pin Definition of SD Card and T-Flash (Micro SD) Card

Pin No.	Pin Name of SD Card	Pin Name of T-Flash (Micro SD) Card
1	CD/DATA3	DATA2
2	CMD	CD/DATA3
3	VSS1	CMD
4	VDD	VDD
5	CLK	CLK
6	VSS2	VSS
7	DATA0	DATA0
8	DATA1	DATA1
9	DATA2	

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

- Keep all the SD card signals far away from RF and VBAT traces.
- Make sure the length of SD card signal lines does not exceed 10cm and be as short as possible.
- The traces of SD_CLK, SD_DATA and SD_CMD are recommended to be routed together and be of equal length; the length difference should be less than 10mm.
- In order to offer good ESD protection, it is recommended to add a TVS diode array whose parasitic capacitance should be not more than 50pF, and should be placed as close as possible to the SD card connector.
- Reserve external pull-up resistors for other data lines except the DATA0 signal.
- The SD_CLK and SD_DATA traces are recommended to be shielded by ground in order to improve EMI suppression capability and prevent the crosstalk.

3.15. ADC

The module provides an ADC input channel to measure the value of voltage. The API function **QI_ADC_Sampling()** can be used to read the voltage value from ADC input channel. For detailed information about the software design, please refer to the ***document [19]***.

Table 30: Pin Definition of the ADC

Pin Name	Pin No.	I/O	Description
ADC	6	AI	Analog-to-digital converter

Table 31: Characteristics of the ADC

Item	Min.	Typ.	Max.	Unit
Voltage Range	0		2.8	V
ADC Resolution		10		bits
ADC Accuracy		2.7		mV

3.16. External Interrupt

MC60-OpenCPU possesses one external interrupt which supports level trigger. The external interrupt is a multiplexed function. When the default function of pin 37 is not used, it can be configured as an external interrupt.

Table 32: Pin List for External Interrupt

Pin No.	Pin Name	Trigger Type
37	DTR	Level

If an external interrupt occurs, the previously registered interrupt callback function will be invoked. For detailed information about the software design, please refer to the ***document [19]***.

NOTE

If external interrupt is not used, the pin can be multiplexed as GPIO. For detailed information about GPIO, please refer to ***Chapter 3.18***.

3.17. PWM

MC60-OpenCPU provides a PWM signal output channel which is called NETLIGHT. NETLIGHT indicates network status by default. For details of NETLIGHT's default function, please refer to ***Chapter 3.20***.

PWM signal parameters can be configured by calling the API function **Ql_PWM_Output()**. For detailed information about the software design, please refer to the ***document [19]***.

3.18. GPIO

MC60-OpenCPU provides 13 GPIOs in all. In order to reduce the pin number, GPIO is multiplexed with other functions. When pin's default function is not used, it can be configured as GPIO. API functions, such as **Ql_GPIO_Init**, **Ql_GPIO_SetLevel**, **Ql_GPIO_SetDirection**, **Ql_GPIO_SetPullSelection**, can be used for GPIO configuration. For detailed information about the software design, please refer to the ***document [19]***.

Table 33: Pin List for GPIO

Pin No.	Pin Name	Mode	Reset		Output Driving
			I/O	PU/PD	
7	SD_CMD	Mode 2	I	PD	4mA
8	SD_CLK	Mode 2	I	PD	4mA
9	SD_DATA	Mode 2	I	PD	4mA
10	SIM2_CLK	Mode 2	I	PD	4mA
11	SIM2_DATA	Mode 2	I	PD	4mA
12	SIM2_RST	Mode 2	I	PD	4mA
35	RI	Mode 2	I	PD	4mA
36	DCD	Mode 2	I	PD	4mA
37	DTR	Mode 2	I	PD	4mA
38	CTS	Mode 2	I	PU	4mA
39	RTS	Mode 2	I	PU	4mA
47	NETLIGHT	Mode 2	I	PD	4mA
57	GPIO_0	Mode 1	I	PD	4mA
58	GPIO_1	Mode 1	I	PD	4mA
59	PCM_CLK	Mode 2	HO	/	4mA
60	PCM_OUT	Mode 2	I	PD	4mA
61	PCM_SYNC	Mode 2	I	PD	4mA
62	PCM_IN	Mode 2	I	PU	4mA
63	GPIO_2	Mode 1	I	PD	4mA
64	GPIO_3	Mode 1	I	PD	4mA
65	GPIO_4	Mode 1	I	PD	4mA

If customers configure GPIO as input or output port, please pay attention to level match when the module is connected with other peripherals. A reference design for 3.3V level match is shown as below.

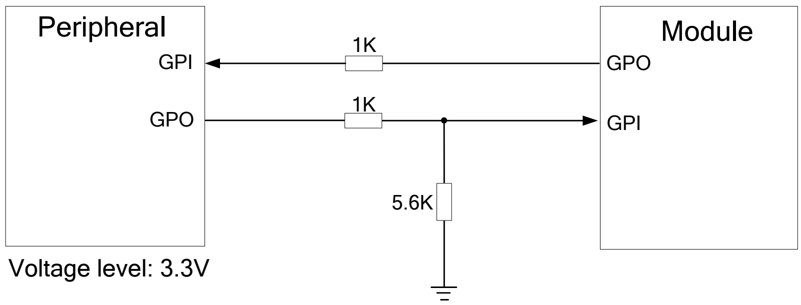


Figure 40: GPIO Level Match Design for 3.3V System

NOTE

If the digital I/O between customer and module does not match, it will cause some unexpected results. So it is highly recommended to add the level match circuit when the module is connected with other peripherals. For more details about digital I/O application, please refer to ***document [13]***.

3.19. Behaviors of the RI

Table 34: Behaviors of the RI

State	RI Response
Standby	HIGH
Voice Call	Change to LOW, and then: ● Change to HIGH when call is established. ● Change to HIGH when use ATH to hang up the call ● Change to HIGH first when calling part hangs up and then change to LOW for 120ms indicating “NO CARRIER” as an URC. After that, RI changes to HIGH again. ● Change to HIGH when SMS is received.
SMS	When a new SMS comes, the RI changes to LOW and holds low level for about 120ms, and then changes to HIGH.
URC	Certain URCs can trigger 120ms low level on RI.

If the module is used as a caller, the RI would maintain high except when the URC or SMS is received. When it is used as a receiver, the timing of RI is shown below.

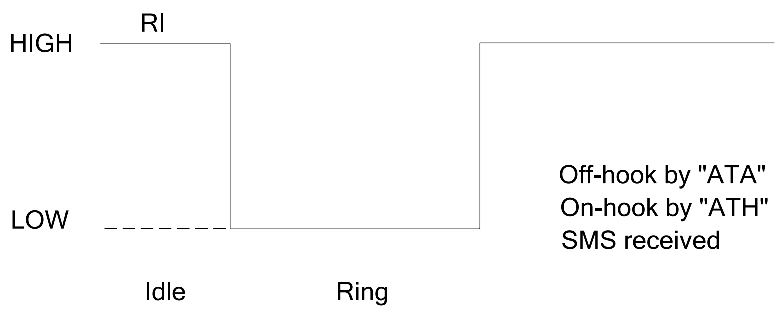


Figure 41: RI Behavior as a Receiver When Voice Calling

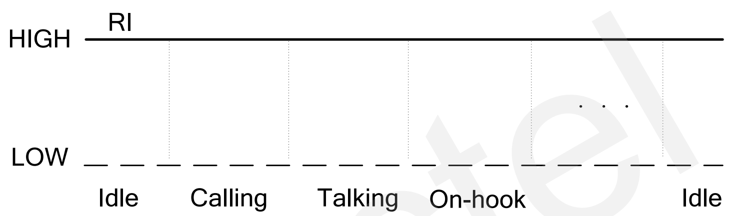


Figure 42: RI Behavior as a Caller

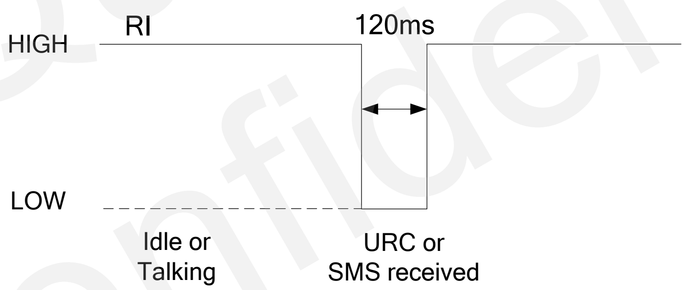


Figure 43: RI Behavior When URC or SMS Received

3.20. Network Status Indication

The NETLIGHT signal can be used to drive a network status indicator LED. The working state of this pin is listed in the following table.

