Hardware Interface Description

PCS3

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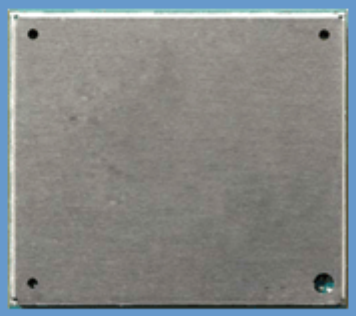

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0 Document History

New document: "PCS3 Hardware Interface Description" Version 01.000-03

Chapter	What is new
--	Initial document release

1 Introduction

The document[1] describes the hardware of the PCS3 module, designed to connect to a cellular device application and the air interface. It helps you quickly retrieve interface specifications, electrical and mechanical details and information on the requirements to be considered for integrating further components.

1.1 Related Documents

[1] PCS3 AT Command Set
[2] PCS3 Release Notes
[3] DSB75 Support Box - Evaluation Kit for Cinterion Wireless Modules
[4] Application Note 48: SMT Module Integration
[5] Universal Serial Bus Specification Revision 2.0, April 27, 2000

1.2 Terms and Abbreviations

Abbreviation	Description
ANSI	American National Standards Institute
AMR	Adaptive Multi-rate
ARP	Antenna Reference Point
BB	Baseband
BC	Band Class
BEP	Bit Error Probability
BTS	Base Transceiver Station
CB or CBM	Cell Broadcast Message
CDMA	Code Division Multiple Access
CE	Conformité Européene (European Conformity)
CS	Coding Scheme
CS	Circuit Switched
CSD	Circuit Switched Data
CTM	Cellular Text Modem
DAC	Digital-to-Analog Converter
DCS	Digital Cellular System
DL	Download
DRX	Discontinuous Reception
DSB	Development Support Board

1. The document is effective only if listed in the appropriate Release Notes as part of the technical documentation delivered with your Cinterion Wireless Modules product.

Abbreviation	Description
DSP	Digital Signal Processor
DTMF	Dual Tone Multi Frequency
DTX	Discontinuous Transmission
EFR	Enhanced Full Rate
EMC	Electromagnetic Compatibility
ERP	Effective Radiated Power
ESD	Electrostatic Discharge
ETSI	European Telecommunications Standards Institute
EVRC	Enhanced Variable Rate Codec
FCC	Federal Communications Commission (U.S.)
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FL	Forward Link
FR	Full Rate
GPS	Global Positioning System
HiZ	High Impedance
HR	Half Rate
I/O	Input / Output
IF	Intermediate Frequency
IMEI	International Mobile Equipment Identity
ISO	International Standards Organization
ITU	International Telecommunications Union
kbps	Kbit per second
LED	Light Emitting Diode
LGA	Land Grid Array
MBB	Moisture barrier bag
Mbps	Mbit per second
MCS	Modulation and Coding Scheme
MO	Mobile Originated
MS	Mobile Station, also referred to as TE
MSL	Moisture Sensitivity Level
MT	Mobile Terminated
NB	Narrow Band
NMEA	National Marine Electronics Association

Abbreviation	Description
NTC	Negative Temperature Coefficient
PBCCH	Packet Switched Broadcast Control Channel
PCB	Printed Circuit Board
PCL	Power Control Level
PCM	Pulse Code Modulation
PCS	Personal Communication System, also referred to as GSM 1900
PD	Pull Down resistor (appr. 100k)
PDU	Protocol Data Unit
PS	Packet Switched
PU	Pull Up resistor (appr. 100k)
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency
RL	Reverse Link
ROPR	Radio Output Power Reduction
RTC	Real Time Clock
Rx	Receive Direction
SAR	Specific Absorption Rate
SCI	Slot Cycle Index
SELV	Safety Extra Low Voltage
SLIC	Subscriber Line Interface Circuit
SMPL	Sudden Momentary Power Loss
SMD	Surface Mount Device
SMS	Short Message Service
SMT	Surface Mount Technology
SNR	Signal-to-Noise Ratio
SRAM	Static Random Access Memory
SRB	Signaling Radio Bearer
SUPL	Secure User Plane Location
TDMA	Time Division Multiple Access
TE	Terminal Equipment
TPC	Transmit Power Control
TTFF	Time To First Fix
TX	Transmit Direction
UL	Upload
URC	Unsolicited Result Code
USB	Universal Serial Bus

1.3 Regulatory and Type Approval Information

1.3.1 Directives and Standards

PCS3 has been designed to comply with the directives and standards listed below.

It is the responsibility of the application manufacturer to ensure compliance of the final product with all provisions of the applicable directives and standards as well as with the technical specifications provided in the "PCS3 Hardware Interface Description".[1]

Table 1: Directives

2002/95/EC	Directive of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)

Table 2: Standards of North American type approval

CFR Title 47	Code of Federal Regulations, Part 22, Part 24 and Part 27; US Equipment Authorization FCC
OET Bulletin 65 (Edition 97-01)	Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields
UL 60 950-1	Product Safety Certification (Safety requirements)
NAPRD.03 V5.11	Overview of PCS Type certification review board Mobile Equipment Type Certification and IMEI control PCS Type Certification Review board (PTCRB)
RSS132, RSS133, RSS139	Canadian Standard

Table 3: Requirements of quality

IEC 60068	Environmental testing
DIN EN 60529	IP codes

[1] Manufacturers of applications which can be used in the US shall ensure that their applications have a PTCRB approval. For this purpose they can refer to the PTCRB approval of the respective module.

Table 4: Standards of the Ministry of Information Industry of the People's Republic of China

SJ/T 11363-2006	"Requirements for Concentration Limits for Certain Hazardous Substances in Electronic Information Products" (2006-06).
SJ/T 11364-2006	"Marking for Control of Pollution Caused by Electronic Information Products" (2006-06).  According to the "Chinese Administration on the Control of Pollution caused by Electronic Information Products" (ACPEIP) the EPUP, i.e., Environmental Protection Use Period, of this product is 20 years as per the symbol shown here, unless otherwise marked. The EPUP is valid only as long as the product is operated within the operating limits described in the Cinterion Hardware Interface Description. Please see Table 5 for an overview of toxic or hazardous substances or elements that might be contained in product parts in concentrations above the limits defined by SJ/T 11363-2006.

Table 5: Toxic or hazardous substances or elements with defined concentration limits

部件名称 Name of the part	有毒有害物质或元素 Hazardous substances					
	铅 (Pb)	汞 (Hg)	镉 (Cd)	六价铬 (Cr(VI))	多溴联苯 (PBB)	多溴二苯醚 (PBDE)
金属部件 (Metal Parts)	O	O	O	O	O	O
电路模块 (Circuit Modules)	X	O	O	O	O	O
电缆及电缆组件 (Cables and Cable Assemblies)	O	O	O	O	O	O
塑料和聚合物部件 (Plastic and Polymeric parts)	O	O	O	O	O	O

O:
表示该有毒有害物质在该部件所有均质材料中的含量均在SJ/T11363-2006 标准规定的限量要求以下。
Indicates that this toxic or hazardous substance contained in all of the homogeneous materials for this part is below the limit requirement in SJ/T11363-2006.

X:
表示该有毒有害物质至少在该部件的某一均质材料中的含量超出SJ/T11363-2006标准规定的限量要求。
Indicates that this toxic or hazardous substance contained in at least one of the homogeneous materials used for this part *might exceed* the limit requirement in SJ/T11363-2006.

1.3.2 SAR requirements specific to portable mobiles

Mobile phones, PDAs or other portable transmitters and receivers incorporating a CDMA module must be in accordance with the guidelines for human exposure to radio frequency energy. This requires the Specific Absorption Rate (SAR) of portable PCS3 based applications to be evaluated and approved for compliance with national and/or international regulations.

Since the SAR value varies significantly with the individual product design manufacturers are advised to submit their product for approval if designed for portable use. For US markets the relevant directives are mentioned below. It is the responsibility of the manufacturer of the final product to verify whether or not further standards, recommendations or directives are in force outside these areas.

Products intended for sale on US markets

ES 59005/ANSI C95.1 Considerations for evaluation of human exposure to electromagnetic fields (EMFs) from mobile telecommunication equipment (MTE) in the frequency range 30MHz - 6GHz

IMPORTANT:
Manufacturers of portable applications based on PCS3 modules are required to have their final product certified and apply for their own FCC Grant and Industry Canada Certificate related to the specific portable mobile.

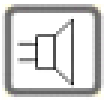
1.3.3 SELV Requirements

The power supply connected to the PCS3 module shall be in compliance with the SELV requirements defined in EN 60950-1.

1.3.4 Safety Precautions

The following safety precautions must be observed during all phases of the operation, usage, service or repair of any cellular terminal or mobile incorporating PCS3. Manufacturers of the cellular terminal are advised to convey the following safety information to users and operating personnel and to incorporate these guidelines into all manuals supplied with the product. Failure to comply with these precautions violates safety standards of design, manufacture and intended use of the product. Cinterion Wireless Modules assumes no liability for customer's failure to comply with these precautions.

	When in a hospital or other health care facility, observe the restrictions on the use of mobiles. Switch the cellular terminal or mobile off, if instructed to do so by the guidelines posted in sensitive areas. Medical equipment may be sensitive to RF energy. The operation of cardiac pacemakers, other implanted medical equipment and hearing aids can be affected by interference from cellular terminals or mobiles placed close to the device. If in doubt about potential danger, contact the physician or the manufacture of the device to verify that the equipment is properly shielded. Pacemaker patients are advised to keep their hand-held mobile away from the pacemaker, while it is on.
	Switch off the cellular terminal or mobile before boarding an aircraft. Make sure it cannot be switched on inadvertently. The operation of wireless appliances in an aircraft is forbidden to prevent interference with communications systems. Failure to observe these instructions may lead to the suspension or denial of cellular services to the offender, 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. Remember that interference can occur if it is used close to TV sets, radios, computers or inadequately shielded equipment. Follow any special regulations and always switch off the cellular terminal or mobile wherever forbidden, or when you suspect that it may cause interference or danger.
	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 speakerphone operation. Before making a call with a hand-held terminal or mobile, park the vehicle. Speakerphones must be installed by qualified personnel. Faulty installation or operation can constitute a safety hazard.

	IMPORTANT! Cellular terminals or mobiles operate using radio signals and cellular networks. Because of this, connection cannot be guaranteed at all times under all conditions. Therefore, you should never rely solely upon any wireless device for essential communications, for example emergency calls. Remember, 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 calls if certain network services or phone features are in use (e.g. lock functions, fixed dialing etc.). You may need to deactivate those features before you can make an emergency call.
	Bear in mind that exposure to excessive levels of noise can cause physical damage to users! With regard to acoustic shock, the cellular application must be designed to avoid unintentional increase of amplification, e.g. for a highly sensitive earpiece. A protection circuit should be implemented in the cellular application.

2 Product Concept

2.1 Key Features at a Glance

Feature	Implementation
General	
Frequency bands	CDMA: Dual band (BC0/BC1/BC10), 800/1900MHz
Power supply	3.3V $\leq V_{BATT+} \leq$ 4.2V
Operating temperature (board temperature)	Normal operation: -30°C to +85°C Restricted operation: -40°C to +95°C
Physical	Dimensions: 33mm x 29mm x 2mm Weight: approx. 4g
RoHS	All hardware components fully compliant with EU RoHS Directive
CDMA features	
3GPP2 CDMA2000	1xRTT Advanced data rates: FL max. 307.2kbps, RL max. 307.2kbps
SMS	Point-to-point MT and MO Cell broadcast Text and PDU mode
General	Power saving modes
Software	
AT commands	Hayes, 3GPP TS 27.007 and 27.005, and proprietary Cinterion Wireless Modules commands as well as provider specific CDMA commands
Audio	Audio speech codecs 3GPP2: EVRC, EVRC-B (4GV-NB), QCELP, AMR-NB Speakerphone operation, echo cancellation, noise suppression, 6 ringing tones, TTY support
Software update	Generic firmware update from host application over ASC0 or USB

Feature	Implementation
Interfaces	
Module interface	Surface mount device with solderable connection pads (SMT application interface). Land grid array (LGA) technology ensures high solder joint reliability and provides the possibility to use an optional module mounting socket. For more information on how to integrate SMT modules see also [4]. This application note comprises chapters on module mounting and application layout issues as well as on additional SMT application development equipment.
Antenna	50Ohms. CDMA main antenna
USB	USB 2.0 Full Speed (12Mbit/s) device interface
Serial interface	ASC0: • 8-wire modem interface with status and control lines, unbalanced, asynchronous • Adjustable baud rates from 1,200bps up to 921,600bps • Supports RTS0/CTS0 hardware flow control
Status	Signal line to indicate network connectivity state
Audio	1 analog interface with microphone feeding 1 digital interface: PCM
Power on/off, Reset	
Power on/off	Switch-on by hardware signal IGT Switch-off by AT command (AT^SMSO) Automatic switch-off in case of critical temperature or voltage conditions
Reset	Orderly shutdown and reset by AT command
Emergency-off	Emergency-off by hardware signal EMERG_OFF if IGT is not active
Special Features	
Phonebook	Phone
TTY/CTM support	TTY only
Antenna	SAIC (Single Antenna Interference Cancellation) / DARP (Downlink Advanced Receiver Performance) Rx diversity (receiver type 3i - 16-QAM)
Over-the-air provisioning	Verizon specific OTASP (Over-the-Air Service Provisioning) and OTAPA (Over-the-Air Parameter Administration)
Evaluation kit	
Evaluation module	PCS3 module soldered onto a dedicated PCB that can be connected to an adapter in order to be mounted onto the DSB75.
DSB75	DSB75 Development Support Board designed to test and type approve Cinterion Wireless Modules and provide a sample configuration for application engineering. A special adapter is required to connect the PCS3 evaluation module to the DSB75.

2.2 PCS3 System Overview

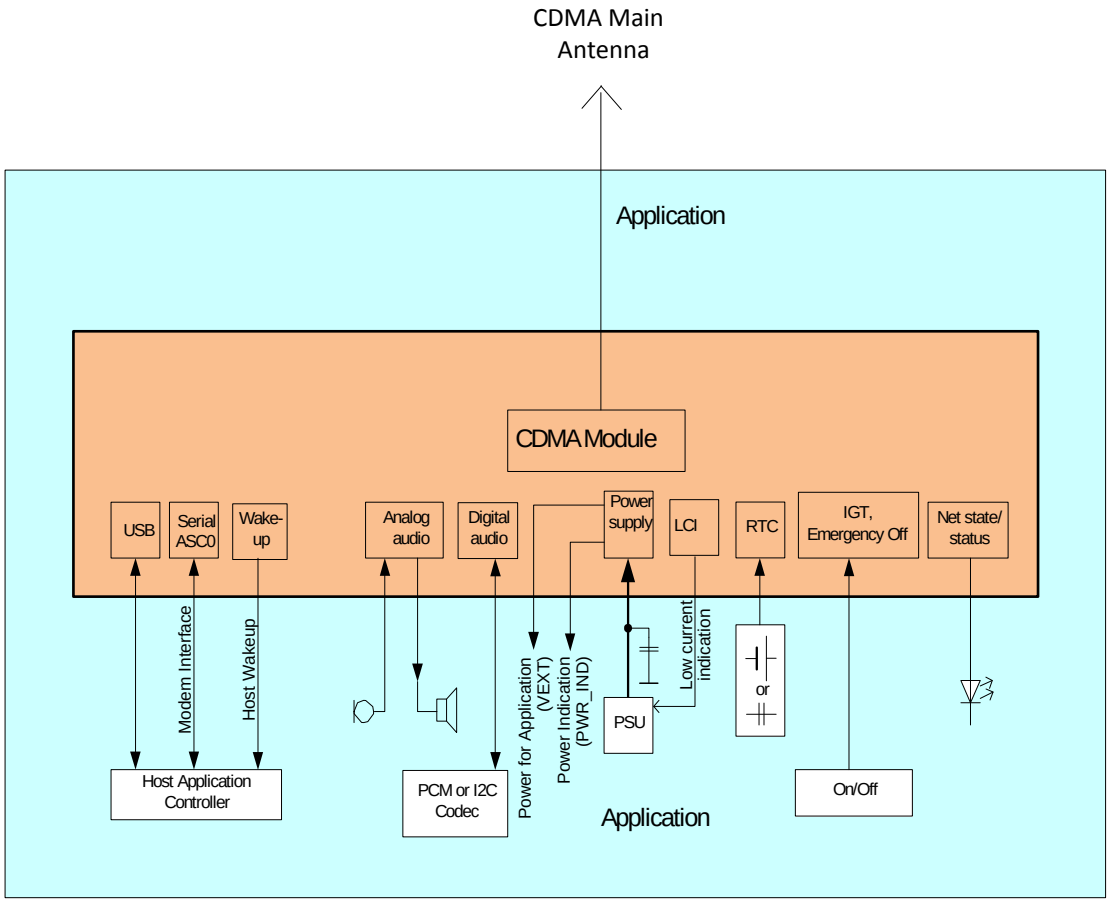


Figure 1: PCS3 system overview

2.3 Circuit Concept

Figure 2 shows a block diagram of the PCS3 module and illustrates the major functional components:

Baseband block:
- CDMA controller/transceiver/power supply
- NOR Flash/pSRAM memory with multiplexed address data bus
- Audio codec
- Application interface (SMT with connecting pads)

RF section:
- RF transceiver
- RF power amplifier/frontend
- RF filter
- Antenna pad

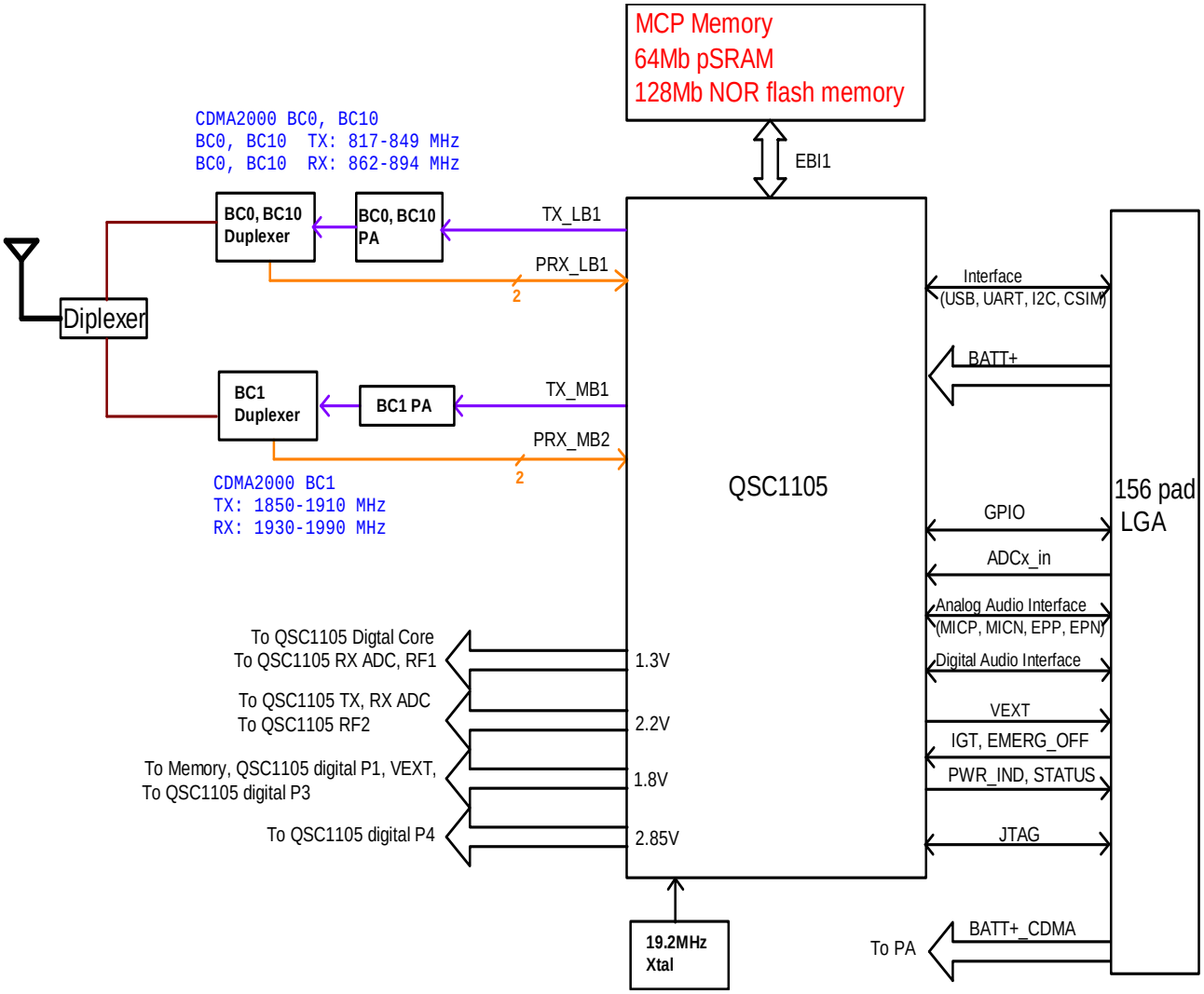


Figure 2: PCS3 block diagram

3 Application Interface

PCS3 is equipped with an SMT application interface that connects to the external application. The host interface incorporates several sub-interfaces described in the following sections:

- Operating modes - see Section 3.1
- Power supply - see Section 3.2
- RTC backup - see Section 3.5
- Serial interface USB - see Section 3.6
- Serial interface ASC0 - Section 3.7
- Analog audio interface - see Section 3.8
- Digital audio interface (PCM) - see Section 3.9
- Status and control lines: IGT, EMERG_OFF, PWR_IND, STATUS - see Table 22

3.1 Operating Modes

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

Table 6: Overview of operating modes

Mode	Function	
Normal operation	CDMA SLEEP	Power saving set automatically when no call is in progress and the USB connection is suspended by host or not present and no active communication via ASC0.
	CDMA IDLE	Power saving disabled (see [1]: AT^SCFG "MEopMode/PwrSave",<PwrSaveMode>) or an USB connection not suspended, but no call in progress.
	CDMA TALK/ CDMA DATA	CDMA data transfer in progress. Power consumption depends on network settings and data transfer rate.
Power Down	Normal shutdown after sending the AT^SMSO command. Only a voltage regulator is active for powering the RTC. Software is not active. Interfaces are not accessible. Operating voltage (connected to BATT+) remains applied.	
Airplane mode	Airplane mode shuts down the radio part of the module, causes the module to log off from the CDMA network and disables all AT commands whose execution requires a radio connection. Airplane mode can be controlled by AT command (see [1]).	

3.2 Power Supply

PCS3 needs to be connected to a power supply at the SMT application interface - 6 lines each BATT+ and GND. There are three separate voltage domains for BATT+:

- BATT+_CDMA with 2 lines for the first power amplifier supply
- BATT+_CDMA with 2 lines for the second power amplifier supply
- BATT+ with 2 lines for the general power management.

The main power supply from an external application has to be a single voltage source and has to be expanded to three sub paths (star structure). Capacitors should be placed as close as possible to the BATT+ pads. Figure 3 shows two sample circuits (minimum requirement and recommended alternative) for decoupling capacitors for BATT+.

