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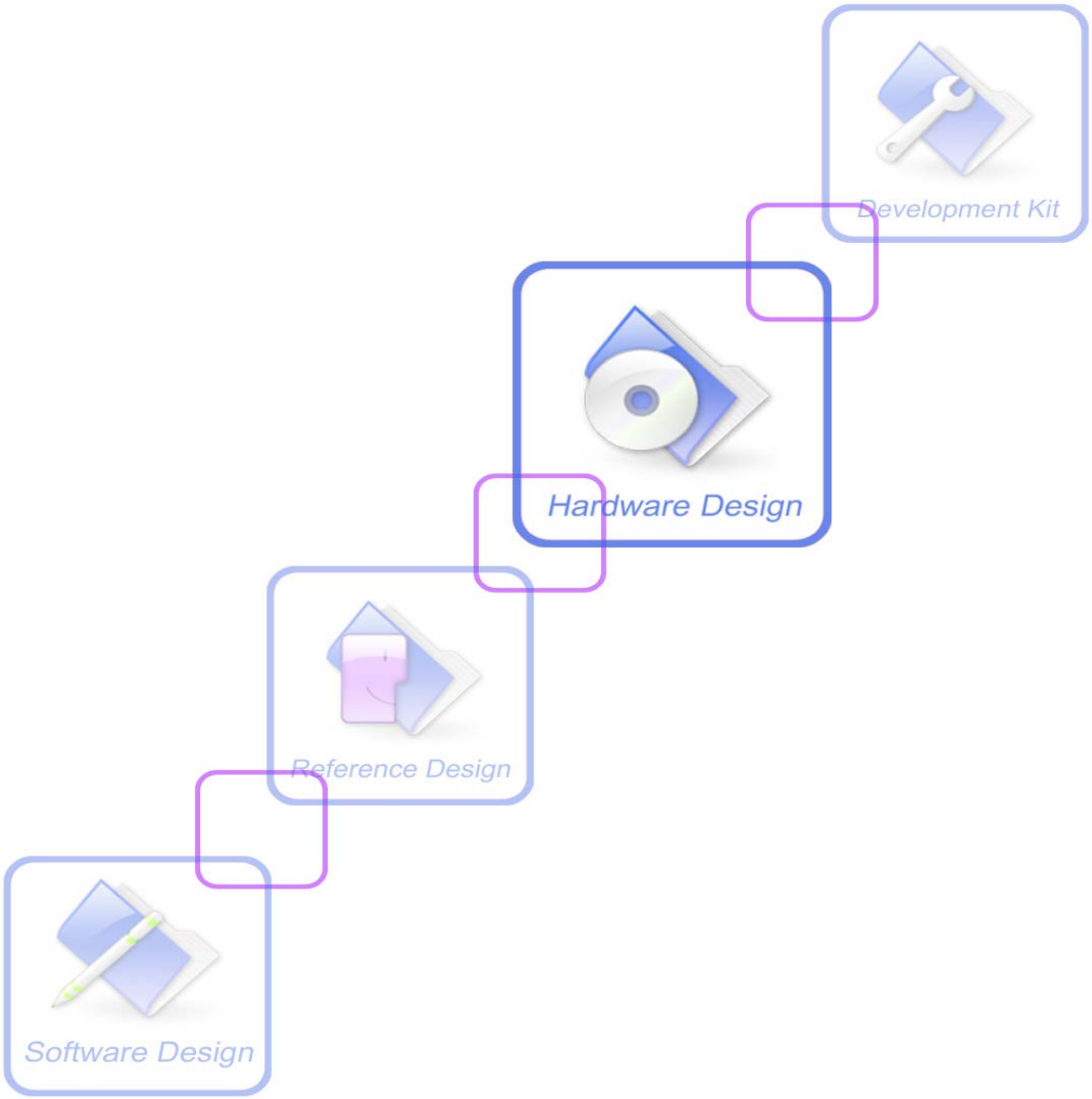
SIM928_Hardware Design_V1.00



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Version History

Date	Version	Description of change	Author
2013-01-25	1.00	Origin	Shengwu.sun，Xiaohan.jin

1 Introduction

This document describes SIM928 hardware interface in great detail.
This document can help user to quickly understand SIM928 interface specifications, electrical and mechanical details. With the help of this document and other SIM928 application notes, user guide, users can use SIM928 to design various applications quickly.

2 SIM928 Overview

Designed for global market, SIM928 is integrated with a high performance GSM/GPRS engine and a GPS engine. They are independent with each other. The GSM/GPRS engine is quad-band ,which works on frequencies GSM 850MHz, EGSM 900MHz, DCS 1800MHz and PCS 1900MHz. SIM928 features GPRS multi-slot class 10/ class 8 (optional) and supports the GPRS coding schemes CS-1, CS-2, CS-3 and CS-4.

The GPS solution offers best-in-class acquisition and tracing sensitivity, Time-To-First-Fix (TTFF) and accuracy. With built-in LNA, SIM928 doesn't need external LNA. SIM928 can track as low as -167dBm signal even without network assistance. The SIM928 has excellent low power consumption characteristic (acquisition 24mA, tracking 19mA). SIM928 supports various location and navigation applications, including autonomous GPS, QZSS, SBAS (WAAS, EGNOS, GAGAN, MSAS), DGPS (RTCM), and A-GPS.

With a tiny configuration of 30*30*3mm, SIM928 can meet almost all the space requirements in user applications, such as M2M, smart phone, PDA, tracker and other mobile devices.

SIM928 has 80 SMT pads, and provides all hardware interfaces between the module and customers' boards.

- Serial port and debug port can help user develop their applications easily.
- GPS Serial port.
- Audio channels include two inputs and two outputs. These can be easily configured by AT command.
- Charging interface.
- Programmable general purpose input and output.
- The keypad and SPI display interfaces will bring users convenience to develop customized applications.
- RF pad interface.
- Output navigation solution in NMEA protocol format.
- Support FCC E911 compliance and A-GPS
- 33tracking/99 acquisition-channel GPS receiver
- Accuracy <2.5m CEP
- RoHS compliant

SIM928 is designed with power saving technique so that the current consumption is as low as 1.2mA in sleep mode (GPS engine is powered down).
SIM928 integrates TCP/IP protocol and extended TCP/IP AT commands which are very useful for data transfer applications. For details about TCP/IP applications, please refer to *document [2]*.

2.1 SIM928 Key Features

Table 1: SIM928 GSM/GPRS engine key features

Feature	Implementation
Power supply	3.2V ~ 4.8V
Power saving	Typical power consumption in sleep mode is 1.2mA (BS-PA-MFRMS=9, GPS engine is powered down)
Charging	Supports charging control for Li-Ion battery
Frequency bands	● SIM928 Quad-band: GSM 850, EGSM 900, DCS 1800, PCS 1900. SIM928 can search the 4 frequency bands automatically. The frequency bands also can be set by AT command "AT+CBAND". For details, please refer to *document [1]*. ● Compliant to GSM Phase 2/2+
Transmitting power	● Class 4 (2W) at GSM 850 and EGSM 900 ● Class 1 (1W) at DCS 1800 and PCS 1900
GPRS connectivity	● GPRS multi-slot class 10（default） ● GPRS multi-slot class 8 (option)
Temperature range	● Normal operation: -30℃ ～+80℃ ● Restricted operation: -40℃～-30℃ and +80℃ ～+85℃ ● Storage temperature -45℃～+90℃
Data GPRS	● GPRS data downlink transfer: max. 85.6 kbps ● GPRS data uplink transfer: max. 42.8 kbps ● Coding scheme: CS-1, CS-2, CS-3 and CS-4 ● Integrate the TCP/IP protocol. ● Support Packet Broadcast Control Channel (PBCCH)
CSD	● Support CSD transmission
USSD	● Unstructured Supplementary Services Data (USSD) support
SMS	● MT, MO, CB, Text and PDU mode ● SMS storage: SIM card
FAX	Group 3 Class 1
SIM interface	Support SIM card: 1.8V, 3V
External antenna	Antenna pad
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 Cancellation ● Noise Suppression
Serial port and debug port	**Serial port:** ● Full modem interface with status and control lines, unbalanced, asynchronous. ● 1200bps to 115200bps. ● Can be used for AT commands or data stream.

	● Support RTS/CTS hardware handshake and software ON/OFF flow control. ● Multiplex ability according to GSM 07.10 Multiplexer Protocol. ● Autobauding supports baud rate from 1200 bps to 57600bps. **Debug port:** ● Null modem interface DBG_TXD and DBG_RXD. ● Can be used for debugging and upgrading firmware.
Phonebook management	Support phonebook types: SM, FD, LD, RC, ON, MC.
SIM application toolkit	GSM 11.14 Release 99
Real time clock	Support RTC
Physical characteristics	Size: 30*30*3mm Weight: 5.3g
Firmware upgrade	Firmware upgradeable by debug port.

*SIM928 does work at this temperature, but some radio frequency characteristics may deviate from the GSM specification.

Table 2: GPS engine Performance

Parameter	Description	Performance			
		Min	Type	Max	Unit
Horizontal Position Accuracy(1)	Autonomous		<2.5		m
Velocity Accuracy(2)	Without Aid		0.1		m/s
	DGPS		0.05		m/s
Acceleration Accuracy	Without Aid		0.1		m/s²
	DGPS		0.05		m/s²
Timing Accuracy			10		nS
Dynamic Performance	Maximum Altitude			18000	m
	Maximum Velocity			515	m/s
	Maximum Acceleration			4	G
Time To First Fix(3)	Hot start		<1		s
	Warm start		26		s
	Cold start		28		s
A-GPS TTFF(EPO in flash mode)	Hot start		0.7		s
	Warm start		1.5		s
	Cold start		12.5		s
Sensitivity	Autonomous acquisition(cold start)		-148		dBm
	Re-acquisition		-160		dBm
	Tracking		-167		dBm
Receiver	Channels		132		
	Update rate		1	5	Hz
	Tracking L1, CA Code				
	Protocol support				

	NMEA,PMTK				
Power consumption (4)	Acquisition		26		mA
	Continuous tracking		21		mA
	Sleep current		<200		uA
	Backup current		14		uA

(1) 50% 24hr static, -130dBm

(2) 50% at 30m/s

(3) –130 dBm, GPS mode

(4) Single Power supply 3.3V under GPS signal

Table 3: 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

2.2 Operating Modes

The table below summarizes the various operating modes of SIM928.

Table 4: Overview of operating modes

Mode	Function	
Normal operation	GSM/GPRS SLEEP	Module will automatically go into sleep mode if the conditions of sleep mode are enabling and there is no on air and no hardware interrupt (such as GPIO interrupt or data on serial port). In this case, the current consumption of module will reduce to the minimal level. In sleep mode, the module can still receive paging message and SMS.
	GSM IDLE	Software is active. Module registered to the GSM network, and the module is ready to communicate.
	GSM TALK	Connection between two subscribers is in progress. In this case, the power consumption depends on network settings such as DTX off/on, FR/EFR/HR, hopping sequences, antenna.
	GPRS STANDBY	Module is ready for GPRS data transfer, but no data is currently sent or received. In this case, power consumption depends on network settings and GPRS configuration.
	GPRS DATA	There is GPRS data transfer (PPP or TCP or UDP) in progress. In this case, power consumption is related with network settings (e.g. power control level); uplink/downlink data rates and GPRS configuration (e.g. used multi-slot settings).
Power down	Normal power down by sending the AT command “AT+CPOWD=1” or using the PWRKEY. The power management unit shuts down the power supply for the baseband part of the	

	module, and only the power supply for the RTC is remained. Software is not active. The serial port is not accessible. Power supply (connected to VBAT) remains applied.
Minimum functionality mode	AT command “AT+CFUN” can be used to set the module to a minimum functionality mode without removing the power supply. In this mode, the RF part of the module will not work or the SIM card will not be accessible, or both RF part and SIM card will be closed, and the serial port is still accessible. The power consumption in this mode is lower than normal mode.
Charge-only mode	The module will enter Charge-only mode automatically when a charger and battery are connected to a switched-off SIM928. In this mode, the module does not search for network and has limited access to available AT commands available. The module can also enter Charge-only mode from Charge mode during normal operation by normally powered down the module.
Charge mode during normal operation	The module will automatically go to this mode when a charger is connected to a Normal operation mode module when battery voltage is not lower than 3.2V. Normal operation mode includes: SLEEP, IDLE, TALK, GPRS IDLE and GPRS DATA.

2.3 SIM928 Functional Diagram

The following figure shows a functional diagram of SIM928:

- The GSM baseband engine
- The GPS engine
- Flash
- The GSM radio frequency part
- The antenna interfaces
- The other interfaces