Table 35: Working State of the NETLIGHT

State	Module Function
OFF	The module is not running.
64ms ON/800ms OFF	The module is not synchronized with network.
64ms ON/2,000ms OFF	The module is synchronized with network.
64ms ON/600ms OFF	GPRS data transmission after dialing the PPP connection.

A reference circuit is shown as below.

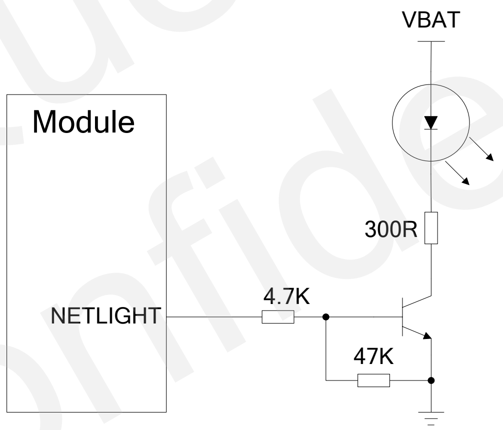


Figure 44: Reference Design for NETLIGHT

3.21. EASY Autonomous AGPS Technology

Supplying aiding information like ephemeris, almanac, rough last position, time and satellite status, can help improve the acquisition sensitivity and the TTFF for a module. This is called as EASY technology and MC60-OpenCPU's GNSS part supports it.

EASY technology works as embedded software which can accelerate TTFF by predicting satellite navigation messages from received ephemeris. The GNSS part will calculate and predict orbit information automatically up to 3 days after first receiving the broadcast ephemeris, and save the predicted information into the internal memory. GNSS part of MC60-OpenCPU will use the information for positioning if no enough information from satellites, so the function is helpful for positioning and TTFF improvement.

The EASY function can reduce TTFF to 5s in warm start. In this case, GNSS's backup domain should be valid. In order to gain enough broadcast ephemeris information from GNSS satellites, the GNSS part should receive the information for at least 5 minutes in good signal conditions after it fixes the position.

EASY function is enabled by default. Command "$PMTK869,1,0*34" can be used to disable EASY function. For more details, please refer to ***document [14]***.

NOTE

Make sure the GNSS part is powered on before sending the PMTK command.

3.22. EPO Offline AGPS Technology

MC60-OpenCPU features a function called EPO (Extended Prediction Orbit) which is a world leading technology. When MC60-OpenCPU is powered on, EPO function can be enabled via AT command **AT+QGNSSEPO=1**. When the GSM part detected that the EPO data has expired, the EPO data will be automatically downloaded to the GSM part's FS from MTK server via GSM/GPRS network; and the GNSS part will get the EPO data via build-in GNSS command from GSM's FS when it detected that the local EPO data has expired. When there is no local EPO data or when the data has expired, MC60-OpenCPU will download the data (4KB) for 6 hours' orbit predictions in order to achieve cold start in the shortest time, and then continue to download the EPO data (96KB) for 6 days (3 days+ 3 days). The technology allows the module to realize fast positioning. Command **AT+QGNSSEPO=0** can be used to turn off the EPO function. For more details, please refer to ***document [14]***.

NOTE

Make sure the EPO function is enabled if customers need to download the EPO data.

3.23. QuecFastFix Online Technology

QuecFastFix Online function can be used in combination with EPO technology to further improve TTFF and acquisition sensitivity in cold start. Based on the latest EPO data, QuecFastFix Online additionally offers adding information such as reference-location and NITZ/NTP time, which shortens TTFF to only several seconds (approx. 4.5s) in cold start. The function makes the cold start TTFF comparable to that in hot start. For more details, please refer to ***document [14]***.

3.24. Multi-tone AIC

MC60-OpenCPU has a function called multi-tone AIC (Active Interference Cancellation) to decease harmonic of RF noise from Wi-Fi, GSM, 3G and 4G.

Up to 12 multi-tone AIC embedded in the module can provide effective narrow-band interference and jamming elimination. The GNSS signal could be demodulated from the jammed signal, which can ensure better navigation quality. AIC function is enabled by default. Enabling AIC function will increase current consumption by about 1mA @VCC=3.3V. The following commands can be used to set AIC function.

Enable AIC function: $PMTK 286,1*23
Disable AIC function: $PMTK 286,0*22

NOTE

Make sure the GNSS part is powered on before sending these PMTK commands.

3.25. LOCUS

MC60-OpenCPU supports the embedded logger function called LOCUS. When enabled by PMTK command "$PMTK185, 0*22", the function allows the module to log GNSS data to internal flash memory automatically without the need to wake up host, and thus, the module can enter into Sleep mode to save power consumption, and does not need to receive NMEA information all the time. MC60-OpenCPU provides a log capacity of more than 16 hours.

The detail procedures of this function are illustrated below:

- The module has fixed the position (only effective in 3D_fixed scenario).
- Sending PMTK command "$PMTK184,1*22" to erase internal flash.
- Sending PMTK command "$PMTK185,0*22" to start logging.
- The module logs the basic information (UTC time, latitude, longitude and height) every 15 seconds to internal flash memory.
- Stop logging the information by sending PMTK command "$PMTK185,1*23".
- MCU can get the data by sending PMTK command "$PMTK622,1*29" to the module.

PMTK Command "$PMTK183*38" can be used to query the state of LOCUS.

The raw data which MCU gets has to be parsed via LOCUS parser code provided by Quectel. For more details, please contact Quectel technical supports.

3.26. PPS VS. NMEA

Pulse per Second (PPS) VS. NMEA can be used for time service. The latency range of the beginning of UART Tx is between 465ms and 485ms, and after the rising edge of PPS.

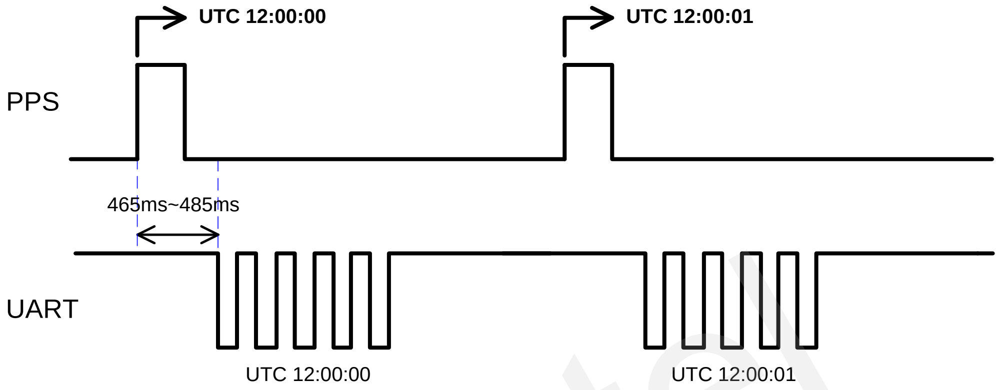


Figure 45: PPS VS. NMEA Timing

The feature only supports 1Hz NMEA output and baud rate at 14400bps~115200bps. When the baud rate is 9600bps or 4800bps, it only supports RMC NMEA sentence output. Because at low baud rates, per second transmission may exceed one second if there are many NMEA sentences output. Customers can enable this function by sending "$PMTK255,1*2D", and disable the function by sending "$PMTK255,0*2C".

NOTE

The GNSS UART port has a fixed baud rate, and it is 115200bps by default.

4 Antenna Interfaces

MC60-OpenCPU has three antenna interfaces which are used for GSM antenna, GNSS antenna and BT antenna, respectively. The Pin 41 is the GSM antenna pad; the Pin 15 is the GNSS antenna pad; and Pin 32 is the BT antenna pad. The RF interface of the three antenna pads has an impedance of 50Ω.

4.1. GSM Antenna Interface

There is a GSM antenna pad named RF_ANT for MC60-OpenCPU.

Table 36: Pin Definition of the RF_ANT

Pin Name	Pin No.	I/O	Description
RF_ANT	41	IO	GSM antenna pad
GND	42		Ground

4.1.1. Reference Design

The external antenna must be matched properly to achieve the best performance, so the matching circuit is necessary. A reference design for GSM antenna is shown below.

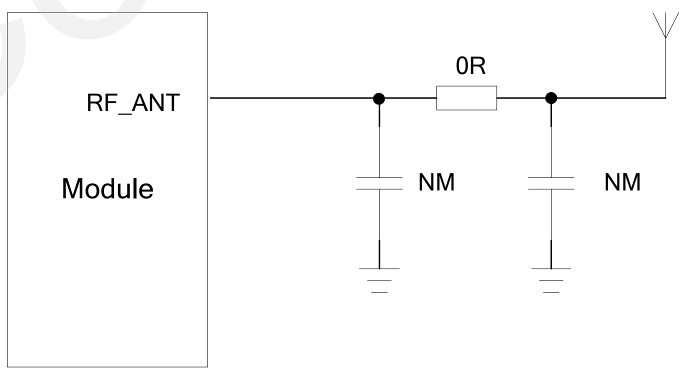


Figure 46: Reference Design for GSM Antenna

MC60-OpenCPU provides an RF antenna pad for antenna connection. The RF trace in host PCB connected to the module's RF antenna pad should be coplanar waveguide line or microstrip line, whose characteristic impedance should be close to 50Ω. MC60-OpenCPU comes with grounding pads which are next to the antenna pad in order to give a better grounding. Besides, a π type matching circuit is suggested to be used to adjust the RF performance.

