Cinterion® ELS31-VA/ELS51-VA

Hardware Interface Description

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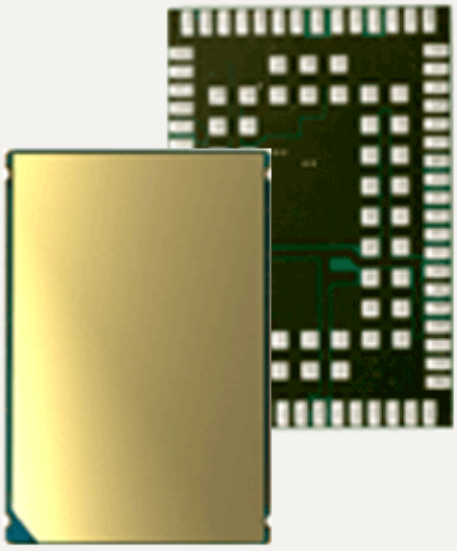

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1 Introduction

This document[1] describes the hardware of the Cinterion® ELS31-VA and ELS51-VA modules for Verizon Networks. It helps you quickly retrieve interface specifications, electrical and mechanical details and information on the requirements to be considered for integrating further components.

The ELS31-VA and ELS51-VA modules include a baseband, a complete dual band RF front-end, memory and required circuitry to meet 3GPP E-UTRA (Long Term Evolution - LTE, Release 10 set of specifications) and Verizon Wireless LTE UE specifications.

The module variants differentiate a follows:
- ELS31-VA provides LTE connectivity with IP Services
- ELS51-VA adds a Linux execution environment available for customer applications

1.1 Key Features at a Glance

Feature	Implementation
General	
Frequency bands	LTE dualband: B4, B13
Output power	Class 3 (+23dBm +-2dB) for LTE AWS, LTE B4 Class 3 (+23dBm +-2dB) for LTE 700, LTE FDD B13
Power supply	3.3V to 4.5V
Operating temperature (board temperature)	Normal operation: -30°C to +80°C Extended operation: -40°C to +90°C
Physical	Dimensions: 27.60mm x 18.80mm x 2.05mm Weight: approx. 3g
RoHS	All hardware components fully compliant with EU RoHS Directive
LTE features	
3GPP Release 9	DL 10Mbps, UL 5Mbps LTE Cat. 1 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 or USB modem OTA over ASC0 and over USB

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 [4]. This application note comprises chapters on module mounting and application layout issues as well as on SMT application development equipment.
USB	USB 2.0 High Speed (480Mbit/s) device interface, Full Speed (12Mbit/s) compliant
2 serial interfaces	ASC0: • 8-wire modem interface with status and control lines, unbalanced, asynchronous • Default baud rate: 115,200 baud • Adjustable baud rates: 4,800 to 921,600, no autobauding support • 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: 4,800bps to 921,600bps • Supports RTS1/CTS1 hardware flow control
UICC interface	Supported SIM/USIM cards: 3V, 1.8V
Embedded UICC	Module is prepared for an embedded UICC
GPIO interface	20 pads of the application interface programmable as GPIO pads (17) or GPO pads (3): GP(I)Os can be configured as COUNTER, FST_SHDN, ASC0, ASC1, SPI, and DAI signal lines Programming is done via AT commands
I^2C interface	Supports I^2C serial interface
SPI interface	Supports SPI interface
SDIO	**ELS51-VA only:** 4 wire interface.
HSIC	**ELS51-VA only:** High Speed Interchip Communication interface.
ADC	Analog-to-Digital Converter with one unbalanced analog input.
Digitial audio interface	4 GPIO lines can be configured as PCM/I^2S lines for VoLTE communication.
Antenna interface pads	50Ω LTE main antenna, 50Ω LTE diversity antenna

Feature	Implementation
Power on/off, Reset	
Power on/off	Switch-on by hardware signal ON Switch-off by AT command Switch off by hardware signal GPIO4/FST_SHDN instead of AT command Automatic switch-off in case of critical temperature and voltage conditions
Reset	Orderly shutdown and reset by AT command Emergency reset by hardware signal EMERG_RST
Evaluation kit	
Evaluation module	ELS31-VA/ELS51-VA 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 ELS31-VA/ELS51-VA evaluation module to the DSB75.