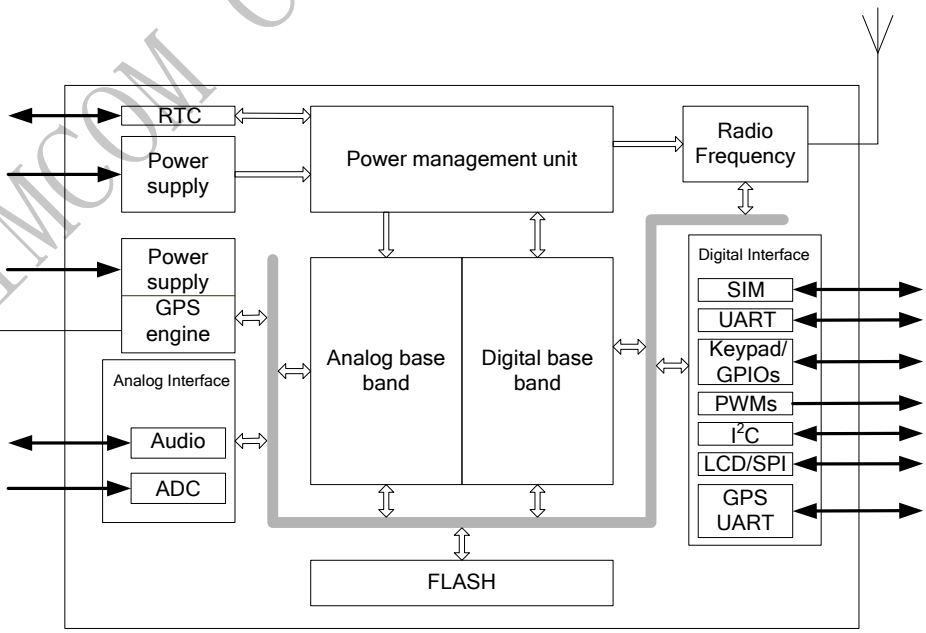

Figure 1: SIM928 functional diagram

3 Package Information

3.1 Pin out Diagram

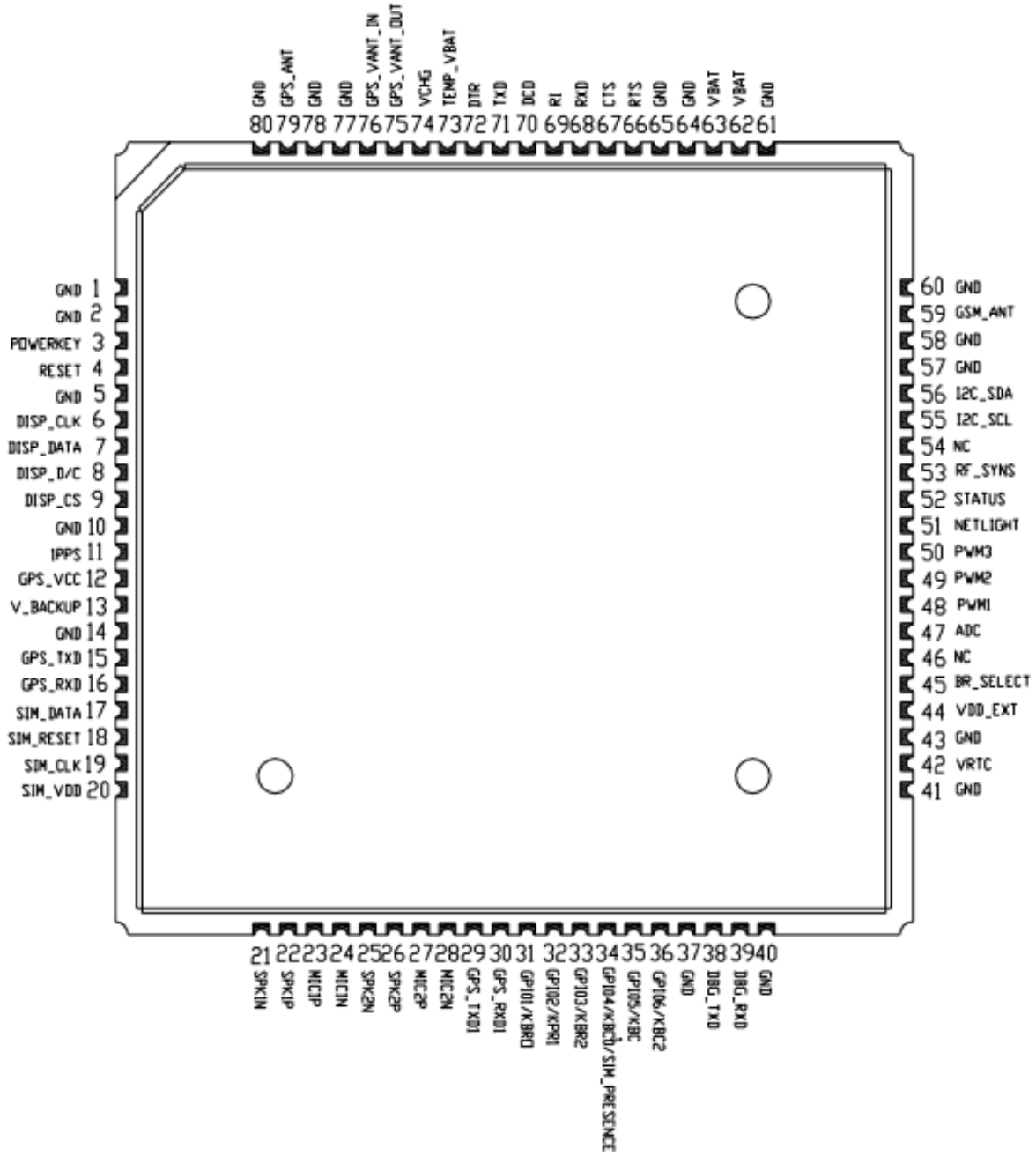

Figure 2: SIM928 pin out diagram (Top view)

3.2 Pin Description

Table 5: Pin description

Pin name	Pin number	I/O	Description	Comment
Power supply				
VBAT	62, 63	I	GSM power supply	3.2V ~ 4.8V
VRTC	42	I/O	Power supply for GSM RTC	It is recommended to connect with a battery or a capacitor (e.g. 4.7uF).
VDD_EXT	44	O	2.8V output power supply	If it is unused, keep open.
GPS_VCC	12	I	GPS Power supply	2.8V~4.3V
V_BACKUP	13	I	Power supply for GPS RTC	It is recommended to connect with a battery or LDO
GPS_VANT_OUT	75	O	2.8V output for GPS active antenna	If it is unused, keep open.
GPS_VANT_IN	76	I	GPS active antenna power supply	If it is unused, keep open.
GND	1, 2, 5, 10, 14, 37, 40, 41, 43, 57, 58, 60, 61, 64, 65, 77, 78, 80		Ground	
Charge interface				
VCHG	74	I	Charger input	
TEMP_BAT	73	I	Battery temperature sensor	
Power on/down				
PWRKEY	3	I	PWRKEY should be pulled low at least 1 second and then released to power on/down the module.	Pulled up internally.
Audio interfaces				
MIC1P	23	I	Differential audio input	If these pins are unused, keep open.
MIC1N	24			
SPK1P	22	O	Differential audio output	
SPK1N	21			
MIC2P	27	I	Differential audio input	
MIC2N	28			
SPK2N	25	O	Differential audio output	
SPK2P	26			
Status				
STATUS	52	O	Power on status	If these pins are unused, keep open.
NETLIGHT	51	O	Network status	
1PPS	11	O	Time Mark outputs timing pulse	If unused, keep open.

			related to receiver time	
LCD interface				
DISP _CLK	6	O	Display interface	If these pins are unused, keep open.
DISP_DATA	7	I/O		
DISP _D/C	8	O		
DISP _CS	9	O		
I²C interface				
I2C_SDA	56	O	I²C serial bus data	If these pins are unused, keep open.
I2C_SCL	55	I/O	I²C serial bus clock	
Keypad interface / GPIOs				
GPIO1/KBR0	31	I/O	GPIO1/keypad row 0	If these pins are unused, keep open.
GPIO2/KBR1	32		GPIO2/keypad row 1	
GPIO3/KBR2	33		GPIO3/keypad row 2	
GPIO4/KBC0/ SIM_PRESENCE	34		GPIO4/keypad column 0/ SIM card detection	
GPIO5/KBC1	35		GPIO5/keypad column 1	
GPIO6/KBC2	36		GPIO6/keypad column 3	
GSM Serial port/ Debug interface				
RXD	68	I	Receive data	If only TXD and RXD are used, it is suggested to pull down DTR, and others pins can be kept open.
TXD	71	O	Transmit data	
RTS	66	O	Request to send	
CTS	67	I	Clear to send	
DCD	70	O	Data carrier detect	
RI	69	O	Ring indicator	
DTR	72	I	Data terminal ready	
DBG_TXD	38	O	For debugging and upgrading firmware	If these pins are unused, keep open.
DBG_RXD	39	I		
GPS Serial port				
GPS_TXD	15	O	For GPS NMEA information output	If these pins are unused, keep open.
GPS_RXD	16	I		
GPS_TXD1	29	O	Serial communication for RTCM	If these pins are unused, keep open.
GPS_RXD1	30	I		
SIM interface				
SIM_VDD	20	O	Voltage supply for SIM card. Support 1.8V or 3V SIM card	All signals of SIM interface should be protected against ESD with a TVS diode array.
SIM_DATA	17	I/O	SIM data input/output	
SIM_CLK	19	O	SIM clock	
SIM_RST	18	O	SIM reset	
ADC				
ADC	47	I	Input voltage range: 0V ~ 2.8V	If it is unused, keep open.
Pulse width modulation(PWM)				
PWM1	48	O	PWM	If these pins are unused,

PWM2	49	O	PWM	keep open.
PWM3	50	O	PWM	
GSM/GPS RF interface				
GSM_ANT	59	I/O	GSM radio antenna connection	Impendence must be controlled to 50Ω.
GPS_ANT	79	I	GPS radio antenna connection	Impendence must be controlled to 50Ω.
RF_SYNS	53	O	RF synchronization	If unused, keep open
Other interface				
RESET	4	I	GSM Reset input, active low	If unused, keep open.
BR_SELECT	45	I	GPS NMEA baud rate set	0:115200, NC:9600 default=NC
NC	46,54			These pins should be kept open.

3.3 Package Dimensions

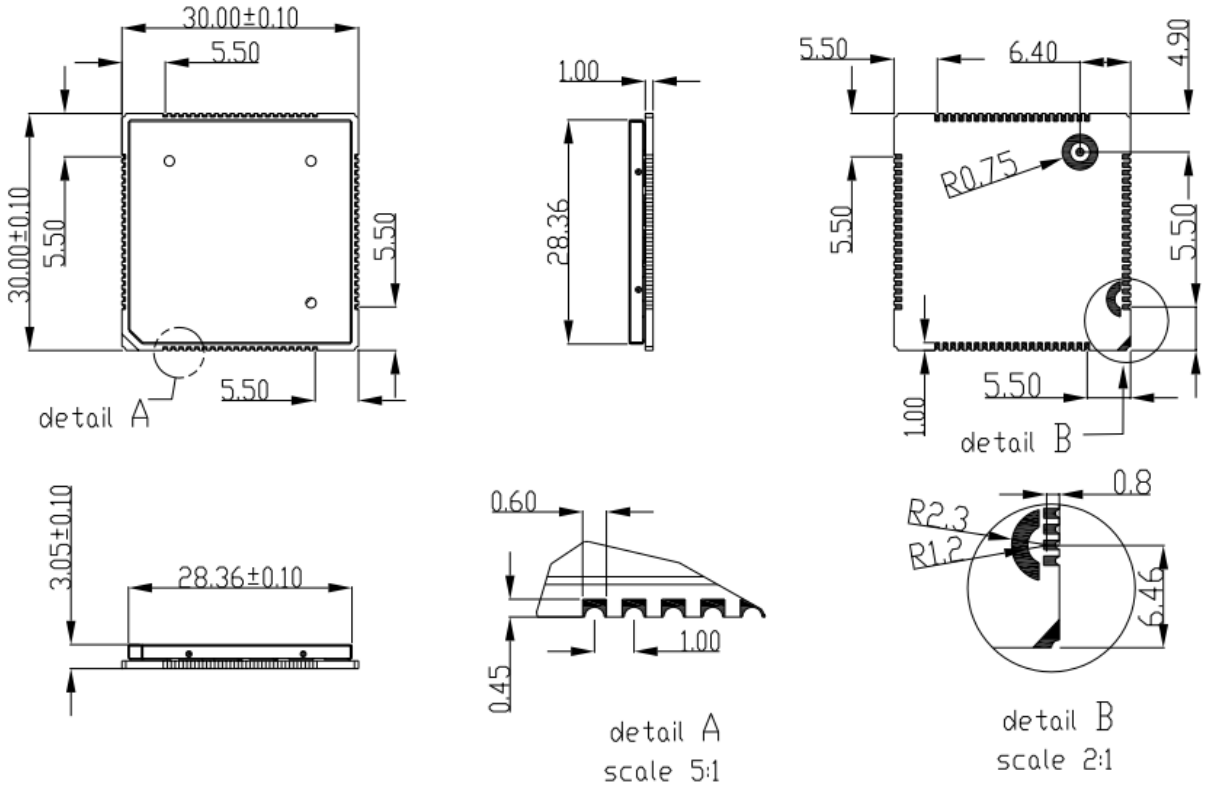

Figure 3: Dimensions of SIM928（Unit: mm）

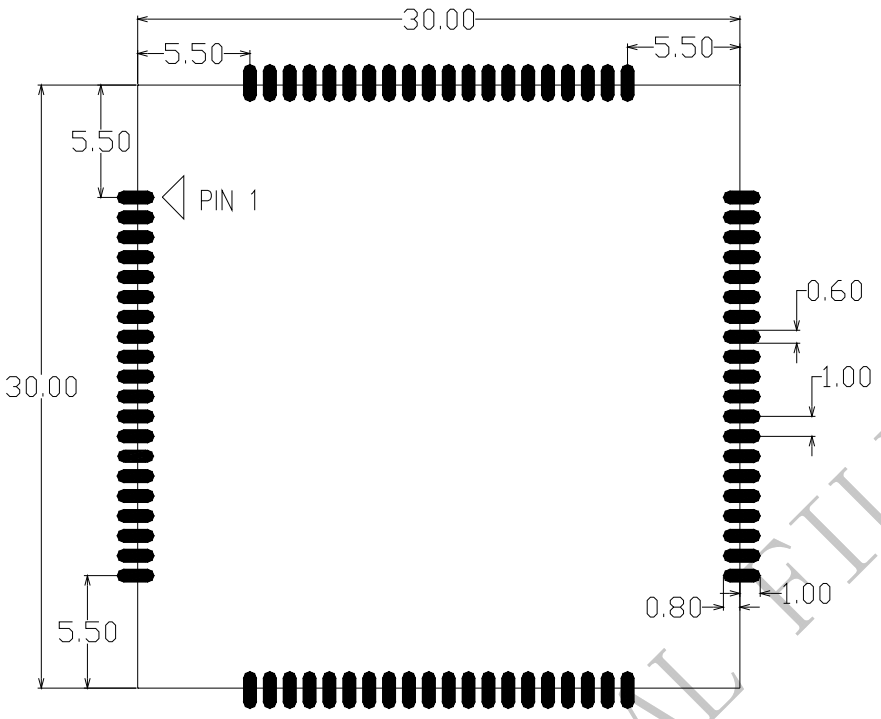

Figure 4: Recommended PCB footprint outline（Unit: mm）

4 GSM Application Interface

4.1 GSM Power Supply

The GSM power supply range of SIM928 is from 3.2V to 4.8V. The transmitting burst will cause voltage drop and the power supply must be able to provide sufficient current up to 2A. For the VBAT input, a bypass capacitor (low ESR) such as a 100 μF is strongly recommended; this capacitor should be placed as close as possible to SIM928 VBAT pins. The following figure is the reference design of +5V input power supply. The designed output for the power supply is 4.1V, thus a linear regulator can be used.

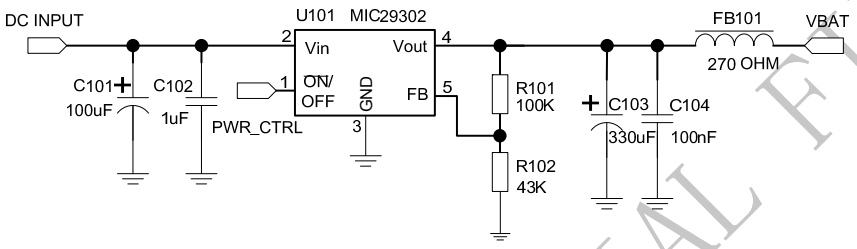

Figure 5: Reference circuit of the LDO power supply

If there is a high drop-out between the input and the desired output (VBAT), a DC-DC power supply will be preferable because of its better efficiency especially with the 2A peak current in burst mode of the module. The following figure is the reference circuit.

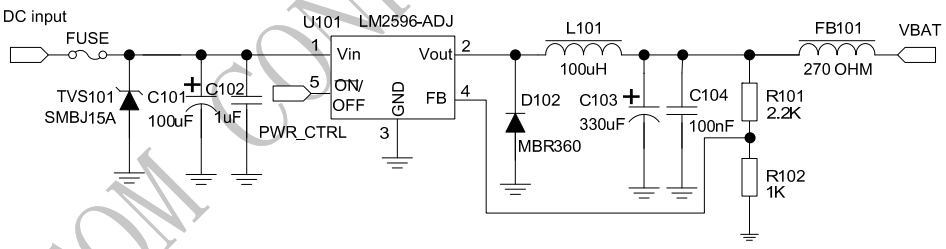

Figure 6: Reference circuit of the DC-DC power supply

The single 3.7V Li-ion cell battery can be connected to SIM928 VBAT pins directly. But the Ni-Cd or Ni-MH battery must be used carefully, since their maximum voltage can rise over the absolute maximum voltage of the module and damage it.