To minimize the loss on RF trace and RF cable, please pay attention to the design. The following table shows the requirements on GSM antenna.

Table 37: Antenna Cable Requirements

Type	Requirements
GSM850/EGSM900	Cable insertion loss <1dB
DCS1800/PCS1900	Cable insertion loss <1.5dB

Table 38: Antenna Requirements

Type	Requirements
Frequency Range	Depend on the frequency band(s) provided by the network operator
VSWR	≤2
Gain (dBi)	1
Max Input Power (W)	50
Input Impedance (Ω)	50
Polarization Type	Vertical

4.1.2. RF Output Power

Table 39: RF Output Power

Frequency	Max.	Min.
GSM850	33dBm±2dB	5dBm±5dB
EGSM900	33dBm±2dB	5dBm±5dB

DCS1800	30dBm±2dB	0dBm±5dB
PCS1900	30dBm±2dB	0dBm±5dB

NOTE

In GPRS 4 slots TX mode, the maximum output power is reduced by 2.5dB. This design conforms to the GSM specification as described in ***Chapter 13.16*** of *3GPP TS 51.010-1*.

4.1.3. RF Receiving Sensitivity

Table 40: RF Receiving Sensitivity

Frequency	Receive Sensitivity
GSM850	< -110dBm
EGSM900	< -110dBm
DCS1800	< -110dBm
PCS1900	< -110dBm

4.1.4. Operating Frequencies

Table 41: Operating Frequencies

Frequency	Receive	Transmit	ARFCH
GSM850	869MHz~894MHz	824MHz~849MHz	128~251
EGSM900	925MHz~960MHz	880MHz~915MHz	0~124; 975~1023
DCS1800	1805MHz~1880MHz	1710MHz~1785MHz	512~885
PCS1900	1930MHz~1990MHz	1850MHz~1910MHz	512~810

4.1.5. RF Cable Soldering

Soldering the RF cable to RF pad of module correctly will reduce the loss on the path of RF. Please refer to the following example for RF cable soldering.

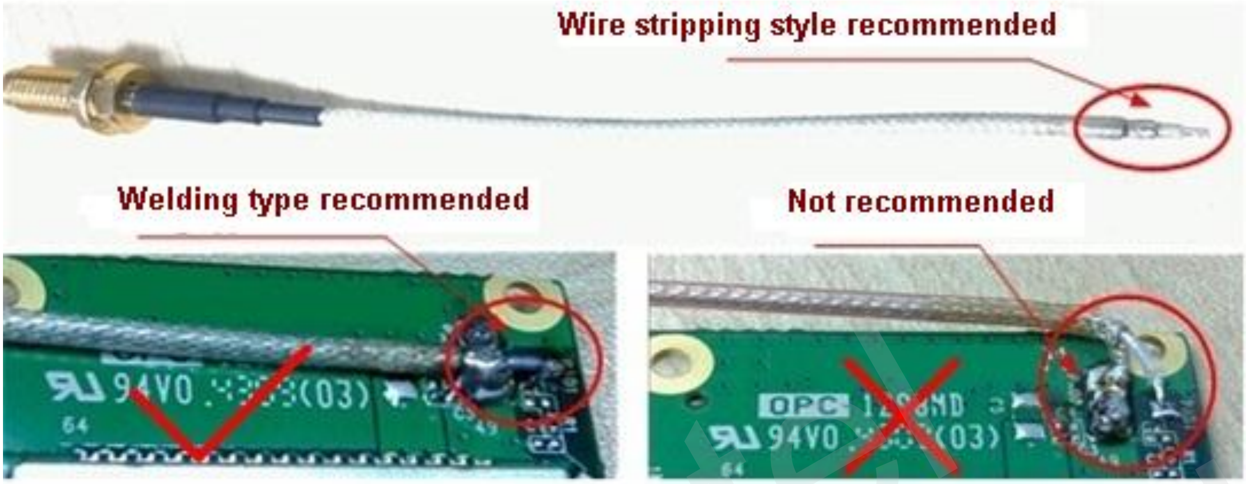


Figure 47: RF Cable Soldering Sample

4.2. GNSS Antenna Interface

The GNSS part of MC60-OpenCPU supports both GPS and GLONASS systems. The RF signal is obtained from the GNSS_ANT pin. The impedance of RF trace should be controlled as 50Ω, and the trace length should be kept as short as possible.

4.2.1. Antenna Specifications

The module can be connected to a dedicated GPS/GLONASS passive or active antenna to receive GPS/GLONASS satellite signals. The recommended antenna specifications are given in the following table.

Table 42: Recommended Antenna Specifications

Antenna Type	Specification
Passive Antenna	GPS frequency: 1575.42±2MHz GLONASS frequency: 1602±4MHz VSWR: <2 (Typ.) Polarization: RHCP or Linear Gain: >0dBi

Active Antenna	GPS frequency: 1575.42±2MHz GLONASS frequency: 1602±4MHz VSWR: <2 (Typ.) Polarization: RHCP or Linear Noise figure: <1.5dB Gain (antenna): > -2dBi Gain (embedded LNA): 20dB (Typ.) Total gain: >18dBi (Typ.)

4.2.2. Active Antenna

The following figure is a typical reference design with active antenna. In this mode, the antenna is powered by GNSS_VCC.

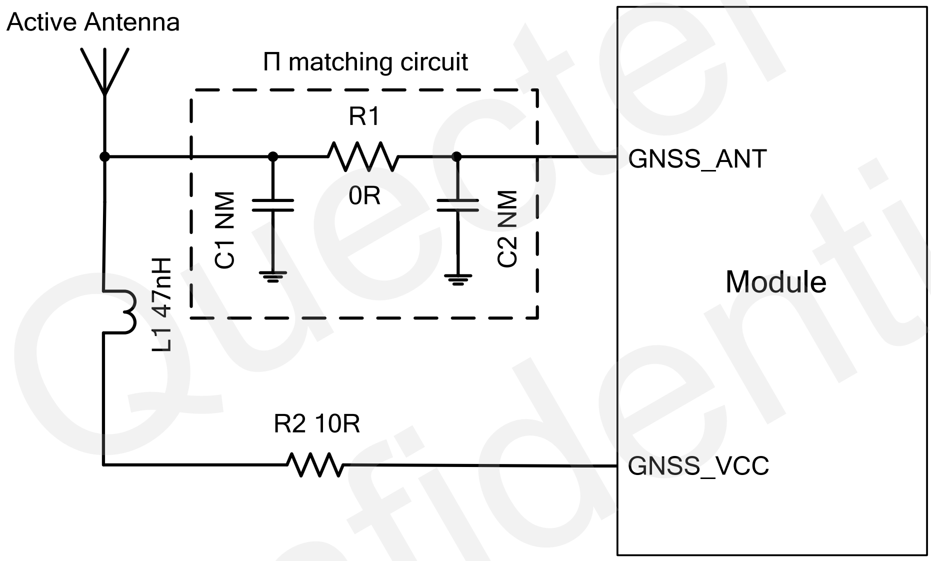


Figure 48: Reference Design with Active Antenna

C1, R1 and C2 are reserved matching circuit for antenna impedance modification. By default, C1 and C2 are not mounted; R1 is 0Ω.

The external active antenna is powered by GNSS_VCC. The voltage ranges from 2.8V to 4.3V, and the typical value is 3.3V. If the voltage does not meet the requirements for powering the active antenna, an external LDO should be used.

The inductor L1 is used to prevent the RF signal from leaking into the GNSS_VCC pin and route the bias supply to the active antenna, and the recommended value of L1 is no less than 47nH. R2 can protect the whole circuit in case the active antenna is shorted to ground.

NOTE

Please note that the power supply of GNSS_VCC is controlled by the GSM part via AT command.