1.2 ELS31-VA/ELS51-VA System Overview

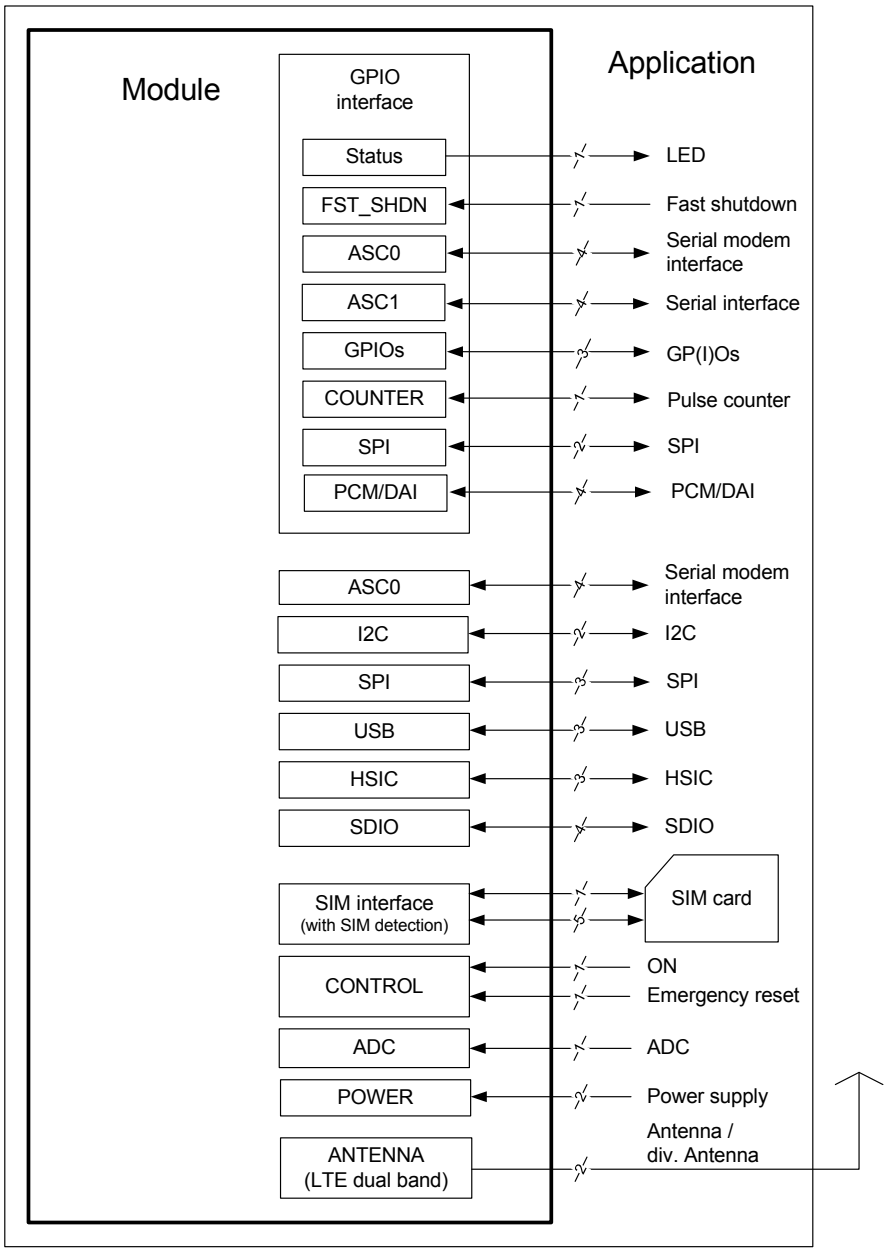


Figure 1: ELS31-VA/ELS51-VA system overview

1.3 Circuit Concept

The following figure shows block diagram of the ELS31-VA/ELS51-VA module and illustrate the major functional components (see Figure 2):

Baseband block:
- baseband processor and power management
- serial NOR flash and LPDDR RAM memory
- Application interface (SMT with connecting pads)

LTE RF section:
- RF transceiver
- RF power amplifier/front-end module and duplexers
- Receive SAW filters