When battery is used, the total impedance between battery and VBAT pins should be less than 150mΩ.
The following figure shows the VBAT voltage drop at the maximum power transmit phase, and the test condition is as following:

VBAT=4.0V,
A VBAT bypass capacitor C_A=100μF tantalum capacitor (ESR=0.7Ω),
Another VBAT bypass capacitor C_B=1μF.

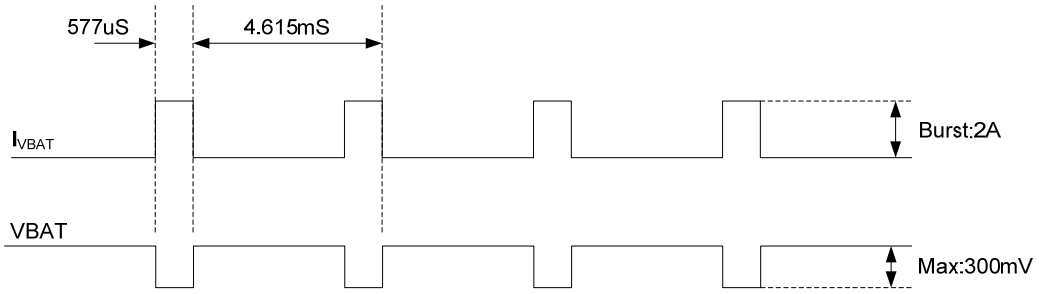

Figure 7: VBAT voltage drop during transmit burst

4.1.1 Minimizing Voltage Drop of VBAT

When designing the power supply in user's application, pay special attention to power losses. Ensure that the input voltage never drops below 3.1V even when current consumption rises to 2A in the transmit burst. If the power voltage drops below 3.1V, the module may be shut down automatically. The PCB traces from the VBAT pins to the power supply must be wide enough (at least 60mil) to decrease voltage drops in the transmit burst. The power IC and the bypass capacitor should be placed to the module as close as possible.

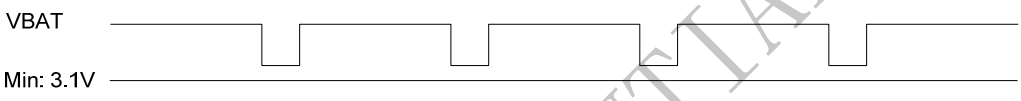

Figure 8: The minimal VBAT voltage requirement at VBAT drop

4.1.2 Monitoring Power Supply

The AT command "AT+CBC" can be used to monitor the VBAT voltage. For detail, please refer to *document [1]*.

4.2 Power on/down Scenarios

4.2.1 Power on SIM928

4.2.1.1 Turn on SIM928 Using the PWRKEY Pin (Power on)

User can power on SIM928 by pulling down the PWRKEY pin for at least 1 second and release. This pin is already pulled up to 3V in the module internal, so external pull up is not necessary. Reference circuit is shown as below.

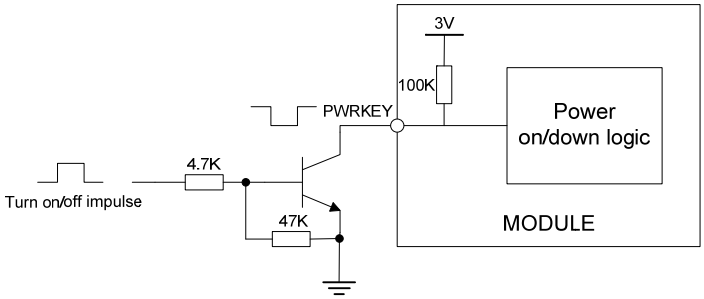

Figure 9: Powered on/down module using transistor

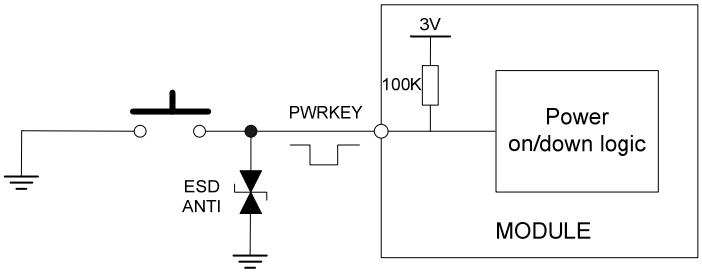

Figure 10: Powered on/down module using button

The power on scenarios is illustrated as following figure.

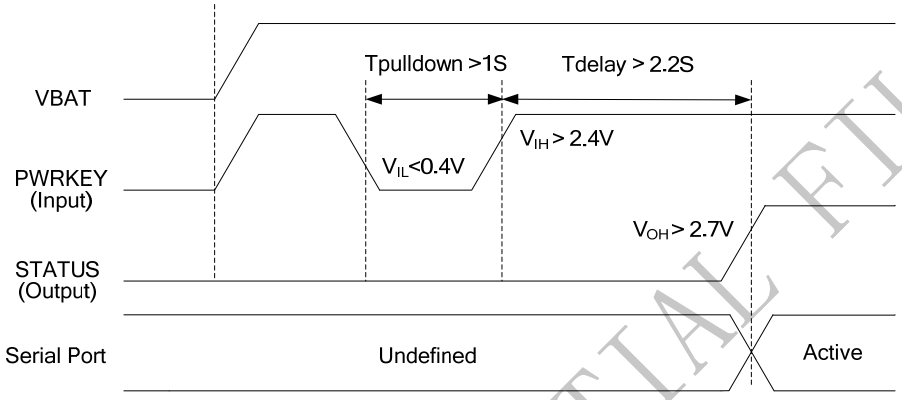

Figure 11: Timing of power on module

When power on procedure is completed, SIM928 will send following URC to indicate that the module is ready to operate at fixed baud rate.

RDY

This URC does not appear when autobauding function is active.

Note: User can use AT command "AT+IPR=x" to set a fixed baud rate and save the configuration to non-volatile flash memory. After the configuration is saved as fixed baud rate, the Code "RDY" should be received from the serial port every time when SIM928 is powered on. For details, please refer to the chapter "AT+IPR" in document [1].

4.2.1.2 Turn on the SIM928 using the VCHG Signal

The SIM928 will be automatically turned on when a charger is connected to the switched-off SIM928 of which VBAT pin voltage is greater than 3.2V. SIM928 will go into the Charge-only Mode. In this mode, the module does not register to the network, and has only a few AT commands available.

When module is powered on using the VCHG signal, SIM928 sends out result code as following when fixed baud rate set:

RDY

CHARGE-ONLY MODE

When user drives the PWRKEY of Charge-only mode SIM928 to a low level voltage for a period of time (please refer to ***Figure 13 Timing of power on module***), the SIM928 will power up and go into Charge mode during normal operation. In this case, SIM928 sends out result code as following:

From CHARGE-ONLY MODE to NORMAL MODE

In Charge mode during normal operation, all operations and AT commands are available.

4.2.2 Power down SIM928

SIM928 will be powered down in the following situations:

- Normal power down procedure: power down SIM928 by the PWRKEY pin.
- Normal power down procedure: power down SIM928 by AT command "AT+CPOWD=1".
- Abnormal power down: over-voltage or under-voltage automatic power down.
- Abnormal power down: over-temperature or under-temperature automatic power down.

4.2.2.1 Power down SIM928 by the PWRKEY Pin

User can power down SIM928 by pulling down the PWRKEY pin for at least 1 second and release. Please refer to the power on circuit. The power down scenario is illustrated in following figure.

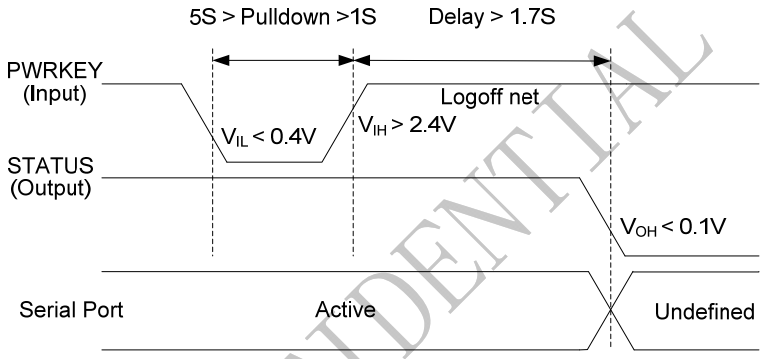

Figure 12: Timing of power down SIM928 by PWRKEY

This procedure makes the module log off from the network and allows the software to enter into a secure state to save data before completely shut down.

Before the completion of the power down procedure, the module will send URC:

NORMAL POWER DOWN

At this moment, AT commands can not be executed any more, and only the RTC is still active. Power down mode can also be indicated by STATUS pin, which is at low level at this time.

4.2.2.2 Power down SIM928 by AT Command

SIM928 can be powered down by AT command "AT+CPOWD=1". This procedure makes the module log off from the network and allows the software to enter into a secure state to save data before completely shut down.

Before the completion of the power down procedure, the module will send URC:

NORMAL POWER DOWN

At this moment, AT commands can not be executed any more, and only the RTC is still active. Power down mode can also be indicated by STATUS pin, which is at low level at this time.

For detail about the AT command "AT+CPOWD", please refer to *document [1]*

4.2.2.3 Over-voltage or Under-voltage Power down

The module software monitors the VBAT voltage constantly.
If the voltage ≤ 3.3V, the following URC will be reported:

UNDER-VOLTAGE WARNNING

If the voltage ≥ 4.7V, the following URC will be reported:

OVER-VOLTAGE WARNNING

If the voltage < 3.2V, the following URC will be reported, and the module will be automatically powered down.

UNDER-VOLTAGE POWER DOWN

If the voltage > 4.8V, the following URC will be reported, and the module will be automatically powered down.

OVER-VOLTAGE POWER DOWN

At this moment, AT commands can not be executed any more, and only the RTC is still active. Power down mode can also be indicated by STATUS pin, which is at low level at this time.

4.2.2.4 Over-temperature or Under-temperature Power down

The module will constantly monitor the temperature of the module,
If the temperature > +80℃, the following URC will be reported:

+CMTE: 1

If the temperature < -30℃, the following URC will be reported:

+CMTE:-1

If the temperature > +85℃, the following URC will be reported, and the module will be automatically powered down.

+CMTE: 2

If the temperature < -40℃, the following URC will be reported, and the module will be automatically powered down.

+CMTE:-2

At this moment, AT commands can not be executed any more, and only the RTC is still active. Power down mode can also be indicated by STATUS pin, which is at low level at this time.

The AT command "AT+CMTE" could be used to read the temperature when the module is running.
For details please refer to *document [1]*.

4.2.3 Restart SIM928 by PWRKEY Pin

When the module works normally, if the user wants to restart the module, follow the procedure below:

1) Power down the module.
2) Wait for at least 800mS after STATUS pin changed to low level.
3) Power on the module.

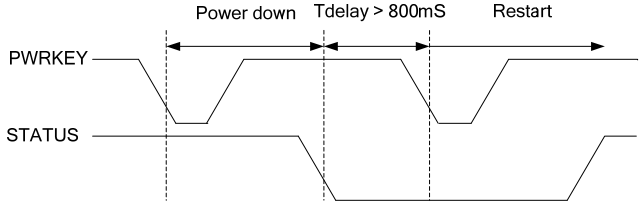

Figure 13: Timing of restart SIM928

4.3 Power Saving Mode

SIM928 have two sleep modes: sleep mode 1 is enabled by hardware pin DTR; sleep mode 2 is only enabled by serial port regardless of the DTR. In sleep mode, the current of module is very low. The AT command "AT+CFUN=<fun>" can be used to set SIM928 into minimum functionality. When SIM928 is in sleep mode and minimum functionality, the current of module is lowest.

4.3.1 Minimum Functionality Mode

There are three functionality modes, which could be set by the AT command "AT+CFUN=<fun>". The command provides the choice of the functionality levels <fun>=0,1,4.

- AT+CFUN=0: minimum functionality.
- AT+CFUN=1: full functionality (default).
- AT+CFUN=4: flight mode (disable RF function).

Minimum functionality mode minimizes the current consumption to the lowest level. If SIM928 is set to minimum functionality by "AT+CFUN=0", the RF function and SIM card function will be disabled. In this case, the serial port is still accessible, but all AT commands correlative with RF function and SIM card function will not be accessible.

For detailed information about the AT Command "AT+CFUN=<fun>", please refer to *document [1]*.

Table 6: The current consumption of Minimum Functionality Mode

<fun>	Current consumption(uA) (sleep mode)
0	651
1	1500
4	715

4.3.2 Sleep Mode 1 (AT+CSCLK=1)

User can control SIM928 module to enter or exit the sleep mode 1 (AT+CSCLK=1) by DTR signal. When DTR is in high level and without interrupt (on air and hardware such as GPIO interrupt or data in serial port), SIM928 will enter sleep mode 1 automatically. In this mode, SIM928 can still receive paging or SMS from network but the serial port is not accessible.

Note: For SIM928, it requests to set AT command "AT+CSCLK=1" and ensure DTR at high level to enable the sleep mode 1; the default value is 0, which can not make the module to enter sleep mode. For more details please refer to document [1].

4.3.3 Wake Up SIM928 from Sleep Mode 1 (AT+CSCLK=1)

When SIM928 is in sleep mode 1 (AT+CSCLK=1), the following methods can wake up the module:

- Pull down DTR pin.
  The serial port will be active after DTR pin is pulled to low level for about 50ms.

- Receive a voice or data call from network.
- Receive a SMS from network.

4.3.4 Sleep Mode 2 (AT+CSCLK=2)

AT+CSCLK=2 can set module to the sleep mode 2.
In this mode, SIM928 will continuously monitor the serial port data signal. When there is no data transfer over 5 seconds on the RXD signal and there is no on air and hardware interrupts (such as GPIO interrupt), SIM928 will enter sleep mode 2 automatically. In this mode, SIM928 can still receive paging or SMS from network but the serial port is not accessible.

Note: For SIM928, It is requested to set AT command "AT+CSCLK=2" to enable the sleep mode 2; the default value is 0, which can not make the module to enter sleep mode. For more details please refer to document [1].

4.3.5 Wake Up SIM928 from Sleep Mode 2 (AT+CSCLK=2)

When SIM928 is in sleep mode 2 (AT+CSCLK=2), the following methods can wake up the module:

- Send data to SIM928 via main serial port. *
- Receive a voice or data call from network.
- Receive a SMS from network.

Note: The first byte of the user's data will not be recognized.

4.4 Charging Interface

SIM928 has integrated a charging circuit inside the module for Li-Ion batteries charging control, which make it very convenient for user's applications that support battery charging. A common connection is shown in the following figure:

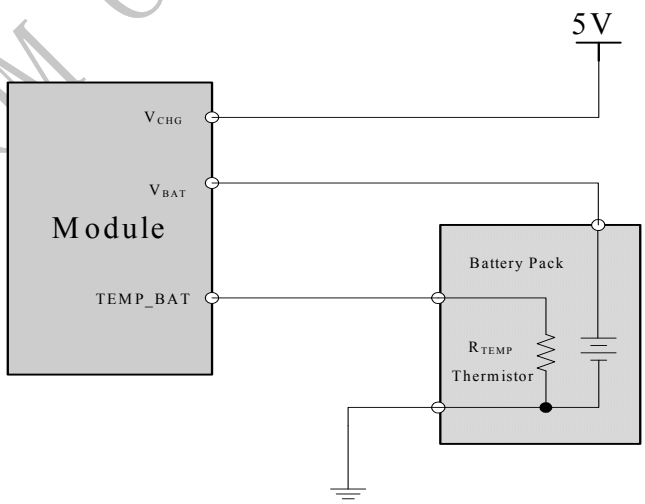

Figure 14: SIM928 with battery charger and pack connection

Battery temperature measurement is a customization function which is supported by the software in the module. In above figure, the R_{TEMP} is a NTC thermistor, and it is recommended to use MURATA NCP15XH103F03RC. Its impedance is 10Kohm at 25℃. Refer to the above figure for the reference circuit.