4.2.3. Passive Antenna

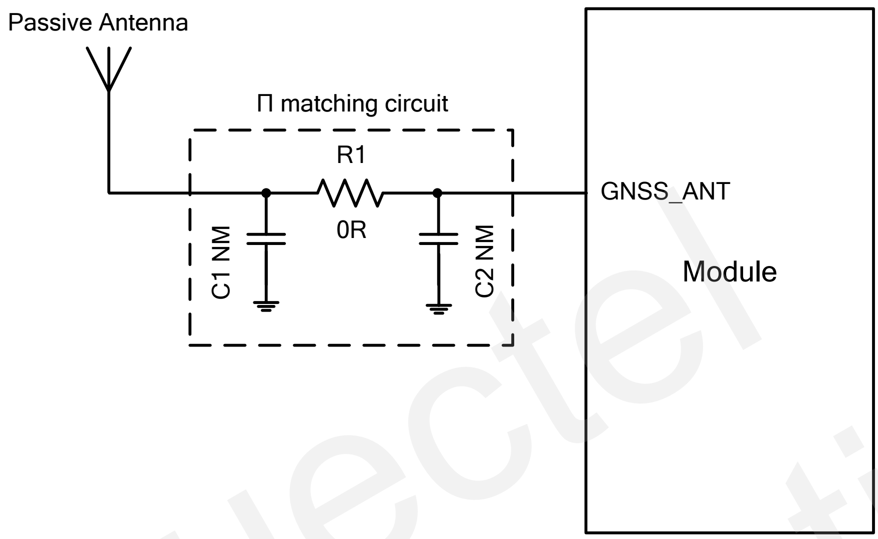


Figure 49: Reference Design with Passive Antenna

The above figure is a typical reference design with passive antenna.

C1, R1 and C2 are reserved matching circuit for antenna impedance modification. C1 and C2 are not mounted by default; R1 is 0Ω. Impedance of RF trace should be controlled as 50Ω and the trace length should be kept as short as possible.

4.3. Bluetooth Antenna Interface

The module provides a Bluetooth antenna pad named BT_ANT, and the pin definition is listed below.

Table 43: Pin Definition of the BT_ANT

Pin Name	Pin No.	I/O	Description
BT_ANT	32	IO	BT antenna pad
GND	31		Ground

The external antenna must be matched properly to achieve the best performance, so the matching circuit is necessary. The connection is recommended as the following figure:

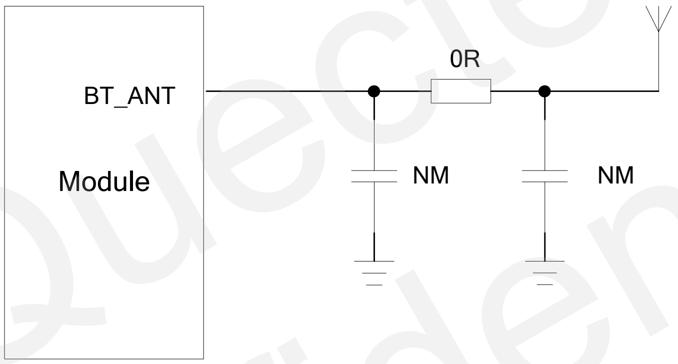


Figure 50: Reference Design for Bluetooth Antenna

There are some suggestions for component placement and RF trace layout for Bluetooth RF traces:

- Antenna matching circuit should be closed to the antenna;
- The impedance of RF trace should be controlled as 50Ω;
- The RF traces should be kept far away from the high frequency signals and strong disturbing source.

5 Electrical, Reliability and Radio Characteristics

5.1. 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 44: Absolute Maximum Ratings

Parameter	Min.	Max.	Unit
VBAT	-0.3	+4.73	V
GNSS_VCC	-0.3	+4.5	V
Peak Current of Power Supply (VBAT)	0	2	A
RMS Current of Power Supply (VBAT, during one TDMA-frame)	0	0.7	A
Voltage at Digital Pins	-0.3	3.08	V
Voltage at Analog Pins	-0.3	3.08	V
Voltage at Digital/analog Pins in Power Down Mode	-0.25	0.25	V

5.2. Operating Temperature

The operating temperature is listed in the following table:

Table 45: Operating Temperature

Parameter	Min.	Typ.	Max.	Unit
Operation temperature range [1)]	-35	+25	+75	℃
Extended temperature range [2)]	-40		+85	℃

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.

5.3. Power Supply Ratings

Table 46: Power Supply Ratings of GSM Part (GNSS is Powered off)

Parameter	Description	Conditions	Min.	Typ.	Max.	Unit
VBAT	Supply voltage	Voltage must stay within the min/max values, including voltage drop, ripple, and spikes.	3.3	4.0	4.6	V
	Voltage drop during transmitting burst	Maximum power control level on GSM850 and EGSM900.			400	mV
I_{VBAT}	Average supply current	Power down mode Sleep mode @DRX=5		220 1.2		uA mA
		Minimum functionality mode **AT+CFUN=0** IDLE mode		13		mA

		Sleep mode		0.68		mA
		AT+CFUN=4				
		IDLE mode		13		mA
		Sleep mode		0.73		mA
		TALK mode GSM850/EGSM900 1) DCS1800/PCS1900 2)		 208/209 142/146		 mA mA
		DATA mode, GPRS (3Rx, 2Tx) GSM850/EGSM900 1) DCS1800/PCS1900 2)		 359/360 232/250		 mA mA
		DATA mode, GPRS (2 Rx, 3Tx) GSM850/EGSM900 1) DCS1800/PCS1900 2)		 431/413 311/339		 mA mA
		DATA mode, GPRS (4 Rx, 1Tx) GSM850/EGSM900 1) DCS1800/PCS1900 2)		 215/153 153/162		 mA mA
		DATA mode, GPRS (1Rx, 4Tx) GSM850/EGSM900 1) DCS1800/PCS1900 2)		 499/469 3) 392/427		 mA mA
	Peak supply current (during transmission slot)	Maximum power control level on GSM850 and EGSM900.		1.6	2	A

NOTES

1. 1) Power control level PCL 5.
2. 2) Power control level PCL 0.
3. 3) Under the EGSM900 spectrum, the maximum power of 1Rx and 4Tx is reduced.

Table 47: Power Supply Ratings of GNSS Part

Parameter	Description	Conditions	Min.	Typ.	Max.	Unit
GNSS_VCC	Supply voltage	Voltage must stay within the min/max values, including voltage drop, ripple, and spikes.	2.8	3.3	4.3	V
I_{VCCP} 1)	Peak supply current	VCC=3.3V			150	mA
VRTC	Backup domain voltage supply		1.5	2.8	3.3	V

NOTE

[1)] This figure can be used to determine the maximum current capability of power supply.

5.4. Current Consumption

Table 48: Current Consumption of GSM Part (GNSS is Powered off)

Condition	Current Consumption
Voice Call	
GSM850	@power level #5 <300mA, Typical 174mA @power level #12, Typical 83mA @power level #19, Typical 62mA
EGSM900	@power level #5 <300mA, Typical 175mA @power level #12, Typical 83mA @power level #19, Typical 63mA
DCS1800	@power level #0 <250mA, Typical 153mA @power level #7, Typical 73mA @power level #15, Typical 60mA
PCS1900	@power level #0 <250mA, Typical 151mA @power level #7, Typical 76mA @power level #15, Typical 61mA
GPRS Data	
DATA Mode, GPRS (3 Rx, 2Tx) CLASS 12	
GSM850	@power level #5 <550mA, Typical 363mA @power level #12, Typical 131mA @power level #19, Typical 91mA
EGSM900	@power level #5 <550mA, Typical 356mA @power level #12, Typical 132mA @power level #19, Typical 92mA
DCS1800	@power level #0 <450mA, Typical 234mA @power level #7, Typical 112mA @power level #15, Typical 88mA
PCS1900	@power level #0 <450mA, Typical 257mA @power level #7, Typical 119mA @power level #15, Typical 89mA

DATA Mode, GPRS (2 Rx, 3Tx) CLASS 12	
GSM850	@power level #5 <640mA, Typical 496mA @power level #12, Typical 159mA @power level #19, Typical 99mA
EGSM900	@power level #5 <600mA, Typical 487mA @power level #12, Typical 160mA @power level #19, Typical 101mA
DCS1800	@power level #0 <490mA, Typical 305mA @power level #7, Typical 131mA @power level #15, Typical 93mA
PCS1900	@power level #0 <480mA, Typical 348mA @power level #7, Typical 138mA @power level #15, Typical 94mA
DATA Mode, GPRS (4 Rx, 1Tx) CLASS 12	
GSM850	@power level #5 <350mA, Typical 216mA @power level #12, Typical 103mA @power level #19, Typical 83mA
EGSM900	@power level #5 <350mA, Typical 222mA @power level #12, Typical 104mA @power level #19, Typical 84mA
DCS1800	@power level #0 <300mA, Typical 171mA @power level #7, Typical 96mA @power level #15, Typical 82mA
PCS1900	@power level #0 <300mA, Typical 169mA @power level #7, Typical 98mA @power level #15, Typical 83mA
DATA Mode, GPRS (1 Rx, 4Tx) CLASS 12	
GSM850	@power level #5 <600mA, Typical 470mA @power level #12, Typical 182mA @power level #19, Typical 106mA
EGSM900	@power level #5 <600mA, Typical 471mA @power level #12, Typical 187mA @power level #19, Typical 109mA
DCS1800	@power level #0 <500mA, Typical 377mA @power level #7, Typical 149mA @power level #15, Typical 97mA
PCS1900	@power level #0 <500mA, Typical 439mA @power level #7, Typical 159mA @power level #15, Typical 99mA

NOTE

GPRS Class 12 is the default setting. The GSM module can be configured from GPRS Class 1 to Class 12. Setting to lower GPRS class would make it easier to design the power supply for the GSM module.

