Cinterion® EMS31-US

Hardware Interface Description

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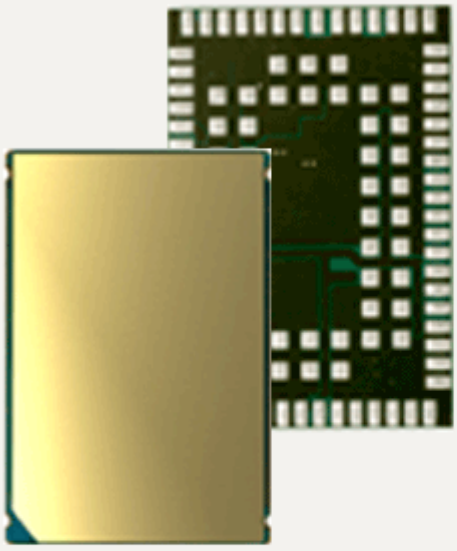

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1 Introduction

This document[1] describes the hardware of the Cinterion® EMS31-US module. It helps you quickly retrieve interface specifications, electrical and mechanical details and information on the requirements to be considered for integrating further components.

The EMS31-US module includes a baseband, a complete dual band RF front-end, memory and required circuitry to meet the 3GPP E-UTRA Long Term Evolution - LTE, Release 13 CAT M1 set of specifications.

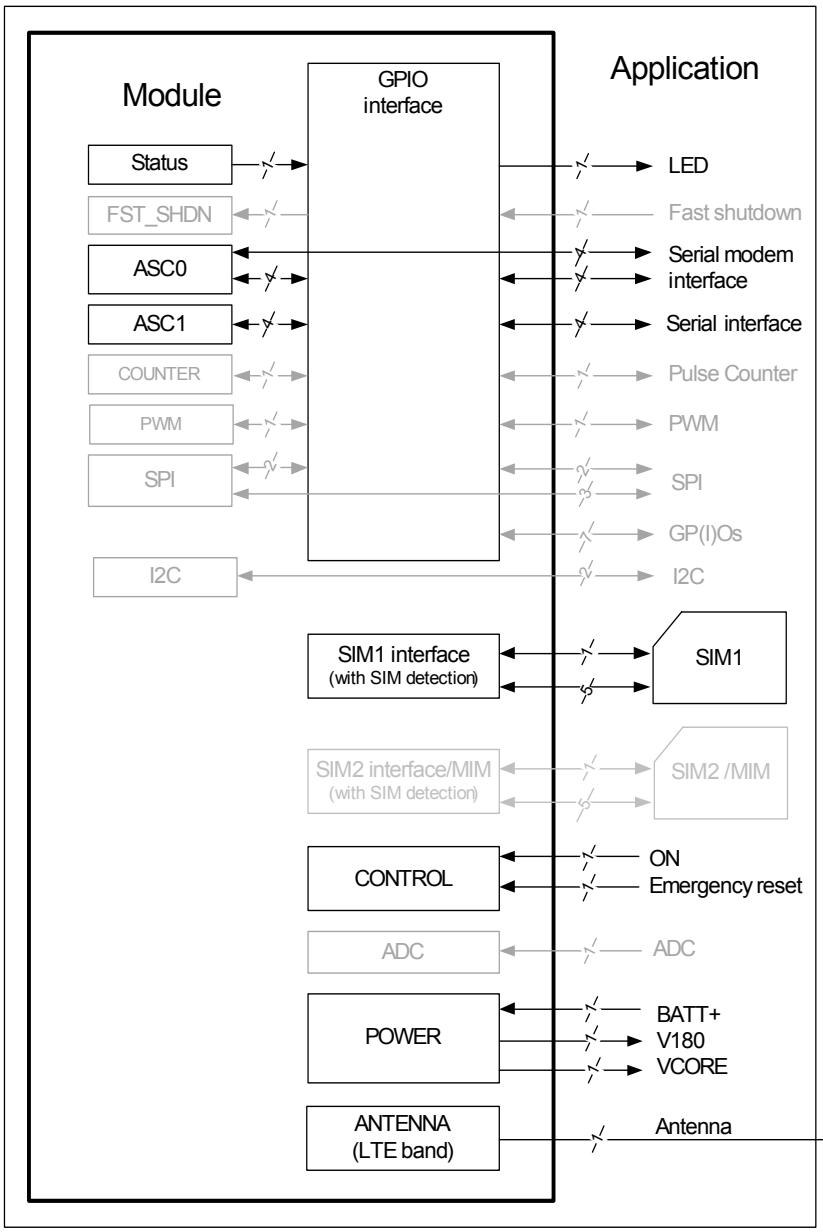
1.1 Key Features at a Glance

Feature	Implementation
General	
Frequency bands	LTE Triband: B2, B4, B12
Output power	Class 3 (+23dBm +-2dB) for LTE 1900, LTE HD-FDD B2 Class 3 (+23dBm +-2dB) for LTE AWS, LTE HD-FDD B4 Class 3 (+23dBm +-2dB) for LTE 700, LTE HD-FDD B12
Power supply	3.2V to 5.5V
Operating temperature (board temperature)	Normal operation: -30°C to +85°C Extended operation: -40°C to +95°C
Physical	Dimensions: 27.60mm x 18.80mm x 2.05mm Weight: approx. 2.2g
RoHS	All hardware components fully compliant with EU RoHS Directive
LTE features	
3GPP Release 13	DL 300 kbps, UL 375 kbps LTE Cat. M1 data rates
SMS	Point-to-point MT and MO Text mode Storage in mobile equipment
Software	
AT commands	Hayes, 3GPP TS 27.007, TS 27.005, product specific
SIM Application Toolkit	SAT Release 99
Firmware update	Generic update from host application over ASC0 OTA over ASC0

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.

Feature	Implementation
Interfaces	
Module interface	Surface mount device with solderable connection pads (SMT application interface). Land grid array (LGA) technology ensures high solder joint reliability and allows the use of 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 SMT application development equipment.
2 serial interfaces	ASC0: • 8-wire modem interface with status and control lines, unbalanced, asynchronous • Default baud rate: 115,200 baud • Adjustable baud rates: 1,200 to 3,686,400 • Supports RTS0/CTS0 hardware flow control. • Indication of incoming data/SMS on RING0 (can be used to wake up host from power down modes) ASC1 (shared with GPIO lines): • 4-wire, unbalanced asynchronous interface • Default baud rate: 115,200 baud • Adjustable baud rates: 1,200 to 3,686,400bps • Supports RTS1/CTS1 hardware flow control
UICC interface	Supported SIM/USIM cards: 3V, 1.8V
Embedded UICC	Module is hardware prepared for an embedded UICC (MIM)
GPIO interface	20 pads of the application interface programmable as GPIO pads: GPIOs can be configured as ASC0 and ASC1 Programming is done via AT commands
Antenna interface pad	50Ω LTE antenna
Power on/off, Reset	
Power on/off	Switch-on by hardware signal ON Switch-off by AT command Automatic switch-off in case of critical temperature and voltage conditions
Reset	Orderly shutdown and reset by AT command
Evaluation kit	
Evaluation module	EMS31-US 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 EMS31-US evaluation module to the DSB75.

1.2 EMS31-US System Overview



Note: The following features are not yet available with the current product release: GPIO, I²C, Pulse Counter, PWM, FST_SHDN, SPI, ADC and 2nd SIM/MIM. Second SIM/MIM interface is hardware prepared only.

Figure 1: EMS31-US system overview

1.3 Circuit Concept

The following figure shows block diagram of the EMS31-US module and illustrates the major functional components:

Baseband block:
- Baseband Chipset (baseband processor, power management and pSRAM memory)
- Serial QSPI NOR flash memory
- Application interface (SMT with connecting pads)

LTE RF section:
- RF power amplifier/front-end module and duplex
- RF front-end

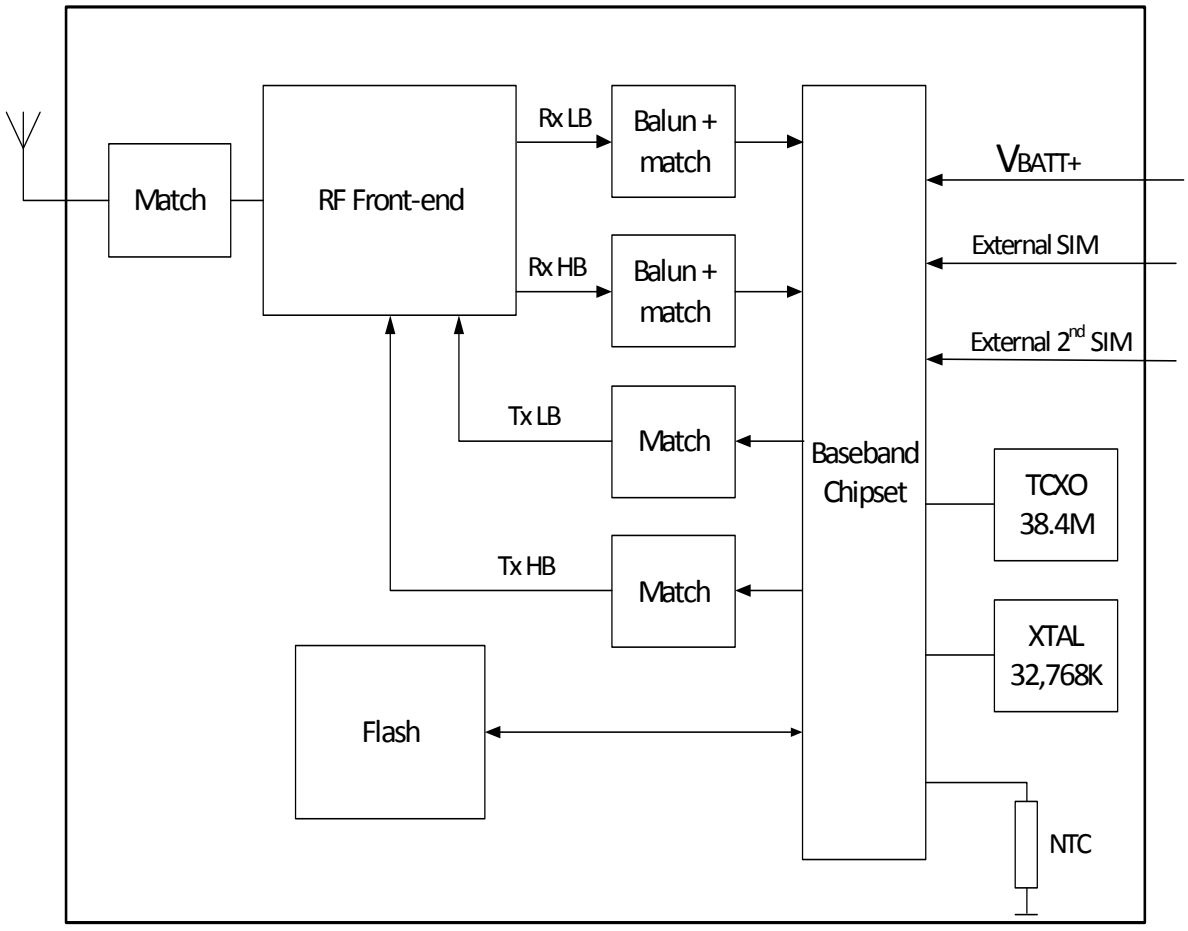


Figure 2: EMS31-US baseband block diagram

2 Interface Characteristics

EMS31-US is equipped with an SMT application interface that connects to the external application. The SMT application interface incorporates the various application interfaces as well as the RF antenna interfaces.

2.1 Application Interface

2.1.1 Pad Assignment

The SMT application interface on the EMS31-US provides connecting pads to integrate the module into external applications. Figure 3 shows the connecting pads' numbering plan, the following Table 1 lists the pads assignments.

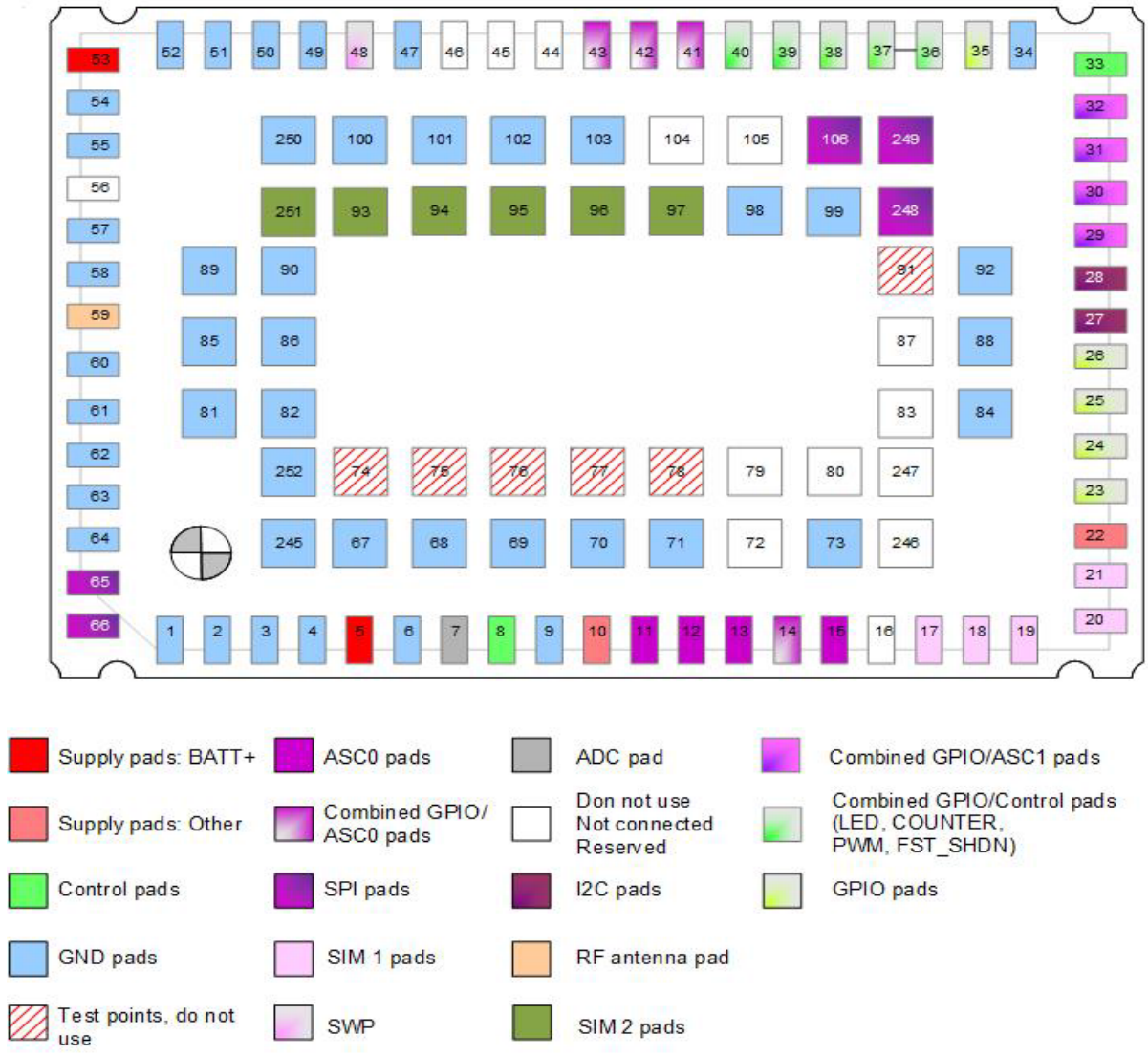


Figure 3: Numbering plan for connecting pads (bottom view)

Table 1: Pad assignments

Pad no.	Signal name	Pad no.	Signal name	Pad no.	Signal name
1	GND	23	GPIO20*	45	NC
2	GND	24	GPIO22*	46	NC
3	GND	25	GPIO21*	47	GND
4	GND	26	GPIO23*	48	SWP
5	BATT+	27	I2CDAT	49	GND
6	GND	28	I2CCLK	50	GND
7	ADC1*	29	GPIO17/TXD1	51	GND
8	ON	30	GPIO16/RXD1	52	GND
9	GND	31	GPIO18/RTS1	53	BATT+
10	V180	32	GPIO19/CTS1	54	GND
11	RXD0	33	EMERG_RST	55	GND
12	CTS0	34	GND	56	NC
13	TXD0	35	GPIO25	57	GND
14	RING0/GPIO24	36	GPIO8/COUNTER*	58	GND
15	RTS0	37	GPIO7/PWM1*	59	RF_OUT
16	NC	38	GPIO6/PWM2*	60	GND
17	CCRST	39	GPIO5/LED	61	GND
18	CCIN	40	GPIO4/FST_SHDN*	62	GND
19	CCIO	41	DSR0/GPIO3	63	GND
20	CCVCC	42	DCD0/GPIO2	64	GND
21	CCCLK	43	DTR0/GPIO1	65	GPIO27/SPI*_CS2
22	VCORE	44	NC	66	GPIO26/SPI*_CS1
Centrally located pads					
67	GND	78	Do not use (test)	89	GND
68	GND	79	NC	90	GND
69	GND	80	NC	91	Do not use (test)
70	GND	81	GND	92	GND
71	GND	82	GND	93	CCIN2
72	NC	83	NC	94	CCCLK2
73	GND	84	GND	95	CCCLK
74	Do not use (test)	85	GND	96	CCIO2
75	Do not use (test)	86	GND	97	CCVCC2
76	Do not use (test)	87	NC	98	GND
77	Do not use (test)	88	GND	99	GND
100	GND	105	NC	248	SPI*_CLK
101	GND	106	SPI*_MOSI	249	SPI*_MISO
102	GND	245	GND	250	GND
103	GND	246	NC	251	CCRST2
104	NC	247	NC	252	GND

*) Note: The following features are not yet available with the current product release: GPIO, I^2C, Pulse Counter, PWM, FST_SHDN, SPI, ADC and 2nd SIM/MIM. Second SIM/MIM is hardware prepared only.

Signal pads that are not used should not be connected to an external application.

Please note that the reference voltages listed in Table 2 are the values measured directly on the EMS31-US module. They do not apply to the accessories connected.

2.1.2 Signal Properties

Table 2: Signal properties

Function	Signal name	IO	Signal form and level	Comment
Power supply	BATT+	I	$V_I$max = 5.5V $V_I$norm = 3.8V $V_I$min = 3.2V Imax=TBD mA at nominal voltage 3.8V	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 3.2V including drop, ripple, spikes and not rise above 5.5V
Power supply	GND		Ground	Application Ground
External supply voltage	V180	O	$V_O$norm = 1.80V $V_O$min = 1.71 V $V_O$max = 1.89 V $I_O$max = 100 mA $C_L$max = TBD µF	V180 and VCORE is switched off by software in certain low power modes of the baseband. If unused keep line open.
	VCORE	O	$V_O$norm = 1.1V $V_O$min= 1.045 $V_O$max= 1.155 $I_O$max = TBD mA $C_L$max = TBD nF	
Ignition	ON	I	V_{IH}max = 5.5V V_{IH}min = 1.4V V_{IL}max = 0.3V V_{IL}min=0V Min low time before rising edge >=100µs R_{IN} = 162k ON _|‾‾|____high pulse >100µs	Edge triggered signal to switch the module on. Set this signal low before and after the startup impulse. Input is Schmitt Trigger The ON signal can be connected to BATT+. In this case, the module cannot be switched off by a fast shutdown, but can only be switched off by disconnecting BATT+.

Table 2: Signal properties

Function	Signal name	IO	Signal form and level	Comment
Emergency restart	EMERG_RST	I	V_{IH}max = 3.6 V or BATT+ if BATT+ is lower than 3.6V V_{IH}min = 0.8V V_{IL}max =0.2V V_{IL}min= 0V Internal pull-up resistor 27k to 1.8V Impulse width > 100µs	Pulse triggered signal (low pulse duration >100µs) to reset the module. This line must be driven low by an open drain or open collector driver connected to GND. - Recommended pulse duration >10ms - 1.8V is a different voltage than V180. 1.8V is always ON when V BATT+ is applied. If unused keep line open.
Fast shutdown*	FST_SHDN	I/O	V_{IL}max = 0.2V V_{IH}min = 0.8V V_{IH}max = 3.6 V or BATT+ if BATT+ is lower than 3.6V. ‾‾ ‾‾ |‾‾‾‾| low impulse width > TBD	This line must be driven low. If unused keep line open. Note that the fast shutdown line is originally available as GPIO line. If configured as fast shut- down, the GPIO line is assigned as follows: GPIO4 --> FST_SHDN
Serial Interface ASC0	RXD0	O	V_{OL}max = 0.3V V_{OH}min = 1.5V V_{OH}max = 1.85V V_{IL}max = 0.5V V_{IL}min = 0V V_{IH}min = 1.35V V_{IH}max = 1.85V DTR0, RTS0, DCD0 V_{IL}max = 0.2V V_{IL}min = 0V V_{IH}min = 0.8V V_{IH}max = 3.6 V or BATT+ if BATT+ is lower than 3.6V.	If unused keep lines open. By delivery default, lines are available as ASC0 interface lines. DTR0 - Internal PU 100k to V180 RTS0 - Internal PD 100k If configured for use as GPIOs the assignment is as follows: GPIO1 --> DTR0 GPIO2 -->DCD0 GPIO3 -->DSR0 GPIO 24 -->RING0 A host can wakeup the module by toggling RTS0.
	CTS0	O		
	RING0	O		
	TXD0	I		
	RTS0	I		
	DTR0	I		
	DCD0	O		
	DSR0	O		
Serial Interface ASC1	RXD1	O	V_{OL}max = 0.3V V_{OH}min = 1.5V V_{OH}max = 1.85V V_{IL}max = 0.5V V_{IL}min = 0V V_{IH}min = 1.35V V_{IH}max = 1.85V RTS1 V_{IL}max = 0.2V V_{IL}min = 0V V_{IH}min = 0.8V V_{IH}max = 3.6 V or BATT+ if BATT+ is lower than 3.6V.	If unused keep lines open. If configured as ASC1 lines, the GPIO lines are assigned as follows: GPIO16 --> RXD1 - Internal PU 100k to V180 GPIO17 --> TXD1 GPIO18 --> RTS1 GPIO19 --> CTS1 ASC1 is available as data interface. A host can wakeup the module by toggling RTS1
	TXD1	I		
	CTS1	O		
	RTS1	I		

Table 2: Signal properties

Function	Signal name	IO	Signal form and level	Comment
I^2C*	I2CCLK	IO	V_{IL}max = 0.5V V_{IL}min = 0V V_{IH}min = 1.35V V_{IH}max = 1.85V	According to the I^2C Bus Specification Version 2.1 for the fast mode a rise time of max. 300ns is permitted. There is also a maximum V_{OL}=0.4V at 3mA specified. Minimum R external pull-up (connected to V180 power supply) is TBD Ohms. The value of the pull-up depends on the capacitive load of the whole system (I^2C Slave + lines). The maximum sink current of I2CDAT and I2CCLK is TBD mA. If lines are unused keep lines open.
	I2CDAT	IO		
SPI*	SPI_CLK	O	V_{OL}max = 0.3V V_{OH}min = 1.5V V_{OH}max = 1.85V V_{IL}max = 0.5V V_{IL}min = 0V V_{IH}min = 1.35V V_{IH}max = 1.85V	If lines are unused keep lines open. By delivery default, the SPI_CS interface lines are available as GPIO lines. If configured as SPI lines, the GPIO lines are assigned as follows: GPIO26 --> SPI_CS1 GPIO27 --> SPI_CS2
	SPI_MOSI	O		
	SPI_MISO	I		
	SPI_CS1 SPI_CS2	O		
GPIO interface*	GPIO1-4 GPIO6-22 GPIO24,25, 27 GPIO5,23,26	IO	V_{OL}max = 0.3V V_{OH}min = 1.5V V_{OH}max = 1.85V V_{IL}max = 0.5V V_{IL}min = 0V V_{IH}min = 1.35V V_{IH}max = 1.85V GPIO 1, 2, 4, 5, 8, 18, 24, 25 V_{OL}max = 0V V_{OH}min = 1.6V V_{OH}max = 1.8V V_{IL}max = 0.2V V_{IL}min = 0V V_{IH}min = 0.8V V_{IH}max = 3.6 V or BATT+ if BATT+ is lower than 3.6V.	If unused keep line open. Please note that some GPIO lines are or can be can be configured by AT command for alternative functions: GPIO1-GPIO3: ASC0 control lines DTR0, DCD0, and DSR0 GPIO4: FST_SHDN* GPIO5: LED GPIO6: PWM2 GPIO6: PWM2* GPIO7: PWM1*; GPIO8: Pulse Counter* GPIO16-GPIO19: ASC1 GPIO24: ASC0 control line RING0 GPIO26-GPIO27: SPI* CS signals.