4.4.1 Battery Pack Characteristics

SIM928 has optimized the charging algorithm for the Li-Ion battery that meets the characteristics listed below.

- The maximum charging voltage of the Li-Ion battery pack is 4.2V and the recommended capacity is 1100mAh. The Battery packs with more than 1100 mAh capacity will take more time for charging.
- The battery pack should have a protection circuit to avoid overcharging, deep discharging and over-current, and the circuit should be insensitive to pulsed current.
- The internal resistance of the battery pack including protection circuit should be as low as possible. Its recommended value does not exceed 150mΩ.
- The battery pack must be protected from reverse pole connection.

On the SIM928, the build-in circuit of the power management chipset monitors the supply voltage constantly. Once the Under-voltage is detected, the SIM928 will be powered down automatically.

4.4.2 Recommended Battery Pack

Following is the specification of recommended battery pack:

Table 7: Specification of recommended battery pack

Items	Description
Battery type	Li-ion
Manufacturer	Jiade Energy Technology
Normal voltage	3.7V
Capacity	NORMAL 1100mAh
Charge Voltage	4.200±0.050V
Max Charge Current	1.0C
Charge Method	CC / CV (Constant Current / Constant Voltage)
Max Discharge Current	1.0C (for continuous discharging mode)
Discharge Cut-off Voltage	3.0V/ cell
Internal resistance	Initial≤130mΩ

4.4.3 Implemented Charging Technique

SIM928 has battery charging function. There are three pins related to the battery charging function: there are VCHG, VBAT and TEMP_BAT/ADC0 pins. The VCHG Pin is driven by an external voltage, system can use this Pin to detect a charger supply and provide most charging current through SIM928 module to battery when charging is in fast charge state. VBAT pin gives charging current to external battery from SIM928 module. TEMP_BAT Pin is for user to measure the battery temperature. Let this Pin open if battery temperature measurement is not user's design concern.

It is very simple to implement charging function, user just needs to connect the charger to the VCHG Pin and connect the battery to the VBAT Pin.
SIM928 battery charging happens only when detecting both charger supply and the presence of battery. If there is

no charger supply or no battery present, charging function will not be enabled.

Normally, there are three main states in the whole charging procedure.

- DDLO charge (Pull-up mode) and UVLO charge (Pre-charge mode);
- Fast charge;

DDLO charge and UVLO charge:

DDLO is the state of battery when its voltage is under 1.5V. And UVLO means the battery voltage is less than 3.3V and more than 1.5V. The battery is not suitable for fast charging when its condition is DDLO or UVLO. The SIM928 provides a small constant current to the battery when the battery is between DDLO and UVLO. In DDLO charging state, SIM928 gives out 1mA current to the battery. And in UVLO charging state, SIM928 provides about less than 200mA current to the battery.

DDLO charging terminates when the battery voltage reaches 1.5V. UVLO charging terminates when the battery voltage is up to 3.3V. Both DDLO and UVLO charge are controlled by the SIM928 hardware only.

Fast charge:

If there is a charger supply and battery present and the battery is not in DDLO and UVLO, SIM928 will enter fast charge state. Fast charge is controlled by the software to make the current/voltage regulation. The charging scheme for the Li-Ion battery is constant current (about 550mA) first, followed by constant voltage charging once 4.2V is reached. Charging is stopped when the charging current at constant voltage has decreased to the pre-set current.

4.4.4 Operating Modes during Charging

The battery can be charged during various operating mode. That means that charging can be in progress while SIM928 is in Normal mode (SLEEP, IDLE, TALK, GPRS IDLE or GPRS DATA mode). In this case the voltage supply should be sufficient. Here Charging in Normal mode is named as Charge mode.

If the charger is connected to the module's VCHG Pin and the battery is connected to the VBAT Pin while SIM928 is in POWER DOWN mode, SIM928 will go into the Charge-only mode.

The following table gives the difference between Charge mode and Charge-only mode：

Table 8: Charge operating modes

	How to activate mode	Features
Charge Mode	Connect charger to module's VCHG Pin and connect battery to VBAT Pin of module while SIM928 is in Normal operating mode, including: IDLE, TALK mode; SLEEP mode etc;	● GSM remains operational and registers to GSM network while charging is in progress; ● The serial interfaces are available in IDLE, TALK mode, the AT command set can be used fully in this case; In SLEEP mode, the serial interfaces are not available. Once the serial port is connected and there is data in transferring. SIM928 will exit the SLEEP mode.

Charge-only Mode	Connect charger to module's VCHG Pin while SIM928 is in POWER DOWN mode. IMPORTANT: Here Charge-only mode is charging when power is down, it means that not all software tasks are running.	● Battery can be charged when GSM engine is not registered to GSM network; ● Only a few AT commands is available, as listed below.

Note: VBAT can not provide more than 5mA current while SIM928 module is during the DDLO charge state. In other words it is strongly recommended that VBAT should not be the main power supply in the application subsystem if SIM928 DDLO charging state occurs.

Table 9: AT command usually used in Charge-only mode

AT command	Function
AT+CCLK	Set data and time of RTC
AT+CPOWD	Power down
AT+CBC	Indicated charge state and voltage
AT+CFUN	Start or close the protocol Set AT command "AT+CFUN=1", module can be transferred from Charge-only mode to Charging in normal mode. In Charge-only mode, the default value is 0.

4.4.5 Charger Requirements

Following is the requirements of charger for SIM928:

- Simple transformer power plug
- Output voltage: 5.0V~6V
- Minimum supply current: 750mA
- A 10V peak voltage is allowed for maximum 1ms when charging current is switched off.
- A 1.6A peak current is allowed for maximum 1ms when charging current is switched on.

4.5 RTC Backup

Current input for RTC when the VBAT is not supplied for the system. Current output for backup battery when the VBAT power supply is in present and the backup battery is in low voltage state. The RTC power supply of module can be provided by an external capacitor or a battery (non-chargeable or rechargeable) through the VRTC. The following figures show various reference circuits for RTC back up.

- **External capacitor for RTC**

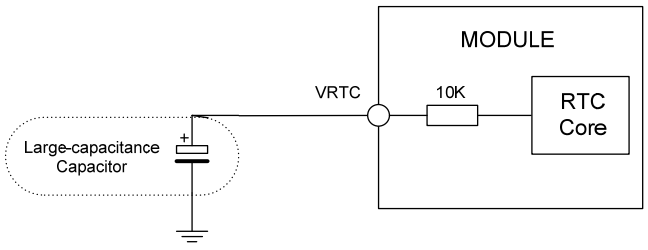

Figure 15: RTC supply from capacitor

- **Non-chargeable battery for RTC**

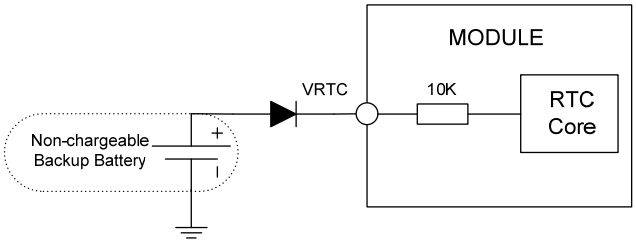

Figure 16: RTC supply from non-chargeable battery

- **Rechargeable battery for RTC**

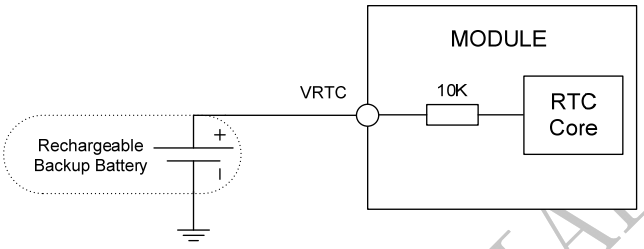

Figure 17: RTC supply from rechargeable battery

Coin-type rechargeable battery is recommended, such as XH414H-IV01E from Seiko can be used. Typical charge-discharge curves for this battery are shown in the following figure.

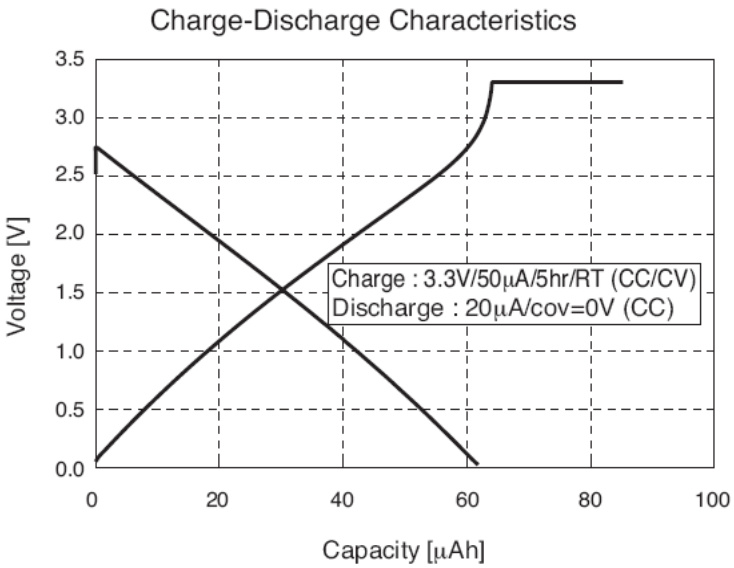

Figure 18: Seiko XH414H-IV01E charge-discharge characteristic

4.6 Serial Interfaces

SIM928 provides two unbalanced asynchronous serial ports. One is the serial port and the other is the debug port. The module is designed as a DCE (Data Communication Equipment). The following figure shows the connection between module and client (DTE).

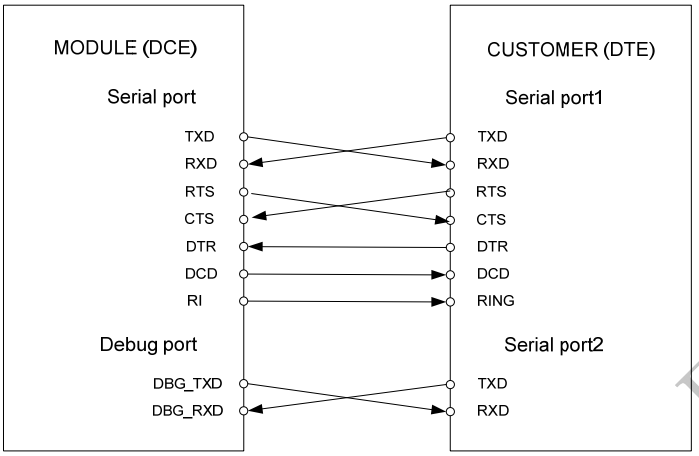

Figure 19: Connection of the serial interfaces

If only RXD and TXD are used in user's application, other serial pins should be kept open. Please refer to following figure.

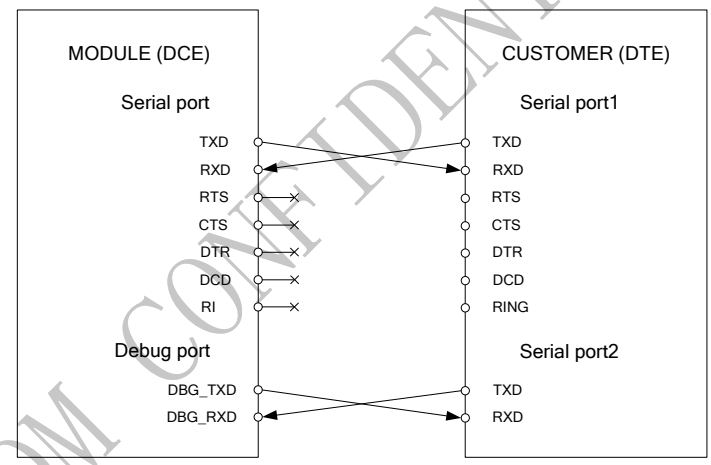

Figure 20: Connection of RXD and TXD only

Note: If user set sleep mode1, the DTR should be connected.

4.6.1 Function of Serial Port and Debug Port

Serial port:

- Full modem device.
- Contains data lines TXD and RXD, hardware flow control lines RTS and CTS, status lines DTR, DCD and RI.
- Serial port can be used for CSD FAX, GPRS service and AT communication. It can also be used for multiplexing function. For details about multiplexing function, please refer to *document [3]*.
- Serial port supports the following baud rates:
  1200, 2400, 4800, 9600, 19200, 38400, 57600 and 115200bps
- Autobauding only supports the following baud rates:

1200, 2400, 4800, 9600, 19200, 38400 and 57600bps

- The default setting is autobauding.

Autobauding allows SIM928 to automatically detect the baud rate of the host device. Pay more attention to the following requirements:

- **Synchronization between DTE and DCE:**

  When DCE powers on with autobauding enabled, user must firstly send character “A” to synchronize the baud rate. It is recommended to send “AT” until DTE receives the “OK” response, which means DTE and DCE are correctly synchronized. For more information please refer to the AT command “AT+IPR”.

- **Restrictions of autobauding operation:**

  The DTE serial port must be set at 8 data bits, no parity and 1 stop bit.

  The URC such as "RDY", "+CFUN: 1" and "+CPIN: READY” will not be reported.

Note: User can use AT command “AT+IPR=x” to set a fixed baud rate and the setting will be saved to non-volatile flash memory automatically. After the configuration is set as fixed baud rate, the URC such as "RDY", "+CFUN: 1" and "+CPIN: READY” will be reported when SIM928 is powered on.

Debug port:

- Used for debugging and upgrading firmware.
- Debug port supports the baud rate of 115200bps for debugging and 460800bps for upgrading firmware.

4.6.2 Software Upgrade and Debug

Refer to the following figure for debugging and upgrading software.

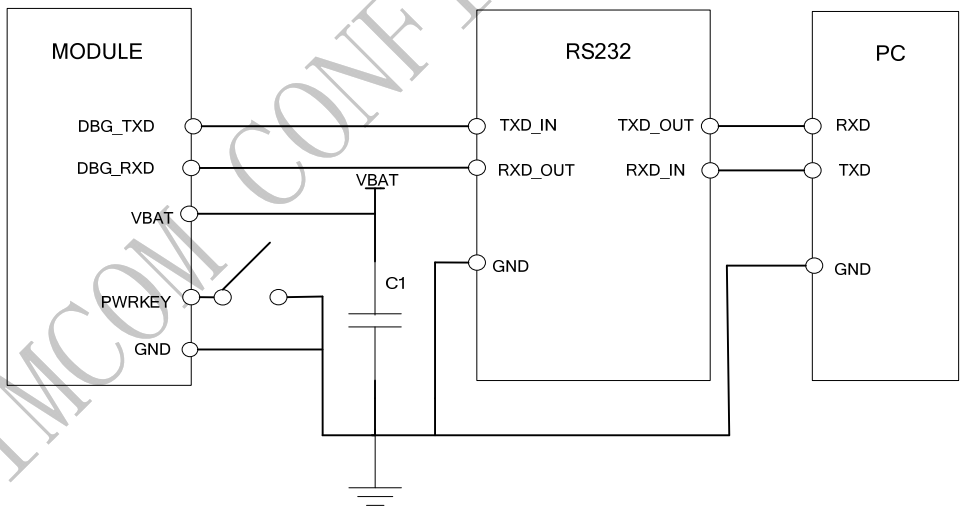

Figure 21: Connection for software upgrading and debugging

The serial port and the debug port support the CMOS level. If user connects the module to the computer, the level shifter should be added between the DCE and DTE.