Table 49: Current Consumption of GNSS Part

Parameter	Conditions	Typ.	Unit
I_{VCC} @Acquisition	@VCC=3.3V (GPS)	25	mA
I_{VCC} @Tracking	@VCC=3.3V (GPS)	19	mA
I_{VCC} @Acquisition	@VCC=3.3V (GPS+GLONASS)	29	mA
I_{VCC} @Tracking	@VCC=3.3V (GPS+GLONASS)	22	mA
I_{VCC} @Standby	@VCC=3.3V	0.3	mA
I_{BCKP} @backup	@V_BCKP=3.3V	14	uA

NOTE

The tracking current is tested in following condition:

- For Cold Start, 10 minutes after First Fix.
- For Hot Start, 15 seconds after First Fix.

Table 50: BT Current Consumption of MC60-OpenCPU Module

GSM State	BT State	Current Consumption
IDLE	IDLE	13.02mA
IDLE	SCAN	32.4mA
IDLE	CONNECT	19.08mA
SLEEP	IDLE	1.31mA
SLEEP	CONNECT	12.6mA

NOTE

When the GSM of MC60-OpenCPU module is in sleep mode, Bluetooth cannot enter into the SCAN mode.

Table 51: BT Current Consumption of MC60E-OpenCPU Module

RF State	GSM State	BT State	Current Consumption
Full function (**AT+CFUN=1**)	IDLE	Off	13.01mA
		Advertising	13.59mA
	SLEEP	Off	1.42mA
		Advertising	2.06mA
Disable from both transmitting and receiving RF signals (**AT+CFUN=4**)	IDLE	Off	12.51mA
		Advertising	13.08mA
	Off/Advertising	Off	0.7mA
		Advertising	1.32mA
Minimum function (**AT+CFUN=0**)	IDLE	Off	12.47mA
		Advertising	13.04mA
	SLEEP	Off	0.64mA
		Advertising	1.26mA

NOTE

The datas are tested when turning off traditional Bluetooth and advertising BLE only.

5.5. Electrostatic Discharge

Although the module is generally protected against Electrostatic Discharge (ESD), ESD protection precautions should still be emphasized. Proper ESD handling and packaging procedures must be applied throughout the processing, handling and operation of any applications using the module.

The measured ESD values of the module are shown in the following table.

Table 52: ESD Performance Parameter (Temperature: 25ºC, Humidity: 45%)

Test Point	Contact Discharge	Air Discharge
VBAT, GND	+/-5KV	+/-10KV
RF_ANT	+/-5KV	+/-10KV
TXD, RXD	+/-2KV	+/-4KV
GNSS_TXD GNSS_RXD	+/-2KV	+/-4KV
Others	+/-0.5KV	+/-1KV

6 Mechanical Dimensions

This chapter describes the mechanical dimensions of the module.

6.1. Mechanical Dimensions of Module

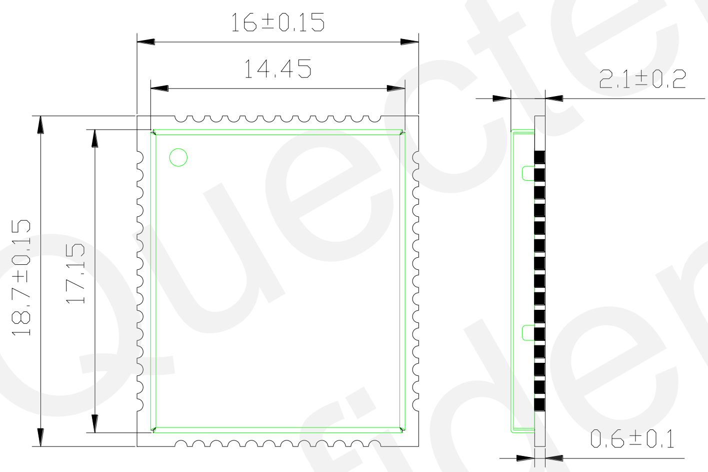


Figure 51: MC60-OpenCPU Top and Side Dimensions (Unit: mm)

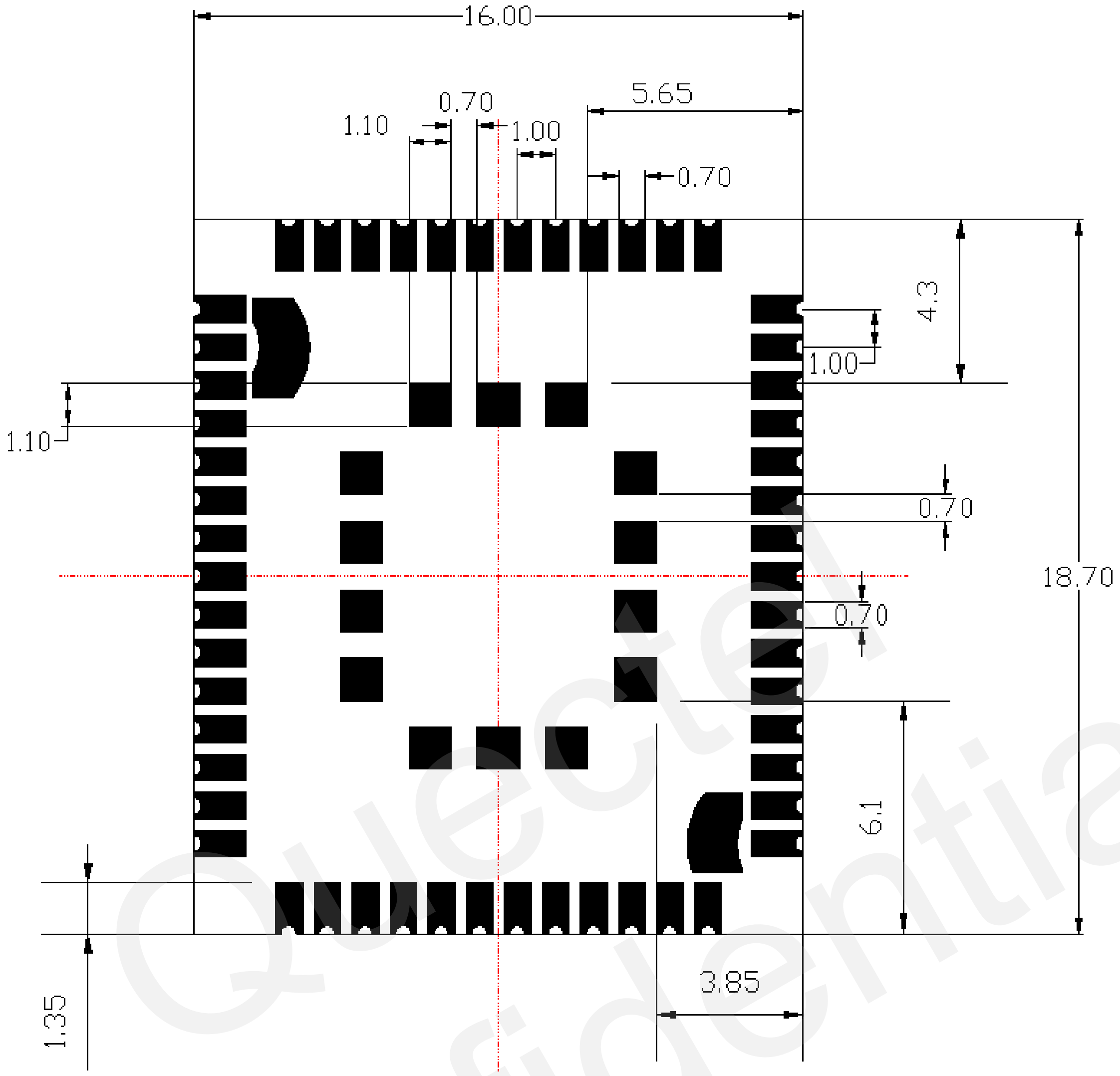


Figure 52: MC60-OpenCPU Bottom Dimensions (Unit: mm)

NOTE

The two arc test points in the above recommended footprint should be treated as keepout areas ("keepout" means do not pour copper on the mother board).