Table 2: Signal properties

Function	Signal name	IO	Signal form and level	Comment
Status LED	LED	O	V_{OL}max = 0V V_{OH}min = 1.6V V_{OH}max = 1.8V	If unused keep line open. By delivery default, the line is available as LED line. If configured for use as GPIO line, the LED line is assigned as follows: LED --> GPIO5
Pulse Counter*	COUNTER	I	V_{IL}max = 0.2V V_{IL}min = 0V V_{IH}min = 0.8V V_{IH}max= 3.1V and BATT+	By delivery default, the COUNTER line is originally available as GPIO line. If configured for use as COUNTER line, the GPIO line is assigned as follows: GPIO8 --> COUNTER If unused keep line open.
ADC* (Analog-to- Digital converter)	ADC	I	R_I = min 1 MOhm V_I = 0V ... 1.8V Resolution 1024 steps Tolerance +/-2%	ADC can be used as input for external measurements. If unused keep line open.
SIM card detection	CCIN1 CCIN2	I	R_I ≈ TBD Ohm V_{IL}max = 0.2V V_{IH}min = 0.8V V_{IH}max = 3.6 V or BATT+ if BATT+ is lower than 3.6V.	CCIN1 = High, SIM card inserted. CCIN2 = High, SIM 2 card inserted. For details please refer to Section 2.1.5. If CCIN is unused, pull-down 220k resistor is mandatory. Note that CCIN2 line can be used as CRST_MIM line.
3V SIM Card Interface	CCRST1 CCRST2	O	V_{OH}typical = TBD V V_{OH}max = TBD V V_{OL}typical = TBD V @ 1mA V_{OL}max = TBD V	Maximum cable length or copper track to SIM card holder should not exceed 100mm. Note: SIM card voltage is determined automatically during UICC activation. Note that CCVCC2 line can be used as CCIO_MIM line.
	CCIO1 CCIO2	I/O	V_{IL}max = TBD V V_{IL}min = TBD V V_{IH}min = TBD V V_{IH}max = TBD V V_{OL}typical = TBD V @1mA V_{OL}max = TBD V V_{OH}min = TBD V at I = -10µA V_{OH}max = TBD V	
	CCCLK1 CCCLK2	O	V_{OH}typical = TBD V V_{OH}max = TBD V V_{OL}typical = TBD V @1mA V_{OL}max = TBD V	
	CCVCC1 CCVCC2	O	$V_O$min = TBD V $V_O$typ = TBD V $V_O$max = TBD V $I_O$max = TBD mA	

Table 2: Signal properties

Function	Signal name	IO	Signal form and level	Comment
1.8V SIM Card Inter-face	CCRST1 CCRST2	O	V_{OH}min = 1.5V V_{OH}max = 1.85V V_{OL}typical = TBD V @1mA V_{OL}max = 0.3V	
	CCIO1 CCIO2	I/O	V_{IL}max = 0.5V V_{IL}min=-0V V_{IH}min = 1.35V V_{IH}max = 1.85V V_{OL}typical = TBD V @1mA V_{OL}max = 0.3V V_{OH}min = 1.5V at I = TBD µA V_{OH}max = 1.85V	
	CCCLK1 CCCLK2	O	V_{OH}min = 1.5V V_{OH}max = 1.85V V_{OL}typical = TBD V @1mA V_{OL}max = 0.3V	
	CCVCC1 CCVCC2	O	$V_O$min = 1.71V $V_O$typical = 1.80V $V_O$max = 1.89V $I_O$max = TBD mA	Note that CCVCC2 line can be used as CCIO_MIM line.
MIM Interface*	CRST_MIM	I	$R_I \approx$ TBD Ohm V_{IL}max = 0.2V V_{IH}min = 0.8V V_{IH}max = 3.6 V or BATT+ if BATT+ is lower than 3.6V.	Hardware prepared for future use.
	CCIO_MIM	O	$V_O$min = TBD V $V_O$typ = TBD V $V_O$max = TBD V $I_O$max = TBD mA	
			$V_O$min = 1.71V $V_O$typical = 1.80V $V_O$max = 1.89V $I_O$max = TBD mA	

*) Note: The following features are not yet available with the current product release: GPIO, I^2C, Pulse Counter, PWM, FST_SHDN, SPI, ADC and 2nd SIM/MIM. Second SIM/MIM interface is hardware prepared only.

2.1.2.1 Absolute Maximum Ratings

The absolute maximum ratings stated in Table 3 are stress ratings under any conditions. Stresses beyond any of these limits will cause permanent damage to EMS31-US.

Table 3: Absolute maximum ratings

Parameter	Min	Max	Unit
Supply voltage BATT+	TBD	+5.5	V
Voltage at all digital lines in Power Down mode	TBD	TBD	V
Voltage at digital lines in normal operation	0	1.89	V
Voltage at SIM/USIM interface, CCVCC in normal operation	-0.5	+3.6	V
Voltage at ADC line in normal operation	TBD	+1.8	V
Voltage at analog lines in Power Down mode	TBD	TBD	V
V180 in normal operation; Note: V180 is shutdown by software when baseband enters certain low power modes	+1.71	+1.89	V
Voltage at VCORE in normal operation; VCORE is shutdown by software when baseband enters certain low power modes	1.045	1.155	V
Current at V180 in normal operation		TBD	mA
Current at VCORE in normal operation; Note: VCORE is shutdown by software when baseband enters certain low power modes		TBD	mA

2.1.3 Serial Interface ASC0

EMS31-US offers an 8-wire unbalanced, asynchronous modem interface ASC0 conforming to ITU-T V.28 protocol DCE signaling. 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 2. For an illustration of the interface line's startup behavior see Figure 5.

EMS31-US 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

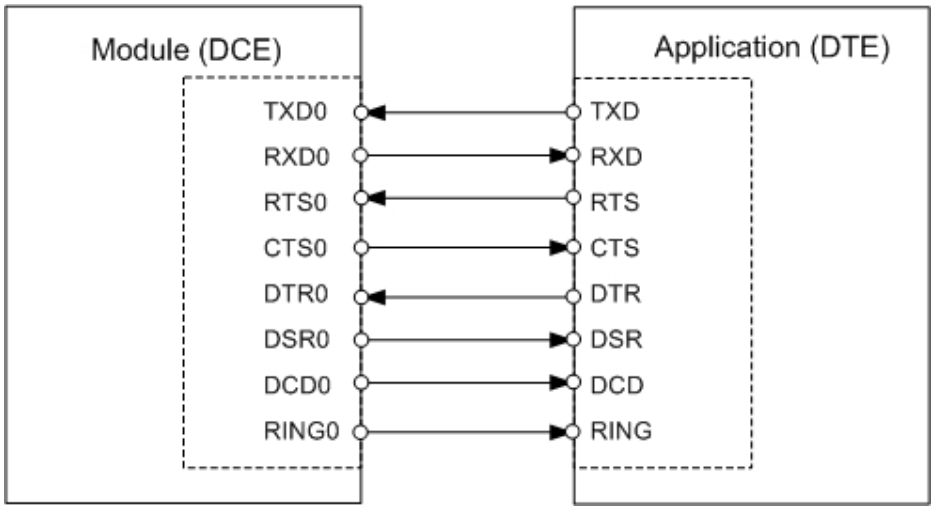


Figure 4: Serial interface ASC0

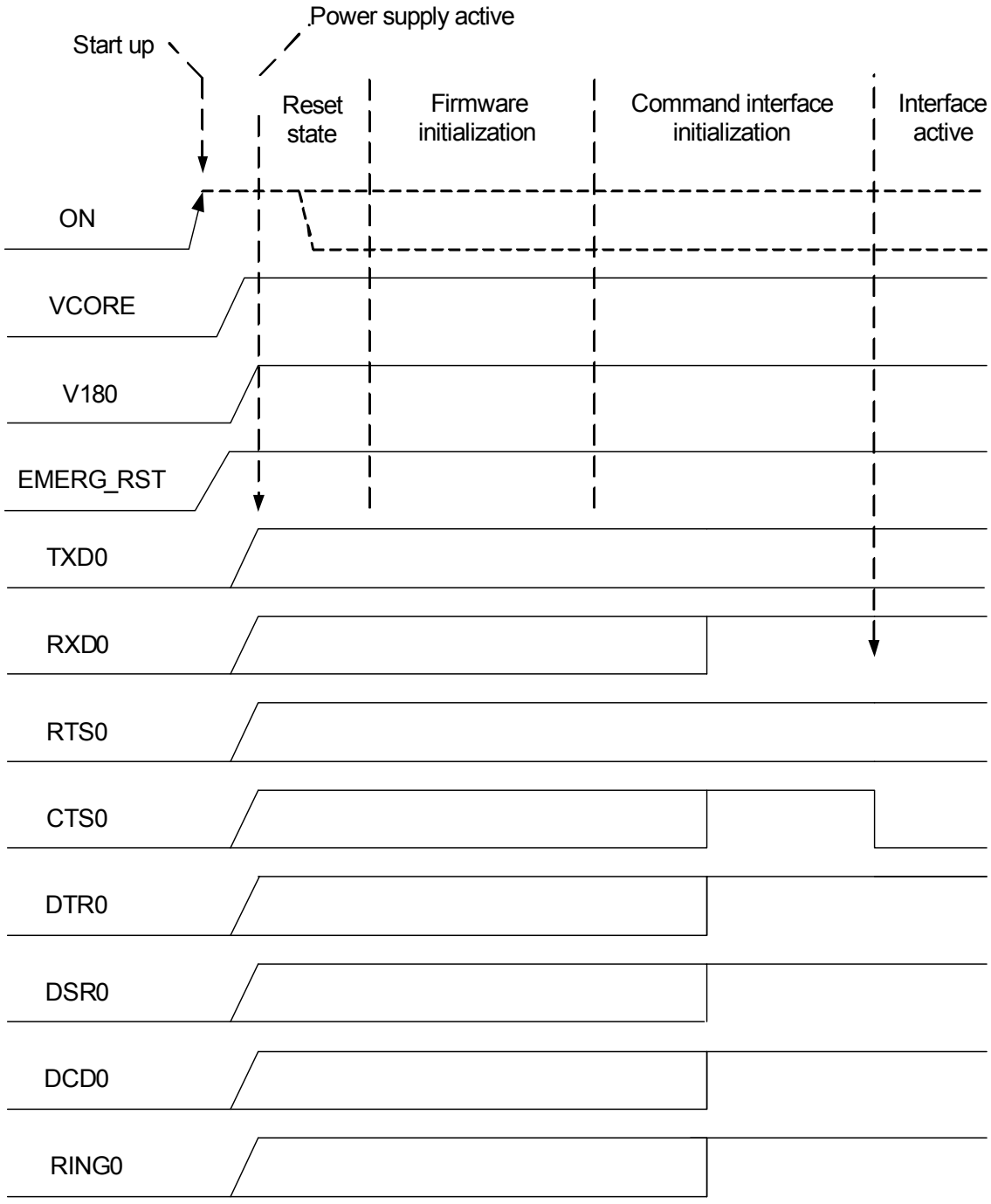
Features:
- Includes the data lines TXD0 and RXD0, the status lines RTS0 and CTS0 and, in addition, the modem control lines DTR0, DSR0, DCD0 and RING0.
- Configured for 8 data bits, no parity and 1 stop bit.
- ASC0 can be operated at fixed bit rates from 1,200bps up to 3,686,400bps.
- Autobauding (supported by future firmware version)
- Supports RTS0/CTS0 hardware flow control. Communication is possible by using only RXD and TXD lines, if RTS0 is pulled low.

The ASC0 interface is dedicated to signaling via AT commands parser and PPP (see [1]).

Note: The ASC0 modem control lines DTR0, DCD0, DSR0 and RING0 can also be configured as GPIO lines. If configured as GPIO lines, these GPIO lines are assigned as follows:
DTR0 --> GPIO1, DCD0 --> GPIO2, DSR0 --> GPIO3 and RING0 --> GPIO24.

2.1.3.1 Serial Interface Start-Up Behavior

The following figure shows the startup behavior of the asynchronous serial interface ASC0.



*) For pull-up and pull-down values see Table 10

Figure 5: ASC0 start-up behavior (TBC)

No data must be sent over the ASC0 interface before the interface is active and ready to receive data (see Section 3.2.1).

2.1.4 Serial Interface ASC1

EMS31-US provides a 4-wire unbalanced, asynchronous modem interface ASC1 conforming to ITU-T V.24 protocol DCE signaling. 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 2. For an illustration of the interface line's startup behavior see Figure 7.

The ASC1 interface lines are available in default configuration. The ASC1 lines are configured as follows: GPIO16 --> RXD1, GPIO17 --> TXD1, GPIO18 --> RTS1 and GPIO19 --> CTS1. Configuration is done by AT command (see [1]: AT^SCFG). The configuration is non-volatile and becomes active after a module restart.

EMS31-US 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 module's TXD1 signal line
- Port RXD @ application receives data from the module's RXD1 signal line

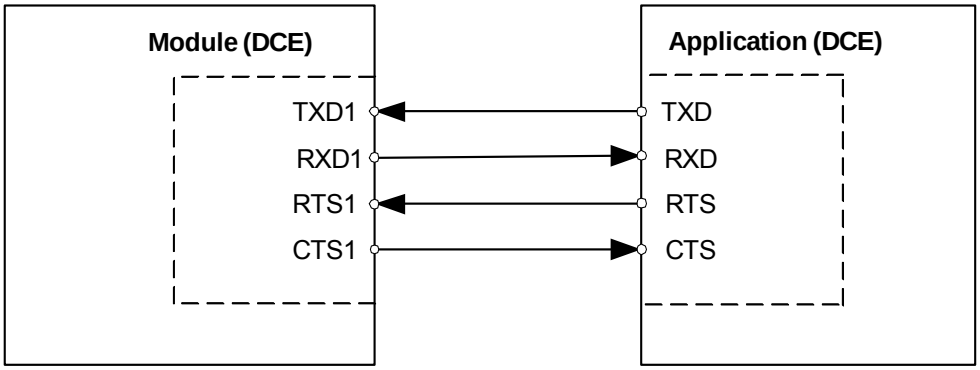
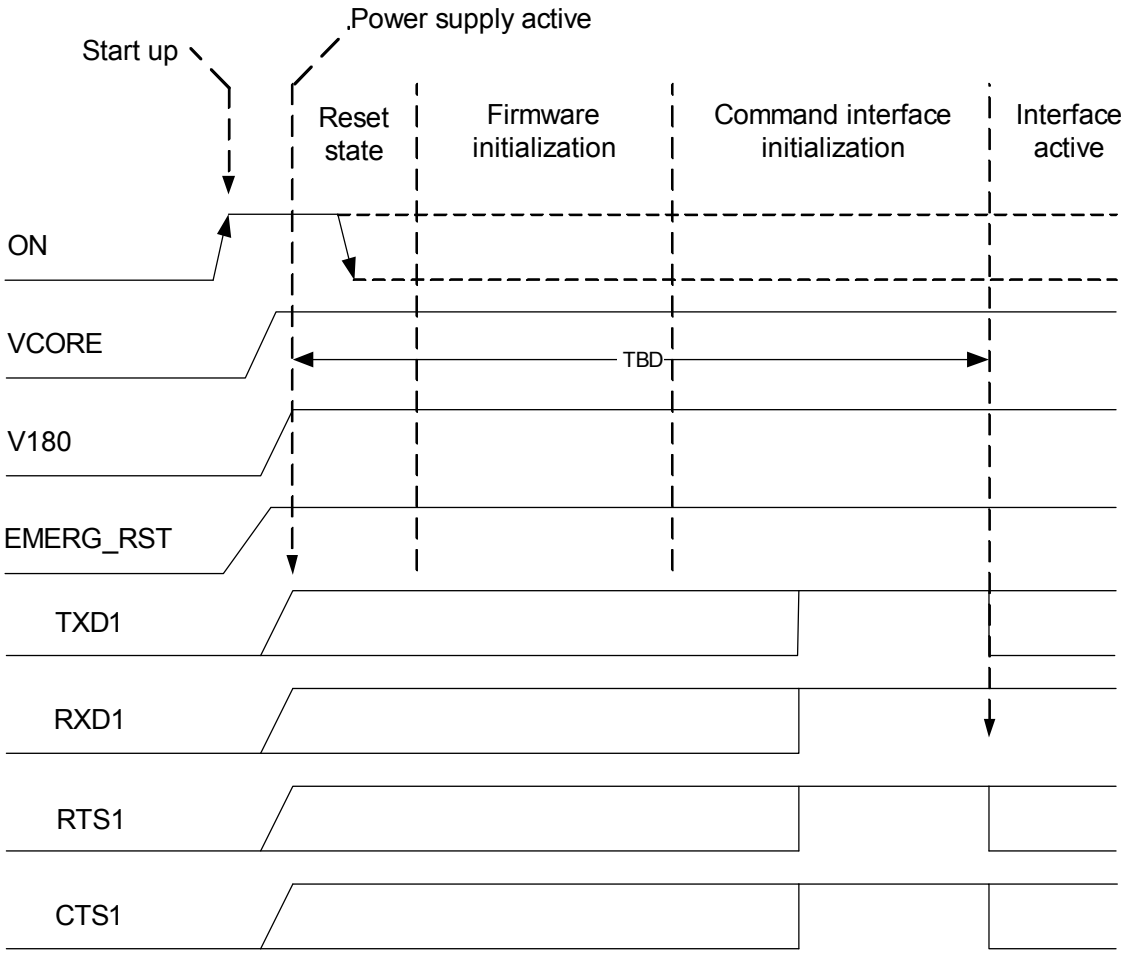


Figure 6: Serial interface ASC1

Features
- Includes only the data lines TXD1 and RXD1 plus RTS1 and CTS1 for hardware handshake.
- On ASC1 no RING line is available.
- Configured for 8 data bits, no parity and 1 or 2 stop bits.
- ASC1 can be operated at fixed bit rates from 1,200 bps to 3,686,400bps.
- Supports RTS1/CTS1 hardware flow control. Communication is possible by using only RXD and TXD lines, if RTS1 is pulled low.

The ASC1 interface can be dynamically switched between AT commands parser and PPP (see [1]).

The following figure shows the startup behavior of the asynchronous serial interface ASC1.



*) For pull-up and pull-down values see Table 10.

Figure 7: ASC1 start-up behavior (TBC)

2.1.5 UICC/SIM/USIM Interface

EMS31-US has two identical integrated UICC/SIM/USIM interfaces compatible with the 3GPP 31.102 and ETSI 102 221. These two interfaces are mutually exclusive, meaning that only one UICC/SIM/USIM interface can be used at a time. This interface 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 each SIM interface.

The UICC/SIM/USIM interface supports 3V and 1.8V SIM cards. Please refer to Table 2 for electrical specifications of the UICC/SIM/USIM interface lines depending on whether a 3V or 1.8V SIM card is used. Note that the second SIM interface is deactivated by default.

The CCINx signal serves to detect whether a tray (with SIM card) is present in the card holder. The CCINx signal must be connected to V180 for the detection to work on the module. Otherwise the SIM card can never be detected by the module.

Using the CCINx 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 EMS31-US and is part of the Gemalto M2M reference equipment submitted for type approval. See Section 7.1 for Molex ordering numbers.

Table 4: Signals of the SIM interface (SMT application interface)

Signal	Description
GND	Separate ground connection for SIM card to improve EMC.
CCCLKx	Chipcard clock
CCVCCx	SIM supply voltage.
CCIOx	Serial data line, input and output.
CCRSTx	Chipcard reset
CCINx	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 CCINx signal is by default low and will change to high level if a SIM card is inserted. The CCINx signal is mandatory for applications that allow the user to remove the SIM card during operation. The CCINx 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 EMS31-US. Pull-down 220k resistor is mandatory.

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 EMS31-US.

The figure below shows a circuit to connect an external SIM card holder.

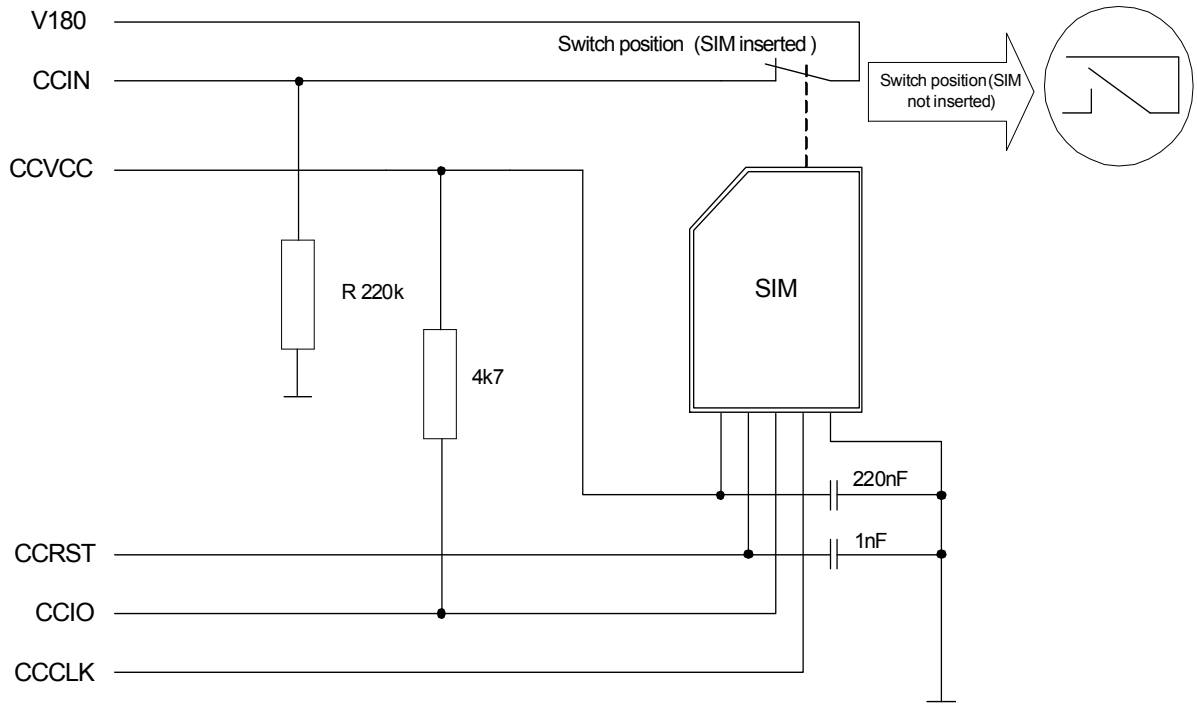


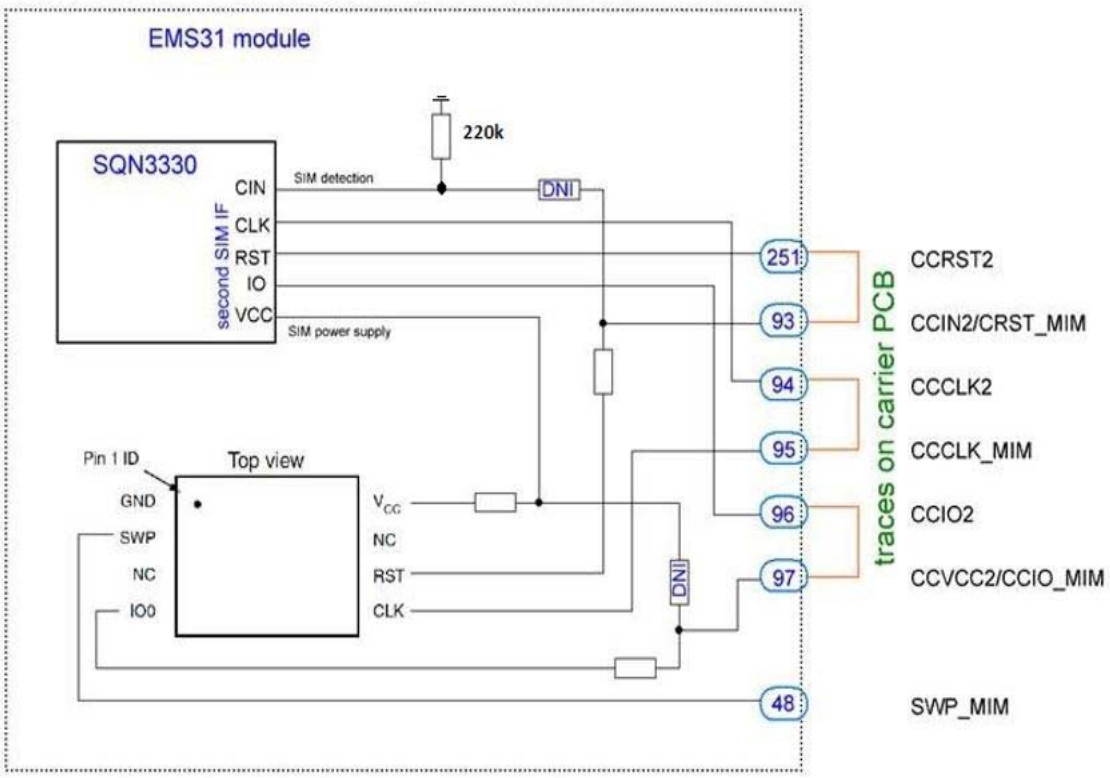
Figure 8: External UICC/SIM/USIM card holder circuit

The total cable length between the SMT application interface pads on EMS31-US 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 CCCLKx signal to the CCIOx signal be careful that both lines are not placed closely next to each other. A useful approach is using a GND line to shield the CCIOx line from the CCCLKx line.

2.1.5.1 Machine Identification Module (MIM)

The second SIM interface is hardware prepared for MIM. If this interface is intended for MIM, traces on carrier PCB should be implemented (see Figure 9).



Note: Second SIM/MIM interface is not yet available with the current product release. It is hardware prepared only.

Figure 9: MIM not populated and module is soldered on carrier PCB

In case there is no MIM inside the module, second interface can be used for second SIM without implementing the traces on carrier PCB (see Figure 10). Note that EMS31-US comes without MIM.