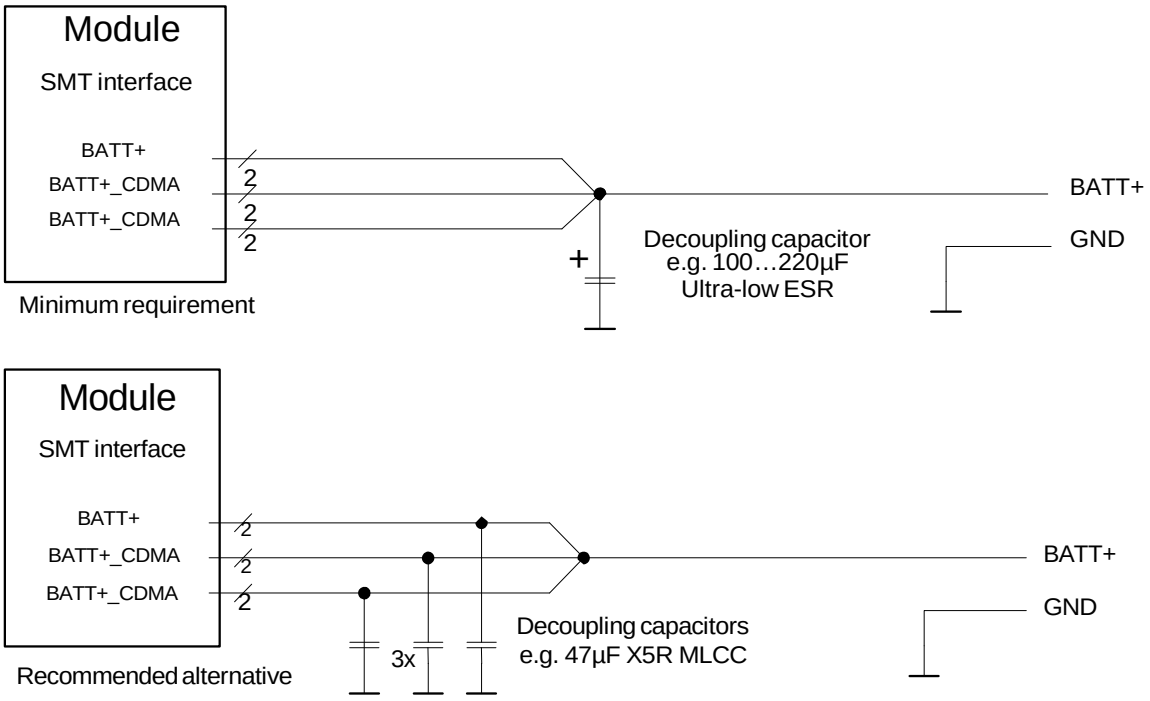


Figure 3: Decoupling capacitor(s) for BATT+

In addition, the VDDLP signal on the SMT application interface may be connected to an external capacitor or a battery to backup the RTC (see Section 3.5).

The power supply of PCS3 must be able to provide the peak current during the uplink transmission.

All key functions for supplying power to the device are handled by the power management IC. It provides the following features:

- Stabilizes the supply voltages for the baseband using switching regulators and low drop linear voltage regulators.
- Switches the module's power voltages for the power-up and -down procedures.
- Delivers, across the VEXT line, a regulated voltage for an external application. This voltage is not available in Power-down mode and can be reduced via AT command to save power (see Table 22: VEXT).

3.2.1 Monitoring Power Supply by AT Command

To monitor the supply voltage you can use the AT^SBV command which returns the averaged value related to BATT+ and GND at the SMT application interface.

The module continuously measures the voltage at intervals depending on the operating mode of the RF interface. The duration of measuring ranges from 0.5s in TALK/DATA mode to 50s when PCS3 is in Limited Service (deregistered). The displayed voltage (in mV) is averaged over the last measuring period before the AT^SBV command was executed.

3.3 Power-Up / Power-Down Scenarios

In general, be sure not to turn on PCS3 while it is beyond the safety limits of voltage and temperature stated in Section 6.1. PCS3 would immediately switch off after having started and detected these inappropriate conditions. In extreme cases this can cause permanent damage to the module.

3.3.1 Turn on PCS3

When the PCS3 module is in Power-down mode, it can be started to Normal mode by driving the IGT (ignition) line to ground. it is recommended to use an open drain/collector driver to avoid current flowing into this signal line. Pulling this signal low triggers a power-on sequence. To turn on PCS3 IGT has to be kept active at least 100ms. After turning on PCS3 IGT should be set inactive to prevent the module from turning on again after a shut down by AT command or EMERG_OFF. For details on signal states during startup see also Section 3.3.2 and Section 3.10.6.

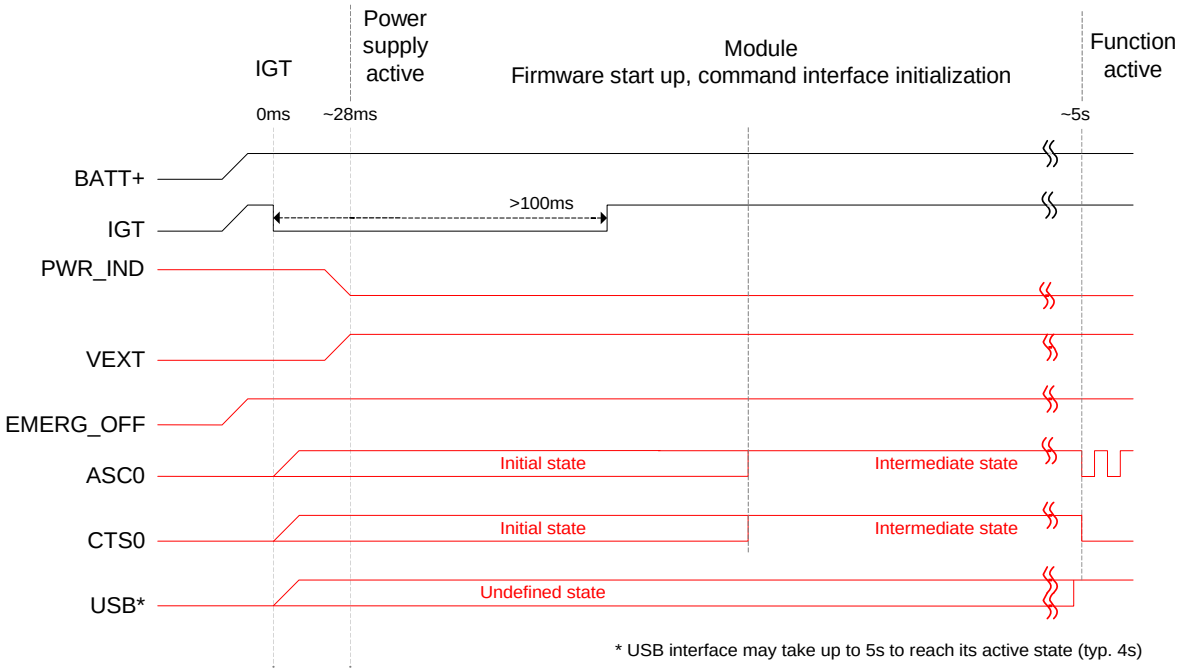


Figure 4: Power-on with IGT

Note: After power up IGT should remain high. Also note that with a USB connection the USB host may take more than 5 seconds to set up the virtual COM port connection.

After startup or mode change the following URCs sent to every port able to receive AT commands indicating the module's ready state:

- "^SYSSTART" indicates that the module has entered Normal mode.
- "^SYSSTART AIRPLANE MODE" indicates that the module has entered Airplane mode.

These URCs notify the external application that the first AT command can be sent to the module. If these URCs are not used to detect then the only way of checking the module's ready state is polling. To do so, try to send characters (e.g. "at") until the module is responding.

3.3.2 Signal States after Startup

Table 7 describes the various states each interface signal passes through after startup and during operation.

Signals are in an initial state while the module is initializing. Once the startup initialization has completed, i.e. when the software is running, all signals are in defined state. The state of several signals will change again once the respective interface is activated or configured by AT command (for more information see also Section 3.10.6).

Table 7: Signal states

Signal name	Power on reset Duration appr. 150ms	Startup phase Duration appr. 4s	State after first firmware initialization After 4-4.5s
RXD0	PD	PU	O, H
TXD0	PD	PD	I, PD
CTS0	PD	PU	O, L
RTS0	PD	PD	I, PD
DTR0	PD	PU	I, PU
DCD0	PD	PU[1]	O, H
DSR0	PU	PU	O, L
RING0	PU	PU	O, H
WAKEUP	PD	PD	PD
LCI_IND	PD	PD	PD
PWR_IND	O, L	O, L	O, L
STATUS	PD	PD	PD
PCM	PD	PD	PD

1. No external pull down allowed during this phase.

L = Low level H = High level I = Input O = Output	PD = Pull down resistor with appr. 100k PD(…k) = Pull down resistor with ...k PU = Pull up resistor with appr. 100k PU(…k) = Pull up resistor with ...k

3.3.3 Turn off PCS3 Using AT Command

The best and safest approach to powering down PCS3 is to issue the AT^SMSO command. This procedure lets PCS3 log off from the network and allows the software to enter into a secure state and safe data before disconnecting the power supply. The mode is referred to as Power Down mode. In this mode, only the RTC stays active. After sending AT^SMSO do not enter any other AT commands. To verify that the module turned off it is possible to monitor the PWR_IND signal. A high state of the PWR_IND signal line definitely indicates that the module is switched off.

Be sure not to disconnect the supply voltage V_{BATT+} before the module has been switched off and the PWR_IND signal has gone high. Otherwise you run the risk of losing data.

While PCS3 is in Power-down mode the application interface is switched off and must not be fed from any other source. Therefore, your application must be designed to avoid any current flow into any digital signal lines of the application interface, especially of the serial interfaces. No special care is required for the USB interface which is protected from reverse current.

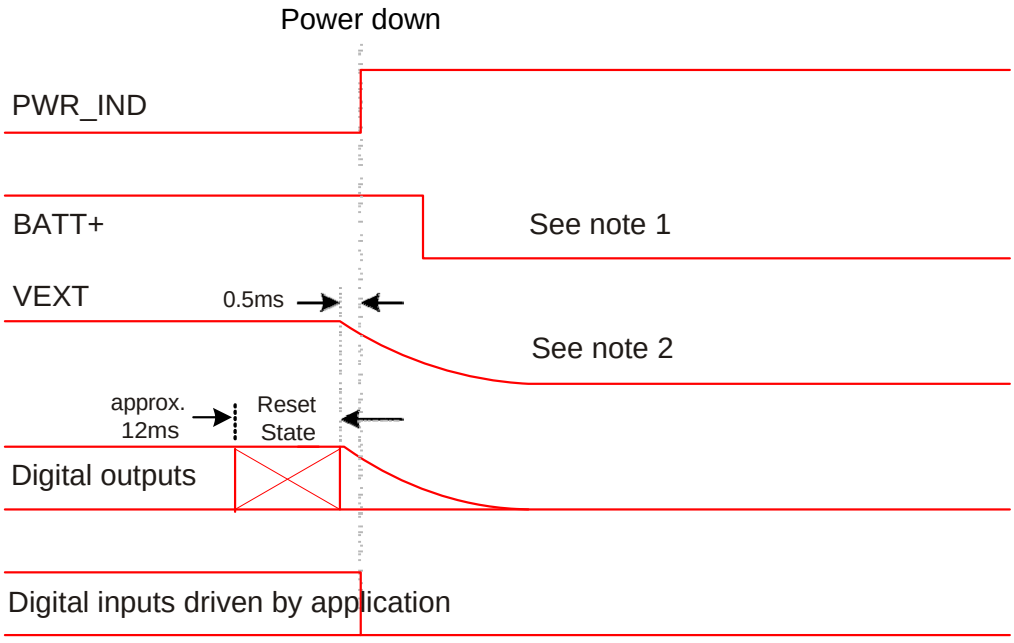


Figure 5: Signal states during turn-off procedure

Note 1: The power supply voltage (BATT+) may be disconnected resp. switched off only after having reached Power Down mode as indicated by the PWR_IND signal going high.

Note 2: Depending on capacitance load from host application.

Note 3: After module shutdown by means of AT command, please allow for a time period of at least 1s before restarting the module.

3.3.4 Configuring the IGT Line for Use as ON/OFF Switch

The IGT line can be configured for use in two different switching modes: You can set the IGT line to switch on the module only, or to switch it on and off. The switching mode is determined by the parameter "MEShutdown/OnIgnition" of the AT^SCFG command. This approach is useful for application manufacturers who wish to have an ON/OFF switch installed on the host device.

By factory default, the ON/OFF switch mode of IGT is disabled:

```
at^scfg=meshutdown/onignition                  # Query the current status of IGT.
^SCFG:"MEShutdown/OnIgnition","off"            # IGT can be used only to switch on PCS3.
OK                                             IGT works as described in Section 3.3.1.
```

To configure IGT for use as ON/OFF switch:

```
at^scfg=meshutdown/onignition                  # Enable the ON/OFF switch mode of IGT.
^SCFG:"MEShutdown/OnIgnition","on"             # IGT can be used to switch on and off PCS3.
OK
```

We strongly recommend taking great care before changing the switching mode of the IGT line. To ensure that the IGT line works properly as ON/OFF switch it is of vital importance that the following conditions are met.

Switch-on condition: If the PCS3 is off, the IGT line must be asserted for at least 100ms before being released.

Switch-off condition: If the PCS3 is on, the IGT line must be asserted for at least 2.1s before being released. The module switches off after the line is released. The switch-off routine is identical with the procedure initiated by AT^SMSO, i.e. the software performs an orderly shutdown as described in Section 3.3.3. Before switching off the module wait at least 5 seconds after startup.

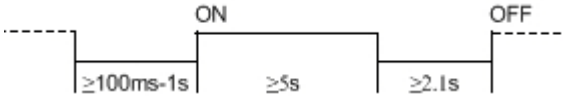


Figure 6: Timing of IGT if used as ON/OFF switch

3.3.5 Automatic Shutdown

Automatic shutdown takes effect if:
- The PCS3 board is exceeding the critical limits of overtemperature or undertemperature
- Undervoltage or overvoltage is detected

The automatic shutdown procedure is equivalent to the power down initiated with the AT^SMSO command, i.e. PCS3 logs off from the network and the software enters a secure state avoiding loss of data.

Alert messages transmitted before the device switches off are implemented as Unsolicited Result Codes (URCs). The presentation of the temperature URCs can be enabled or disabled with the AT commands AT^SCTM. The URC presentation mode varies with the condition, please see Section 3.3.5.1 to Section 3.3.5.3 for details. For further instructions on AT commands refer to [1].

3.3.5.1 Thermal Shutdown

The board temperature is constantly monitored by an internal NTC resistor located on the PCB. The values detected by the NTC resistor are measured directly on the board and therefore, are not fully identical with the ambient temperature.

Each time the board temperature goes out of range or back to normal, PCS3 instantly displays an alert (if enabled).

- URCs indicating the level "1" or "-1" allow the user to take appropriate precautions, such as protecting the module from exposure to extreme conditions. The presentation of the URCs depends on the settings selected with the AT^SCTM write command:
  AT^SCTM=1: Presentation of URCs is always enabled.
  AT^SCTM=0 (default): Presentation of URCs is enabled during the 15 second guard period after start-up of PCS3. After expiry of the 15 second guard period, the presentation will be disabled, i.e. no URCs with alert levels "1" or "-1" will be generated.
- URCs indicating the level "2" or "-2" are instantly followed by an orderly shutdown. The presentation of these URCs is always enabled, i.e. they will be output even though the factory setting AT^SCTM=0 was never changed.

The maximum temperature ratings are stated in Section 6.2. Refer to Table 8 for the associated URCs.

Table 8: Temperature dependent behavior

Sending temperature alert (15sec after PCS3 start-up, otherwise only if URC presentation enabled)	
^SCTM_B: 1	Caution: Board close to over temperature limit, i.e., board is 5°C below over temperature limit.
^SCTM_B: -1	Caution: Board close to under temperature limit, i.e., board is 5°C above under-temperature limit.
^SCTM_B: 0	Board back to uncritical temperature range, i.e., board is 6°C below its over- or above its under temperature limit.
Automatic shutdown (URC appears no matter whether or not presentation was enabled)	
^SCTM_B: 2	Alert: Board equal or beyond over temperature limit. PCS3 switches off.
^SCTM_B: -2	Alert: Board equal or below under temperature limit. PCS3 switches off.

The AT^SCTM command can also be used to check the present status of the board. Depending on the selected mode, the read command returns the current board temperature in degrees Celsius or only a value that indicates whether the board is within the safe or critical temperature range. See [1] for further instructions.

3.3.5.2 Under voltage Shutdown

If the measured battery voltage is no more sufficient to set up a call the following URC will be presented:

^SBC: Under voltage.

The URC indicates that the module is close to the under voltage threshold. If under voltage persists the module keeps sending the URC several times before switching off automatically.

This type of URC does not need to be activated by the user. It will be output automatically when fault conditions occur.

3.3.5.3 Over voltage Shutdown

The overvoltage shutdown threshold is 100mV above the maximum supply voltage V_{BATT+} specified in Table 22.

When the supply voltage approaches the overvoltage shutdown threshold the module will send the following URC:

^SBC: Overvoltage warning

This alert is sent once.

When the overvoltage shutdown threshold is exceeded the module will send the following URC

^SBC: Overvoltage shutdown

before it shuts down cleanly:

This type of URC does not need to be activated by the user. It will be output automatically when fault conditions occur.

Keep in mind that several PCS3 components are directly linked to BATT+ and, therefore, the supply voltage remains applied at major parts of PCS3, even if the module is switched off. Especially the power amplifier is very sensitive to high voltage and might even be destroyed.

3.3.6 Automatic Reset

An automatic reset takes effect if

- A sudden momentary power loss (SMPL) occurs - e.g., a very brief battery disconnect - and the power returns within 2 seconds.

The SMPL feature ensures that if VBATT+ drops out-of-range (< 2.55V nominal) and then returns into range within 2 seconds, the power-on sequence is executed and the module switches on again. Thus the SMPL feature achieves immediate and automatic recovery from momentary power loss such as a brief battery disconnect.

To employ the SMPL feature the VDDLP line has to supplied for at least 2 seconds after a possible power loss (e.g., by connecting a 10µF capacitor).

3.3.7 Turn off PCS3 in Case of Emergency

Caution: Use the EMERG_OFF line only when, due to serious problems, the software is not responding for more than 5 seconds. Pulling the EMERG_OFF line causes the loss of all information stored in the volatile memory. Therefore, this procedure is intended only for use in case of emergency, e.g. if PCS3 does not respond, if reset or shutdown via AT command fails.

The EMERG_OFF line is available on the application interface and can be used to switch off the module. To control the EMERG_OFF line it is recommended to use an open drain / collector driver.

To switch off, the EMERG_OFF line must be pulled to ground for longer than 40ms. After the 40ms and an additional delay period of 500ms the module shuts down as shown in Figure 7.

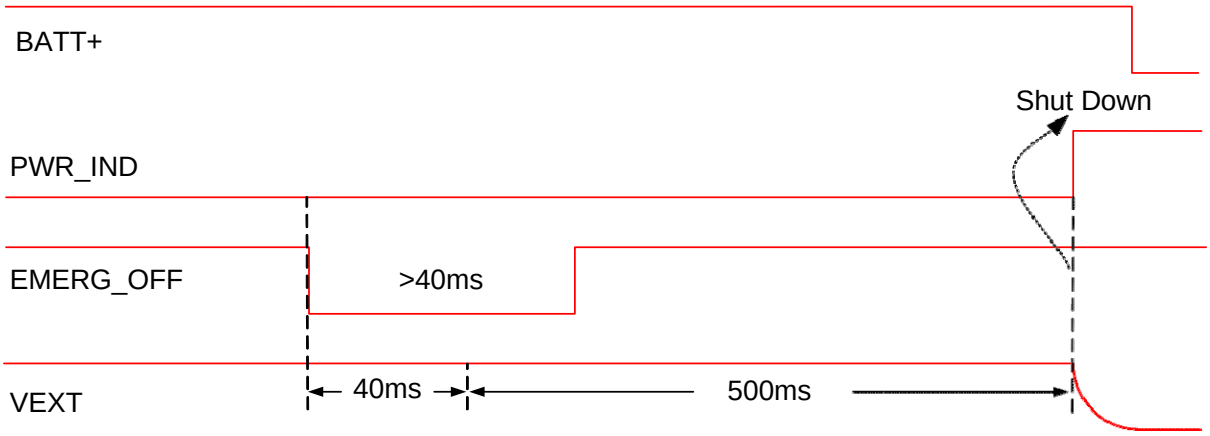


Figure 7: Shutdown by EMERG_OFF signal

Please note that the power supply voltage (BATT+) may be disconnected resp. switched off only after having reached Shut Down as indicated by the PWR_IND signal going high. The power supply has to be available (again) before the module is restarted.

3.4 Power Saving

PCS3 is able to reduce its functionality to a minimum (during the so-called SLEEP mode) in order to minimize its current consumption. The following sections explain the module's CTS0 behavior and also mention how to wake up from or disable the so-called SLEEP mode.

The implementation of the USB host interface also influences the module's power saving behavior and therefore its current consumption. For more information see Section 3.6.

Note. The module's SLEEP mode current consumption can be reduced significantly (0.8mA) by enabling the VEXT power save mode. Hence, it is recommended to enable power saving on VEXT if at all possible. For more information see Table 22: VEXT.

Another feature influencing the current consumption is the configuration of the GNSS antenna interface. For details see Section 6.9.

3.4.1 Power Saving while Attached to CDMA Networks

The so-called slotted paging in CDMA is similar to the WCDMA paging timing cycles for power saving.

During normal CDMA operation, i.e., the module is connected to a CDMA network, the duration of a power saving period varies. It may be calculated using the following formula:

$T=2^i$ * 1.28s (16 slots of 80ms)

The slot cycle index i is determined by the CDMA network and can be an integer between -4 to 7 inclusive. The typical value is 2. Therefore, the typical power saving period would be (2^2)*1.28s = 5.12s.

3.4.2 Timing of the CTS0 Signal, CDMA

As long as PCS3 is operated via the ASC0 interface and not in power saving mode, the CTS0 line is always active. This means that while attached to a network the CTS0 signal will be tem poraly active during each paging.

After a concluding activity on the serial interface ASC0 - and depending on the module's other activities - it takes by default 5 seconds before CTS0 goes inactive (again) and power saving starts. The 5 second delay period can be configured using the AT^SCFG parameter "MEop-Mode/PwrSave", <PwrSaveDelay> (see [1]).

With regard to programming or using timeouts, the UART must take the varying CTS0 inactivity periods into account.

Note: Hardware handshaking is mandatory if employing PCS3's ASC0 interface with enabled power saving. Thus AT commands are only recognized by the module while CTS0 is active.

3.4.3 Wake up from or Disabling Power Saving

The RTS0 line can be used to wake up the module from its power saving SLEEP mode. RTS0 activation (high to low transition) may be employed to cut short pauses between listening to paging messages. Following an RTS toggle the module will return to SLEEP mode 5 seconds after the last character was sent over the interface. This default delay period can be configured using the AT^SCFG parameter "MEopMode/PwrSave", <PwrSaveDelay>.

If not regularly woken up from power saving (through network requirements or by means of RTS toggling as described above), the power saving timeout recommended for the AT^SCFG parameter "MEopMode/PwrSave", <PwrSaveTimeout> ensures that the module regularly wakes up from its power saving state (SLEEP mode). It is recommended to configure a regular module wake up, especially if the radio interface is switched off (Airplane mode) and the module is connected via serial interface (i.e., AT^SDPORT=2) to an external application without direct access to its RTS0 line (e.g., an application using standard Windows/Linux serial device drivers).