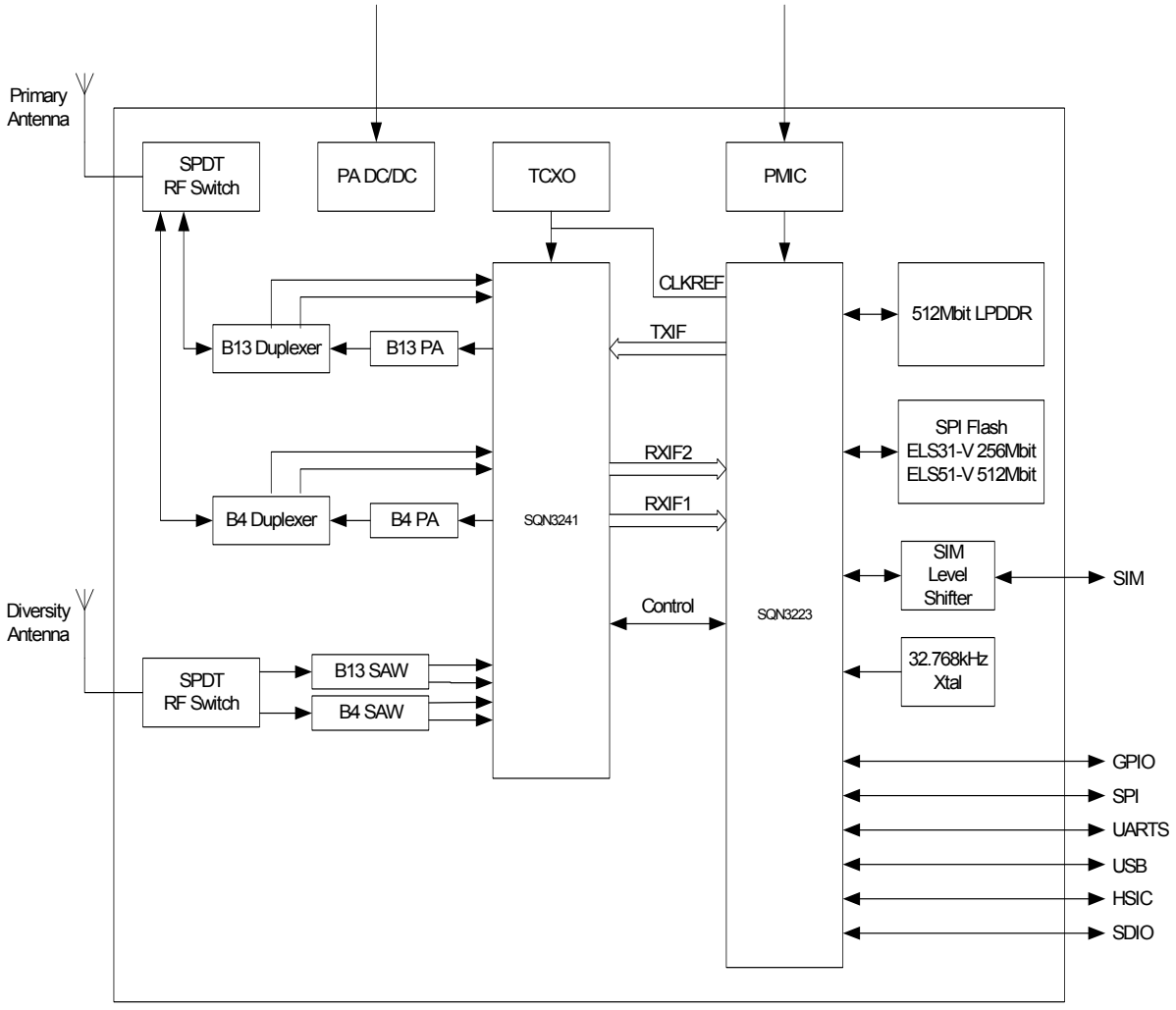


Figure 2: ELS31-VA/ELS51-VA baseband block diagram

2 Interface Characteristics

ELS31-VA/ELS51-VA 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 ELS31-VA/ELS51-VA 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.

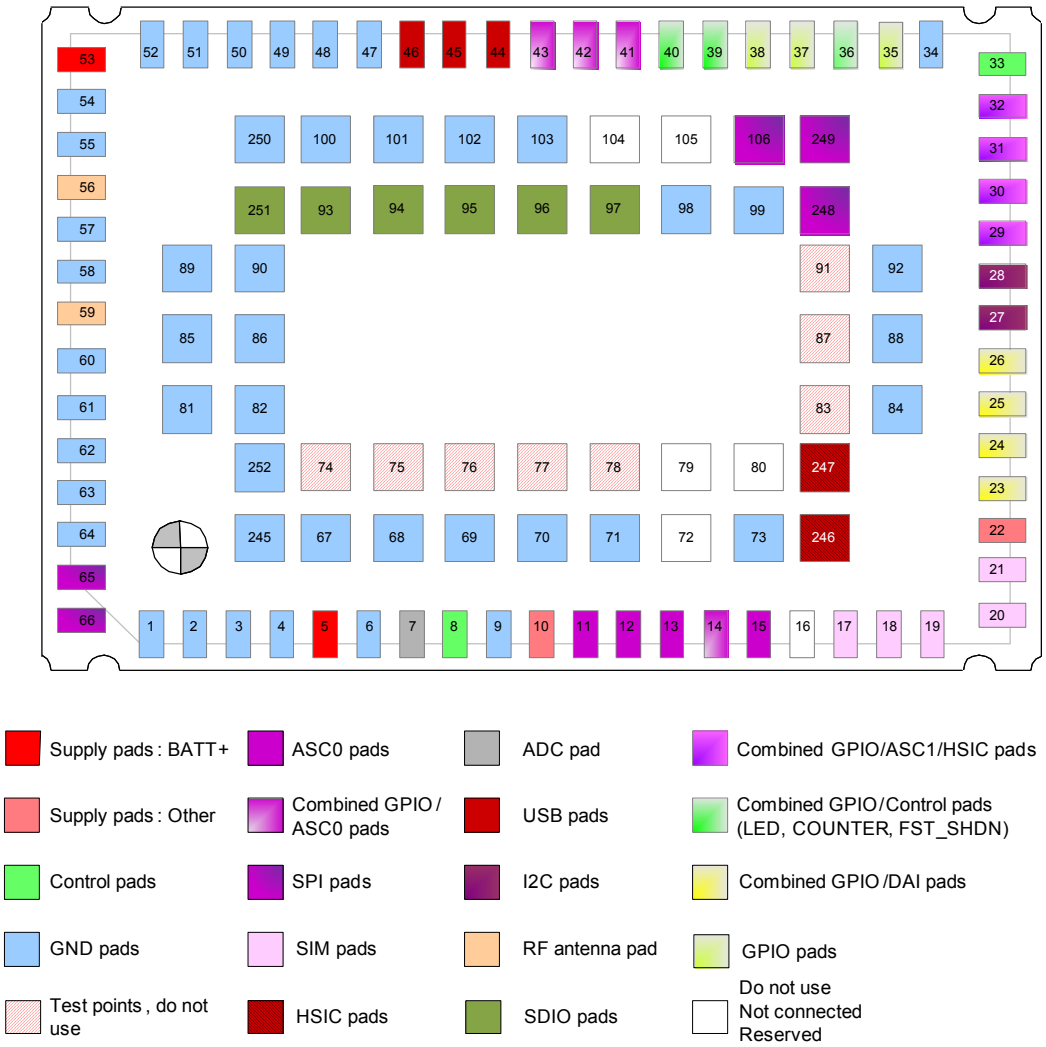


Figure 3: Numbering plan for connecting pads (bottom view)