For details about software upgrading, please refer to *document [4]*.

4.7 Audio Interfaces

SIM928 provides two analog inputs, MIC1P/1N and MIC2P/2N, which could be used for electret microphone. The module also provides two analog outputs, SPK1P/1N and SPK2P/2N. The output can directly drive 32Ω receiver.

AT command “AT+CMIC” is used to adjust the input gain level of microphone. AT command “AT+SIDET” is used to set the side-tone level. In addition, AT command “AT+CLVL” is used to adjust the output gain level. For more details, please refer to *document [1]* and *document [5]*.

In order to improve audio performance, the following reference circuits are recommended. The audio signals have to be layout according to differential signal layout rules as shown in following figures. If user needs to use an amplifier circuit for audio, National Semiconductor Company’s LM4890 is recommended.

4.7.1 Speaker Interface Configuration

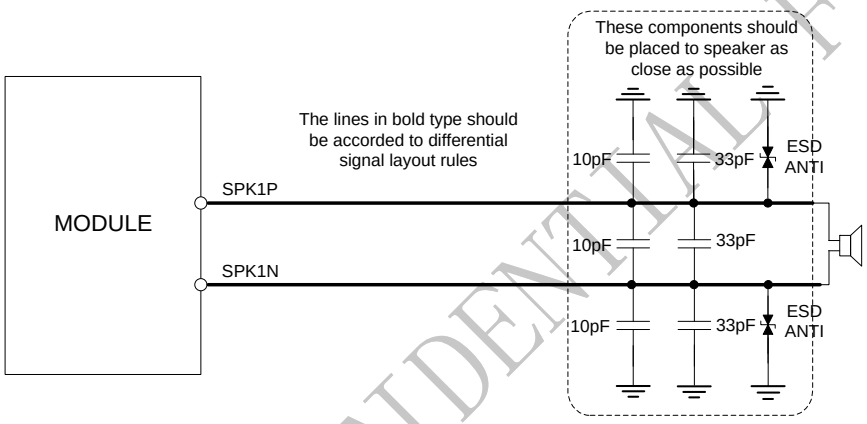

Figure 22: Speaker reference circuit

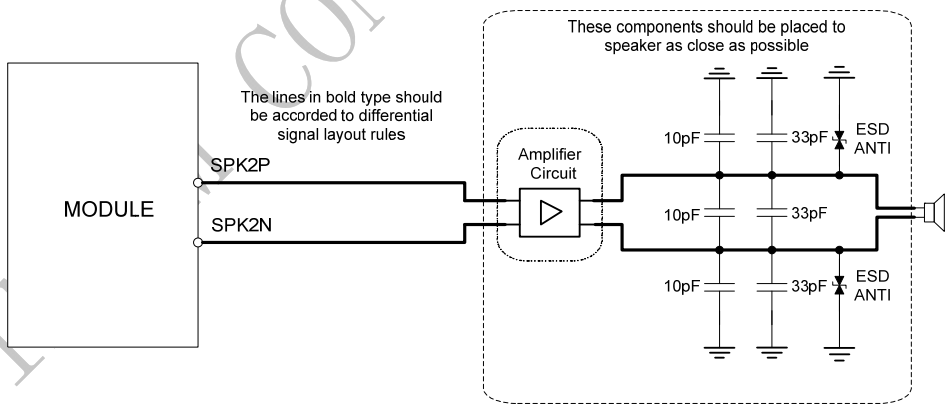

Figure 23: Speaker with amplifier reference circuit

4.7.2 Microphone Interfaces Configuration

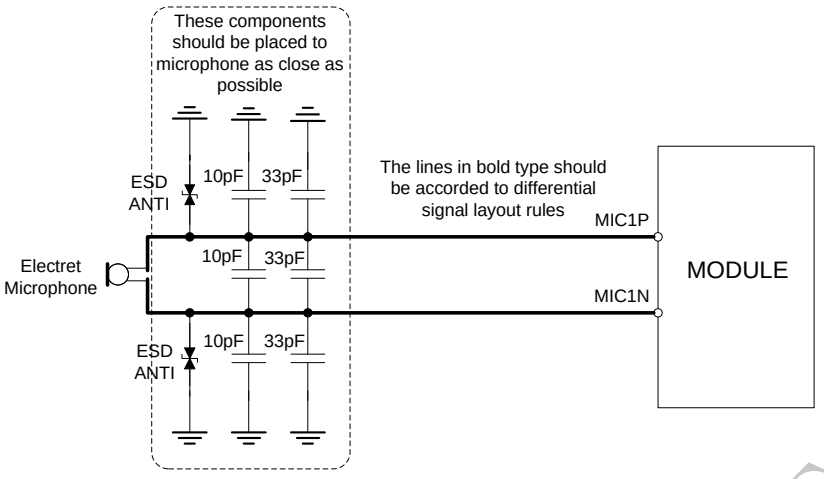

Figure 24 : Microphone reference circuit

Microphone input also could be used to LINE-IN input. For details, please refer to *document [6]*.

4.7.3 Earphone Interface Configuration

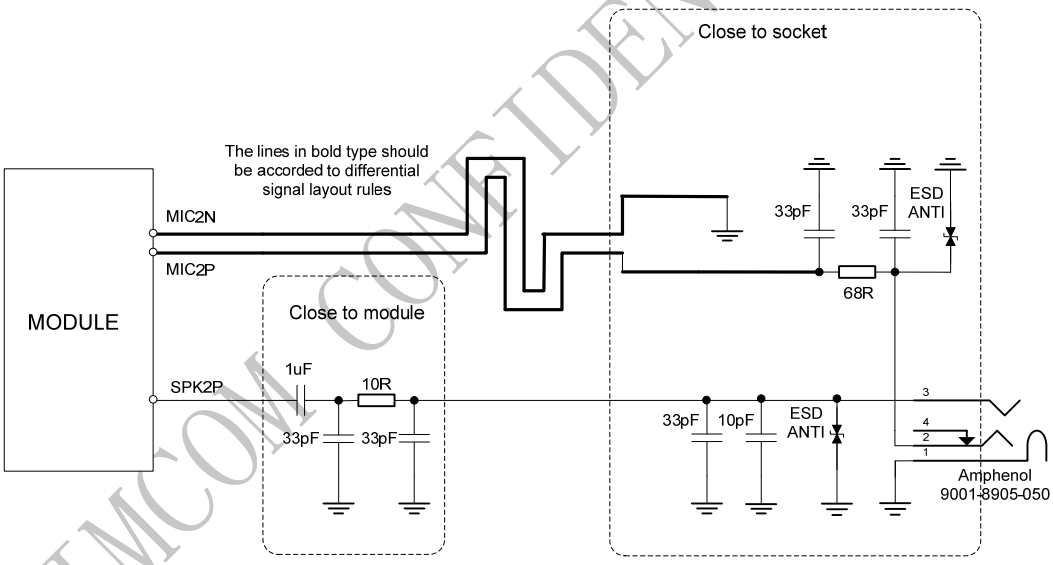

Figure 25: Earphone reference circuit

4.7.4 Audio Electronic Characteristics

Table 10: Microphone input characteristics

Parameter	Min	Typ	Max	Unit
Working Voltage	1.2	1.5	2.0	V
Working Current	200		500	uA
External Microphone Load Resistance	1.2	2.2		kΩ
Internal biasing DC Characteristics			2.5	V

Differential input voltage	THD <1% at F=1KHz; pre-amp gain = 20 dB; PGA gain = 14 dB		15.9		mVrms
	THD <5% at F=1KHz; pre-amp gain = 0 dB; PGA gain = 0 dB		740		mVrms

Table 11: Audio output characteristics

Parameter	Conditions	Min	Typ	Max	Unit
Normal Output(SPK)	RL=32Ω THD=0.1%	-	91	-	mW
	RL=32Ω THD=1%	-	96	-	mW
	Output swing voltage (single ended)			1.1	Vpp
	Output swing voltage (differential)			2.2	Vpp

4.8 SIM Card Interface

4.8.1 SIM Card Application

The SIM interface complies with the GSM Phase 1 specification and the new GSM Phase 2+ specification for FAST 64 kbps SIM card. Both 1.8V and 3.0V SIM card are supported. The SIM interface is powered from an internal regulator in the module.

It is recommended to use an ESD protection component such as ST (www.st.com) ESDA6V1W5 or ON SEMI (www.onsemi.com) SMF05C.The pull up resistor (15KΩ) on the SIM_DATA line is already added in the module internal. Note that the SIM peripheral circuit should be close to the SIM card socket. The reference circuit of the 8-pin SIM card holder is illustrated in the following figure.

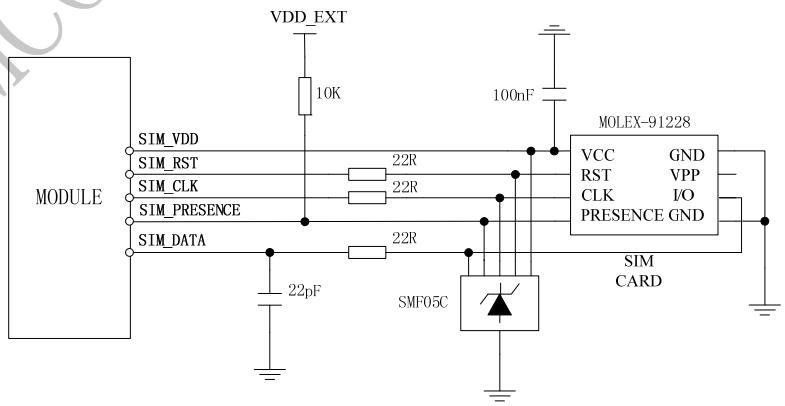

Figure 26: Reference circuit of the 8-pin SIM card holder

Note: The SIM_Presence pin is multiplexing with KBC0 (PIN 34).

The SIM_PRESENCE pin is used for detection of the SIM card hot plug in. User can select the 8-pin SIM card holder to implement SIM card detection function. AT command "AT+CSDT" is used to enable or disable SIM card detection function. For details of this AT command, please refer to *document [1]*.

If the SIM card detection function is not used, user can keep the SIM_PRESENCE pin open. The reference circuit of 6-pin SIM card holder is illustrated in the following figure.

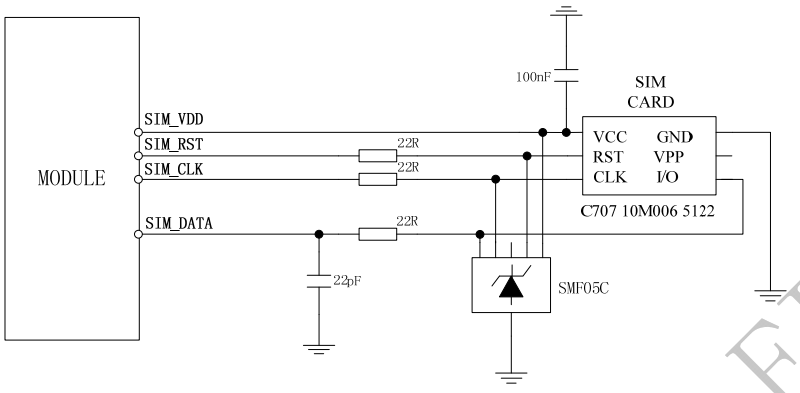

Figure 27: Reference circuit of the 6-pin SIM card holder

4.8.2 Design Considerations for SIM Card Holder

For 6-pin SIM card holder, SIMCom recommends to use Amphenol C707 10M006 5122 .User can visit http://www.amphenol.com for more information about the holder.

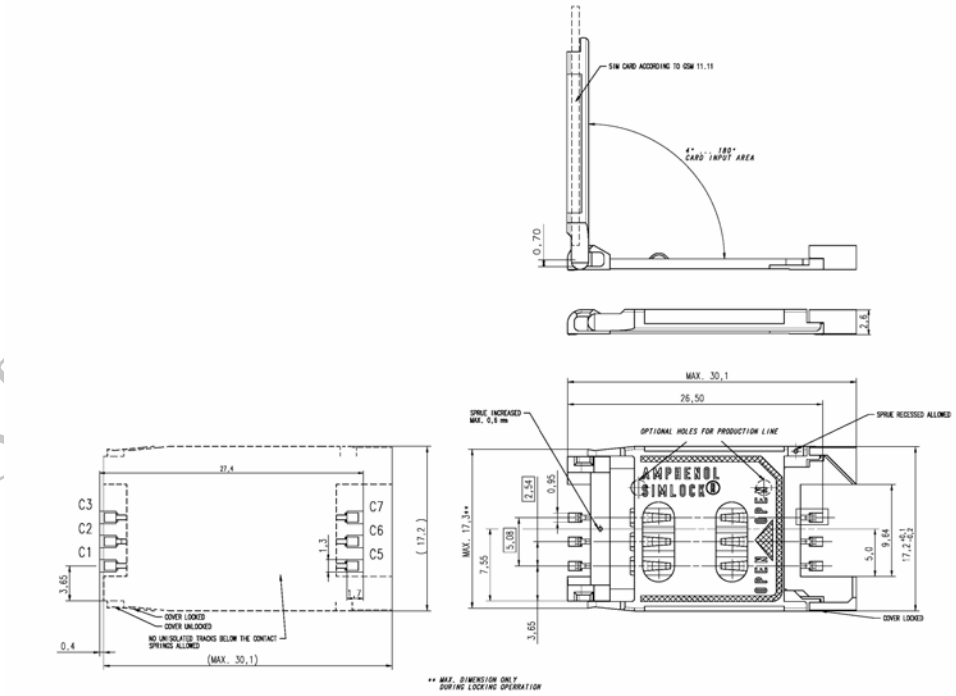

Figure 28: Amphenol C707 10M006 5122 SIM card holder

Table 12: Pin description (Amphenol SIM card holder)

Pin name	Signal	Description
C1	SIM_VDD	SIM card power supply
C2	SIM_RST	SIM card reset
C3	SIM_CLK	SIM card clock
C5	GND	Connect to GND
C6	VPP	Not connect
C7	SIM_DATA	SIM card data I/O

For 8 pins SIM card holder, SIMCom recommends to use Molex 91228.User can visit http://www.molex.com for more information about the holder.