The AT^SCFG parameter "MEopMode/PwrSave", <PwrSaveMode> can be used to disable power saving completely, i.e., the module will no longer enter SLEEP mode but remain in IDLE mode instead. Please note that if this setting is used to avoid implementing hardware handshaking on ASC0, it is mandatory to have RTS0 pulled down or left open (an internal pull down is available).

For more information on power saving and the appropriate AT^SCFG parameters to configure the power save behavior see [1].

3.5 RTC Backup

The internal Real Time Clock of PCS3 is supplied from a separate voltage regulator in the power supply component which is also active when PCS3 is in Power Down mode and BATT+ is available.

In addition, you can use the VDDLP line on the SMT interface to backup the RTC from an external capacitor or a battery (rechargeable or non-chargeable). The capacitor is charged from the internal LDO of PCS3. If the voltage supply at BATT+ is disconnected the RTC can be powered by the capacitor. The size of the capacitor determines the duration of buffering when no voltage is applied to PCS3, i.e. the greater the capacitor the longer PCS3 will save the date and time. It limits the output current of an empty capacitor or battery.

Figure 8 show various sample configurations.

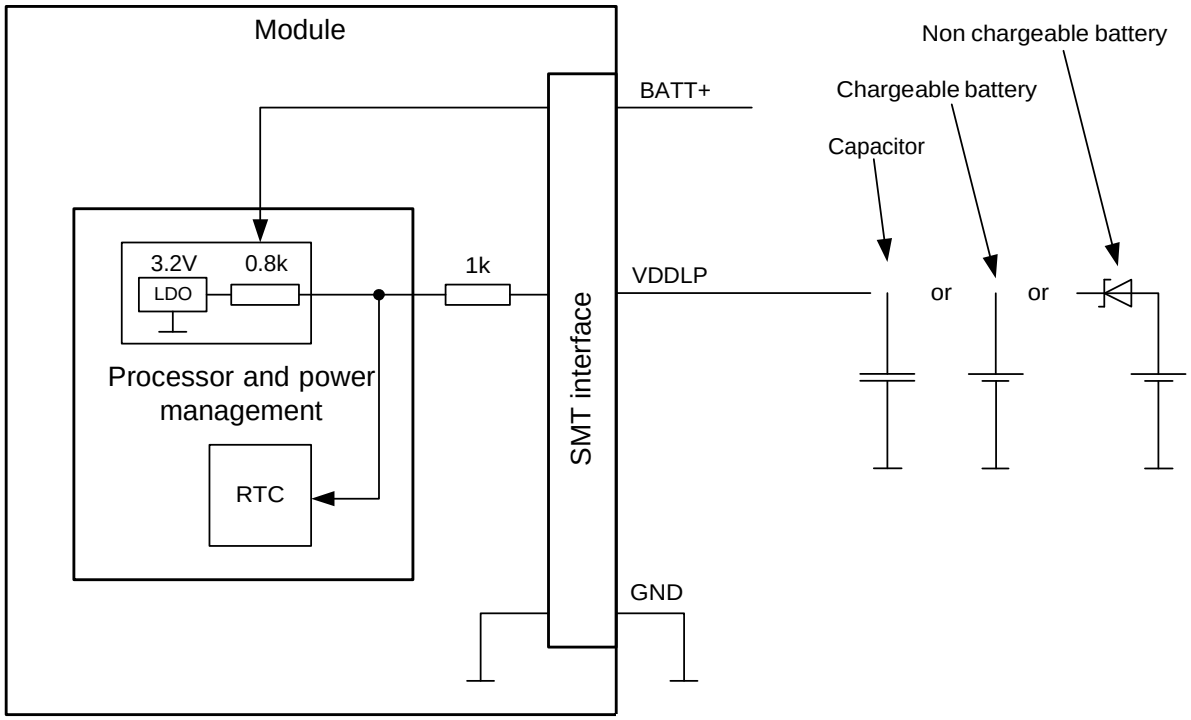
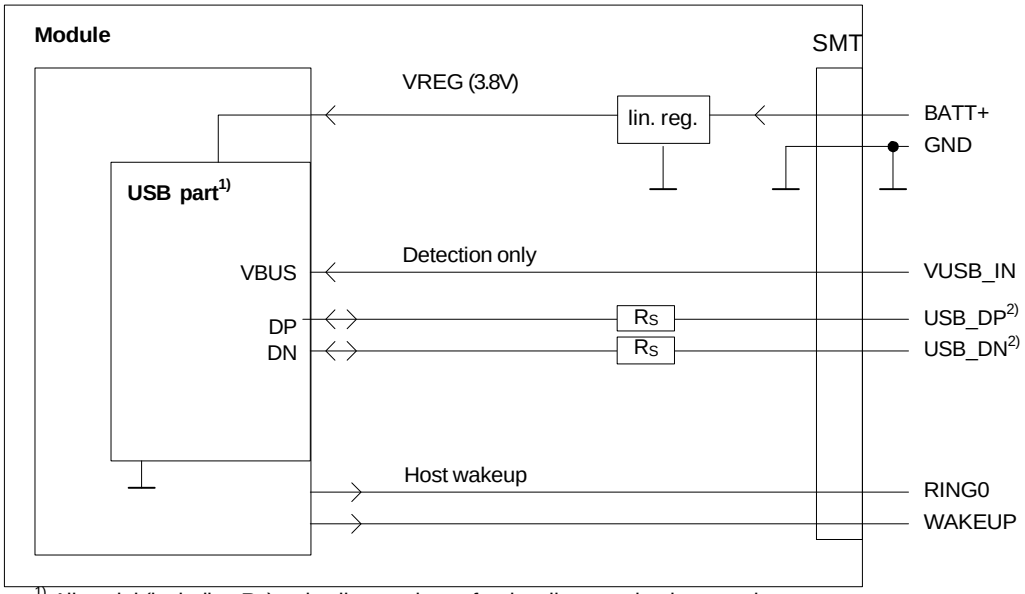


Figure 8: RTC supply variants

3.6 USB Interface

PCS3 supports a USB 2.0 Full Speed (12Mbit/s) compliant. The USB interface is primarily intended for use as command and data interface and for downloading firmware.

The external application is responsible for supplying the VUSB_IN line. This line is used for cable detection only. The USB part (driver and transceiver) is supplied by means of BATT+. This is because PCS3 is designed as a self-powered device compliant with the “Universal Serial Bus Specification Revision 2.0”[1].



1) All serial (including R_S)and pull-up resistors for data lines are implemented.
2) The USB interface is operated in Full Speed (12Mbit/s), it is recommended to take special care routing the data lines USB_DP and USB_DN. Application layout should in this case implement a differential impedance of 90Ohm for proper signal integrity.

Figure 9: USB circuit

To properly connect the module's USB interface to the external application, a USB 2.0 compatible connector and cable or hardware design is required. For more information on the USB related electrical signals see Table 22.

1. The specification is ready for download on http://www.usb.org/developers/docs/

3.6.1 Reducing Power Consumption

While a USB connection is active, the module will never switch into SLEEP Mode. Only if the USB interface is in Suspended state or Detached (i.e., VUSB_IN = 0) is the module able to switch into SLEEP mode thereby saving power. There are two possibilities to enable power reduction mechanisms:

- **Recommended implementation of USB Suspend/Resume/Remote Wakeup:**
  The USB host should be able to bring its USB interface into the Suspended state as described in the “Universal Serial Bus Specification Revision 2.0“[1]. For this functionality to work, the VUSB_IN line should always be kept enabled. On incoming calls and other events PCS3 will then generate a Remote Wakeup request to resume the USB host controller.

  See also [5] (USB Specification Revision 2.0, Section 10.2.7, p.282):
  "If USB System wishes to place the bus in the Suspended state, it commands the Host Controller to stop all bus traffic, including SOFs. This causes all USB devices to enter the Suspended state. In this state, the USB System may enable the Host Controller to respond to bus wakeup events. This allows the Host Controller to respond to bus wakeup signaling to restart the host system."

- **Implementation for legacy USB applications not supporting USB Suspend/Resume:**
  As an alternative to the regular USB suspend and resume mechanism it is possible to employ the RING0 or WAKEUP line to wake up the host application in case of incoming calls or events signalized by URCs while the USB interface is in Detached state (i.e., VUSB_IN = 0). Every wakeup event will force a new USB enumeration. Therefore, the external application has to carefully consider the enumeration timings to avoid loosing any signalled events. For details on this host wakeup functionality see Section 3.10.4.

[1] The specification is ready for download on http://www.usb.org/developers/docs/

3.7 Serial Interface ASC0

PCS3 offers an 8-wire unbalanced, asynchronous modem interface ASC0 conforming to ITU-T V.24 protocol DCE signalling. The electrical characteristics do not comply with ITU-T V.28. The significant levels are 0V (for low data bit or active state) and 1.8V (for high data bit or inactive state). For electrical characteristics please refer to Table 22. For an illustration of the interface line's startup behavior see Section 3.10.6.

PCS3 is designed for use as a DCE. Based on the conventions for DCE-DTE connections it communicates with the customer application (DTE) using the following signals:
- Port TXD @ application sends data to the module's TXD0 signal line
- Port RXD @ application receives data from the module's RXD0 signal line

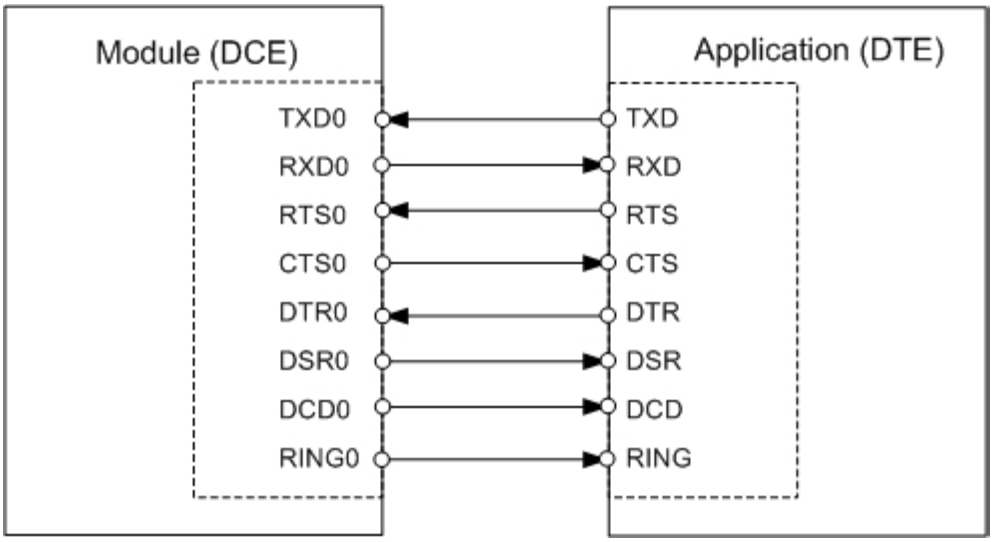


Figure 10: Serial interface ASC0

Features:
- Includes the data lines TXD0 and RXD0, the status lines RTS0 and CTS0 and, in addition, the modem control lines DTR0, DSR0, DCD0 and RING0.
- ASC0 is designed for controlling voice calls, transferring data and for controlling the module with AT commands.
- Full multiplexing capability allows the interface to be partitioned into virtual channels.
- The RING0 signal serves to indicate incoming calls and other types of URCs (Unsolicited Result Code). It can also be used to send pulses to the host application, for example to wake up the application from power saving state. See [1] for details on how to configure the RING0 line by AT^SCFG.
- Configured for 8 data bits, no parity and 1 stop bit.
- ASC0 can be operated at fixed bit rates from 9600bps up to 921600bps.
- Supports RTS0/CTS0 hardware flow control.
- Wake up from SLEEP mode by RTS0 activation (high to low transition).

Note. If the ASC0 serial interface is the application's only interface, it is suggested to connect test points on the USB signal lines as a potential tracing possibility.

Table 9: DCE-DTE wiring of ASC0

V.24 circuit	DCE		DTE	
	Line function	**Signal direction**	**Line function**	**Signal direction**
103	TXD0	Input	TXD	Output
104	RXD0	Output	RXD	Input
105	RTS0	Input	RTS	Output
106	CTS0	Output	CTS	Input
108/2	DTR0	Input	DTR	Output
107	DSR0	Output	DSR	Input
109	DCD0	Output	DCD	Input
125	RING0	Output	RING	Input

3.8 Analog Audio Interface

PCS3 has an analog audio interface with a balanced analog microphone input and a balanced analog earpiece output. A supply voltage and an analog ground connection are provided at dedicated lines.

PCS3 offers eight audio modes which can be selected with the AT^SNFS command. The electrical characteristics of the voiceband part vary with the audio mode. For example, sending and receiving amplification, sidetone paths, noise suppression etc. depend on the selected mode and can in parts be altered with AT commands (except for mode 1).

Please refer to Section 6.7 for specifications of the audio interface and an overview of the audio parameters. Detailed instructions on using AT commands are presented in [1]. Table 25 summarizes the characteristics of the various audio modes and shows what parameters are supported in each mode.

When shipped from factory, all audio parameters of PCS3 are set to audio mode 1. This is the default configuration optimized for the Votronic HH-SI-30.3/V1.1/0 handset and used for type approving the Cinterion Wireless Modules reference configuration. Audio mode 1 has fix parameters which cannot be modified. To adjust the settings of the Votronic handset simply change to another audio mode.

3.8.1 Microphone Inputs and Supply

The differential microphone inputs MICP and MICN present variable impedances depending on the gain. The microphone inputs must be decoupled by capacitors Ck (typical 1µF). The input stage uses a differential operational amplifier circuit with programmable resistors in the input and the feedback path. The detailed structure of this stage and the following uplink path is shown in Figure 11. The input can be controlled by the AT command AT^SNFI. Command parameters with their effect are mentioned in the figure and marked in <red>. More information about audio AT commands can be found in Section 6.7 and [1].

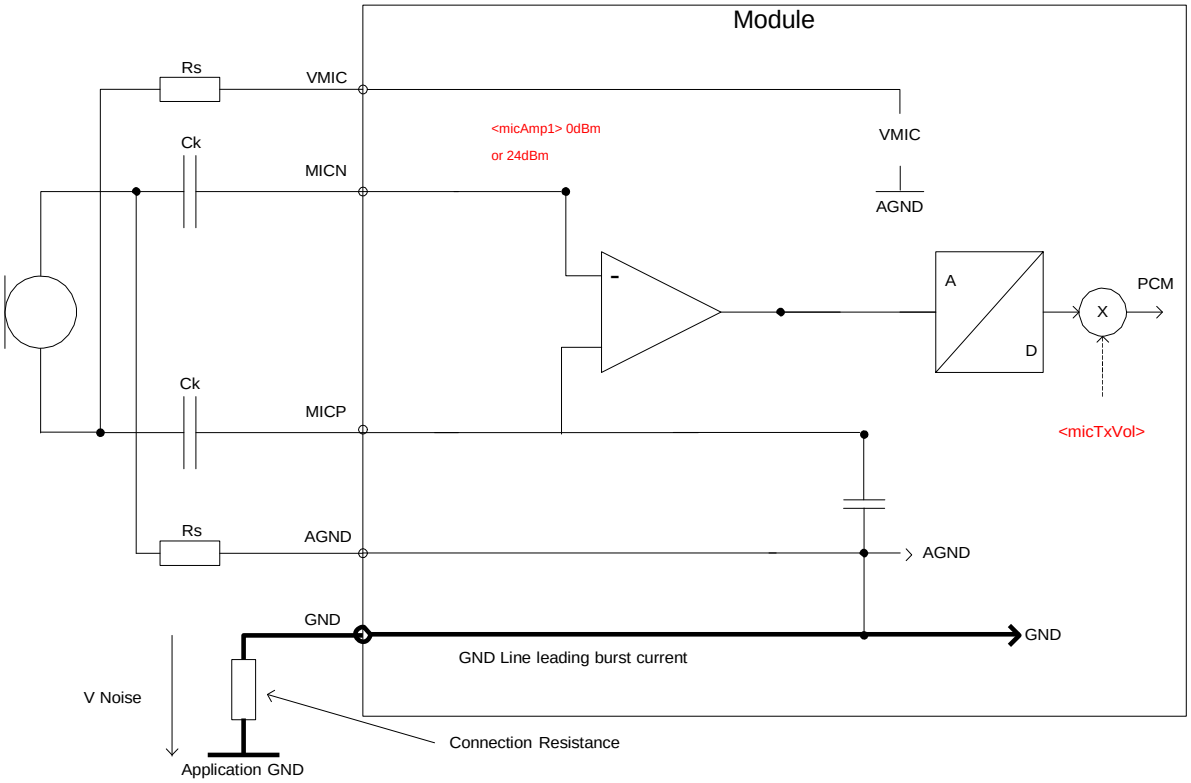


Figure 11: Structure of Audio Input and Supply

MICP leads the signal via to the non-inverting input of the operational amplifier which is then connected via to AGND. The gain of the input stage can be programmed by the parameter <micAmp1>, A gain stage follows that can be set to 0dB or 24dB using <micAmp1>. If 24dB is spec- ified, the common mode rejection ratio is reduced accordingly.

Finally, the uplink gain can be scaled in the PCM path by the <micTxVol> parameter.

It is recommended to use the AGND line for grounding the microphone circuit. AGND provides for the same module ground potential the analog circuits of the module refer to. AGND must not be connected to the system GND anywhere. Otherwise high burst peak currents may flow across AGND causing humming in the uplink audio signal.

A regulated power supply for electret microphones is available at VMIC. The voltage at VMIC is rated at 1.8V at 3mA and is available while audio is active (e.g., during a call).

The following figures show possible microphone and line connections.

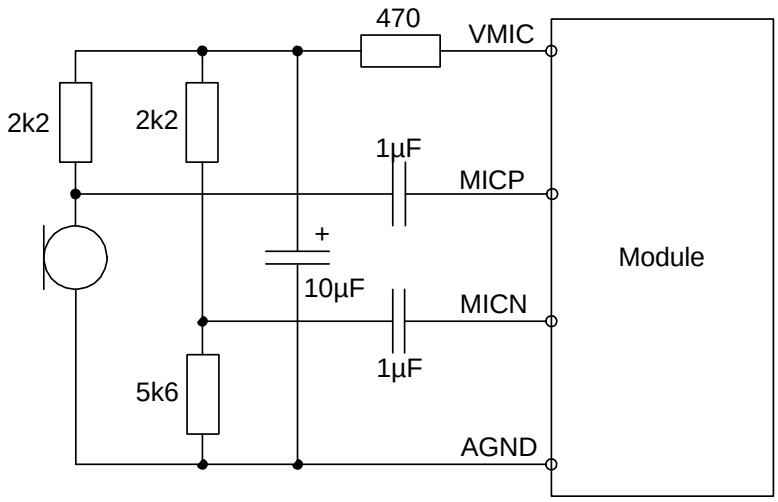


Figure 12: Single ended microphone connection

The configuration shown in Figure 12 is suitable for short distances between microphone and module. A typical electric microphone has a metal case connected to its ground pad. Since this is routed directly to AGND, electro static discharges applied to the microphone will be easily led away. It is recommended to use an additional RC-filter for VMIC (for example 470 Ohm and 10µF as shown in the figure) in case a high microphone gain is necessary.

If the microphone lines are longer, use the configuration shown in Figure 13. It is recommended to use an additional RC-filter for VMIC (for example 1kOhm, 10µF and 1kOhm as shown in the figure) in case a high microphone gain is necessary.

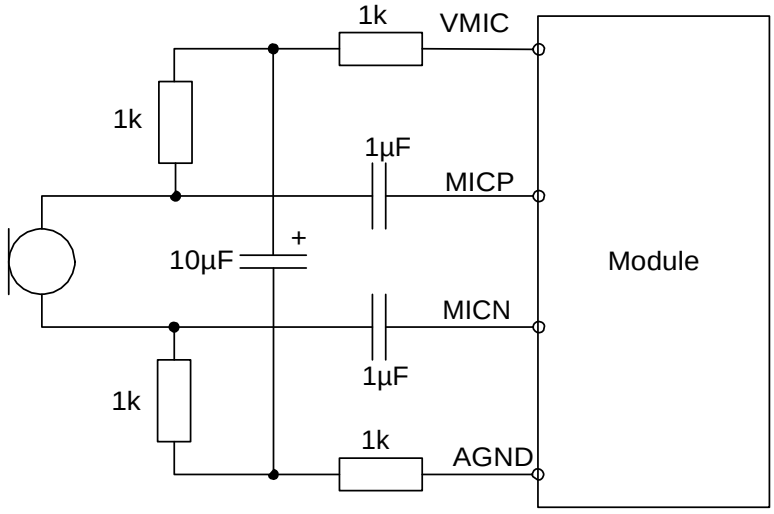


Figure 13: Differential microphone connection

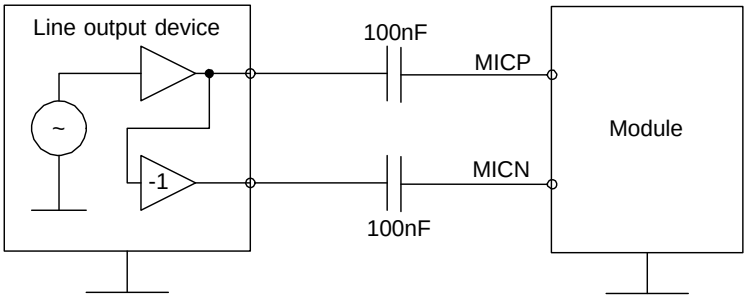


Figure 14: Line input

Using the line input configuration the output level of the ground related balanced source should be as high as possible to achieve the best SNR. Since the input impedance of PCS3 is quite high at low gains, the coupling capacitances may be smaller.

3.8.2 Loudspeaker Output

PCS3 provides a differential loudspeaker output EPP/EPN. If it is used as line output, the application should provide a capacitor decoupled differential input to eliminate humming. A single ended connection to a speaker or a line input is strongly not recommended.

The following figures show the typical output configurations.

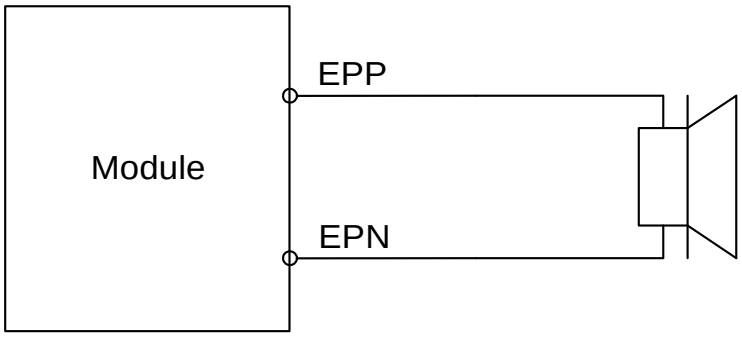


Figure 15: Differential loudspeaker connection

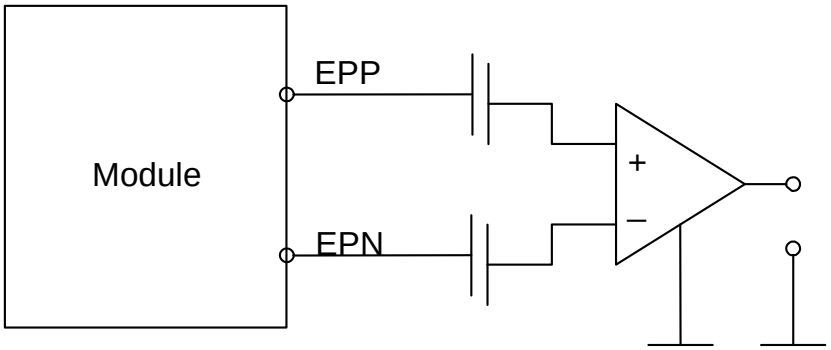


Figure 16: Line output connection

3.9 Digital Audio Interface

PCS3 supports a digital audio interface that can be employed either as pulse code modulation (see Section 3.9.1) or as inter IC sound interface (see Section 3.9.2). Operation of these interface variants is mutually exclusive.

