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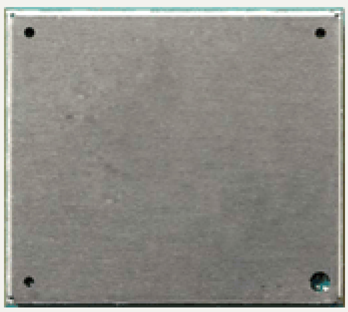
Cinterion® PLS8-E

Hardware Interface Description

Version: 01.460a
DocId: PLS8-E_HD_v01.460a



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Document Name:	**Cinterion® PLS8-E Hardware Interface Description**
Version:	**01.460a**
Date:	**2014-11-26**
DocId:	**PLS8-E_HD_v01.460a**
Status	**Confidential / Preliminary**

Contents

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0 Document History

Preceding document: "PLS8-E Hardware Interface Description" Version 01.460
New document: "PLS8-E Hardware Interface Description" Version **01.460a**

Chapter	What is new
Throughout document	Added LTE 2100MHz (Bd1).
7.2.3.1	Added note regarding reflow profile features and ratings listed in Table 29.

Preceding document: "PLS8-E Hardware Interface Description" Version 01.438
New document: "PLS8-E Hardware Interface Description" Version 01.460

Chapter	What is new
7.2.3.1	Revised average ramp-down rate listed in Table 29.
8.1	New section Sample Level Conversion Circuit.

Preceding document: "PLS8-E Hardware Interface Description" Version 01.000c
New document: "PLS8-E Hardware Interface Description" Version 01.438

Chapter	What is new
Throughout document	Added power saving (SLEEP mode). See particularly Section 3.4.1 - Section 3.4.3. Added ASC0 interface. See particularly Section 3.6. Added PCM / I^2S interface. See particularly Section 3.8. Added ADC3_IN line. See particularly Section 3.9. Added host wakeup via RING0 line. See particularly Section 3.11.2. Added Low Current indicator. See particularly Section 3.11.4 Added STATUS line. See particularly Section 3.11.5. Added GNSS receiver description. See particularly Section 4. Added GNSS interface. See particularly Section 5.2.
3.3.1	Added information on "^SYSSTART" and "^SYSSTART AIRPLANE" URCs.
3.3.5.2	New section Deferred Shutdown at Extreme Temperature Conditions.
3.10	Added: GPIOs can be used to wake up the module from SLEEP mode.
3.11.3	New section Host Wakeup.
6.6	Completed Table 24: Current consumption ratings.
10.1	Updated ordering numbers.

1 Introduction

The document[1] describes the hardware of the Cinterion® PLS8-E 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 Supported Products

This document applies to the following Gemalto M2M products:
- Cinterion® PLS8-E module

1.2 Related Documents

[1] AT Command Set for your Gemalto M2M product
[2] Release Notes for your Gemalto M2M product
[3] Application Note 48: SMT Module Integration
[4] Universal Serial Bus Specification Revision 2.0, April 27, 2000

1.3 Terms and Abbreviations

Abbreviation	Description
ANSI	American National Standards Institute
ARP	Antenna Reference Point
CE	Conformité Européene (European Conformity)
CS	Coding Scheme
CS	Circuit Switched
CSD	Circuit Switched Data
DCS	Digital Cellular System
DL	Download
dnu	Do not use
DRX	Discontinuous Reception
DSB	Development Support Board
DTX	Discontinuous Transmission
EDGE	Enhanced Data rates for GSM Evolution
EGSM	Extended GSM

1. The document is effective only if listed in the appropriate Release Notes as part of the technical documentation delivered with your Gemalto M2M product.

Abbreviation	Description
EMC	Electromagnetic Compatibility
ESD	Electrostatic Discharge
ETS	European Telecommunication Standard
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Duplex
GPRS	General Packet Radio Service
GSM	Global Standard for Mobile Communications
HiZ	High Impedance
HSDPA	High Speed Downlink Packet Access
I/O	Input/Output
IMEI	International Mobile Equipment Identity
ISO	International Standards Organization
ITU	International Telecommunications Union
kbps	kbits per second
LED	Light Emitting Diode
LGA	Land Grid Array
LTE	Long term evolution
MBB	Moisture barrier bag
Mbps	Mbits per second
MCS	Modulation and Coding Scheme
MIMO	Multiple Input Multiple Output
MLCC	Multi Layer Ceramic Capacitor
MO	Mobile Originated
MS	Mobile Station, also referred to as TE
MSL	Moisture Sensitivity Level
MT	Mobile Terminated
nc	Not connected
NTC	Negative Temperature Coefficient
PCB	Printed Circuit Board
PCL	Power Control Level
PCS	Personal Communication System, also referred to as GSM 1900
PD	Pull Down resistor
PDU	Protocol Data Unit
PS	Packet Switched
PSK	Phase Shift Keying
PU	Pull Up resistor

Abbreviation	Description
QAM	Quadrature Amplitude Modulation
R&TTE	Radio and Telecommunication Terminal Equipment
RF	Radio Frequency
rfu	Reserved for future use
ROPR	Radio Output Power Reduction
RTC	Real Time Clock
Rx	Receive Direction
SAR	Specific Absorption Rate
SELV	Safety Extra Low Voltage
SIM	Subscriber Identification Module
SMD	Surface Mount Device
SMS	Short Message Service
SMT	Surface Mount Technology
SRAM	Static Random Access Memory
SRB	Signalling Radio Bearer
TE	Terminal Equipment
TPC	Transmit Power Control
TS	Technical Specification
Tx	Transmit Direction
UL	Upload
UMTS	Universal Mobile Telecommunications System
URC	Unsolicited Result Code
USB	Universal Serial Bus
UICC	USIM Integrated Circuit Card
USIM	UMTS Subscriber Identification Module
WCDMA	Wideband Code Division Multiple Access

1.4 Regulatory and Type Approval Information

1.4.1 Directives and Standards

PLS8-E 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 "PLS8-E Hardware Interface Description".

Table 1: Directives

99/05/EC	Directive of the European Parliament and of the council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (in short referred to as R&TTE Directive 1999/5/EC). The product is labeled with the CE conformity mark CE 0682
ECE-R 10	Economic Commission for Europe (ECE) Regulation No. 10: Uniform provisions concerning the approval of vehicles with regard to electromagnetic compatibility
2002/95/EC (RoHS 1) 2011/65/EC (RoHS 2)	Directive of the European Parliament and of the Council of 27 January 2003 (and revised on 8 June 2011) on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) RoHS compliant

Table 2: Standards of European type approval

3GPP TS 51.010-1	Digital cellular telecommunications system (Release 7); Mobile Station (MS) conformance specification;
ETSI EN 301 511 V9.0.2	Global System for Mobile communications (GSM); Harmonized standard for mobile stations in the GSM 900 and DCS 1800 bands covering essential requirements under article 3.2 of the R&TTE directive (1999/5/EC)
GCF-CC V3.48	Global Certification Forum - Certification Criteria
ETSI EN 301 489-01 V1.9.1	Electromagnetic Compatibility and Radio spectrum Matters (ERM); Electromagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common Technical Requirements
ETSI EN 301 489-07 V1.3.1	Electromagnetic Compatibility and Radio spectrum Matters (ERM); Electromagnetic Compatibility (EMC) standard for radio equipment and services; Part 7: Specific conditions for mobile and portable radio and ancillary equipment of digital cellular radio telecommunications systems (GSM and DCS)
ETSI EN 301 489-24 V1.5.1	Electromagnetic Compatibility and Radio spectrum Matters (ERM); Electromagnetic Compatibility (EMC) standard for radio equipment and services; Part 24: Specific conditions for IMT-2000 CDMA Direct Spread (UTRA) for Mobile and portable (UE) radio and ancillary equipment
EN 301 908-01 V5.2.1	Electromagnetic compatibility and Radio spectrum Matters (ERM); Base Stations (BS) and User Equipment (UE) for IMT-2000 Third Generation cellular networks; Part 1: Harmonized EN for IMT-2000, introduction and common requirements of article 3.2 of the R&TTE Directive

Table 2: Standards of European type approval

EN 301 908-02 V5.2.1	Electromagnetic compatibility and Radio spectrum Matters (ERM); Base Stations (BS) and User Equipment (UE) for IMT-2000 Third Generation cellular networks; Part 2: Harmonized EN for IMT-2000, CDMA Direct Spread (UTRA FDD) (UE) covering essential requirements of article 3.2 of the R&TTE Directive
EN 301 908-13 V5.2.1	IMT cellular networks; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 13: Evolved Universal Terrestrial Radio Access (E-UTRA) User Equipment (UE)
EN 300 440-02 V1.3.1	Electromagnetic compatibility and Radio spectrum Matters (ERM); Short range devices; Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Part 2: Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive
EN 62311:2008	Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz)
IEC/EN 60950-1:2006+ A11:2009+A1:2010+ A12:2011	Safety of information technology equipment

Table 3: Requirements of quality

IEC 60068	Environmental testing
DIN EN 60529	IP codes

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 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.

1.4.2 SAR requirements specific to portable mobiles

Mobile phones, PDAs or other portable transmitters and receivers incorporating a GSM module must be in accordance with the guidelines for human exposure to radio frequency energy. This requires the Specific Absorption Rate (SAR) of portable PLS8-E 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 European 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 European markets

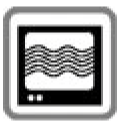
EN 50360	Product standard to demonstrate the compliance of mobile phones with the basic restrictions related to human exposure to electromagnetic fields (300MHz - 3GHz)

1.4.3 SELV Requirements

The power supply connected to the PLS8-E module shall be in compliance with the SELV requirements defined in EN 60950-1.

1.4.4 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 PLS8-E. 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. Gemalto M2M 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 manufacturer 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.
	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. Some networks require that a valid SIM card be properly inserted in the cellular terminal or mobile.

2 Product Concept

2.1 Key Features at a Glance

Feature	Implementation
General	
Frequency bands	GSM/GPRS/EDGE: Dual band, 900/1800MHz UMTS/HSPA+: Triple band, 900 (BdVIII) / 1800 (BdIII) / 2100MHz (BdI) LTE: Five band, 800 (Bd20) / 900 (Bd8) / 1800 (Bd3) / 2100 (Bd1) / 2600MHz (Bd7)
GSM class	Small MS
Output power (according to Release 99)	Class 4 (+33dBm ±2dB) for EGSM900 Class 1 (+30dBm ±2dB) for GSM1800 Class E2 (+27dBm ± 3dB) for GSM 900 8-PSK Class E2 (+26dBm +3 /-4dB) for GSM 1800 8-PSK Class 3 (+24dBm +1/-3dB) for UMTS 2100, WCDMA FDD BdI Class 3 (+24dBm +1/-3dB) for UMTS 1800, WCDMA FDD BdIII Class 3 (+24dBm +1/-3dB) for UMTS 900, WCDMA FDD BdVIII
Output power (according to Release 8)	Class 3 (+23dBm +-2dB) for LTE 2600, LTE FDD Bd7 Class 3 (+23dBm +-2dB) for LTE 2100, LTE FDD Bd1 Class 3 (+23dBm +-2dB) for LTE 1800, LTE FDD Bd3 Class 3 (+23dBm +-2dB) for LTE 900, LTE FDD Bd8 Class 3 (+23dBm +-2dB) for LTE 800, LTE FDD Bd20
Power supply	$3.3V \leq V_{BATT+} \leq 4.2V$
Operating temperature (board temperature)	Normal operation: -30°C to +85°C Extended operation: -40°C to +95°C
Physical	Dimensions: 33mm x 29mm x 2.2mm Weight: approx. 4.5g
RoHS	All hardware components fully compliant with EU RoHS Directive
LTE features	
3GPP Release 9	UE CAT 3 supported DL 100Mbps, UL 50Mbps 2x2 MIMO in DL direction
HSPA features	
3GPP Release 8	UE CAT. 14, 24 DC-HSPA+ – DL 42Mbps HSUPA – UL 5.76Mbps Compressed mode (CM) supported according to 3GPP TS25.212
UMTS features	
3GPP Release 8	PS data rate – 384 kbps DL / 384 kbps UL

Feature	**Implementation**
GSM / GPRS / EGPRS features	
Data transfer	GPRS: • Multislot Class 12 • Mobile Station Class B • Coding Scheme 1 – 4 EGPRS: • Multislot Class 12 • EDGE E2 power class for 8 PSK • Downlink coding schemes – CS 1-4, MCS 1-9 • Uplink coding schemes – CS 1-4, MCS 1-9 • SRB loopback and test mode B • 8-bit, 11-bit RACH • 1 phase/2 phase access procedures • Link adaptation and IR • NACC, extended UL TBF • Mobile Station Class B
SMS	Point-to-point MT and MO Cell broadcast Text and PDU mode
Software	
AT commands	Hayes, 3GPP TS 27.007 and 27.005, and proprietary Gemalto M2M commands
Firmware update	Generic update from host application over USB and ASC0
GNSS Features	
Protocol	NMEA
Modes	Standalone GNSS Assisted GNSS - Control plane - E911 - User plane - gpsOneXTRA™
General	Power saving modes Power supply for active antenna
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 [3]. This application note comprises chapters on module mounting and application layout issues as well as on additional SMT application development equipment.
Antenna	50Ω. GSM/UMTS/LTE main antenna, UMTS/LTE Diversity/MIMO antenna, (active/passive) GNSS antenna
USB	USB 2.0 High Speed (480Mbit/s) device interface

Feature	Implementation
Serial interface	ASC0: • 8-wire modem interface with status and control lines, unbalanced, asynchronous • Fixed baud rate of 115,200bps • Supports RTS0/CTS0 hardware flow control
UICC interface	Supported chip cards: UICC/SIM/USIM 3V, 1.8V
Audio	1 digital interface (PCM or I^2S)
Status	Signal line to indicate network connectivity state
RING0	Signal line to indicate incoming calls and other types of URCs
Power on/off, Reset	
Power on/off	Switch-on by hardware signal IGT Switch-off by AT command (AT^SMSO) or IGT 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	
Antenna	SAIC (Single Antenna Interference Cancellation) / DARP (Downlink Advanced Receiver Performance) Rx Diversity (receiver type 3i - 64-QAM) / MIMO
GPIO	10 I/O pins of the application interface programmable as GPIO. GPIO6 can be configured as low current indicator (LCI). Programming is done via AT commands.
ADC inputs	Analog-to-Digital Converter with three unbalanced analog inputs.
Evaluation kit	
Evaluation module	PLS8-E 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 Gemalto M2M modules and provide a sample configuration for application engineering. A special adapter is required to connect the PLS8-E evaluation module to the DSB75.

2.2 PLS8-E System Overview

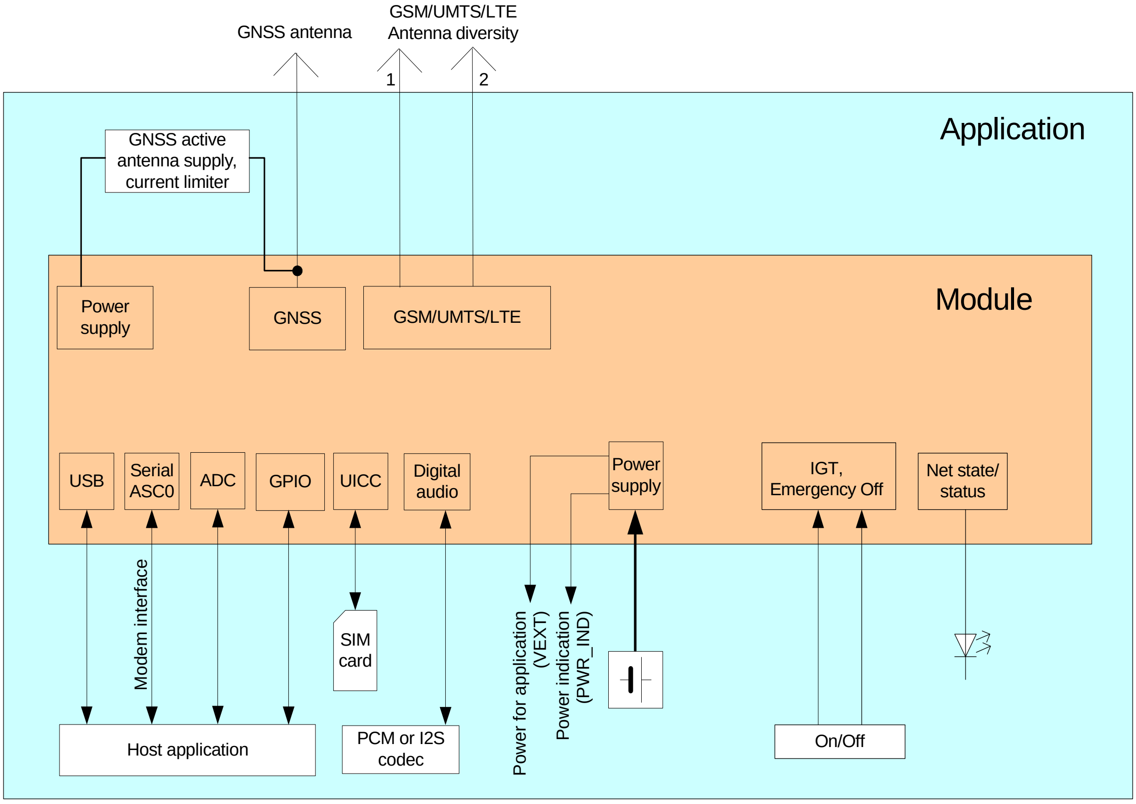


Figure 1: PLS8-E system overview

2.3 Circuit Concept

Figure 2 shows a block diagram of the PLS8-E module and illustrates the major functional components:

Baseband block:
- GSM/UMTS controller/transceiver/power supply
- Stacked Flash/RAM memory with multiplexed address data bus
- Application interface (SMT with connecting pads)

RF section:
- RF transceiver
- RF power amplifier/frontend
- RF filter
- GNSS receiver/Front end
- Antenna pad

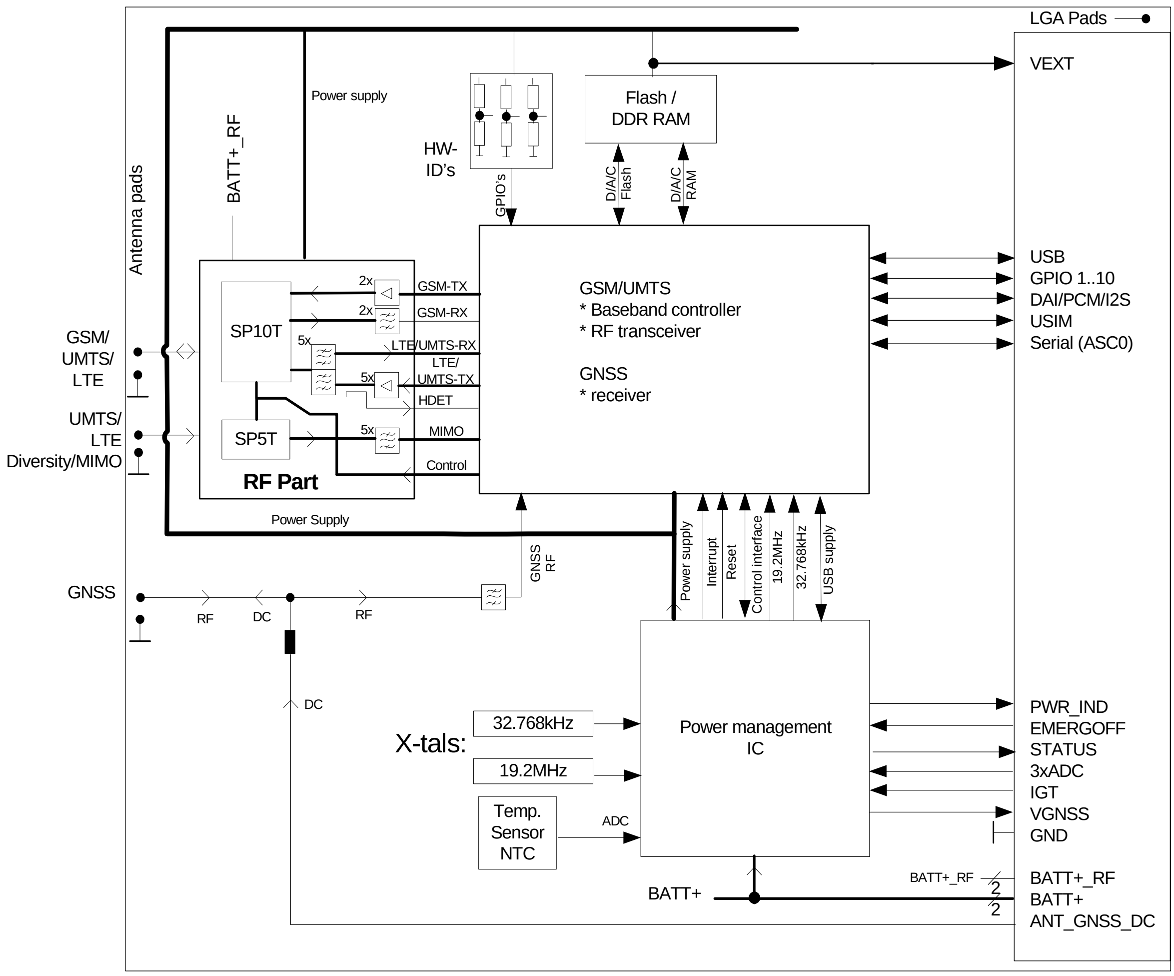


Figure 2: PLS8-E block diagram

3 Application Interface

PLS8-E is equipped with an SMT application interface (LGA pads) 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
- Serial interface USB - see Section 3.5
- Serial interface ASC0 - Section 3.6
- UICC/SIM/USIM interface - see Section 3.7
- Digital audio interface (PCM or I^2S) - see Section 3.8.1
- ADC interface - Section 3.9
- GPIO interface - Section 3.10
- Control and status lines: PWR_IND, STATUS, RING0, STATUS, LCI - see Section 3.11

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	GSM / GPRS / UMTS / HSPA / LTE SLEEP	Power saving set automatically when no call is in progress and the USB connection is detached and no active communication via ASC0. Also, the GNSS active antenna mode has to be turned off or set to "auto".
	GSM / GPRS / UMTS / HSPA / LTE IDLE	Power saving disabled or an USB connection active, but no data transfer in progress.
	GPRS DATA	GPRS data transfer in progress. Power consumption depends on network settings (e.g. power control level), uplink / downlink data rates and GPRS configuration (e.g. used multislot settings).
	EGPRS DATA	EGPRS data transfer in progress. Power consumption depends on network settings (e.g. power control level), uplink / downlink data rates and EGPRS configuration (e.g. used multislot settings).
	UMTS DATA	UMTS data transfer in progress. Power consumption depends on network settings (e.g. TPC Pattern) and data transfer rate.
	HSPA DATA	HSPA data transfer in progress. Power consumption depends on network settings (e.g. TPC Pattern) and data transfer rate.
	LTE DATA	LTE data transfer in progress. Power consumption depends on network settings (e.g. TPC Pattern) and data transfer rate.
Power Down	Normal shutdown after sending the AT^SMSO command. 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 GSM/GPRS 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

PLS8-E needs to be connected to a power supply at the SMT application interface - 4 lines BATT+, and GND. There are two separate voltage domains for BATT+:

- BATT+_RF with 2 lines for the RF 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 two sub paths (star structure). Each voltage domain must be decoupled by application with low ESR capacitors (≥ 47µF MLCC @ BATT+; ≥ 4x47µF MLCC @ BATT+_RF) as close as possible to LGA pads. Figure 3 shows a sample circuit for decoupling capacitors for BATT+.