Table 1: Pad assignments

Pad no.	Signal name	Pad no.	Signal name	Pad no.	Signal name
1	GND	23	GPIO20/PCM_I2S_OUT	45	USB_DP
2	GND	24	GPIO22/PCM_I2S_FSC	46	USB_DN
3	GND	25	GPIO21/PCM_I2S_IN	47	GND
4	GND	26	GPO23/PCM_I2S_CLK	48	GND
5	BATT_RF	27	I2CDAT	49	GND
6	GND	28	I2CCLK	50	GND
7	ADC1	29	GPIO17/TXD1/HOST_ACTIVE	51	GND
8	ON	30	GPIO16/RXD1/AP_WAKEUP	52	GND
9	GND	31	GPIO18/RTS1/CP_WAKEUP	53	BATT_BB
10	V180	32	GPIO19/CTS1/SUSPEND	54	GND
11	RXD0	33	EMERG_RST	55	GND
12	CTS0	34	GND	56	DIV_ANT
13	TXD0	35	GPIO25	57	GND
14	RING0/GPIO24	36	GPIO8/COUNTER	58	GND
15	RTS0	37	GPIO7	59	RF_OUT
16	Not connected	38	GPIO6	60	GND
17	CCRST	39	LED/GPO5	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	VUSB	66	GPO26/SPI_CS1
Centrally located pads					
67	GND	83	Do not use (test)	99	GND
68	GND	84	GND	100	GND
69	GND	85	GND	101	GND
70	GND	86	GND	102	GND
71	GND	87	Do not use (test)	103	GND
72	Not connected	88	GND	104	Not connected
73	GND	89	GND	105	Not connected
74	Do not use (test)	90	GND	106	SPI_MOSI
75	Do not use (test)	91	Do not use (test)	245	GND
76	Do not use (test)	92	GND	246	HSIC_DATA
77	Do not use (test)	93	SDIO0	247	HSIC_STRB
78	Do not use (test)	94	SDIOCLK	248	SPI_CLK
79	Not connected	95	SDIO1	249	SPI_MISO
80	Do not use	96	SDIO2	250	GND
81	GND	97	SDIO3	251	SDIOCMD
82	GND	98	GND	252	GND

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 ELS31-VA/ELS51-VA 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_BB BATT_RF	I	$V_I$max = 4.5V $V_I$norm = 3.8V $V_I$min = 3.3V Imax=720mA nominal voltage 3.8V - 300 mA for BATT_RF - 420 mA for BATT_BB	Lines of BATT+ and GND must be connected in parallel for supply purposes because higher peak currents may occur. Minimum voltage must not fall below 3.3V including drop, ripple, spikes and not rise above 4.5V.
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 = 1.89V $I_O$max = 50mA CLmax = 2µF	V180 may be used to supply level shifters at the interfaces or to supply external application circuits. If unused keep line open.
	VCORE	O	$V_O$norm = 1.1V $V_O$min= 1.09 $V_O$max= 1.12 $I_O$max = 50mA CLmax = 100nF	
Ignition	ON	I	BATT_BB= 4.5V V_{IH}max = 5.5V V_{IH}min = 2.16V V_{IL}max = 1.79V V_{IL}min=0V BATT_BB= 3.3V V_{IH}max = 5.5V V_{IH}min = 1.7V V_{IL}max = 1.3V V_{IL}min = 0V Min low time before rising edge <=100µs Rin = 380k ON ___|¯|____ high level min. 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_BB. In this case, the module cannot be switched off by a fast shutdown, but can only be switched off by disconnecting BATT_BB.
Emergency restart	EMERG_RST	I	V_{IH}max = 5.5V V_{IH}min = 0.85V V_{IL}max =0.65V V_{IL}min= 0V Internal pull-up resistor Low impulse width > 10ms	Pulse triggered signal to reset the module. This line must be driven low by an open drain or open collector driver connected to GND. See also Section 3.2.2.2. If unused keep line open.

Table 2: Signal properties (Continued)