3.9.1 Pulse Code Modulation Interface (PCM)

PCS3's PCM interface can be used to connect audio devices capable of pulse code modulation. The PCM functionality allows the use of a codec like the Freescale MC145483. Using the AT^SAIC command you can activate and configure the PCM interface (see [1]).

The PCM interface supports the following modes:
- Master mode, slave mode
- Short frame synchronization
- 256kHz, 512kHz and 2048kHz bit clock
- Additional master mode with 128kHz, long frame synchronization

For the PCM interface configuration the parameters <clock>, <mode> <frame_mode> and <ext_clk_mode> of the AT^SAIC command can be configured. The following table lists possible combinations:

Table 11: Configuration combinations for the PCM interface

Configuration	<clock>	<mode>	<frame_mode>	<ext_clk_mode>
Master, 128kHz, long frame	0	0	1	0 or 1
Master, 256kHz, short frame	1	0	0	0 or 1
Master, 512kHz, short frame	2	0	0	0 or 1
Master, 2048kHz, short frame	3	0	0	0 or 1
Slave, 256kHz, short frame	1	1	0	1
Slave, 512kHz, short frame	2	1	0	1
Slave, 2048kHz, short frame	3	1	0	1

In slave mode <clock> must be set according the source clock frequency. Being in master mode clock and frame synchronization signals may be permanently switched on by <ext_clk_mode> parameter. These signals may be used for clocking digital audio periphery outside a call.

Table 12 lists the available PCM interface signals.

Table 12: Overview of PCM signal functions

Signal name on SMT application interface	Signal configuration inactive[1]	Signal direction: Master	Signal direction: Slave	Description
PCM_OUT	PD	O	O	PCM Data from PCS3 to external codec
PCM_IN	PD	I	I	PCM Data from external codec to PCS3

Table 12: Overview of PCM signal functions

Signal name on SMT application interface	Signal configuration inactive[1]	Signal direction: Master	Signal direction: Slave	Description
PCM_FSC	PD	O	I	Frame synchronization signal to/from external codec
PCM_CLK	PD	O	I	Bit clock to/from external codec

1. Inactive means no call, no tone generation and no external clock mode. PD = Pull down

The timing of a PCM short frame is shown in Figure 17. The timing for master and slave mode is identical, except for the PCM_FSC and PCM_CLK signal direction (see Table 12).

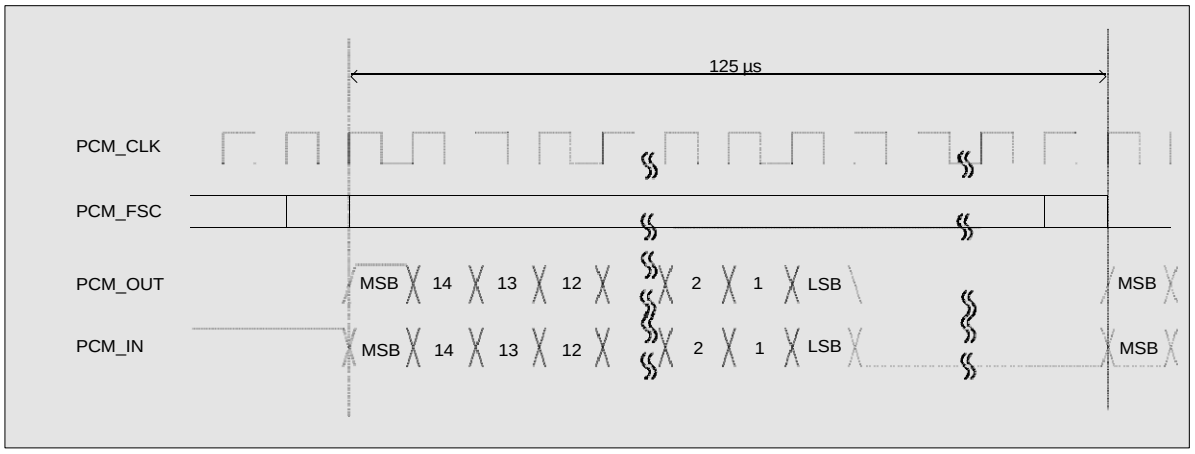


Figure 17: PCM timing short frame (External codec 2048KHz)

The timing of a PCM long frame for the additional 128kHz master mode is shown in Figure 18.

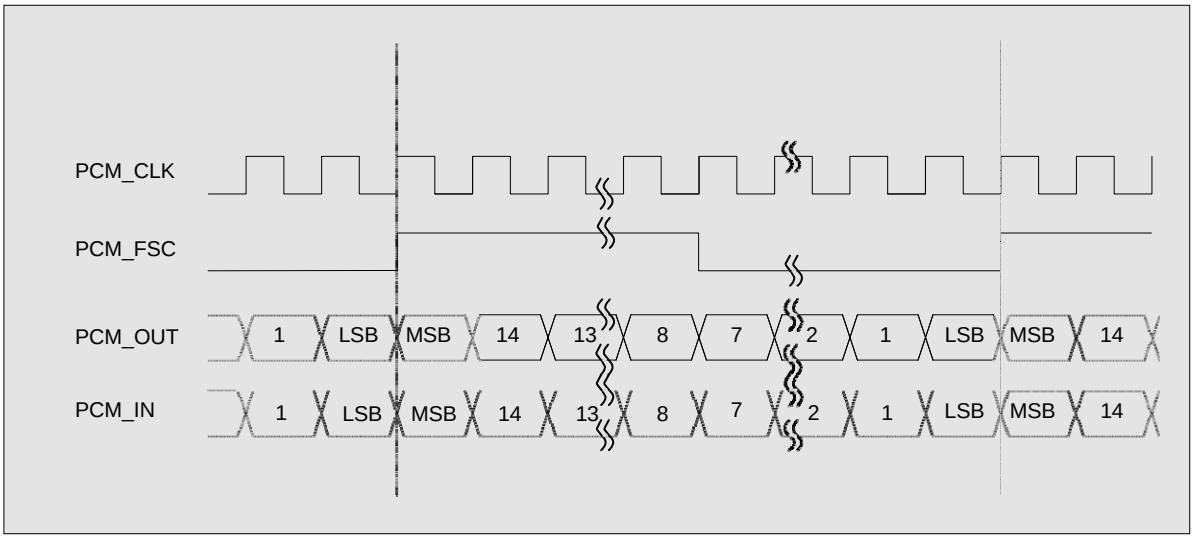


Figure 18: PCM timing long frame (master, 128kHz)

Please note that PCM data is always formatted as 16-bit uncompressed two's complement. Also, all PCM data and frame synchronization signals are written to the PCM bus on the rising clock edge and read on the falling edge.

3.9.2 I²C Interface

PCS3's I²C compatible interface for FM radio support and Camera

I2C_SDA and I2C_SCL: I2C control bus Serial data line of the I2C bus (I2C_SDA) – the standard required pull-up resistor is placed on the QSC device side; a pull-up resistor is not required in the camera module. Serial clock line of the I2C bus (I2C_SCL) – the standard required pull-up resistor is placed on the QSC device side; a pull-up resistor is not required in the camera module.

The I²C interface features and limitation:

- Two-wire bus for inter-IC communication
- Support for external devices fabricated using any process (1.8 V only)
- Support for external functions such as camera sensors, microcontrollers, FM radio ICs, LCD driver, stereo DAC, and keyboard interface
- Two operating modes with different transfer rates
  - Standard-mode: up to ~100 kbps
  - Fast-mode: up to ~400 kbps
- The controller functions only as an I2C master, not a slave

Table 13 lists the available I²C interface signals.

Table 13: Overview of I²C signal functions

Signal name	Alternate name	Signal configuration inactive[1]	I/O	Description
I2CDAT	I2CDAT	PD	I/O	Serial data line of the I2C bus
I2CCLK	2CCLK	PD	I/O	Serial clock line of the I2C bus

1. Inactive means no call, no tone generation and no external clock mode. PD = Pull down

3.10 Control Signals

3.10.1 PWR_IND Signal

PWR_IND notifies the on/off state of the module. High state of PWR_IND indicates that the module is switched off. The state of PWR_IND immediately changes to low when IGT is pulled low. For state detection an external pull-up resistor is required.

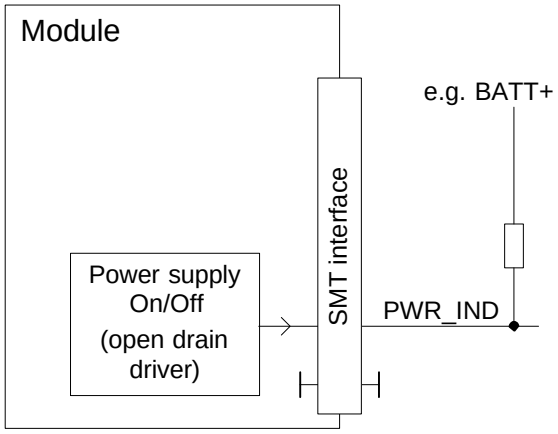


Figure 21: PWR_IND signal

3.10.2 Network Connectivity Status Signals

The STATUS line serves to indicate the module's network connectivity state and can be used to control an externally connected LED as shown in Figure 22. To operate the LED a buffer, e.g. a transistor or gate, must be included in the external application.

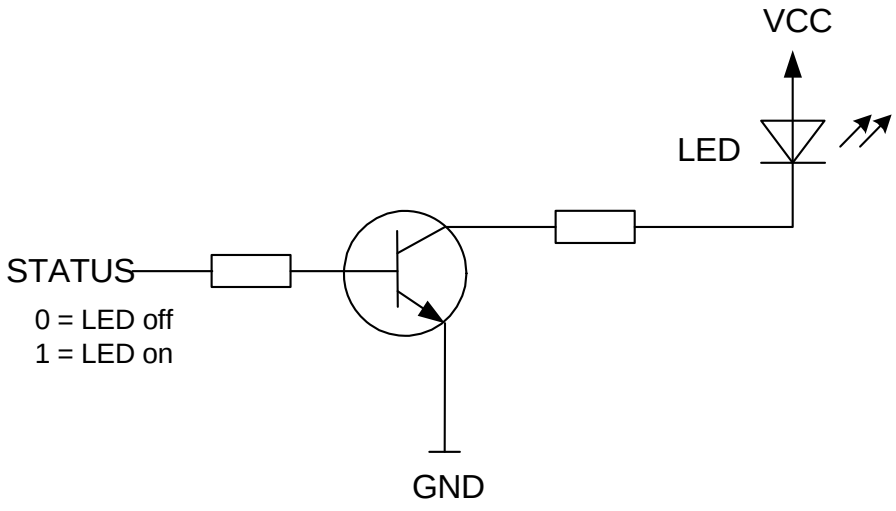


Figure 22: LED Circuit (Example)

For electrical characteristics of the STATUS line see Table 22. The network connectivity signal function is volatile and has to be activated after module startup with AT^SLED. For details on the command as well as status and mode indications through blinking intervals see [1].

3.10.3 Behavior of the RING0 Line (ASC0 Interface only)

The RING0 line is available on the first serial interface ASC0 (see also Section 3.7). The signal serves to indicate incoming calls and other types of URCs (Unsolicited Result Code).

Although not mandatory for use in a host application, it is strongly suggested that you connect the RING0 line to an interrupt line of your application. In this case, the application can be designed to receive an interrupt when a falling edge on RING0 occurs. This solution is most effective, particularly, for waking up an application from power saving. Note that if the RING0 line is not wired, the application would be required to permanently poll the data and status lines of the serial interface at the expense of a higher current consumption. Therefore, utilizing the RING0 line provides an option to significantly reduce the overall current consumption of your application.

The RING0 line behavior and usage can be configured by AT command. For details see [1]: AT^SCFG.

3.10.4 Host Wakeup

If no call, data or message transfer is in progress, the host may shut down its own USB interface to save power. If a call or other request (URC) arrives, the host can be notified of this event and be woken up again by a state transition of either the RING0 or the WAKEUP line. This functionality should only be used with legacy USB applications not supporting the recommended USB suspend and resume mechanism as described in in the “Universal Serial Bus Specification Revision 2.0“[1] (see also Section 3.6.1).

The behaviour of these RING0 or WAKEUP lines as host wakeup line has to be enabled and configured by AT command (see [1]: AT^SCFG). Possible states are listed in Table 14. Please note that it is not possible to use both lines in parallel. The WAKEUP signal just inverts the RING0 signal in order to meet different application needs.

Table 14: Host wakeup lines

Signal	I/O	Description
RING0	O	Inactive to active low transition: 0 = The host shall wake up 1 = No wake up request
WAKEUP	O	Inactive to active high transition: 0 = No wake up request 1 = The host shall wake up

1. The specification is ready for download on http://www.usb.org/developers/docs/

3.10.5 Low Current Indicator

A low current indication is optionally available over the LC_IND line. By default, low current indication is disabled.

For the LC_IND signal to work as a low current indicator the feature has to be enabled by AT command (see [1]: AT^SCFG: MEopMode/PowerMgmt/LCI).

If enabled, the LC_IND signal is high when the module is sleeping. During its sleep the module will for the most part be slow clocked with 32kHz RTC.

Table 15: Low current indicator line

Signal	I/O/P	Description
LC_IND	O	Inactive to active high transition: 0 = High current consumption The module draws its power via BATT+ 1 = Low current consumption (only reached during SLEEP mode) The module draws only a low current via BATT+

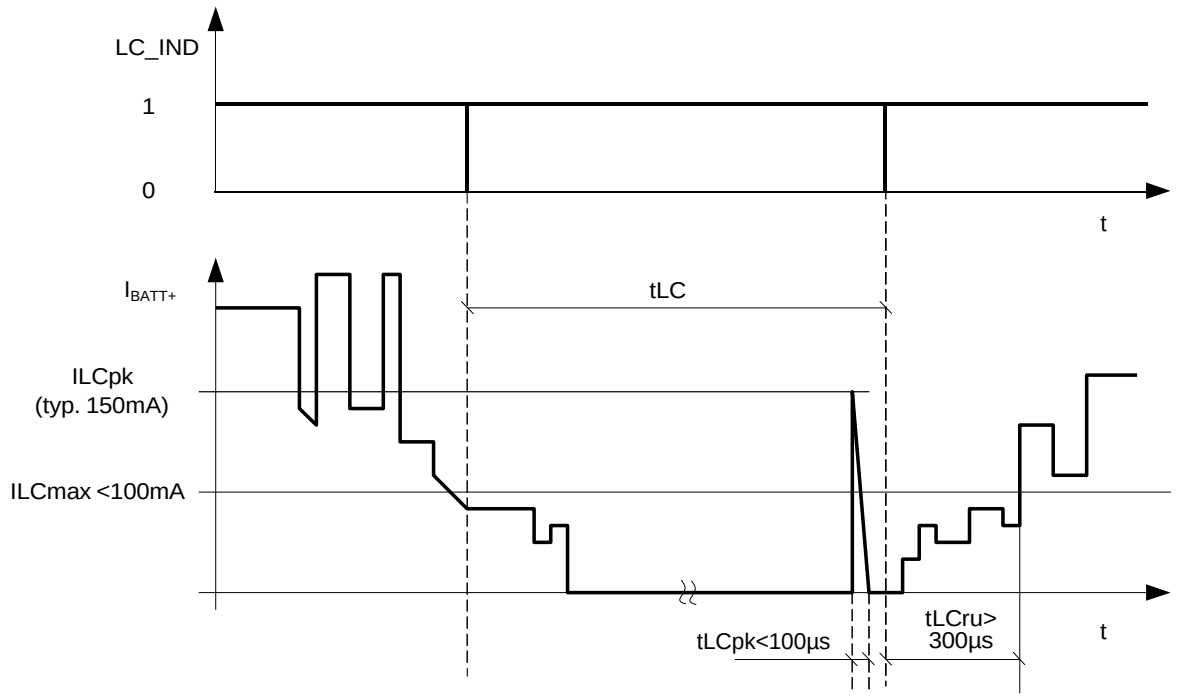
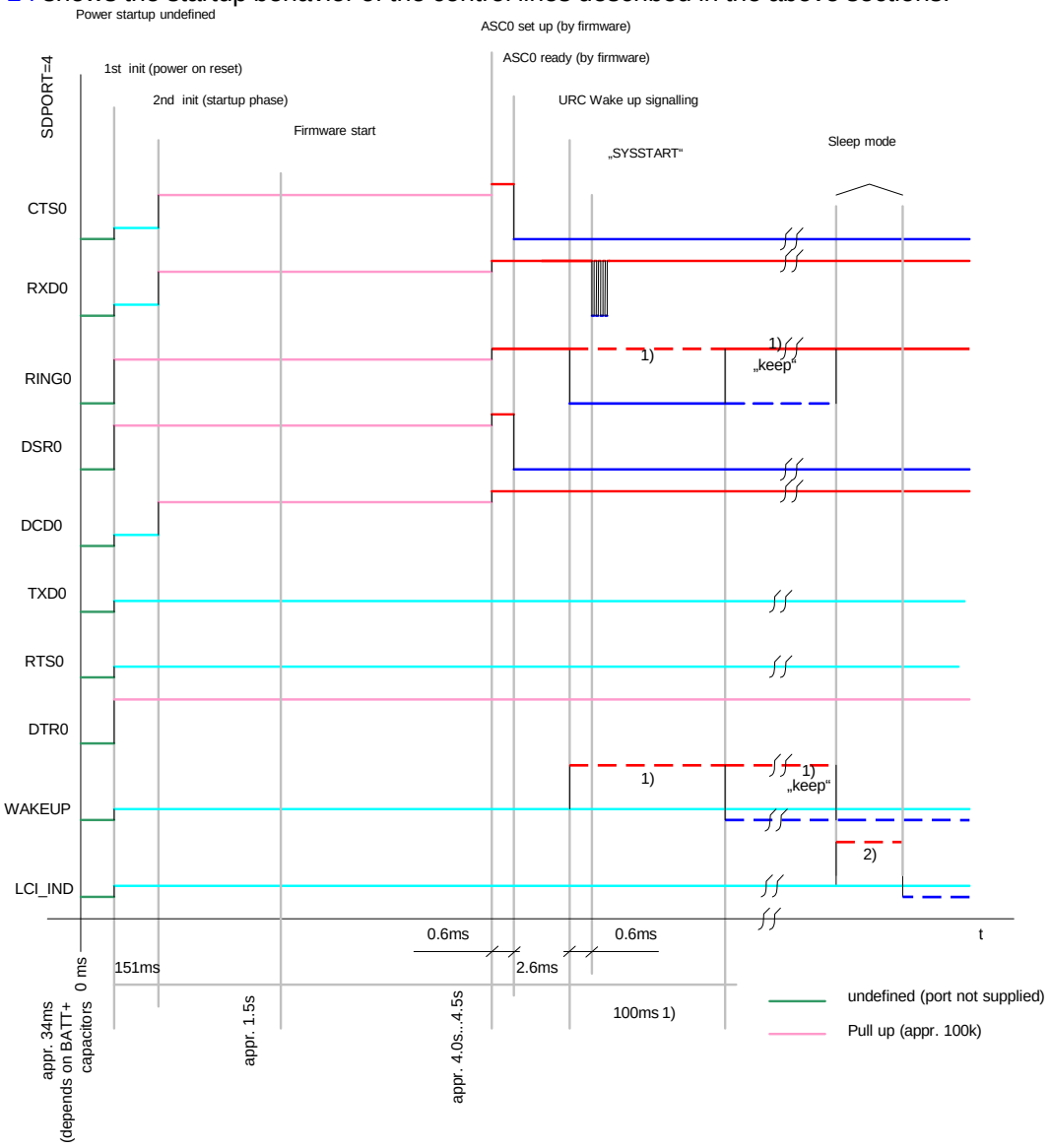


Figure 23: Low current indication timing

tLC	Time for the I_{BATT+} current consumption: ILCmax<100mA.
tLCpk	Max. time duration for the inrush current peak at the end of the low current period.
tLCru	When the LC_IND signal becomes inactive (low) the current ramps up to the maximum low current value within tLCru.
ILCpk	When the module turns from sleep to normal operation some internal supply voltages will be switched on. That causes a small inrush current peak.
ILCmax	During the low current period tLC the current consumption does not exceed the ILCmax value.

3.10.6 RING0 (ASC0), WAKEUP and LCI_IND Startup Behavior

Table 24 shows the startup behavior of the control lines described in the above sections.



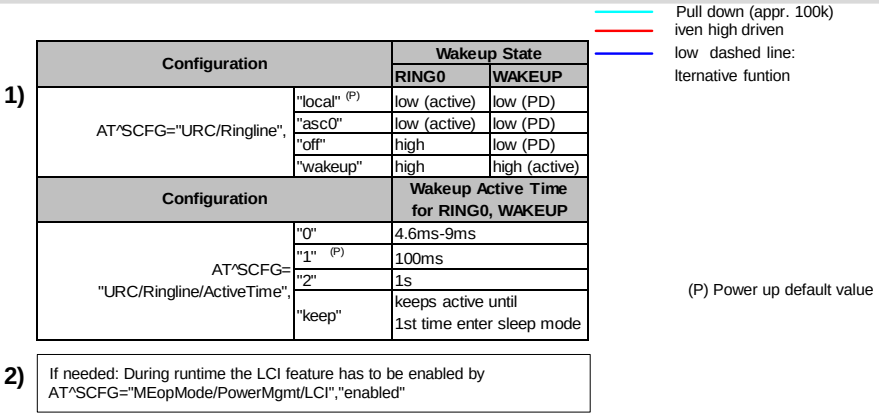


Figure 24: RING0 (ASC0), WAKEUP and LCI_IND startup behavior

4 Antenna Interfaces

The PCS3 only CDMA main Antenna, PCS3 didn't have GPS for a GNSS receiver

5.1 CDMA Antenna Interface

The PCS3 CDMA antenna interface comprises a main CDMA antenna as well as an optional CDMA Rx diversity antenna to improve signal reliability and quality[1]. The interface has an impedance of 50ohm PCS3 is capable of sustaining a total mismatch at the antenna interface without any damage, even when transmitting at maximum RF power.

The external antenna must be matched properly to achieve best performance regarding radiation power, modulation accuracy and harmonic suppression. Matching networks are not included on the PCS3 PCB and should be placed in the host application, if the antenna does not have an impedance of 50ohm.