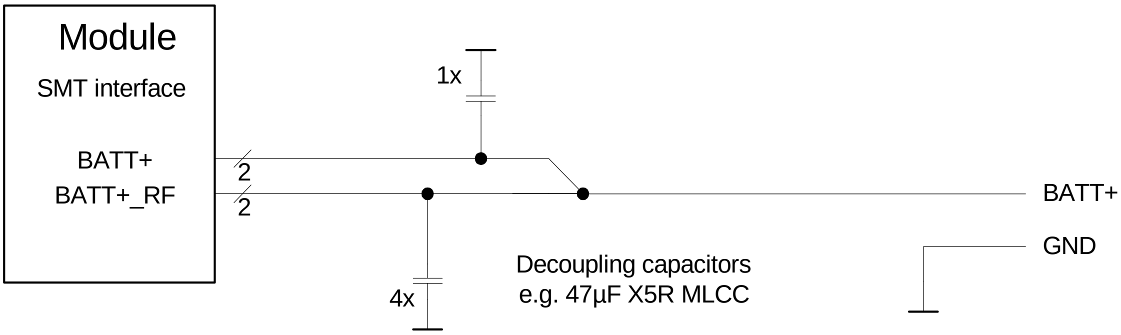


Figure 3: Decoupling capacitor(s) for BATT+

The power supply of PLS8-E 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.
- LDO to provide SIM power supply.

3.2.1 Minimizing Power Losses

When designing the power supply for your application please pay specific attention to power losses. Ensure that the input voltage V_{BATT+} never drops below 3.3V on the PLS8-E board, not even in a transmit burst where current consumption can rise to typical peaks of 2A. It should be noted that PLS8-E switches off when exceeding these limits. Any voltage drops that may occur in a transmit burst should not exceed 400mV to ensure the expected RF performance in 2G networks.

The module switches off if the minimum battery voltage (V_{BATT}min) is reached.

Example:
$V_I$min = 3.3V
Dmax = 0.4V

V_{BATT}min = $V_I$min + Dmax
V_{BATT}min = 3.3V + 0.4V = 3.7V

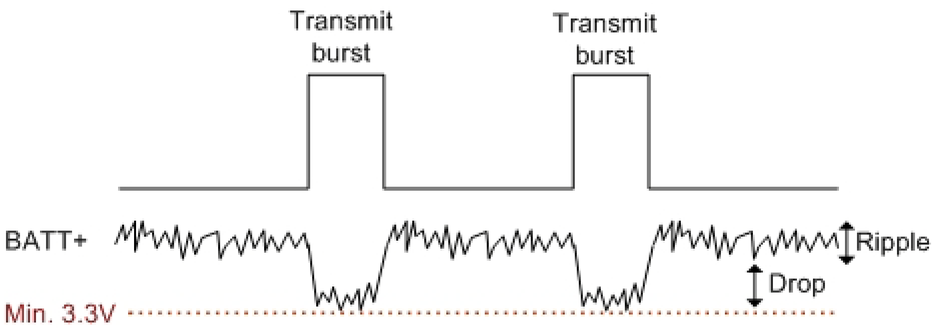


Figure 4: Power supply limits during transmit burst

3.2.2 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 0.5 seconds in DATA mode to 50 seconds when PLS8-E 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 PLS8-E while it is beyond the safety limits of voltage and temperature stated in Section 6.1. PLS8-E immediately switches 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 PLS8-E

When the PLS8-E 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 PLS8-E, IGT has to be kept active at least 100 milliseconds. After turning on PLS8-E, 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.

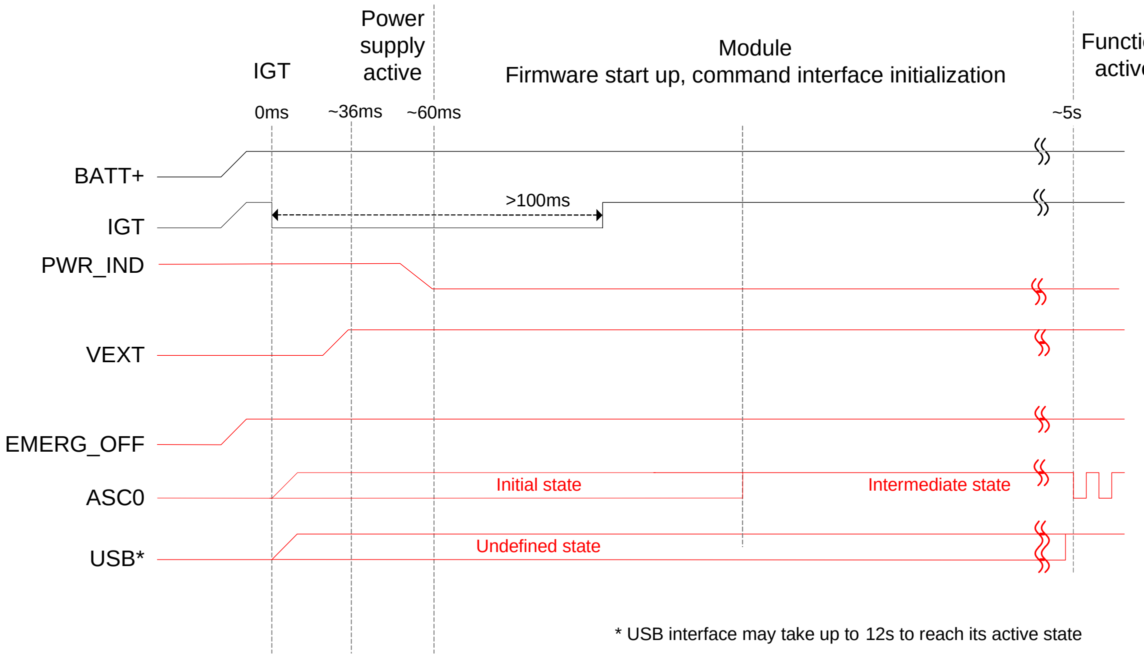


Figure 5: Power-on with IGT

Note: After power up IGT should remain high. Also note that with a USB connection the USB host may take up to 12 seconds to set up the virtual COM port connection.

After startup or mode change the following URCs are 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.

Table 7: Signal states

Signal name	Power on reset Duration appr. 60ms	Startup phase Duration appr. 4s	State after first firmware initialization After 4-5s
CCIN	PD and PU (24k)	PU(24k)	I, PU(24k)
CCRST	Not driven (similar PD)	Not driven (similar PD)	O, L[1] O, H[2]
CCIO	PD(10k)	PD(10k)	PD(10k)[1] PU(10k)[2]
CCCLK	Not driven (similar PD)	Not driven (similar PD)	O, L[1] Clock[2]
CCVCC	Off	Off	Off[1] 1.8V/3V[2]
RXD0	PD	PU	PU
TXD0	PD	PD	PD
CTS0	PD	PD	PD
RTS0	PU and PD	PD	PD
DTR0	PD	PD	PD
DCD0	PD	PU[3]	PD
DSR0	PD	PD	PD
RING0	PD	O, H	O, H
PCM_I2S_IN	PU	PD	PD
PCM_I2S_CLK	PD	PD	PD
PCM_I2S_FSC	PD	PD	PD
PCM_I2S_OUT	PD	PD	PD
I2S_MCLKOUT	PD	PD	PD
PWR_IND	Z	O, L	O, L
STATUS	PD	PD	PD
EMERG_OFF	PU	I, PU	I, PU
IGT	I, PU	I, PU	I, PU
GPIO1...10[4]	PD	PD	PD

1. If CCIN = High level
2. If CCIN = Low level
3. No external pull down allowed during this phase.
4. Please note that during its startup phase the GPIO8 signal will be in an active low state for appr. 80ms.

L = Low level H = High level I = Input O = Output	PD = Pull down resistor with appr. 100k[1] PD(…k) = Pull down resistor with ...k PU = Pull up resistor with appr. 100k PU(…k) = Pull up resistor with ...k, Z = High impedance

1. Internal pulls are implemented using JFETs; strengths vary between devices, possible range: 55k…390k

3.3.3 Turn off PLS8-E Using AT Command

The best and safest approach to powering down PLS8-E is to issue the AT^SMSO command. This procedure lets PLS8-E log off from the network and allows the software to enter into a secure state and save data before disconnecting the power supply. The mode is referred to as Power Down mode. After sending AT^SMSO do not enter any other AT commands. While powering down the module may still send some URCs. 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 indicates that the module is being switched off as shown in Figure 6.

Be sure not to disconnect the supply voltage V_{BATT+} before the module's switch off procedure has been completed and the VEXT signal has gone low. Otherwise you run the risk of losing data. Signal states during switch off are shown in Figure 6.

While PLS8-E 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. No special care is required for the USB interface which is protected from reverse current.

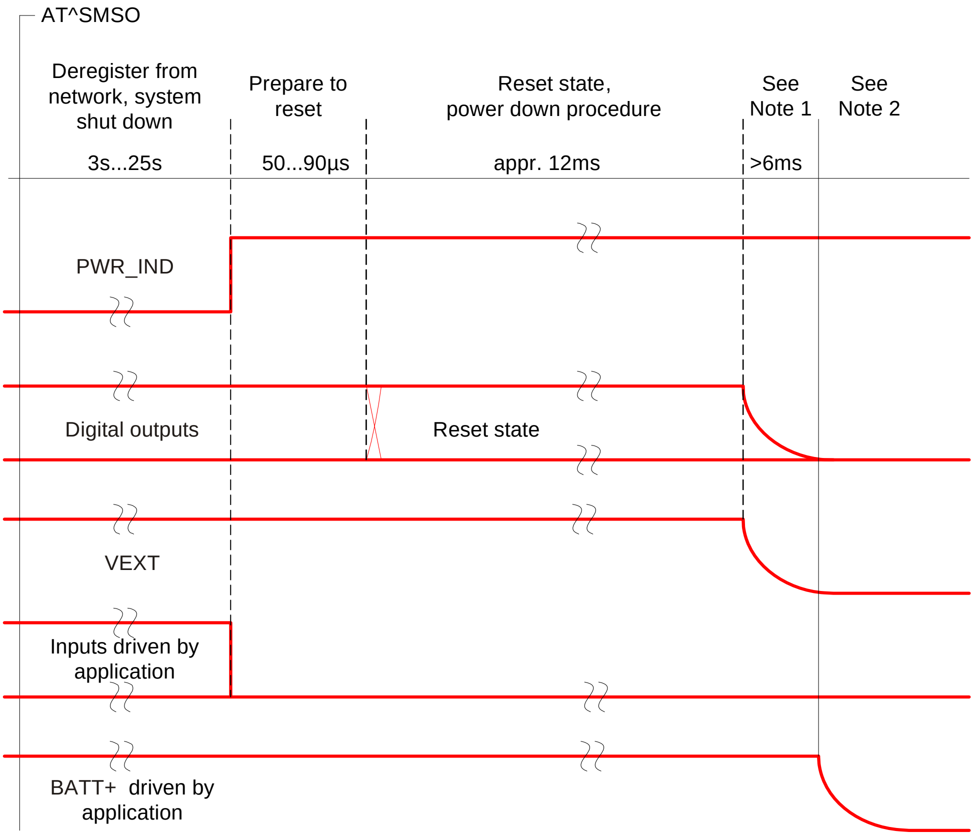


Figure 6: Signal states during turn-off procedure

Note 1: Depending on capacitance load from host application
Note 2: The power supply voltage (BATT+) may be disconnected or switched off only after the VEXT went low.
Note 3: After module shutdown by means of AT command is completed, please allow for a time period of at least 1 second before restarting the module.

3.3.4 Turn off PLS8-E Using IGT Line

The IGT line can be used to switch off PLS8-E. If the module is on, the IGT line must be asserted for at least 2.1 seconds 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 12 seconds after startup.

Figure 7: Timing of IGT if used to switch off the module

3.3.5 Automatic Shutdown

Automatic shutdown takes effect if:
- The PLS8-E 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. PLS8-E 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 3.3.5.4 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, PLS8-E 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 2 minutes guard period after start-up of PLS8-E. After expiry of the 2 minutes 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 (2 minutes after PLS8-E start-up, otherwise only if URC presentation enabled)	
^SCTM_B: 1	Caution: Board close to overtemperature limit, i.e., board is 5°C below overtemperature limit.
^SCTM_B: -1	Caution: Board close to undertemperature limit, i.e., board is 5°C above undertemperature limit.
^SCTM_B: 0	Board back to uncritical temperature range, i.e., board is 6°C below its over- or above its undertemperature limit.
Automatic shutdown (URC appears no matter whether or not presentation was enabled)	
^SCTM_B: 2	Alert: Board equal or beyond overtemperature limit. PLS8-E switches off.
^SCTM_B: -2	Alert: Board equal or below undertemperature limit. PLS8-E 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 Deferred Shutdown at Extreme Temperature Conditions

In the following cases, automatic shutdown will be deferred if a critical temperature limit is exceeded:
- While an emergency call is in progress.
- During a two minute guard period after power-up. This guard period has been introduced in order to allow for the user to make an emergency call. The start of any one of these calls extends the guard period until the end of the call. Any other network activity may be terminated by shutdown upon expiry of the guard time.

While in a "deferred shutdown" situation, PLS8-E continues to measure the temperature and to deliver alert messages, but deactivates the shutdown functionality. Once the 2 minute guard period is expired or the call is terminated, full temperature control will be resumed. If the temperature is still out of range, PLS8-E switches off immediately (without another alert message).

CAUTION! Automatic shutdown is a safety feature intended to prevent damage to the module. Extended usage of the deferred shutdown facilities provided may result in damage to the module, and possibly other severe consequences.

3.3.5.3 Undervoltage Shutdown

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

^SBC: Undervoltage.

The URC indicates that the module is close to the undervoltage threshold. If undervoltage 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.

3.3.5.4 Overvoltage 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 PLS8-E components are directly linked to BATT+ and, therefore, the supply voltage remains applied at major parts of PLS8-E, 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 Turn off PLS8-E 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 PLS8-E 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 40 milliseconds. After the 40 milliseconds and an additional delay period of 500 milliseconds the module shuts down as shown in Figure 8.

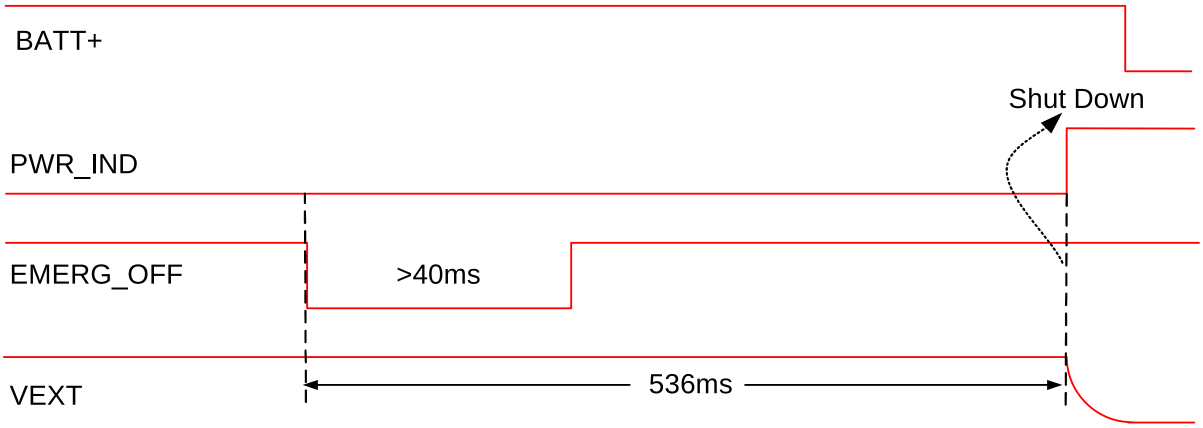


Figure 8: Shutdown by EMERG_OFF signal

Note: The power supply voltage (BATT+) may be disconnected or 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

PLS8-E 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 network dependant power saving behavior.

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 3.5. Another feature influencing the current consumption is the configuration of the GNSS antenna interface. For details see Section 6.8.

3.4.1 Power Saving while Attached to GSM Networks

The power saving possibilities while attached to a GSM network depend on the paging timing cycle of the base station. The duration of a power saving interval can be calculated using the following formula:

t = 4.615 ms (TDMA frame duration) * 51 (number of frames) * DRX value.

DRX (Discontinuous Reception) is a value from 2 to 9, resulting in paging intervals between 0.47 and 2.12 seconds. The DRX value of the base station is assigned by the GSM network operator.

In the pauses between listening to paging messages, the module resumes power saving, as shown in Figure 9.

Figure 9: Power saving and paging in GSM networks

The varying pauses explain the different potential for power saving. The longer the pause the less power is consumed.

Generally, power saving depends on the module's application scenario and may differ from the above mentioned normal operation. The power saving interval may be shorter than 0.47 seconds or longer than 2.12 seconds.

3.4.2 Power Saving while Attached to WCDMA Networks

The power saving possibilities while attached to a WCDMA network depend on the paging timing cycle of the base station.

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

$t = 2^{\text{DRX value}} * 10$ ms (WCDMA frame duration).

DRX (Discontinuous Reception) in WCDMA networks is a value between 6 and 9, thus resulting in power saving intervals between 0.64 and 5.12 seconds. The DRX value of the base station is assigned by the WCDMA network operator.

In the pauses between listening to paging messages, the module resumes power saving, as shown in Figure 10.

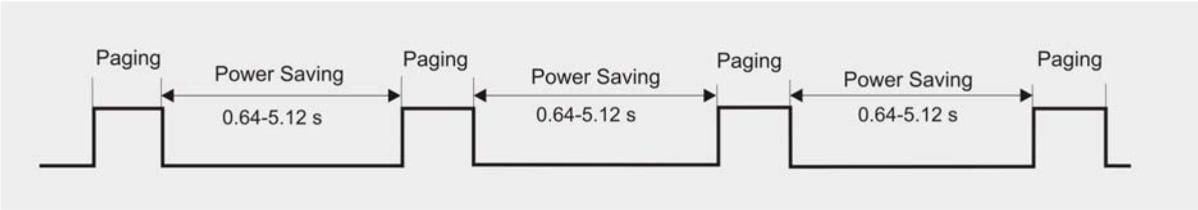


Figure 10: Power saving and paging in WCDMA networks

The varying pauses explain the different potential for power saving. The longer the pause the less power is consumed.

Generally, power saving depends on the module's application scenario and may differ from the above mentioned normal operation. The power saving interval may be shorter than 0.64 seconds or longer than 5.12 seconds.

3.4.3 Power Saving while Attached to LTE Networks

The power saving possibilities while attached to an LTE network depend on the paging timing cycle of the base station.

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

t = DRX Cycle Value * 10 ms

DRX cycle value in LTE networks is any of the four values: 32, 64, 128 and 256, thus resulting in power saving intervals between 0.32 and 2.56 seconds. The DRX cycle value of the base station is assigned by the LTE network operator.

In the pauses between listening to paging messages, the module resumes power saving, as shown in Figure 11.

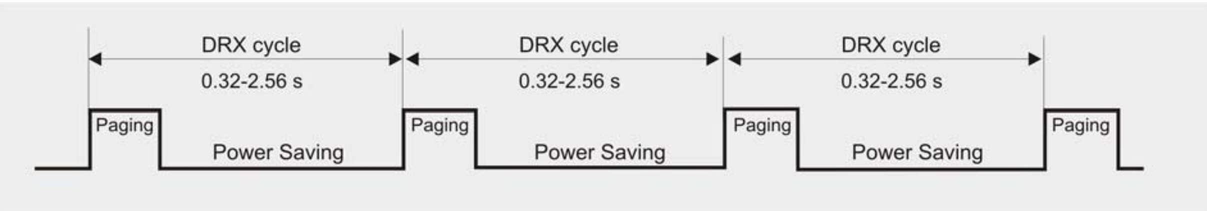


Figure 11: Power saving and paging in LTE networks

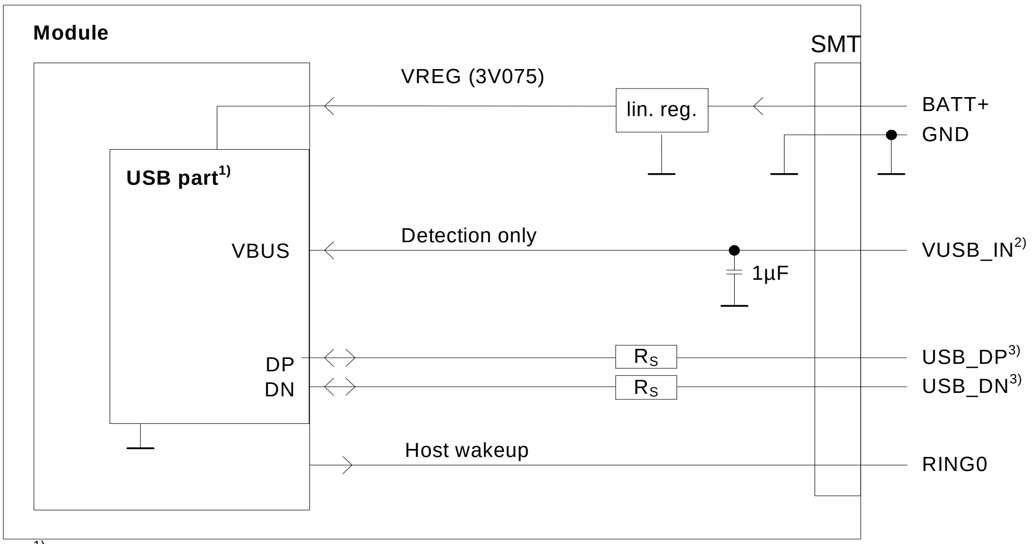
The varying pauses explain the different potential for power saving. The longer the pause the less power is consumed.

Generally, power saving depends on the module's application scenario and may differ from the above mentioned normal operation. The power saving interval may be shorter than 0.32 seconds or longer than 2.56 seconds.

3.5 USB Interface

PLS8-E supports a USB 2.0 High Speed (480Mbps) device interface. The USB interface is primarily intended for use as command and data interface and for downloading firmware.

The USB host is responsible for supplying the VUSB_IN line. This line is for voltage detection only. The USB part (driver and transceiver) is supplied by means of BATT+. This is because PLS8-E 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) Since VUSB_IN is used for detection only it is recommended not to add any further blocking capacitors on the VUSB_IN line.
3) If the USB interface is operated in High Speed mode (480MHz), 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 90 ohms for proper signal integrity.

Figure 12: 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 signals see Table 22. Furthermore, the USB modem driver distributed with PLS8-E needs to be installed.