6.2. Recommended Footprint

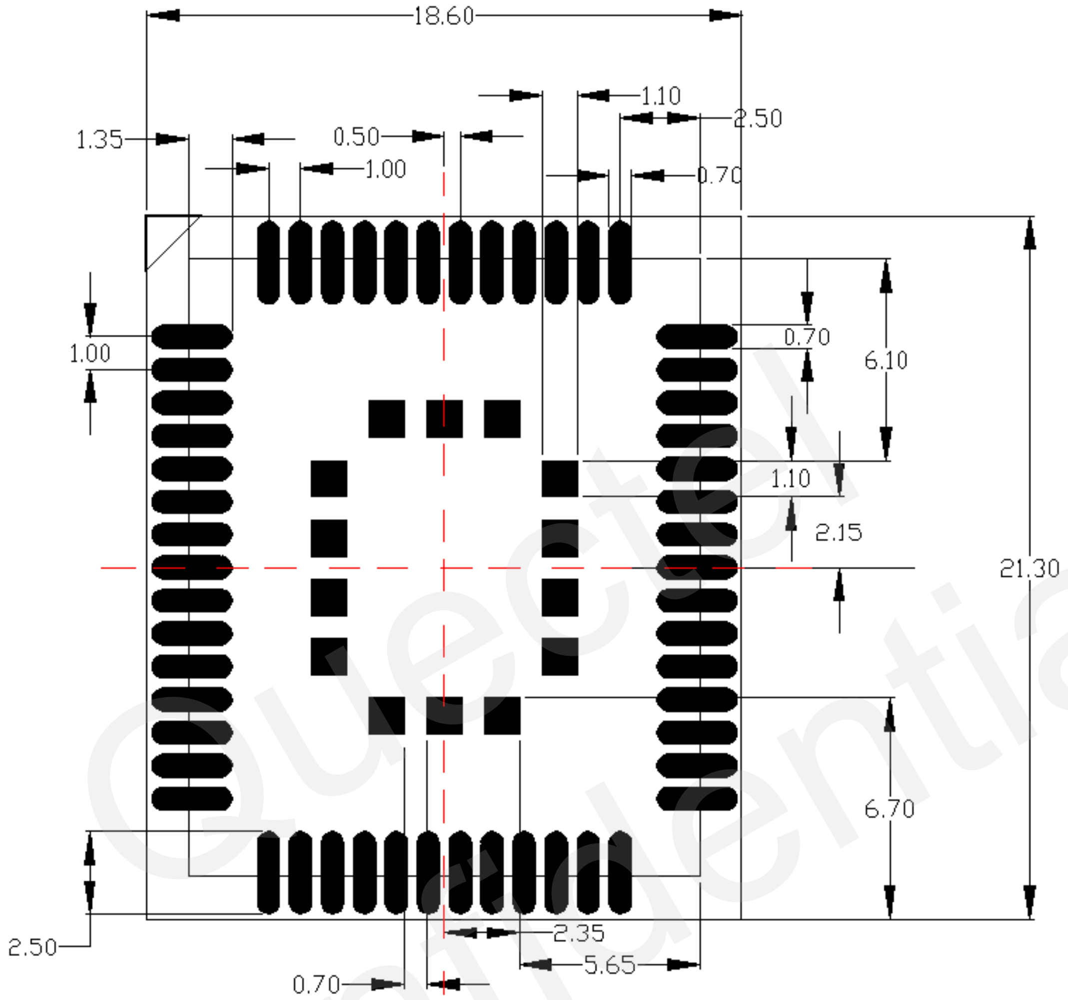


Figure 53: Recommended Footprint (Unit: mm)

NOTE

For easy maintenance of the module, please keep about 3mm between the module and other components in the host PCB.

6.3. Top and Bottom Views of the Module

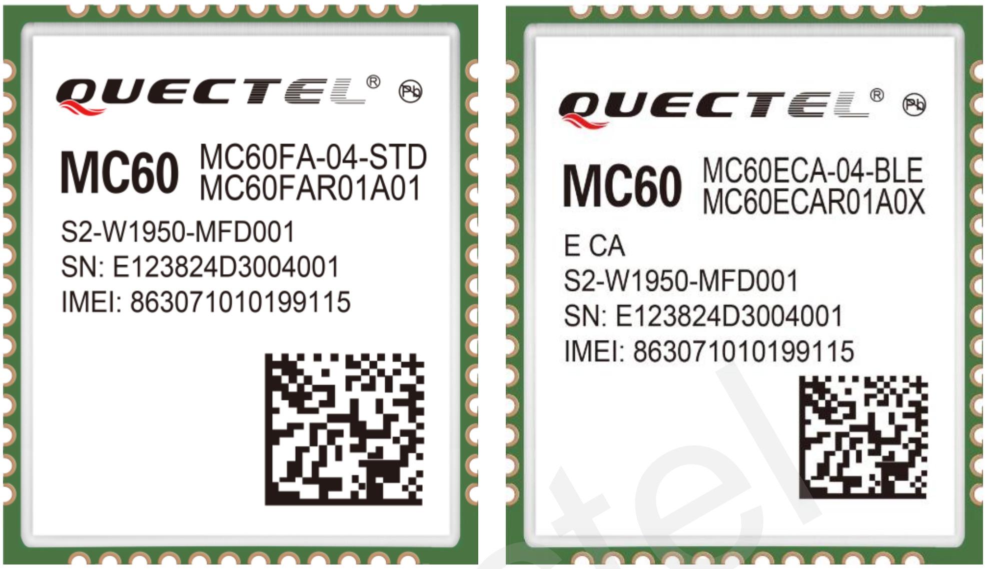


Figure 54: Top Views of the Module

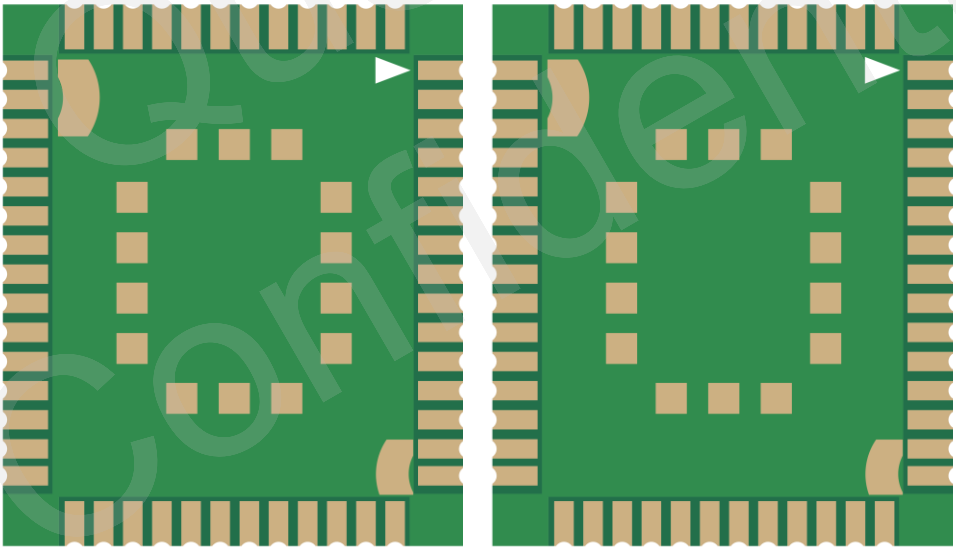


Figure 55: Bottom Views of the Module

NOTE

These are design effect drawings of MC60-OpenCPU and MC60E-OpenCPU modules. For more accurate pictures, please refer to the module that customers get from Quectel.

7 Storage, Manufacturing and Packaging

7.1. Storage

MC60-OpenCPU is stored in a vacuum-sealed bag. The storage restrictions are shown as below.

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

2. After the vacuum-sealed bag is opened, devices that need to be mounted directly must be:

   - Mounted within 72 hours at the factory environment of ≤30ºC and <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 72 hours when the ambient temperature is <30ºC and the humidity is <60%.
   - Stored at >10%RH.

4. If baking is required, devices should be baked for 48 hours at 125ºC±5ºC.

NOTE

As the plastic package cannot be subjected to high temperature, it should be removed from devices before high temperature (125ºC) baking. If shorter baking time is desired, please refer to *IPC/JEDECJ-STD-033* for baking procedure.

7.2. 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 0.2mm. For more details, please refer to ***document [12]***.