Regarding the return loss PCS3 provides the following values in the active band:

Table 16: Return loss in the active band

State of module	Return loss of module	Recommended return loss of application
Receive	≥ 8dB	≥ 12dB
Transmit	not applicable	≥ 12dB
Idle	≤ 5dB	not applicable

1. By delivery default the optional CDMA Rx diversity antenna is configured as available for the module. To avoid negative side effects and performance degradation it is recommended to disable the diversity antenna path if
- the host application does not support a diversity antenna
- the host application includes a diversity antenna - but a network simulator is used for development and performance tests.
Please refer to [1] for details on how to configure antenna settings.

5.1.1 Antenna Installation

The antenna is connected by soldering the antenna pads and their neighboring ground pads directly to the application's PCB.

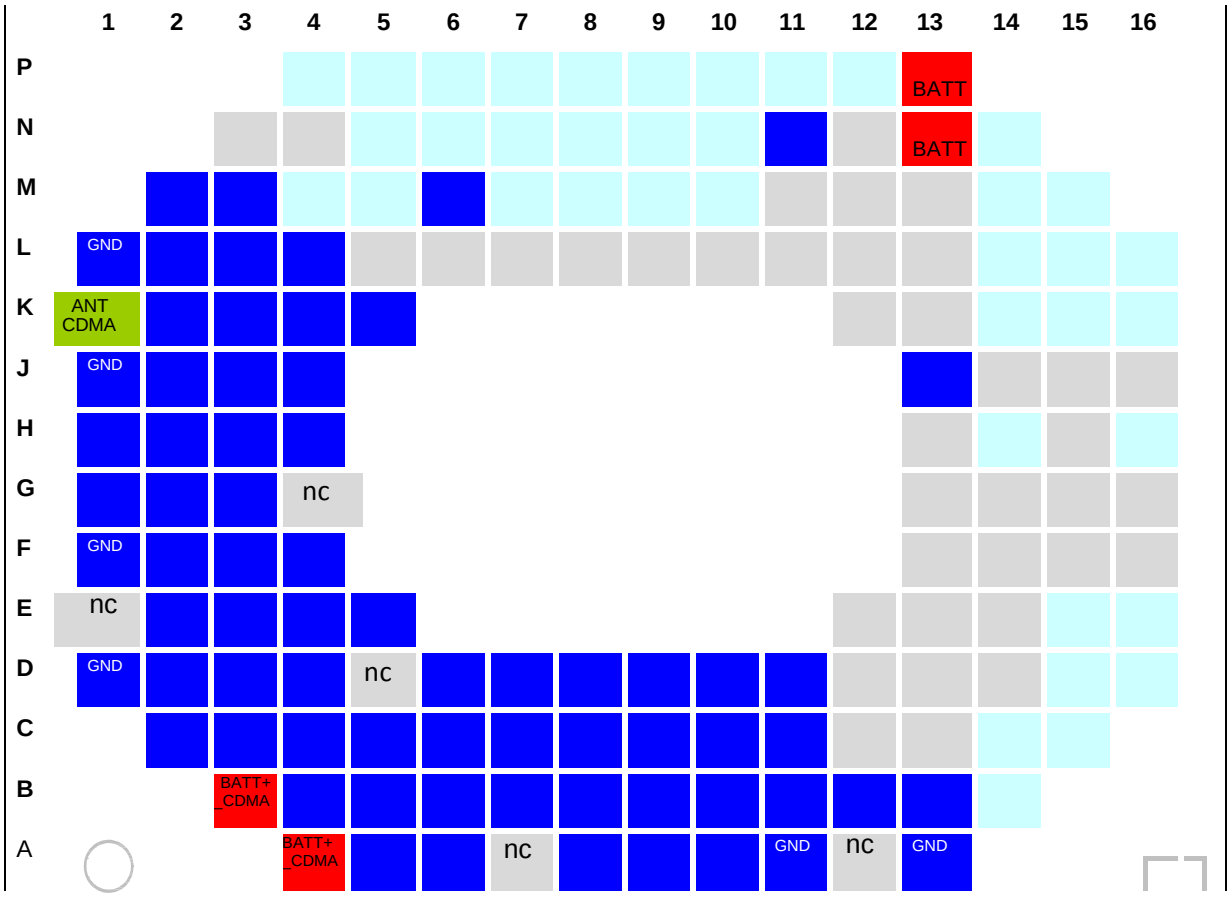


Figure 25: Antenna pads

The distance between the antenna pads and their neighboring GND pads has been optimized for best possible impedance. To prevent mismatch, special attention should be paid to these pads on the application' PCB.

The wiring of the antenna connection, starting from the antenna pad to the application's antenna should result in a 50 line impedance. Line width and distance to the GND plane need to be optimized with regard to the PCB's layer stack. Some examples are given in Section 5.1.2.

To prevent receiver desensitization due to interferences generated by fast transients like high speed clocks on the external application PCB, it is recommended to realize the antenna connection line using embedded Stripline rather than Micro-Stripline technology. Please see Section 5.1.2 for examples of how to design the antenna connection in order to achieve the required 50 line impedance.

For type approval purposes, the use of a 50 coaxial antenna connector (U.FL-R-SMT) might be necessary. In this case the U.FL-R-SMT connector should be placed as close as possible to PCS3's antenna pad.

5.1.2 RF Line Routing Design

5.1.2.1 Line Arrangement Examples

Several dedicated tools are available to calculate line arrangements for specific applications and PCB materials - for example from http://www.polarinstruments.com/ (commercial software) or from http://web.awrcorp.com/Usa/Products/Optional-Products/TX-Line/ (free software).

Coated coplanar strips with ground
This section gives two line arrangement examples for differential coated coplanar strip with ground

Figure 26: coated coplanar strip with ground

Differential coated coplanar strips with ground

This section gives two line arrangement examples for differential coated coplanar strip with ground

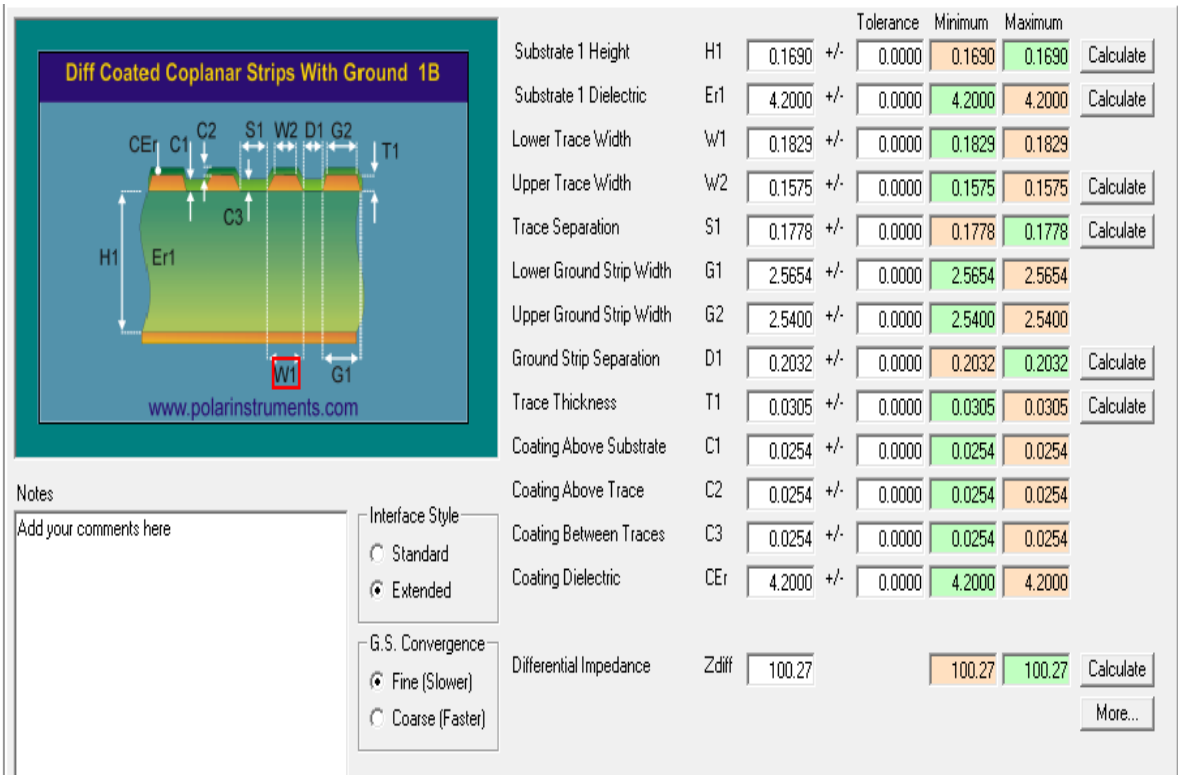


Figure 27: differential coated coplanar strip with ground

5.1.2.2 Routing Example

Interface to RF Connector

Figure 28 shows a sample connection of a module's antenna pad at the bottom layer of the module PCB with an application PCB's coaxial antenna connector. Line impedance depends on line width, but also on other PCB characteristics like dielectric, height and layer gap. The sample stripline width of 0.33mm is recommended for an application with a PCB layer stack resembling the one of the PCS3 evaluation board shown in Figure 29. For different layer stacks the stripline width will have to be adapted accordingly.

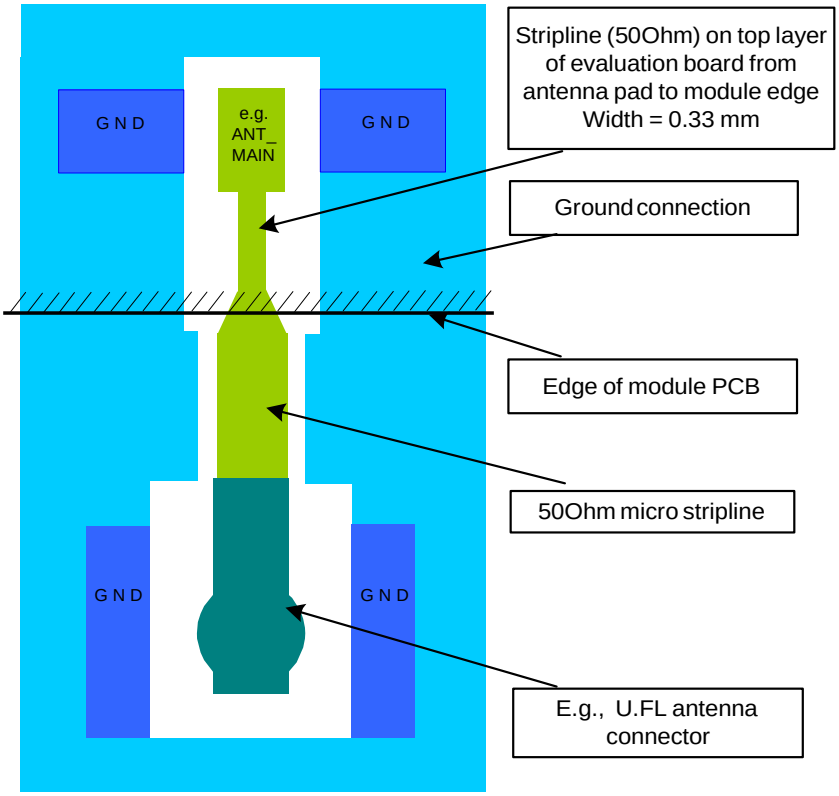


Figure 28: Routing to application's RF connector

Layer Name	Layer Type		FOX CONN	Materials (um)	Finished (um)	Tolerance (um)	R/C (%)	Dk	Supplier
S/M	SolderMask				Min.10um				PSR-4000 GEC50 (SS)
FRONT	Copper(Base+Plating)			12	30	+10/-10			
	Prepreg/1-1080 (0080)			80	70	+15/-15	65%	4.1	HITACHI GEA-75G(Tg 180) Prepreg
L2	Copper(Base+Plating)			12	28	+10/-8			
	Prepreg/1-1080 (0080)			80	71	+15/-15	65%	4.1	HITACHI GEA-75G(Tg 180) Prepreg
L3	Copper(Base+Plating)			18	33	+10/-10			
	Core			179	179	+20/-20		4.44	HITACHI MCL-E-75G Laminate
L4	Copper(Base+Plating)			18	33	+10/-10			
	Prepreg/1-1080 (0080)			80	71	+15/-15	65%	4.1	HITACHI GEA-75G(Tg 180) Prepreg
L5	Copper(Base+Plating)			12	28	+10/-8			
	Prepreg/1-1080 (0080)			80	70	+15/-15	65%	4.1	HITACHI GEA-75G(Tg 180) Prepreg
BACK	Copper(Base+Plating)			12	30	+10/-10			
S/M	SolderMask				Min.10um				PSR-4000 GEC50 (SS)
	Finished Board Thickness				680				

Figure 29: PCS3 evaluation board layer table

6 Electrical, Reliability and Radio Characteristics

6.1 Absolute Maximum Ratings

The absolute maximum ratings stated in Table 17 are stress ratings under any conditions. Stresses beyond any of these limits will cause permanent damage to PCS3.

Table 17: Absolute maximum ratings

Parameter	Min	Max	Unit
Supply voltage BATT+	-0.5	+4.2	V
Voltage at all digital lines in POWER DOWN mode	-0.3	+0.3	V
Voltage at digital lines in normal operation	-0.3	+2.1	V
Voltage at analog audio lines in normal operation (VMIC=on)	-0.3	+1.8	V
Voltage at analog audio lines during audio off mode (VMIC=off)	-0.3	+0.3	V
VDDLP input voltage	-0.3	+3.5	V
Microphone supply (VMIC) maximum current to GND		3	mA
VEXT maximum current shorted to GND		-300	mA
VUSB_IN, USB_DN, USB_DP	-0.3	5.75	V
Voltage at PWR_IND line	-0.5	5.5	V
PWR_IND input current if PWR_IND= low		2	mA
Voltage at following signals: IGT, EMERG_OFF	-0.5	V_{BATT+}	V

6.2 Operating Temperatures

Table 18: Board temperature

Parameter	Min	Typ	Max	Unit
Operating temperature range	-30	+25	+85	°C
Restricted temperature range[1]	-40		+95	°C
Automatic shutdown[2] Temperature measured on PCS3 board	<-40	---	>+95	°C

1. Restricted operation allows normal mode speech calls or data transmission for limited time until automatic thermal shutdown takes effect. Within the restricted temperature range (outside the operating temperature range) the specified electrical characteristics may be in- or decreased.
2. Due to temperature measurement uncertainty, a tolerance on the stated shutdown thresholds may occur. The possible deviation is in the range of ± 2°C at the overtemperature and undertemperature limit.

6.3 Storage Conditions

The conditions stated below are only valid for modules in their original packed state in weather protected, non-temperature-controlled storage locations. Normal storage time under these conditions is 12 months maximum.

Table 19: Storage conditions

Type	Condition	Unit	Reference
Air temperature: Low High	-25 +40	°C	IPC/JEDEC J-STD-033A
Humidity relative: Low High	10 90 at 40°C	%	IPC/JEDEC J-STD-033A
Air pressure: Low High	70 106	kPa	IEC TR 60271-3-1: 1K4 IEC TR 60271-3-1: 1K4
Movement of surrounding air	1.0	m/s	IEC TR 60271-3-1: 1K4
Water: rain, dripping, icing and frosting	Not allowed	---	---
Radiation: Solar Heat	1120 600	W/m^2	ETS 300 019-2-1: T1.2, IEC 60068-2-2 Bb ETS 300 019-2-1: T1.2, IEC 60068-2-2 Bb
Chemically active substances	Not recommended		IEC TR 60271-3-1: 1C1L
Mechanically active substances	Not recommended		IEC TR 60271-3-1: 1S1
Vibration sinusoidal: Displacement Acceleration Frequency range	 1.5 5 2-9 9-200	 mm m/s^2 Hz	IEC TR 60271-3-1: 1M2
Shocks: Shock spectrum Duration Acceleration	 semi-sinusoidal 1 50	 ms m/s^2	IEC 60068-2-27 Ea

6.4 Reliability Characteristics

The test conditions stated below are an extract of the complete test specifications.

Table 20: Summary of reliability test conditions

Type of test	Conditions	Standard
Vibration	Frequency range: 10-20Hz; acceleration: 5g Frequency range: 20-500Hz; acceleration: 20g Duration: 20h per axis; 3 axes	DIN IEC 60068-2-6[1]
Shock half-sinus	Acceleration: 500g Shock duration: 1msec 1 shock per axis 6 positions (± x, y and z)	DIN IEC 60068-2-27
Dry heat	Temperature: +70 ±2×C Test duration: 16h Humidity in the test chamber: < 50%	EN 60068-2-2 Bb ETS 300 019-2-7
Temperature change (shock)	Low temperature: -40×C ±2×C High temperature: +85×C ±2×C Changeover time: < 30s (dual chamber system) Test duration: 1h Number of repetitions: 100	DIN IEC 60068-2-14 Na ETS 300 019-2-7
Damp heat cyclic	High temperature: +55×C ±2×C Low temperature: +25×C ±2×C Humidity: 93% ±3% Number of repetitions: 6 Test duration: 12h + 12h	DIN IEC 60068-2-30 Db ETS 300 019-2-5
Cold (constant exposure)	Temperature: -40 ±2×C Test duration: 16h	DIN IEC 60068-2-1

1. For reliability tests in the frequency range 20-500Hz the Standard's acceleration reference value was increased to 20g.

6.5 Pad Assignment and Signal Description

The SMT application interface on the PCS3 provides connecting pads to integrate the module into external applications. The following Table 21 lists the pads' assignments, Figure 32 (bottom view) and Figure 33 (top view) show the connecting pads' numbering plan.

Please note that a number of connecting pads are marked as reserved for future use (rfu) or ground (GND) and further qualified as either (dnu), (GND) or (nc):

- Pads marked "rfu" and qualified as "dnu" (do not use) may be soldered but should not be connected to an external application.
- Pads marked "rfu" and qualified as "GND" (ground) are assigned to ground with PCS3 modules, but may have different assignments with future Cinterion products using the same pad layout.
- Pads marked "GND" and qualified as "nc" (not connected) are internally not connected with PCS3 modules but may be soldered and arbitrarily be connected to external ground.

Because with surface mount modules the heat is transported through the solder pads to the external application's PCB, it is generally recommended to solder all pads.

Table 21: Overview: Pad assignments

Pad No.	Signal Name	Pad No.	Signal Name	Pad No.	Signal Name
A4	BATT+ CDMA2	E2	GND	L2	GND
A5	GND	E3	GND	L3	GND
A6	GND	E4	GND	L4	GND
A7	nc	E5	GND	L5	nc
A8	GND	E12	nc	L6	nc
A9	GND	E13	nc	L7	nc
A10	GND	E14	nc	L8	nc
A11	GND	E15	EPP(voice&data variant only)	L9	nc
A12	nc	E16	EPN(voice&data variant only)	L10	nc
13	GND	F1	GND	L11	nc
B3	BATT+ CDMA	F2	GND	L12	nc
B4	GND	F3	GND	L13	nc
B5	GND	F4	GND	L14	CCRST(option CSIM)
B6	GND	F13	nc	L15	CCCLK(option CSIM)
B7	GND	F14	I2CCLK	L16	IGT
B8	GND	F15	I2CDAT	M2	GND
B9	GND	F16	GPIO10	M3	GND
B10	GND	G1	GND	M4	PWR_IND
B11	GND	G2	GND	M5	VEXT
B12	GND	G3	GND	M6	GND
B13	GND	G4	nc	M7	PCM_IN(voice&data variant only)
B14	STATUS	G13	nc	M8	PCM_CLK(voice&data variant only)
C2	GND	G14	GPIO7	M9	PCM_FSC(voice&data variant only)
C3	GND	G15	GPIO8	M10	PCM_OUT(voice&data variant only)
C4	GND	G16	GPIO9	M11	nc
C5	GND	H1	GND	M12	ADC2_IN
C6	GND	H2	GND	M13	ADC1_IN
C7	GND	H3	GND	M14	CCIN(option CSIM)
C8	GND	H4	GND	M15	VDDLP
C9	GND	H13	nc	N3	nc
C10	GND	H14	GPIO4	N4	nc
C11	GND	H15	GPIO5	N5	VUSB_IN
C12	nc	H16	GPIO6	N6	nc
C13	nc	J1	GND	N7	nc
C14	VMIC	J2	GND	N8	CTS0
C15	AGND	J3	GND	N9	DCD0
D1	GND	J4	GND	N10	RTS0
D2	GND	J13	nc	N11	GND
D3	GND	J14	GPIO1	N12	nc
D4	GND	J15	GPIO2	N13	BATT+
D5	nc	J16	GPIO3	N14	EMERG_OFF
D6	GND	K1	ANT_CDMA	P4	USB_DP
D7	GND	K2	GND	P5	USB_DN
D8	GND	K3	GND	P6	nc
D9	GND	K4	GND	P7	nc
D10	GND	K5	GND	P8	DTR0
D11	GND	K12	nc	P9	DSR0
D12	GND	K13	nc	P10	RING0
D13	GND	K14	CCIO(option CSIM)	P11	RXD0
D14	GND	K15	CCVCC(option CSIM)	P12	TXD0
D15	MICP	K16	nc	P13	BATT+
D16	MICN	L1	GND		
E1	nc				

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
P				USB_DP	USB_DN	nc	nc	DTR0	DSR0	RING0	RXD0	TXD0	BATT+			
N			nc	nc	VUSB_IN	nc	nc	CTS0	DCD0	RTS0	GND	nc	BATT+	EMERG_OFF		
M		GND	GND	PWR_IND	VEXT	GND	PCM_IN	PCM_CLK	PCM_FSC	PCM_OUT	nc	nc	ADC1_IN	CCIN (option CSIM)	VDDLP	
L	GND	GND	GND	GND	nc	nc	nc	nc	nc	nc	nc	nc	nc	CCRST (Option CSIM)	CCCLK (option CSIM)	IGT
K	ANT_CDMA	GND	GND	GND	GND							nc	nc	CCIO (option CSIM)	CCVCC (option CSIM)	nc
J	GND	GND	GND	GND									nc	GPIO1	GPIO2	GPIO3
H	GND	GND	GND	GND									nc	GPIO4	GPIO5	GPIO6
G	GND	GND	GND	nc									nc	GPIO7	GPIO8	GPIO9
F	GND	GND	GND	GND									nc	I2CCLK	I2CDAT	GPIO10
E	nc	GND	GND	GND	GND							nc	nc	nc	EPP	EPN
D	GND	GND	GND	GND	nc	GND	GND	GND	GND	GND	GND	nc	nc	nc	MICP	MICN
C		GND	GND	GND	GND	GND	GND	GND	GND	GND	GND	nc	nc	VMIC	AGND	
B			BATT+_CDMA	GND	GND	GND	GND	GND	GND	GND	GND	GND	GND	STATUS		
A				BATT+_CDMA	GND	GND	nc	GND	GND	GND	GND	nc	GND			

Figure 32: PCS3 bottom view: Pad assignments

Please note that the reference voltages listed in Table 22 are the values measured directly on the PCS3 module. They do not apply to the accessories connected.