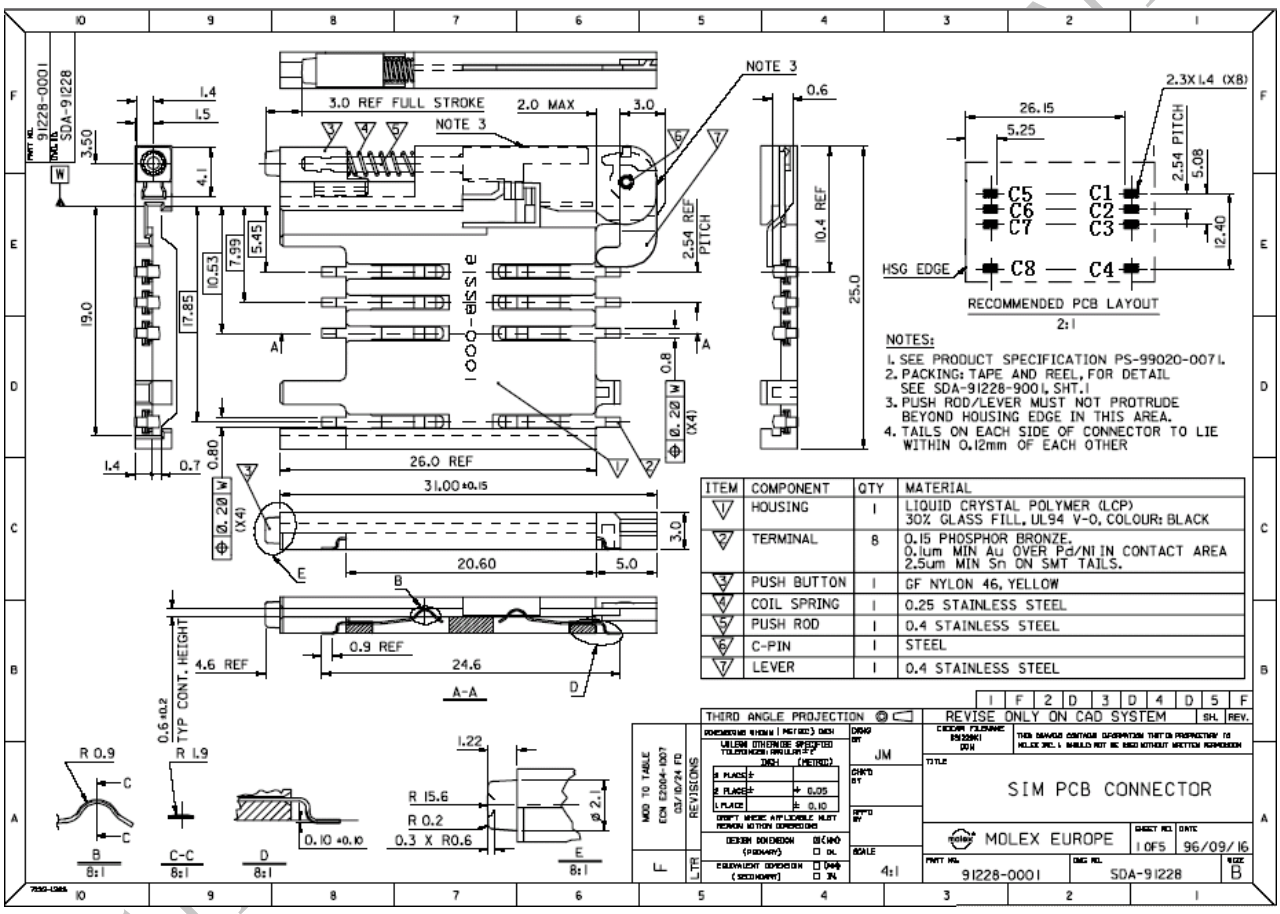

Figure 29: Molex 91228 SIM card holder

Table 13: Pin description (Molex SIM card holder)

Pin name	Signal	Description
C1	SIM_VDD	SIM card power supply
C2	SIM_RST	SIM card reset
C3	SIM_CLK	SIM card clock
C4	GND	Connect to GND
C5	GND	Connect to GND
C6	VPP	Not connect

C7	SIM_DATA	SIM card data I/O
C8	SIM_PRESENCE	Detect SIM card presence

4.9 LCD Display/SPI Interface

SIM928 provides a serial LCD display interface. It could also be used as SPI interface in the embedded AT application. For details about embedded AT application, please refer to *document [7]*.

Note: This function is not supported in the standard firmware. If user wants this function, the firmware must be customized. Please contact SIMCom for more details.

4.10 Keypad Interface

The keypad interface consists of 3 keypad column outputs and 3 keypad row inputs. The basic configuration is 3 keypad columns and 3 keypad rows, total 9 keys.

Table 14: Pin definition of the keypad interface

Pin name	Pin number	Default function	Second function	Default state
GPIO1/ KBR0	31	GPIO1	Keypad matrix	Output, Pull down
GPIO2/ KBR1	32	GPIO2		Output, Pull down
GPIO3/ KBR2	33	GPIO3		Output, Pull down
GPIO4/ KBC0	34	GPIO4		Output, Pull down
GPIO5/ KBC1	35	GPIO5		Output, Pull down
GPIO6/ KBC2	36	GPIO6		Output, Pull down

The keypad interface allows a direct external matrix connection. A typical recommended circuit of the keypad is shown in the following figure.

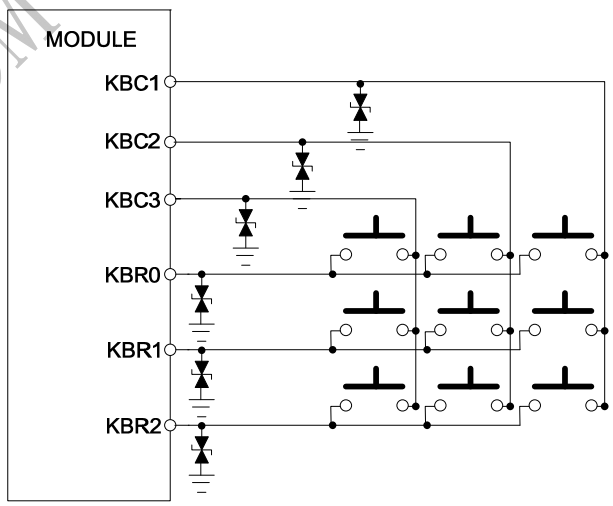

Figure 30: Reference circuit of the keypad interface

Note: This function is not supported in the standard firmware. If user wants this function, the firmware must be customized. Please contact SIMCom for more details.

4.11 ADC

SIM928 provides an auxiliary ADC, which can be used to measure the voltage. User can use AT command "AT+CADC" to read the voltage value. For details of this AT command, please refer to *document [1]*.

Table 15: ADC specification

Parameter	Min	Typ	Max	Unit
Voltage range	0	-	2.8	V
ADC Resolution	-	10	-	bits
Sampling rate	-	-	200K	Hz

4.12 RI Behaviors

Table 16: RI behaviors

State	RI response
Standby	High
Voice call	The pin is changed to low. When any of the following events occur, the pin will be changed to high: （1）Establish the call （2）Hang up the call
Data call	The pin is changed to low. When any of the following events occur, the pin will be changed to high: （1）Establish the call （2）Hang up the call
SMS	The pin is changed to low, and kept low for 120ms when a SMS is received. Then it is changed to high.
URC	The pin is changed to low, and kept low for 120ms when some URCs are reported. Then it is changed to high. For more details, please refer to *document [8]*.

The behavior of the RI pin is shown in the following figure when the module is used as a receiver.

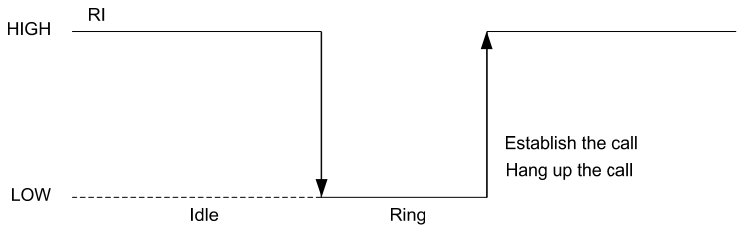

Figure 31: RI behaviour of voice calling as a receiver

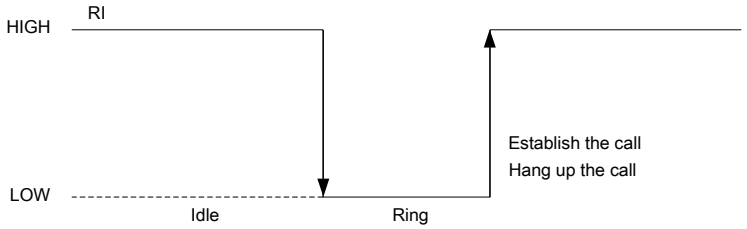

Figure 32: RI behaviour of data calling as a receiver

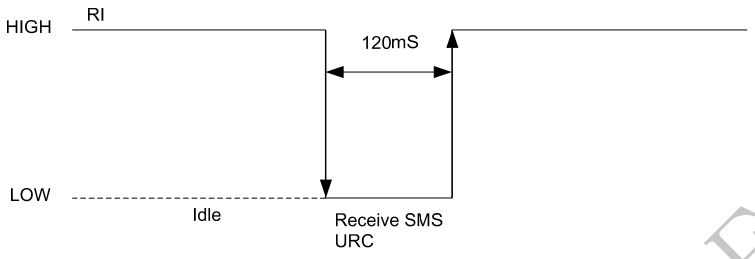

Figure 33: RI behaviour of URC or receive SMS

However, if the module is used as caller, the RI will remain high. Please refer to the following figure.

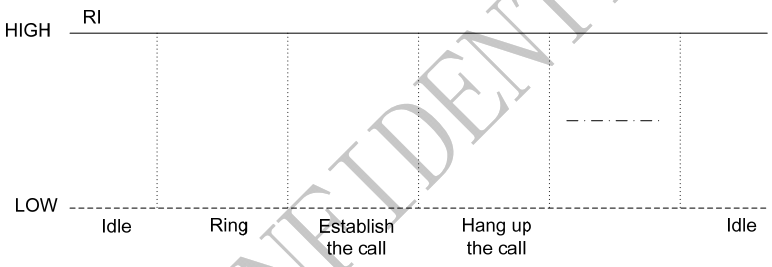

Figure 34: RI behaviour as a caller

4.13 Network Status Indication

The NETLIGHT pin can be used to drive a network status indication LED. The status of this pin is listed in following table:

Table 17: Status of the NETLIGHT pin

Status	SIM928 behavior
Off	SIM928 is not running
64ms On/ 800ms Off	SIM928 not registered the network
64ms On/ 3000ms Off	SIM928 registered to the network
64ms On/ 300ms Off	PPP GPRS communication is established

A reference circuit is recommended in the following figure:

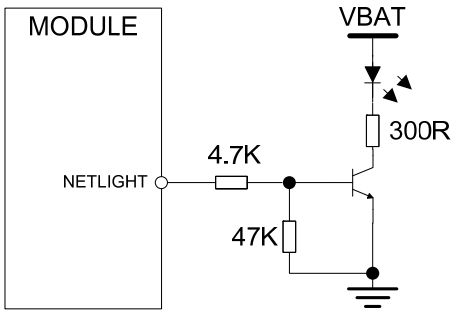

Figure 35: Reference circuit of NETLIGHT

4.14 General Purpose Input/Output (GPIO)

SIM928 provides up to 6 GPIO pins. The output voltage level of the GPIO can be set by the AT command "AT+ SGPIO". The input voltage level of the GPIO can also be read by the AT command "AT+ SGPIO". For more details, please refer to *document [1]*.

Table 18: Pin definition of the GPIO interface

Pin name	Pin number	Default function	Second function	Default state
GPIO1/ KBR0	31	GPIO1	KBR0	Output, pull down
GPIO2/ KBR1	32	GPIO2	KBR1	Output, pull down
GPIO3/ KBR2	33	GPIO3	KBR2	Output, pull down
GPIO4/ KBC0	34	GPIO4	KBC0	Output, pull down
GPIO5/ KBC1	35	GPIO5	KBC1	Output, pull down
GPIO6/ KBC2	36	GPIO6	KBC2	Output, pull down

4.15 External Reset

The external NRESET pin is used to reset the module. This function is used as an emergency reset only when AT command "AT+CPOWD=1" and the PWRKEY pin have no effect. The NRESET pin could be pulled down to reset the module. The reset timing is illustrated in the following figure.

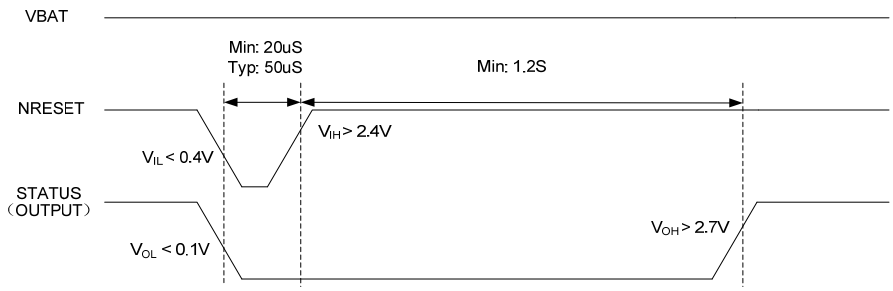

Figure 36: Reset timing

This pin is already pulled up in the module, so the external pull-up resistor is not necessary. A 100nF capacitor

close to the NRESET pin is strongly recommended. A reference circuit is shown in the following figure.

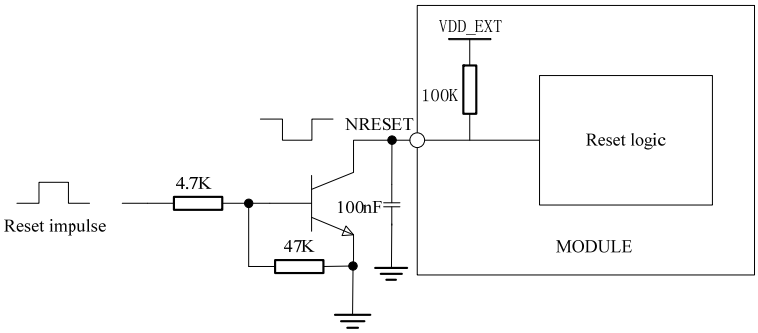

Figure 37: Reset reference design circuit

NOTE: It is recommended to cut off the VBAT power supply directly instead of using external reset pin when SIM928 can not respond to the AT command "AT+CPOWD=1" and PWRKEY pin.

4.16 PWM

SIM928 provides 3 PWMs which can be used to drive a vibrator, and a backlight LED for display or keyboard. PWM1 and PWM2 output frequency varies from 25.6KHz to 3.25MHz.Two 7-bit unsigned binary parameters are used for the output period and for the duty cycle. The PWM3 for the buzzer outputs a square wave at the desired tone frequency. The tone frequencies are programmable from 200 Hz to 5 kHz and can be re-programmed on-the-fly to generate monophonic audio ring tones or alert tones. The tone level can be adjusted over a 24 dB range in 4 dB steps, or it can be muted.

The AT command "AT + SPWM" is used to set the output period and duty cycle of the PWM. For details, please refer to *document [1]*.

4.17 I^2C Bus

The SIM928 provides an I^2C interface which is only used in the embedded AT application.

Note: This function is not supported in the standard firmware. If user wants this function, the firmware must be customized. Please contact SIMCom for more details.

4.18 GSM Antenna Interface

The RF interface has an impedance of 50Ω. To suit the physical design of individual applications, SIM928 offers the interface as GSM_ANT PAD.

Figure 38: The RF interface of module

The customer's main board under the GSM_ANT pad should be copper keep out.
The customer's GSM antenna can be located in the customer's main board and connect to module's GSM_ANT pad through microstrip line or other type RF trace which impendence must be controlled in 50Ω. To facilitate the antenna tuning and certification test, a RF connector and an antenna matching circuit should be added. The following figure is the recommended circuit.