It is suggested that the peak reflow temperature is from 235ºC to 245ºC (for SnAg3.0Cu0.5 alloy). The absolute maximum reflow temperature is 260ºC. To avoid damage to the module caused by repeated heating, it is suggested that the module should be mounted after reflow soldering for the other side of PCB has been completed. Recommended reflow soldering thermal profile is shown below:

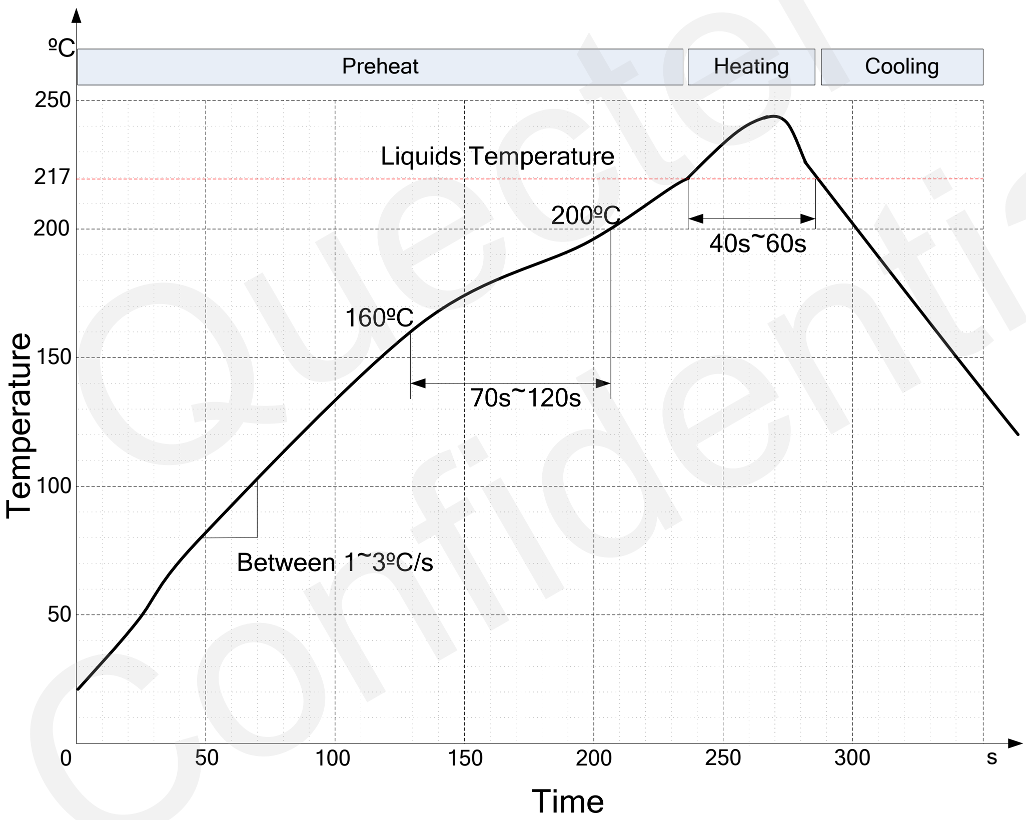


Figure 56: Reflow Soldering Thermal Profile

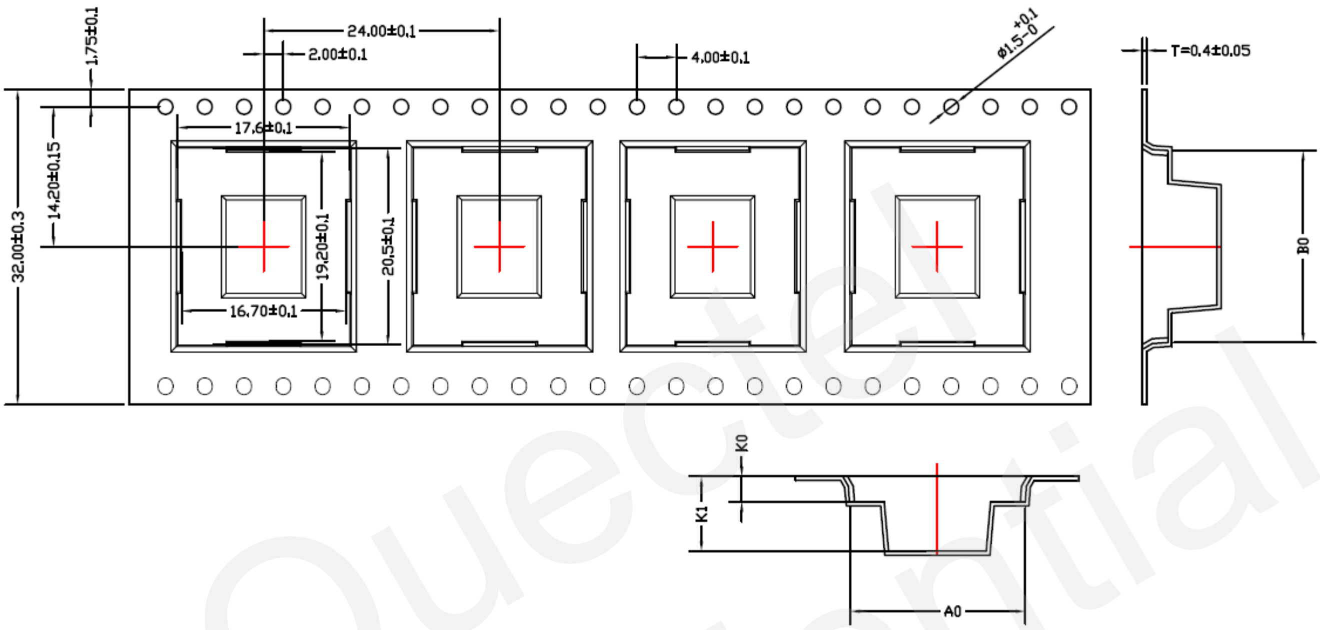
NOTE

During manufacturing and soldering, or any other processes that may contact the module directly, NEVER wipe the module label with organic solvents, such as acetone, ethyl alcohol, isopropyl alcohol, trichloroethylene, etc.

7.3. Packaging

MC60-OpenCPU 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 following figures show the packaging details, measured in mm.



ITEM	W	T	A0	A1	B0	B1	B2	K0	K1	P	F	E	D	P0	P2
DIM	32.0	0.4	17.6		20.5			2.6	7.6	24.0	14.2	1.75	1.5	4.0	2.0
TOLE	±0.3	±0.05	±0.1	±0.15	±0.10	±0.10	±0.10	±0.10	±0.10	±0.1	±0.10	±0.1	+0.10 −0.00	±0.1	±0.1

Figure 57: Tape Dimensions

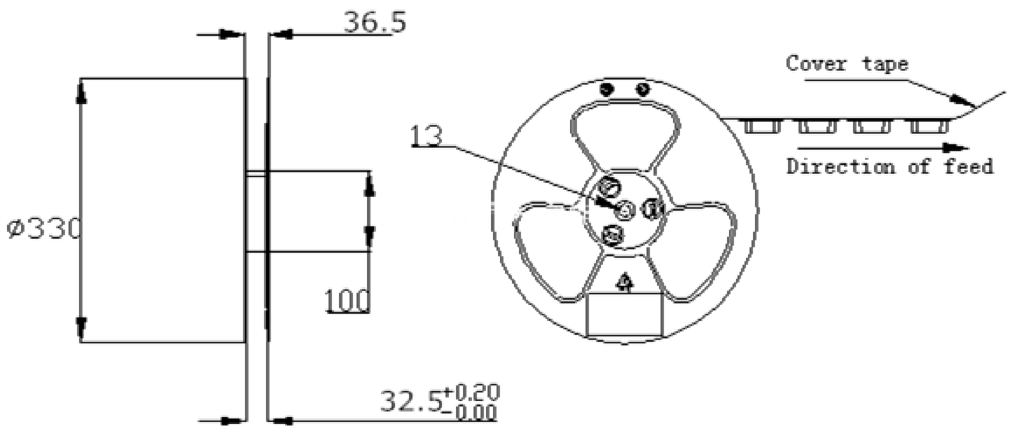


Figure 58: Reel Dimensions

Table 53: Reel Packaging

Model Name	MOQ for MP	Minimum Package: 250pcs	Minimum Package x 4=1000pcs
MC60-OpenCPU	250pcs	Size: 370mm × 350mm × 56mm N.W: 0.32kg G.W: 1.08kg	Size: 380mm × 250mm × 365mm N.W: 1.28kg G.W: 4.8kg

8 Appendix A References

Table 54: Related Documents

SN	Document Name	Remarks
[1]	Quectel_MC60_AT_Commands_Manual	MC60-OpenCPU AT commands manual
[2]	ITU-T Draft New Recommendation V.25ter	Serial asynchronous automatic dialing and control
[3]	GSM 07.07	Digital cellular telecommunications (Phase 2+); AT command set for GSM Mobile Equipment (ME)
[4]	GSM 07.10	Support GSM 07.10 multiplexing protocol
[5]	GSM 07.05	Digital cellular telecommunications (Phase 2+); Use of Data Terminal Equipment – Data Circuit terminating Equipment (DTE – DCE) interface for Short Message Service (SMS) and Cell Broadcast Service (CBS)
[6]	GSM 11.14	Digital cellular telecommunications (Phase 2+); Specification of the (U)SIM Application Toolkit for the Subscriber Identity module – Mobile Equipment ((U)SIM – ME) interface
[7]	GSM 11.11	Digital cellular telecommunications (Phase 2+); Specification of the Subscriber Identity module – Mobile Equipment ((U)SIM – ME) interface
[8]	GSM 03.38	Digital cellular telecommunications (Phase 2+); Alphabets and language-specific information
[9]	GSM 11.10	Digital cellular telecommunications (Phase 2); Mobile Station (MS) conformance specification; Part 1: Conformance specification