Table 22: Signal description

Function	Signal name	IO	Signal form and level	Comment
Power supply	BATT+_CDMA BATT+_CDMA	I	$V_I$max = 4.2V $V_I$norm = 3.8V $V_I$min = 3.3V during Tx burst on board Imax 800mA, during Tx burst	Lines of BATT+ and GND must be connected in parallel for supply purposes because higher peak currents may occur. Minimum voltage must not fall below 3.3V including drop, ripple, spikes.
	BATT+	I	$V_I$max = 4.2V $V_I$norm = 3.8V $V_I$min = 3.3V during Tx burst on board Imax = 250mA	
Power supply	GND		Ground	Application Ground
External supply voltage	VEXT	O	CLmax = 1µF High power mode: V_O = 1.80V +1% -5% $I_O$max = -50mA Power save mode: V_O = 1.80V +2% -5% $I_O$max = -10mA	VEXT may be used for application circuits. Not available in Power down mode. If unused keep line open and enable power save mode via AT^SCFG= "MEopMode/PowerMgmt/ VEXT", "low" (see [1]) The external digital logic must not cause any spikes or glitches on voltage VEXT.
Ignition	IGT	I	R_{PU} 160k , C_I 1nF V_{OH}max=*1.85V* V_{IH}max =*2.2V* V_{IH}min = *1.17V* V_{IL}max = *300mV* Low impulse width > 100ms	This signal switches the module ON. It is recommended to drive this line low by an open drain or open collector driver connected to GND.
Emergency Off	EMERG_OFF	I	R_{PU} 160k , C_I 1nF V_{OH}max=*1.85V* V_{IH}max =*2.2V* V_{IH}min = *1.17V* V_{IL}max = *300mV* ~~|___|~~ low impulse width > 40ms	It is recommended to drive this line low by an open drain or open collector driver connected to GND. If unused keep line open.

Table 22: Signal description

Function	Signal name	IO	Signal form and level	Comment
RTC Back up	VDDLP	O	$V_O$max = 3.20V while BATT+ =>3.3V R_I = 1.8k	If unused keep line open. To employ the SMPL feature the VDDLP line has to supplied for at least 2 seconds after a possible power loss (e.g., by connecting a 10µF capacitor). See also Section 3.3.6.
		I	V_I = 1.5V…3.25V at I_{max}= 10µA while BATT+ = 0V	
Connectivity Status	STATUS	O	V_{OL}max = 0.45V at I = 2mA V_{OH}min = 1.35V at I = -2mA V_{OH}max = 1.85V	Status signalling e.g. with ext. LED circuit
Serial Modem Interface ASC0	RXD0	O	V_{OL}max = 0.45V at I = 2mA V_{OH}min = 1.35V at I = -2mA V_{OH}max = 1.85V	If unused keep line open.
	CTS0	O		
	DSR0	O		
	DCD0	O		
	RING0	O		
	TXD0	I	V_{IL}max = 0.6V at 30µA V_{IH}min = 1.20V at -30µA V_{IH}max = 2V	
	RTS0	I		
	DTR0	I		
Analog Audio interface	VMIC	O	$V_O$typ = 1.8V I_{max} = 3 mA	Microphone supply for customer feeding circuits. If unused keep line open.
	EPP	O	Differential, Minimum load resistance 32 typ. 5.0Vpp at no load PCM level = +3dBm0, 1.02kHz sine wave	Balanced output for earphone or balance output for line out. See also Section 6.7.4. If unused keep line open.
	EPN	O		
	MICP	I	$Z_I$typ = 94k @ 0dB gain $Z_I$typ = 5.8k @ 30dB gain Vinmax = 2.57Vpp (for 3dBm0 @ 0dB gain)	Balanced differential microphone with external feeding circuit (using VMIC and AGND) or balanced differential line input. See also Section 6.7.4. Use coupling capacitors. If unused keep lines open.
	MICN	I		
	AGND		Analog ground	GND level for external audio circuits

Table 22: Signal description

Function	Signal name	IO	Signal form and level	Comment
Pulse Code Modulation (PCM)	PCM_IN	I	V_{IL}max = 0.6V at 30µA V_{IH}min = 1.20V at -30µA V_{IH}max = 2V V_{OL}max = 0.45V at I = 2mA V_{OH}min = 1.35V at I = -2mA V_{OH}max = 1.85V	In Master mode PCM_FSC and PCM_CLK are output signals[1]. In Slave mode PCM_FSC and PCM_CLK are input signals. See also Section 3.9.1. If unused keep line open.
	PCM_CLK	I/O		
	PCM_FSC	I/O		
	PCM_OUT	O		
Inter IC interface (I^2C)	I2CDAT	O	VOLmax = 0.45V at I = 2mA VOHmin = 1.35V at I = -2mA VOHmax = 1.85V	
	I2CCLK	O		
Power Indicator	PWR_IND	O	V_{IH}max = 5.5V V_{OL}max = 0.4V at Imax = 2mA	PWR_IND (Power Indicator) notifies the module's on/off state. PWR_IND is an open collector that needs to be connected to an external pull-up resistor. Low state of the open collector indicates that the module is on. Vice versa, high level notifies the power-down mode. Therefore, the signal may be used to enable external voltage regulators which supply an external logic for communication with the module, e.g. level converters.
USB	VUSB_IN	I	V_{IN}min = 3.0V V_{IN}max = 5.25V Active current $I_I$typ = 105µA (max 130µA) Suspend current $I_I$typ = 135µA (max 200µA)	If the USB interface is not used please connect this line to GND.
	USB_DN	I/O	All electrical characteristics according to USB Implementers' Forum, USB 2.0 Full Speed Specification.	If lines are unused keep lines open. USB only support Full Speed mode operation requires a differential impedance of 90ohm
	USB_DP	I/O		
Host wakeup	WAKEUP	O	V_{OL}max = 0.45V at I = 2mA V_{OH}min = 1.35V at I = -2mA V_{OH}max = 1.85V	Can be used as a host wakeup line similar to RING0 (see Section 3.10.4)[1].

Table 22: Signal description

Function	Signal name	IO	Signal form and level	Comment
Low Current Indication	LC_IND	O	V_{OL}max = 0.45V at I = 2mA V_{OH}min = 1.35V at I = -2mA V_{OH}max = 1.85V	If the function is enabled (see Section 3.10.5)[1].
		I	V_{IH}max = 2V R_{PD}= appr. 100kOhm	If the function is disabled (see Section 3.10.5)[1].

1. Signal state if not configured: I, PD (appr. 100k)

6.6 Power Supply Ratings

Table 23: Power supply ratings

	Description	Conditions	Min	Typ	Max	Unit
BATT+	Supply voltage	Directly measured at Module. Voltage must stay within the min/max values, including voltage drop, ripple, spikes	3.3	3.8	4.2	V
	Maximum allowed voltage drop during transmit burst	Normal condition, power control level for Pout max			400	mV
	Voltage ripple	Normal condition, power control level for Pout max @ f <= 250 kHz @ f > 250 kHz			 20 16	 mV_{pp} mV_{pp}
I_{VDDLP} @ 3V	OFF State supply current	RTC backup @ BATT+ = 0V		4.0		µA
I_{BATT+} [1]	OFF State supply current	POWER DOWN		39		µA
	Average CDMA supply current	SLEEP[2] (USB Suspend or Disconnected and no communication via ASC0) @ SCI=0		8		mA
		SLEEP[2] (USB Suspend or Disconnected and no communication via ASC0) @ SCI=2		8		mA
		SLEEP[2] (USB Suspend or Disconnected and no communication via ASC0) @ SCI=7		8		mA
		1xRTT Data transfer BC0 @ +24dBm		450		mA
		1xRTT Data transfer BC1 @ +24dBm		500		mA
		1xRTT Data transfer BC10 @ +24dBm		460		mA
I_{VUSB_IN}	USB suspend and active ratings are mentioned in Table 22: VUSB_IN.					

1. With an impedance of Z_{LOAD}=50Ohm at the antenna connector.
2. Average time for SLEEP mode: 5min

6.7 Electrical Characteristics of the Voiceband Part

6.7.1 Setting Audio Parameters by AT Commands

Audio mode 1 is the basic audio mode optimized for the Votronic reference handset (see Section 10.1). The default parameters are determined for type approval and are not adjustable with AT commands.

The audio modes 2 to 8 can be temporarily adjusted according to the AT command parameters listed in the table below. The audio parameters are set with the AT commands AT^SNFI as well as AT^SNFO and stored volatile for the current audio mode (see [1]). For a model of how the parameters influence the audio signal path see Section 6.7.2.

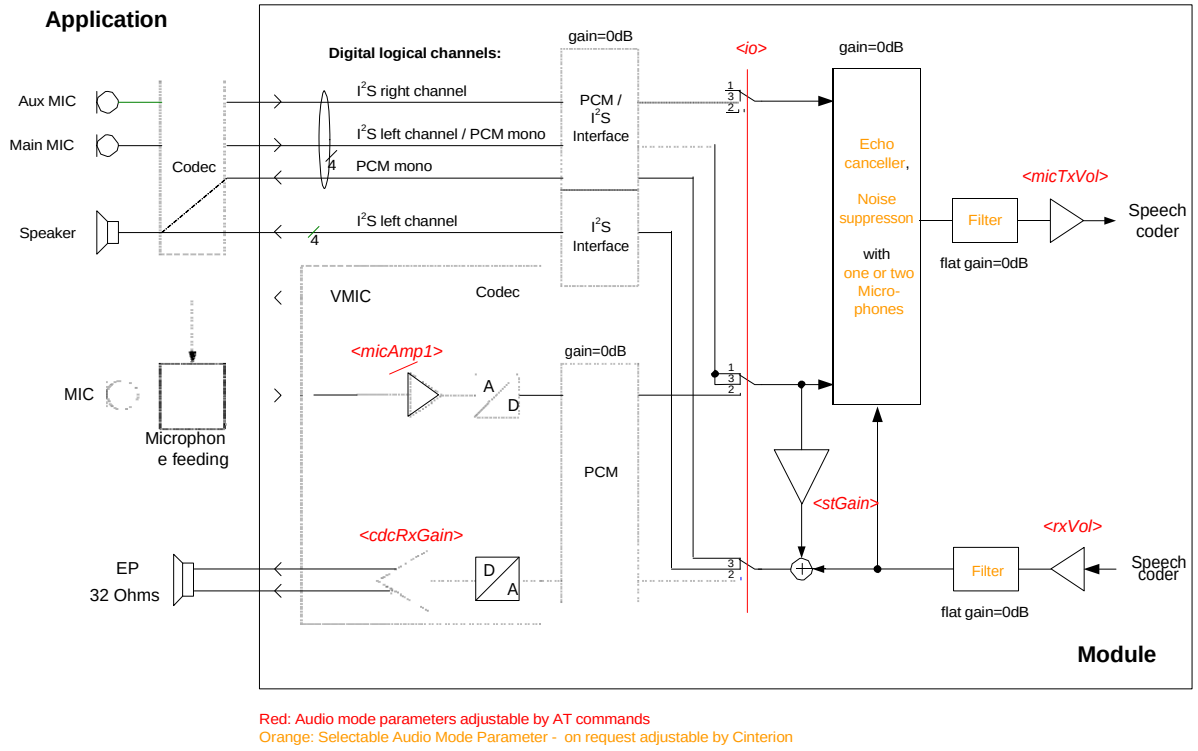
Table 24: Audio parameters adjustable by AT command

Parameter	Influence to	Range	Gain range	Calculation
AT^SNFI=				
micAmp1	MICP/MICN second analog amplifier gain of before ADC	0,1	0 or 24dB	
micTxVol	Digital gain of input signal after ADC	0, 1...65535	Mute, -84...+12dB	20 * log (micTxVol/ 16384)
AT^SNFO=				
cdcRxGain	Analog gain of output signal after summation of sidetone	0...63	-57...+6dB	1dB steps
rxVol	Digital Volume of output signal after speech decoder, before summation of sidetone and DAC	0, 1…41	Mute, -48...+12dB	1.5dB steps
stGain	Digital attenuation of sidetone	0, 1...65535	Mute, -96...0dB	20 * log (stGain/ 16384) -12

6.7.2 Audio Programming Model

The audio programming model shows how the signal path can be influenced by varying AT command parameters: AT^SNFI allows to set the parameters <micAmp1>, and<mic TxVol>, whereas the parameters <cdcRxGain>, <stGain> and <rxVol> can be adjusted with AT^SNFO. For more information on the AT commands and parameters see Section 6.7.1 and [1].

If the digital audio interface (PCM) is selected, the parameters <micAmp1>, and <cdcRxGain> have no influence; because they are not involved in the signal paths.(PCS3 didn't support I2S)



Red: Audio mode parameters adjustable by AT commands
Orange: Selectable Audio Mode Parameter - on request adjustable by Cinterion

Figure 34: Audio programming model

6.7.3 Characteristics of Audio Modes

The electrical characteristics of the voiceband part depend on the current audio mode set with AT command. All values are noted for default gains, e.g. the default parameters are left unchanged.

Table 25: Voiceband characteristics

Audio mode no. AT^SNFS=	**1**[1]	**2**	**3**	**4**	**5**	**6**
Name	Default Handset	Router	User Handset	Headset	Speaker phone	Transparent
Purpose	DSB with Votronic handset	Analog phone interface		Mono Headset	Handheld speakerphone	Direct access to speech coder
TX-Filters	Adjusted	Flat	Adjusted	Flat	Flat	Flat
RX-Filters	Adjusted to fit artificial ear type 3.2 low leakage	Flat	Adjusted to fit artificial ear type 3.2 low leakage	800Hz	800Hz	Flat
Default SNFI Parameters <micAmp1> <txVol>	 0 (0dB) 0x23FD (-5dB)	 0 (0dB) 0x4000 (0dB)	 0 (0dB) 0x23FD (-5dB)	 1 (24dB) 0x4000 (0dB)	 1 (24dB) 0xB461(9dB)	 0 (0dB) 0x4000 (0dB)
Default SNFO Parameters <cdcRxGain> <rxVol> <stGain>	0x2861 (-4dB) 33 (0dB) 0x261F (-16.5dB)	0x2000 (-6dB) 33 (0dB) 0x0000 (mute)	0x2861 (-4dB) 33 (0dB) 0x261F (-16.5dB)	0x2000 (-6dB) 33 (0dB) 0x1000 (-24dB)	0x6570 (4dB) 33 (0dB) 0x0000 (mute)	0x4000 (0dB) 33 (0dB) 0x0000 (mute)
Echo canceller mode	VOC_EC_ESEC	VOC_EC_ESEC	VOC_EC_ESEC	VOC_EC_HEADSET	VOC_EC_SPEAKER	VOC_EC_OFF
Noise Supersession	VOC_NS_ON	VOC_NS_OFF	VOC_NS_ON	VOC_NS_ON	VOC_NS_ON	VOC_NS_FF
Tx codec gain	0x4000 (0dB)	0x4000 (0dB)	0x4000 (0dB)	0x4000 (0dB)	0x4000 (0dB)	0x4000 (0dB)

Table 25: Voiceband characteristics

Audio mode no. AT^SNFS=	**1**[1]	**2**	**3**	**4**	**5**	**6**
MIC input signal for 0dBm0,[2] f = 1024 Hz	15mV	650mV	15mV	12mV	5mV	420mV
EP output signal in mV rms. @ 0dBm0, 1024 Hz, no load (default gain) / @ 3.14 dBm0	465mV 2.1Vpp	512mV 2.1Vpp	465mV 2.1Vpp	370mV 1.6Vpp	1485mV 5.7Vpp	1290mV 5.5Vpp
Sidetone gain at default settings	-16.5dB	0dB	-16.5dB	-24dB	0dB	0dB
Digital audio characteristics (PCM)						
Uplink gain at 1024Hz	14602(-1dBm)	16384(0dBm)	14602(-1dBm)	16384(0dBm)	16384(0dBm)	16384(0dBm)
Downlink gain at 1024Hz	25	33	25	32	32	33
Sidetone gain	5514(-21.5dBm)	0	5514(-21.5dBm)	12288(-15dBm)	0	0

1. Fixed audio mode. Values cannot be adapted.
2. All values measured before the noise reduction attenuates the sine wave after a few seconds.

n.a. = not applicable

Note: With regard to acoustic shock, the cellular application must be designed to avoid sending false AT commands that might increase amplification, e.g. for a highly sensitive earpiece. A protection circuit should be implemented in the cellular application.

6.7.4 Voiceband Receive Path

Test conditions:

- The values specified below were tested to 1024Hz using AT^SNFO=57,33,0 in audio mode 6 during a voice call unless otherwise stated.

Table 26: Voiceband receive path

Parameter	Min	Typ	Max	Unit	Test condition / remark
Maximum differential output voltage (peak to peak) EPP to EPN		4.5 5.0		V V	32 , No load, @ 3.14dBm0 (Full Scale)
Nominal differential output voltage (peak to peak) EPP to EPN		3.1 3.4		V V	32 , No load, @ 0dBm0 (Nominal level)
Output bias voltage		1.5		V	From EPP or EPN to GND
Differential output load resistance	16				

6.7.5 Voiceband Transmit Path

Test conditions:

- The values specified below were tested to 1024Hz using AT^SNFI=0,16,16384 in audio mode 6 during a voice call unless otherwise stated.

Table 27: Voiceband transmit path

Parameter	Min	Typ	Max	Unit	Test condition / Remark
Full scale input voltage (peak to peak) for 3.14dBm0 MICP to MICN		2.57		V	Balanced
Nominal input voltage (rms) for 0dBm0 MICP to MICN		0.64		V	Balanced
Input amplifier 1 gain (micAmp1)	0		24	dB	Set with AT^SNFI
Fine scaling by DSP (micTxVol)	-84		12	dB	Set with AT^SNFI
Microphone supply voltage VMIC		1.8		V	No load
Microphone supply voltage VMIC	1.8			V	@ 3mA

6.8 RF Antenna Interface Characteristics

Table 28: RF Antenna interface CDMA

Parameter	Conditions	Min.	Typical	Max.	Unit
CDMA connectivity	BC0, BC1,BC10				
Receiver Input Sensitivity @ ARP	CDMA BC0 1xRTT	-108.5	-110		dBm
	CDMA BC1 1xRTT	-107.5	-108.5		dBm
	CDMA BC10 1xRTT	-108.5	-110		dBm
RF Power@ ARP with 50Ohm Load	CDMA BC0 1xRTT	+21 +21	+24 +24	+25 +25	dBm
	CDMA BC1 1xRTT	+21 +21	+24 +24	+25 +25	dBm
	CDMA BC10	+21 +21	+24 +24	+25 +25	dBm

6.9 Electrostatic Discharge

The module is not protected against Electrostatic Discharge (ESD) in general. Consequently, it is subject to ESD handling precautions that typically apply to ESD sensitive components. Proper ESD handling and packaging procedures must be applied throughout the processing, handling and operation of any application that incorporates a PCS3 module.

Special ESD protection provided on PCS3*:*
All antenna interfaces: Inductor/capacitor
BATT+: Inductor/capacitor

The remaining interfaces of PCS3 are not accessible to the user of the final product (since they are installed within the device) and are therefore only protected according to the JEDEC JESD22-A114D requirements.

PCS3 has been tested according to the following standards. Electrostatic values can be gathered from the following table.

Table 31: Electrostatic values

Specification / Requirements	Contact discharge	Air discharge
JEDEC JESD22-A114D		
All SMT interfaces	± 1kV Human Body Model	n.a.
ETSI EN 301 489-1/7		
All antenna interfaces (CDMA/GNSS)	± 4kV	± 8kV
BATT+	± 4kV	± 8kV

Note: Please note that the values may vary with the individual application design. For example, it matters whether or not the application platform is grounded over external devices like a computer or other equipment, such as the Cinterion Wireless Modules reference application described in Chapter 9.

7 Mechanics, Mounting and Packaging

7.1 Mechanical Dimensions of PCS3

Figure 35 shows a 3D view[1] of PCS3 and provides an overview of the board's mechanical dimensions. For further details see Figure 36.

Length: 33mm
Width: 29mm
Height: 2mm

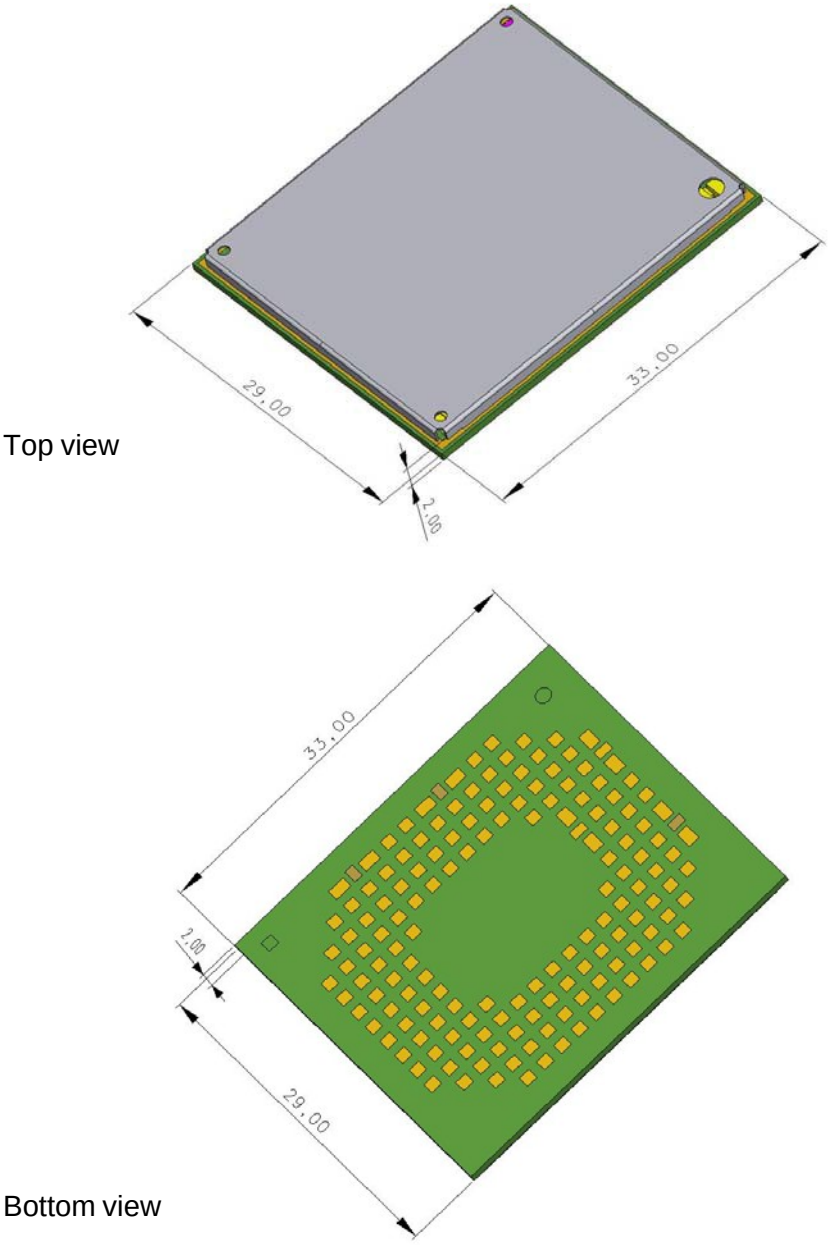


Figure 35: PCS3 – top and bottom view

1. The coloring of the 3D view does not reflect the module's real color.

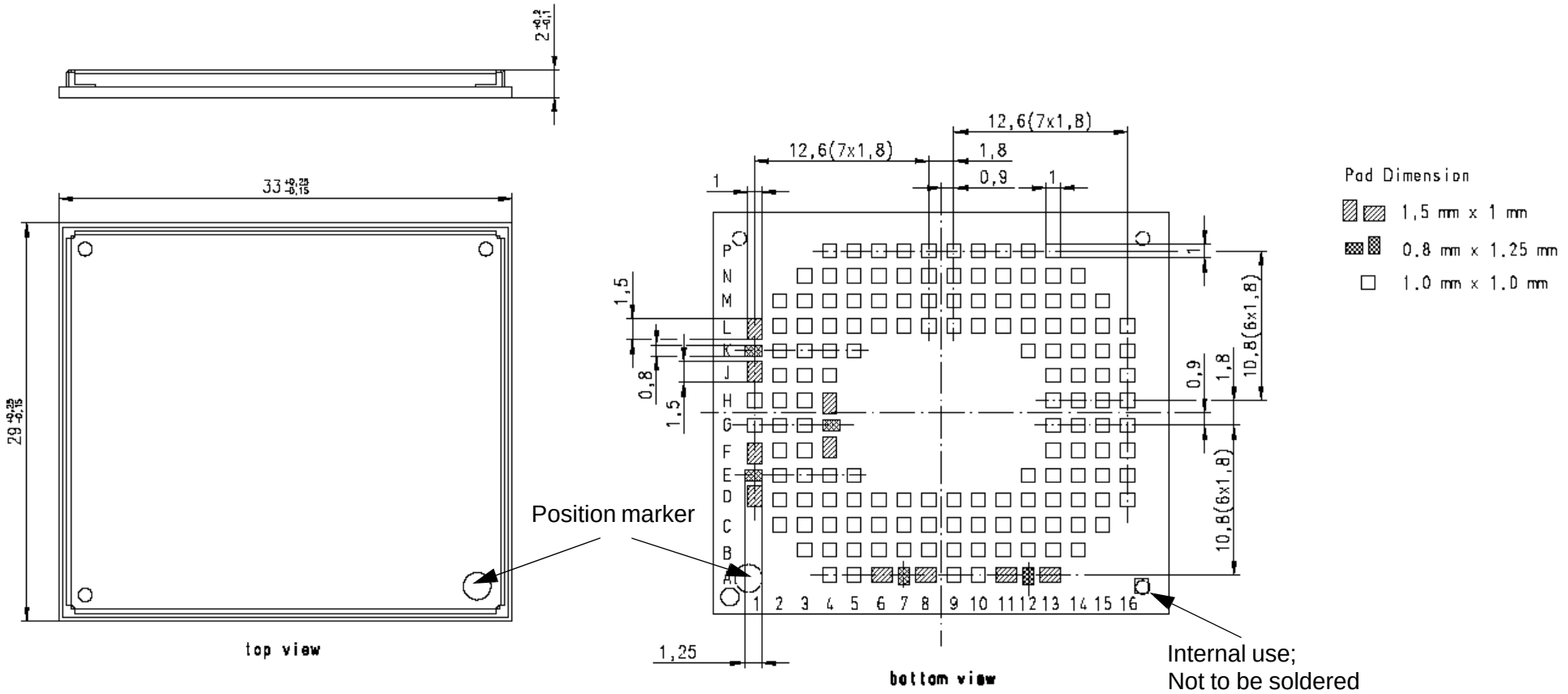


Figure 36: Dimensions of PCS3 (all dimensions in mm)

7.2 Mounting PCS3 onto the Application Platform

This section describes how to mount PCS3 onto the PCBs (=printed circuit boards), including land pattern and stencil design, board-level characterization, soldering conditions, durability and mechanical handling. For more information on issues related to SMT module integration see also [4].