Function	Signal name	IO	Signal form and level	Comment
Fast shutdown	FST_SHDN	I	V_{IL}max = 0.63V V_{IH}min = 1.17V V_{IH}max = 1.85V ~~|___|~~ low impulse width > 10ms	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 shutdown, the GPIO line is assigned as follows: GPIO4 --> FST_SHDN
USB	VUSB_IN	I	$V_I$min = 3V $V_I$max = 5.25V Active and suspend current: I_{max} < 100µA	All electrical characteristics according to USB Implementers' Forum, USB 2.0 Specification. If unused keep lines open.
	USB_DN	I/O	Full and high speed signal characteristics according USB 2.0 Specification.	
	USB_DP			
Serial Interface ASC0	RXD0	O	V_{OL}max = 0.45V V_{OH}min = 1.35V V_{OH}max = 1.85V V_{IL}max = 0.63V V_{IL}min = -0.3V V_{IH}min = 1.17V V_{IH}max = 1.85V	If unused keep lines open. By delivery default, lines are available as ASC0 interface lines. If configured for use as GPIOs the assignment is as follows: DTR0 --> GPIO1 DCD0 --> GPIO2 DSR0 --> GPIO3 RING0 --> GPIO24
	CTS0	O		
	RING0	O		
	TXD0	I		
	RTS0	I		
	DTR0	I		
	DCD0	O		
	DSR0	O		
Serial Interface ASC1	RXD1	O	V_{OL}max = 0.45V V_{OH}min = 1.35V V_{OH}max = 1.85V V_{IL}max = 0.63V V_{IL}min = -0.3V V_{IH}min = 1.17V V_{IH}max = 1.85V	If unused keep lines open. By delivery default, ASC1 interface lines are available as GPIO lines. If configured as ASC1 lines, the GPIO lines are assigned as follows: GPIO16 --> RXD1 GPIO17 --> TXD1 GPIO18 --> RTS1 GPIO19 --> CTS1 ASC1 is available as data interface.
	CTS1	O		
	TXD1	I		
	RTS1	I		

Table 2: Signal properties (Continued)

Function	Signal name	IO	Signal form and level	Comment
I^2C	I2CCLK	IO	V_{OL}max = 0.45V V_{OH}min = 1.35V V_{OH}max = 1.85V V_{IL}max = 0.63V V_{IL}min = -0.3V V_{IH}min = 1.17V 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 391 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 4.6mA. If lines are unused keep lines open.
	I2CDAT	IO		
SPI	SPI_CLK	O	V_{OL}max = 0.45V V_{OH}min = 1.35V V_{OH}max = 1.85V V_{IL}max = 0.63V V_{IL}min = -0.3V V_{IH}min = 1.17V 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: GPO26 --> 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	IO	V_{OL}max = 0.45V V_{OH}min = 1.35V V_{OH}max = 1.85V V_{IL}max = 0.63V V_{IL}min = -0.3V V_{IH}min = 1.17V V_{IH}max = 1.85V	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 GPO5: LED GPIO8: Pulse Counter GPIO16-GPIO19: ASC1, HSIC control lines GPIO20-GPO23: PCM/ I^2S lines GPIO24: ASC0 control line RING0 GPO26-GPIO27: SPI CS signals
	GPO5,23,26	O		

Table 2: Signal properties (Continued)

Function	Signal name	IO	Signal form and level	Comment
Status LED	LED	O	V_{OL}max = 0.45V V_{OH}min = 1.35V V_{OH}max = 1.85V	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 --> GPO5
Pulse counter	COUNTER	I	V_{OL}max = 0.45V V_{OH}min = 1.35V V_{OH}max = 1.85V V_{IL}max = 0.63V V_{IL}min = -0.3V V_{IH}min = 1.17V V_{IH}max = 1.85V	If unused keep line open. 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
ADC (Analog-to-Digital converter)	ADC1	I	R_I = 10kOhm V_I = 0V ... 2.0V Resolution 1024 steps Tolerance +/-2%	ADC1 can be used as input for external measurements. If unused keep line open.
SIM card detection	CCIN	I	R_I ≈ 90kOhm V_{IL}max = 0.63V V_{IH}min = 1.17V V_{IH}max = 1.85V	CCIN = High, SIM card inserted. For details please refer to Section 2.1.6. If unused keep line open.
3V SIM Card Interface	CCRST	O	V_{OH}typical = 2.065V V_{OH}max = 2.95V V_{OL}typical = 0.1V @1mA V_{OL}max = 0.3V	Maximum cable length or copper track to SIM card holder should not exceed 100mm.
	CCIO	I/O	V_{IL}max = 0.44V V_{IL}min = -0.15V V_{IH}min = 2.065V V_{IH}max = 3.15V V_{OL}typical = 0.1V @1mA V_{OL}max = 0.3V V_{OH}min = 2.065V at I = -10µA V_{OH}max = 2.95V	
	CCCLK	O	V_{OH}typical = 2.065V V_{OH}max = 2.95V V_{OL}typical = 0.1V @1mA V_{OL}max = 0.3V	
	CCVCC	O	$V_O$min = 2.85V $V_O$typ = 2.95V $V_O$max = 3.10V $I_O$max = -50mA	

Table 2: Signal properties (Continued)