[10]	Quectel_GSM_UART_Application_Note	UART port application note
[11]	Quectel_GSM_EVB_User_Guide	GSM EVB user guide
[12]	Quectel_Module_Secondary_SMT_User_Guide	Module secondary SMT user guide
[13]	Quectel_GSM_Module_Digital_IO_Application_Note	GSM module digital IO application note
[14]	Quectel_MC60_GNSS_AGPS_Application_Note	MC60 GNSS AGPS application note
[15]	Quectel_GSM_BT_Application_Note	GSM BT application note
[16]	Quectel_MC60_GNSS_AT_Commands_Manual	MC60 GNSS AT commands manual
[17]	Quectel_MC60_GNSS_Protocol_Specification	MC60 GNSS protocol specification
[18]	Quectel_MC60-TE-A_User_Guide	MC60-TE-A user guide
[19]	Quectel_MC60-OpenCPU_User_Guide	MC60-OpenCPU user guide

Table 55: Terms and Abbreviations

Abbreviation	Description
ADC	Analog-to-Digital Converter
AG	Audio Gateway
AGPS	Assisted GPS
AIC	Active Interference Cancellation
AIN	Audio In
AMR	Adaptive Multi-Rate
ARP	Antenna Reference Point
ASIC	Application Specific Integrated Circuit
BER	Bit Error Rate
BT	Bluetooth
BTS	Base Transceiver Station
CHAP	Challenge Handshake Authentication Protocol

CS	Coding Scheme
CSD	Circuit Switched Data
CTS	Clear to Send
DGPS	Differential GPS
DRX	Discontinuous Reception
DSP	Digital Signal Processor
DCE	Data Communications Equipment (typically module)
DTE	Data Terminal Equipment (typically computer, external controller)
DTR	Data Terminal Ready
DTX	Discontinuous Transmission
EASY	Embedded Assist System
EFR	Enhanced Full Rate
EGSM	Enhanced GSM
EMC	Electromagnetic Compatibility
EPO	Extended Prediction Orbit
ESD	Electrostatic Discharge
ETS	European Telecommunication Standard
FCC	Federal Communications Commission (U.S.)
FDMA	Frequency Division Multiple Access
FR	Full Rate
FS	File System
FTP	File Transfer Protocol
GAGAN	GPS Aided Geo Augmented Navigation
GGA	NMEA: Global Positioning System Fix Data
GLL	NMEA: Geographic Latitude and Longitude

GLONASS	Global Navigation Satellite System
GLP	GNSS Low Power
GMSK	Gaussian Minimum Shift Keying
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSA	NMEA: GPS DOP and Active Satellites
GSM	Global System for Mobile Communications
GSV	NMEA: GPS Satellites in View
G.W	Gross Weight
HFP	Hands-free Profile
HO	High Output
HR	Half Rate
HTTP	Hypertext Transfer Protocol
I/O	Input/Output
IC	Integrated Circuit
IEEE	Institute of Electrical and Electronics Engineers
IMEI	International Mobile Equipment Identity
$I_O$max	Maximum Output Load Current
kbps	Kilo Bits Per Second
LCC	Leadless Chip Carriers
LED	Light Emitting Diode
LGA	Land Grid Array
Li-Ion	Lithium-Ion
MCU	Micro Control Unit

MMS	Microsoft Media Server
LNA	Low Noise Amplifier
MO	Mobile Originated
MOQ	Minimum Order Quantity
MP	Manufacture Product
MS	Mobile Station (GSM engine)
MSAS	Multi-Functional Satellite Augmentation System
MT	Mobile Terminated
NMEA	National Marine Electronics Association
NTP	Network Time Protocol
N.W	Net Weight
PAP	Password Authentication Protocol
PBCCH	Packet Switched Broadcast Control Channel
PCB	Printed Circuit Board
PCL	Power Control Level
PCM	Pulse Code Modulation
PD	Pull-down
PDP	Packet Data Protocol
PDU	Protocol Data Unit
PING	Packet Internet Groper
PMOS	Positive Channel Metal Oxide Semiconductor
PMTK	MTK Proprietary Protocol
PMU	Power Management Unit
PPP	Point-to-Point Protocol
PPS	Pulse per Second

PU	Pull-up
QZSS	Quasi-Zenith Satellite System
RF	Radio Frequency
RMC	NMEA: Recommended Minimum Position Data
RMS	Root Mean Square (value)
RoHS	Restriction of Hazardous Substances
RTC	Real Time Clock
RX	Receive Direction
SBAS	Satellite-based Augmentation System
SIM	Subscriber Identification Module
SMD	Surface Mounted Devices
SMS	Short Message Service
SMTP	Simple Mail Transfer Protocol
SPI	Serial Peripheral Interface
SPP	Standard Parallel Port
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
TE	Terminal Equipment
3GPP	3rd Generation Partnership Project
TTFF	Time to First Fix
TX	Transmitting Direction
UART	Universal Asynchronous Receiver & Transmitter
UDP	User Datagram Protocol
URC	Unsolicited Result Code
USIM	Universal Mobile Telecommunication System

USSD	Unstructured Supplementary Service Data
VSWR	Voltage Standing Wave Ratio
VTG	NMEA: Track Made Good and Ground Speed
$V_O$max	Maximum Output Voltage Value
$V_O$norm	Normal Output Voltage Value
$V_O$min	Minimum Output 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
$V_I$norm	Absolute Normal 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
WAAS	Wide Area Augmentation System
Phonebook Abbreviations	
LD	(U)SIM Last Dialing phonebook (list of numbers most recently dialed)
MC	Mobile Equipment list of unanswered MT Calls (missed calls)
ON	(U)SIM (or ME) Own Numbers (MSISDNs) list
RC	Mobile Equipment list of Received Calls
SM	(U)SIM phonebook

9 Appendix B GPRS Coding Schemes

Four coding schemes are used in GPRS protocol. The differences between them are shown in the following table.

Table 56: Description of Different Coding Schemes

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

Radio block structure of CS-1, CS-2 and CS-3 is shown as the figure below.

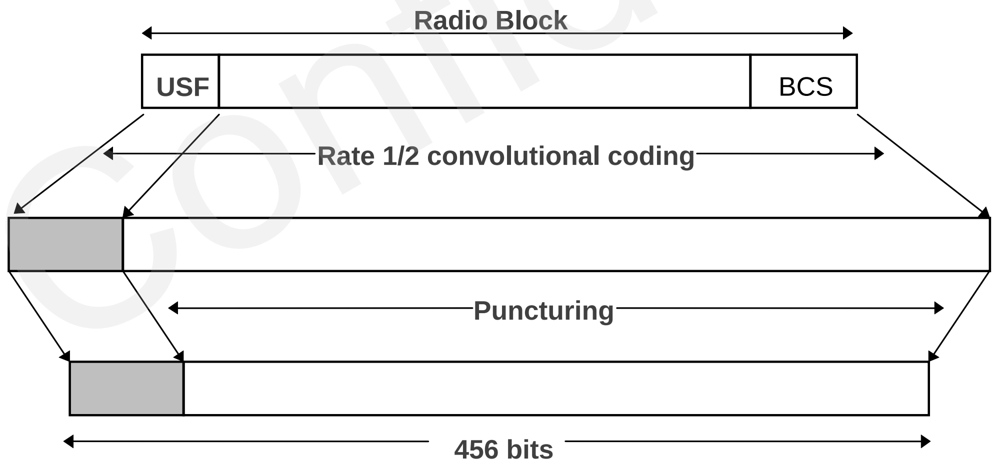


Figure 59: Radio Block Structure of CS-1, CS-2 and CS-3

Radio block structure of CS-4 is shown as the following figure.

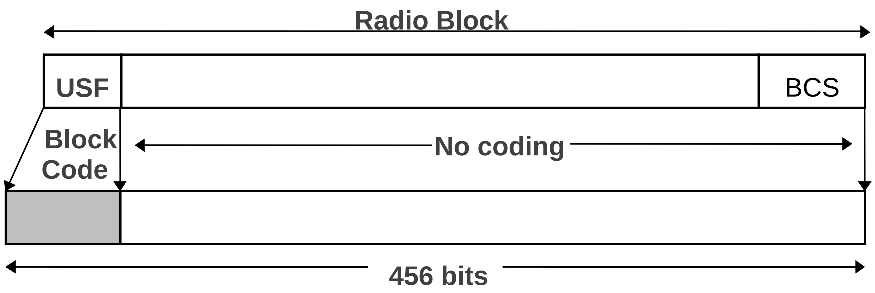


Figure 60: Radio Block Structure of CS-4

10 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 57: 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