Note: All SMT module pads need to be soldered to the application's PCB. Not only must all supply pads and signals be connected appropriately, but all pads denoted as "Do not use" will also have to be soldered (but not electrically connected) in order to ensure the best possible mechanical stability.

7.2.1 SMT PCB Assembly

7.2.1.1 Land Pattern and Stencil

The land pattern and stencil design as shown below is based on Cinterion characterizations for lead-free solder paste on a four-layer test PCB and a 110 respectively 150 micron-thick stencil.

The land pattern given in Figure 37 reflects the module's pad layout, including signal pads and ground pads (for pad assignment see Section 6.5). Besides these pads there are ground areas on the module's bottom side that must not be soldered, e.g., the position marker. To prevent short circuits, it has to be ensured that there are no wires on the external application side that may connect to these module ground areas.

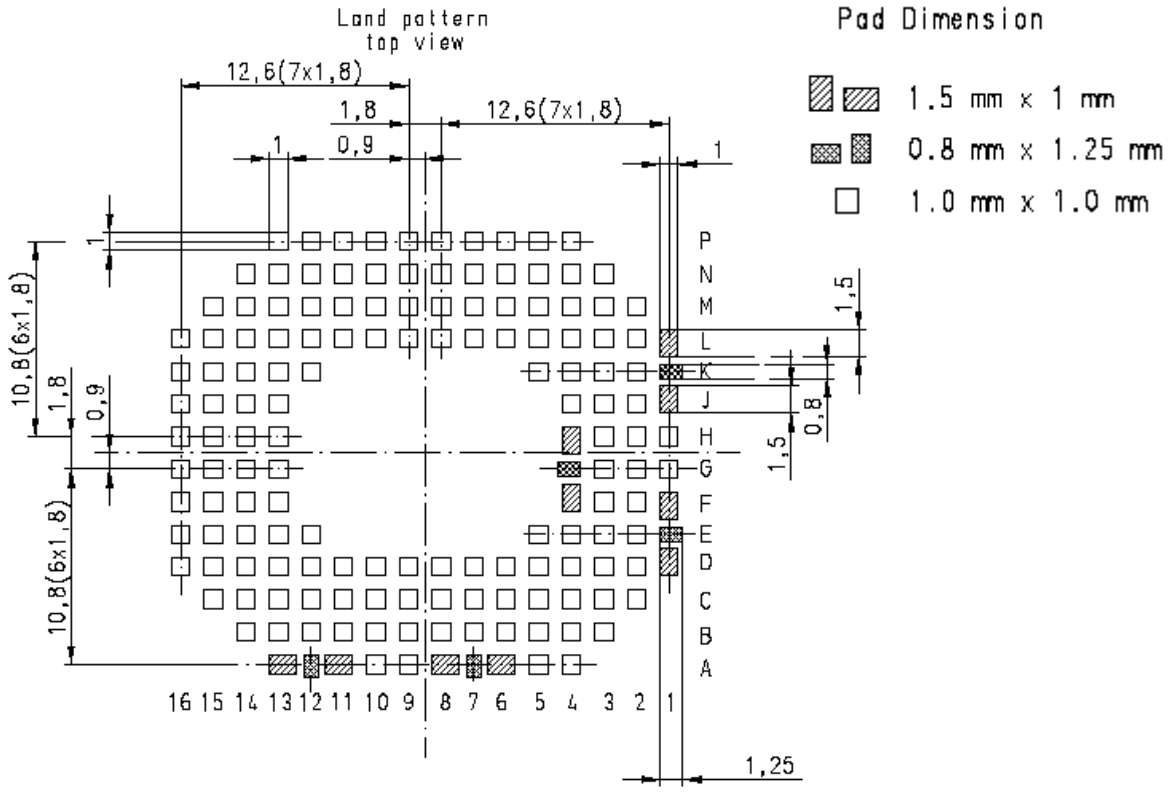


Figure 37: Land pattern (top view)

The stencil design illustrated in Figure 38 and Figure 39 is recommended by Cinterion as a result of extensive tests with Cinterion Daisy Chain modules.

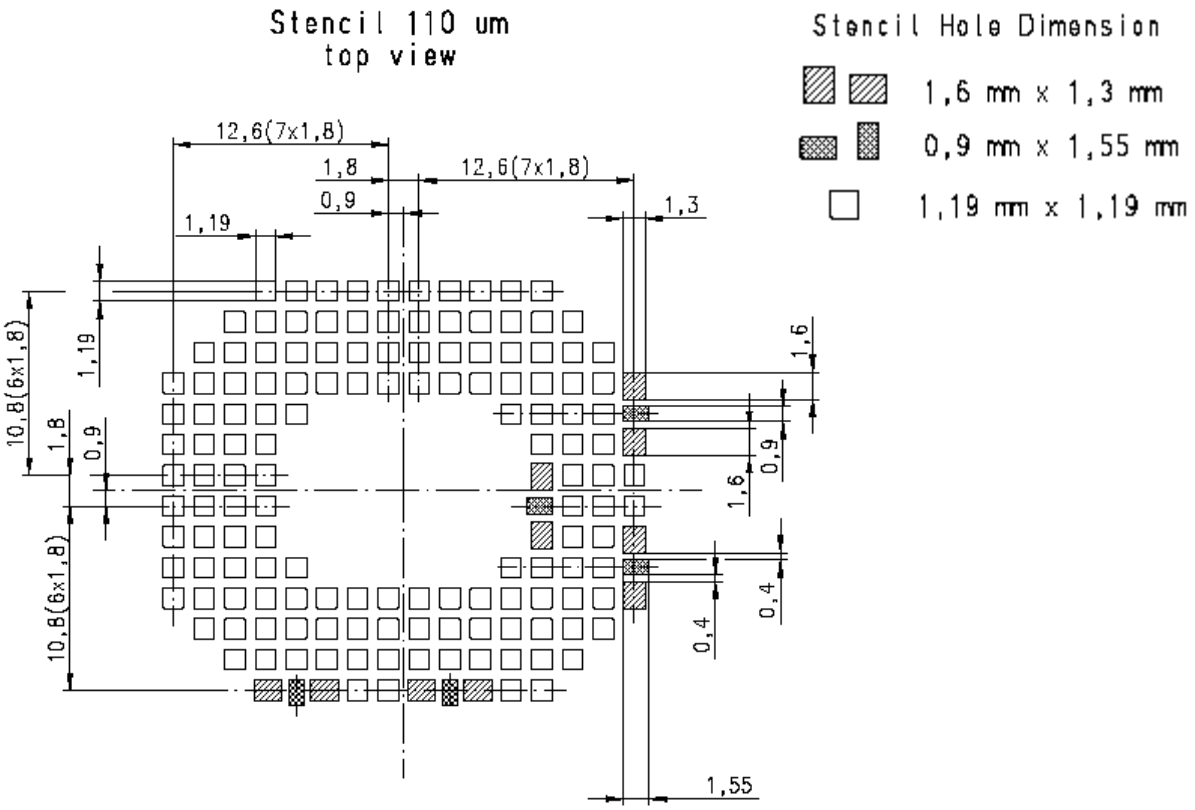


Figure 38: Recommended design for 110 micron thick stencil (top view)

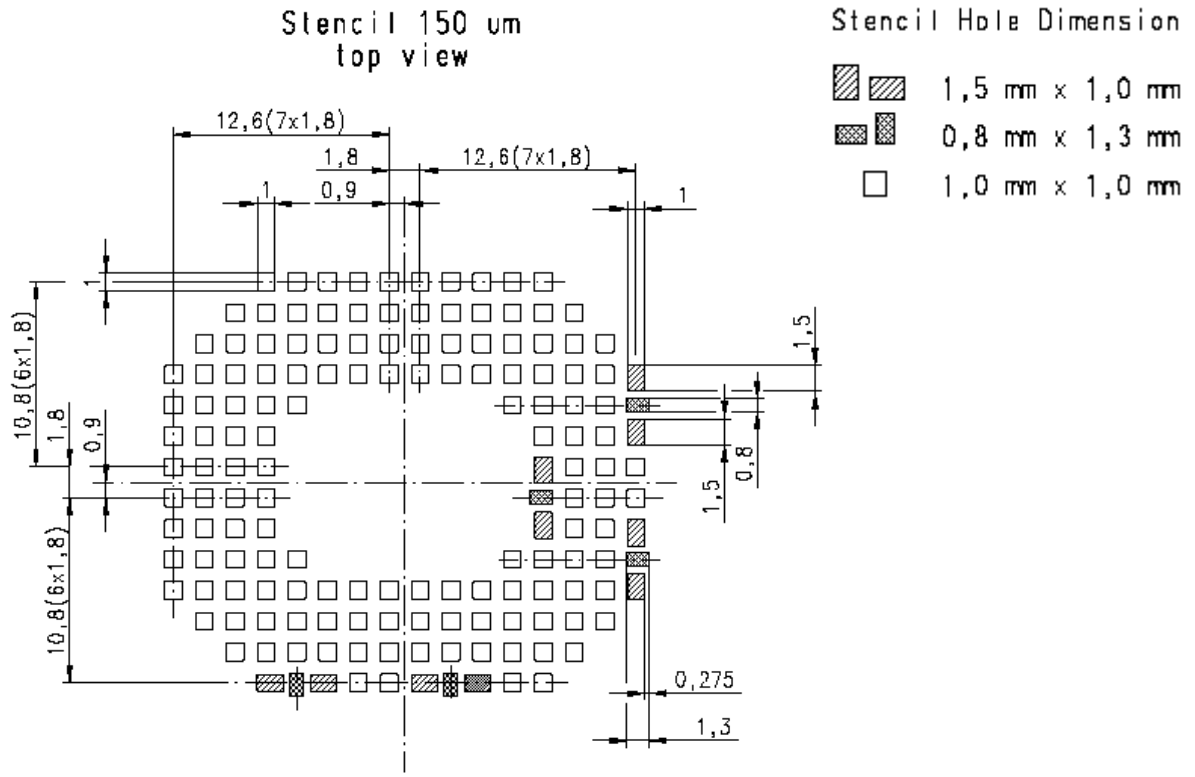


Figure 39: Recommended design for 150 micron thick stencil (top view)

7.2.1.2 Board Level Characterization

Board level characterization issues should also be taken into account if devising an SMT process.

Characterization tests should attempt to optimize the SMT process with regard to board level reliability. This can be done by performing the following physical tests on sample boards: Peel test, bend test, tensile pull test, drop shock test and temperature cycling. Sample surface mount checks are described in [4].

It is recommended to characterize land patterns before an actual PCB production, taking individual processes, materials, equipment, stencil design, and reflow profile into account. For land and stencil pattern design recommendations see also Section 7.2.1.1. Optimizing the solder stencil pattern design and print process is necessary to ensure print uniformity, to decrease sol- der voids, and to increase board level reliability.

Daisy chain modules for SMT characterization are available on request. For details refer to [4].

Generally, solder paste manufacturer recommendations for screen printing process parameters and reflow profile conditions should be followed. Maximum ratings are described in Section 7.2.3.

7.2.2 Moisture Sensitivity Level

PCS3 comprises components that are susceptible to damage induced by absorbed moisture.

Cinterion's PCS3 module complies with the latest revision of the IPC/JEDEC J-STD-020 standard for moisture sensitive surface mount devices and is classified as MSL 4.

For additional MSL (=moisture sensitivity level) related information see Section 7.2.4 and Section 7.3.2.

7.2.3 Soldering Conditions and Temperature

7.2.3.1 Reflow Profile

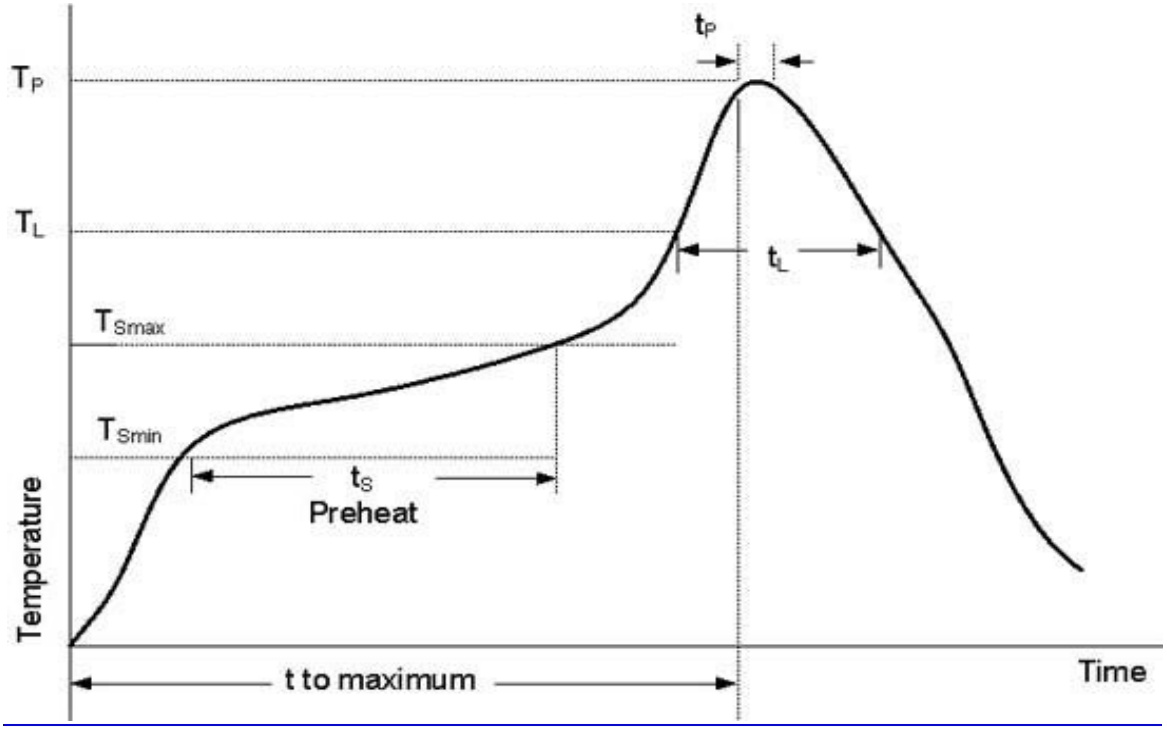


Figure 40: Reflow Profile

Table 31: Reflow temperature ratings

Profile Feature	Pb-Free Assembly
Preheat & Soak Temperature Minimum (T_{Smin}) Temperature Maximum (T_{Smax}) Time (t_{Smin} to t_{Smax}) (t_S)	 150°C 200°C 60-120 seconds
Average ramp up rate (T_{Smax} to T_P)	3K/second max.
Liquidous temperature (T_L) Time at liquidous (t_L)	217°C 60-90 seconds
Peak package body temperature (T_P)	245°C +0/-5°C
Time (t_P) within 5 °C of the peak package body temperature (T_P)	30 seconds max.
Average ramp-down rate (T_P to T_{Smax})	6 K/second max.
Time 25°C to maximum temperature	8 minutes max.

7.2.3.2 Maximum Temperature and Duration

The following limits are recommended for the SMT board-level soldering process to attach the module:

- A maximum module temperature of 245°C. This specifies the temperature as measured at the module’s top side.
- A maximum duration of 30 seconds at this temperature.

Please note that while the solder paste manufacturers' recommendations for best temperature and duration for solder reflow should generally be followed, the limits listed above must not be exceeded.

PCS3 is specified for one soldering cycle only. Once PCS3 is removed from the application, the module will very likely be destroyed and cannot be soldered onto another application.

7.2.4 Durability and Mechanical Handling

7.2.4.1 Storage Life

PCS3 modules, as delivered in tape and reel carriers, must be stored in sealed, moisture barrier anti-static bags. The shelf life in a sealed moisture bag is an estimated 12 month. However, such a life span requires a non-condensing atmospheric environment, ambient temperatures below 40°C and a relative humidity below 90%. Additional storage conditions are listed in Table 24.

7.2.4.2 Processing Life

PCS3 must be soldered to an application within 72 hours after opening the MBB (=moisture barrier bag) it was stored in.

As specified in the IPC/JEDEC J-STD-033 Standard, the manufacturing site processing the modules should have ambient temperatures below 30°C and a relative humidity below 60%.

7.2.4.3 Baking

Baking conditions are specified on the moisture sensitivity label attached to each MBB (see Figure 45 for details):

- It is *not necessary* to bake PCS3, if the conditions specified in Section 7.2.4.1 and Section 7.2.4.2 were not exceeded.
- It is *necessary* to bake PCS3, if any condition specified in Section 7.2.4.1 and Section 7.2.4.2 was exceeded.

If baking is necessary, the modules must be put into trays that can be baked to at least 125°C. Devices should not be baked in tape and reel carriers at any temperature.

7.2.4.4 Electrostatic Discharge

ESD (=electrostatic discharge) may lead to irreversible damage for the module. It is therefore advisable to develop measures and methods to counter ESD and to use these to control the electrostatic environment at manufacturing sites.

Please refer to Section 5.9 for further information on electrostatic discharge.

7.3 Packaging

7.3.1 Tape and Reel

The single-feed tape carrier for PCS3 is illustrated in Figure 41. The figure also shows the proper part orientation. The tape width is 44mm and the PCS3 modules are placed on the tape with a 40mm pitch. The reels are 330mm in diameter with 100mm hubs. Each reel contains 500 modules.

7.3.1.1 Orientation

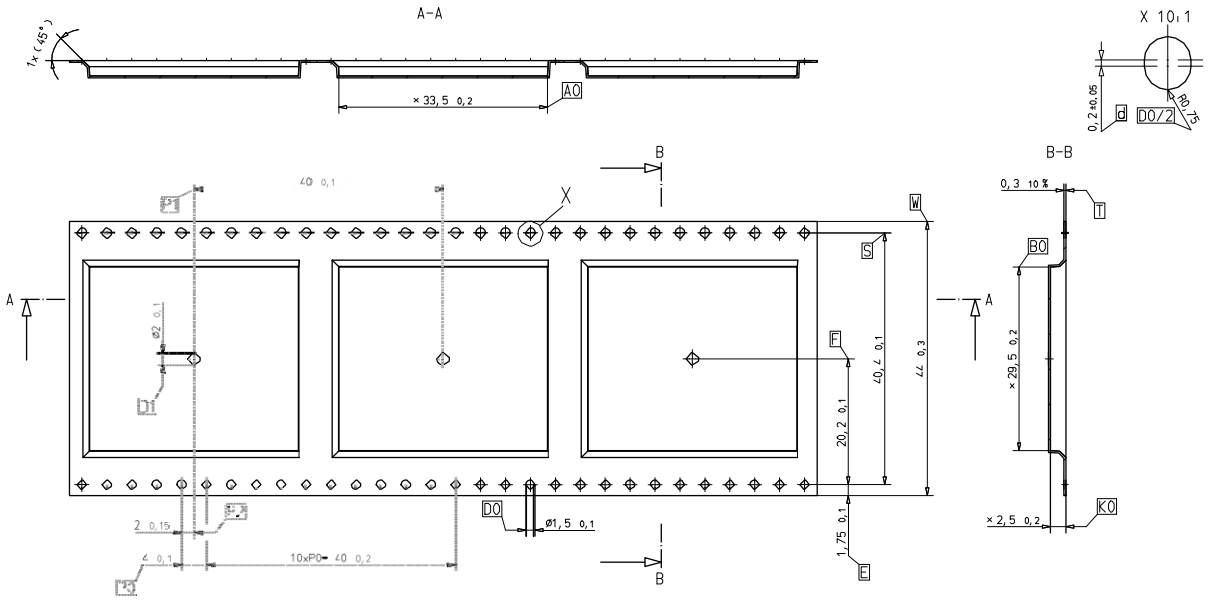


Figure 41: Carrier tape

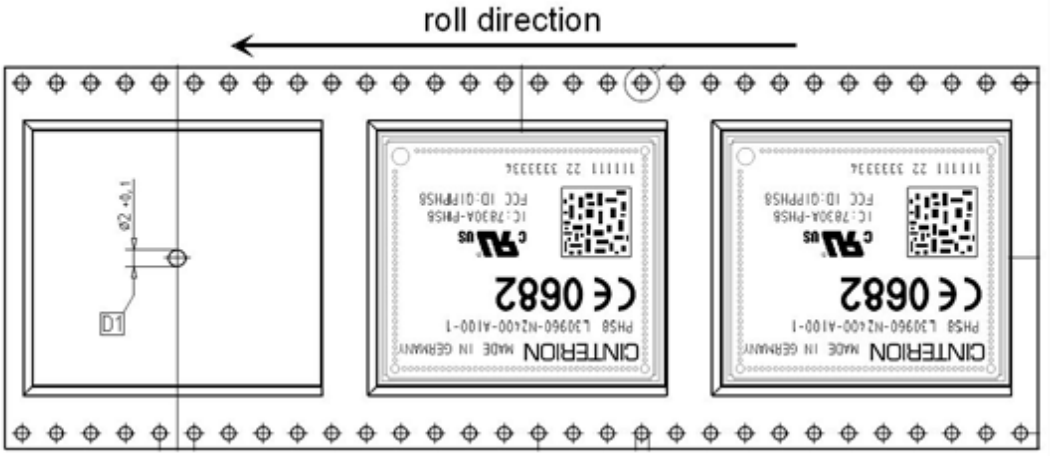


Figure 42: Roll direction

7.3.1.2 Barcode Label

A barcode label provides detailed information on the tape and its contents. It is attached to the reel.