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

3.5.1 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[1]. 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“[2]. For this functionality to work, the VUSB_IN line should always be kept enabled. On incoming calls and other events PLS8-E will then generate a Remote Wakeup request to resume the USB host controller.

  See also [4] (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 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 3.11.3. To prevent existing data call connections from being disconnected while the USB interface is in detached state (i.e., VUSB_IN=0) it is possible to call AT&D0, thus ignoring the status of the DTR line (see also [1]).

1. Please note that if the USB interface is employed, and a USB cable is connected, there should also be a terminal programm linked to the USB port in order to receive and process the initial SYSSTART URC after module startup. Otherwise, the SYSSTART URC remains pending in the USB driver's output buffer and this unprocessed data prevents the module from power saving.
2. The specification is ready for download on http://www.usb.org/developers/docs/

3.6 Serial Interface ASC0

PLS8-E 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.

PLS8-E 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

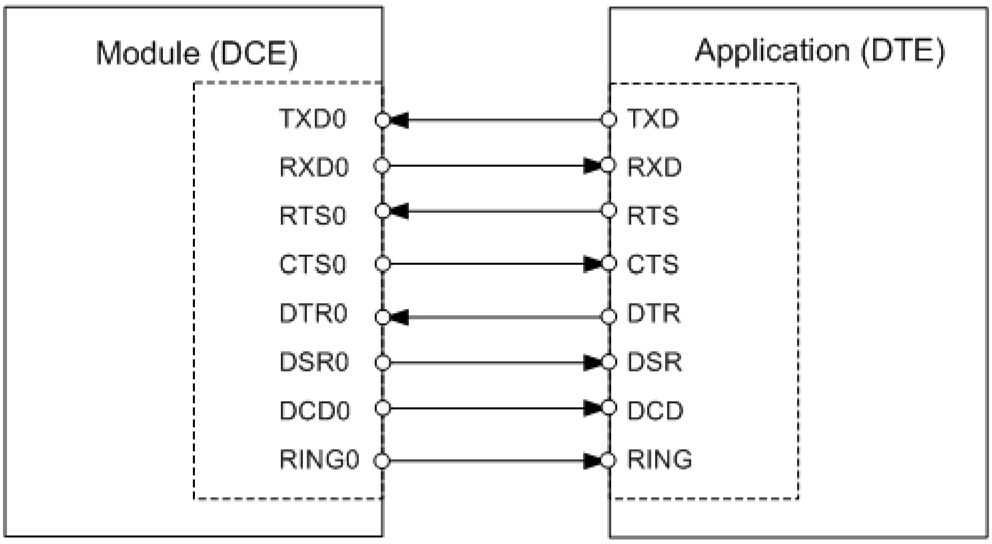


Figure 13: Serial interface ASC0

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.
- 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 a fixed bit rate of 115200bps.
- 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

3.7 UICC/SIM/USIM Interface

PLS8-E has an integrated UICC/SIM/USIM interface compatible with the 3GPP 31.102 and ETSI 102 221. This is wired to the host interface in order to be connected to an external SIM card holder. Five pads on the SMT application interface are reserved for the SIM interface.

The UICC/SIM/USIM interface supports 3V and 1.8V SIM cards. Please refer to Table 22 for electrical specifications of the UICC/SIM/USIM interface lines depending on whether a 3V or 1.8V SIM card is used.

The CCIN signal serves to detect whether a tray (with SIM card) is present in the card holder. Using the CCIN signal is mandatory for compliance with the GSM 11.11 recommendation if the mechanical design of the host application allows the user to remove the SIM card during operation. To take advantage of this feature, an appropriate SIM card detect switch is required on the card holder. For example, this is true for the model supplied by Molex, which has been tested to operate with PLS8-E and is part of the Gemalto M2M reference equipment submitted for type approval. See Chapter 10 for Molex ordering numbers.

Table 10: Signals of the SIM interface (SMT application interface)

Signal	Description
GND	Ground connection for SIM. Optionally a separate SIM ground line using e.g., pad N11 may be used to improve EMC.
CCCLK	Chipcard clock
CCVCC	SIM supply voltage.
CCIO	Serial data line, input and output.
CCRST	Chipcard reset
CCIN	Input on the baseband processor for detecting a SIM card tray in the holder. If the SIM is removed during operation the SIM interface is shut down immediately to prevent destruction of the SIM. The CCIN signal is active low. The CCIN signal is mandatory for applications that allow the user to remove the SIM card during operation. The CCIN signal is solely intended for use with a SIM card. It must not be used for any other purposes. Failure to comply with this requirement may invalidate the type approval of PLS8-E.

Note: No guarantee can be given, nor any liability accepted, if loss of data is encountered after removing the SIM card during operation. Also, no guarantee can be given for properly initializing any SIM card that the user inserts after having removed the SIM card during operation. In this case, the application must restart PLS8-E.

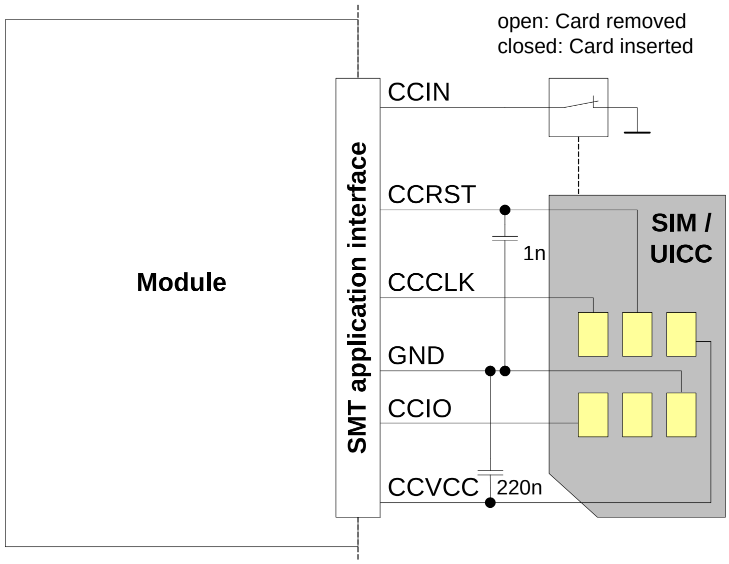


Figure 14: UICC/SIM/USIM interface

The total cable length between the SMT application interface pads on PLS8-E and the pads of the external SIM card holder must not exceed 100mm in order to meet the specifications of 3GPP TS 51.010-1 and to satisfy the requirements of EMC compliance.

To avoid possible cross-talk from the CCCLK signal to the CCIO signal be careful that both lines are not placed closely next to each other. A useful approach is using the GND line to shield the CCIO line from the CCCLK line.

An example for an optimized ESD protection for the SIM interface is shown in Section 3.7.1.

3.7.1 Enhanced ESD Protection for SIM Interface

To optimize ESD protection for the SIM interface it is possible to add ESD diodes to the SIM interface lines as shown in the example given in Figure 15.

The example was designed to meet ESD protection according ETSI EN 301 489-1/7: Contact discharge: ± 4kV, air discharge: ± 8kV.

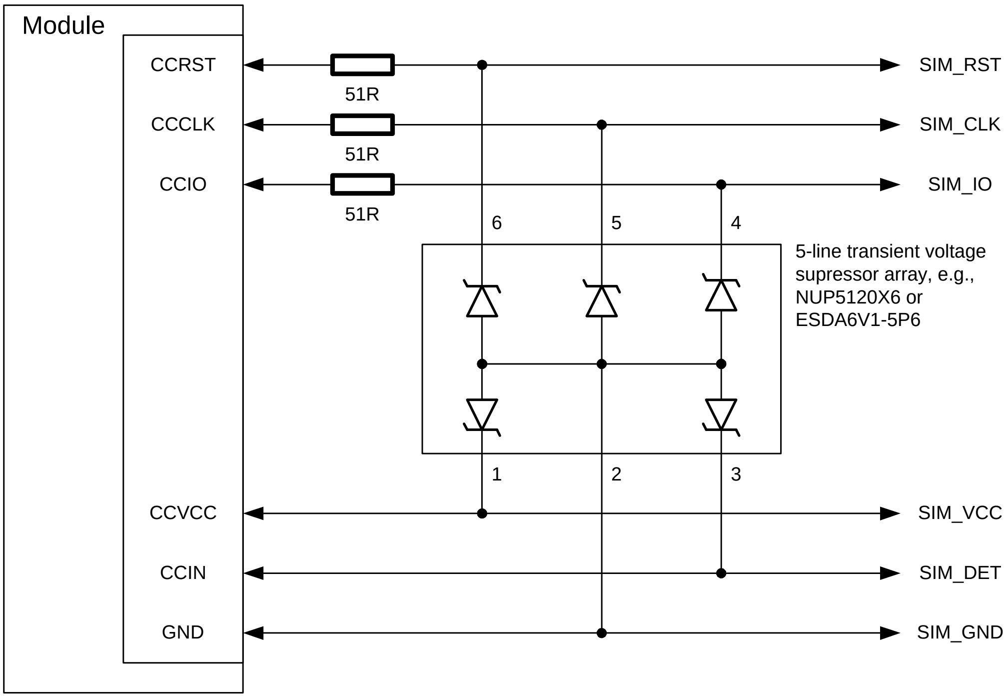


Figure 15: SIM interface - enhanced ESD protection

3.8 Digital Audio Interface

PLS8-E supports a digital audio interface that can be employed either as pulse code modulation interface (see Section 3.8.1) or as inter IC sound interface (see Section 3.8.2). Operation of these interface variants is mutually exclusive, and can be configured by AT command (see [1]). Default setting is pulse code modulation.

3.8.1 Pulse Code Modulation Interface (PCM)

PLS8-E's PCM interface can be used to connect audio devices capable of pulse code modulation. The PCM functionality covers the use of narrowband codecs with 8kHz sample rate and wideband codecs with 16kHz sample rate as well. Configured for wideband the PCM interface runs at 16 kHz sample rate (62.5µs frame length), while the signal processing maintains this rate in a wideband AMR call or samples automatically down to 8kHz in a narrowband call. Therefore, the PCM sample rate is independent of the audio bandwidth of the call.

The PCM interface has the following implementation:
- Master mode, slave mode
- Short frame synchronization, long frame synchronization
- 8kHz and 16kHz sample rate
- 128kHz, 256kHz, 512kHz, 2048kHz bit clock at 8kHz sample rate
- 256kHz, 512kHz, 1024kHz, 4096kHz bit clock at 16kHz sample rate
- Permanent clock option

For the PCM interface configuration the parameters <clock>, <mode>, <frame_mode>, <ext_clk_mode> and <sample_rate> of the AT^SAIC command can be configured in any combination (for details on AT^SAIC see [1]). But the following hints should be considered while configuring the PCM interface:
The external clock mode should be switched off in slave mode.
In Slave Mode <clock>, <frame_mode> and <sample_rate> must be set according to the characteristics of the external master. There is no automatic detection of the received clock frequency, frame length and sample rate.
Table 11 lists the available PCM interface signals.

Table 11: Overview of PCM pin functions

Signal name on SMT application interface	Signal configuration inactive	Signal direction: Master	Signal direction: Slave	Description
PCM_I2S_OUT	PD	O	O	PCM data from PLS8-E to external codec
PCM_I2S_IN	PD	I	I	PCM data from external codec to PLS8-E
PCM_I2S_FSC	PD	O	I	Frame synchronization signal to/from external codec
PCM_I2S_CLK	PD	O	I	Bit clock to/from external codec

Note: 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.

The timing of a PCM short frame is shown in Figure 16.

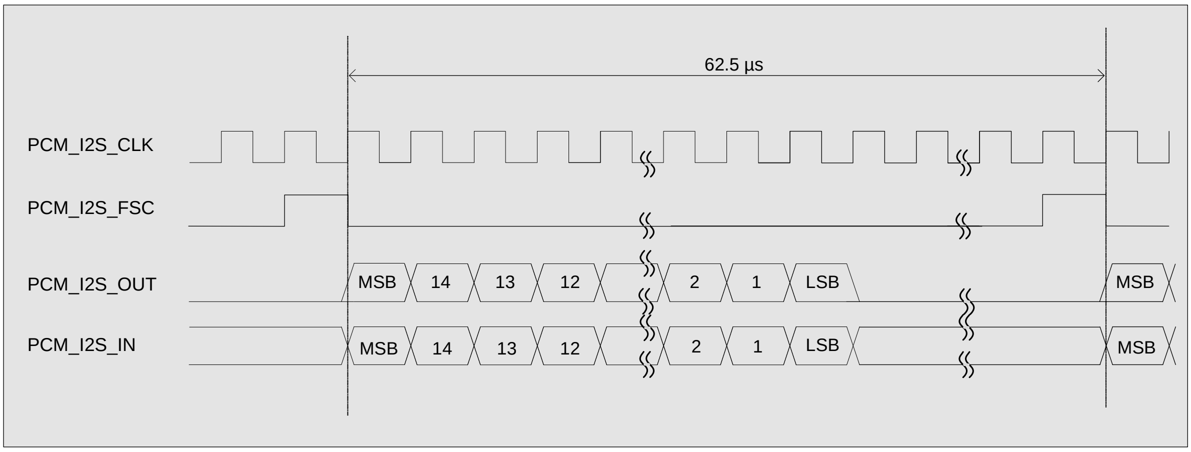


Figure 16: PCM timing short frame (master, 4096KHz, 16kHz sample rate)

Configured to short frame synchronization, the pulse on PCM_I2S_FSC is one clock period wide and occurs one clock before the data, using long frame the pulse has a duty cycle of 50% starting with the first data bit.

The timing of a PCM long frame is shown in Figure 17.

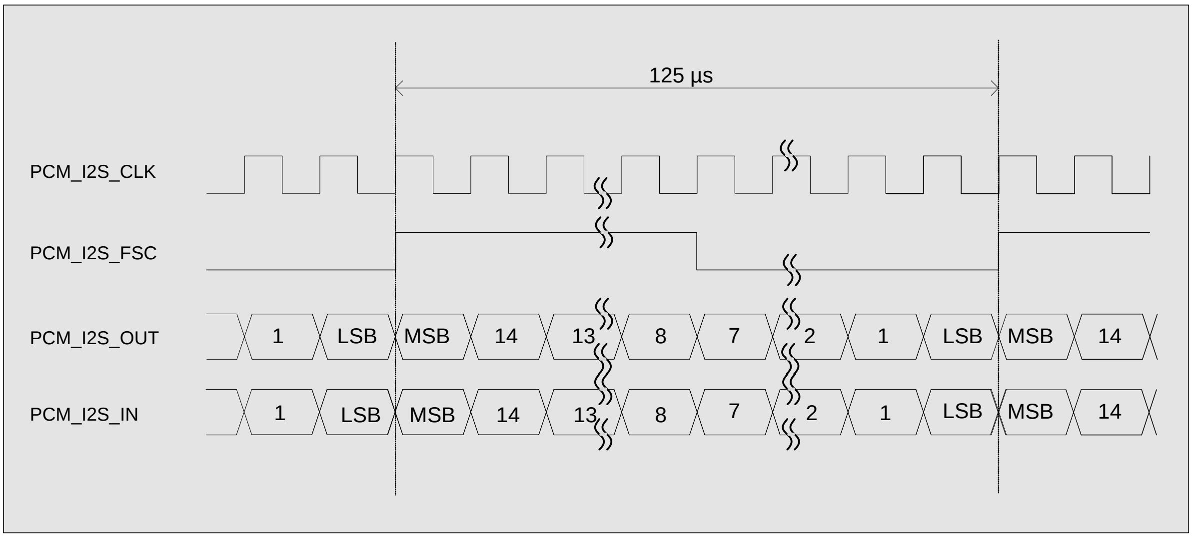


Figure 17: PCM timing long frame (master, 128kHz, 8kHz sample rate)

Characteristics of Audio Modes
PLS8-E has various audio modes selectable with AT^SNFS (for details on AT^SNFS see [1]).

Audio mode 1 is only used for type approval with the Votronic handset via the DSB75 codec adapter. The handset is adjusted for the type 3.2 low-leakage ear simulator for narrowband and wideband calls. The characteristics of this mode cannot be changed.

Audio mode 6 is used for transparent access to the narrowband or wideband speech coders without any signal processing (except for sample rate converters in case of narrowband calls). The full scale level of the PCM interface is mapped to the full scale level of the speech coders.

3.8.2 Inter IC Sound Interface (I²S)

The I²S Interface is a standardized bidirectional I²S ("Inter-IC Sound Interface") based digital audio interface for transmission of mono voice signals for telephony services.

The I²S interface can be enabled and configured using the AT command AT^SAIC (see [1]). An activation is possible only out of call and out of tone presentation. The I²S properties and capabilities comply with the requirements layed out in the Phillips I2S Bus Specifications, revised June 5, 1996.

The I²S interface has the following characteristics:
- Bit clock mode: Master, optional master clock output
- Sampling rate: 8KHz (narrowband), 16KHz (wideband)
- 256kHz bit clock at 8kHz sample rate
- 512kHz bit clock at 16kHz sample rate
- Frame length: 32 bit stereo voice signal (16 bit word length)
- Optional Master clock: 2048KHz (8KHz sample rate) or 4096KHz (16KHz sample rate)

The digital audio interface pads available for the PCM interface are also available for the I²S interface. In I²S mode they have the same electrical characteristics. For the master clock option there is a separate line (see Section 6.5 for more information on these lines).

Table 12 lists the available I²S interface signals, Figure 18 shows the I²S timing.

Table 12: Overview of I²S pin functions

Signal name on SMT application interface	Signal configuration inactive	Signal direction: Master	Description
PCM_I2S_OUT	PD	O	I²S data from PLS8-E to external codec
PCM_I2S_IN	PD	I	I²S data from external codec to PLS8-E
PCM_I2S_FSC	PD	O	Frame synchronization signal to/from external codec Word alignment (WS)
PCM_I2S_CLK	PD	O	Bit clock to external codec
I2S_MCLKOUT	PD	O	I²S Master clock to supply external codecs without PLL.

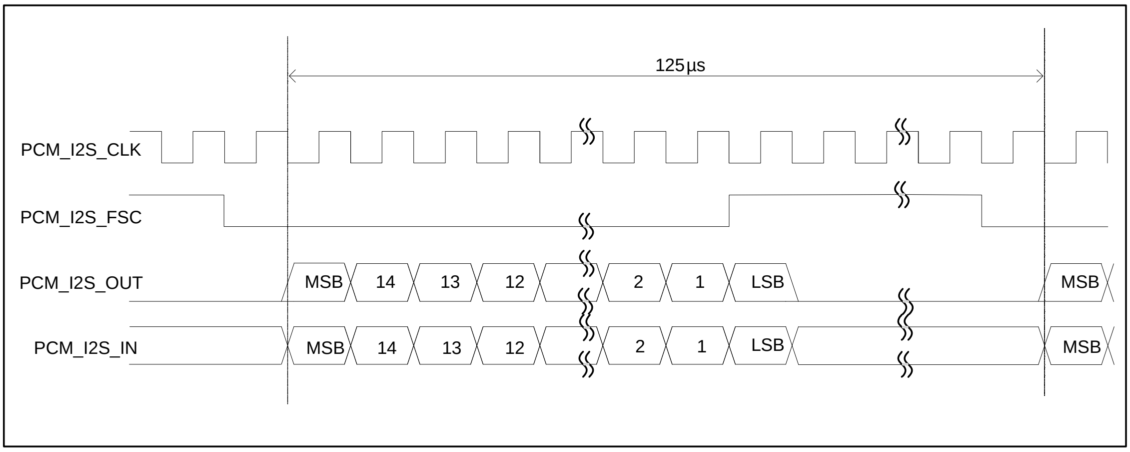


Figure 18: I²S timing (master mode)

3.9 Analog-to-Digital Converter (ADC)

PLS8-E provides three unbalanced ADC input lines: ADC1_IN, ADC2_IN and ADC3_IN. They can be used to measure three independent, externally connected DC voltages in the range of 0.3V to 3.075V.

The AT^SRADC command can be employed to select the ADC line, set the measurement mode and read out the measurment results.

3.10 GPIO Interface

PLS8-E has 10 GPIOs for external hardware devices. Each GPIO can be configured for use as input or output. All settings are AT command controlled.

The IO port driver has to be open before using and configuring GPIOs. Before changing the configuration of a GPIO pin (e.g. input to output) the pin has to be closed. If the GPIO pins are not configured or the pins/driver were closed, the GPIO pins are high-Z with pull down resistor. If a GPIO is configured to input, the pin has high-Z without pull resistor.

GPIO6 can be configured as low current indicator signal (see Section 3.11.4).

If the PLS8-E stays in power save (SLEEP) mode a level state transition at GPIO1, GPIO3, GPIO4, GPIO5 and GPIO9 will wake up the module. To query the level state the AT^SCPOL command may be used.

3.11 Control Signals

3.11.1 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.

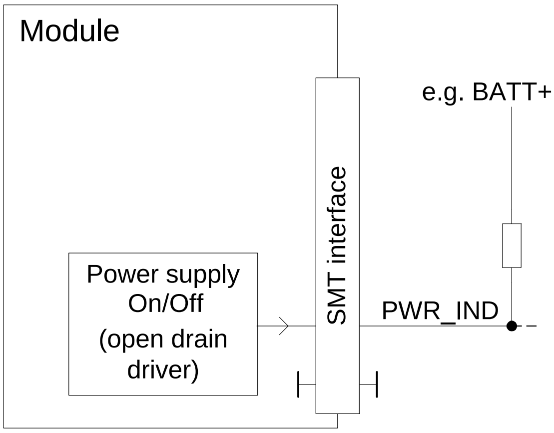


Figure 19: PWR_IND signal

3.11.2 Behavior of the RING0 Line

The RING0 line 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. 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.

3.11.3 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 the RING0 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 3.5.1).

The behaviour of the RING0 line as host wakeup line has to be enabled and configured by AT command (see [1]: AT^SCFG). Possible states are listed in Table 13.

Table 13: Host wakeup lines

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

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

3.11.4 Low Current Indicator

A low current indication is optionally available over the GPIO6 line. By default, low current indication is disabled and the GPIO6 pin can be configured and employed as any other GPIO pin.