If second SIM interface is not used, the following is recommended:

- CCIN2 - pull down 220k
- CCRST2 - leave open
- CCIN2/CRST_MIM - leave open
- CCCLK2 - leave open
- CCCLK_MIM - leave open
- CCIO2 - leave open
- CCVCC2 - leave open
- SWP_MIM - leave open

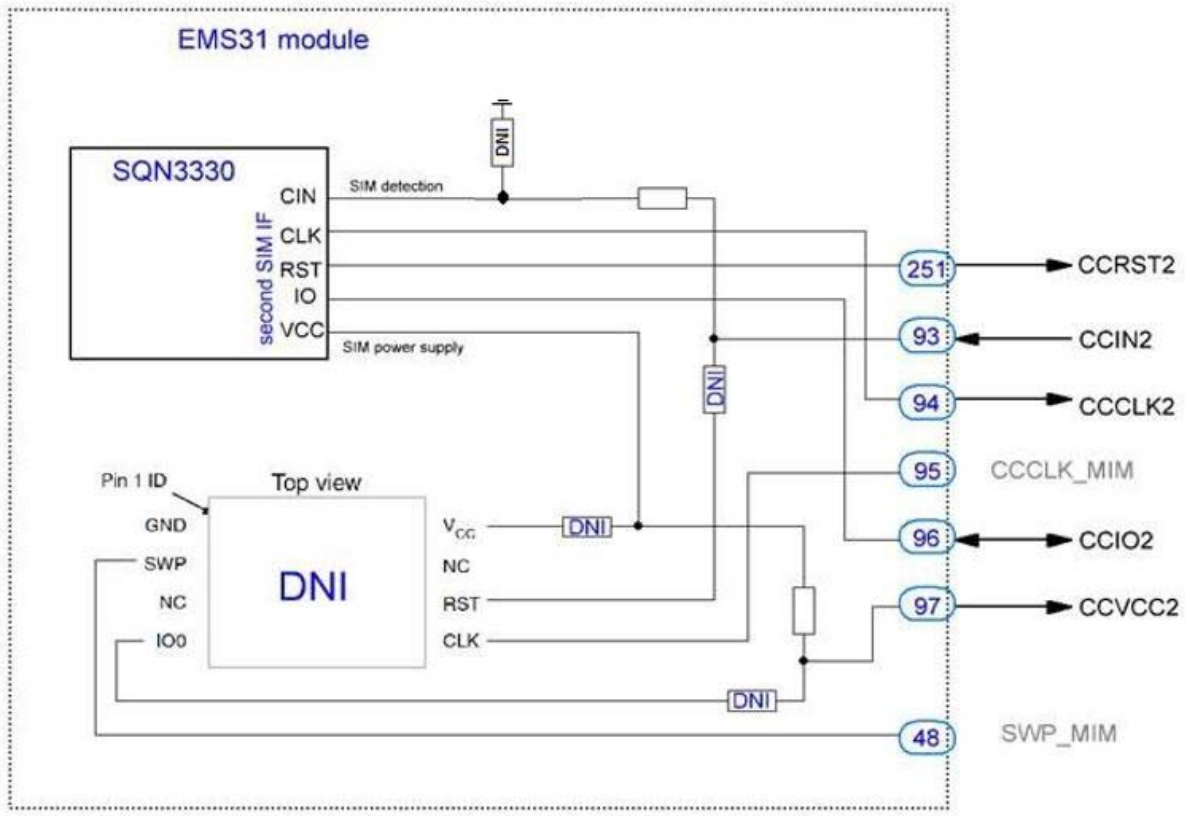


Figure 10: MIM is not populated and 2nd SIM interface is used externally

2.1.6 GPIO Interface

EMS31-US offers a GPIO interface with 20 GPIO lines. The lines are shared with other interfaces or functions: ASC0 (see Section 2.1.3), ASC1 (see Section 2.1.4),
The following table shows the configuration variants for the GPIO pads. All variants are mutually exclusive, i.e. a pad configured for instance as ASC0 is locked for alternative usage.

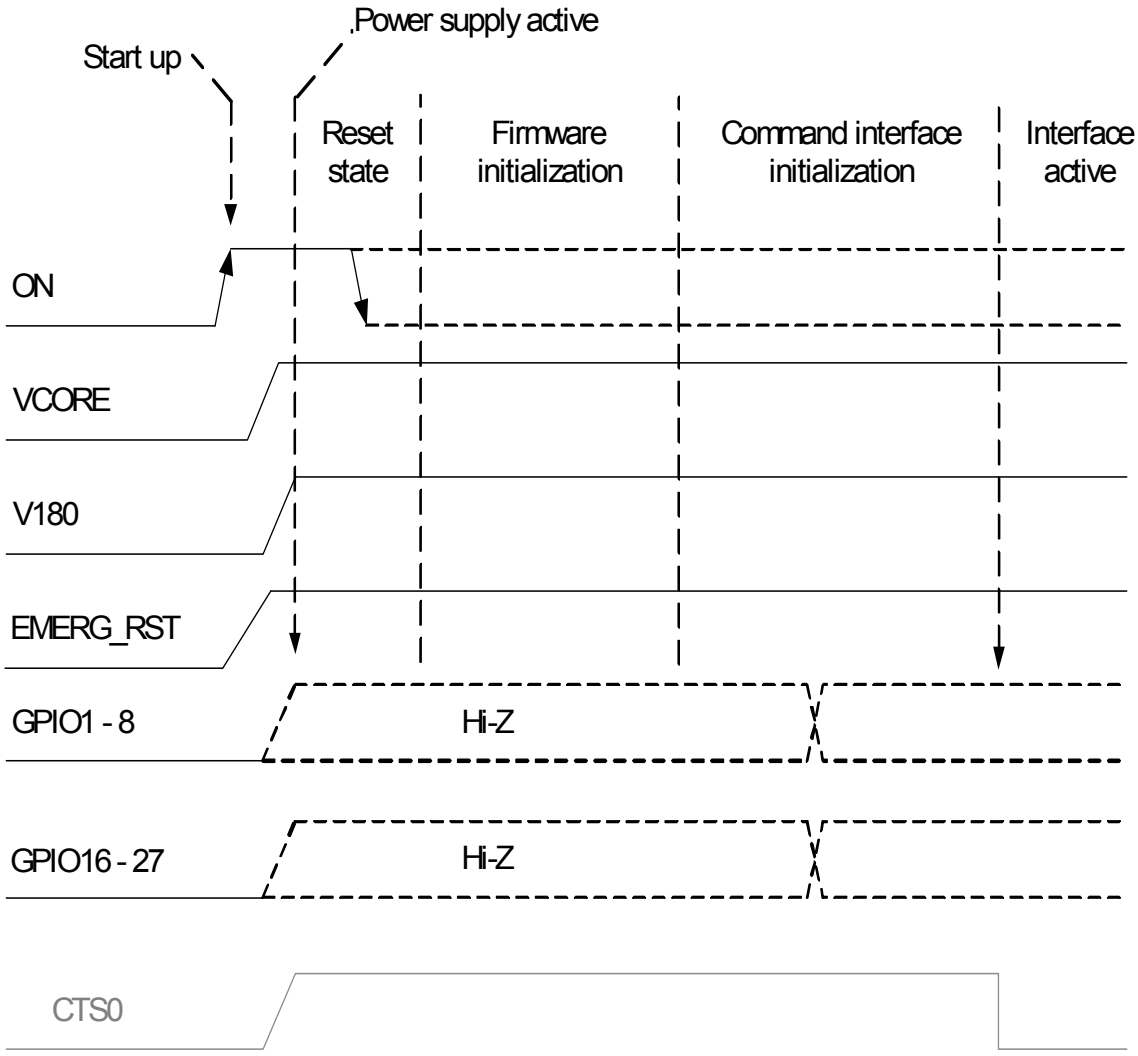
Table 5: GPIO lines and possible alternative assignment

GPIO*	Fast Shut-down*	Status LED	Pulse Counter*	ASC0	ASC1	SPI*	PWM*	WAKE capability
GPIO1				DTR0				Available
GPIO2				DCD0				
GPIO3				DSR0				
GPIO4	FST_SHDN							
GPIO5		LED						
GPIO6							PWM2	
GPIO7							PWM1	
GPIO8			COUNTER					Available
GPIO16					RXD1			
GPIO17					TXD1			
GPIO18					RTS1			Available
GPIO19					CTS1			
GPIO20								
GPIO21								
GPIO22								
GPIO23								
GPIO24				RING0				Available
GPIO25								Available
GPIO26						SPI_CS1		
GPIO27						SPI_CS2		
n/a				RST0				Available

*) Note: The following features are not yet available with the current product release: GPIO, I^2C, Pulse Counter, PWM, FST_SHDN and SPI.

After startup, the above mentioned alternative GPIO line assignments can be configured using AT commands (see [1]). The configuration is non-volatile and available after module restart.

The following figure shows the startup behavior of the GPIO interface. With an active state of the ASC0 interface line CTS0, the initialization of the GPIO interface lines is also finished.



*) For pull-up and pull-down values see Table 10.

Figure 11: GPIO start-up behavior

2.1.7 Control Signals

2.1.7.1 Status LED

Note that this feature is not available with release 1.

The LED line can also be configured as GPIO5 line, and can be used to drive a status LED that indicates different operating modes of the module (for GPIOs see Section 2.1.6). LED and GPIO5 functionality are mutually exclusive.

To take advantage of this function connect LED to the LED/GPIO5 line as shown in Figure 12. Note, that this circuit can influence Deep Sleep mode current consumption because it depends on transistor specification.

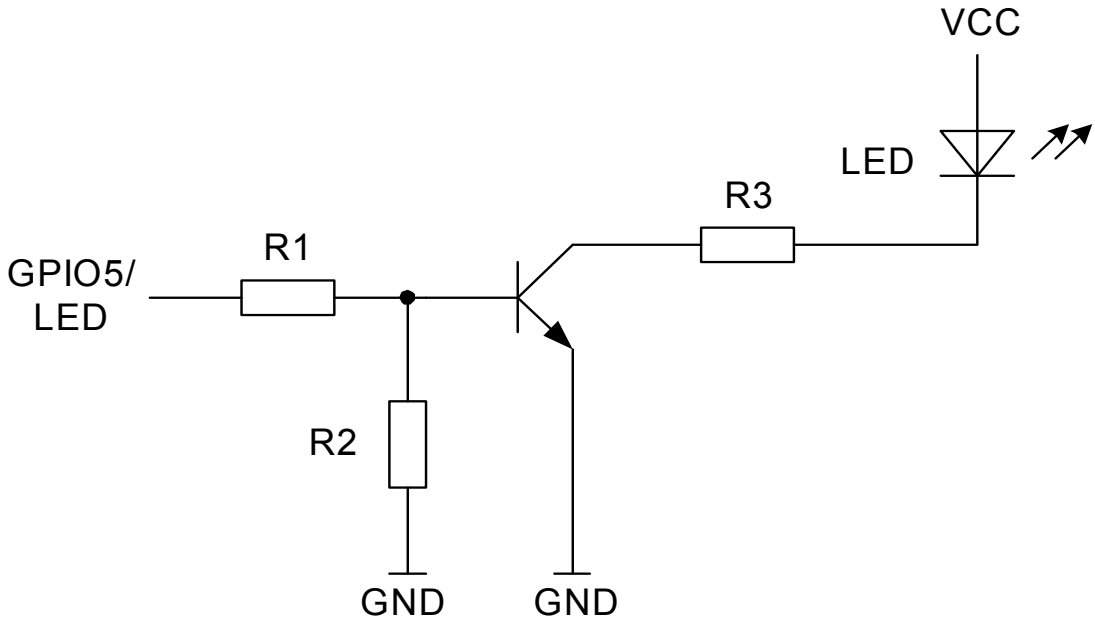


Figure 12: Status signaling with LED driver

2.1.7.2 Power Indication Circuit

In Power Down mode all digital pins are unpowered. Pulling these pins high will cause current leakage.

It is recommended to implement a power indication signal that reports the module's power state and shows whether it is active, in Power Down. While the module is in Power Down mode all signals with a high level from an external application need to be set to low state or high impedance state. The sample power indication circuit illustrated in Figure 13 denotes the module's active state with a low signal and the module's Power Down mode with a high signal.

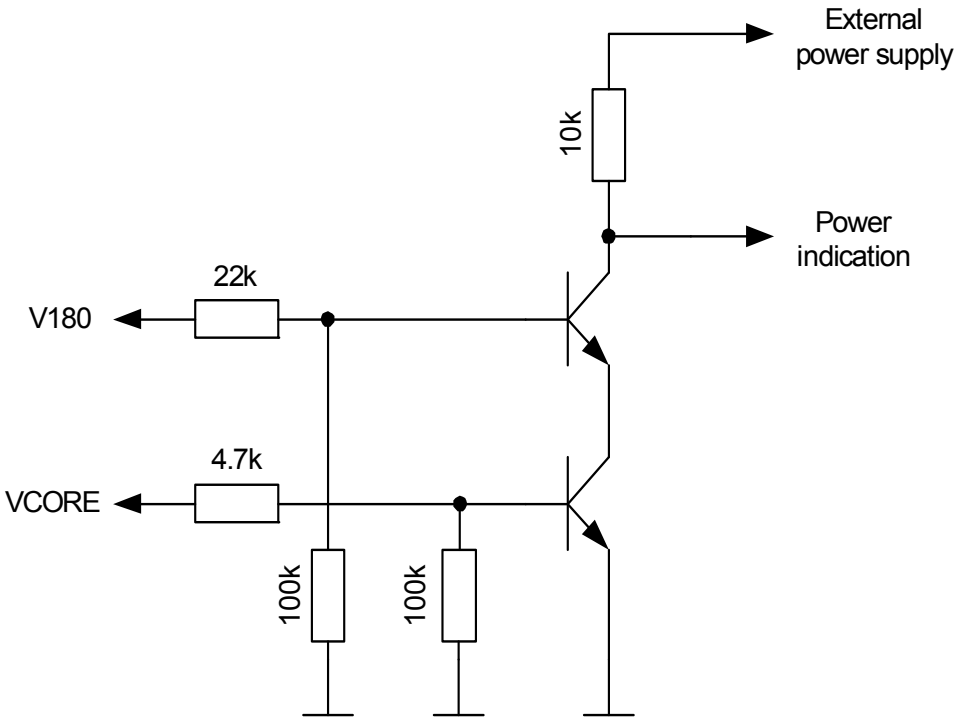


Figure 13: Power indication circuit

2.1.7.3 Host Wakeup

If no call, data or message transfer is in progress, the host may shut down its own interfaces to save power. If a call or other request (URC's, messages) arrives, the host can be notified of these events and be woken up again by a state transition of the ASC0 interface's RING0 line. For more information on how to configure the RING0 line by AT^SCFG command see [1].

Possible RING0 line states are listed in Table 6.

Table 6: Host wake-up line

Signal	I/O	
RING0	O	Inactive high to active low transition: 0 = The host shall wake up 1 = No wake up request
	High Z	When the module is in sleep mode this pin is not driven as output and should be pulled high by external power supply. Note: High Z is high impedance state.

Figure 14 shows the described RING0 wake up mechanism:

- RING0 shall be high
- After a given programmable timeout with no activity on ASC0, RTS0 will be driven high and the host will fall asleep if RING0 remains high (note: Host shall wait at least for one UART character after RTS0 is driven high before entering sleep mode, to catch the last potential character transmission over UART)
- The module will wake-up the host driving RING0 from high to low
- The host will inform the module it is ready to receive over UART by driving RTS0 to low.

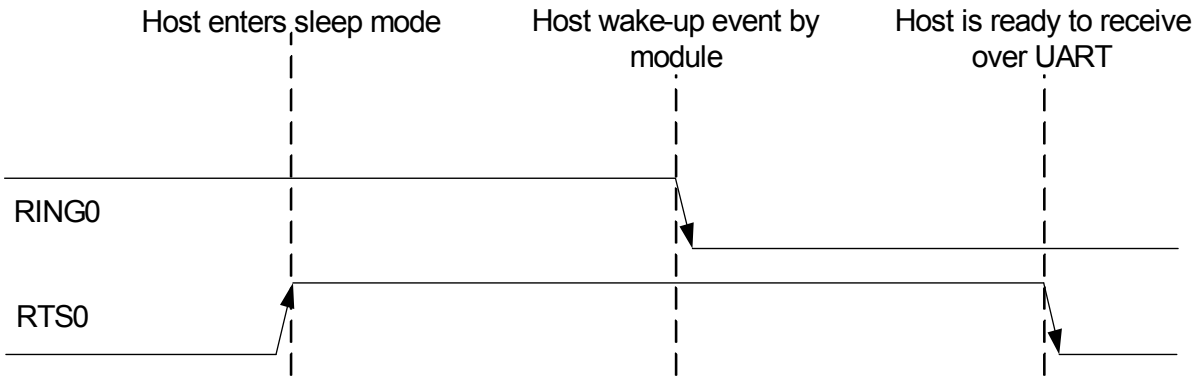


Figure 14: Wake-up via RING0

Note that it is strongly recommended to pull up RING0 with the resistor connected to an external power source. Take into consideration that the resistor value depends on application circuit in place, so it has to be determined as applicable. Figure 15 below shows an example of RING0 pull-up resistor.

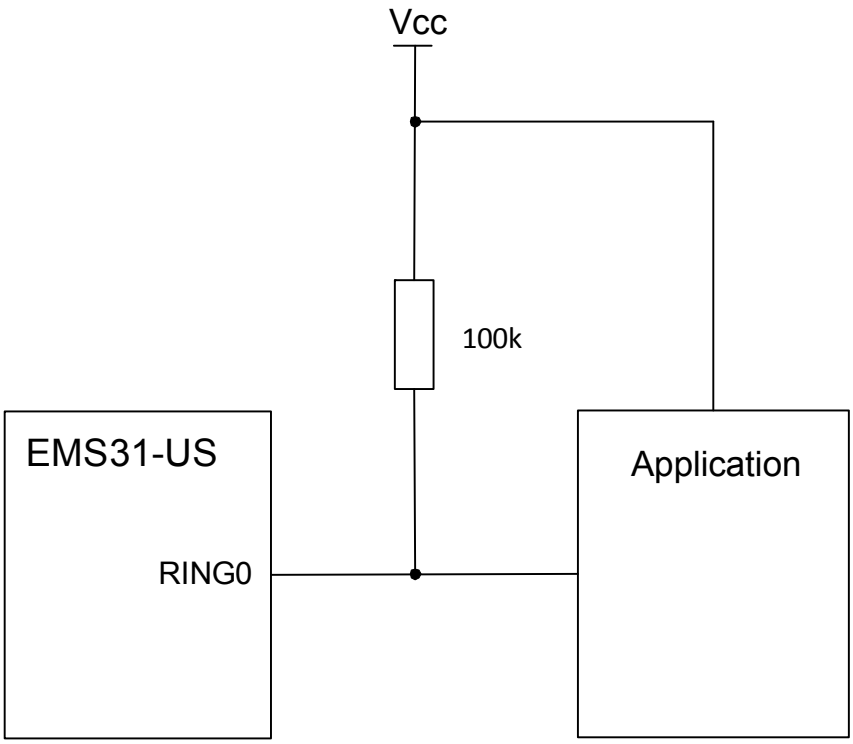


Figure 15: Example of RING0 pull-up resistor

2.2 RF Antenna Interface

The RF interface has an impedance of 50Ω. EMS31-US is capable of sustaining a 10:1 voltage standing wave ratio (VSWR) mismatch at the antenna line without any damage, even when transmitting at maximum RF power.

The external antenna must be matched properly to achieve best performance regarding radiated power, modulation accuracy and harmonic suppression. Antenna matching networks are not included on the EMS31-US module and should be placed in the host application if the antenna does not have an impedance of 50Ω.

Regarding the return loss EMS31-US provides the following values in the active band:

Table 7: 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

2.2.1 Antenna Interface Specification

Table 8: RF Antenna interface LTE

Parameter	Conditions	Min.	Typical	Max.	Unit
LTE Connectivity	• Band 2 • Band 4, AWS (1700/2100 MHz) (LTE HD-FDD) • Band 12, 700 MHz (LTE HD-FDD)				
Static Receiver input Sensitivity @ ARP (ch. bandwidth 1.4MHz)	LTE Band 2		-107 dBm		
	LTE Band 4	TBD	-106.5 dBm	TBD	dBm
	LTE Band 12	TBD	-107 dBm	TBD	dBm
RF Power @ ARP with 50 Load	LTE Band 2	TBD		TBD	
	LTE Band 4	TBD	23dBm	TBD	dBm
	LTE Band 12	TBD	23dBm	TBD	dBm

2.2.2 Antenna Installation

The antenna is connected by soldering the antenna pad (RF_OUT, pad #59) its neighboring ground pads (GND, i.e., pads #58 and #60) directly to the application's PCB. The antenna pad is the antenna reference point (ARP) for EMS31-US. All RF data specified throughout this document is related to the ARP.

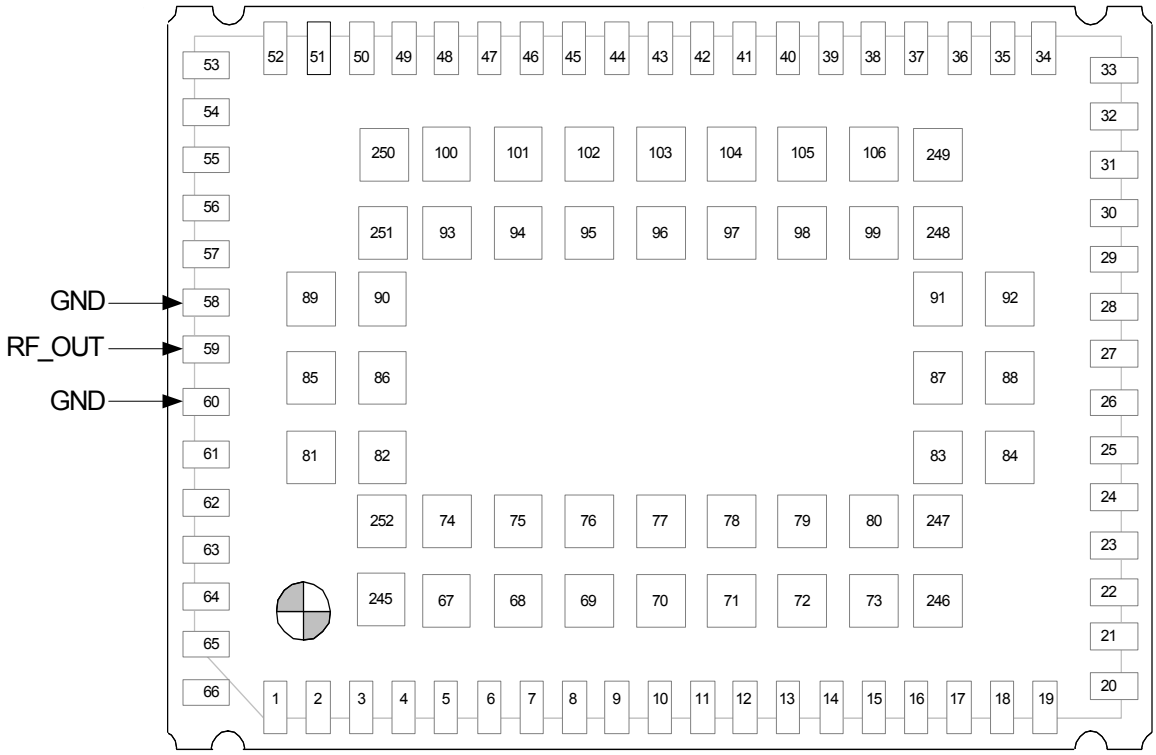


Figure 16: Antenna pad (bottom view)

The distance between the antenna RF pads and its neighboring GND pads has been optimized for best possible impedance. On the application PCB, special attention should be paid to these 3 pads, in order to prevent mismatch.

The wiring of the antenna connection line, starting from the antenna pad to the application antenna should result in a 50Ω line impedance. Line width and distance to the GND plane needs to be optimized with regard to the PCB's layer stack. Some examples are given in Section 2.2.3.

To prevent receiver desensitization due to interferences generated by fast transients like high speed clocks on the application PCB, it is recommended to realize the antenna connection line using embedded Stripline rather than Microstrip line technology. Please see Section 2.2.3.3 for an example.

For type approval purposes an external application must connect the RF signal in one of the following ways:

- Via 50Ω coaxial antenna connector (common connectors are U-FL or SMA) placed as close as possible to the module's antenna pad.
- By soldering the antenna to the antenna connection line on the application's PCB (without the use of any connector) as close as possible to the module's antenna pad.
- By routing the application PCB's antenna to the module's antenna pad in the shortest way.

In case FCC certification of application using EMS31-US is required, the implementation of the connection between module's antenna pad and antenna has to be designed similar to the implementation of this connection on evaluation board and according to KDB 996369 related to modular approval requirements.

2.2.3 RF Line Routing Design

2.2.3.1 RF Interface Signals Circuit Diagram Example

Important: Figure 17 is a topology reference, and it is recommended not to deviate from this circuit for your application. More information is provided in this document on the layout constraint which is too very important to abide by.

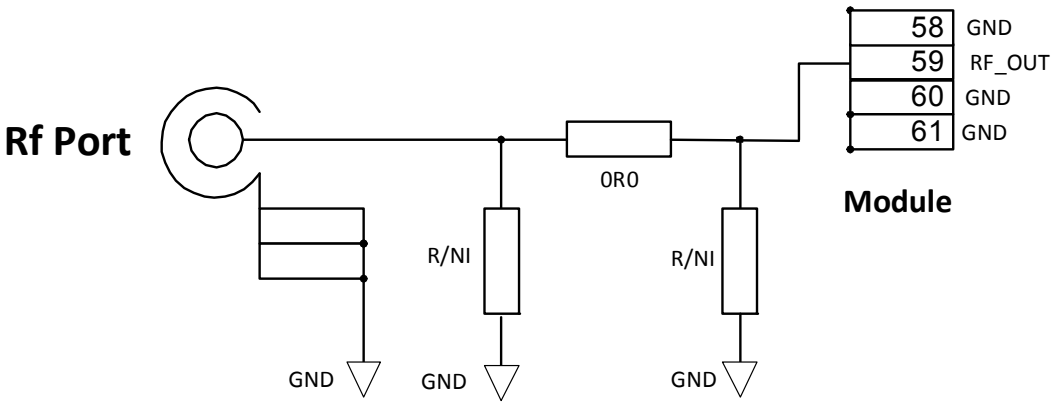


Figure 17: RF interface signals example

Awareness for ESD protection on the RF interfaces should also be considered. This protection could be utilized through the pi-network above (primarily for managing any additional RF optimization needs) or by additional component addition in series with the above pi-network matching. For more details please see Section 3.6.1.

Note: No DC blocking is needed on RF_OUT port.

2.2.3.2 Routing Example

Interface to RF Connector

Figure 18 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, as well as on other PCB characteristics like dielectric, height and layer gap. The sample stripline width of 0.15mm is recommended for an application with a PCB layer stack resembling the one of the EMS31-US evaluation board (see Figure 19). For different layer stacks the stripline width will have to follow stripline routing rules, avoiding 90 degree corners and using the shortest distance to the PCB's coaxial antenna connector.