Function	Signal name	IO	Signal form and level	Comment
1.8V SIM Card Inter-face	CCRST	O	V_{OH}typical = 1.26V V_{OH}max = 1.8V V_{OL}typical = 0.1V @1mA V_{OL}max = 0.3V	
	CCIO	I/O	V_{IL}max = 0.27V V_{IL}min=-0.15V V_{IH}min = 1.26V V_{IH}max = 2V V_{OL}typical = 0.1V @1mA V_{OL}max = 0.3V V_{OH}min = 1.26V at I = -10µA V_{OH}max = 1.85V	
	CCCLK	O	V_{OH}typical = 1.26V V_{OH}max = 1.8V V_{OL}typical = 0.1V @1mA V_{OL}max = 0.3V	
	CCVCC	O	$V_O$min = 1.7V $V_O$typ = 1.80V $V_O$max = 1.9V $I_O$max = -50mA	
HSIC	HSIC_DATA HSIC_STRB	IO	Signal characteristics according to “High-Speed Inter-Chip USB Electrical Specification”, Version 1, September 23, 2007	HSIC available with ELS51-VA only. See also Section 2.1.14.
SDIO	SDIOCMD SDIOCLK SDIO0 SDIO1 SDIO2 SDIO3	IO	V_{OL}max = 0.45V V_{OH}min = 1.35V V_{OH}max = 1.85V V_{IL}max = 0.63V V_{IH}min = 1.17V V_{IH}max = 1.85V	SDIO available with ELS51-VA only. See also Section 2.1.15.
Digital audio interface (PCM/I^2S)	PCM_I2S_-CLK	I	V_{IL}max = 0.63V V_{IH}min = 1.17V V_{IH}max = 1.85V	If unused keep line open. Note that the PCM inter-face lines are originally available as GPIO lines. If configured as PCM lines, the GPIO lines are assigned as follows: GPIO23 --> PCM_I2S_-CLK GPIO22 --> PCM_I2S_ FSC GPIO20 --> PCM_I2S_ OUT GPIO21 --> PCM_I2S_ IN
	PCM_I2S_ FSC	I		
	PCM_I2S_ IN	I		
	PCM_I2S_ OUT	O	V_{OL}max = 0.45V V_{OH}min = 1.35V V_{OH}max = 1.85V	

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 ELS31-VA/ELS51-VA.

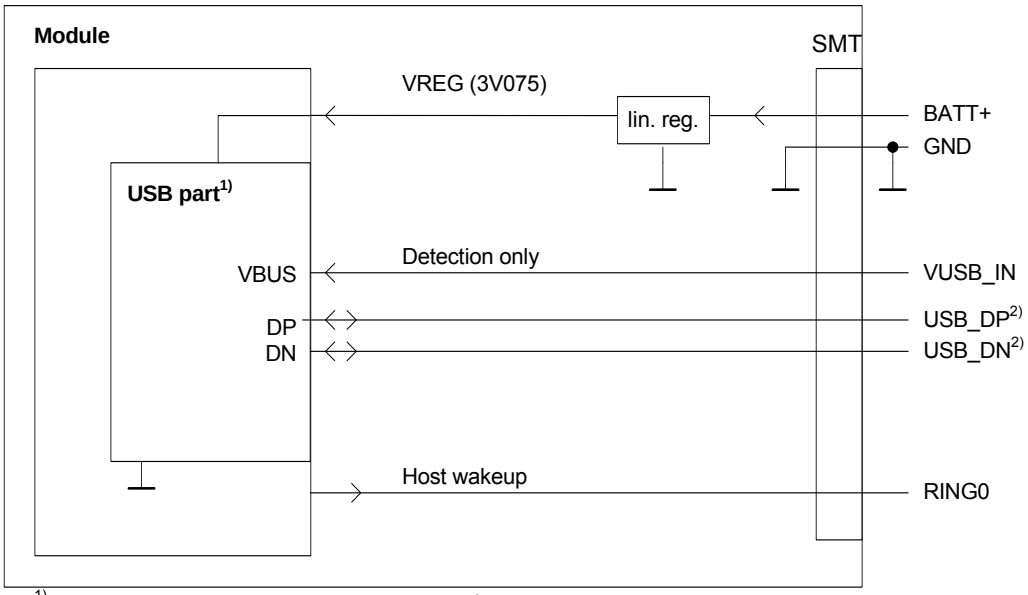
Table 3: Absolute maximum ratings

Parameter	Min	Max	Unit
Supply voltage $BATT+_{BB}$, $BATT+_{RF}$	-0.3	+4.5	V
Voltage at all digital lines in Power Down mode	-0.3	+0.3	V
Voltage at digital lines in normal operation	-0.2	2.0	V
Voltage at SIM/USIM interface, CCVCC in normal operation	-0.5	+3.6	V
Voltage at ADC line in normal operation	0	2	V
Voltage at analog lines in Power Down mode	-0.3	+0.3	V
V180 in normal operation	+1.7	+1.9	V
Current at V180 in normal operation		50	mA
Current at VCORE in normal operation		50	mA

2.1.3 USB Interface

ELS31-VA/ELS51-VA supports a USB 2.0 High Speed (480Mbit/s) device interface that is Full Speed (12Mbit/s) compliant. The USB interface is primarily intended for use as command and data interface and for downloading firmware.

The V_{USB} line is used for cable detection only, this is to be supplied by the external device. The USB circuitry in the ELS31-VA/ELS51-VA is designed to meet the USB 2.0 specification for self-power.2.0"[1].



1) It is recommended to add EMI suppression filter (see section 2.1.3.1)
2) If the USB interface is operated in High Speed mode (480MHz), it is recommended to take special care routing the data lines USB_DP and USB_DN. Application layout should in this case implement a differential impedance of 90Ohm for proper signal integrity.

Figure 4: USB circuit

To properly connect the module's USB interface to the external application, a USB 2.0 compatible connector and cable or hardware design is required. For more information on the USB related signals see Table 2. Furthermore, the USB modem driver distributed with ELS31-VA/ELS51-VA needs to be installed.