For the GPIO6 pin 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 GPIO6/LCI_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 14: Low current indicator line

Signal	I/O/P	Description
GPIO6/LCI_IND	O	Inactive to actice 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+

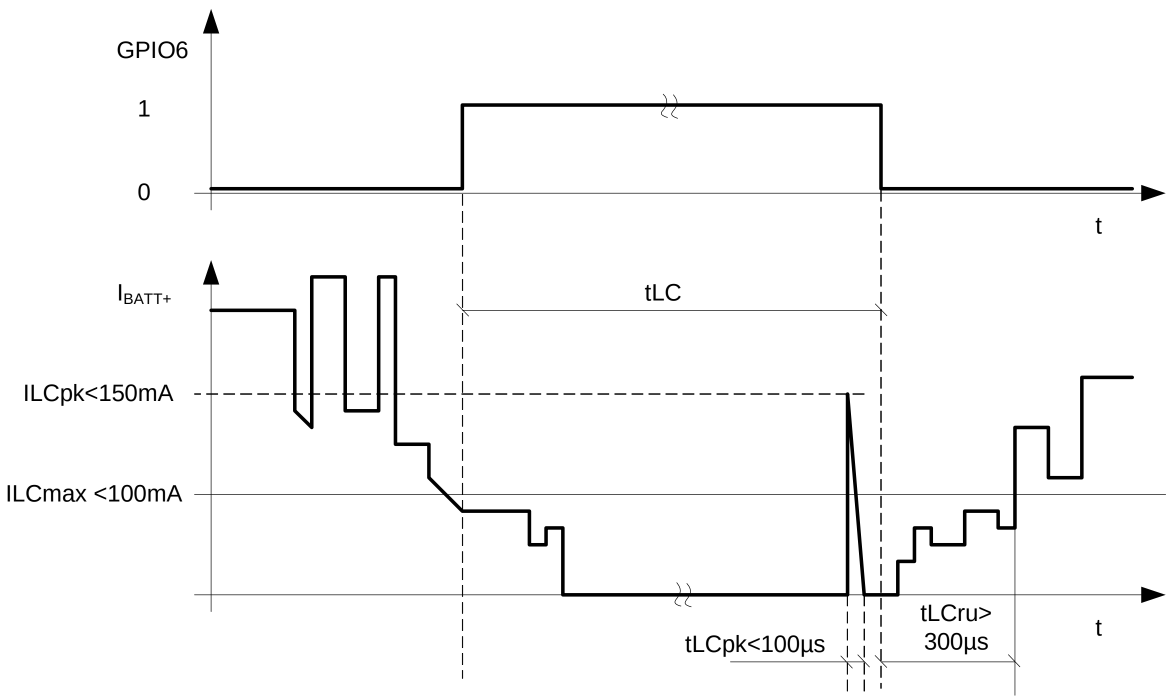


Figure 20: Low current indication timing (still to be confirmed)

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 GPIO6 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.

3.11.5 Network Connectivity and Technology Status Signals

The STATUS line serves to indicate the module's network connectivity state or the underlying network technology (2G or 3G/4G) and can be used to control an externally connected LED as shown in Figure 21. To operate the LED a buffer, e.g. a transistor or gate, must be included in the external application.

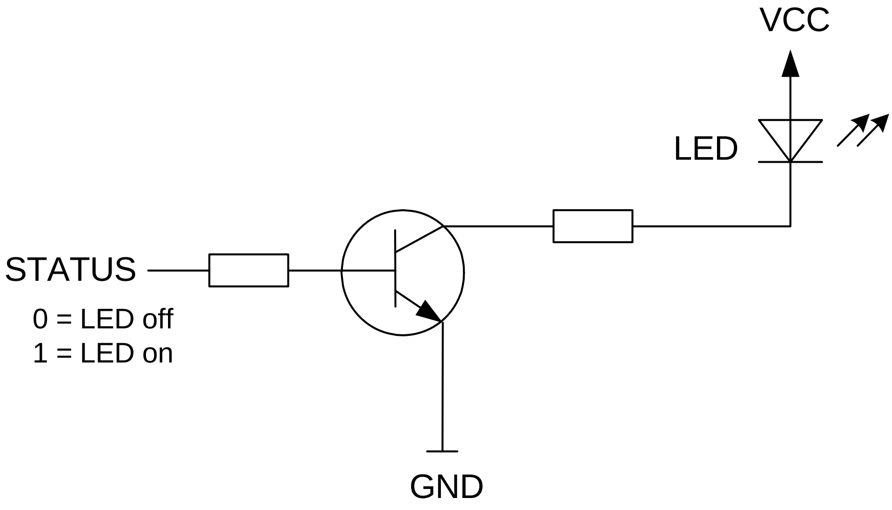


Figure 21: LED circuit (example)

For electrical characteristics of the STATUS line see Table 22. The network connectivity and technology 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].

4 GNSS Receiver

PLS8-E integrates a GNSS receiver that offers the full performance of GPS/GLONASS technology. The GNSS receiver is able to continuously track all satellites in view, thus providing accurate satellite position data.

The integrated GNSS receiver supports the NMEA protocol via USB or ASC0 interface. NMEA is a combined electrical and data specification for communication between various (marine) electronic devices including GNSS receivers. It has been defined and controlled by the US based National Marine Electronics Association. For more information on the NMEA Standard please refer to http://www.nmea.org.

Depending on the receiver's knowledge of last position, current time and ephemeris data, the receiver's startup time (i.e., TTFF = Time-To-First-Fix) may vary: If the receiver has no knowledge of its last position or time, a startup takes considerably longer than if the receiver has still knowledge of its last position, time and almanac or has still access to valid ephimeris data and the precise time. For more information see Section 6.8.

By default, the GNSS receiver is switched off. It has to be switched on and configured using AT commands. For more information on how to control the GNSS interface via the AT commands see [1].

5 Antenna Interfaces

5.1 GSM/UMTS/LTE Antenna Interface

The PLS8-E GSM/UMTS/LTE antenna interface comprises a GSM/UMTS/LTE main antenna as well as a UMTS/LTE Rx diversity/MIMO antenna to improve signal reliability and quality[1]. The interface has an impedance of 50Ω. PLS8-E is capable of sustaining a total mismatch at the antenna interface without any damage, even when transmitting at maximum RF power.

The external antennas must be matched properly to achieve best performance regarding radiated power, modulation accuracy and harmonic suppression. Matching networks are not included on the PLS8-E PCB and should be placed in the host application, if the antenna does not have an impedance of 50Ω.

Regarding the return loss PLS8-E provides the following values in the active band:

Table 15: 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 UMTS/LTE Rx diversity/MIMO antenna is configured as available for the module since its usage is mandatory for LTE. 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 (ANT_MAIN; ANT_DRX_MIMO) and their neighboring ground pads directly to the application's PCB.

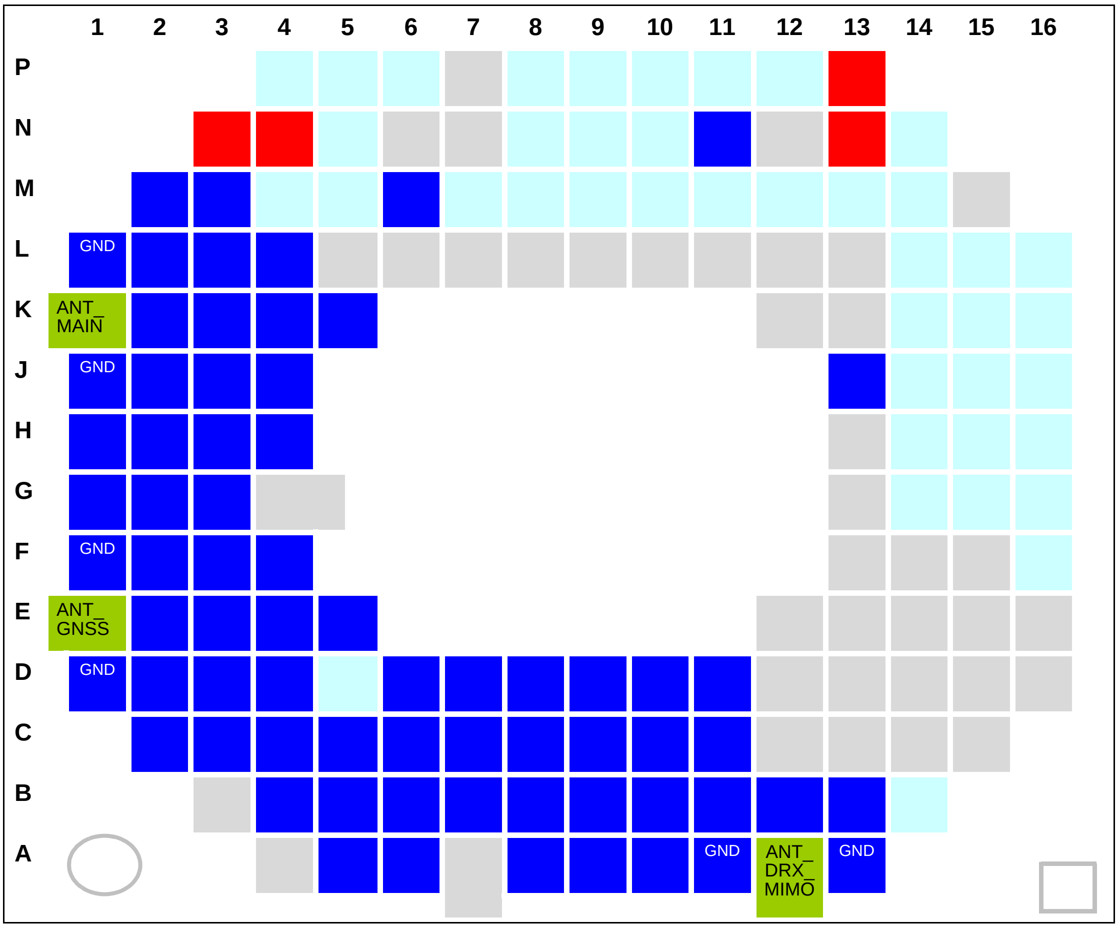


Figure 22: Antenna pads (bottom view)

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 50Ω 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 50Ω line impedance.

For type approval purposes, the use of a 50Ω 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 PLS8-E'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).

Embedded Stripline
This below figure shows line arrangement examples for embedded stripline.

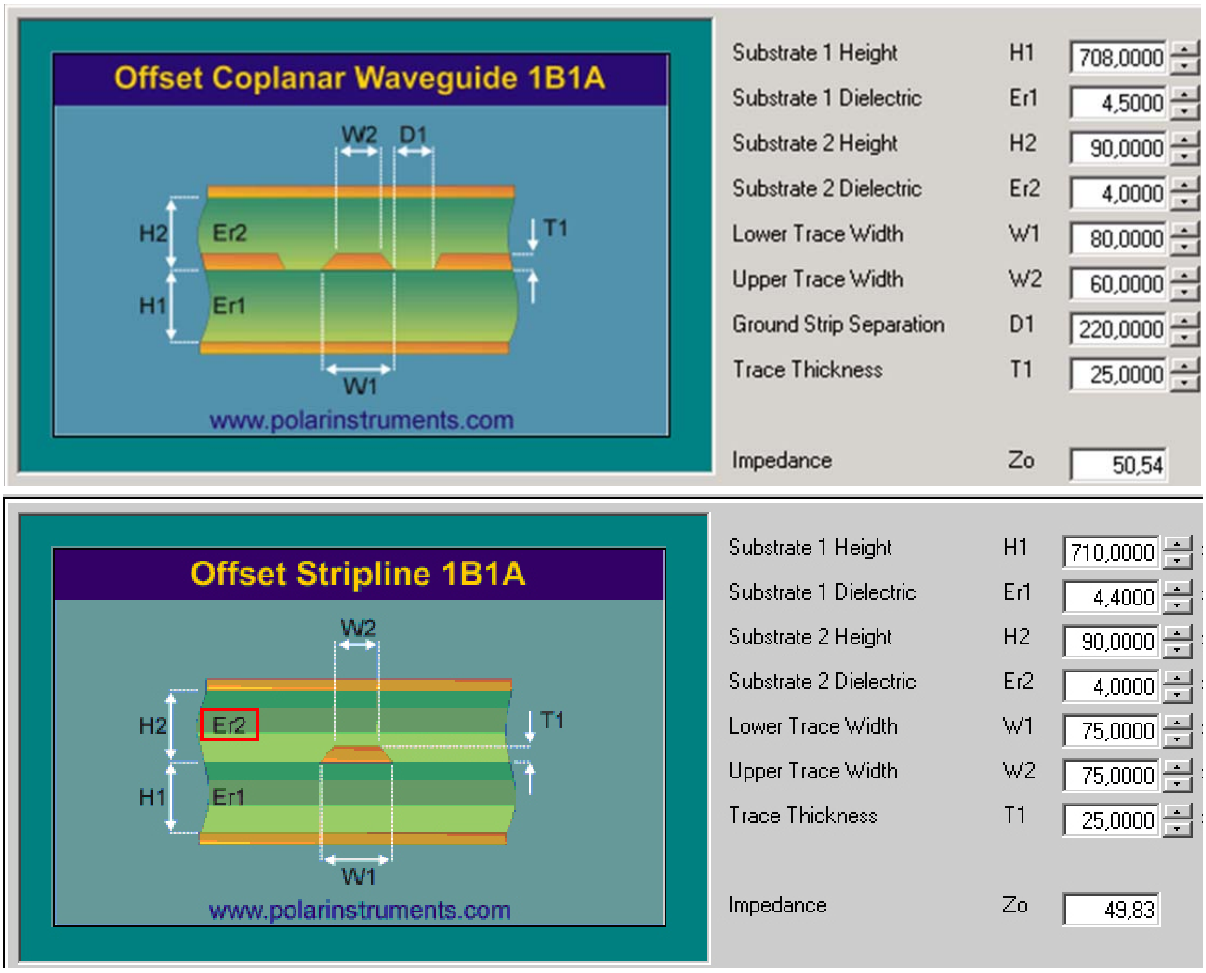


Figure 23: Embedded Stripline line arrangement

Micro-Stripline
This section gives two line arrangement examples for micro-stripline.

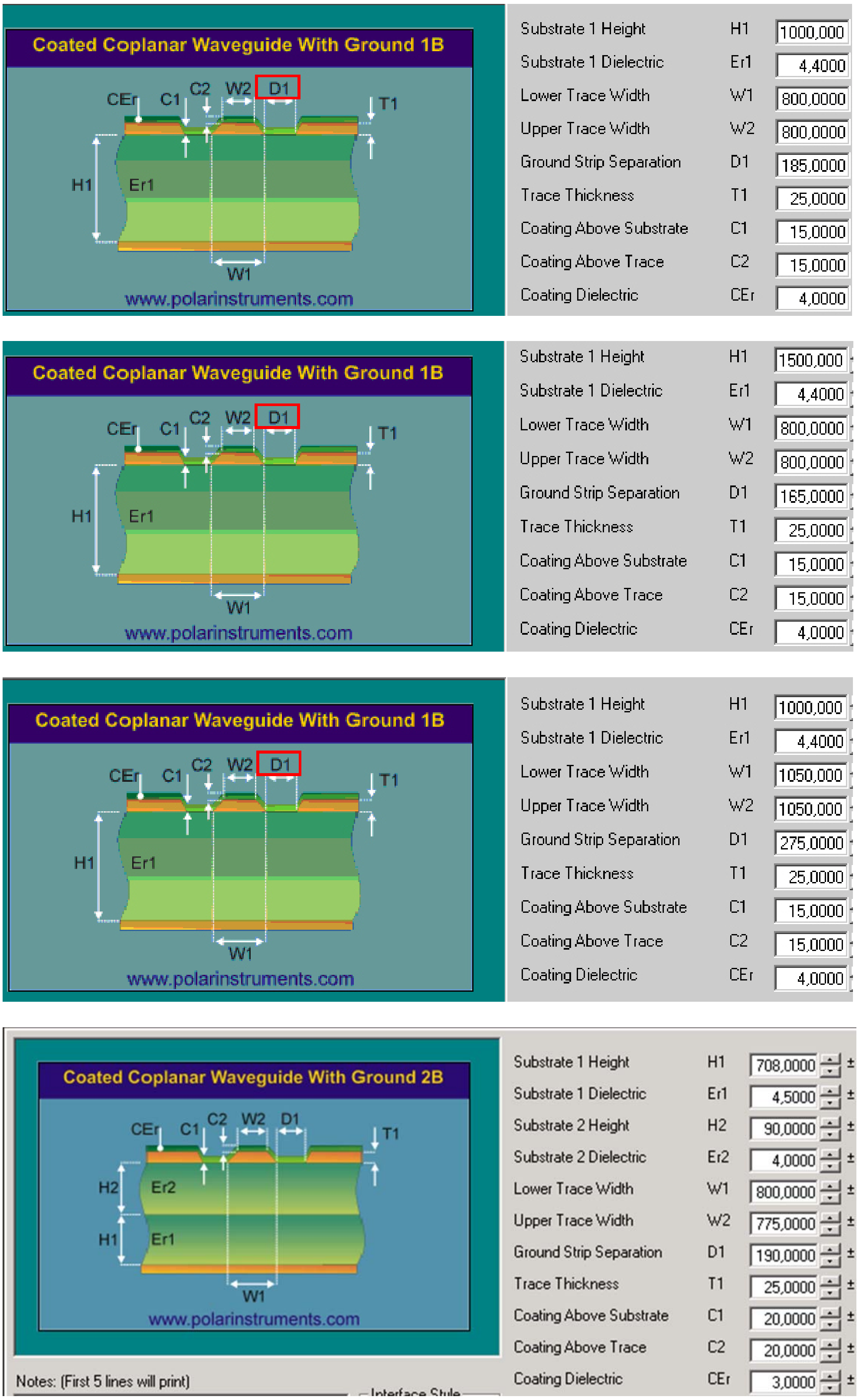


Figure 24: Micro-Stripline line arrangement samples

5.1.2.2 Routing Example

Interface to RF Connector

Figure 25 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 PLS8-E evaluation board shown in Figure 26. For different layer stacks the stripline width will have to be adapted accordingly.

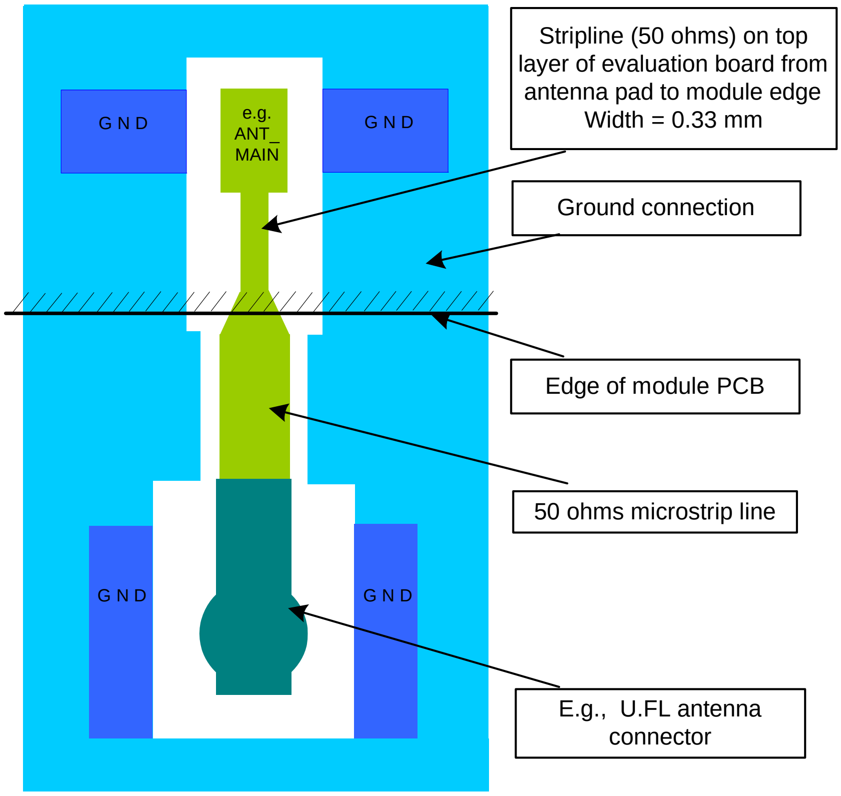


Figure 25: Routing to application‘s RF connector

Layer No.	Construction	Finished thkness (um)
s/m		15
1		25
	Prepreg :1080X1 RC:64%	65
2		25
	CORE:28mil H/Hoz 7628x4	708
3		25
	Prepreg :1080X1 RC:64%	65
4		25
s/m		15
	Total thickness (including S/M):	**968**

Figure 26: PLS8-E evaluation board layer table

5.2 GNSS Antenna Interface

In addition to the RF antenna interface PLS8-E also has a GNSS antenna interface. See Section 6.5 to find out where the GNSS antenna pad is located. The GNSS pad itself is the same as for the RF antenna interface (see Section 5.1.1).

It is possible to connect active or passive GNSS antennas. In either case they must have 50Ω impedance. The simultaneous operation of GSM and GNSS is implemented. For electrical characteristics see Section 6.8.

PLS8-E provides the supply voltage VGNSS for the GNSS active antenna (3.05V). It has to be enabled by software when the GNSS receiver becomes active, otherwise VGNSS should be off (power saving). VGNSS is not short circuit protected. This will have to be provided for by an external application. The DC voltage should be fed back via ANT_GNSS_DC for coupling into the GNSS antenna path. Figure 27 shows the flexibility in realizing the power supply for an active GNSS antenna by giving two sample circuits realizing the supply voltage for an active GNSS antenna - one with short circuit protection and one with an external LDO employed.

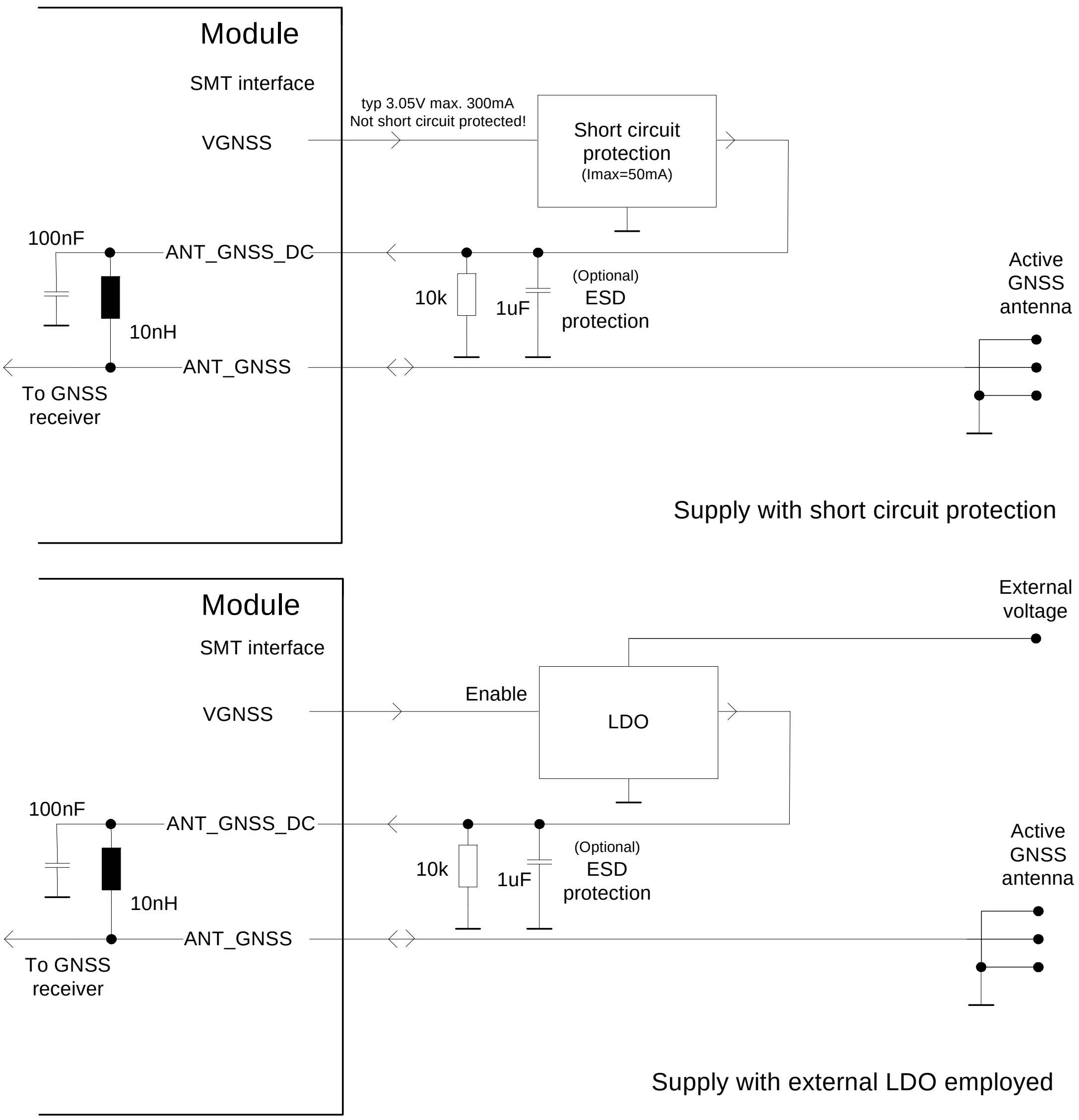


Figure 27: Supply voltage for active GNSS antenna

Figure 28 shows sample circuits realizing ESD protection for a passive GNSS antenna.