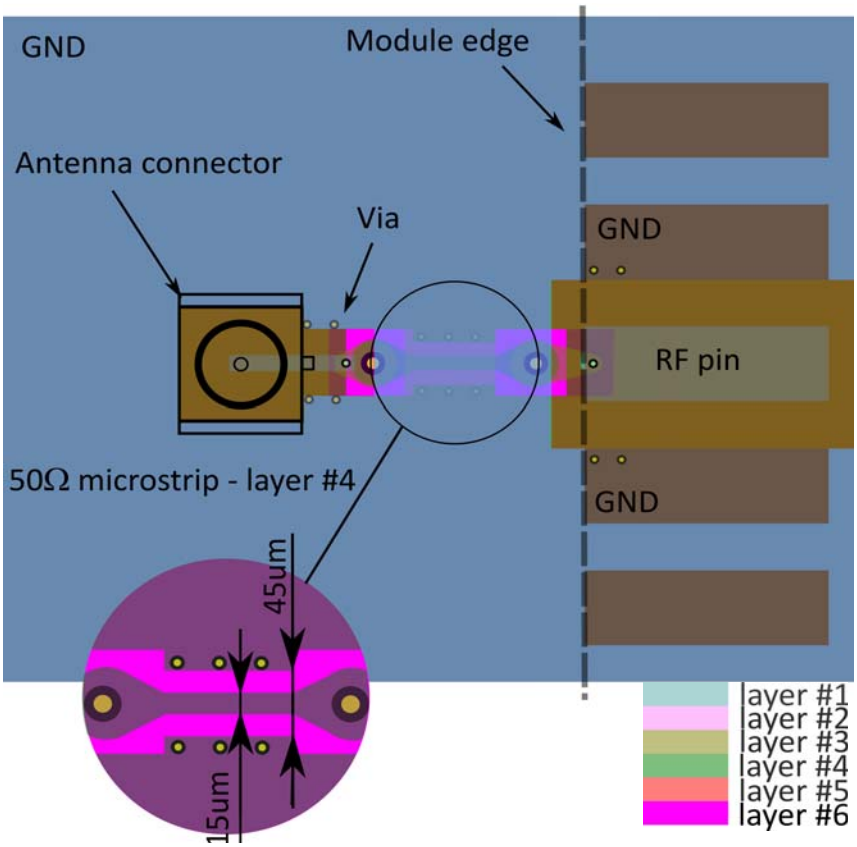


Figure 18: Routing to application's RF connector - Top view

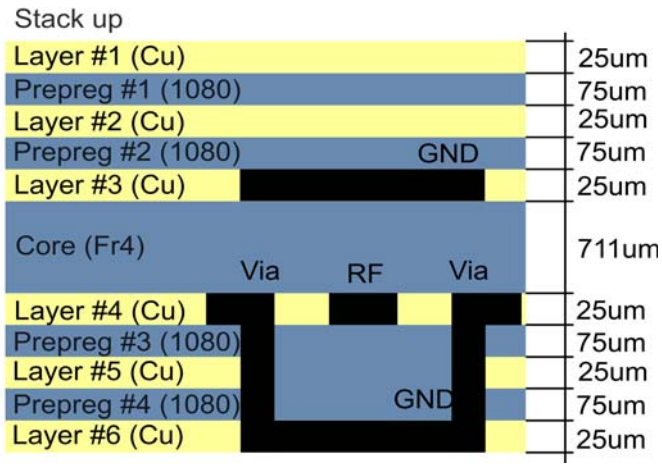


Figure 19: PCB layer stack of the EMS31-US evaluation board

2.2.3.3 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 figure below shows a line arrangement example for embedded stripline with 65µm FR4 prepreg (type: 1080) and 710µm FR4 core (4-layer PCB).

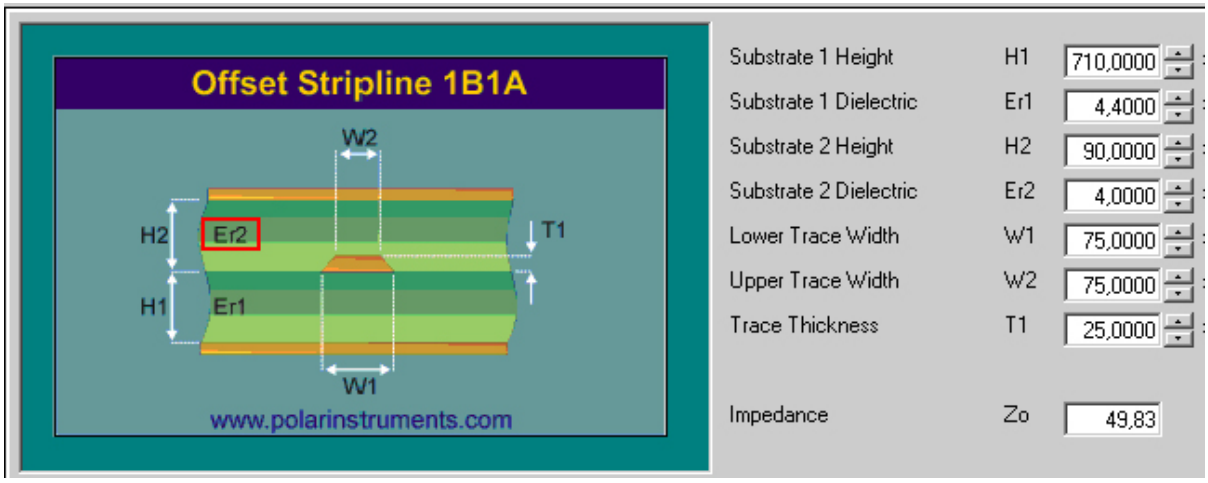
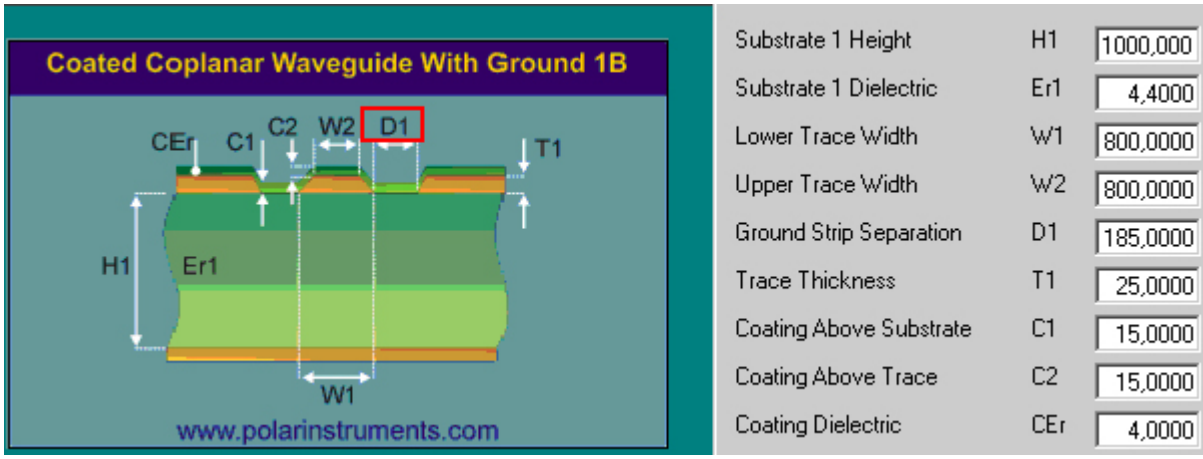


Figure 20: Embedded Stripline with 65µm prepreg (1080) and 710µm core

Microstrip Line

This section gives two line arrangement examples for microstrip line.

- Microstrip line on 1.0mm Standard FR4 2-Layer PCB
  The following two figures show examples with different values for D1 (ground strip separation).



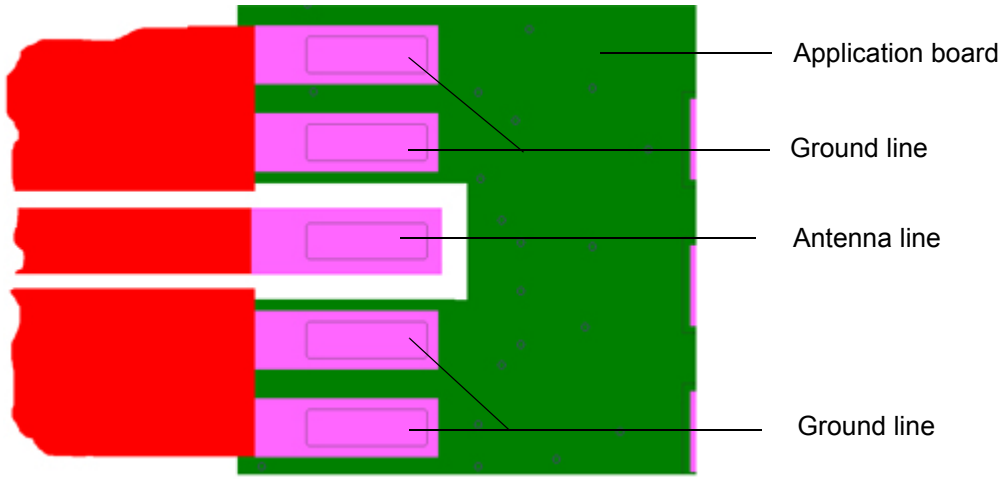


Figure 21: Microstrip line on 1.0mm standard FR4 2-layer PCB - example 1

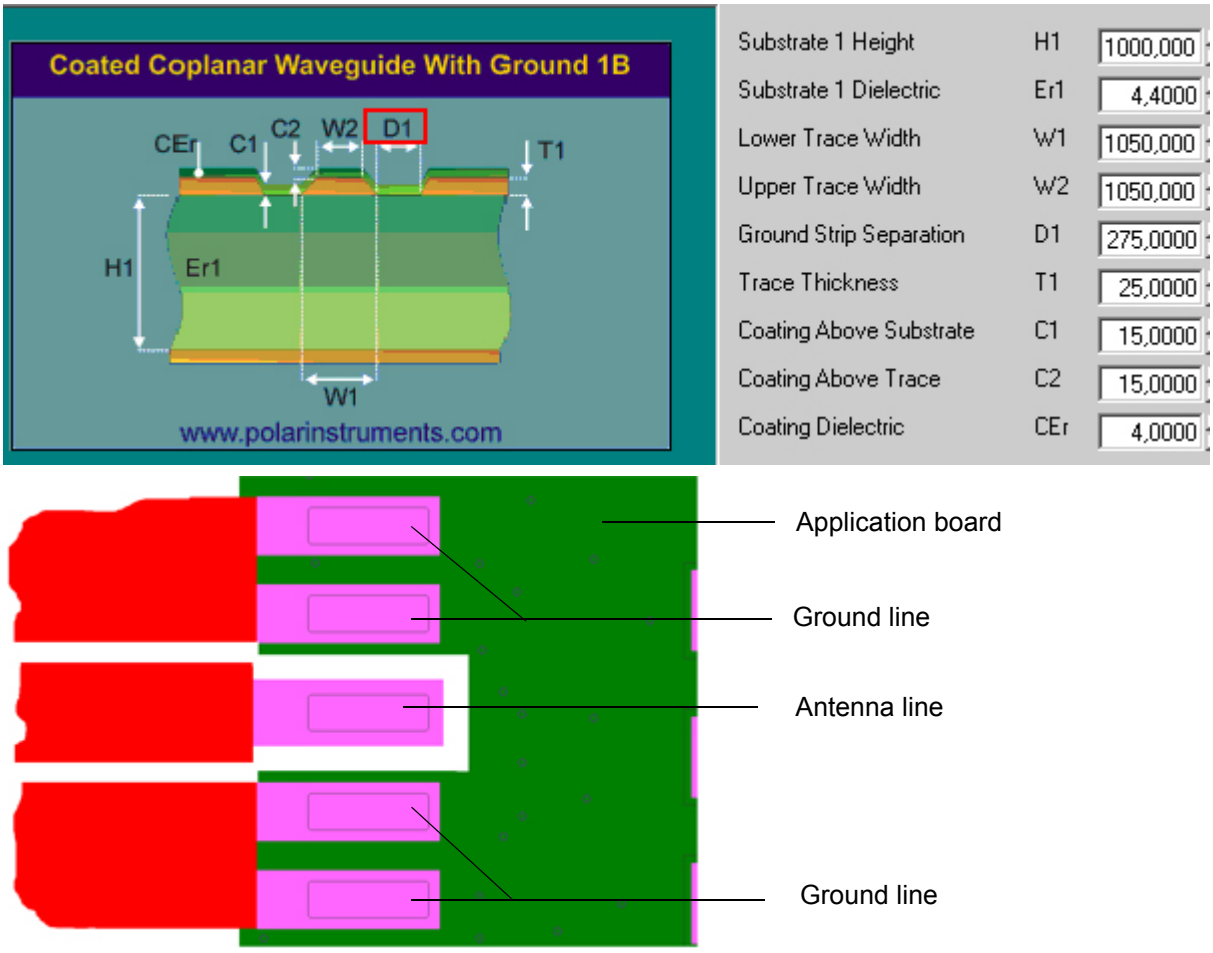


Figure 22: Microstrip line on 1.0mm Standard FR4 PCB - example 2

- Microstrip line on 1.5mm Standard FR4 2-Layer PCB
  The following two figures show examples with different values for D1 (ground strip separation).

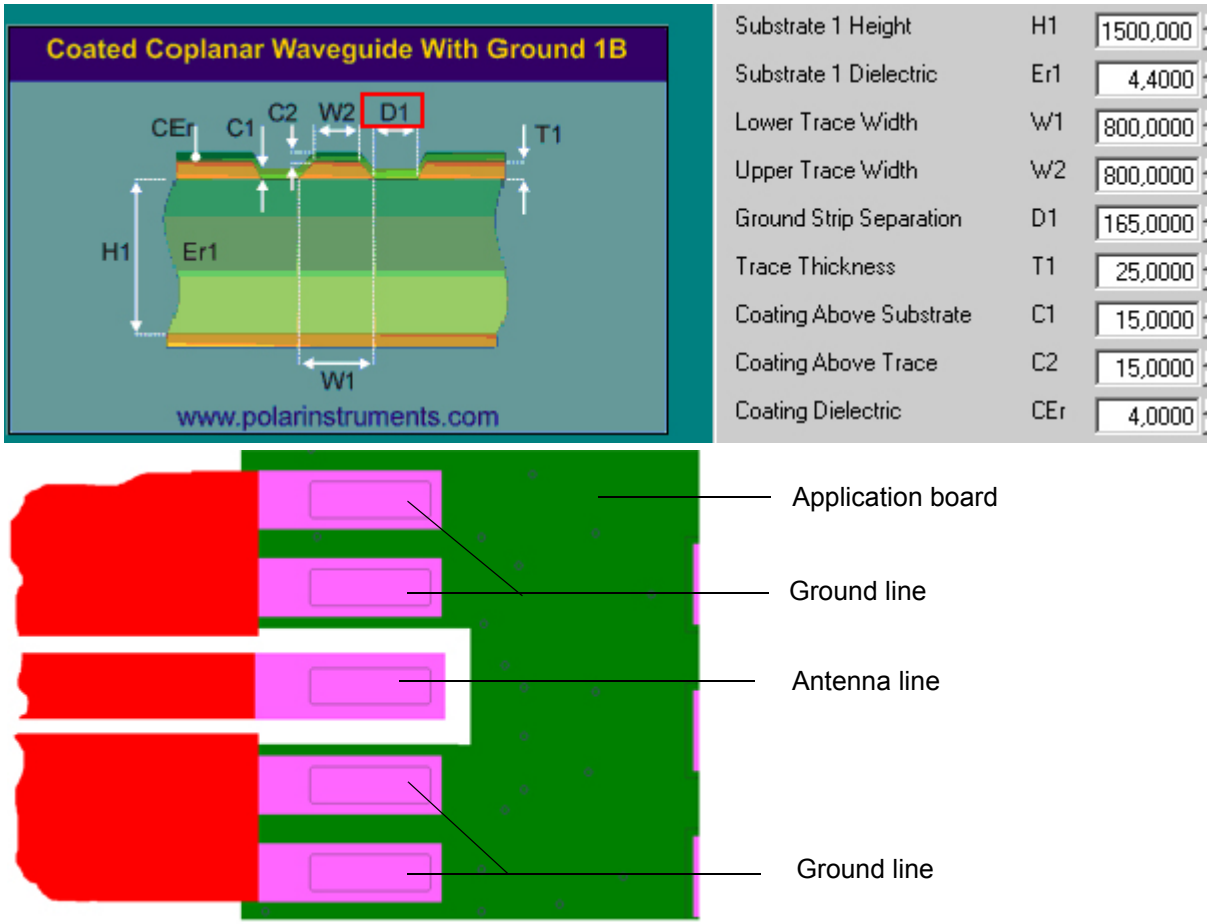


Figure 23: Microstrip line on 1.5mm Standard FR4 PCB - example 1

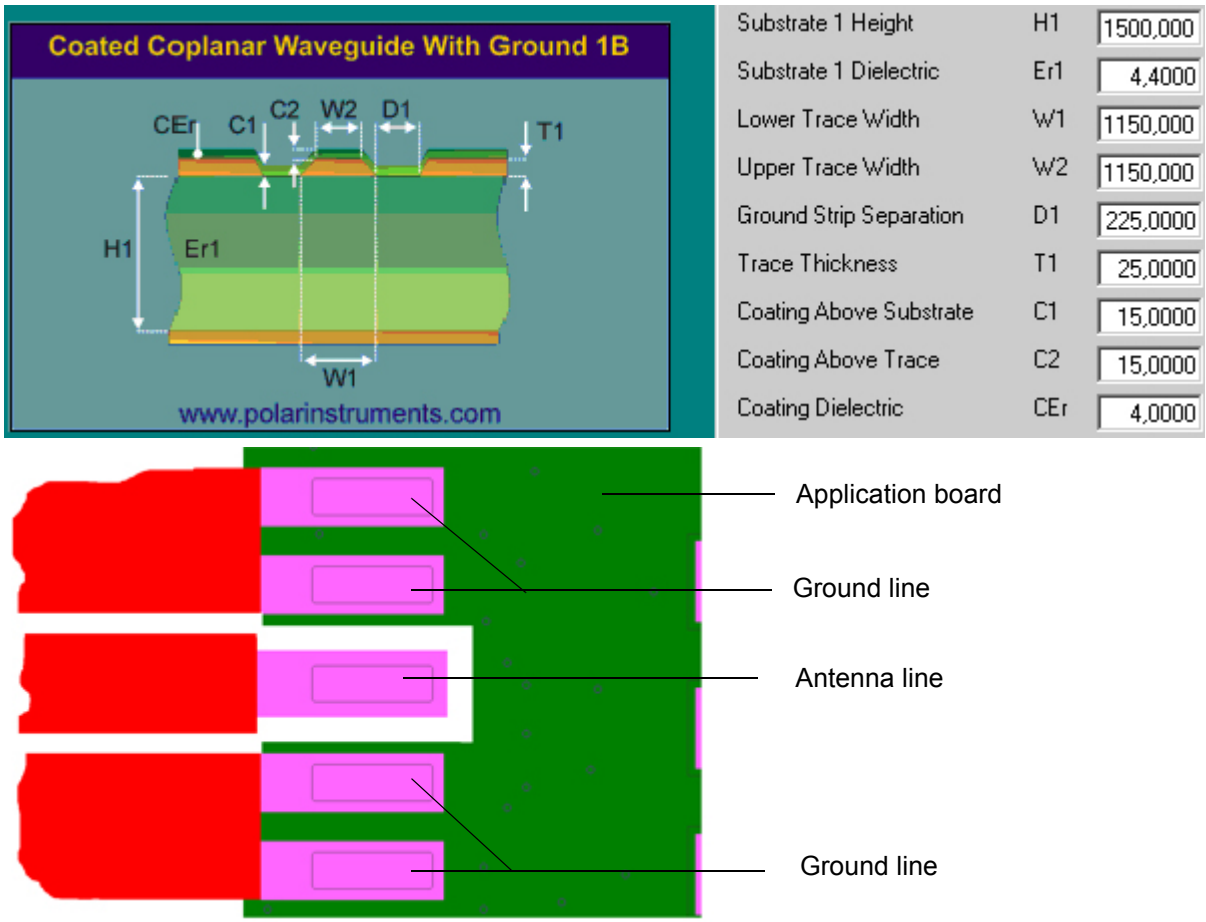


Figure 24: Microstrip line on 1.5mm Standard FR4 PCB - example 2

2.3 Sample Application

Figure 25 shows a typical example of how to integrate an EMS31-US module with an application. Usage of the various host interfaces depends on the desired features of the application.

Because of the high RF field density inside the module, it cannot be guaranteed that no self interference might occur, depending on frequency and the applications grounding concept. The potential interferers may be minimized by placing small capacitors (47pF) at suspected lines (e.g. RXD0, or ON).

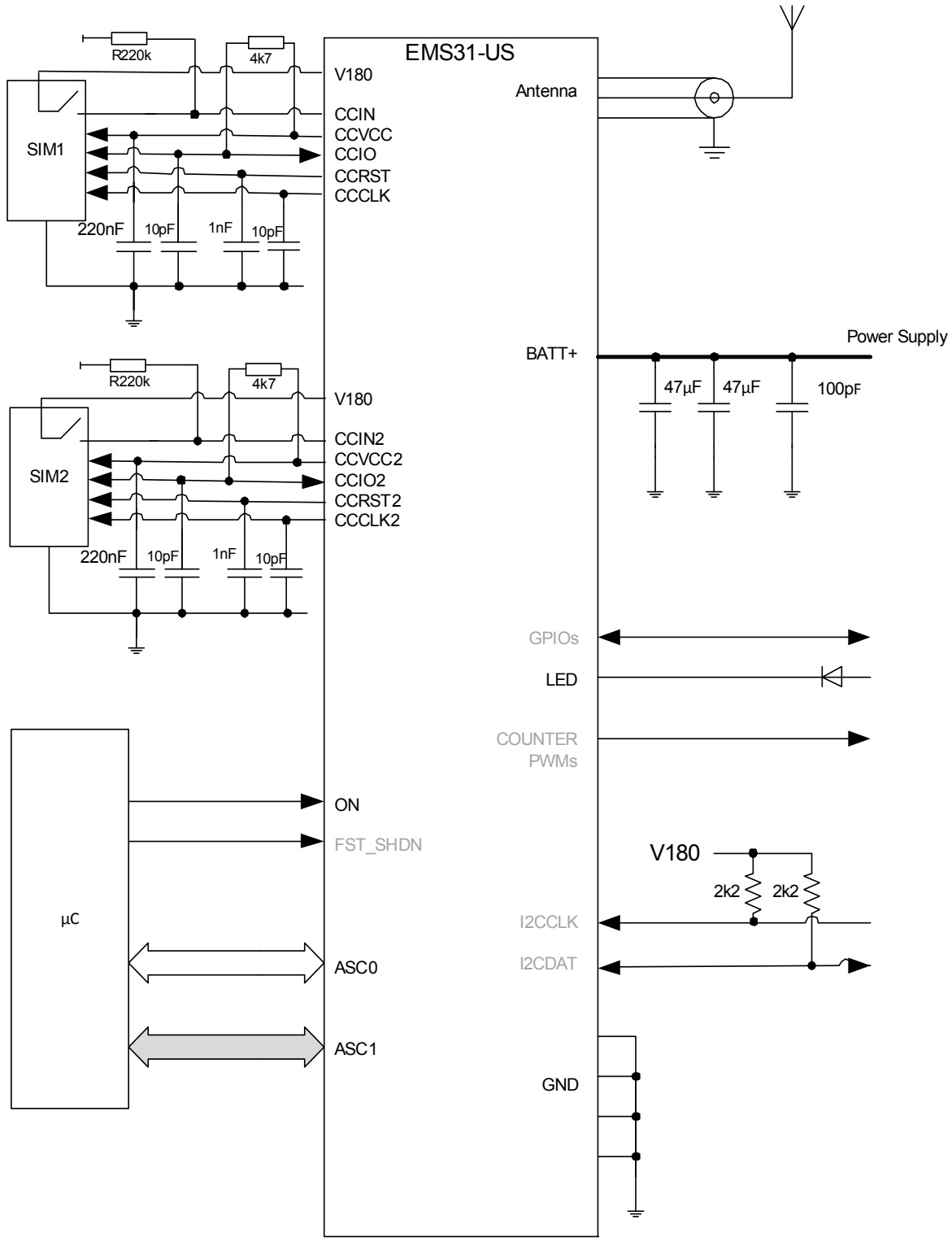
While developing SMT applications it is strongly recommended to provide test points for certain signals, i.e., lines to and from the module - for debug and/or test purposes. The SMT application should allow for an easy access to these signals. For details on how to implement test points see [3].

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.

Depending on the micro controller used by an external application the module's digital input and output lines may require level conversion. Section 2.3.2 shows a possible sample level conversion circuit.

Note: EMS31-US is not intended for use with cables longer than 3m.

Disclaimer: No warranty, either stated or implied, is provided on the sample schematic diagram shown in Figure 25 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 EMS31-US module.



Note: The following features are not yet available with the current product release: GPIO, I²C, Pulse Counter, PWM, FST_SHDN, SPI, ADC and 2nd SIM/MIM. Second SIM/MIM interface is hardware prepared only.

Figure 25: Schematic diagram of EMS31-US sample application

2.3.1 Preventing Back Powering

Because of the very low power consumption design, current flowing from any other source into the module circuit must be avoided in any case, for example reverse current from high state external control lines while the module is powered down mode. Therefore, the controlling application must be designed to prevent reverse current flow. Otherwise there is the risk of undefined states of the module during startup and shutdown or even of damaging the module. A simple solution preventing back powering is the usage of V180 for level shifters, as Figure 26 shows.

While the module is in power down mode, V180 must have a level lower than 0.3V after certain time. If this is not the case the module is back feeded by the application interface - recognizing such fault state is possible by V180 (see Figure 26).

2.3.2 Sample Level Conversion Circuit

Depending on the micro controller used by an external application the module's digital input and output lines (i.e., ASC0, ASC1 or GPIO lines) may require level conversion. The following Figure 26 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.