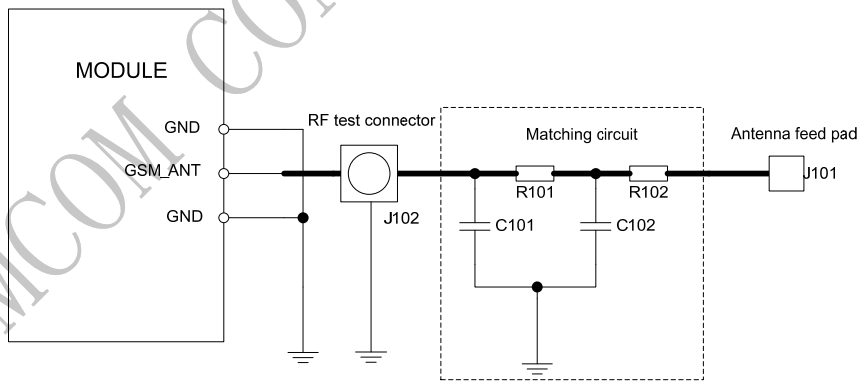

Figure 39: GSM antenna matching circuit

In this figure, the components R101,R102,C101 and C102 is used for antenna matching, the components' value only can be got after the antenna tuning. Usually, matching components' value is provided by antenna vendor, the default value of R101 and R102 are 0Ω, and reserve the place of C101 and C102 without soldering.

The RF test connector in figure 39 is used for conducted RF performance test, and should be placed as close as possible to the module's RF_ANT pad. The traces in bold type should be treated as 50Ω impedance controlled line in PCB layout. For details about radio frequency trace layout, please refer to *document [9]*.

5 GPS Application Interface

5.1 Power Management

5.1.1 GPS Power Input

The GPS_VCC supply range is from 2.8V to 4.3V, and it should be able to provide sufficient current up to 100mA.

5.1.2 Starting GPS Engine

- When GPS power is first applied, The GPS Engine goes into operation mode.

5.1.3 Verification of GPS Engine Start

System activity indication depends upon the chosen serial interface:

- When it is activated, SIM928 will output messages at the selected UART speed, and message types.

5.1.4 Power Saving Modes

SIM928 supports operating modes for reduced average power consumption like sleep mode, backup mode, periodic mode, and AlwaysLocate™ mode.

- Sleep mode**:** In this mode the receiver stays at full on power state. When this mode that can be wake up by the host sends the command through the communication interface or external interrupt.
- Periodic mode**:** In this mode the SIM928 enters tracking and sleep modes according to the interval configured by users in the commands.
- AlwaysLocate™ mode: AlwaysLocate™ is an intelligent controller of SIM928 periodic mode. Depending on the environment and motion conditions, SIM928 can adaptive adjust the on/off time to achieve balance of positioning accuracy and power consumption.

Note: the modes mentioned above are operated by PMTK commands, users can refer to document [19] for more information.

SIM928 provides very low leakage battery back up memory, which contains all the necessary GPS information for quick start up and a small amount of user configuration variables. It needs a 3V power supply for V_BACKUP pin, and the stable operation region ranges from very light load to about 3mA.

5.1.5 Operating Mode

Table 19: Power supply and clock state according to operation mode

Mode	GPS_VCC	V_BACKUP	Internal LDO	Main clock	RTC clock
Full on	on	on	on	on	on
Sleep	on	on	on	off	on

5.1.5.1 Full on Mode

The module will enter full on mode after first power up with factory configuration settings. Power consumption will vary depending on the amount of satellites acquisitions and the number of satellites in track. This mode is also referenced as Full on, Full Power or Navigation mode.

Navigation is available and any configuration settings are valid as long as the GPS_VCC power supply is active. When the power supply is off, settings are reset to factory configuration and receiver performs a cold start on next power up.

5.1.5.2 Sleep Mode

Sleep mode means a low quiescent (<200uA type.) power state, non-volatile RTC, and backup RAM block is powered on. Other internal blocks like digital baseband and RF are internally powered off. The power supply input GPS_VCC shall be kept active all the time, even during sleep mode.
Entering into sleep mode is sent PMTK command through the communication interface by host side.

The GPS engine can be waked up from sleep mode by sent any byte through the communication interface.

5.1.6 GPS_VANT_OUT and GPS_VANT_IN

GPS_VANT_OUT is a 2.8V output for active external antenna, if the active external antenna works at 2.8V voltage supply domain, user can connect the GPS_VANT_OUT and GPS_VANT_IN through a resistor (for example 10ohm) in the following picture. If the antenna's power is not 2.8V, a proper voltage should be provided to the pin GPS_VANT_IN through a resistor (for example 10ohm) and the pin GPS_VANT_OUT should be kept open in the following picture.

For passive antennas, both the pin GPS_VANT_OUT and the pin GPS_VANT_IN should be kept open.

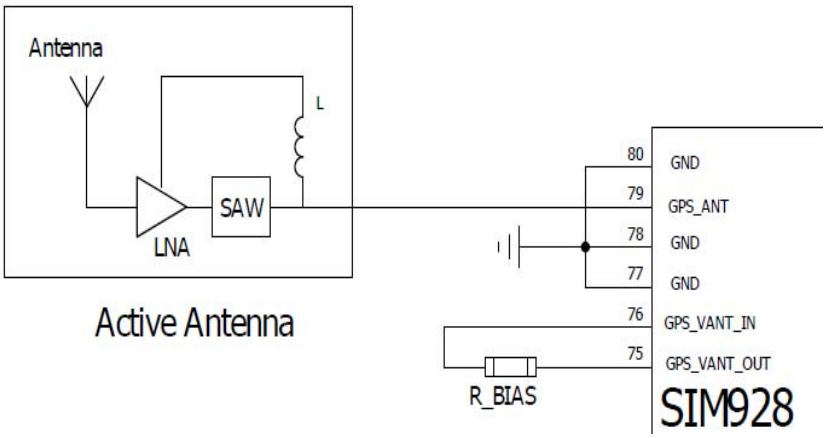

Figure 40: Internal supply Antenna bias voltage

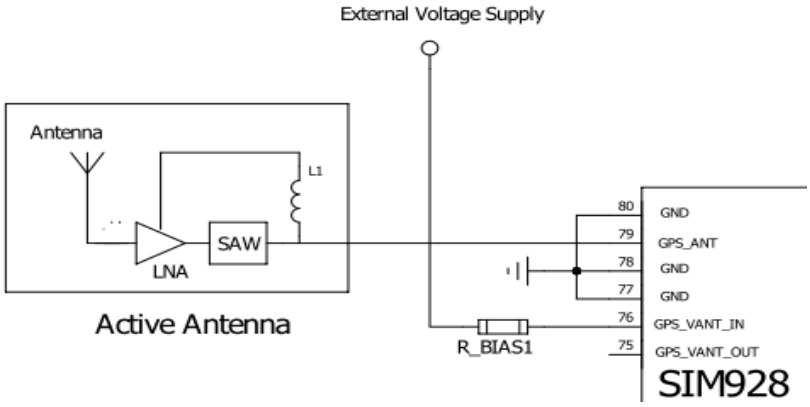

Figure 41: External supply Antenna bias voltage

5.2 UART Interface

SIM928 GPS includes two UARTS (UART and UART1) interface for serial communication. The UART is as NMEA output and PMTK command input. The receiver (GPS_RXD) and transmitter (GPS_TXD) side of every port contains a 16-byte FIFO and has 256 bytes URAM. The baud rates are selectable 9600bps and 115200bps by BR_SELECT in the following table. The default baud rate is 9600bps. UART can provide the developers signal or message outputs.

UART1 is as RTCM input.

Table 20: the baud rates select

Baud rate	BR_SELECT
9600bps	NC
115200bps	0

5.3 1PPS Output

The 1PPS pin outputs pulse-per-second (1PPS) pulse signal for precise timing purposes. It will come out after successfully positioning .The 1PPS signal can be provided through designated output pin for many external applications.

5.4 A-GPS

A-GPS is the meaning of Assisted GPS, which is a system that can improve the startup performance, and time-to-first-fix (TTFF) of a GPS satellite-based positioning under certain conditions . SIM928 module supports EPO file, and SBAS/RTCM.

5.4.1 EPO

The SIM928 supports the EPO (Extended Prediction Orbit) data service. The EPO data service is supporting 6 hours orbit predictions to customers. It needs occasional download from EPO server. Supply of aiding information like ephemeris, almanac, rough last position and time and satellite status and an optional time synchronization signal will reduce time to first fix significantly and improve the acquisition sensitivity.

The user should update the EPO files from the EPO server daily through the internet. Then the EPO data should send to the SIM928 by the HOST side. SIM928 has the short cold TTFF and warm TTFF, when the A-GPS is used.

Note: For more information about EPO, please contact SIMCom sales. users can refer to document [20] for more information

5.4.2 SBAS and RTCM

SBAS is the abbreviation of Satellite Based Augmentation System. The SBAS concept is based on the transmission of differential corrections and integrity messages for navigation satellites that are within sight of a network of reference stations deployed across an entire continent. SBAS messages are broadcast via geostationary satellites able to cover vast areas.

Several countries have implemented their own satellite-based augmentation system. Europe has the European Geostationary Navigation Overlay Service (EGNOS) which covers Western Europe and beyond. The USA has its Wide Area Augmentation System (WAAS). Japan is covered by its Multi-functional Satellite Augmentation System (MSAS). India has launched its own SBAS program named GPS and GEO Augmented Navigation (GAGAN) to cover the Indian subcontinent.

SIM928 module supports SBAS and RTCM, but only one mode can be applied at one time, and SBAS is the default feature, customers who want to apply RTCM in the design can contact SIMCom sales for supporting

5.5 GPS Antenna Interface

5.5.1 GPS Antenna Interface

The RF interface has an impedance of 50Ω. To suit the physical design of individual applications, SIM928 offers the interface as GPS_ANT pad.

The customer's GPS antenna can be located in the customer's main board and connect to module's GPS_ANT pad through microstrip line or other type RF trace, which impendence must be controlled in 50Ω. The customer's main board under the GPS_ANT pad should be copper keep out. To minimize the loss on the PCB RF path, it must be very careful in layout.

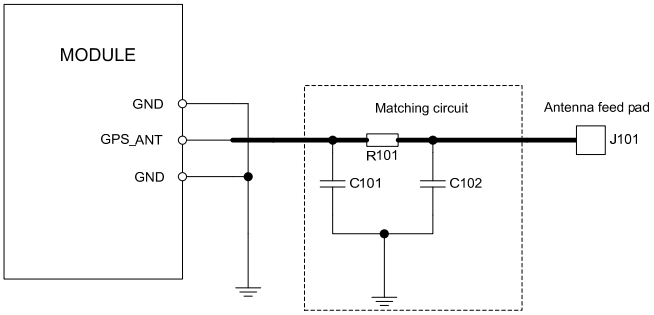

Figure 42: GPS antenna matching circuit

In this figure, the components R101, C101 and C102 is used for antenna matching, the components' value only can be got after the antenna tuning. Usually, matching components' value is provided by antenna vendor, the default value of R101 is 0Ω, and users need to reserve the place of C101 and C102 without soldering.

The traces in bold type should be treated as 50Ω impedance controlled line in PCB layout.

5.5.2 GPS Antenna Choice Consideration

To obtain excellent GPS reception performance, a good antenna will always be required. The antenna is the most critical item for successful GPS reception in a weak signal environment. Proper choice and placement of the antenna will ensure that satellites at all elevations can be seen, and therefore, accurate fix measurements are obtained.
Most customers contract with antenna design houses to properly measure the radiation pattern of the final mounted configuration in a plastic housing with associated components near the antenna. Linear antennas are becoming more popular, and the gain is reasonable, since a smaller ground plane can be used.

User can consider following factors as:

- Choose a linear antenna with a reasonably uniform hemispherical gain pattern of >-4dBi.
- Use of an antenna with lower gain then this will give less than desirable results. Please note that a RHCP antenna with a gain of 3dBi, equates to a linear polarized antenna of 0dBi.
- Proper ground plane sizing is a critical consideration for small GPS antennas.
- Proper placement of the GPS antenna should always be the FIRST consideration in integrating the SIM928 GPS Module.

If the customer's design will allow for a ceramic RHCP patch antenna with an appropriately sized ground plane, and the patch is normally oriented towards the sky, then that particular solution usually works the best. Note that if the patch antenna ground plane is less than 60x60mm, then compromises to the beam width and gain pattern could result. Usually the gain becomes very directional, and looses several dB of performance. Since results can vary, measuring the antenna radiation pattern in the final housing in an appropriate anechoic chamber is required.

Some customers do not have the size availability to implement a patch antenna approach. In that instance, use of a Linear Polarized (LP) antenna is the next best alternative. There are new ceramic LP antennas on the market that exhibit reasonable gain characteristics once properly mounted in the housing, and when matched to an appropriate sized ground. Generally the ground plane requirements are smaller for a LP antenna when compared to a patch, but once again, proper testing in an anechoic chamber is a mandatory requirement. These ceramic elements will need to be located near the end of the ground plane, and will require several millimeters of clearance between the closest component. It is important to note that use of a LP antenna will result in a minimum of 3dB of gain loss when compared to a RHCP antenna at a defined elevation. This is due to the right hand gain rule of antenna propagation.

Use of PIFA antenna is another LP possibility, but the PIFA usually exhibits a considerable amount of gain nulls, or "holes" in the radiation pattern. This will be undesirable for obtaining a low circular error probability (CEP), since the antenna may not allow the receiver to capture the desired satellite at the ideal orientation due to these noted gain nulls. Once again, careful testing in an appropriate anechoic chamber is required.

If the customer's design is for automotive applications, then an active antenna can be used and located on top of

the car in order for guarantee the best signal quality. GPS antenna choice should be based on the designing product and other conditions.

For detailed Antenna designing consideration, please refer to related antenna vendor's design recommendation. The antenna vendor will offer further technical support and tune their antenna characteristic to achieve successful GPS reception performance depending on the customer's design.

6 Electrical, Reliability and Radio Characteristics

6.1 Absolute Maximum Ratings

The absolute maximum ratings stated in following table are stress ratings under non-operating conditions. Stresses beyond any of these limits will cause permanent damage to SIM928.

Table 21: Absolute maximum ratings of GSM

Symbol	Parameter	Min	Typ	Max	Unit
VBAT	GSM Power supply voltage	-	-	5.5	V
V_I*	Input voltage	-0.3	-	3.1	V
I_I*	Input current	-	-	10	mA
I_O*	Output current	-	-	10	mA

*These parameters are for digital interface pins, such as keypad, GPIO, I^2C, UART, LCD, PWMs and DEBUG.

Table 22: Absolute maximum ratings of GPS

Symbol	Parameter	Min	Typ	Max	Unit
GPS_VCC	GPS Power supply voltage	-	-	4.3	V
GPS_VANT_IN	GPS active antenna power supply	-5.5V	-	+5.5	V
GPS_ANT	GPS radio antenna connection	-	-	3.08	V
V_BACKUP	Power supply for GPS RTC	-	-	4.6	V
I_I	I/O pin voltage	-	-	3.6	V

6.2 Recommended Operating Conditions

Table 23: Recommended operating conditions

Symbol	Parameter	Min	Typ	Max	Unit
VBAT	Power supply voltage	3.2	4.0	4.8	V
GPS_VCC	GPS Power supply voltage	2.8	3.3	4.3	V
V_BACKUP	Power supply for GPS RTC	2	2.8	4.6	V
T_{OPER}	Operating temperature	-40	+25	+85	℃
T_{STG}	Storage temperature	-45		+90	℃

Note: Operation in the temperature range –40°C~ –30°C is allowed but Time-to-First-Fix performance and tracking sensitivity may be degraded.