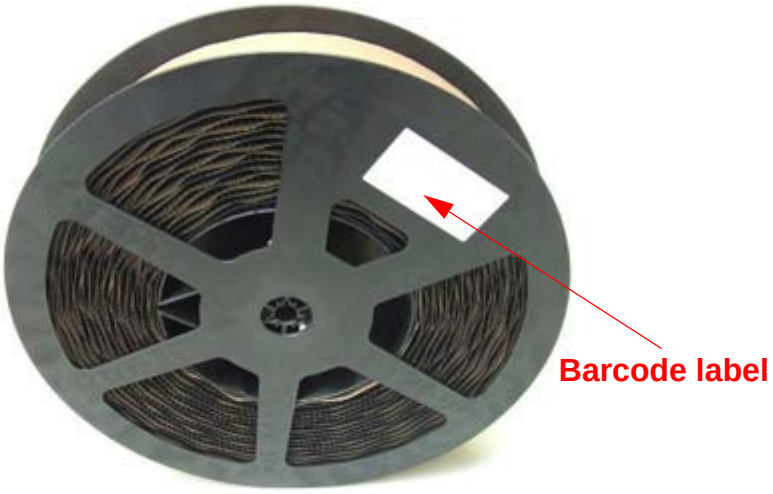


Figure 43: Barcode label on tape reel

7.3.2 Shipping Materials

PCS3 is distributed in tape and reel carriers. The tape and reel carriers used to distribute PCS3 are packed as described below, including the following required shipping materials:

- Moisture barrier bag, including desiccant and humidity indicator card
- Transportation bag

7.3.2.1 Moisture Barrier Bag

The tape reels are stored inside an MBB (=moisture barrier bag), together with a humidity indicator card and desiccant pouches - see Figure 44. The bag is ESD protected and delimits moisture transmission. It is vacuum-sealed and should be handled carefully to avoid puncturing or tearing. The bag protects the PCS3 modules from moisture exposure. It should not be opened until the devices are ready to be soldered onto the application.

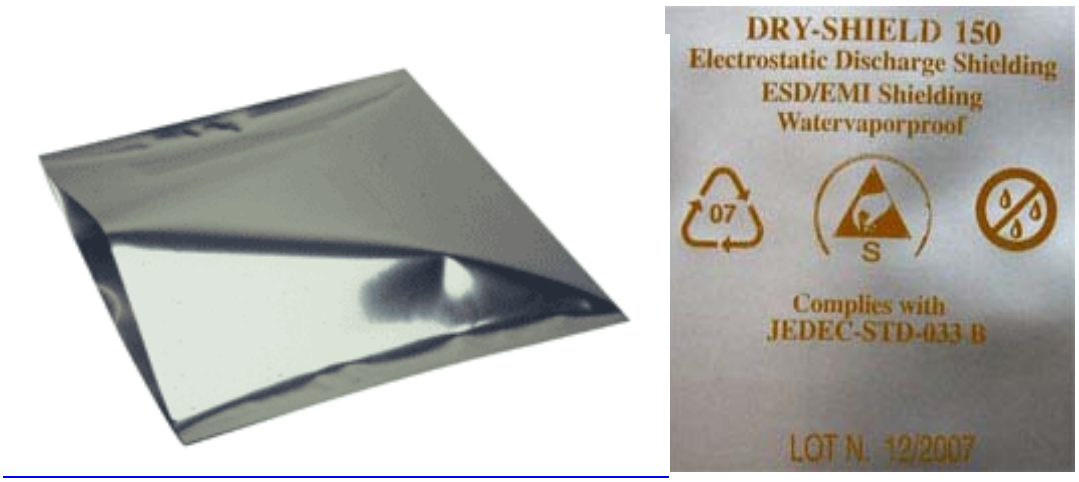


Figure 44: Moisture barrier bag (MBB) with imprint

The label shown in Figure 45 summarizes requirements regarding moisture sensitivity, including shelf life and baking requirements. It is attached to the outside of the moisture barrier bag.

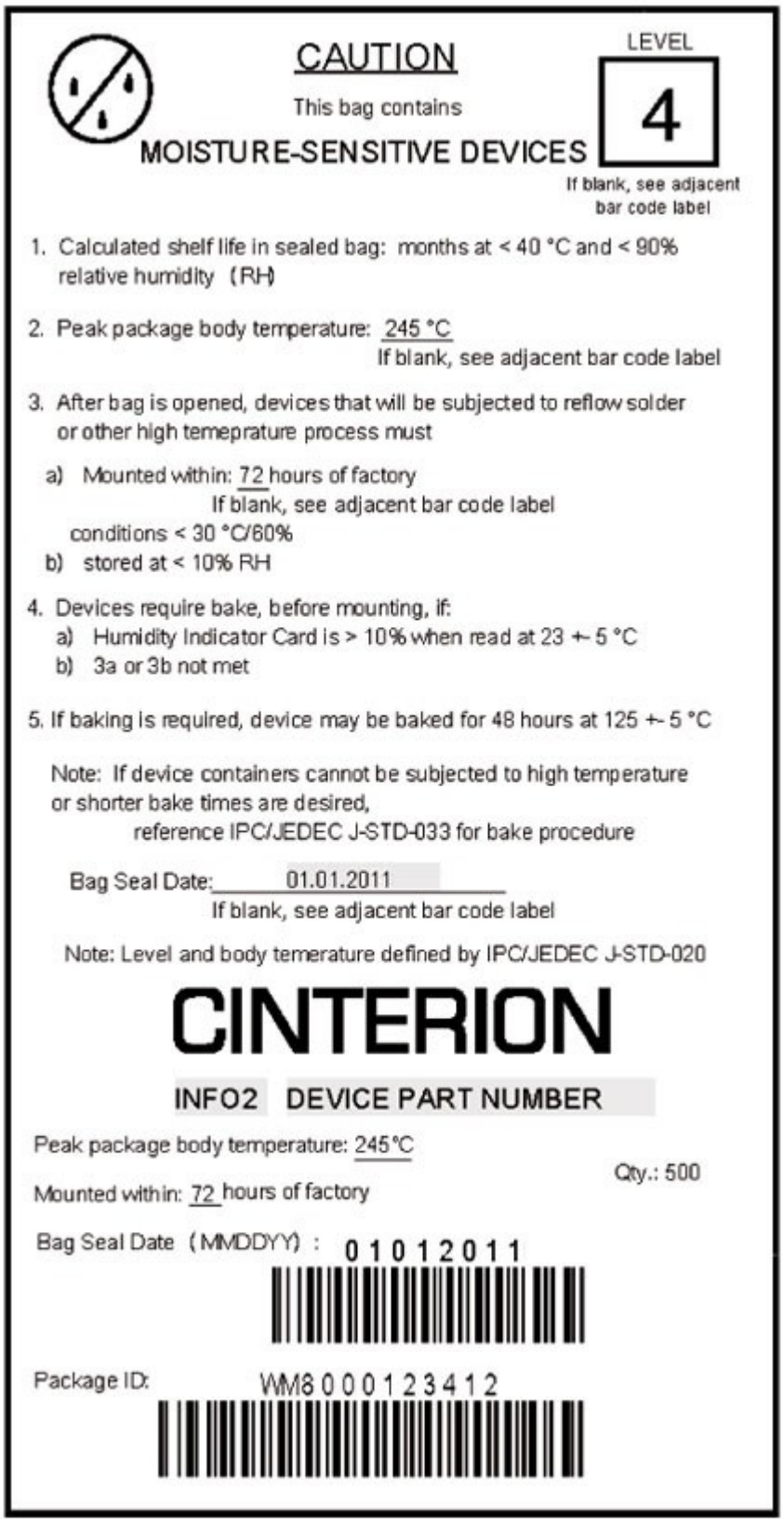


Figure 45: Moisture Sensitivity Label

MBBs contain one or more desiccant pouches to absorb moisture that may be in the bag. The humidity indicator card described below should be used to determine whether the enclosed components have absorbed an excessive amount of moisture.

The desiccant pouches should not be baked or reused once removed from the MBB.

The humidity indicator card is a moisture indicator and is included in the MBB to show the approximate relative humidity level within the bag. Sample humidity cards are shown in Figure 46. If the components have been exposed to moisture above the recommended limits, the units will have to be rebaked.

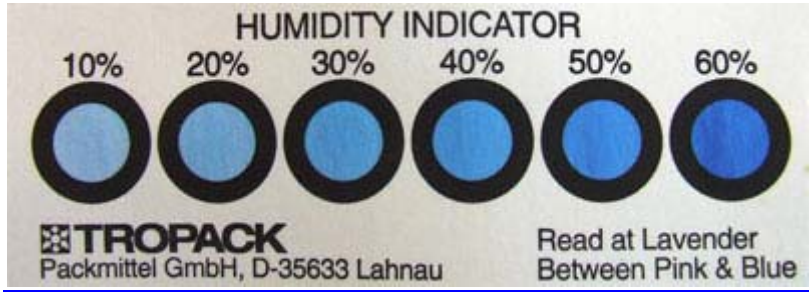


Figure 46: Humidity Indicator Card - HIC

A baking is required if the humidity indicator inside the bag indicates 10% RH or more.

7.3.2.2 Transportation Box

Tape and reel carriers are distributed in a box, marked with a barcode label for identification purposes. A box contains 2 reels with 500 modules each.

8 Sample Application

Figure 47 shows a typical example of how to integrate an PCS3 module with an application.

The audio interface demonstrates the balanced connection of microphone and earpiece. This solution is particularly well suited for internal transducers.

The PWR_IND line is an open collector that needs an external pull-up resistor which connects to the voltage supply VCC µC of the microcontroller. Low state of the open collector pulls the PWR_IND signal low and indicates that the PCS3 module is active, high level notifies the Power-down mode.

If the module is in Power-down mode avoid current flowing from any other source into the module circuit, for example reverse current from high state external control lines. Therefore, the controlling application must be designed to prevent reverse flow. If an external level controller is required, this can be done by using for example a 5V I/O tolerant buffer/driver like a "74AVC4T245" with OE (Output Enable) controlled by PWR_IND.

While developing SMT applications it is strongly recommended to provide test points for certain signals resp. lines to and from the module - for debug and/or test purposes. The SMT application should allow for an easy access to these signals. For details on how to implement test points see [4].

The EMC measures are best practice recommendations. In fact, an adequate EMC strategy for an individual application is very much determined by the overall layout and, especially, the position of components.

Disclaimer:
No warranty, either stated or implied, is provided on the sample schematic diagram shown in Figure 47 and the information detailed in this section. As functionality and compliance with national regulations depend to a great amount on the used electronic components and the individual application layout manufacturers are required to ensure adequate design and operating safeguards for their products using PCS3 modules.

9 Reference Approval

9.1 Reference Equipment for Type Approval

The Cinterion Wireless Modules reference setup submitted to type approve PCS3 is shown in Figure 48. The module (i.e., the evaluation module) is connected to the DSB75 by means of a flex cable and a special DSB75 adapter. The CDMA test equipment is connected via edge mount SMA connectors soldered to the module's antenna pads.((Only Main Antenna of PCS3, Didn't have GPS)

For ESD tests and evaluation purposes, it is also possible connect the module to the CDMA test equipment through an SMA-to-Hirose-U.FL antenna cable and the SMA antenna connectors of the DSB75 adapter.

A further option is to mount the evaluation module directly onto the DSB75 adapter's 80-pin board-to-board connector and to connect the test equipment as shown below.

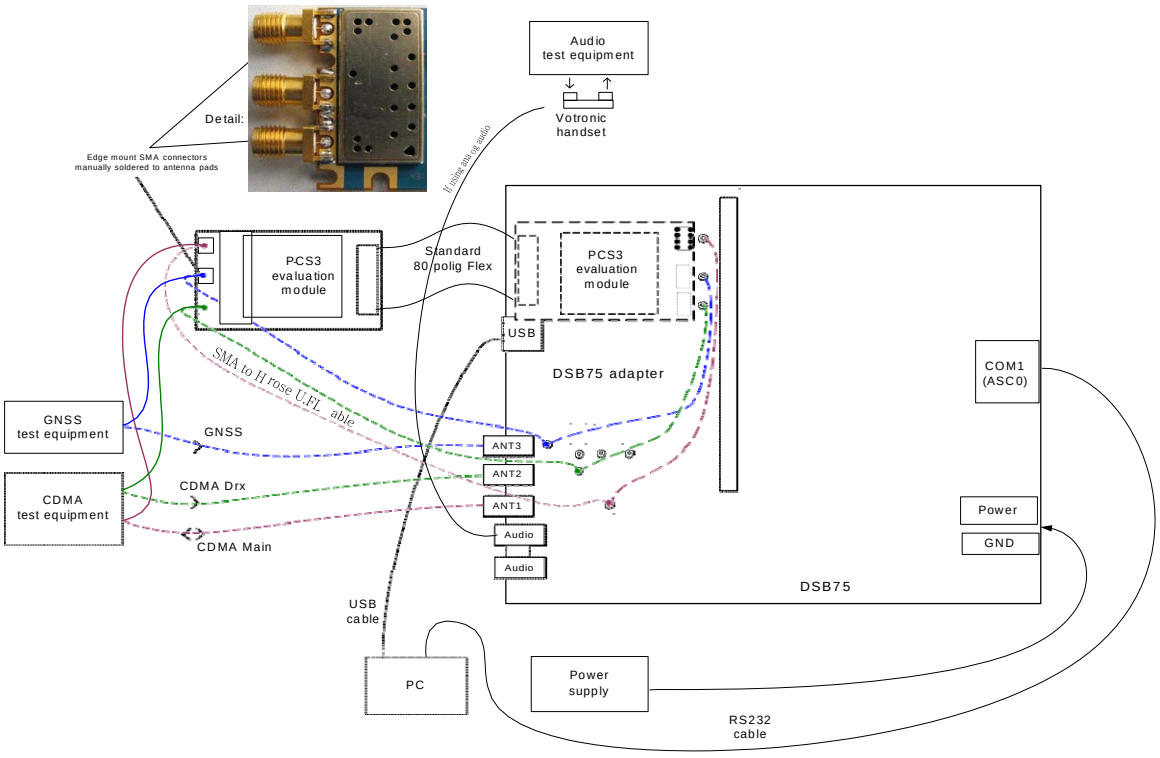


Figure 48: Reference equipment for type approval

9.2 Compliance with FCC and IC Rules and Regulations

The Equipment Authorization Certification for the Cinterion Wireless Modules reference application described in Section 9.1 will be registered under the following identifiers:

FCC Identifier QIPPCS3
Industry Canada Certification Number: 7830A-PCS3
Granted to Cinterion Wireless Modules GmbH

Manufacturers of mobile or fixed devices incorporating PCS3 modules are authorized to use the FCC Grants and Industry Canada Certificates of the PCS3 modules for their own final products according to the conditions referenced in these documents. In this case, the FCC label of the module shall be visible from the outside, or the host device shall bear a second label stating "Contains FCC ID QIPPCS3" and accordingly “Contains IC 7830A-PCS3“. The integration is limited to fixed or mobile categorised host devices, where a separation distance between the antenna and any person of min. 20cm can be assured during normal operating conditions. For mobile and fixed operation configurations the antenna gain, including cable loss, must not exceed the limits 9.0 dBi (BC0), 9.0 dBi (BC10) and 7.5 dBi (BC1).

IMPORTANT:
Manufacturers of portable applications incorporating PCS3 modules are required to have their final product certified and apply for their own FCC Grant and Industry Canada Certificate related to the specific portable mobile. This is mandatory to meet the SAR requirements for portable mobiles (see Section 1.3.1 for detail).

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Note-1: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules and with Industry Canada licence-exempt RSS standard(s). These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

This Class B digital apparatus complies with Canadian ICES-003.

Note-2: This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.
This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions:
(1) This device may not cause interference, and
(2) This device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes:
(1) l'appareil ne doit pas produire de brouillage, et
(2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement."

CAN ICES-3(B)/ NMB-3(B)

10 Appendix

10.1 List of Parts and Accessories

Table 32: List of parts and accessories

Description	Supplier	Ordering information
PCS3	Cinterion	Standard module Cinterion Wireless Modules IMEI: Ordering number: L30960-N2650-A280
PCS3 Evaluation Module	Cinterion	Ordering number: L30960-N2651-TBD.
DSB75 Support Box	Cinterion	Ordering number: L36880-N8811-A100
DSB75 adapter for mounting the PCS3 evaluation module	Cinterion	Ordering number: L30960-N2301-A100
Votronic Handset	VOTRONIC	Votronic HH-SI-30.3/V1.1/0 VOTRONIC Entwicklungs- und Produktionsgesellschaft für elektronische Geräte mbH Saarbrücker Str. 8 66386 St. Ingbert Germany Phone: +49-(0)6 89 4 / 92 55-0 Fax: +49-(0)6 89 4 / 92 55-88 Email: contact@votronic.com
U.FL antenna connector	Hirose or Molex	Sales contacts are listed in Table 34 and Table 35.

Table 33: Molex sales contacts (subject to change)

Molex For further information please click: http://www.molex.com	Molex Deutschland GmbH Otto-Hahn-Str. 1b 69190 Walldorf Germany Phone: +49-6227-3091-0 Fax: +49-6227-3091-8100 Email: mxgermany@molex.com	American Headquarters Lisle, Illinois 60532 U.S.A. Phone: +1-800-78MOLEX Fax: +1-630-969-1352
Molex China Distributors Beijing, Room 1311, Tower B, COFCO Plaza No. 8, Jian Guo Men Nei Street, 100005 Beijing P.R. China Phone: +86-10-6526-9628 Fax: +86-10-6526-9730	Molex Singapore Pte. Ltd. 110, International Road Jurong Town, Singapore 629174 Phone: +65-6-268-6868 Fax: +65-6-265-6044	Molex Japan Co. Ltd. 1-5-4 Fukami-Higashi, Yamato-City, Kanagawa, 242-8585 Japan Phone: +81-46-265-2325 Fax: +81-46-265-2365

Table 34: Hirose sales contacts (subject to change)

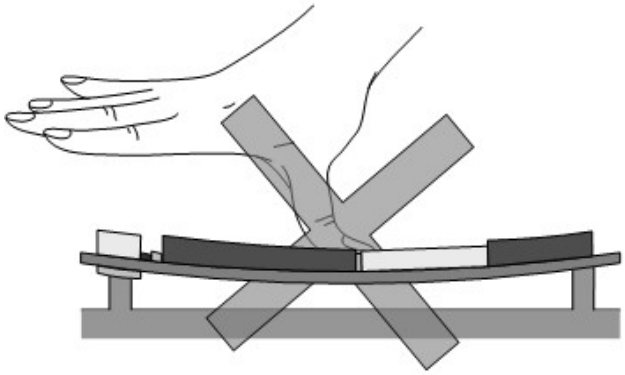
Hirose Ltd. For further information please click: http://www.hirose.com	Hirose Electric (U.S.A.) Inc 2688 Westhills Court Simi Valley, CA 93065 U.S.A. Phone: +1-805-522-7958 Fax: +1-805-522-3217	Hirose Electric Europe B.V. German Branch: Herzog-Carl-Strasse 4 73760 Ostfildern Germany Phone: +49-711-456002-1 Fax: +49-711-456002-299 Email:info@hirose.de
Hirose Electric Europe B.V. UK Branch: First Floor, St. Andrews House, Caldecotte Lake Business Park, Milton Keynes MK7 8LE Great Britain Phone: +44-1908-369060 Fax: +44-1908-369078	Hirose Electric Co., Ltd. 5-23, Osaki 5 Chome, Shinagawa-Ku Tokyo 141 Japan Phone: +81-03-3491-9741 Fax: +81-03-3493-2933	Hirose Electric Europe B.V. Hogehillweg 8 1101 CC Amsterdam Z-O Netherlands Phone: +31-20-6557-460 Fax: +31-20-6557-469

10.2 Mounting Advice Sheet

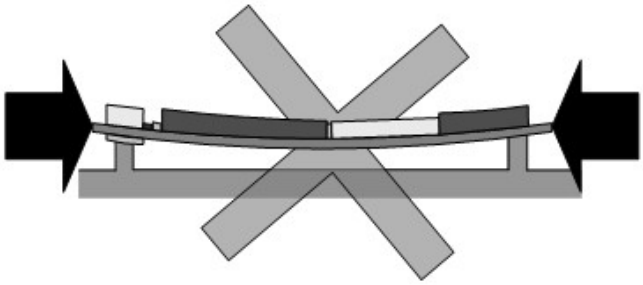
To prevent mechanical damage, be careful not to force, bend or twist the module. Be sure it is soldered flat against the host device (see also Section 7.2). The advice sheet on the next page shows a number of examples for the kind of bending that may lead to mechanical damage of the module (the module as part of an external application is integrated into a housing).

Mounting Advice

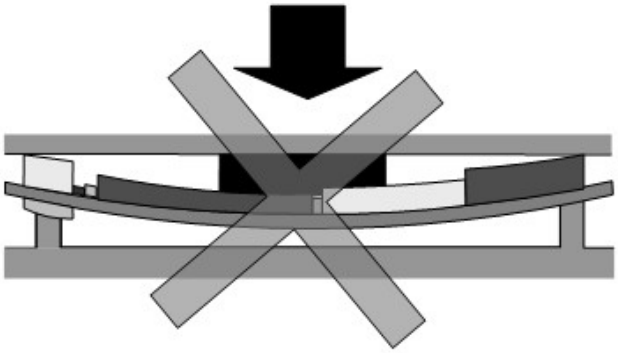
Do NOT BEND the Module



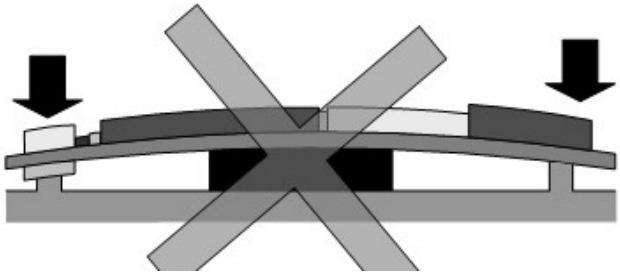
- By pressing from above



- By mounting under pressure



- By putting objects on top



- By putting objects below