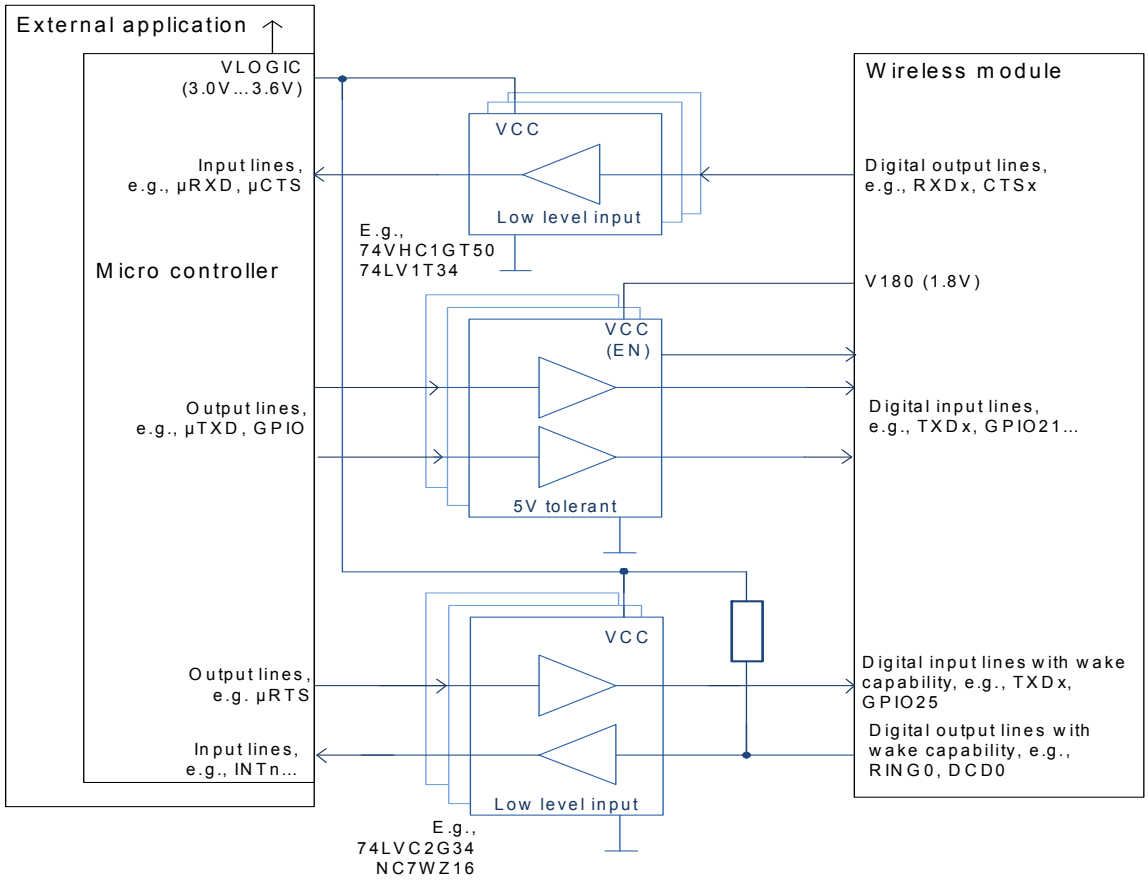


Figure 26: Sample level conversion circuit

Note: Bidirectional level shifters without directions control signal are not suitable for RTS0 and DCD0 as they may force the module into a wrong state while starting up. Level shifters for VLOGIC (3.0V...3.6V) are not required for inputs that can handle V_{IH}max = 3.6 V or BATT+ if BATT+ is lower than 3.6V.

3 Operating Characteristics

3.1 Operating Modes

The table below briefly summarizes the various operating modes referred to throughout the document.

Table 9: Overview of operating modes

Mode	Function	
Normal operation	Active TX	LTE data transfer in progress. Power consumption depends on network settings, data transfer rate and radio conditions. No data transfer is in progress and no active communication via ASC0/ ASC1.
	IDLE	No data transfer is in progress. The LTE part of the device can be in LTE DRX, LTE eDRX or LTE PSM mode. Activity on ASC0 /ASC1 interfaces can be present. Power consumption depends on the LTE power saving mode and its parameters and on the activity on the ASC interfaces.
Sleep	The module is in low power consumption state. There is no activity inside the module but module preserves the state in which it was before entering the sleep mode, including the electrical states of the GPIOs. The module will enter sleep state only when the LTE part of the module is in LTE DRX, LTE eDRX or LTE PSM mode or if it is in airplane mode. To allow sleep mode the host application shall indicate via RTS lines that it has no intention to send data.	
Power Down	Normal shutdown after sending the power down command. Software is not active. Interfaces are not accessible. Operating voltage remains applied.	
Airplane mode	Airplane mode shuts down the radio part of the module, causes the module to log off from the LTE network and disables all AT commands whose execution requires a radio connection. Airplane mode can be controlled by AT command (see [1]). Sleep mode can be entered when airplane mode is enabled.	

3.2 Power Up/Power Down Scenarios

Do not turn on EMS31-US while it is beyond the safety limits of voltage and temperature stated in Section 2.1.2.1. EMS31-US will immediately switch off when these conditions are detected. In extreme cases this can cause permanent damage to the module.

3.2.1 Turn on EMS31-US

EMS31-US can be turned on following the steps described in the following sections:
1. Connecting the operating voltage BATT+ (see Section 3.2.1.1).
2. Sending signal ON line: Starts Normal mode (see Section 3.2.1.2).

After startup or restart, the module will send the URC ^SYSSTART that notifies the host application that the first AT command can be sent to the module (see also [1]).

3.2.1.1 Connecting EMS31-US BATT+ Lines

Figure 27 shows sample external application circuits that allow to connect (and also to temporarily disconnect) the module's BATT+ line from the external application's power supply.

Figure 27 illustrates the application of power employing an externally controlled microcontroler. The transistor T2 mentioned in Figure 27 should have an R_{DS_ON} value < 50mΩ in order to minimize voltage drops.
Such circuits could be useful to maximize power savings for battery driven applications or to completely switch off and restart the module after a firmware update.

After connecting the BATT+ line the module can then be (re-)started as described in Section 3.2.1.2.

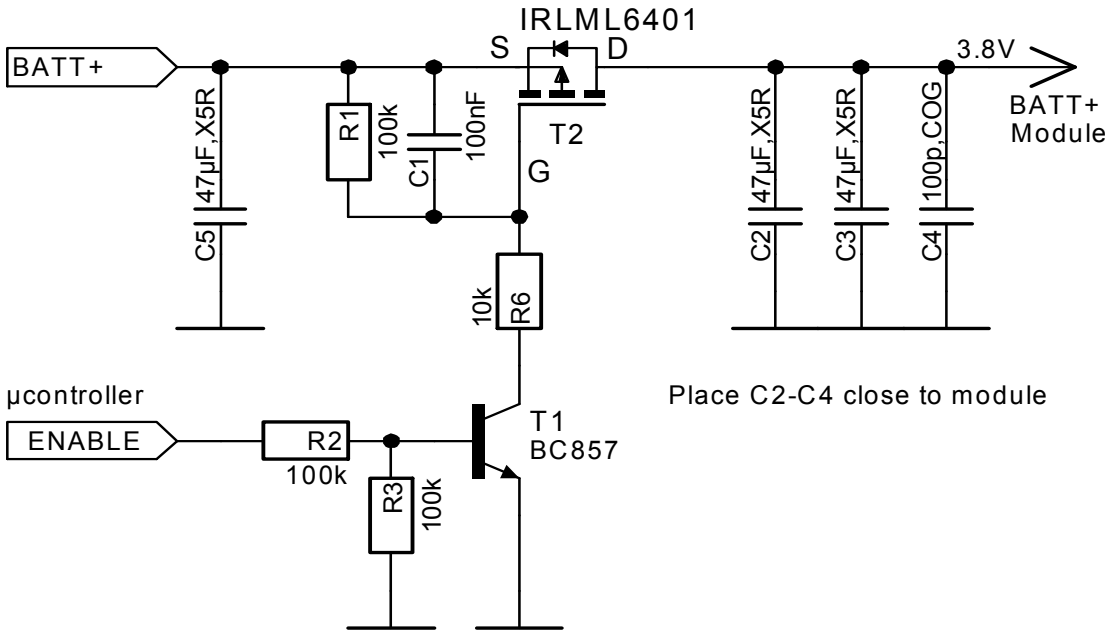


Figure 27: Simple circuit for applying power using an external µC

Important: When the transistor T2 is switched on this circuit will cause permanent leakage current via R1, R6 and T1 (for BATT+=3.8V it is 34,5µA).

3.2.1.2 Switch ON EMS31-US Using ON Signal

When the operating voltage BATT+ is applied, EMS31-US can be switched on by means of the ON signal.

The ON signal is a level triggered signal or directly connected to BATT+. The module starts into normal mode on detecting a high level at the ON signal. The high level should be a minimum of 100µs. Note that if the ON signal is set to high before BATT+ is applied, EMS31-US may not start up correctly.

It is recommended to use pulse > 100 µs. Direct connection to the BATT+ will cause constant current leakage (see Figure 28).

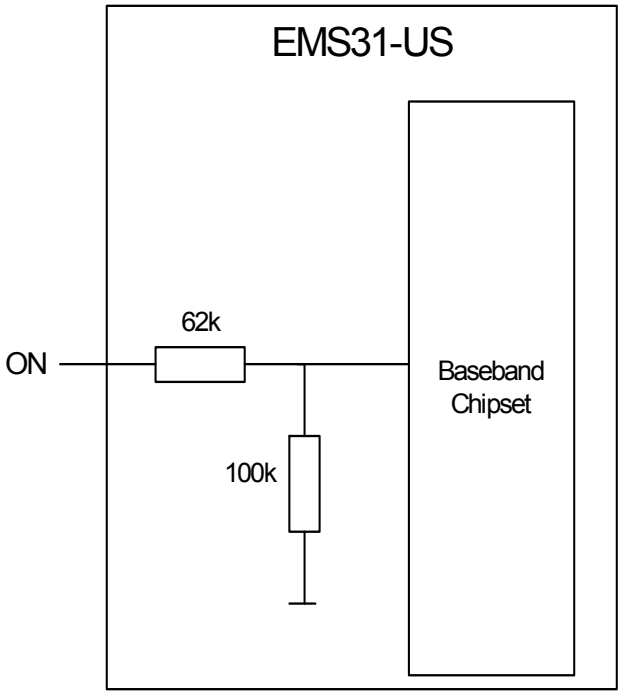


Figure 28: ON pin connection

When the operating voltage BATT+ is applied, EMS31-US can also be switched on by means of the ON signal.

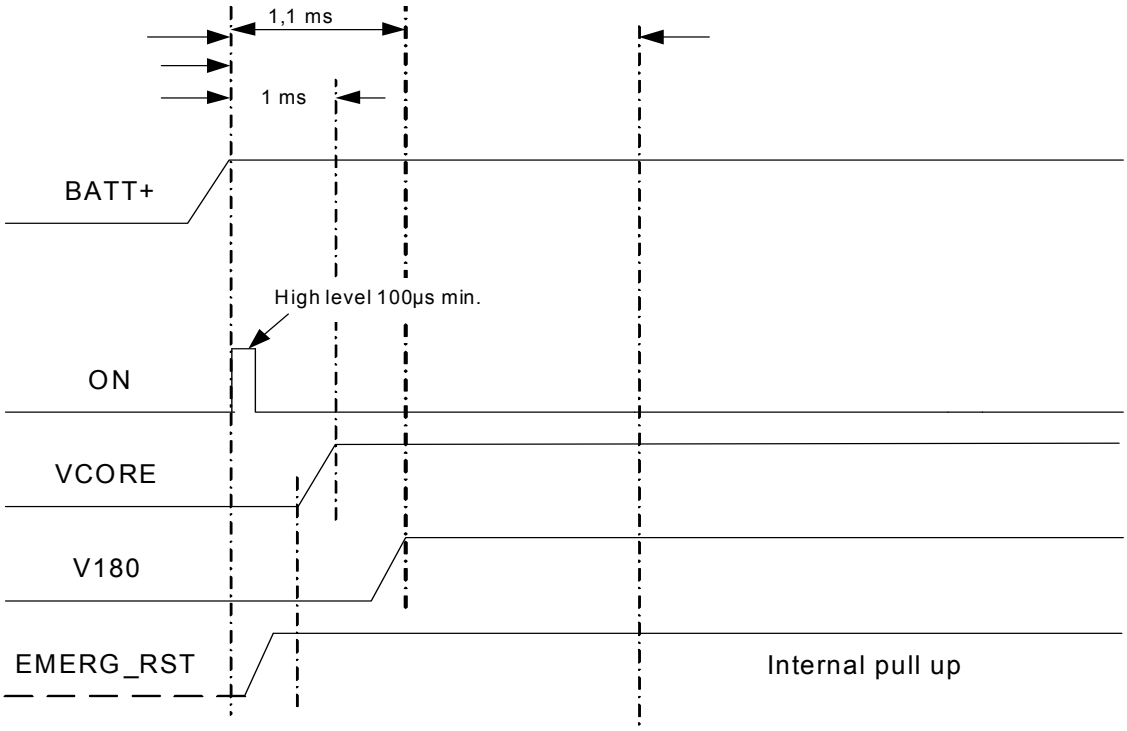


Figure 29: ON Timing

The module can start immediately after applying the BATT+. For this mode the ON pad needs to be connected to BATT+ (auto start mode). In the case ON is connected to BATT+ and the module switches off, it will immediately switch on again.

3.2.2 Restart EMS31-US

After startup EMS31-US can be re-started as described in the following sections:

- Software controlled reset by AT+CFUN command: Starts Normal mode (see Section 3.2.2.1).
- Hardware controlled reset by EMERG_RST line: Starts Normal mode (see Section 3.2.2.2).

3.2.2.1 Restart EMS31-US via AT+CFUN Command

To reset and restart the EMS31-US module use AT+CFUN command. For more details please see [1].

3.2.2.2 Restart EMS31-US Using EMERG_RST

The EMERG_RST signal is internally connected to baseband chipset (see Figure 30). A low level for more than 100µs (100µs is recommended) sets the processor and all other respective signal pads to their respective reset state. The reset state is described in Section 3.2.3 as well as in the figures showing the startup behavior of an interface.

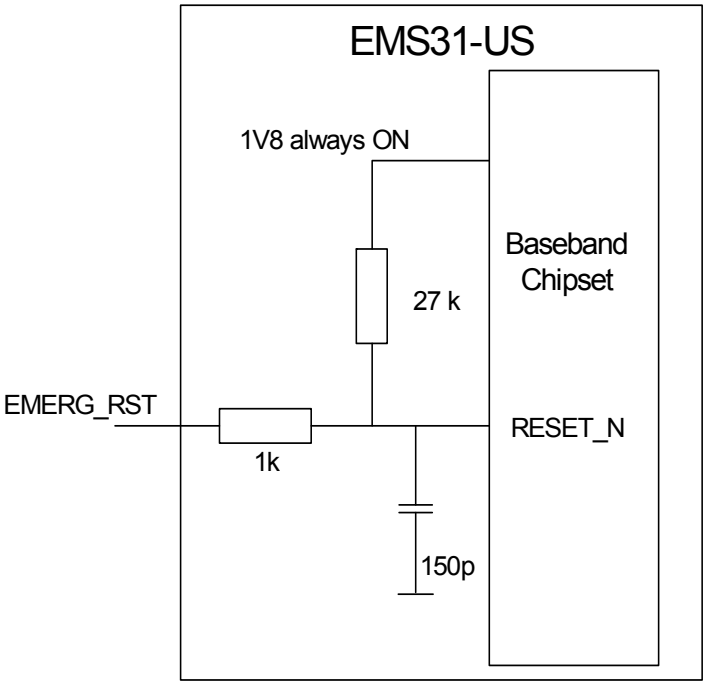


Figure 30: EMERG_RST signal internal connection to chipset

When EMERG_RST goes Low then High while module is in active or sleeping state, the module starts its boot cycle. The other signals continue from their reset state as if the module was switched on by the ON signal.

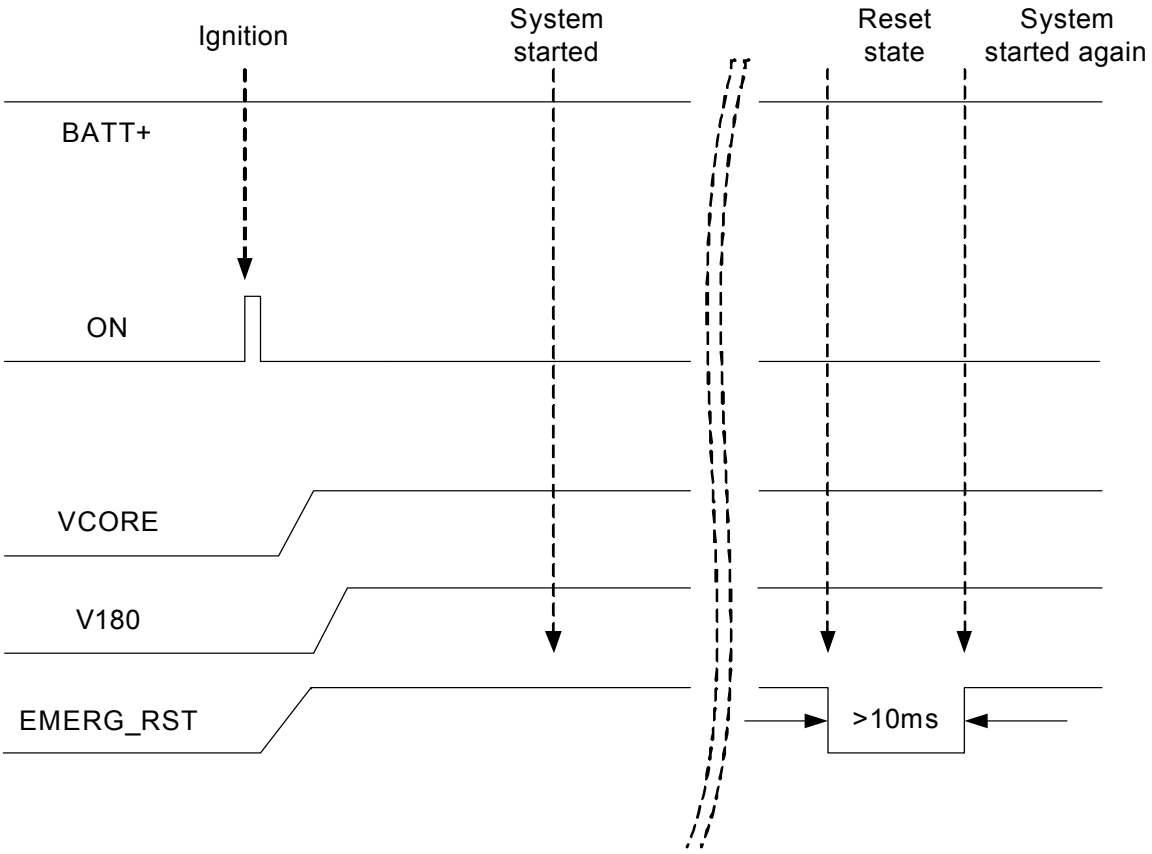


Figure 31: Emergency restart timing

It is recommended to control this EMERG_RST line with an open collector transistor or an open drain field-effect transistor.

Caution: Use the EMERG_RST line only when, due to serious problems, the software is not responding for more than 5 seconds. Pulling the EMERG_RST 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 EMS31-US does not respond, if restart or shutdown via AT command fails.

3.2.3 Signal States after First Startup

Table 10 lists the states each interface signal passes through during reset and first firmware initialization. For further firmware startup initializations the values may differ because of different GPIO line configurations.

The reset state is reached when EMERG_RST signal goes Low and then High while the module is active or sleeping - either with a normal module startup after about TBD milliseconds (see Section 3.2.1) or after a restart (see Section 3.2.2). After the reset state has been reached the firmware initialization state begins. The firmware and command interface initialization is completed as soon as the ASC0 interface line CTS0 has turned low (see Section 2.1.3). Now, the module is ready to receive and transmit data.

Table 10: Signal states

Signal name	Default functionality	Reset state	First startup configuration
CCIO1	CCIO1	I/PU	O/L
CCRST1	CCRST1	I	O/L
CCCLK1	CCCLK1	I/PU	O/L
CCIN1	CCIN1	I	I (external PD needed)
RXD0	RXD0	I/PU	O/H
TXD0	TXD0	I/PU	I
CST0	CST0	I/PU	I/OH
RST0	RST0	I/PU	I/PD
GPIO1/DTR0	DTR0	I/PU	I/PU
GPIO2/DCD0	DCD0	I	O/H
GPIO3/DSR0	RDS0	I	O/H
GPIO4/FST_SHDN*	GPIO4	I	I
GPIO5/LED	LED	I	O/L
GPIO6/PWM2*	GPIO6	I/PU	I/PD
GPIO7/PWM1*	GPIO7	I/PU	I/PD
GPIO8/COUNTER*	GPIO8	I	I
GPIO16/RXD1	RXD1	I/PU	O/H
GPIO17/TXD1	TXD1	I/PU	I
GPIO18/RTS1	RST1	I/PU	I/PU
GPIO19/CTS1	CTS1	I/PU	O/H
GPIO20	GPIO20	I/PU	I/PD
GPIO21	GPIO21	I/PU	I/PD
GPIO22	GPIO22	I/PU	I/PD
GPIO23	GPIO23	I/PU	I/PD
GPIO24/RING0	RING0	I	O/H
GPIO25	GPIO25	I	I

Table 10: Signal states

Signal name	Default functionality	Reset state	First startup configuration
GPIO26/SPI*_CS1	GPIO26	I/PU	I/PD
GPIO27/SPI*_CS2	GPIO27	I/PU	I/PD
I2CCLK	n/a	I/PU	T/OD
I2CDAT	n/a	I/PU	T/OD
SPI_MISO	n/a	I/PU	TBD
SPI_MOSI	n/a	I/PU	TBD
SPI_SCK	n/a	I/PU	TBD
CCRST2	CCRST2	I	O/L
CCIN2	CCIN2	I	I
CCCLK2	CCCLK2	I/PU	O/L
CCIO2	CCIO2	I/PU	O/L

*) Note: The following features are not yet implemented and are foreseen for future release: GPIO, I^2C, Pulse Counter, PWM, FST_SHDN, SPI and ADC.

Abbreviations used in Table 10:

L = Low level H = high level T = Tristate I = Input	O = Output OD = Open drain PD = Pull down PU = Pull up

3.2.4 Turn Off EMS31-US

To switch the module off the following procedures may be used:

- *Software controlled shutdown procedure*: Software controlled by sending an AT command over the serial application interface. See Section 3.2.4.1.
- *Automatic shutdown (software controlled)*: See Section 3.2.5.
  - Takes effect if EMS31-US board temperature exceeds a critical limit.

3.2.4.1 Turn off EMS31-US Using AT Command

The best and safest approach to powering down EMS31-US is to issue the appropriate AT command. This procedure lets EMS31-US log off from the network and allows the software to enter into a secure state and safe data before disconnecting the power supply. The mode is referred to as Power Down mode. In this mode. Before issuing the switch off AT command, the ON signal should be set to low (see Figure 32). Otherwise there might be back powering at the ON line in Power Down mode.

While EMS31-US is in Power Down mode the application interface is switched off and must not be fed from any other voltage source. Therefore, your application must be designed to avoid any current flow into any digital pads of the application interface.

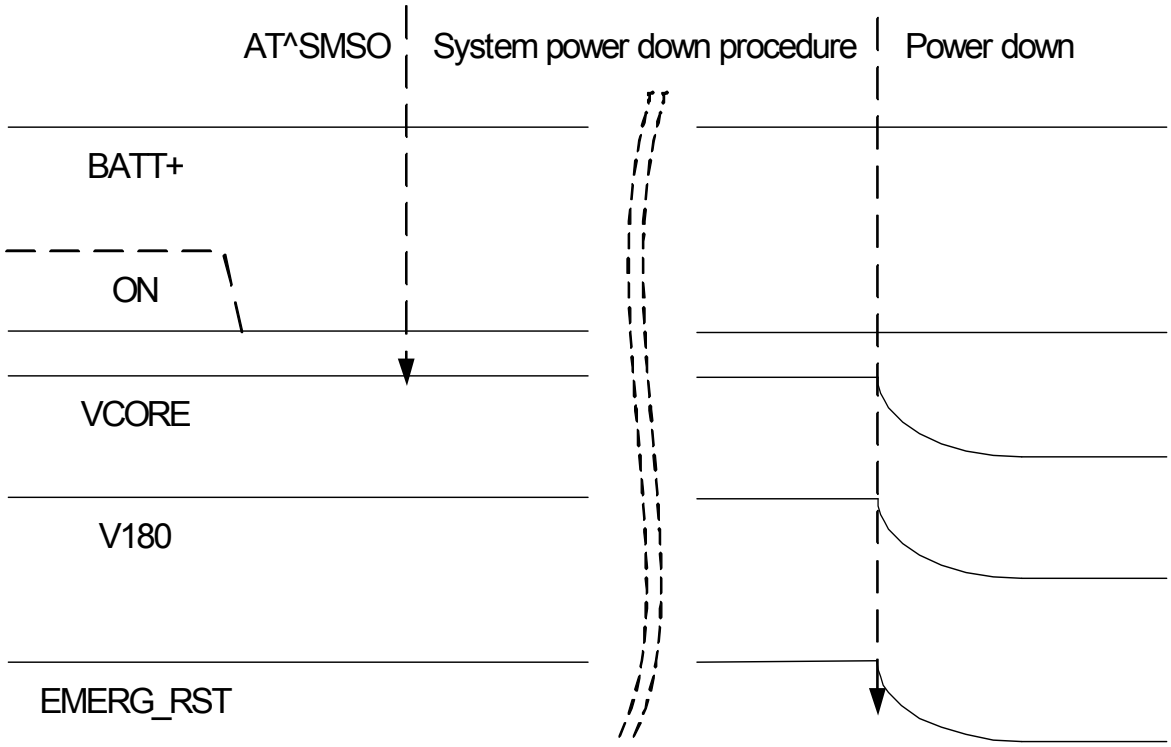


Figure 32: Switch off behavior

3.2.5 Automatic Shutdown

Automatic shutdown takes effect if the following event occurs:
- The EMS31-US board is exceeding the critical limits of overtemperature or undertemperature (see Section 3.2.5.1)
- Undervoltage or overvoltage is detected (see Section 3.2.5.2 and Section 3.2.5.3)

The automatic shutdown procedure is equivalent to the power-down initiated with an AT command, i.e. EMS31-US logs off from the network and the software enters a secure state avoiding loss of data.

3.2.5.1 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, EMS31-US 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 (for details see [1]):
  AT^SCTM=1: Presentation of URCs is always enabled.
  AT^SCTM=0 (default): Presentation of URCs is enabled during the 2 minute guard period after start-up of EMS31-US. After expiry of the 2 minute guard period, the presentation of URCs 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 3.5. Refer to Table 11 for the associated URCs.

Table 11: Temperature dependent behavior

Sending temperature alert (2 min after module start-up, otherwise only if URC presentation enabled)	
^SCTM_B: 1	Board close to overtemperature limit.
^SCTM_B: -1	Board close to undertemperature limit.
^SCTM_B: 0	Board back to non-critical temperature range.
Automatic shutdown (URC appears no matter whether or not presentation was enabled)	
^SCTM_B: 2	Alert: Board equal or beyond overtemperature limit. EMS31-US switches off.
^SCTM_B: -2	Alert: Board equal or below undertemperature limit. EMS31-US switches off.