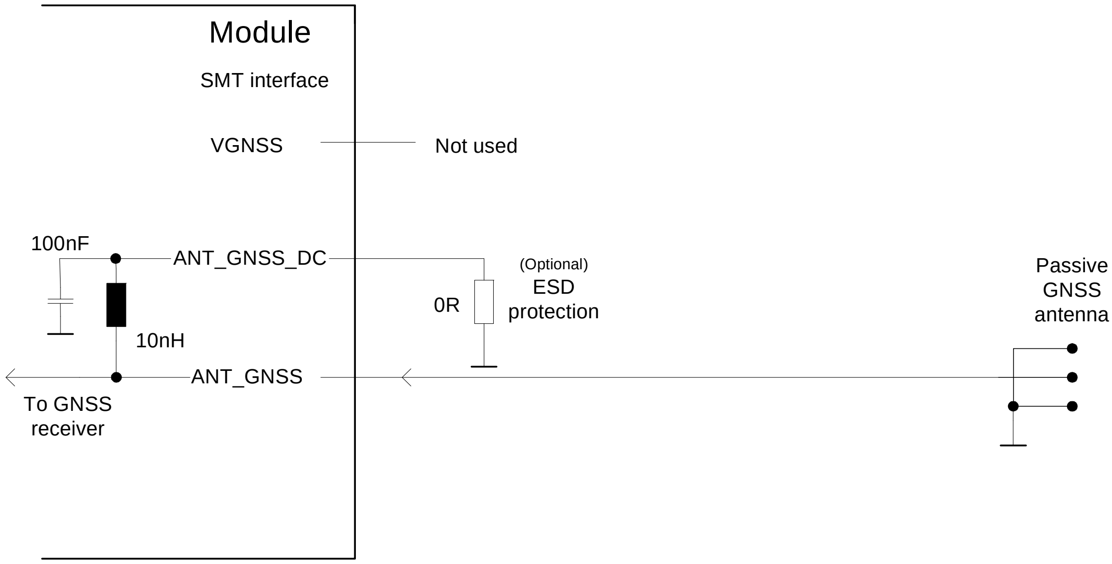


Figure 28: ESD protection for passive GNSS antenna

6 Electrical, Reliability and Radio Characteristics

6.1 Absolute Maximum Ratings

The absolute maximum ratings stated in Table 16 are stress ratings under any conditions. Stresses beyond any of these limits will cause permanent damage to PLS8-E.

Table 16: Absolute maximum ratings

Parameter	Min	Max	Unit
Supply voltage BATT+	-0.5	+6.0	V
Voltage at all digital lines in Power Down mode	-0.5	+0.5	V
Voltage at digital lines in normal operation	-0.5	+2.3	V
Voltage at SIM/USIM interface, CCVCC 1.8V in normal operation	-0.5	+2.3	V
Voltage at SIM/USIM interface, CCVCC 3.0V in normal operation	-0.5	+3.4	V
Voltage at ADC lines if the module is powered by BATT+	-0.5	+3.5	V
Voltage at ADC lines if the module is not powered	-0.5	+0.5	V
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	2.5	V
GNSS antenna supply VGNSS		300	mA

6.2 Operating Temperatures

Table 17: Board temperature

Parameter	Min	Typ	Max	Unit
Operating temperature range[1] Normal temperature range Extreme temperature range	 +15 -30	 +25	 +55 +85	 °C °C
Extended temperature range[2]	-40		+95	°C
Automatic shutdown[3] Temperature measured on PLS8-E board	 <-40	 ---	 >+95	 °C

1. Operating temperature range according to 3GPP type approval specification.
2. Extended operation allows normal mode data transmissions for limited time until automatic thermal shutdown takes effect.
   Within the extended temperature range (outside the operating temperature range) there should not be any unrecoverable malfunctioning. General performance parameters like Pout or RX sensitivity however may be reduced in their values. The module's life time may also be affected, if deviating from a general temperature allocation model (for details see Section 6.2.1).
3. 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.

See also Section 3.3.5 for information about the NTC for on-board temperature measurement, automatic thermal shutdown and alert messages.

Note that within the specified operating temperature ranges the board temperature may vary to a great extent depending on operating mode, used frequency band, radio output power and current supply voltage. Note also the differences and dependencies that usually exist between board (PCB) temperature and ambient temperature as shown in the following Figure 29. The possible ambient temperature range depends on the mechanical application design including the module and the PCB with its size and layout. A thermal solution will have to take these differences into account and should therefore be an integral part of application design.

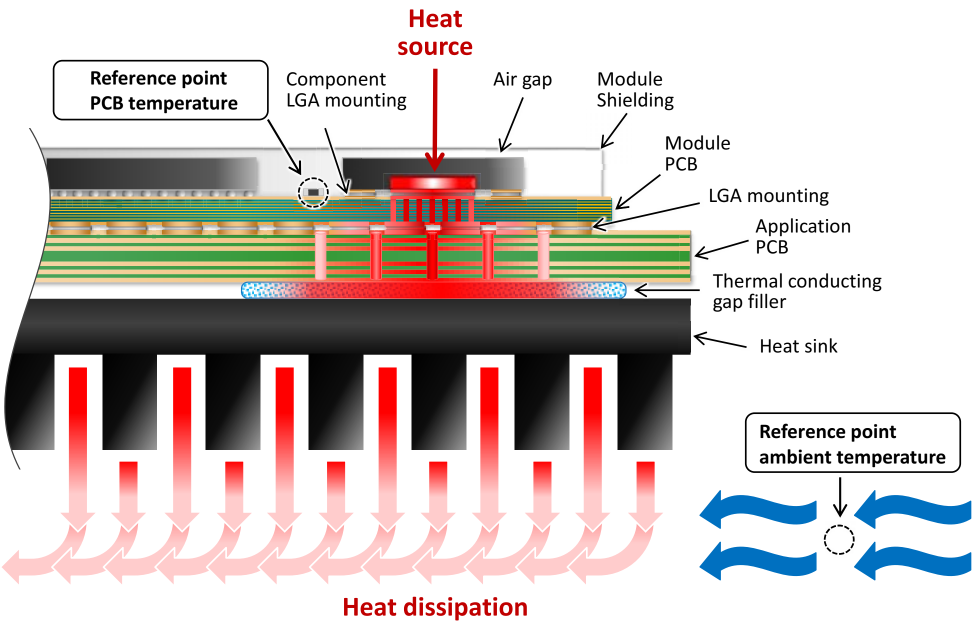


Figure 29: Board and ambient temperature differences

6.2.1 Temperature Allocation Model

The temperature allocation model shown in Table 18 assumes shares of a module's average lifetime of 10 years (given in %) during which the module is operated at certain temperatures.

Table 18: Temperature allocation model

Module lifetime share (in %)[1]	6	20	65	7	1	1
Module Temperature (in °C)	-40	20	40	75	85	95

1. Based on an assumed average module lifetime of 10 years (=100%).

Any deviations from the above temperature allocation model may reduce the module's life span, for example if the module is operated close to the maximum automatic shutdown temperature not only for 1% but for 20% of its product life.

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. The modules will be delivered in a packaging that meets the requirements according "IPD/JEDEC J-STD-033B.1" for Low Temperature Carriers.

Table 19: Storage conditions

Type	Condition	Unit	Reference
Humidity relative: Low High	10 90 at 40°C	%	CbIPC/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: 20hper axis; 3 axes	DIN IEC 60068-2-6[1]
Shock half-sinus	Acceleration: 500g Shock duration: 1ms 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.

6.4.1 Bending Tests

From experience with other modules an elongation of up to 200µm/m is acceptable for PLS8-E modules as a result of bending strains.

Tests (based on EN 60068-2-21) showed that if applying a force of 10N at the middle of the module, i.e., the evaluation module with the actual PLS8-E module soldered onto the evaluation PCB as shown in Figure 30, the possible elongation is clearly below the value of 200µm/m. Therefore, a force of 10N is recommended as maximum force.

Please note that these values only apply for a one-off short stress. The module will have to be mounted free of any strains and without being exposed to dynamic pressures.

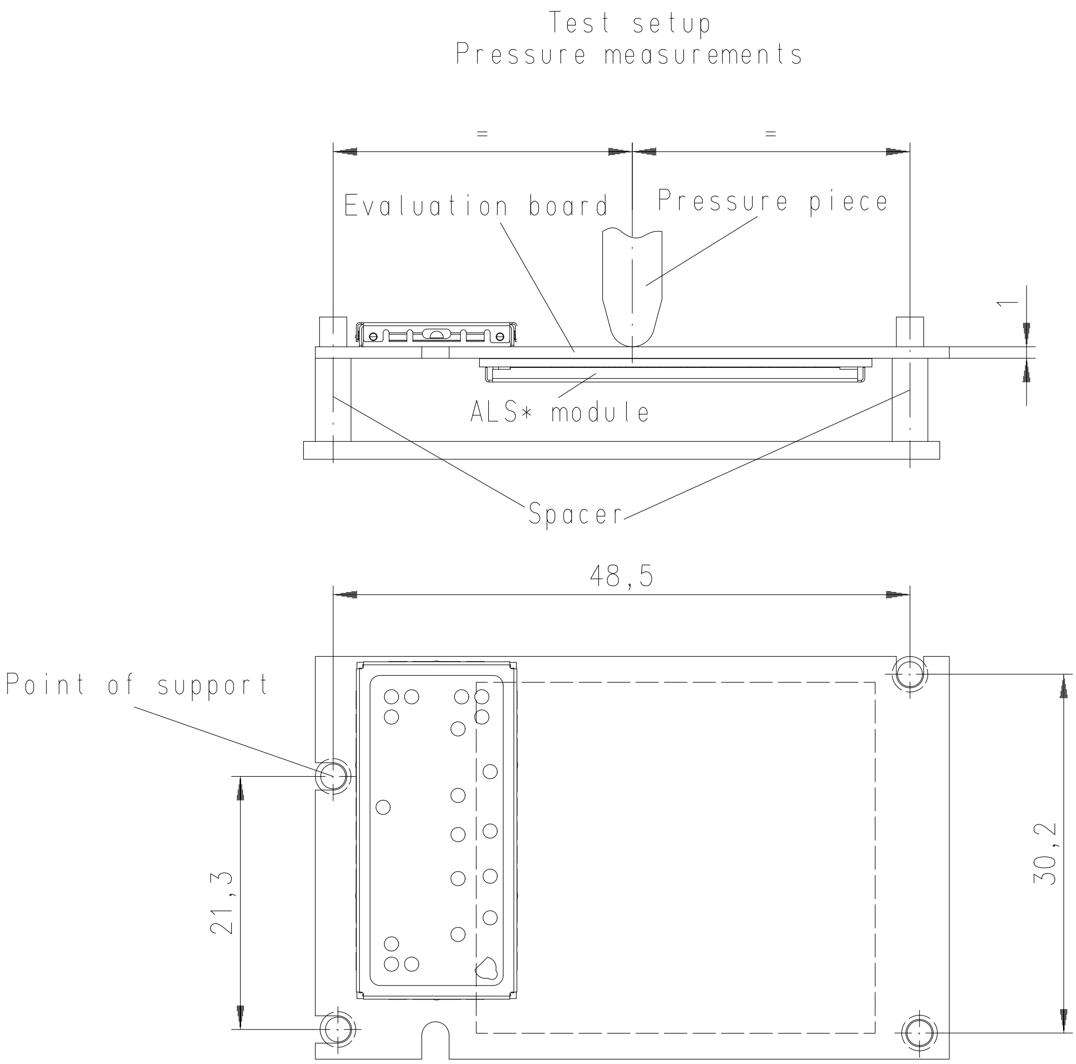


Figure 30: Bending test setup

6.5 Pad Assignment and Signal Description

The SMT application interface on the PLS8-E provides connecting pads to integrate the module into external applications. Table 21 lists the pads' assignments. Figure 31 (bottom view) and Figure 32 (top view) show the connecting pads' numbering plan.

Please note that pads marked "rfu" (reserved for future use) and further 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 PLS8-E modules, but may have different assignments with future Gemalto M2M products using the same pad layout.

Gemalto strongly recommends to solder all connecting pads for mechanical stability and heat dissipation.

Table 21: Overview: Pad assignments[1]

Pad No.	Signal Name	Pad No.	Signal Name	Pad No.	Signal Name
A4	nc	E2	GND	L2	GND
A5	GND	E3	GND	L3	GND
A6	GND	E4	GND	L4	GND
A7	rfu (dnu)	E5	GND	L5	rfu (dnu)
A8	GND	E12	rfu (dnu)	L6	rfu (dnu)
A9	GND	E13	rfu (dnu)	L7	rfu (dnu)
A10	GND	E14	rfu (dnu)	L8	rfu (dnu)
A11	GND	E15	rfu (dnu)	L9	rfu (dnu)
A12	ANT_DRX_MIMO	E16	rfu (dnu)	L10	rfu (dnu)
A13	GND	F1	GND	L11	rfu (dnu)
B3	nc	F2	GND	L12	rfu (dnu)
B4	GND	F3	GND	L13	rfu (dnu)
B5	GND	F4	GND	L14	CCRST
B6	GND	F13	rfu (dnu)	L15	CCCLK
B7	GND	F14	rfu (dnu)	L16	IGT
B8	GND	F15	rfu (dnu)	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	rfu (dnu)	M7	PCM_I2S_IN
B14	STATUS	G13	rfu (dnu)	M8	PCM_I2S_CLK
C2	GND	G14	GPIO7	M9	PCM_I2S_FSC
C3	GND	G15	GPIO8	M10	PCM_I2S_OUT
C4	GND	G16	GPIO9	M11	ADC3_IN
C5	GND	H1	GND	M12	ADC2_IN
C6	GND	H2	GND	M13	ADC1_IN
C7	GND	H3	GND	M14	CCIN
C8	GND	H4	GND	M15	rfu (dnu)
C9	GND	H13	rfu (dnu)	N3	BATT+_RF
C10	GND	H14	GPIO4	N4	BATT+_RF
C11	GND	H15	GPIO5	N5	VUSB_IN
C12	rfu (dnu)	H16	GPIO6/LCI_IND	N6	rfu (dnu)
C13	rfu (dnu)	J1	GND	N7	rfu (dnu)
C14	rfu (dnu)	J2	GND	N8	CTS0
C15	rfu (GND)	J3	GND	N9	DCD0
D1	GND	J4	GND	N10	RTS0
D2	GND	J13	GND	N11	GND
D3	GND	J14	GPIO1	N12	rfu (dnu)
D4	GND	J15	GPIO2	N13	BATT+
D5	ANT_GNSS_DC	J16	GPIO3	N14	EMERG_OFF
D6	GND	K1	ANT_MAIN	P4	USB_DP
D7	GND	K2	GND	P5	USB_DN
D8	GND	K3	GND	P6	I2S_MCLKOUT
D9	GND	K4	GND	P7	rfu (dnu)
D10	GND	K5	GND	P8	DTR0
D11	GND	K12	rfu (dnu)	P9	DSR0
D12	rfu (dnu)	K13	rfu (dnu)	P10	RING0
D13	rfu (dnu)	K14	CCIO	P11	RXD0
D14	rfu (dnu)	K15	CCVCC	P12	TXD0
D15	rfu (dnu)	K16	VGNSS	P13	BATT+
D16	rfu (dnu)	L1	GND		
E1	ANT_GNSS				

1. nc = not connected; rfu = reserved for future use; dnu = do not use

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
P				USB_DP	USB_DN	I2S_MCLK-OUT	rfu (dnu)	DTR0	DSR0	RING0	RXD0	TXD0	BATT+			
N			BATT+_RF	BATT+_RF	VUSB_IN	rfu (dnu)	rfu (dnu)	CTS0	DCD0	RTS0	GND	rfu (dnu)	BATT+	EMERG_OFF		
M		GND	GND	PWR_IND	VEXT	GND	PCM_I2S_IN	PCM_I2S_CLK	PCM_I2S_FSC	PCM_I2S_OUT	ADC3_IN	ADC2_IN	ADC1_IN	CCIN	rfu (dnu)	
L	GND	GND	GND	GND	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	CCRST	CCCLK	IGT
K	ANT_MAIN	GND	GND	GND	GND							rfu (dnu)	rfu (dnu)	CCIO	CCVCC	VGNSS
J	GND	GND	GND	GND									GND	GPIO1	GPIO2	GPIO3
H	GND	GND	GND	GND									rfu (dnu)	GPIO4	GPIO5	GPIO6/ LCI_IND
G	GND	GND	GND	rfu (dnu)									rfu (dnu)	GPIO7	GPIO8	GPIO9
F	GND	GND	GND	GND									rfu (dnu)	rfu (dnu)	rfu (dnu)	GPIO10
E	ANT_GNSS	GND	GND	GND	GND							rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)
D	GND	GND	GND	GND	ANT_GNSS_DC	GND	GND	GND	GND	GND	GND	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)
C		GND	GND	GND	GND	GND	GND	GND	GND	GND	GND	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (GND)	
B			nc	GND	GND	GND	GND	GND	GND	GND	GND	GND	GND	STATUS		
A				nc	GND	GND	rfu (dnu)	GND	GND	GND	GND	ANT_DRX_MIMO	GND			

rfu: Reserved for future use (should not be connected to external application)
nc: Internally not connected (may be arbitrarily connected to external application)
(**dnu**): Do not use

Position marker

For internal use: Not to be soldered

Figure 31: PLS8-E bottom view: Pad assignments

	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
P				BATT+	TXD0	RXD0	RING0	DSR0	DTR0	rfu (dnu)	I2S_MCLK-OUT	USB_DN	USB_DP			
N			EMERG_OFF	BATT+	rfu (dnu)	GND	RTS0	DCD0	CTS0	rfu (dnu)	rfu (dnu)	VUSB_IN	BATT+_RF	BATT+_RF		
M		rfu (dnu)	CCIN	ADC1_IN	ADC2_IN	ADC3_IN	PCM_I2S_OUT	PCM_I2S_FSC	PCM_I2S_CLK	PCM_I2S_IN	GND	VEXT	PWR_IND	GND	GND	
L	IGT	CCCLK	CCRST	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	GND	GND	GND	GND
K	VGNSS	CCVCC	CCIO	rfu (dnu)	rfu (dnu)							GND	GND	GND	GND	ANT_MAIN
J	GPIO3	GPIO2	GPIO1	GND									GND	GND	GND	GND
H	GPIO6/LCI_IND	GPIO5	GPIO4	rfu (dnu)									GND	GND	GND	GND
G	GPIO9	GPIO8	GPIO7	rfu (dnu)									rfu (dnu)	GND	GND	GND
F	GPIO10	rfu (dnu)	rfu (dnu)	rfu (dnu)									GND	GND	GND	GND
E	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)							GND	GND	GND	GND	ANT_GNSS
D	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	rfu (dnu)	GND	GND	GND	GND	GND	GND	ANT_GNSS_DC	GND	GND	GND	GND
C		rfu (GND)	rfu (dnu)	rfu (dnu)	rfu (dnu)	GND	GND	GND	GND	GND	GND	GND	GND	GND	GND	
B			STATUS	GND	GND	GND	GND	GND	GND	GND	GND	GND	GND	nc		
A				GND	ANT_DRX_MIMO	GND	GND	GND	GND	rfu (dnu)	GND	GND	nc			

rfu: Reserved for future use (should not be connected to external application)
nc: Internally not connected (may be arbitrarily connected to external application)
(**dnu**): Do not use

For internal use: Not to be soldered

Position marker

Figure 32: PLS8-E top view: Pad assignments

Please note that the reference voltages listed in Table 22 are the values measured directly on the PLS8-E 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+_RF	I	$V_I$max = 4.2V $V_I$norm = 3.8V $V_I$min = 3.3V during Tx burst on board Imax ≈ 2A, during Tx burst (GSM)  n Tx = n x 577µs peak current every 4.615ms	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 = 350mA	
Power supply	GND		Ground	Application Ground
External supply voltage	VEXT	O	CLmax = 1µF V_O = 1.80V +1% -5% $I_O$max = -50mA	VEXT may be used for application circuits. If unused keep line open. The external digital logic must not cause any spikes or glitches on voltage VEXT. Do not exeed IOmax
Supply voltage for active GNSS antenna (Output)	VGNSS	O	CLmax = 2.2µ V_O = 3.05V ±1% @I_O = -20mA $I_O$max = -50mA	Available if GNSS antenna DC power is enabled (configurable by AT command; see Section 6.8).
Supply voltage for active GNSS antenna (Input)	ANT_GNSS_DC	I	$V_I$max = 6V The input curren has to be limited at 50mA (antenna short circuit protection)	If unused connect to GND.
Ignition	IGT	I	R_{PU} ≈ 200kΩ V_{OH}max=*1.8V* V_{IH}max =*2.1V* 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} ≈ 40kΩ V_{OH}max=*1.8V* V_{IH}max =*2.1V* 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
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
SIM card detection	CCIN	I	R_{PU} ≈ 24.2kΩ V_{OH}max=1.9V V_{IH}min = 1.15V V_{IH}max= 1.9V V_{IL}max = 0.4V	CCIN = Low, SIM card inserted. If unused connect to GND.
3V SIM card interface	CCRST	O	V_{OL}max = 0.45V at I = 2mA V_{OH}min = 2.57V at I = -2mA V_{OH}max = 3.08V	Maximum cable length or copper track should be not longer than 100mm to SIM card holder.
	CCIO	I/O	R_{PU} ≈ 4.8...9.5kΩ V_{IL}max = 0.76V V_{IL}min = -0.3V V_{IH}min = 1.98V V_{IH}max = 3.35V V_{OL}max = 0.45V at I = 2mA V_{OH}min = 2.57V at I = -0.05mA V_{OH}max = 3.08V	
	CCCLK	O	V_{OL}max = 0.45V at I = 2mA V_{OH}min = 2.57V at I = -2mA V_{OH}max = 3.08V	
	CCVCC	O	V_{O}min = 3.0V V_{O}typ =3.05V V_{O}max = 3.08V I_{O}max = -50mA	
1.8V SIM card interface	CCRST	O	V_{OL}max = 0.45V at I = 2mA V_{OH}min = 1.35V at I = -2mA V_{OH}max = 1.85V	Maximum cable length or copper track should be not longer than 100mm to SIM card holder.
	CCIO	I/O	R_{I} ≈ 4.8...9.5kΩ V_{IL}max = 0.62V V_{IL}min = -0.3V V_{IH}min = 1.20V V_{IH}max = 2.1V V_{OL}max = 0.45V at I = 2mA V_{OH}min = 1.32V at I = -0.05mA V_{OH}max = 1.82V	
	CCCLK	O	V_{OL}max = 0.45V at I = 2mA V_{OH}min = 1.32V at I = -2mA V_{OH}max = 1.82V	
	CCVCC	O	V_{O}min = 1.75V V_{O}typ = 1.80V V_{O}max = 1.82V I_{O}max = -50mA	