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

2.1.3.1 Interface implementation

Figure 5 shows a standard USB interfacing circuit for "off board" interfacing (connection directly to a USB connector).

If the USB interface is directly wired to a Host interface, the additional ESD protection (U1 on Figure 5) is not necessary, as the final product will not be a "hot swappable" item. The filter is used to offer high impedance to higher frequency components of the USB signals. This helps reduce any potential RF noise coming from these USB wires.

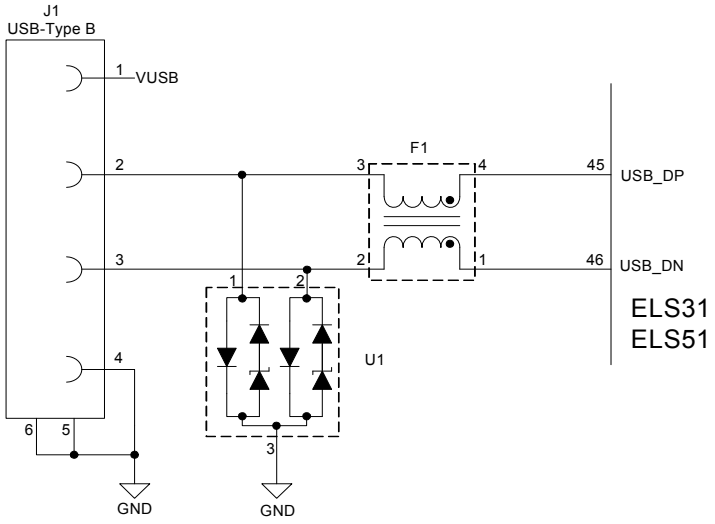


Figure 5: USB Additional ESD Protection Implementation

The digital signals USB_DP and USB_DN are sensitive to track design. Make sure these signals are routed with 90 Ohms differential resistance. If the host product is containing other USB interfaces, then ensure that the rules used to design those are replicated here too. An overvoltage protection device U1 is recommended, such as ESD5V3U2U-03F.

2.1.3.2 Reducing Power Consumption

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

- **Recommended implementation of USB Suspend/Resume/Remote Wakeup:**
  The USB host should be able to bring its USB interface into the Suspended state as described in the “Universal Serial Bus Specification Revision 2.0“[1]. For this functionality to work, the VUSB_IN line should always be kept enabled. On incoming calls and other events ELS31-VA/ELS51-VA will then generate a Remote Wakeup request to resume the USB host controller.

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

- **Implementation for legacy USB applications not supporting USB Suspend/Resume:**
  As an alternative to the regular USB suspend and resume mechanism it is possible to employ the RING0 line to wake up the host application in case of incoming calls or events signalized by URCs while the USB interface is in Detached state (i.e., VUSB_IN = 0). Every wakeup event will force a new USB enumeration. Therefore, the external application has to carefully consider the enumeration timings to avoid loosing any signalled events. For details on this host wakeup functionality see Section 2.1.16.3.

Note: Existing data connections will not be disconnected even if the USB interface is in detached state. URCs will be queued during detached state, but may be signaled to the host via host wakeup line RING0.

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

2.1.4 Serial Interface ASC0

ELS31-VA/ELS51-VA offers an 8-wire unbalanced, asynchronous modem interface ASC0 conforming to ITU-T V.24 protocol DCE signalling. The electrical characteristics do not comply with ITU-T V.28. The significant levels are 0V (for low data bit or active state) and 1.8V (for high data bit or inactive state). For electrical characteristics please refer to Table 2. For an illustration of the interface line's startup behavior see Figure 7.