3.2.5.2 Undervoltage Shutdown

The undervoltage shutdown threshold is the specified minimum supply voltage V_{BATT+} given in Table 2. When the average supply voltage measured by EMS31-US approaches the undervoltage shutdown threshold (i.e., 0.05V offset) the module will send the following URC:

^SBC: Undervoltage Warning

The undervoltage warning is sent only once - until the next time the module is close to the undervoltage shutdown threshold.

If the voltage continues to drop below the specified undervoltage shutdown threshold, the module will send the following URC:

^SBC: Undervoltage Shutdown

This alert is sent only once before the module shuts down cleanly without sending any further messages.

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

Note: For battery powered applications it is strongly recommended to implement a BATT+ connecting circuit as described in Section 3.2.1.1 in order to not only be able save power, but also to restart the module after an undervoltage shutdown where the battery is deeply discharged. Also note that the undervoltage threshold is calculated for max. 400mV voltage drops during transmit burst. Power supply sources for external applications should be designed to tolerate 400mV voltage drops without crossing the lower limit of 3.3 V. For external applications operating at the limit of the allowed tolerance the default undervoltage threshold may be adapted by subtracting an offset. For details see [1]: AT^SCFG= "MEShutdown/sVsup/threshold".

3.2.5.3 Overvoltage Shutdown

The overvoltage shutdown threshold is 4.8V. When the average supply voltage measured by EMS31-US approaches the overvoltage shutdown threshold (i.e., 0.05V offset) the module will send the following URC:

^SBC: Overvoltage Warning

The overvoltage warning is sent only once - until the next time the module is close to the overvoltage shutdown threshold.

If the voltage continues to rise above the specified overvoltage shutdown threshold, the module will send the following URC:

^SBC: Overvoltage Shutdown

This alert is sent only once before the module shuts down cleanly without sending any further messages.

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 module components are directly linked to BATT+ and, therefore, the supply voltage remains applied at major parts of EMS31-US. Especially the power amplifier linked to $BATT+_{RF}$ is very sensitive to high voltage and might even be destroyed.

3.3 Power Saving

EMS31-US can be configured to control power consumption. UART interfaces (ASC0 and ASC1) can be configured for the power saving mode. It will then be deactivated with predefined timeout after last character is sent. CTS/RTS flow control must be configured on module and the host application to support module wake-up and informing the host-application about module events.
Note: RTS0/RTS1 must to be set to high before the EMS31UScan change into power saving mode. Being triggered by LTE network protocol while attached to LTE networks.

3.3.1 Power Saving while Attached to LTE Networks

The power saving possibilities while attached to a LTE network depend on the module configuration set by the host application and the configuration of the LTE network itself.

There are three basic LTE network power saving modes implemented in the module:

- LTE DRX (Discontinuous Reception) with the cycle up to 10.24s
- LTE eDRX (Enhanced Discontinuous Reception) with cycle up to 43 minutes
- LTE PSM (Power Saving Mode) with cycle up to 413 days

The main difference between these features is the length of the cycle where the LTE part of the module can stay in low power state to minimize power consumption. The drawback is that during the low power state of the LTE part of the module it is not reachable from the network. Please note that LTE network does not have to support all above mentioned modes and it can also restrict the cycle duration of these modes.

Configuration of these modes depends on host application use-cases. In case host application is expected to be reachable from the network, the cycles should be short. Otherwise, in case host application does not have to be reachable, the cycles can be very long.

In case the host application needs to send data towards the network, it can be done at any time and there is no need to wait until the end of the sleeping cycle.

The high level operation of DRX and eDRX is illustrated in Figure 33. The scenario assumes there is no data exchange between the module and the network.

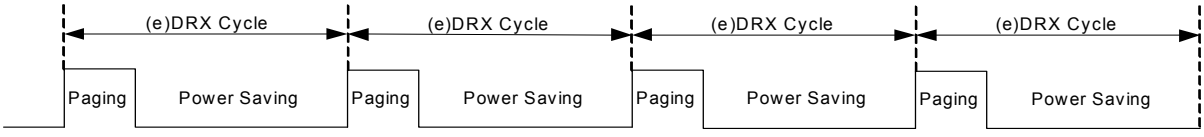
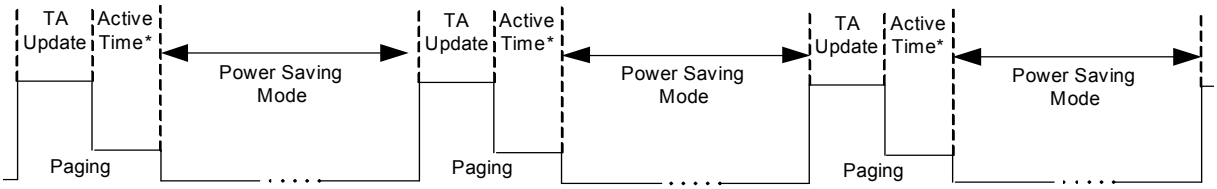


Figure 33: Power saving and paging in LTE networks in DRX and (e)DRX modes

The high level operation of PSM is illustrated in Figure 34. The scenario assumes there is no data exchange between the module and network (except for the minimum required network signaling). The PSM cycles can be very long and for the whole duration of the cycle the module (and the application) is not reachable by the network.



*) In case (e)DRX is configured, it will be applied during Active Time.

Figure 34: Behavior in LTE PSM

The varying pauses explain the different potential for power saving. The longer the pause the less power is consumed. The overall module power saving is not based solely on the LTE power saving features but depends also on other features of the module and its configuration.

3.3.2 Wake-up via RTS0/RTS1

RTS0/RTS1 can be used to wake up EMS31-US from SLEEP mode configured with AT command. Assertion of either RTS0 or RTS1 (i.e., toggle from inactive high to active low) serves as wake up event, thus allowing an external application to almost immediately terminate power saving. After RTS0/RTS1 assertion, the CTS0/CTS1 line signals module wake up, i.e., readiness of the AT command interface. It is therefore recommended to enable RTS/CTS flow control (default setting).

Figure 35 shows the described RTS0/RTS1 wake up mechanism.

- RTS0/RTS1 must be high.
- After a given programmable timeout (100ms up to 10s, default 5s) with no activity on ASC0 and ASC1 (and no data to transmit by module to host in Linux /dev/tty driver), CTS0/CTS1 will be driven high.
- After a 2nd timeout (equal or greater than the duration needed to receive one character at UART baudrate; ex: ~1.05ms for 10bit @ 9600baud), and while RTS0/RTS1 remains high (which means an external application does not request the module to wake up), the module will enter sleep mode.
- Now, the host can wake-up the module driving RTS0/RTS1 from high to low.
- Module will inform the host it is ready to receive over UART by driving CTS0/CTS1 to low.

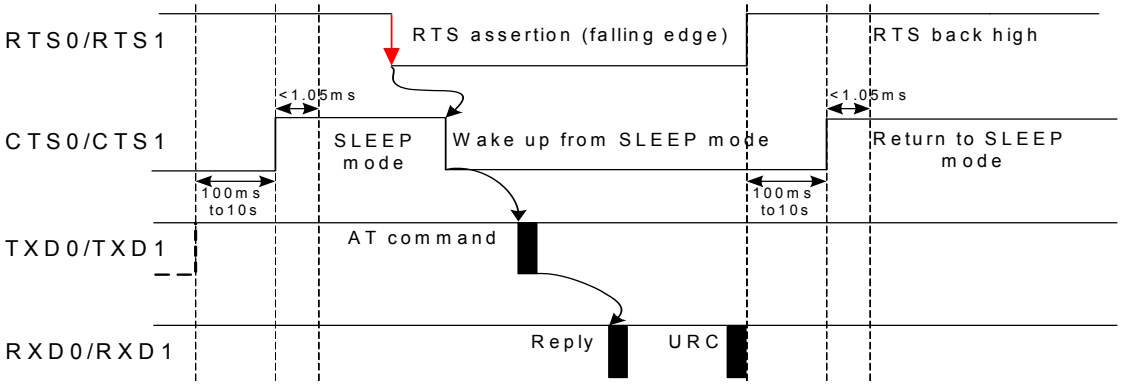


Figure 35: Wake-up via RTS0/RTS1

Note: It is recommended to always have RTS0/RTS1 lines driven by the host application regardless of the module state (active or sleeping). The RTS0/RTS1 has to be high for EMS31-US to be able to change into SLEEP mode.

3.4 Power Supply

The power supply of EMS31-US has to be a single voltage source at BATT+. It must be able to provide the current for all operation modes of the module.

All the key functions for supplying power to the device are handled by the power management section of the analog controller. This IC provides the following features:

- Stabilizes the supply voltages for the baseband using low drop linear voltage regulators and a DC-DC step down switching regulator.
- Switches the module's power voltages for the power-up and -down procedures.
- SIM switch to provide SIM power supply.

3.4.1 Power Supply Ratings

Table 12 and Table 13 assemble various voltage supply and current consumption ratings of the module.

Table 12: Voltage supply ratings

	Description	Conditions	Min	Type	Max	Unit
BATT+	Supply voltage	Directly measured at Module. Voltage must stay within the min/max values, including voltage drop, ripple, spikes	3.2V		5.5	V
	Voltage ripple	Normal condition, power control level for Pout max at f <= 250 kHz at f > 250 kHz			 110 30	 mV_{pp} mV_{pp}

Table 13: Current consumption ratings

	Description	Conditions		Power [mW]	Typical rating at 3.8V [mA]
I_{BATT+}	Power Down Mode			TBD	TBD
	Airplane mode			TBD	TBD
	LTE PSM	Dormant state		TBD	TBD
	LTE extended DRX	Paging cycle @ 10.24s Paging cycle @ 43min		TBD	TBD
	LTE IDLE	RRC Paging cycle @ 2.56 s		TBD	TBD
		RRC Paging cycle @ 1.28 s		TBD	TBD
	LTE DATA	LTE cDRX mode No traffic	cDRX period 320ms	TBD	TBD
		LTE FDD CatM1 DL/ UL 375Kbps/ 300Kbps	B4, 1.4MHz 23 dBm	TBD	TBD
			B13 1.4MHz 23dBm	TBD	TBD
		Cell search		TBD	TBD

3.4.2 Minimizing Power Losses

When designing the power supply for your application please pay specific attention to power losses. Ensure that the input voltage of BATT+ never drops below 3.2V on the EMS31-US board.

3.4.3 Measuring the Supply Voltage (BATT+)

To measure the supply voltage of BATT+ it is possible to define two reference points GND, BATT+. GND should be the module's shielding, while BATT+ should be a test pad on the external application the module is mounted on. The external BATT+ reference points have to be connected to and positioned close to the SMT application interface's BATT+ pads 5 or 53 as shown in Figure 36.

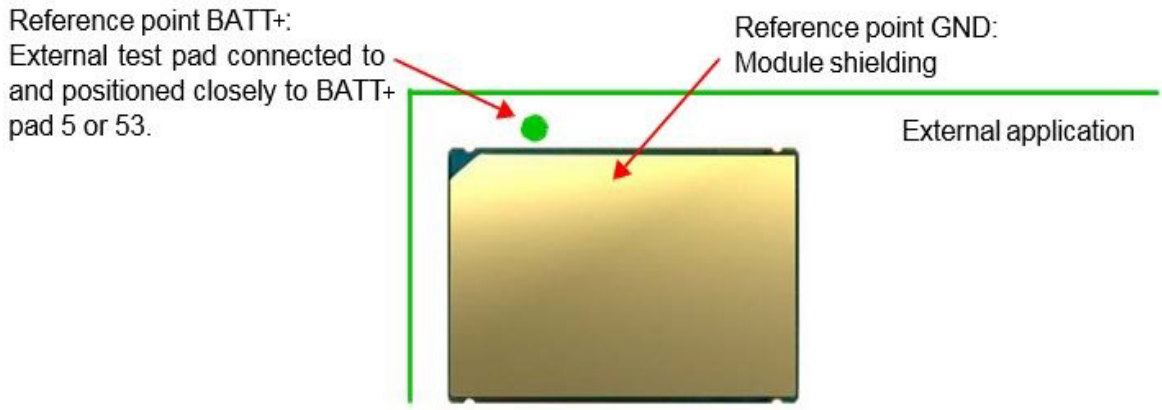


Figure 36: Position of reference points BATT+ and GND

3.4.4 Monitoring Power Supply Using AT Command

To monitor the supply voltage you can also use the AT^SBV command which returns the value related to the reference points BATT+ and GND.

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 TALK/DATA mode to 50 seconds when EMS31-US is in IDLE mode or Limited Service (deregistered). The displayed voltage (in mV) is averaged over the last measuring period before the AT^SBV command was executed.

If the measured voltage drops below or rises above the voltage shutdown thresholds, the module will send an "^SBC" URC and shut down (for details see Section 3.2.5).

3.5 Operating Temperatures

Please note that the module's lifetime, i.e., the MTTF (mean time to failure) may be reduced, if operated outside the extended temperature range.

Table 14: Board temperature

Parameter	Min	Typical	Max	Unit
Normal operation	-30	+25	+85	°C
Extended operation[1]	-40		+95	°C
Automatic shutdown[2] Temperature measured on EMS31-US board	<-40	-	>+95	°C

1. Extended operation allows normal mode data transmission for limited time until automatic thermal shutdown takes effect. Within the expended temperature range (outside normal operating temperature range) the specified electrical characteristics may be in- or decreased.
2. Due to temperature measurement uncertainly, a tolerance of ±3°C on the threshold may occur.

See also Section 3.2.5 for information about the NTC for on-board temperature measurement, automatic thermal shutdown and alert messages.

Note: 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.

3.6 Electrostatic Discharge

The LTE 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 EMS31-US module.

Interfaces of EMS31-US 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-001-2014 requirements.

EMS31-US has been tested according to following standards. Electrostatic values can be gathered from the following table.

Table 15: Electronic values

Specification/Requirements	Contact discharge	Air discharge
ANSI/ESDA/JEDEC JS-001-2014		
All SMT interfaces	±4kV Human Body Model	n.a.
ANSI/ESDA/JEDEC JS-002-2014		
All SMT interfaces	±500VCharge Device Model (CDM)	n.a.

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 reference application described in Section 5.3.

3.6.1 ESD Protection for Antenna Interface

The following Figure 37 shows how to implement an external ESD protection for the RF antenna interface with a T pad attenuator circuit (for RF line routing design see also Section 2.2.3).

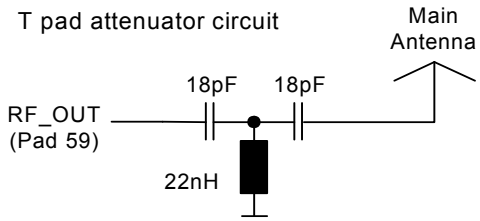


Figure 37: ESD protection for RF antenna interface

Recommended inductor types for the above sample circuit: Size 0402 SMD from Panasonic ELJRF series (22nH).

3.7 Blocking against RF on Interface Lines

To reduce EMI issues there are serial resistors, or capacitors to GND, implemented on the module for the ignition, emergency restart, and SIM interface lines (see Section 2.3). However, all other signal lines have no EMI measures on the module and there are no blocking measures at the module's interface to an external application.

Dependent on the specific application design, it might be useful to implement further EMI measures on some signal lines at the interface between module and application. These measures are described below.

There are three possible variants of EMI measures (A-C) that may be implemented between module and external application depending on the signal line (see Figure 38 and Table 16). Pay attention not to exceed the maximum input voltages and prevent voltage overshots if using inductive EMC measures.

The maximum value of the serial resistor should be lower than 1kΩ on the signal line. The maximum value of the capacitor should be lower than 50pF on the signal line. Please observe the electrical specification of the module's SMT application interface and the external application's interface.

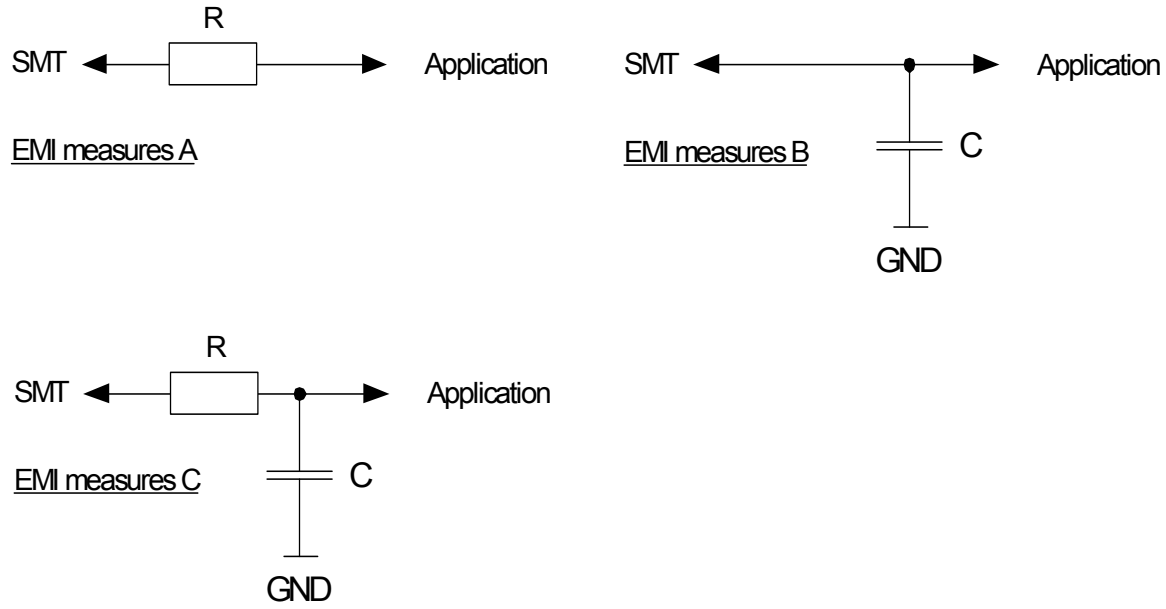


Figure 38: EMI circuits

Note: In case the application uses an internal antenna that is implemented close to the EMS31-US module, Gemalto strongly recommends sufficient EMI measures, e.g. of type B or C, for each digital input or output.

The following table lists for each signal line at the module's SMT application interface the EMI measures that may be implemented.

Table 16: EMI measures on the application interface

Signal name	EMI measures			Remark
	A	B	C	
CCIN	x			
CCRST	x	x	x	The external capacitor should be not higher than 10pF. The value of the capacitor depends on the external application.
CCIO	x	x	x	
CCCLK	x	x	x	
RXD0	x	x	x	
TXD0	x	x	x	
CTS0	x	x	x	
RTS0	x	x	x	
GPIO1/DTR0	x	x	x	
GPIO2/DCD0	x	x	x	
GPIO3/DSR0	x	x	x	
GPIO4/FST_SHDN*	x	x	x	
GPIO5/LED*	x	x	x	
GPIO6/PWM2*	x	x	x	
GPIO7/PWM1*	x	x	x	
GPIO8/COUNTER*	x	x	x	
GPIO16/RXD1	x	x	x	
GPIO17/TXD1	x	x	x	
GPIO18/RTS1	x	x	x	
GPIO19/CTS1	x	x	x	
GPIO20	x	x	x	
GPIO21	x	x	x	
GPIO22	x	x	x	
GPIO23/SCLK	x	x	x	
GPIO24/RING0	x	x	x	
GPIO25	x	x	x	
GPIO26/SPI*_CS1	x	x	x	
GPIO27/SPI*_CS2	x	x	x	
I2CCLK*		x		The rising signal edge is reduced with an additional capacitor.
I2CDAT*		x		
V180		x		
VCORE		x		
BATT+		X		Measures required if BATT+ is close to internal LTE antenna - e.g., 39pF blocking capacitor to ground

*) Note: The following features are not yet available with the current product release: GPIO, I^2C, Pulse Counter, PWM, FST_SHDN, and SPI.

3.8 Reliability Characteristics

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

Table 17: Summary of reliability test conditions

Test type	Conditions	Standard
Vibration	Frequency range: 10-20Hz; acceleration: 5g Frequency range: 20-500Hz; acceleration: 20g Duration: 2h per 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.

4 Mechanical Dimensions, Mounting and Packaging

The following sections describe the mechanical dimensions of EMS31-US and give recommendations for integrating EMS31-US into the host application.

4.1 Mechanical Dimensions of EMS31-US

Figure 39 shows the top and bottom view of EMS31-US and provides an overview of the board's mechanical dimensions. For further details see Figure 40.

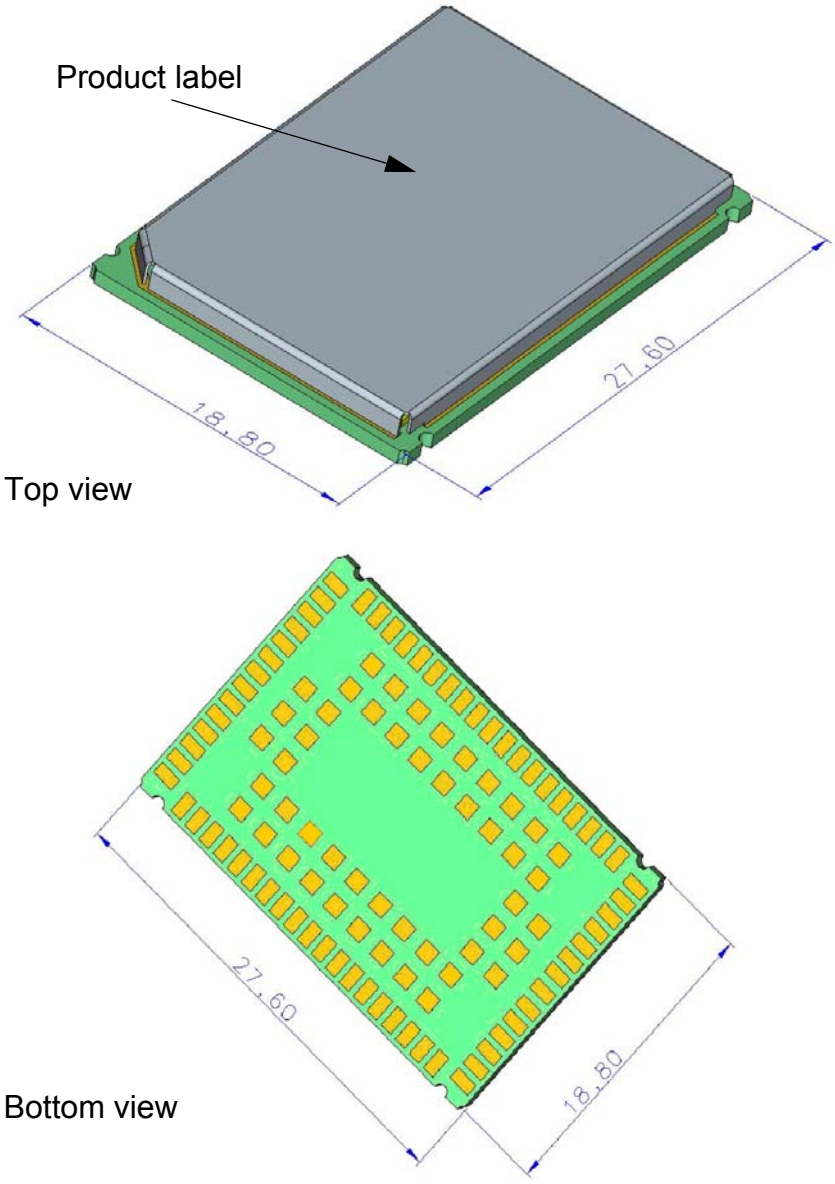


Figure 39: EMS31-US - top and bottom view

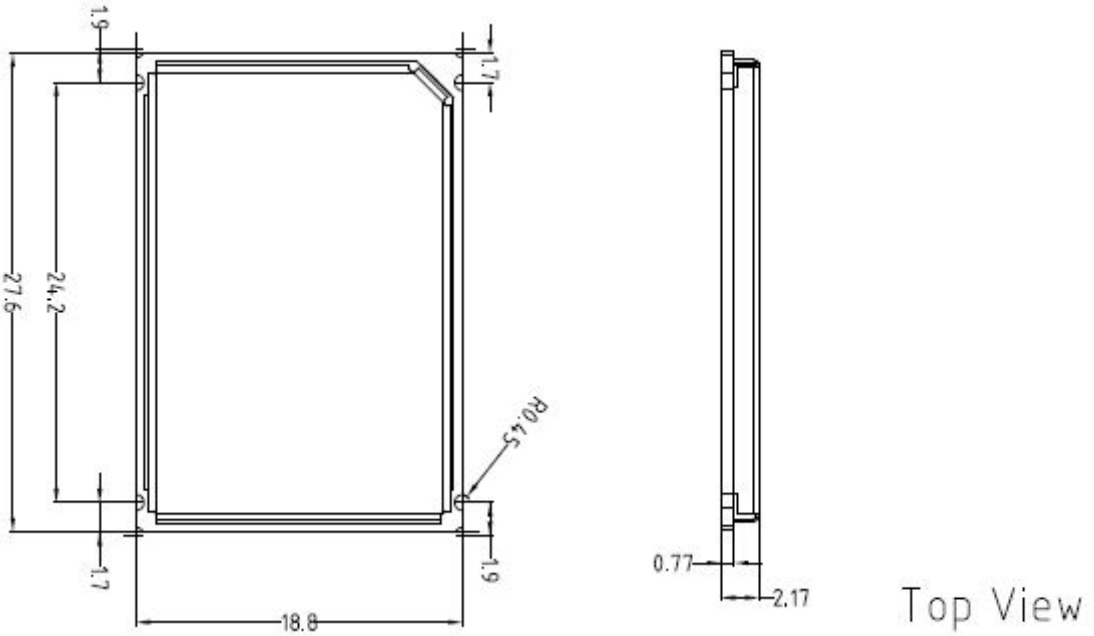


Figure 40: Dimensions of EMS31-US (all dimensions in mm)

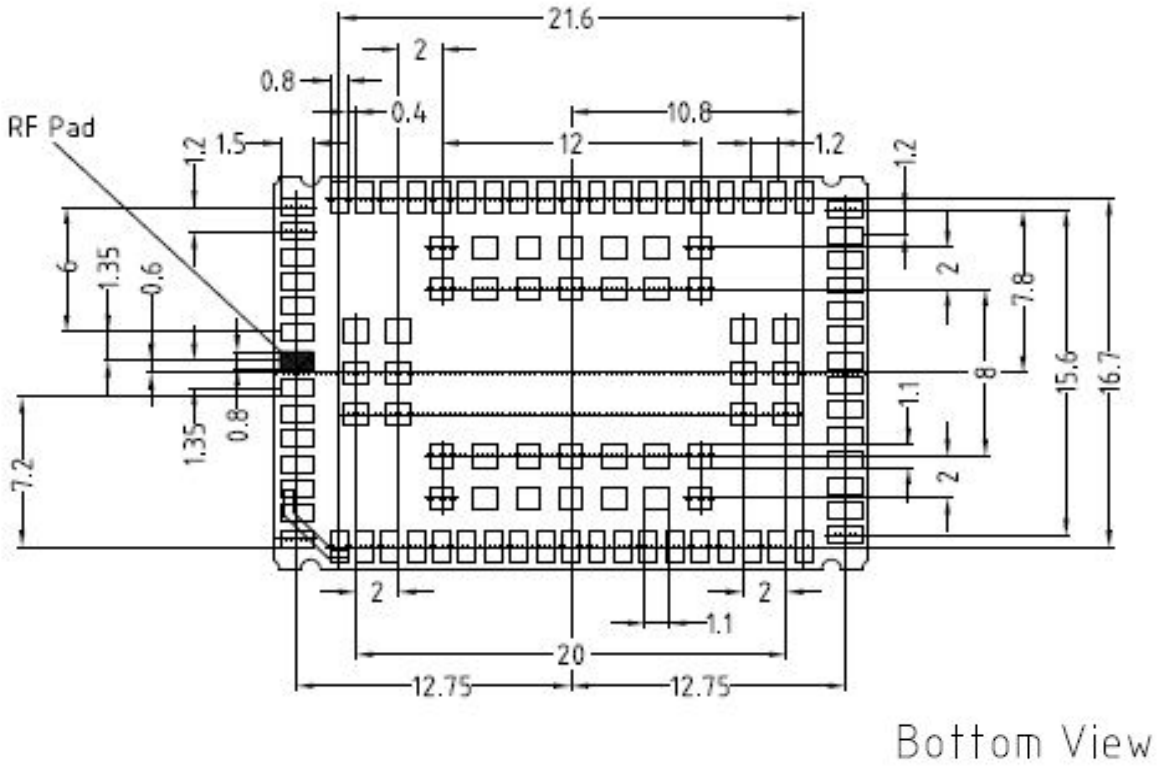


Figure 41: Dimensions of EMS31-US (all dimensions in mm) - bottom view

4.2 Mounting EMS31-US onto the Application Platform

This section describes how to mount EMS31-US onto the PCBs (=printed circuit boards), including land pattern and stencil design, board-level characterization, soldering conditions, durability and mechanical handling. For more information on issues related to SMT module integration. See also [3].