Table 22: Signal description

Function	Signal name	IO	Signal form and level	Comment
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		
Power indicator	PWR_IND	O	V_{IH}max = 5.5V V_{OL}max = 0.4V at Imax = 1mA	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, signal may be used to enable external voltage regulators that supply an external logic for communication with the module, e.g. level converters.
Host wakeup	RING0	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.
USB	VUSB_IN	I	V_{IN}min = 3.0V V_{IN}max = 5.25V $I_I$typ = 150µA $I_I$max = 200µA Cin=1µF In case of Vripple ≥ 10mVpp (with f>300kHz), and VBUS_IN driven in the voltage range 4.08V...4.11V, use of an RC filter 1kΩ/100nF is required.	If the USB interface is not used please connect this line to GND. Since VUSB_IN is used for detection only it is recommended not to add any further blocking capacitors on the VUSB_IN line.
	USB_DN	I/O	All electrical characteristics according to USB Implementers' Forum, USB 2.0 High Speed Specification.	Keep lines open if VUSB_IN connects to GND. USB High Speed mode operation requires a differential impedance of 90Ω.
	USB_DP	I/O		

Table 22: Signal description

Function	Signal name	IO	Signal form and level	Comment
Digital audio interface (PCM or I^{2}S)	PCM_I2S_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	PCM Master/Slave mode. I^{2}S Master mode. If unused keep lines open.
	PCM_I2S_CLK	I/O		
	PCM_I2S_FSC	I/O		
	PCM_I2S_OUT	O		
	I2S_MCLKOUT	O	V_{OL}max = 0.45V at I = 2mA V_{OH}min = 1.35V at I = -2mA V_{OH}max = 1.85V F=2048KHz (at 8KHz sample rate) F=4096KHz (at 16KHz sample rate)	Master clock option for audio codecs without PLL. If unused keep line open.
GPIO interface	GPIO1 GPIO2 GPIO3 GPIO4 GPIO5 GPIO6 GPIO7 GPIO8 GPIO9 GPIO10	I/O	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	If unused keep lines open. GPIO6 can be configured as Low Current Indicator using AT commands.
Low Current Indication	GPIO6	O	V_{OL}max = 0.45V at I = 2mA V_{OH}min = 1.35V at I = -2mA V_{OH}max = 1.85V	If the feature is enabled (see Section 3.11.4).
		I	V_{IH}max = 2V R_{PD}= appr. 100kΩ	If the feature is disabled (see Section 3.11.4).
ADC interface	ADC1_IN, ADC2_IN, ADC3_IN	I	Full specification compliance range V_{Imin}>=0.3V V_{Imax}<=3.075V Degraded accuracy range V_{Imin} 0.05V ... 0.3V Ridc>1MΩ Resolution: 12 Bit Offset error: <+-10mV Gain error: <1% analog bandwidth: <16kHz conversation time: 853µs	If unused keep line open.

6.6 Power Supply Ratings

Table 23 and Table 24 assemble various voltage supply and current consumption ratings of the module.

Table 23: Voltage 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			 120 90	 mV_{pp} mV_{pp}

Table 24: Current consumption ratings

	Description	Conditions		Typical rating	Unit
I_{BATT+} [1]	OFF State supply current	Power Down		40	µA
	Average GSM / GPRS supply current (GNSS off)	SLEEP[2] @ DRX=9 (no communication via UART)	USB disconnected	2.0	mA
		SLEEP[2] @ DRX=5 (no communication via UART)	USB disconnected	2.5	mA
		SLEEP[2] @ DRX=2 (no communication via UART)	USB disconnected	3.7	mA
		IDLE @ DRX=2 UART active, but no communication	USB disconnected	75	mA
			USB active	90	mA
		Voice call GSM900; PCL=5	@50Ω	330	mA
		GPRS Data transfer GSM900; PCL=5; 1Tx/4Rx	ROPR=8 (max. reduction)	320	mA
			ROPR=4 (no reduction)		
		GPRS Data transfer GSM900; PCL=5; 2Tx/3Rx	ROPR=8 (max. reduction)	430	mA
			ROPR=4 (no reduction)	540	
		GPRS Data transfer GSM900; PCL=5; 4Tx/1Rx	ROPR=8 (max. reduction)	600	mA
			ROPR=4 (no reduction)	930	

Table 24: Current consumption ratings

	Description	Conditions		Typical rating	Unit
I_{BATT+} [1]	Average GSM / GPRS supply current (GNSS off)	EDGE Data transfer GSM900; PCL=5; 1Tx/4Rx	ROPR=8 (max. reduction)	220	mA
			ROPR=4 (no reduction)		
		EDGE Data transfer GSM900; PCL=5; 2Tx/3Rx	ROPR=8 (max. reduction)	300	mA
			ROPR=4 (no reduction)	340	
		EDGE Data transfer GSM900; PCL=5; 4Tx/1Rx	ROPR=8 (max. reduction)	490	mA
			ROPR=4 (no reduction)	570	
		Voice call GSM1800; PCL=0	@50Ω	240	mA
		GPRS Data transfer GSM1800; PCL=0; 1Tx/4Rx	ROPR=8 (max. reduction)	230	mA
			ROPR=4 (no reduction)		
		GPRS Data transfer GSM1800; PCL=0; 2Tx/3Rx	ROPR=8 (max. reduction)	300	mA
			ROPR=4 (no reduction)	360	
		GPRS Data transfer GSM1800; PCL=0; 4Tx/1Rx	ROPR=8 (max. reduction)	410	mA
			ROPR=4 (no reduction)	590	
		EDGE Data transfer GSM1800; PCL=0; 1Tx/4Rx	ROPR=8 (max. reduction)	190	mA
			ROPR=4 (no reduction)		
		EDGE Data transfer GSM1800; PCL=0; 2Tx/3Rx	ROPR=8 (max. reduction)	250	mA
			ROPR=4 (no reduction)	290	
		EDGE Data transfer GSM1800; PCL=0; 4Tx/1Rx	ROPR=8 (max. reduction)	380	mA
			ROPR=4 (no reduction)	460	
	Peak current during GSM transmit burst	Voice call GSM900; PCL=5	@50Ω	2.1	A
			@total mismatch	2.4	
		Voice call GSM1800; PCL=0	@50Ω	1.3	A
			@total mismatch	1.6	

Table 24: Current consumption ratings

	Description	Conditions		Typical rating	Unit
I_{BATT+}[1]	Average GSM supply current (GNSS on)	GSM active (UART/USB active); @DRX=2 & GNSS NMEA output off		46	mA
		GSM active (UART/USB active); @DRX=2 & GNSS NMEA output on[3]		75	mA
I_{BATT+}[1]	Average UMTS supply current (GNSS off) Voice calls and Data transfers measured @maximum Pout	SLEEP[2] @ DRX=9	USB disconnected	1.8	mA
		SLEEP[2] @ DRX=8	USB disconnected	2.1	mA
		SLEEP[2] @ DRX=6	USB disconnected	3.3	mA
		IDLE @ DRX=6	USB disconnected	50	mA
			USB active	65	mA
		Voice call Band I		540	mA
		Voice call Band III	@50Ω	600	mA
			@total mismatch	780	
		Voice call Band VIII		460	mA
		UMTS Data transfer Band I		560	mA
		UMTS Data transfer Band III		620	mA
		UMTS Data transfer Band VIII		500	mA
		HSDPA Data transfer Band I		590	mA
		HSDPA Data transfer Band III		620	mA
		HSDPA Data transfer Band VIII		510	mA
	Average UMTS supply current (GNSS on)	WCDMA active (UART / USB active); @DRX=6 & GNSS NMEA output off		46	mA
		WCDMA active (UART / USB active); @DRX=6 & GNSS NMEA output on[3]		75	mA
	Average LTE supply current[4] (GNSS off) Data transfers measured @maximum Pout	SLEEP[2] @ "Paging Occasions" = 256	USB disconnected	2.3	mA
		SLEEP[2] @ "Paging Occasions" = 128	USB disconnected	2.7	mA
		SLEEP[2] @ "Paging Occasions" = 64	USB disconnected	3.5	mA
		SLEEP[2] @ "Paging Occasions" = 32	USB disconnected	5.4	mA
		IDLE	USB disconnected	55	mA
			USB active	70	mA
		LTE Data transfer Band 1		570	mA
		LTE Data transfer Band 3	@ 50Ω	650	mA
			@ total mismatch	830	mA
		LTE Data transfer Band 7		640	mA
		LTE Data transfer Band 8		520	mA
		LTE Data transfer Band 20		520	mA

Table 24: Current consumption ratings

	Description	Conditions	Typical rating	Unit
I_{BATT+} [1]	Average LTE supply current (GNSS on)	LTE active (UART / USB active); @DRX=6 & GNSS NMEA output off	46	mA
		LTE active (UART / USB active); @DRX=6 & GNSS NMEA output on[3]	75	mA
I_{VUSB_IN}	USB typical and maximum ratings are mentioned in Table 22: VUSB_IN.			

1. With an impedance of Z_{LOAD}=50Ω at the antenna pads. Measured at 25°C and 4.2V - except for Power Down ratings that were measured at 3.4V.
2. Measurements start 6 minutes after switching ON the module,
   Averaging times: SLEEP mode - 3 minutes, transfer modes - 1.5 minutes
   Communication tester settings:no neighbour cells, no cell reselection etc,
   RMC (Reference Measurement Channel)
3. One fix per second.
4. Communication tester settings:
   - Channel Bandwidth: 5MHz
   - Number of Resource Blocks: 25 (DL), 1 (UL)
   - Modulation: QPSK

6.7 RF Antenna Interface Characteristics

Table 25: RF Antenna interface GSM / UMTS/LTE (at operating temperature range[1])

Parameter	Conditions	Min.	Typical	Max.	Unit
LTE connectivity[2]	Band 1, 3, 7, 8, 20				
Receiver Input Sensitivity @ ARP (ch. bandwidth 5MHz)	LTE 800 Band 20	-97	-103		dBm
	LTE 900 Band 8	-97	-104		dBm
	LTE 1800 Band 3	-97	-103		dBm
	LTE 2100 Band 1	-100	-103		dBm
	LTE 2600 Band 7	-98	-102		dBm
RF Power @ ARP with 50Ω Load	LTE 800 Band 20	+21	+23	+25	dBm
	LTE 900 Band 8	+21	+23	+25	dBm
	LTE 1800 Band 3	+21	+23	+25	dBm
	LTE 2100 Band 1	+21	+23	+25	dBm
	LTE 2600 Band 7	+21	+23	+25	dBm
UMTS/HSPA connectivity[2]	Band I, III, VIII				
Receiver Input Sensitivity @ ARP	UMTS 900 Band VIII	-103.7	-111		dBm
	UMTS 1800 Band III	-103.7	-110		dBm
	UMTS 2100 Band I	-106.7	-110		dBm
RF Power @ ARP with 50Ω Load	UMTS 900 Band VIII	+21	+24	+25	dBm
	UMTS 1800 Band III	+21	+24	+25	dBm
	UMTS 2100 Band I	+21	+24	+25	dBm
Tx noise @ ARP with max. RF power for UMTS: Band 1 channel 9777 Band 2 channel 9477	GNSS band		-170		dBm/Hz
GPRS coding schemes	Class 12, CS1 to CS4				
EGPRS	Class 12, MCS1 to MCS9				
GSM Class	Small MS				
Static Receiver input Sensitivity @ ARP	E-GSM 900	-102	-111		dBm
	GSM 1800	-102	-110		dBm
RF Power @ ARP with 50Ω Load GSM	E-GSM 900		33		dBm
	GSM 1800		30		dBm

Table 25: RF Antenna interface GSM / UMTS/LTE (at operating temperature range[1])

Parameter		Conditions	Min.	Typical	Max.	Unit
RF Power @ ARP with 50Ω Load (**ROPR=4**, i.e., no reduction)	GPRS, 1 TX	E-GSM 900		33		dBm
		GSM 1800		30		dBm
	EDGE, 1 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
	GPRS, 2 TX	E-GSM 900		33		dBm
		GSM 1800		30		dBm
	EDGE, 2 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
	GPRS, 3 TX	E-GSM 900		33		dBm
		GSM 1800		30		dBm
	EDGE, 3 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
	GPRS, 4 TX	E-GSM 900		33		dBm
		GSM 1800		30		dBm
	EDGE, 4 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
RF Power @ ARP with 50Ω Load (**ROPR=5**)	GPRS, 1 TX	E-GSM 900		33		dBm
		GSM 1800		30		dBm
	EDGE, 1 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
	GPRS, 2 TX	E-GSM 900		33		dBm
		GSM 1800		30		dBm
	EDGE, 2 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
	GPRS, 3 TX	E-GSM 900		32.2		dBm
		GSM 1800		29.2		dBm
	EDGE, 3 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
	GPRS, 4 TX	E-GSM 900		31		dBm
		GSM 1800		28		dBm
	EDGE, 4 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm

Table 25: RF Antenna interface GSM / UMTS/LTE (at operating temperature range[1])

Parameter		Conditions	Min.	Typical	Max.	Unit
RF Power @ ARP with 50Ω Load (**ROPR=6**)	GPRS, 1 TX	E-GSM 900		33		dBm
		GSM 1800		30		dBm
	EDGE, 1 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
	GPRS, 2 TX	E-GSM 900		31		dBm
		GSM 1800		28		dBm
	EDGE, 2 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
	GPRS, 3 TX	E-GSM 900		30.2		dBm
		GSM 1800		27.2		dBm
	EDGE, 3 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
	GPRS, 4 TX	E-GSM 900		29		dBm
		GSM 1800		26		dBm
	EDGE, 4 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
RF Power @ ARP with 50Ω Load (**ROPR=7**)	GPRS, 1 TX	E-GSM 900		33		dBm
		GSM 1800		30		dBm
	EDGE, 1 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
	GPRS, 2 TX	E-GSM 900		30		dBm
		GSM 1800		27		dBm
	EDGE, 2 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
	GPRS, 3 TX	E-GSM 900		28.2		dBm
		GSM 1800		25.2		dBm
	EDGE, 3 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
	GPRS, 4 TX	E-GSM 900		27		dBm
		GSM 1800		24		dBm
	EDGE, 4 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm

Table 25: RF Antenna interface GSM / UMTS/LTE (at operating temperature range[1])

Parameter		Conditions	Min.	Typical	Max.	Unit
RF Power @ ARP with 50Ω Load (**ROPR=8**, i.e., max. reduction)	GPRS, 1 TX	E-GSM 900		33		dBm
		GSM 1800		30		dBm
	EDGE, 1 TX	E-GSM 900		27		dBm
		GSM 1800		26		dBm
	GPRS, 2 TX	E-GSM 900		30		dBm
		GSM 1800		27		dBm
	EDGE, 2 TX	E-GSM 900		24		dBm
		GSM 1800		23		dBm
	GPRS, 3 TX	E-GSM 900		28.2		dBm
		GSM 1800		25.2		dBm
	EDGE, 3 TX	E-GSM 900		22.2		dBm
		GSM 1800		21.2		dBm
	GPRS, 4 TX	E-GSM 900		27		dBm
		GSM 1800		24		dBm
	EDGE, 4 TX	E-GSM 900		21		dBm
		GSM 1800		20		dBm

1. At extended temperature range no active power reduction is implemented - any deviations are hardware related.
2. Applies also to UMTS/LTE Rx diversity/MIMO antenna.

6.8 GNSS Interface Characteristics

The following tables list general characteristics of the GNSS interface.

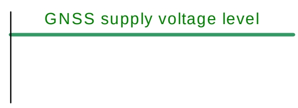
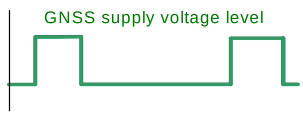
Table 26: GNSS properties

Parameter	Conditions	Min.	Typical	Max.	Unit
Frequency	GPS GLONASS	 1597.551	1575.42 	 1605.886	MHz
Tracking Sensitivity	Open sky Active antenna or LNA Passive antenna		 -159 -156		dBm
Acquisition Sensitivity	Open sky Active antenna or LNA Passive antenna		 -149 -145		dBm
Cold Start sensitivity[1]			-145		dBm
Time-to-First-Fix (TTFF)[2]	Cold		25	32	s
	Warm		10	29	s

1. Test condition: Assumes 300 seconds timeout, QoS=1000m, and 50% yield.
2. Test condition: TTFF is defined for an open sky environment, i.e., with a clear view to the sky and a minimum signal level of -130dBm at the antenna for at least 3…4 satellites. This signal level represents C/No=42dB in an NMEA $GPGSV message.

Through the external GNSS antenna DC feeding the module is able to supply an active GNSS antenna. The supply voltage level at the GNSS antenna interface depends on the GNSS configuration done with AT command as shown in Table 27.

Table 27: Power supply for active GNSS antenna

Function	Setting samples	IO	Signal form and level
GNSS active antenna supply	Supply voltage with: GNSS receiver off Active antenna off	O	
	Supply voltage with: GNSS receiver on Active antenna on SLEEP mode	O	
	Supply voltage with: GNSS receiver on Active antenna auto	O	

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 PLS8-E module.

Special ESD protection provided on PLS8-E*:*
BATT+: Inductor/capacitor
An example for an enhanced ESD protection for the SIM interface is shown in Section 3.7.1.

The remaining interfaces of PLS8-E with the exception of the antenna interface 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 ANSI/ESDA/JEDEC JS-001-2011 requirements.

PLS8-E has been tested according to the following standards. Electrostatic values can be gathered from the following table.

Table 28: Electrostatic values

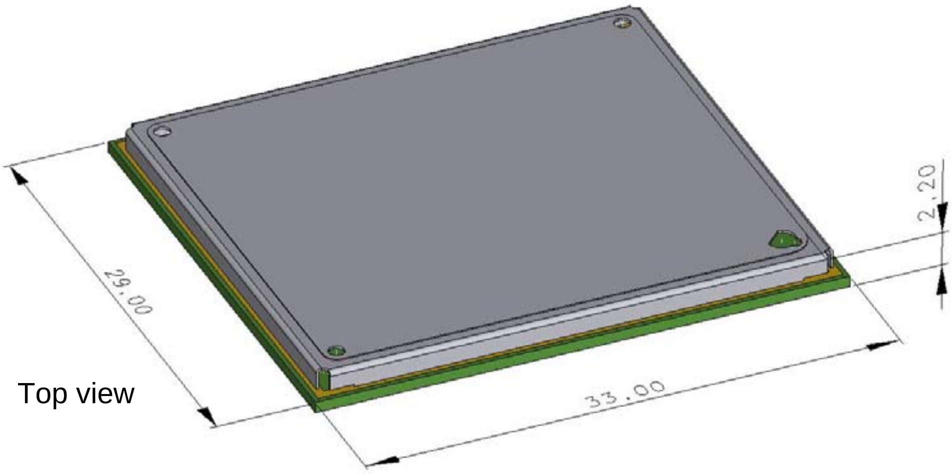
Specification / Requirements	Contact discharge	Air discharge
ANSI/ESDA/JEDEC JS-001-2011		
All SMT interfaces	± 1kV Human Body Model	n.a.
JESD22-A114-F		
All SMT interfaces	± 500V Charge Device Model (CDM)	n.a.
ETSI EN 301 489-1/7		
BATT+	± 4kV	± 8kV

Note: 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 Gemalto M2M reference application described in Chapter 9.