6.3 Digital Interface Characteristics

Table 24: Digital interface characteristics of GSM

Symbol	Parameter	Min	Typ	Max	Unit

I_{IH}	High-level input current	-10	-	10	uA
I_{IL}	Low-level input current	-10	-	10	uA
V_{IH}	High-level input voltage	2.4	-	-	V
V_{IL}	Low-level input voltage	-	-	0.4	V
V_{OH}	High-level output voltage	2.7	-	-	V
V_{OL}	Low-level output voltage	-	-	0.1	V

- These parameters are for digital interface pins, such as keypad, GPIO, I^2C, UART, LCD, PWMs and DEBUG.

Table 25: Digital interface characteristics of GPS

Parameter	Symbol	Min	Typ	Max	Unit
Low level output voltage Test conditions IOL = 2mA and 4.0mA	V_{ol}	-0.3		0.40	V
High level output voltage Test conditions IOL = 2mA and 4.0mA	V_{oh}	2.4		3.1	V
Low level input voltage	V_{il}	-0.3		0.8	V
High level input voltage	V_{ih}	2.0		3.6	V
Input Pull-up resistance	R_{PU}	40		190	K Ω
Input Pull-dowm resistance	R_{PD}	40		190	K Ω
Input capacitance	C_{in}		5		pF
Load capacitance	C_{load}			8	pF
Tri-state leakage current	I_{OZ}	-10		10	uA

6.4 SIM Card Interface Characteristics

Table 26: SIM card interface characteristics

Symbol	Parameter	Min	Typ	Max	Unit
I_{IH}	High-level input current	-10	-	10	uA
I_{IL}	Low-level input current	-10	-	10	uA
V_{IH}	High-level input voltage	1.4	-	-	V
		2.4	-	-	V
V_{IL}	Low-level input voltage	-	-	0.4	V
				2.4	V
V_{OH}	High-level output voltage	1.7	-	-	V
		2.7	-	-	V
V_{OL}	Low-level output voltage	-	-	0.1	V
		-	-	0.1	V

6.5 VDD_EXT Characteristics

Table 27: VDD_EXT characteristics

Symbol	Parameter	Min	Typ	Max	Unit

V_O	Output voltage	2.70	2.80	2.95	V
I_O	Output current	-	-	10	mA

6.6 SIM_VDD Characteristics

Table 28: SIM_VDD characteristics

Symbol	Parameter	Min	Typ	Max	Unit
V_O	Output voltage	2.75	2.9	3.00	V
		1.65	1.80	1.95	
I_O	Output current	-	-	10	mA

6.7 VRTC Characteristics

Table 29: VRTC characteristics

Symbol	Parameter	Min	Typ	Max	Unit
V_{RTC-IN}	VRTC input voltage	2.00	3.00	3.15	V
I_{RTC-IN}	VRTC input current	-	2	-	uA
$V_{RTC-OUT}$	VRTC output voltage	-	3.00	-	V
$I_{RTC-OUT}$	VRTC output current	-	10	-	uA

6.8 Current Consumption (VBAT = 3.8V)

Table 30: GSM current consumption*

Symbol	Parameter	Conditions			Value	Unit
I_{VRTC}	VRTC current	VBAT disconnects. Backup battery is 3 V			2	uA
I_{VBAT}	VBAT current	Power down mode			50	uA
		Sleep mode	BS-PA-MFRMS=9		1.2	mA
			BS-PA-MFRMS=5		1.5	
			BS-PA-MFRMS=2		1.7	
		Idle mode	GSM 850		21	mA
			EGSM 900			
			DCS 1800			
			PCS 1900			
		Voice call	GSM 850 EGSM 900	PCL=5	240	mA
				PCL=12	110	
				PCL=19	76	
			DCS 1800 PCS 1900	PCL=0	180	
				PCL=7	89	
				PCL=15	76	

		Data mode GPRS(1Rx,1Tx)	GSM 850 EGSM 900	PCL=5	240	mA
				PCL=12	110	
				PCL=19	83	
			DCS 1800 PCS 1900	PCL=0	170	mA
				PCL=7	95	
				PCL=15	80	
		Data mode GPRS(4Rx,1Tx)	GSM 850 EGSM 900	PCL=5	270	mA
				PCL=12	150	
				PCL=19	120	
			DCS 1800 PCS 1900	PCL=0	210	mA
				PCL=7	130	
				PCL=15	115	
		Data mode GPRS(3Rx,2Tx)	GSM 850 EGSM 900	PCL=5	435	mA
				PCL=12	185	
				PCL=19	130	
			DCS 1800 PCS 1900	PCL=0	320	mA
				PCL=7	155	
				PCL=15	122	
$I_{VBAT-peak}$	Peak current	During Tx burst			2	A

* In above table the current consumption value is the typical one of the module tested in laboratory. In the mass production stage, there may be differences among each individual.

6.9 Electro-Static Discharge

SIM928 is an ESD sensitive component, so more attention should be paid to the procedure of handling and packaging. The ESD test results are shown in the following table.

Table 31: The ESD characteristics (Temperature: 25℃, Humidity: 45 %)

Pin	Contact discharge	Air discharge
VBAT	±5KV	±10KV
GPS_VCC	±5KV	±10KV
GND	±5KV	±10KV
RXD, TXD	±4KV	±8KV
GPS_RXD,GPS_RXD	±4KV	±8KV
Antenna port	±5KV	±10KV
SPKP/ SPKN MICP/ MICN	±4KV	±8KV
PWRKEY	±4KV	±8KV

Note: It is suggested that customers in serials with 100ohm resistances on UART lines for ESD consideration.

6.10 Radio Characteristics

6.10.1 Module RF Output Power

The following table shows the module conducted output power, it is followed by the 3GPP TS 05.05 technical specification requirement.

Table 32: SIM928 GSM 900 and GSM 850 conducted RF output power

GSM 900 and EGSM 850			
PCL	Nominal output power (dBm)	Tolerance (dB) for conditions	
		Normal	Extreme
0-2	39	±2	±2.5
3	37	±3	±4
4	35	±3	±4
5	33	±3	±4
6	31	±3	±4
7	29	±3	±4
8	27	±3	±4
9	25	±3	±4
10	23	±3	±4
11	21	±3	±4
12	19	±3	±4
13	17	±3	±4
14	15	±3	±4
15	13	±3	±4
16	11	±5	±6
17	9	±5	±6
18	7	±5	±6
19-31	5	±5	±6

Table 33: SIM928 DCS 1800 and PCS 1900 conducted RF output power

DCS 1800 and PCS 1900			
PCL	Nominal output power (dBm)	Tolerance (dB) for conditions	
		Normal	Extreme
29	36	±2	±2.5
30	34	±3	±4
31	32	±3	±4
0	30	±3	±4
1	28	±3	±4
2	26	±3	±4

3	24	±3	±4
4	22	±3	±4
5	20	±3	±4
6	18	±3	±4
7	16	±3	±4
8	14	±3	±4
9	12	±4	±5
10	10	±4	±5
11	8	±4	±5
12	6	±4	±5
13	4	±4	±5
14	2	±5	±6
15-28	0	±5	±6

For the module's output power, the following should be noted:

At GSM900 and GSM850 band, the module is a class 4 device, so the module's output power should not exceed 33dBm, and at the maximum power level, the output power tolerance should not exceed +/-2dB under normal condition and +/-2.5dB under extreme condition.

At DCS1800 and PCS1900 band, the module is a class 1 device, so the module's output power should not exceed 30dBm, and at the maximum power level, the output power tolerance should not exceed +/-2dB under normal condition and +/-2.5dB under extreme condition.

6.10.2 Module RF Receive Sensitivity

The following table shows the module's conducted receive sensitivity, it is tested under static condition.

Table 34: SIM928 conducted RF receive sensitivity

Frequency	Receive sensitivity（Typical）	Receive sensitivity(Max)
GSM850	-109dBm	-107dBm
EGSM900	-109dBm	-107dBm
DCS1800	-109dBm	-107dBm
PCS1900	-109dBm	-107dBm

6.10.3 Module Operating Frequencies

The following table shows the module's operating frequency range; it is followed by the 3GPP TS 05.05 technical specification requirement.

Table 35: SIM928 operating frequencies

Frequency	Receive	Transmit

GSM850	869 ~ 894MHz	824 ~ 849 MHz
EGSM900	925 ~ 960MHz	880 ~ 915MHz
DCS1800	1805 ~ 1880MHz	1710 ~ 1785MHz
PCS1900	1930 ~ 1990MHz	1850 ~ 1910MHz

6.11 Module label information

The following figure marked the information of SIM928 module.

Figure 43: Module label information

Table 36: illustration of module label

Item	Description
A	Logo of SIMCom
B	Module name
C	Module part number Hardware number and software number included; ex.S2-105E0 is hardware number 0901 is software number
D	Module serial number and bar code
E	Module IMEI and bar code
F	CE authenticated logo

Appendix

A. Related Documents

Table 37: Related documents

SN	Document name	Remark
[1]	SIM908_AT Command Manual	SIM908 AT Command Manual
[2]	AN_SIM900_TCPIP	TCP/IP Applications User Manual
[3]	SIM900_Multiplexer User Manual_Application Note	SIM928 Multiplexer User Manual Application Note
[4]	AN_SIM900 Series_Update Tool_UGD	SIM928 Series Update Tool User Guide
[5]	AN_SIM900_AUDIO	Applications Note About SIM928 Audio
[6]	AN_SIM900_Audio LINE-IN input	Applications Note About SIM928 LINE-IN Input
[7]	SIM900_Embedded AT Application Note	SIM928 Embedded AT Application Note
[8]	AN_Serial Port	Application Note About Serial Port
[9]	AN_SIM900-TE PCB Layout & Schematic for Reference	Application Note About SIM928-TE PCB Layout & Schematic
[10]	Module secondary-SMT-UGD	Module secondary SMT User Guide
[11]	ITU-T Draft new recommendation V.25ter:	Serial asynchronous automatic dialing and control
[12]	GSM 07.07:	Digital cellular telecommunications (Phase 2+); AT command set for GSM Mobile Equipment (ME)
[13]	GSM 07.10:	Support GSM 07.10 multiplexing protocol
[14]	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)
[15]	GSM 11.14:	Digital cellular telecommunications system (Phase 2+); Specification of the SIM Application Toolkit for the Subscriber Identity Module – Mobile Equipment (SIM – ME) interface
[16]	GSM 11.11:	Digital cellular telecommunications system (Phase 2+); Specification of the Subscriber Identity Module – Mobile Equipment (SIM – ME) interface
[17]	GSM 03.38:	Digital cellular telecommunications system (Phase 2+); Alphabets and language-specific information
[18]	GSM 11.10	Digital cellular telecommunications system (Phase 2)； Mobile Station (MS) conformance specification； Part 1: Conformance specification
[19]	SIM28 / 68R / 68V	

	NMEA Messages SpecificationV1.00	
[20]	EPO-II_Format_Protocol _Customer	EPO-II_Format and Protocol

B. Terms and Abbreviations

Table 38: Terms and Abbreviations

Abbreviation	Description
ADC	Analog-to-Digital Converter
A-GPS	Assisted Global Positioning System
AMR	Adaptive Multi-Rate
CS	Coding Scheme
CSD	Circuit Switched Data
CTS	Clear to Send
DTE	Data Terminal Equipment (typically computer, terminal, printer)
DTR	Data Terminal Ready
DTX	Discontinuous Transmission
DGPS	Difference Global Positioning System
EFR	Enhanced Full Rate
EGSM	Enhanced GSM
ESD	Electrostatic Discharge
ETS	European Telecommunication Standard
EPO	Extended Prediction Orbit
EGNOS	European Geostationary Navigation Overlay Service
FR	Full Rate
GPRS	General Packet Radio Service
GSM	Global Standard for Mobile Communications
GPS	Global Positioning System
GAGAN	The GPS Aided Geo Augmented Navigation
HR	Half Rate
IMEI	International Mobile Equipment Identity
Li-ion	Lithium-Ion
MO	Mobile Originated
MS	Mobile Station (GSM engine), also referred to as TE
MT	Mobile Terminated
MSAS	Multi-Functional Satellite Augmentation System
NMEA	National Marine Electronics Association
PAP	Password Authentication Protocol
PBCCH	Packet Broadcast Control Channel
PCB	Printed Circuit Board
PCL	Power Control Level

PCS	Personal Communication System, also referred to as GSM 1900
PDU	Protocol Data Unit
PPP	Point-to-point protocol
QZSS	Quasi-Zenith Satellites System
RF	Radio Frequency
RMS	Root Mean Square (value)
RTC	Real Time Clock
RX	Receive Direction
RTCM	Radio Technical Commission for Maritime services
SIM	Subscriber Identification Module
SMS	Short Message Service
SBAS	Satellite Based Augmentation Systems
TE	Terminal Equipment, also referred to as DTE
TX	Transmit Direction
UART	Universal Asynchronous Receiver & Transmitter
URC	Unsolicited Result Code
USSD	Unstructured Supplementary Service Data
WAAS	Wide Area Augmentation System
Phonebook abbreviations	
FD	SIM fix dialing phonebook
LD	SIM last dialing phonebook (list of numbers most recently dialed)
MC	Mobile Equipment list of unanswered MT calls (missed calls)
ON	SIM (or ME) own numbers (MSISDNs) list
RC	Mobile Equipment list of received calls
SM	SIM phonebook
NC	Not connect

C. Safety Caution

Table 39: Safety caution

Marks	Requirements
	When in a hospital or other health care facility, observe the restrictions about the use of mobiles. Switch the cellular terminal or mobile off, medical equipment may be sensitive to not operate normally for RF energy interference.
	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 to prevent interference with communication systems. Forget to think much of these instructions may lead to the flight safety or offend against local legal action, or both.
	Do not operate the cellular terminal or mobile in the presence of flammable gases or fumes. Switch off the cellular terminal when you are near petrol stations, fuel depots, chemical plants or where blasting operations are in progress. Operation of any electrical equipment in potentially explosive atmospheres can constitute a safety hazard.

	Your cellular terminal or mobile receives and transmits radio frequency energy while switched on. RF interference can occur if it is used close to TV sets, radios, computers or other electric equipment.
	Road safety comes first! Do not use a hand-held cellular terminal or mobile when driving a vehicle, unless it is securely mounted in a holder for hands free operation. Before making a call with a hand-held terminal or mobile, park the vehicle.
	GSM cellular terminals or mobiles operate over radio frequency signals and cellular networks and cannot be guaranteed to connect in all conditions, for example no mobile fee or a invalid SIM card. While you are in this condition and need emergent help, please remember using emergency calls. In order to make or receive calls, the cellular terminal or mobile must be switched on and in a service area with adequate cellular signal strength. Some networks do not allow for emergency call if certain network services or phone features are in use (e.g. lock functions, fixed dialing etc.). You may have to deactivate those features before you can make an emergency call. Also, some networks require that a valid SIM card be properly inserted in the cellular terminal or mobile.

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