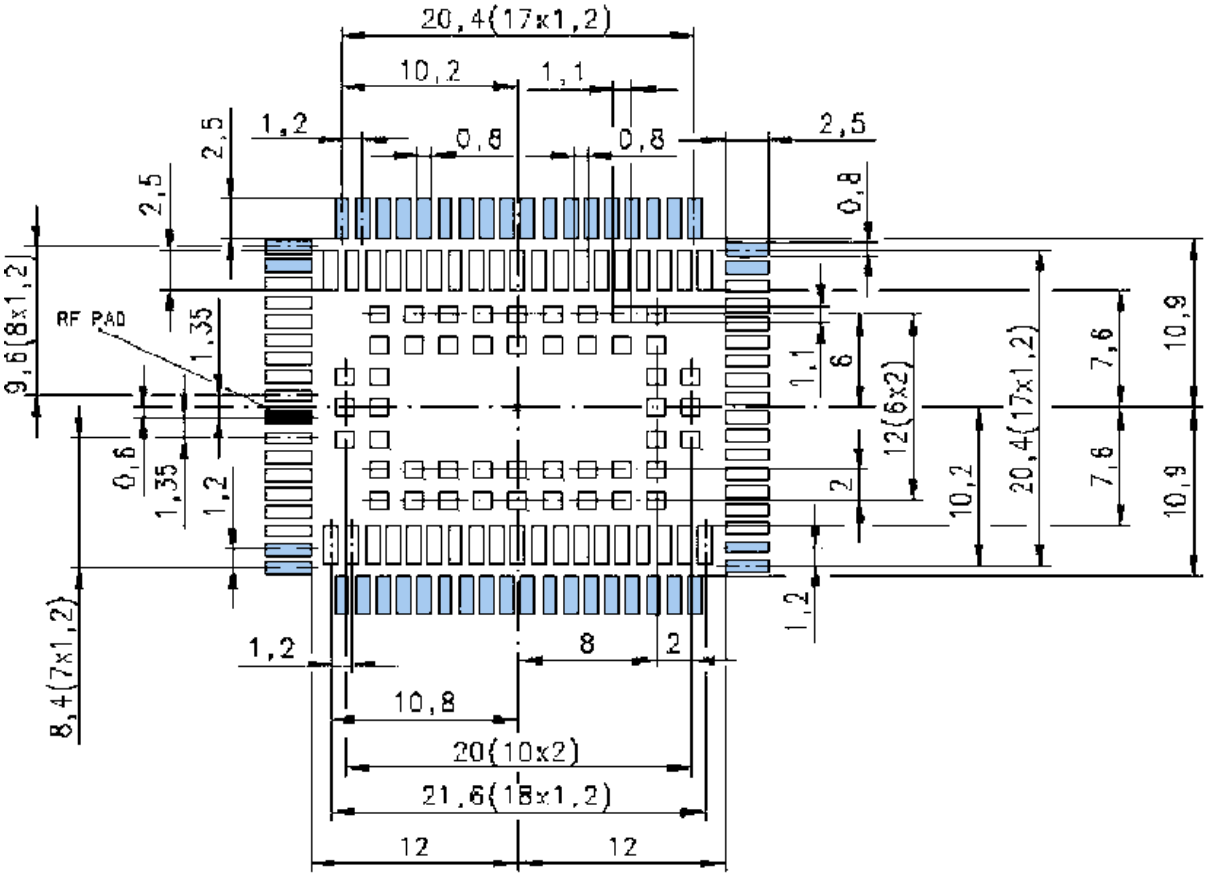
Note: To avoid short circuits between signal tracks on an external application's PCB and various markings at the bottom side of the module, it is recommended not to route the signal tracks on the top layer of an external PCB directly under the module, or at least to ensure that signal track routes are sufficiently covered with solder resist.

4.2.1 SMT PCB Assembly

4.2.1.1 Land Pattern and Stencil

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

The combined land pattern given in Figure 42 reflects the module's pad layout, including signal pads and ground pads (for pad assignment see Section 2.1.1)

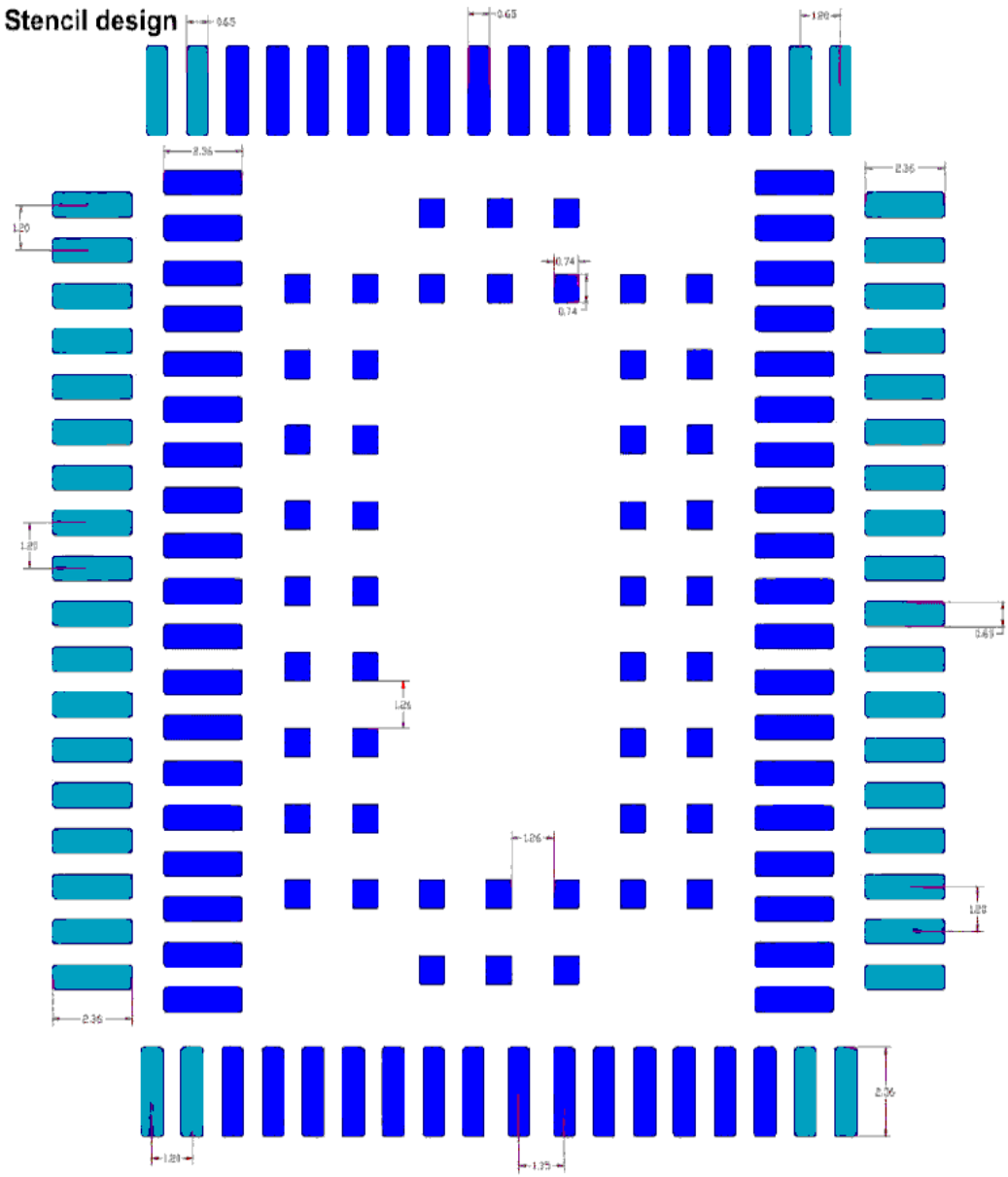


Note: Pins marked with light blue are pins compatible with other modules.

Figure 42: Combined land pattern (top view)

The stencil design illustrated in Figure 43 is recommended by Gemalto M2M as a result of extensive tests with Gemalto M2M Daisy Chain modules.

Note that depending on co-planarity or other properties of the external PCB, it could be that all of the central ground pads may have to be soldered. For this reason the land pattern design shown in Figure 42 provides for both of these alternatives and only a modification of the stencil may be needed.



Note: Pins marked with light blue are pins compatible with other modules

Figure 43: Recommended design for 150 micron thick stencil (top view, dual design)

4.2.1.2 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. For more information on issues related to SMT module integration see also [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 4.2.1.1. 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 4.2.3.

4.2.2 Moisture Sensitivity Level

EMS31-US comprises components that are susceptible to damage induced by absorbed moisture.

Gemalto M2M's EMS31-US module complies with the latest revision of the IPC/JEDEC J-STD-020 Standard for moisture sensitive surface mount devices and is classified as MSL 4.

For additional MSL (=moisture sensitivity level) related information see Section 4.2.4 and Section 4.3.2.

4.2.3 Soldering Conditions and Temperature

4.2.3.1 Reflow Profile

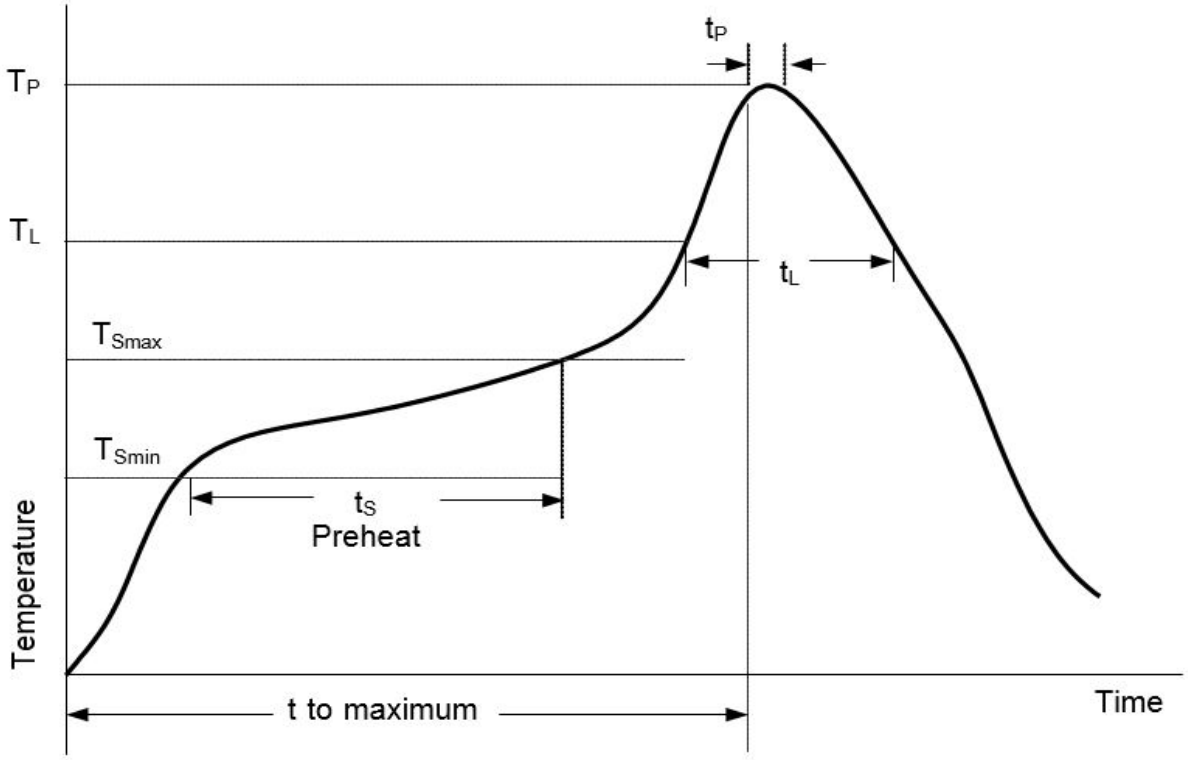


Figure 44: Reflow profile

Table 18: 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)	TBD°C +0/-10°C
Time (t_P) within 5 °C of the peak package body temperature (T_P)	TBD seconds max.
Average ramp-down rate (T_P to T_{Smax})	3 K/second max
Time 25°C to maximum temperature	6 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].

4.2.3.2 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 TBD°C. This specifies the temperature as measured at the module's top side.
- A maximum duration of TBD 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.

EMS31-US is specified for one soldering cycle only. Once EMS31-US is removed from the application, the module will very likely be destroyed and cannot be soldered onto another application.

4.2.4 Durability and Mechanical Handling

4.2.4.1 Storage Conditions

EMS31-US modules, as delivered in tape and reel carriers, must be stored in sealed, moisture barrier anti-static bags. The conditions stated below are only valid for modules in their original packed state in weather protected, non-temperature-controlled storage locations. Normal storage time under these conditions is 12 months maximum.

Table 19: Storage conditions

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

4.2.4.2 Processing Life

EMS31-US must be soldered to an application within 72 hours after opening the MBB (=moisture barrier bag) it was stored in.

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

4.2.4.3 Baking

Baking conditions are specified on the moisture sensitivity label attached to each MBB (see Figure 48 for details):

- It is *not necessary* to bake EMS31-US, if the conditions specified in Section 4.2.4.1 and Section 4.2.4.2 were not exceeded.
- It is *necessary* to bake EMS31-US, if any condition specified in Section 4.2.4.1 and Section 4.2.4.2 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.

4.2.4.4 Electrostatic Discharge

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

Please refer to Section 3.6 for more information on electrostatic discharge.

4.3 Packaging

4.3.1 Tape and Reel

The single-feed tape carrier for EMS31-US is illustrated in Figure 45. The figure also shows the proper part orientation. The tape width is 44 mm and the EMS31-US modules are placed on the tape with a 28-mm pitch. The reels are 330 mm in diameter with a core diameter of 100 mm. Each reel contains 500 modules.

4.3.1.1 Orientation

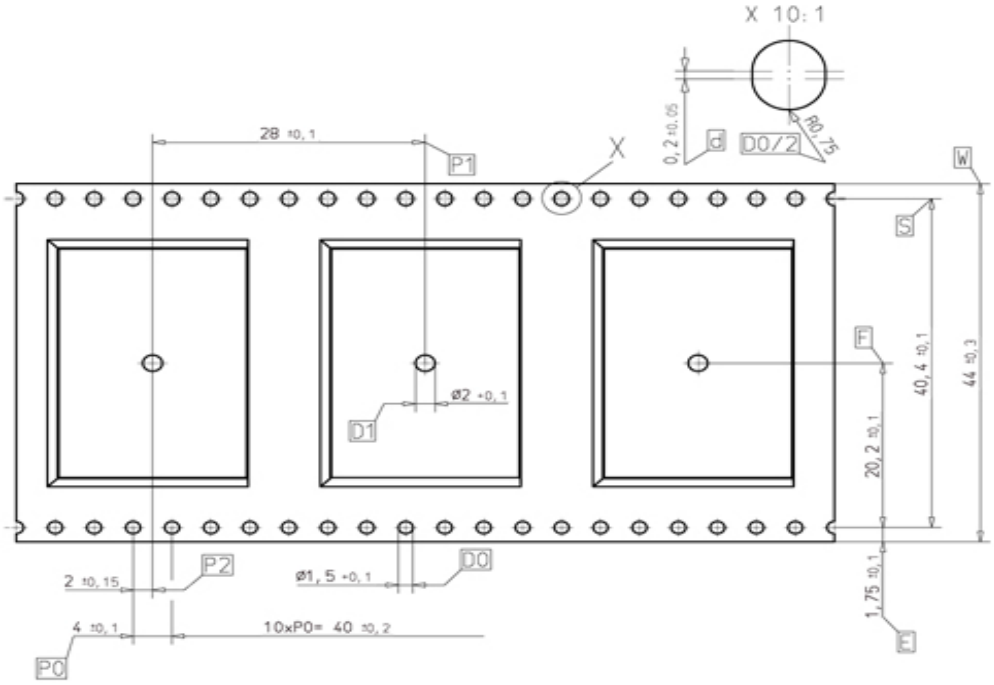


Figure 45: Carrier tape

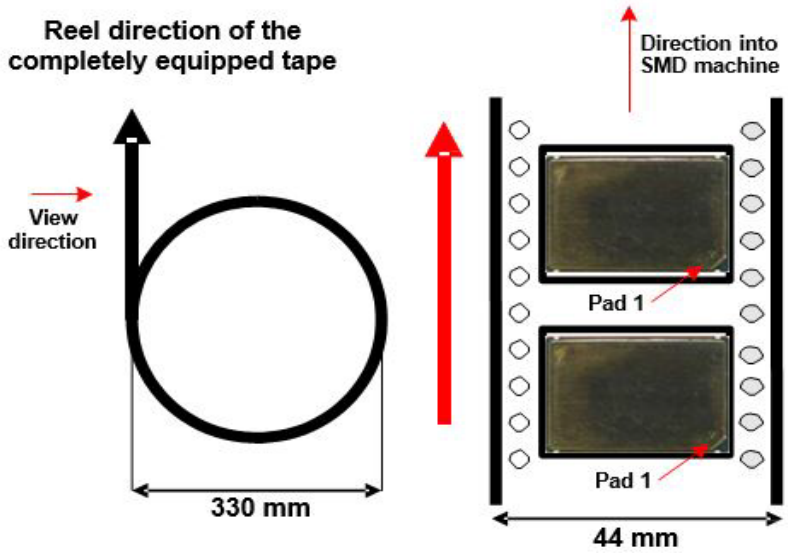


Figure 46: Reel direction

4.3.1.2 Barcode Label

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

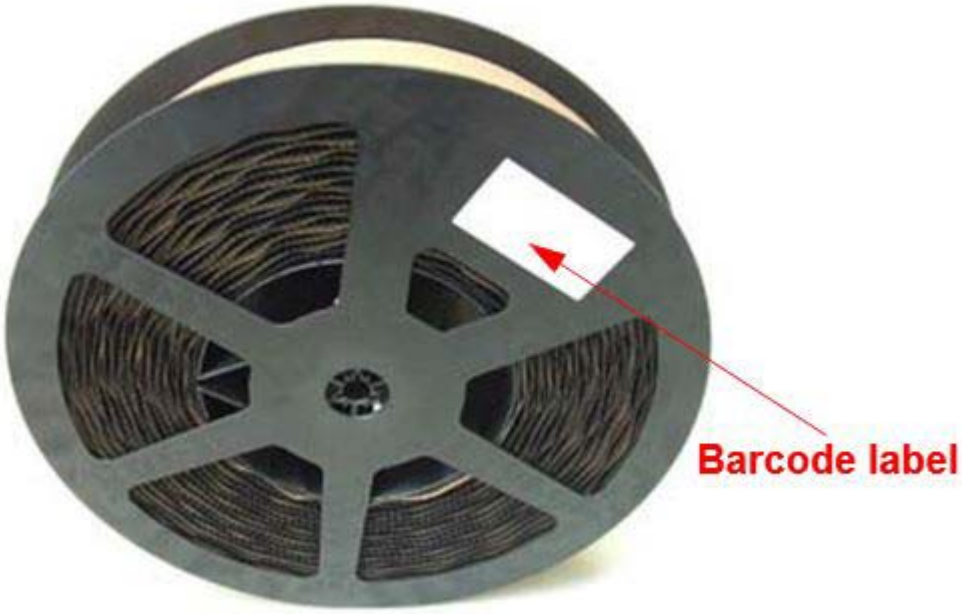


Figure 47: Barcode label on tape reel

4.3.2 Shipping Materials

EMS31-US is distributed in tape and reel carriers. The tape and reel carriers used to distribute EMS31-US are packed as described below, including the following required shipping materials:

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

4.3.2.1 Moisture Barrier Bag

The tape reels are stored inside an MBB (=moisture barrier bag), together with a humidity indicator card and desiccant pouches - see Figure 48. 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 EMS31-US modules from moisture exposure. It should not be opened until the devices are ready to be soldered onto the application.

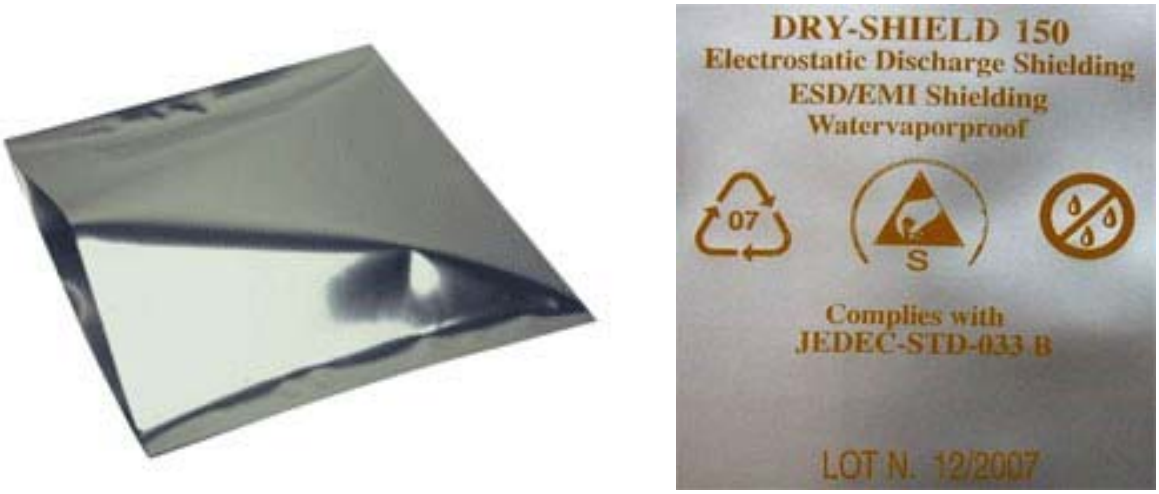


Figure 48: Moisture barrier bag (MBB) with imprint

The label shown in Figure 49 summarizes requirements regarding moisture sensitivity, including shelf life and baking requirements. It is attached to the outside of the moisture barrier bag.