7 Mechanics, Mounting and Packaging

7.1 Mechanical Dimensions of PLS8-E

Figure 33 shows a 3D view[1] of PLS8-E and provides an overview of the board's mechanical dimensions. For further details see Figure 34.
Length: 33mm
Width: 29mm
Height: 2.2mm



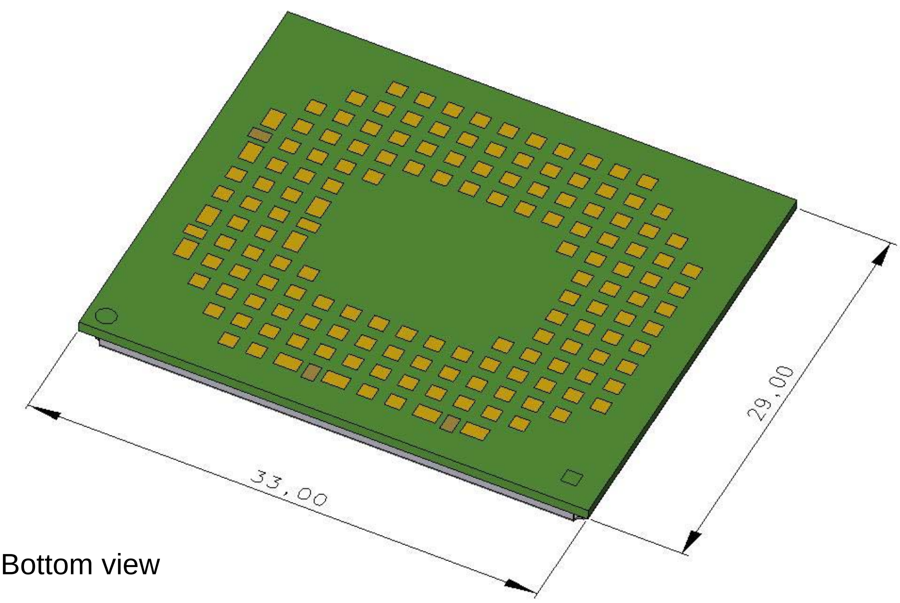


Figure 33: PLS8-E – top and bottom view

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

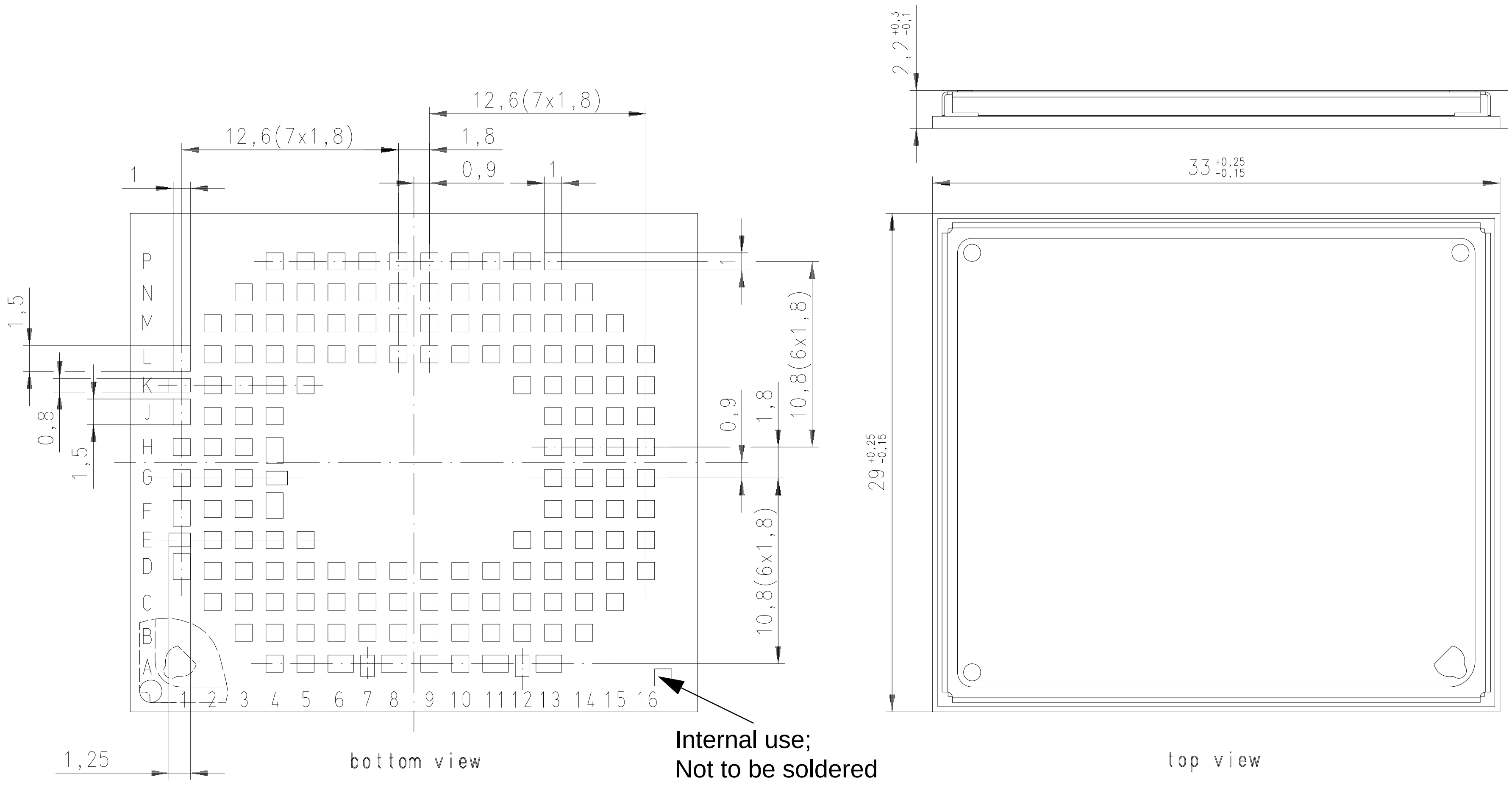


Figure 34: Dimensions of PLS8-E (all dimensions in mm)

7.2 Mounting PLS8-E onto the Application Platform

This section describes how to mount PLS8-E onto the PCBs, 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 [3].

Note: Gemalto strongly recommends to solder all connecting pads for mechanical stability and heat dissipation. Not only must all supply pads and signals be connected appropriately, but all pads denoted as “Do not use“ should also be soldered (but not electrically connected). Note also that in order to avoid short circuits between signal tracks on an external application's PCB and various markings at the bottom side of the module, it is recommended not to route the signal tracks on the top layer of an external PCB directly under the module, or at least to ensure that signal track routes are sufficiently covered with solder resist.

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 Gemalto M2M characterizations for lead-free solder paste on a four-layer test PCB and a 110 as well as a 150 micron-thick stencil.

The land pattern given in Figure 35 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.

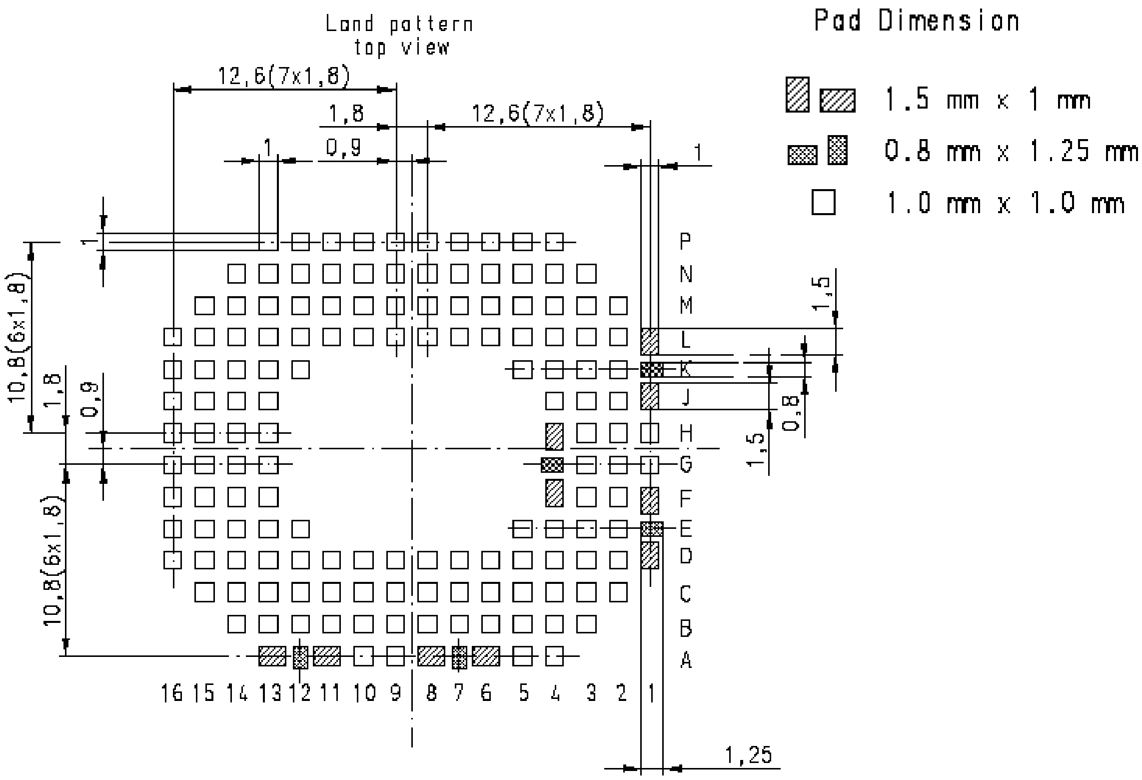


Figure 35: Land pattern (top layer)

The stencil design illustrated in Figure 36 and Figure 37 is recommended by Gemalto M2M as a result of extensive tests with Gemalto M2M Daisy Chain modules.

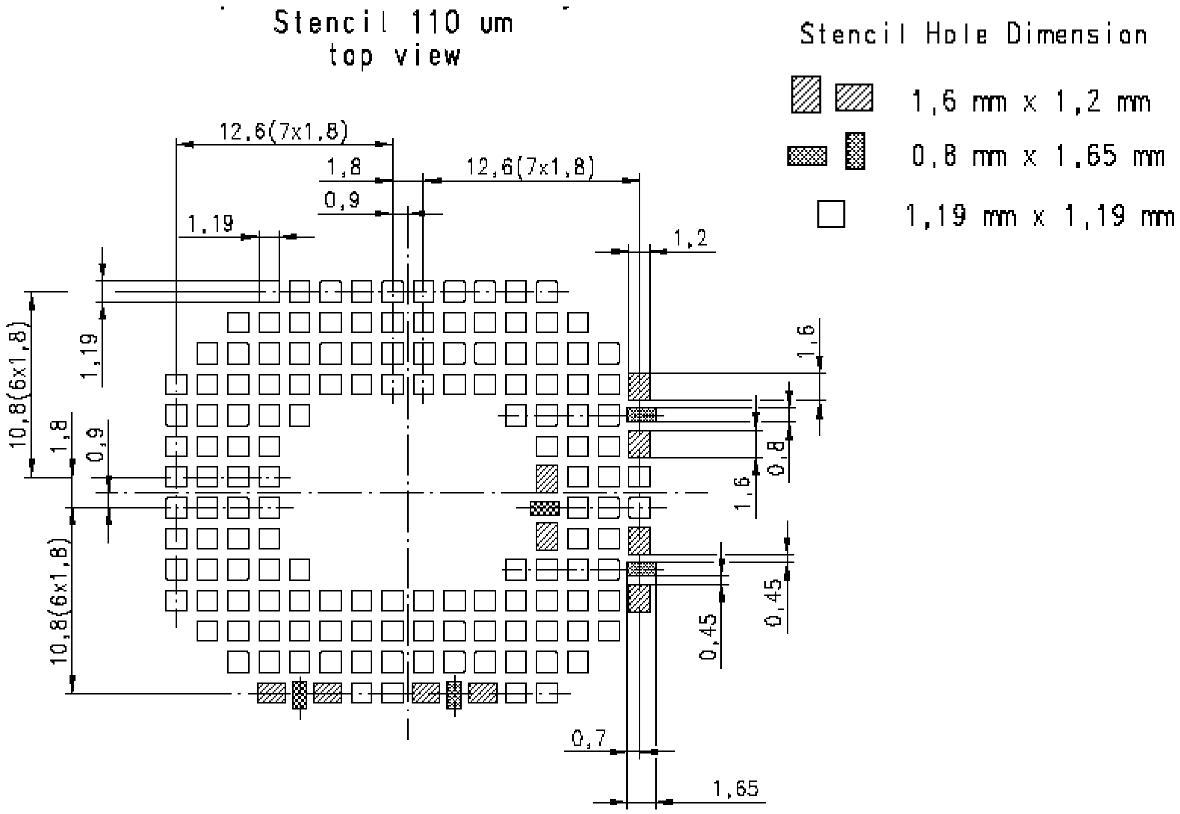


Figure 36: Recommended design for 110 micron thick stencil (top layer)

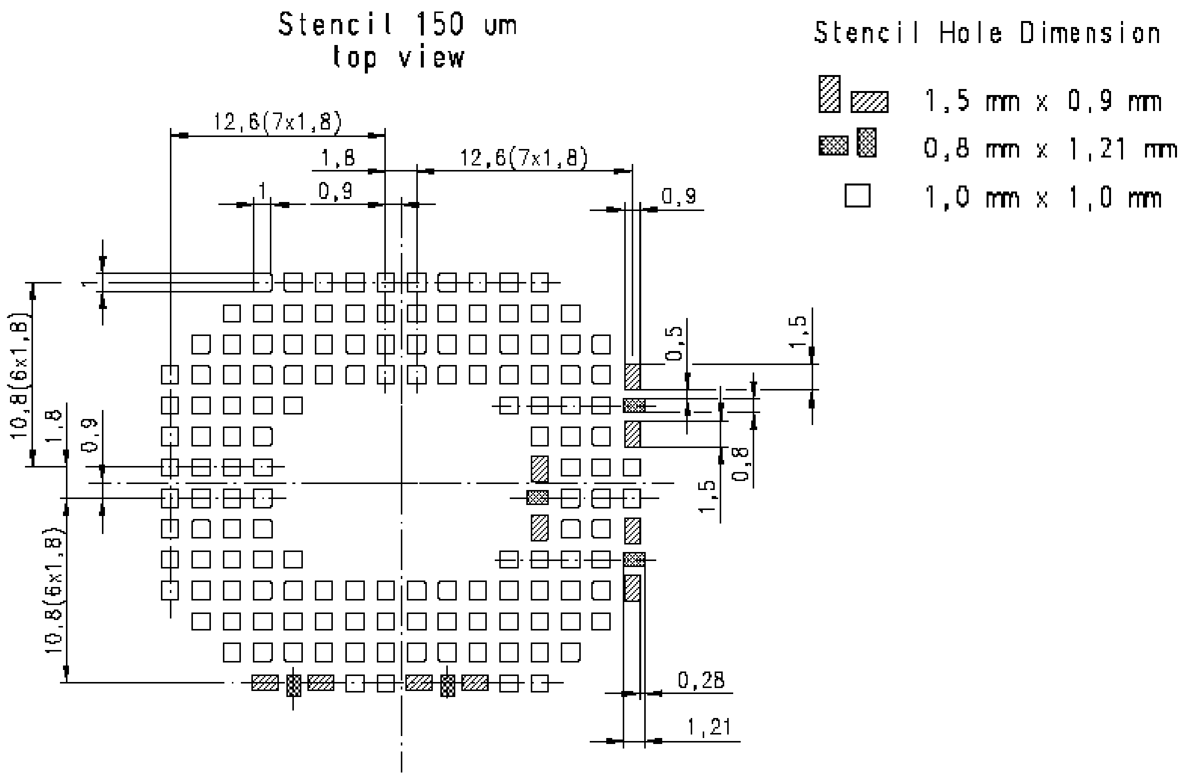


Figure 37: Recommended design for 150 micron thick stencil (top layer)

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 [3].

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 solder voids, and to increase board level reliability.

Daisy chain modules for SMT characterization are available on request. For details refer to [3].

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

PLS8-E comprises components that are susceptible to damage induced by absorbed moisture.

Gemalto M2M's PLS8-E 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 moisture sensitivity level (MSL) 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

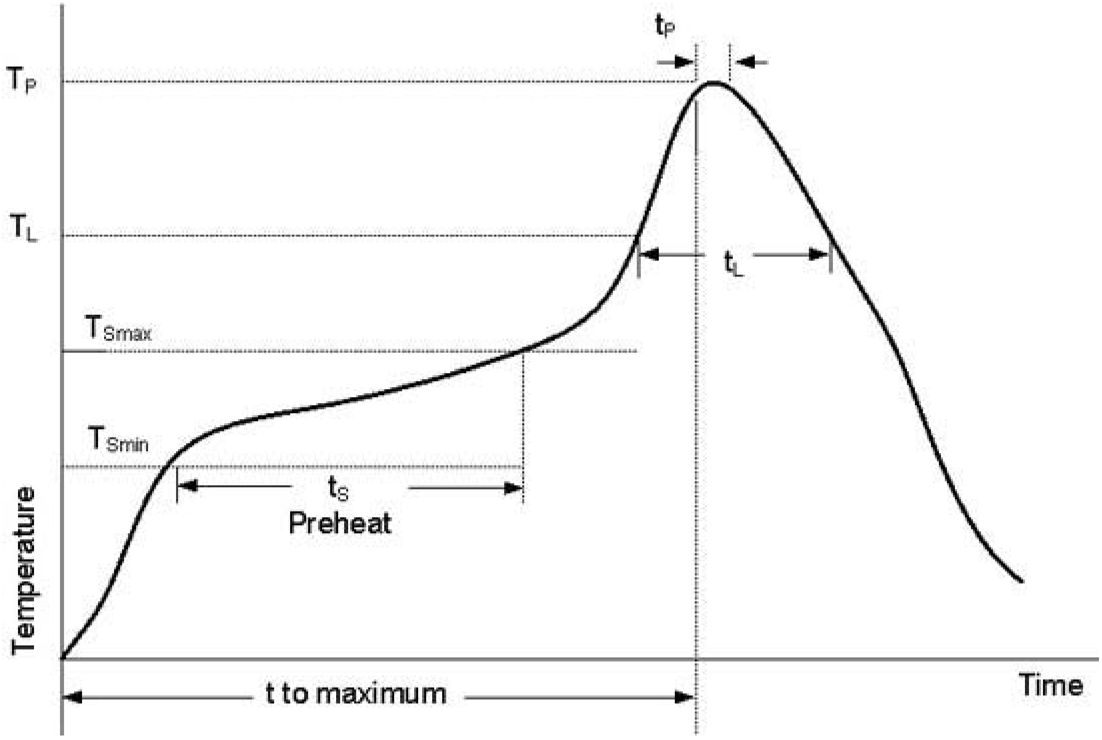


Figure 38: Reflow Profile

Table 29: Reflow temperature ratings[1]

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})	3 K/second max.
Time 25°C to maximum temperature	8 minutes max.

1. Please note that the reflow profile features and ratings listed above are based on the joint industry standard IPC/JEDEC J-STD-020D.1, and are as such meant as a general guideline. For more information on reflow profiles and their optimization please refer to [3].

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.

PLS8-E is specified for one soldering cycle only. Once PLS8-E 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

PLS8-E 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 months. 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 22.

7.2.4.2 Processing Life

PLS8-E must be soldered to an application within 72 hours after opening the moisture barrier bag (MBB) 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 43 for details):
- It is *not necessary* to bake PLS8-E, if the conditions specified in Section 7.2.4.1 and Section 7.2.4.2 were not exceeded.
- It is *necessary* to bake PLS8-E, 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

Electrostatic discharge (ESD) 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 6.9 for further information on electrostatic discharge.

7.3 Packaging

7.3.1 Tape and Reel

The single-feed tape carrier for PLS8-E is illustrated in Figure 39. The figure also shows the proper part orientation. The tape width is 44mm and the PLS8-E 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

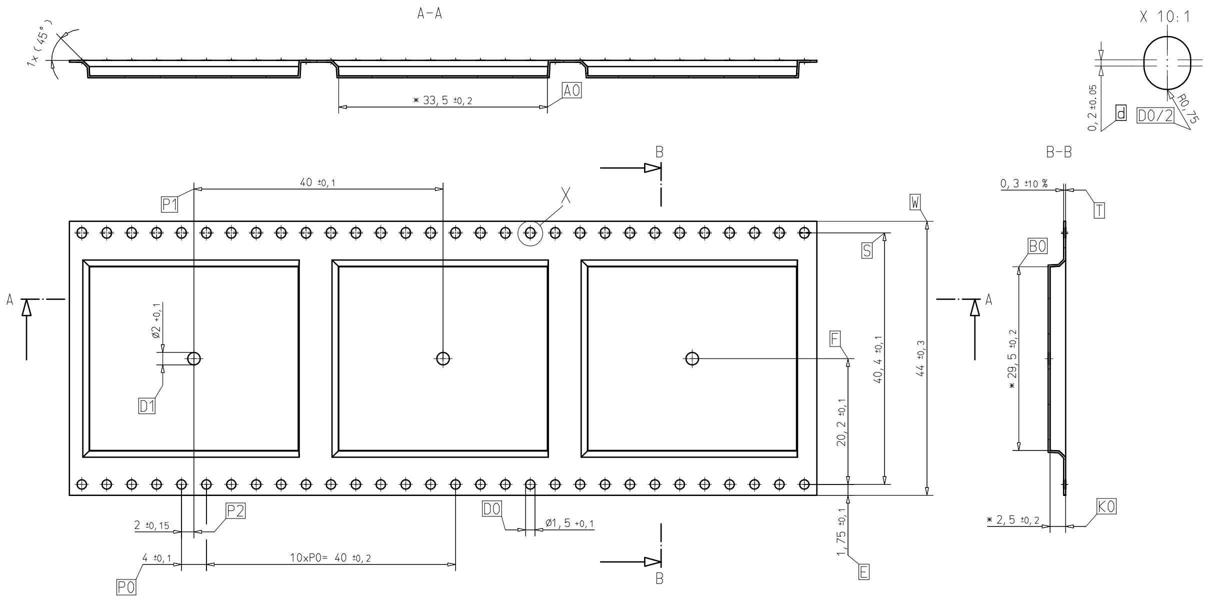


Figure 39: Carrier tape

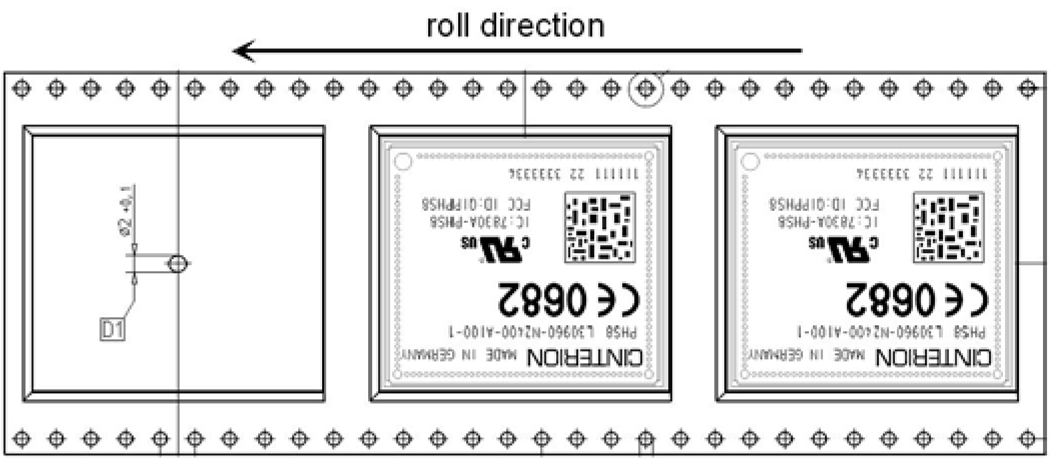


Figure 40: Roll direction

7.3.1.2 Barcode Label

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

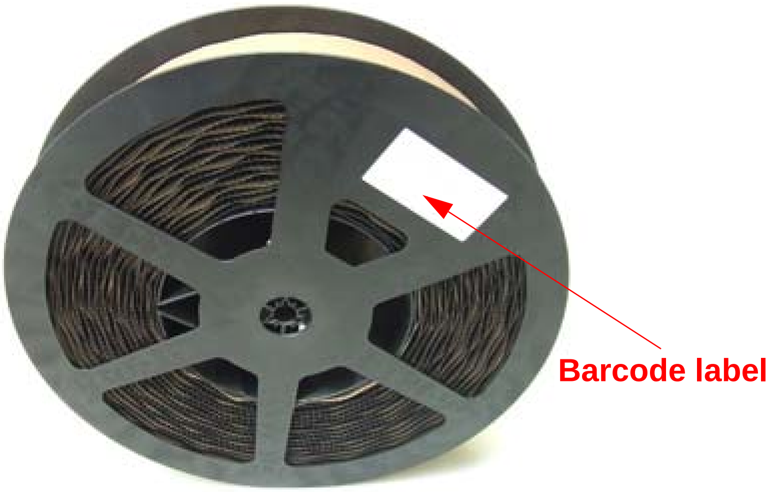


Figure 41: Barcode label on tape reel

7.3.2 Shipping Materials

PLS8-E is distributed in tape and reel carriers. The tape and reel carriers used to distribute PLS8-E 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 a moisture barrier bag (MBB), together with a humidity indicator card and desiccant pouches - see Figure 42. 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 PLS8-E modules from moisture exposure. It should not be opened until the devices are ready to be soldered onto the application.