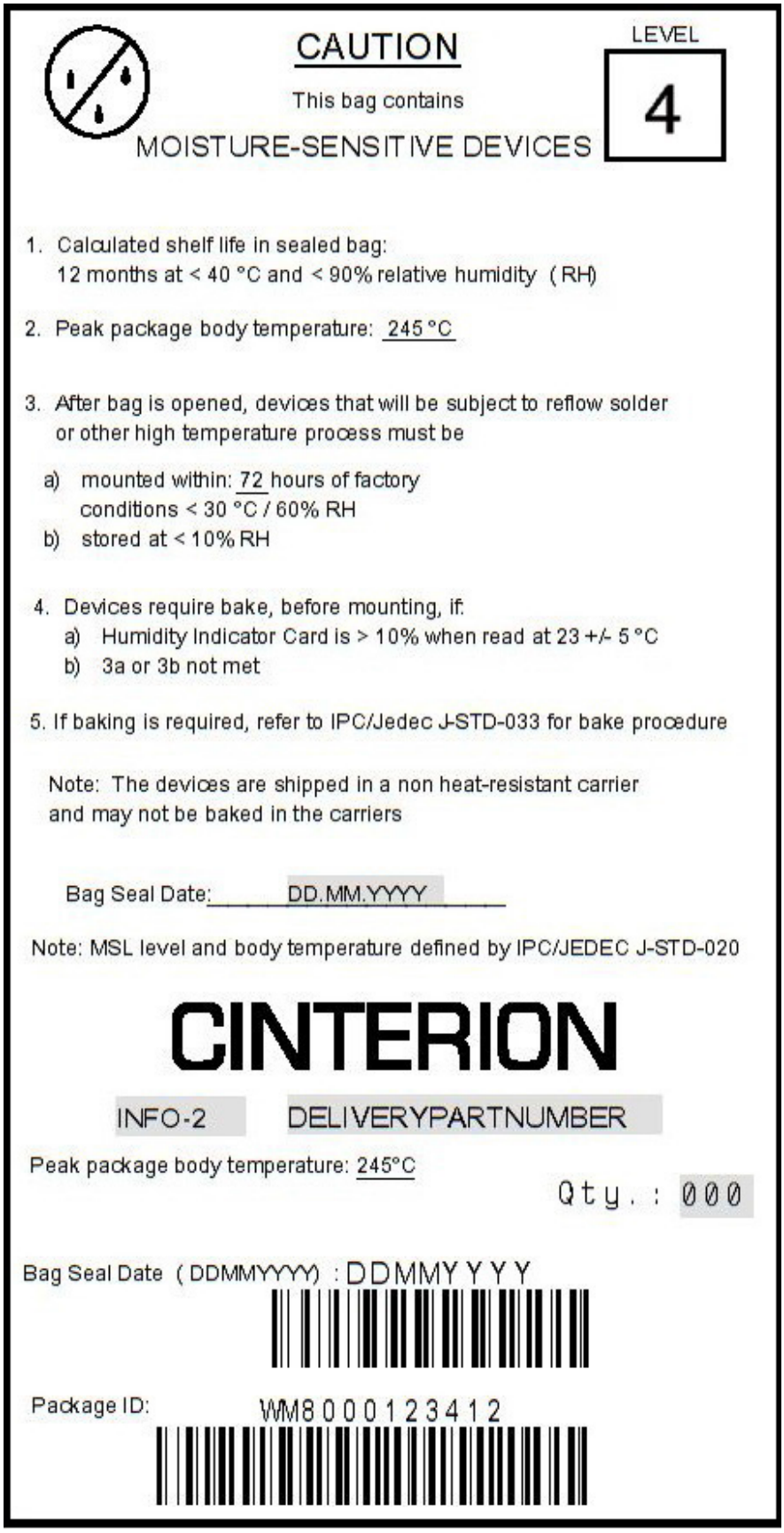


Figure 49: Moisture sensitivity label

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

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

The humidity indicator card is a moisture indicator and is included in the MBB to show the approximate relative humidity level within the bag. Sample humidity cards are shown in Figure 50. If the components have been exposed to moisture above the recommended limits, the units will have to be re-baked.

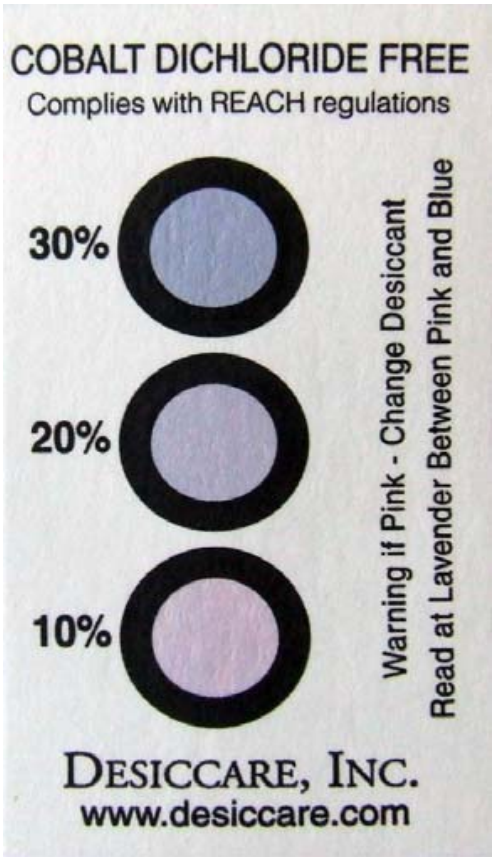


Figure 50: Humidity indicator card - HIC

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

4.3.2.2 Transportation Box

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

4.3.3 Trays

If small module quantities are required, e.g., for test and evaluation purposes, EMS31-US may be distributed in trays (for dimensions see Figure 54). The small quantity trays are an alternative to the single-feed tape carriers normally used. However, the trays are not designed for machine processing. They contain modules to be (hand) soldered onto an external application (for more information on hand soldering see [3]).

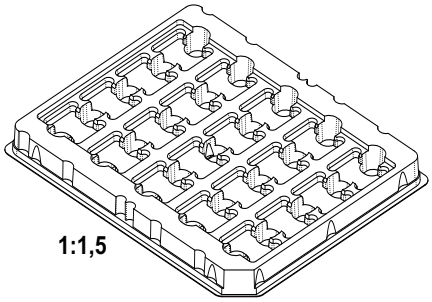


Figure 51: Small quantity tray

Trays are packed and shipped in the same way as tape carriers, including a moisture barrier bag with desiccant and humidity indicator card as well as a transportation box (see also Section 4.2.3).

Figure 52: Tray to ship odd module amounts

Figure 53: Tray with packaging materials

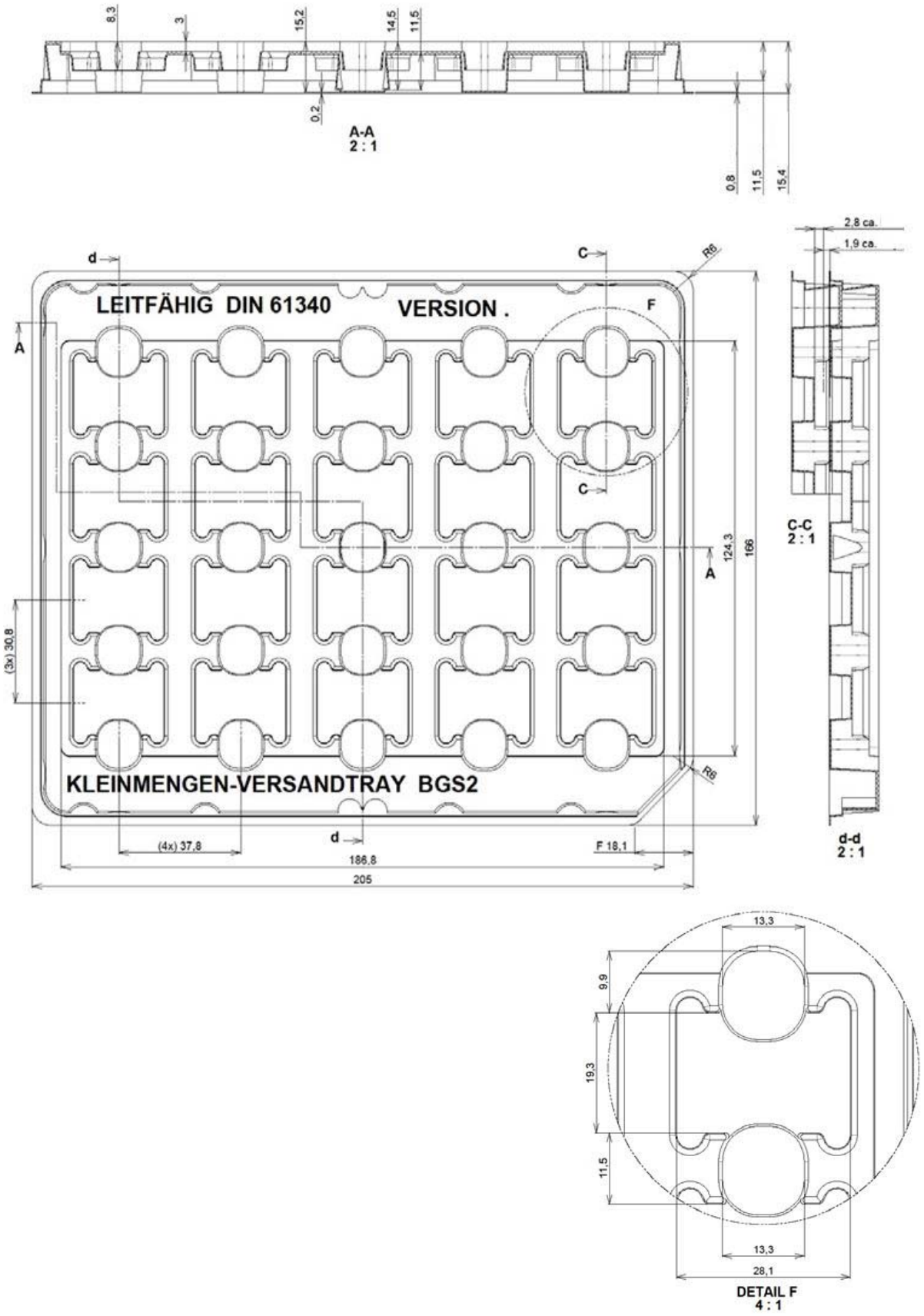


Figure 54: Tray dimensions

5 Regulatory and Type Approval Information

5.1 Directives and Standards

EMS31-US is 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 "EMS31-US Hardware Interface Description".

Table 20: Directives

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)

Table 21: Standards of North American type approval

CFR Title 47	Code of Federal Regulations, Part 22 and Part 24 (Telecommunications, PCS); US Equipment Authorization FCC
OET Bulletin 65 (Edition 97-01)	Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields
UL 60 950-1	Product Safety Certification (Safety requirements)
California Leadfree Mandate	Covered by European RoHS requirements
RSS130 (Issue 1) RSS133 (Issue 5) RSS139 (Issue 3)	Canadian Standard

Table 22: Standards of GCF and PTCRB type approval

3GPP TS 51.010-1	Digital cellular telecommunications system (Release 13); Mobile Station (MS) conformance specification;
GCF-CC V3.58	Global Certification Forum - Certification Criteria
NAPRD03 V5.32	Version Specific Technical Overview of PTCRB Mobile/User Equipment Type Certification

Table 23: Requirements of quality

IEC 60068	Environmental testing
DIN EN 60529	IP codes

Table 24: 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 Gemalto M2M Hardware Interface Description. Please see Table 25 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 25: 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.

5.2 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 EMS31-US based applications to be evaluated and approved for compliance with national and/or international regulations.

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

Products intended for sale on US markets

ES 59005/ANSI C95.1 Considerations for evaluation of human exposure to Electromagnetic Fields (EMFs) from Mobile Telecommunication Equipment (MTE) in the frequency range 30MHz - 6GHz

Please note that SAR requirements are specific only for portable devices and not for mobile devices as defined below:

- Portable device:
  A portable device is defined as a transmitting device designed to be used so that the radiating structure(s) of the device is/are within 20 centimeters of the body of the user.
- Mobile device:
  A mobile device is defined as a transmitting device designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between the transmitter's radiating structure(s) and the body of the user or nearby persons. In this context, the term "fixed location" means that the device is physically secured at one location and is not able to be easily moved to another location.

5.3 Reference Equipment for Type Approval

The Gemalto M2M reference setup submitted to type approve EMS31-US (including a special approval adapter for the DSB75) is shown in the following figure[1]:

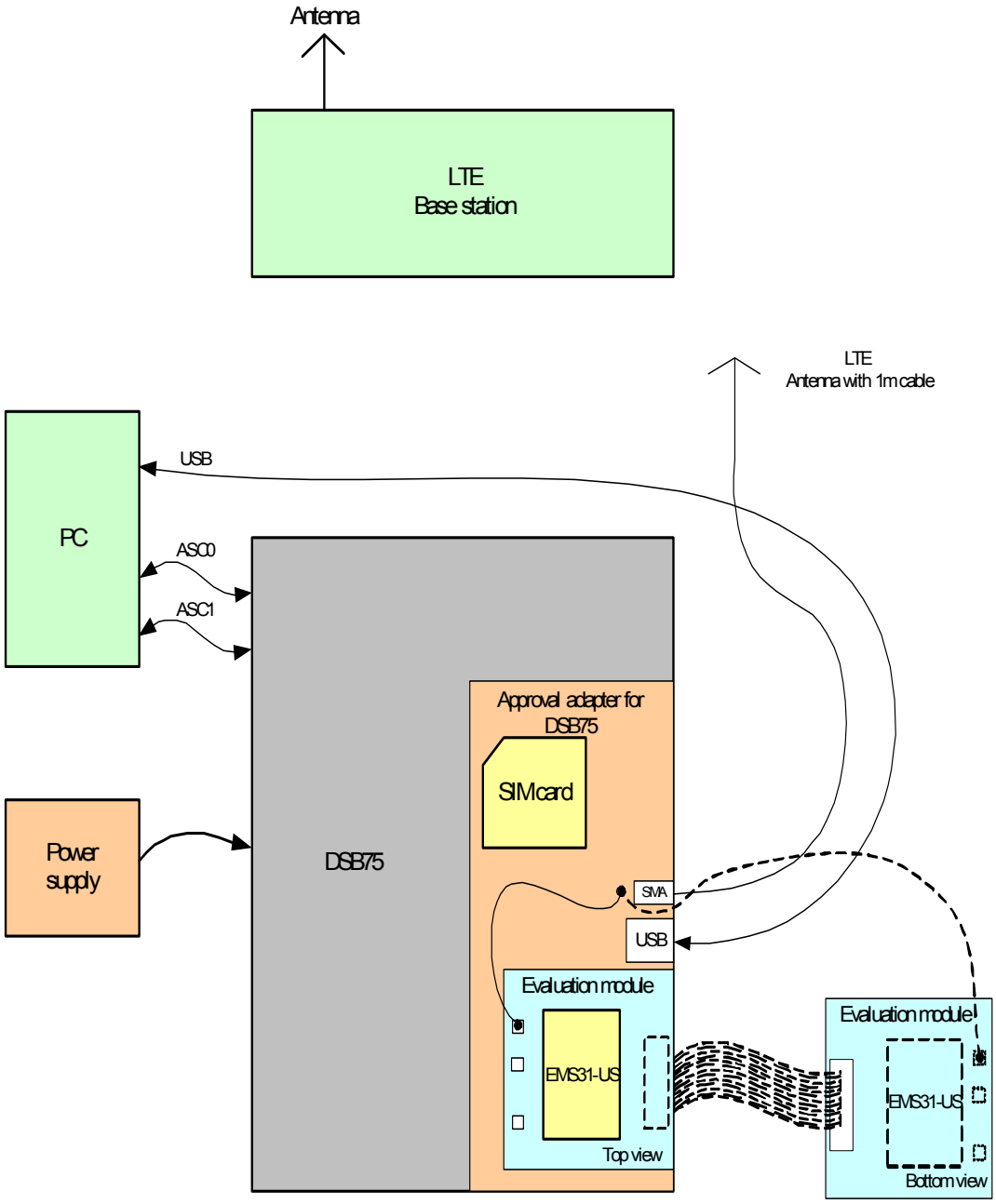


Figure 55: Reference equipment for Type Approval

1. For RF performance tests a mini-SMT/U.FL to SMA adapter with attached 6dB coaxial attenuator is chosen to connect the evaluation module directly to the LTE test equipment instead of employing the SMA antenna connectors on the EMS31-US-DSB75 adapter as shown in Figure 55. The following products are recommended:
   Hirose SMA-Jack/U.FL-Plug conversion adapter HRMJ-U.FLP(40)
   (for details see see http://www.hirose-connectors.com/ or http://www.farnell.com/
   Aeroflex Weinschel Fixed Coaxial Attenuator Model 3T/4T
   (for details see http://www.aeroflex.com/ams/weinschel/pdfiles/wmod3&4T.pdf)

5.4 Compliance with FCC and ISED Rules and Regulations

The Equipment Authorization Certification for the Gemalto M2M reference application described in Section 5.3 will be registered under the following identifiers:

- *EMS31-US:*
  FCC Identifier: QIPEMS31-US
  Innovation, Science and Economic Development Canada: 7830A-EMS31US
  Granted to Gemalto M2M GmbH

Manufacturers of mobile or fixed devices incorporating EMS31-US modules are authorized to use the FCC Grants and Innovation, Science and Economic Development Certificates of the EMS31-US modules for their own final products according to the conditions referenced in these documents. In this case, an FCC/ ISED label of the module shall be visible from the outside, or the host device shall bear a second label stating "Contains FCC ID: QIPEMS31-US", and accordingly “Contains IC: 7830A-EMS31US“. The integration is limited to fixed or mobile categorized host devices, where a separation distance between the antenna and any person of min. 20cm can be assured during normal operating conditions.

For mobile and fixed operation configurations the antenna gain, including cable loss, must not exceed the limits in the following Table 26 for FCC and ISED.

Table 26: Antenna gain limits for FCC and ISED

Operating band	FCC limit	ISED limit	Unit
Maximum gain in higher operating bands with f=1900MHz (LTE Bd2)	12.0	8.5	dBi
Maximum gain in higher operating bands with f=1700MHz (LTE Bd4)	12.0	8.3	dBi
Maximum gain in lower operating bands with f< 1GHz (LTE Bd12)	8.7	5.6	dBi

IMPORTANT:
Manufacturers of portable applications incorporating EMS31-US modules are required to have their final product certified and apply for their own FCC Grant and Innovation, Science and Economic Development Certificate related to the specific portable mobile. This is mandatory to meet the SAR requirements for portable mobiles (see Section 5.2 for detail).

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

Note: Manufacturers/OEM Integrators must ensure that the final user documentation does not contain any information on how to install or remove the module from the final product.

Notes (FCC):

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

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

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

Notes (ISED):

(EN) This Class B digital apparatus complies with Canadian ICES-003 and RSS-210. Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

(FR) Cet appareil numérique de classe B est conforme aux normes canadiennes ICES-003 et RSS-210. Son fonctionnement est soumis aux deux conditions suivantes: (1) cet appareil ne doit pas causer d'interférence et (2) cet appareil doit accepter toute interférence, notamment les interférences qui peuvent affecter son fonctionnement.

(EN) Radio frequency (RF) Exposure Information
The radiated output power of the Wireless Device is below the Innovation, Science and Economic Development (ISED) radio frequency exposure limits. The Wireless Device should be used in such a manner such that the potential for human contact during normal operation is minimized.
This device has also been evaluated and shown compliant with the ISED RF Exposure limits under mobile exposure conditions (antennas at least 20cm from a person‘s body).

(FR) Informations concernant l'exposltion aux fréquences radio (RF)
La puissance de sortie émise par l'appareil de sans fil est inférieure à la limite d'exposition aux fréquences radio d’Innovation, Sciences et Développement économique Canada (ISDE). Utilisez l'appareil de sans fil de façon à minimiser les contacts humains lors du fonctionnement normal.

Ce périphérique a également été évalué et démontré conforme aux limites d'exposition aux RF d'ISDE dans des conditions d'exposition à des appareils mobiles (les antennes se situent à moins de 20cm du corps d'une personne).

6 Document Information

6.1 Revision History

New document: Cinterion® EMS31-US Hardware Interface Description Version **00.105**

Chapter	What is new
--	Initial document setup

6.2 Related Documents

[1] EMS31-US AT Command Set
[2] EMS31-US Release Note
[3] Application Note 48: SMT Module Integration
[4] Universal Serial Bus Specification Revision 2.0, April 27, 2000

6.3 Terms and Abbreviations

Abbreviation	Description
ADC	Analog-to-digital converter
AGC	Automatic Gain Control
ANSI	American National Standards Institute
ARFCN	Absolute Radio Frequency Channel Number
ARP	Antenna Reference Point
ASC0/ASC1	Asynchronous Controller. Abbreviations used for first and second serial interface of the module
B	Thermistor Constant
BER	Bit Error Rate
BTS	Base Transceiver Station
CB or CBM	Cell Broadcast Message
CE	Conformité Européene (European Conformity)
CHAP	Challenge Handshake Authentication Protocol
CPU	Central Processing Unit
CS	Coding Scheme
CSD	Circuit Switched Data
CTS	Clear to Send
DAC	Digital-to-Analog Converter
DAI	Digital Audio Interface
dBm0	Digital level, 3.14dBm0 corresponds to full scale, see ITU G.711, A-law
DCE	Data Communication Equipment (typically modems, e.g. Gemalto M2M module)
DCS 1800	Digital Cellular System, also referred to as PCN
DNI	Does not implemented
DRX	Discontinuous Reception
DSB	Development Support Box
DSP	Digital Signal Processor
DSR	Data Set Ready
DTE	Data Terminal Equipment (typically computer, terminal, printer or, for example, GSM application)

Abbreviation	Description
DTR	Data Terminal Ready
DTX	Discontinuous Transmission
eDRX	Enhanced Discontinuous Reception
EFR	Enhanced Full Rate
EGSM	Enhanced GSM
EIRP	Equivalent Isotropic Radiated Power
EMC	Electromagnetic Compatibility
ERP	Effective Radiated Power
ESD	Electrostatic Discharge
ETS	European Telecommunication Standard
FCC	Federal Communications Commission (U.S.)
FDMA	Frequency Division Multiple Access
FR	Full Rate
GMSK	Gaussian Minimum Shift Keying
GPIO	General Purpose Input/Output
GPRS	General Packet Radio Service
GSM	Global Standard for Mobile Communications
HiZ	High Impedance
HR	Half Rate
HSIC	High-Speed Inter-Chip
I/O	Input/Output
IC	Integrated Circuit
IMEI	International Mobile Equipment Identity
ISO	International Standards Organization
ITU	International Telecommunications Union
kbps	kbits per second
LED	Light Emitting Diode
Li-Ion/Li+	Lithium-Ion
Li battery	Rechargeable Lithium Ion or Lithium Polymer battery
LTE	Long Term Evolution
Mbps	Mbits per second
MIM	Machine Identification Module
MMI	Man Machine Interface
MO	Mobile Originated
MS	Mobile Station (GSM module), also referred to as TE
MSISDN	Mobile Station International ISDN number
MT	Mobile Terminated

Abbreviation	Description
NI	Not implemented
NTC	Negative Temperature Coefficient
OEM	Original Equipment Manufacturer
PA	Power Amplifier
PAP	Password Authentication Protocol
PBCCH	Packet Switched Broadcast Control Channel
PCB	Printed Circuit Board
PCL	Power Control Level
PCM	Pulse Code Modulation
PCN	Personal Communications Network, also referred to as DCS 1800
PCS	Personal Communication System, also referred to as GSM 1900
PLL	Phase Locked Loop
PPP	Point-to-point protocol
PTCRB	PCS Type Certification Review Board
PSK	Phase Shift Keying
PSU	Power Supply Unit
RAM	Random Access Memory
RED	Radio Equipment Directive
RF	Radio Frequency
RLS	Radio Link Stability
RoHS	Restriction of the use of certain hazardous substances in electrical and electronic equipment.
RTS	Request to Send
Rx	Receive Direction
SAR	Specific Absorption Rate
SAW	Surface Acoustic Wave
SDIO	Secure Digital Input Output
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
TA	Terminal adapter (e.g. GSM module)
TDMA	Time Division Multiple Access
TE	Terminal Equipment, also referred to as DTE
TLS	Transport Layer Security
Tx	Transmit Direction

Abbreviation	Description
UART	Universal asynchronous receiver-transmitter
UICC	Universal Integrated Circuit Card
URC	Unsolicited Result Code
USIM	Universal Subscriber Identity Module
USSD	Unstructured Supplementary Service Data
VSWR	Voltage Standing Wave Ratio

6.4 Safety Precaution Notes

The following safety precautions must be observed during all phases of the operation, usage, service or repair of any cellular terminal or mobile incorporating EMS31-US. 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.
	Road safety comes first! Do not use a hand-held cellular terminal or mobile when driving a vehicle, unless it is securely mounted in a holder for speakerphone operation. Before making a call with a hand-held terminal or mobile, park the vehicle. Speakerphones must be installed by qualified personnel. Faulty installation or operation can constitute a safety hazard.
	IMPORTANT! Cellular terminals or mobiles operate using radio signals and cellular networks. Because of this, connection cannot be guaranteed at all times under all conditions. Therefore, you should never rely solely upon any wireless device for essential communications, for example emergency calls. Remember, in order to make or receive calls, the cellular terminal or mobile must be switched on and in a service area with adequate cellular signal strength. Some networks do not allow for emergency calls if certain network services or phone features are in use (e.g. lock functions, fixed dialing etc.). You may need to deactivate those features before you can make an emergency call. Some networks require that a valid SIM card be properly inserted in the cellular terminal or mobile.

7 Appendix

7.1 List of Parts and Accessories

Table 27: List of parts and accessories

Description	Supplier	Ordering information
EMS31-US	Gemalto M2M	Standard module Gemalto M2M IMEI: Packaging unit (ordering) number: L30960-N4730-A100 Module label number: S30960-S4730-A100-1[1]
EMS31-US Evaluation Module	Gemalto M2M	Ordering number: L30960-N4731-A100
DSB75 Evaluation Kit	Gemalto M2M	Ordering number: L36880-N8811-A100
DSB Mini Compact Evaluation Board	Gemalto M2M	Ordering number: L30960-N0030-A100
Starter Kit B80	Gemalto M2M	Ordering Number L30960-N0040-A100
Multi-Adapter R1 for mounting EMS31-US evaluation modules onto DSB75	Gemalto M2M	Ordering number: L30960-N0010-A100
Approval adapter for mounting EMS31-US evaluation modules onto DSB75	Gemalto M2M	Ordering number: L30960-N2301-A100
SIM card holder incl. push button ejector and slide-in tray	Molex	Ordering numbers: 91228 91236 Sales contacts are listed in Table 28.

1. Note: At the discretion of Gemalto M2M, module label information can either be laser engraved on the module's shielding or be printed on a label adhered to the module's shielding.

Table 28: 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

About Gemalto

Since 1996, Gemalto has been pioneering groundbreaking M2M and IoT products that keep our customers on the leading edge of innovation.

We work closely with global mobile network operators to ensure that Cinterion® modules evolve in sync with wireless networks, providing a seamless migration path to protect your IoT technology investment.

Cinterion products integrate seamlessly with Gemalto identity modules, security solutions and licensing and monetization solutions, to streamline development timelines and provide cost efficiencies that improve the bottom line.

As an experienced software provider, we help customers manage connectivity, security and quality of service for the long lifecycle of IoT solutions.

For more information please visit
www.gemalto.com/m2m, www.facebook.com/gemalto, or Follow@gemaltoIoT on Twitter.

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