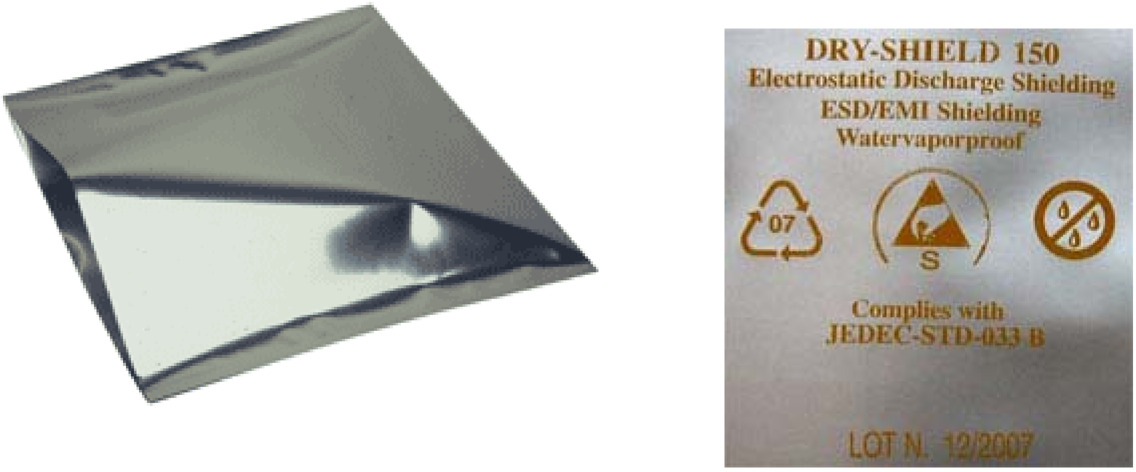


Figure 42: Moisture barrier bag (MBB) with imprint

The label shown in Figure 43 summarizes requirements regarding moisture sensitivity, including shelf life and baking requirements. It is attached to the outside of the moisture barrier bag.

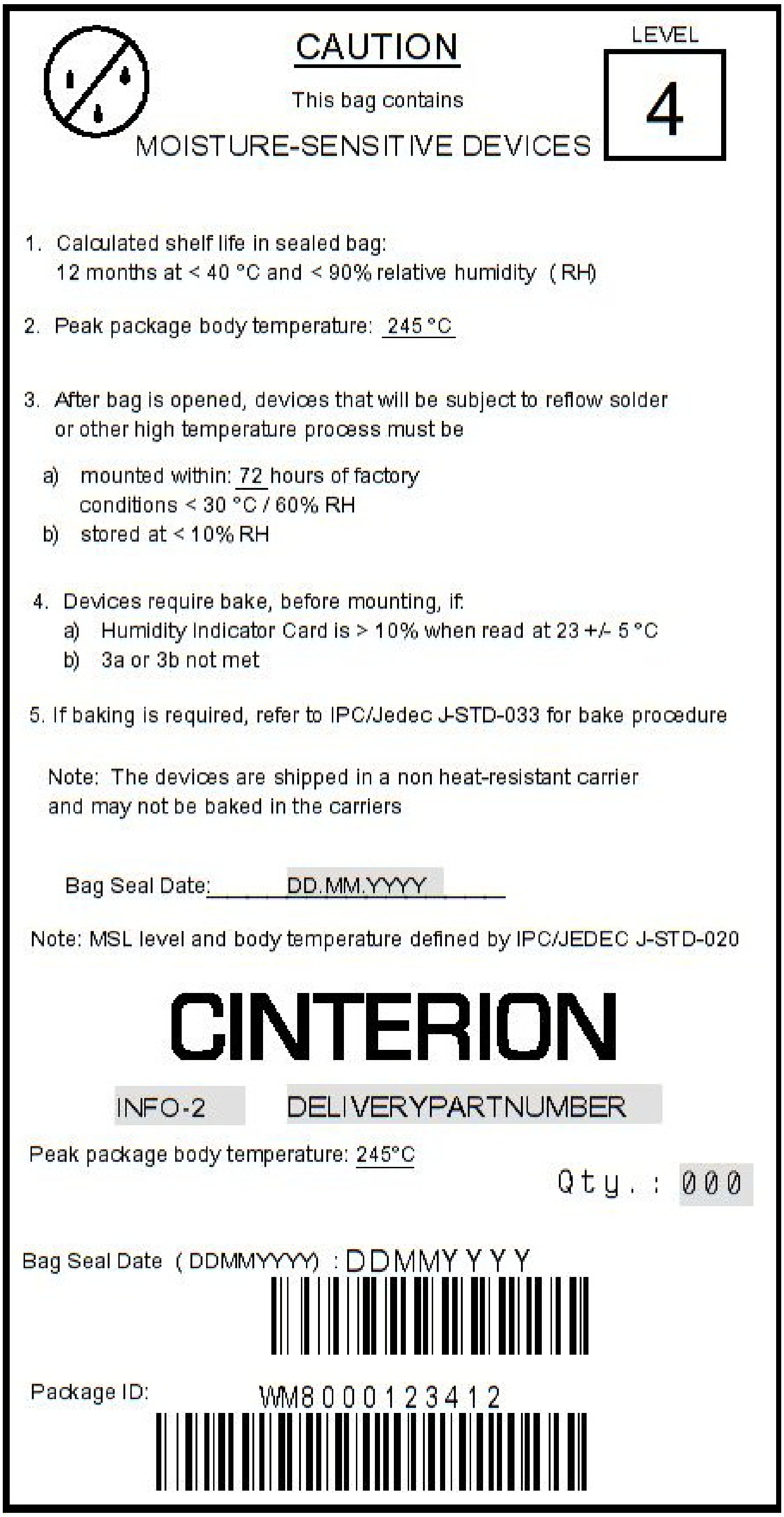


Figure 43: Moisture Sensitivity Label

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. A sample humidity card is shown in Figure 44. If the components have been exposed to moisture above the recommended limits, the units will have to be rebaked.

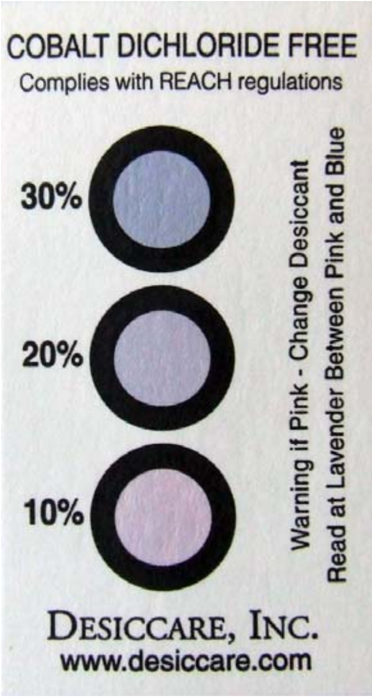


Figure 44: Humidity Indicator Card - HIC

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 45 shows a typical example of how to integrate an PLS8-E module with an application.

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 PLS8-E 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.

While developing SMT applications it is strongly recommended to provide test points for certain signals, i.e., 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 [3].

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.

Some LGA pads are connected to clocks or high speed data streams that might interfere with the module's antenna. The RF receiver would then be blocked at certain frequencies (self interference). The external application's PCB tracks connected to these pads should therefore be well shielded or kept away from the antenna. This applies especially to the USB and UICC/SIM interfaces.

Depending on the micro controller used by an external application PLS8-E's digital input and output lines may require level conversion. Section 8.1 shows a possible sample level conversion circuit.

Disclaimer:
No warranty, either stated or implied, is provided on the sample schematic diagram shown in Figure 45 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 PLS8-E modules.

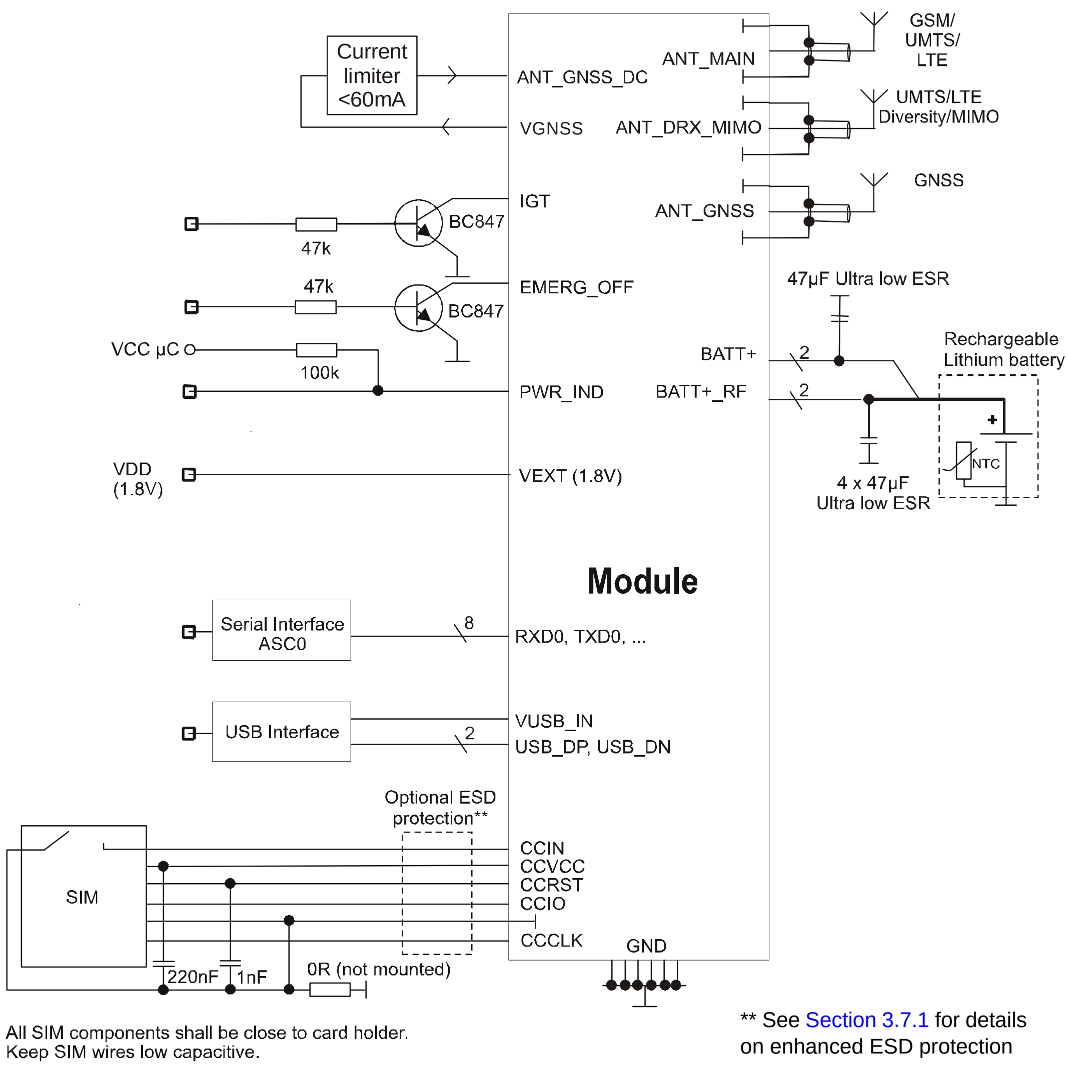


Figure 45: PLS8-E sample application

8.1 Sample Level Conversion Circuit

Depending on the micro controller used by an external application PLS8-E's digital input and output lines (i.e., ASC0 lines) may require level conversion. The following Figure 46 shows a sample circuit with recommended level shifters for an external application's micro controller (with VLOGIC between 3.0V...3.6V). The level shifters can be used for digital input and output lines with V_{OH}max=1.85V or V_{IH}max =1.85V.

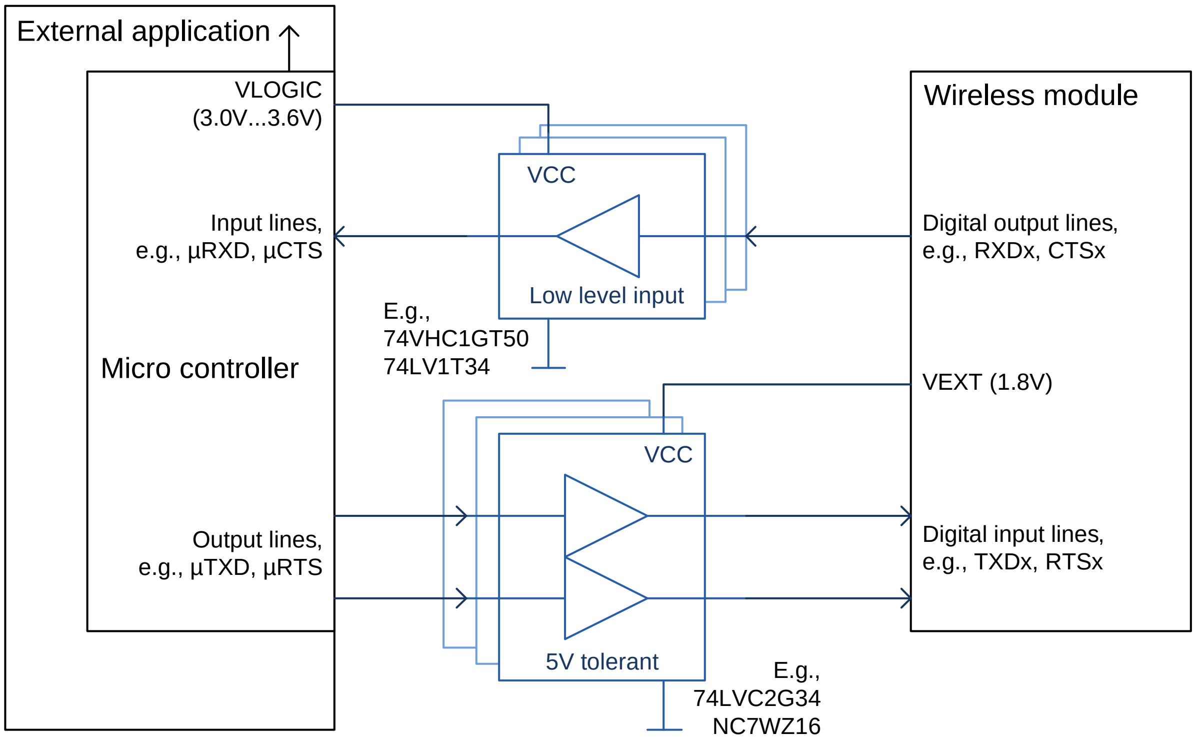


Figure 46: Sample level conversion circuit

9 Reference Approval

9.1 Reference Equipment for Type Approval

The Gemalto M2M reference setup submitted to type approve PLS8-E is shown in Figure 47. The module (i.e., the evaluation module) is connected to the DSB75 by means of a flex cable and a special DSB75 adapter. The GSM/UMTS/LTE test equipment is connected via edge mount SMA connectors soldered to the module's antenna pads.

For ESD tests and evaluation purposes, it is also possible connect the module to the GSM/UMTS/LTE 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.

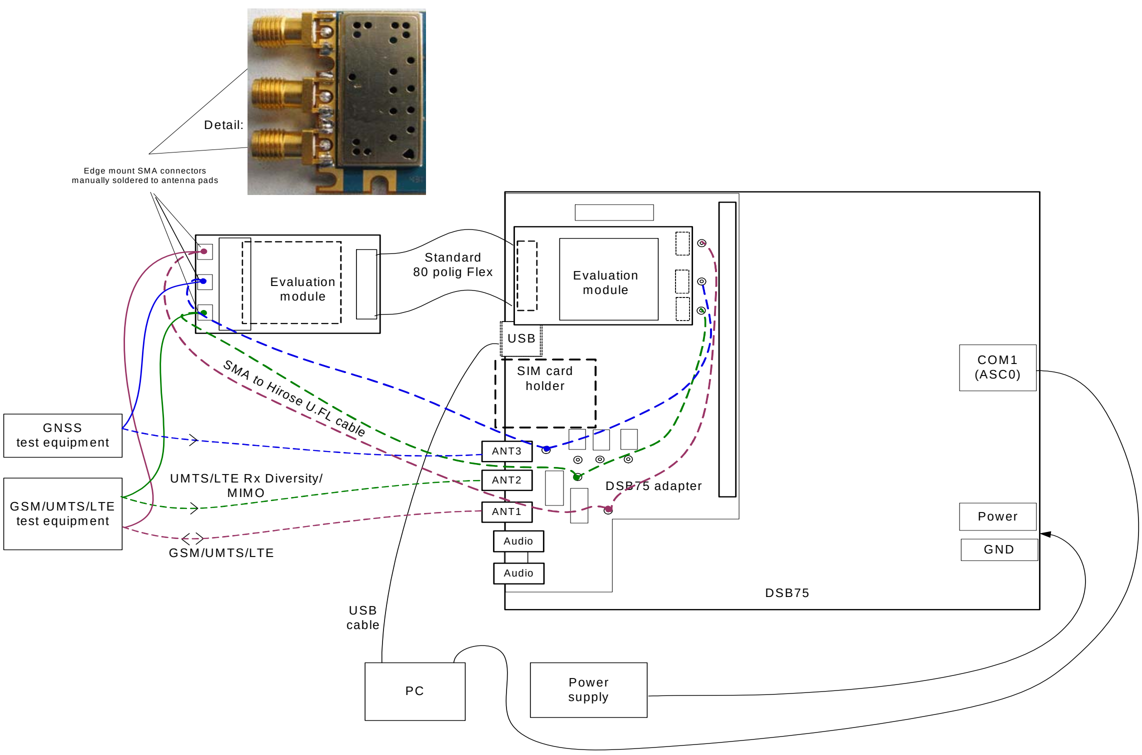


Figure 47: Reference equipment for type approval

10 Appendix

10.1 List of Parts and Accessories

Table 30: List of parts and accessories

Description	Supplier	Ordering information
PLS8-E	Gemalto M2M	Standard module Gemalto M2M IMEI: Packaging unit (ordering) number: L30960-N3400-A210 Module label number: S30960-S3400-A210
PLS8-E Evaluation Module	Gemalto M2M	Packaging unit (ordering) number: L30960-N3401-A210 Module label number: S30960-S3401-A210
DSB75 Support Box	Gemalto M2M	Ordering number: L36880-N8811-A100
DSB75 adapter for mounting the evaluation module	Gemalto M2M	Ordering number: L30960-N2301-A100
Votronic handset for approval purposes	Votronic / Gemalto M2M	Gemalto M2M ordering number: L36880-N8301-A107 Votronic ordering number: 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
SIM card holder incl. push button ejector and slide-in tray	Molex	Ordering numbers: 91228 91236 Sales contacts are listed in Table 31.
U.FL antenna connector	Hirose or Molex	Sales contacts are listed in Table 31 and Table 32.

Table 31: 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 32: Hirose sales contacts (subject to change)

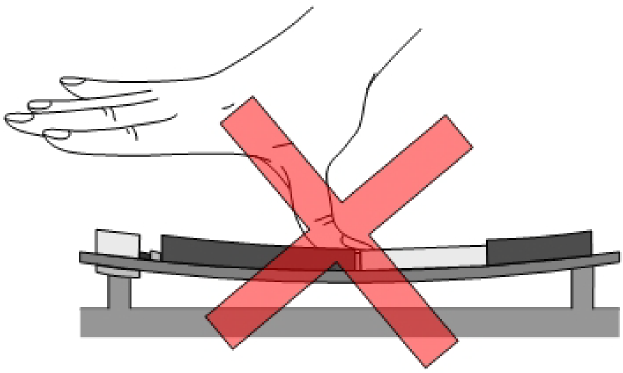
Hirose Ltd. For further information please click: http://www.hirose.com	Hirose Electric (U.S.A.) Inc 2688 Westhills Court Simi Valley, CA 93065 U.S.A. Phone: +1-805-522-7958 Fax: +1-805-522-3217	Hirose Electric Europe B.V. German Branch: Herzog-Carl-Strasse 4 73760 Ostfildern Germany Phone: +49-711-456002-1 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

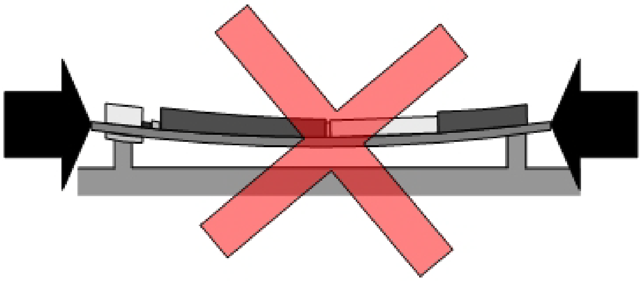
To prevent mechanical damage, be careful not to force, bend or twist the module. Be sure it is soldered flat against the host device (see also Section 7.2). The advice sheet on the next page shows a number of examples for the kind of bending that may lead to mechanical damage of the module (the module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

Mounting Advice

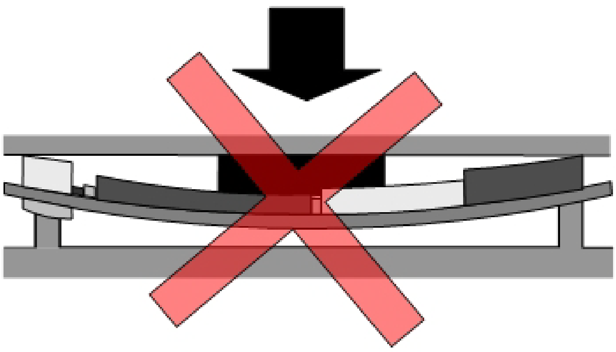
Do NOT BEND the Module



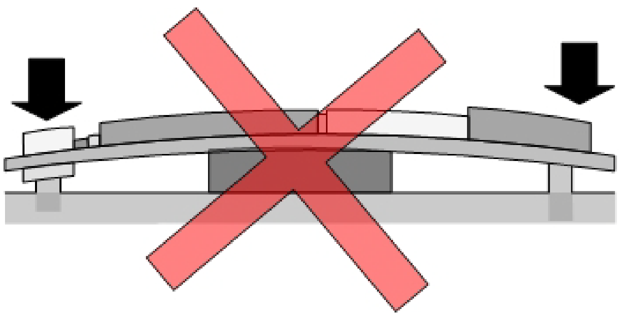
- By pressing from above



- By mounting under pressure



- By putting objects on top



- By putting objects below

About Gemalto

Gemalto (Euronext NL0000400653 GTO) is the world leader in digital security with 2011 annual revenues of €2 billion and more than 10,000 employees operating out of 74 offices and 14 Research & Development centers, located in 43 countries.

We are at the heart of the rapidly evolving digital society. Billions of people worldwide increasingly want the freedom to communicate, travel, shop, bank, entertain and work - anytime, everywhere - in ways that are enjoyable and safe. Gemalto delivers on their expanding needs for personal mobile services, payment security, authenticated cloud access, identity and privacy protection, eHealthcare and eGovernment efficiency, convenient ticketing and dependable machine-to-machine (M2M) applications.

Gemalto develops secure embedded software and secure products which we design and personalize. Our platforms and services manage these secure products, the confidential data they contain and the trusted end-user services they enable. Our innovations enable our clients to offer trusted and convenient digital services to billions of individuals.

Gemalto thrives with the growing number of people using its solutions to interact with the digital and wireless world.

For more information please visit
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