ELS31-VA/ELS51-VA 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

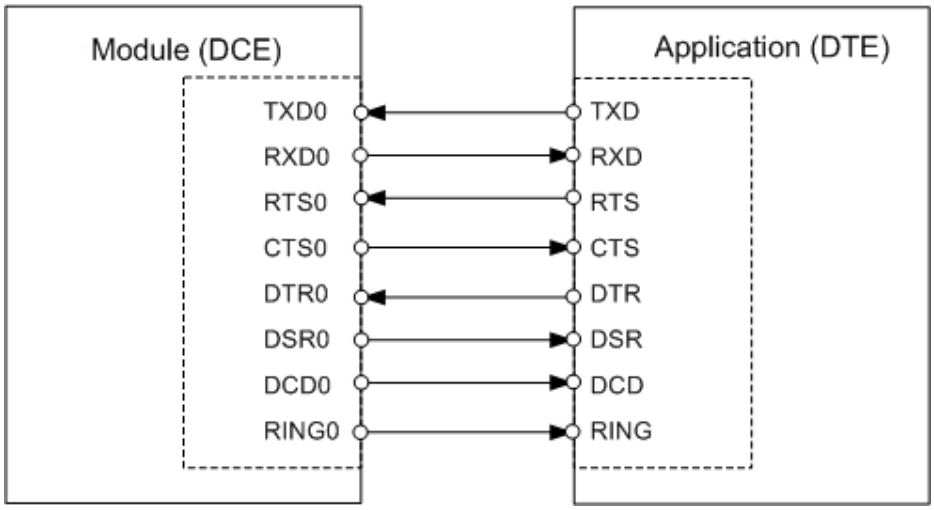


Figure 6: Serial interface ASC0

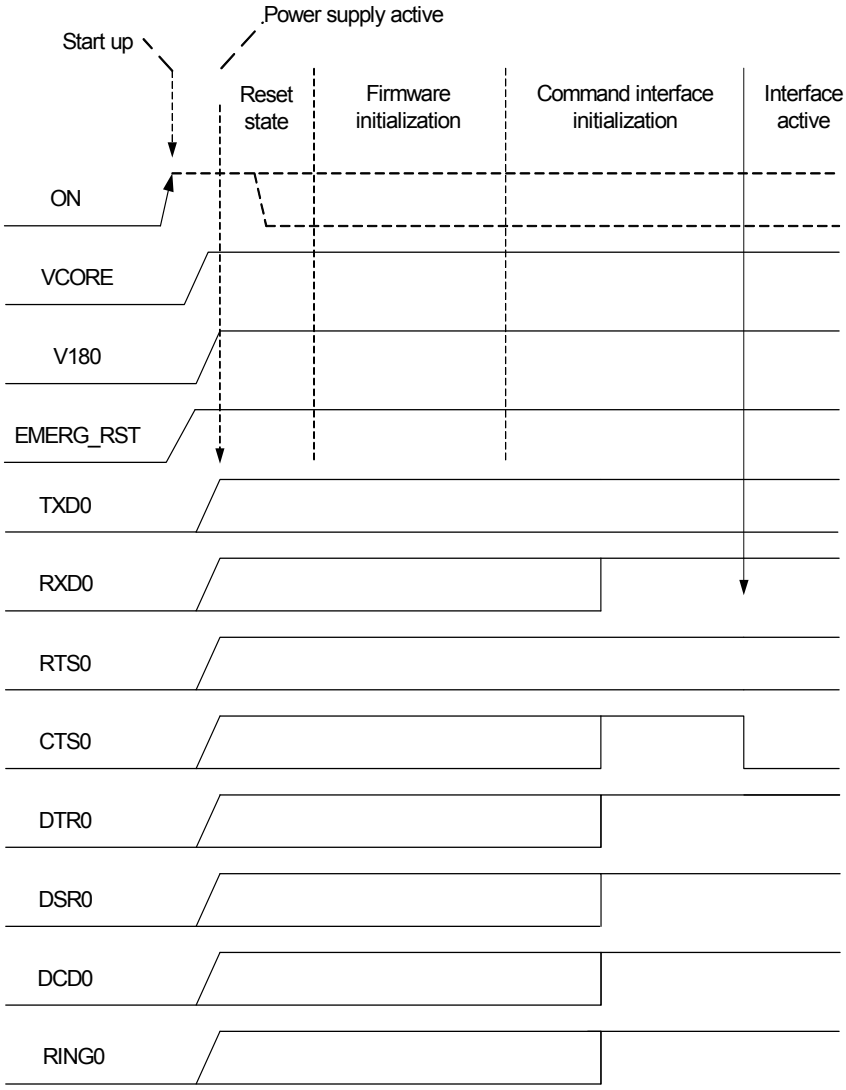
Features:
- Includes the data lines TXD0 and RXD0, the status lines RTS0 and CTS0 and, in addition, the modem control lines DTR0, DSR0, DCD0 and RING0.
- Configured for 8 data bits, no parity and 1 stop bit.
- ASC0 can be operated at fixed bit rates from 4800bps up to 921600bps.
- Supports RTS0/CTS0 hardware flow control. Communication is possible by using only RXD and TXD lines, if RTS0 is pulled low.
- Wake up from SLEEP mode by RTS0 activation (high to low transition; see Section 3.3.2).

The ASC0 interface is dedicated to signaling via AT commands (3GPP standard 27.007 + module specific AT commands).

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.

2.1.4.1 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 15.

Figure 7: ASC0 startup behavior

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

2.1.5 Serial Interface ASC1

ELS31-VA/ELS51-VA 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 9. ASC1 can only be used as data interface.

The ASC1 interface lines are originally available as GPIO lines. If configured as ASC1 lines, the GPIO lines are assigned 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.

ELS51-VA 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

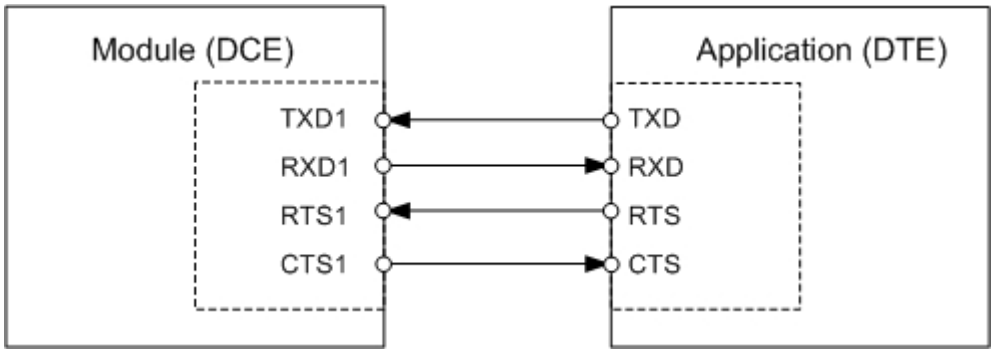
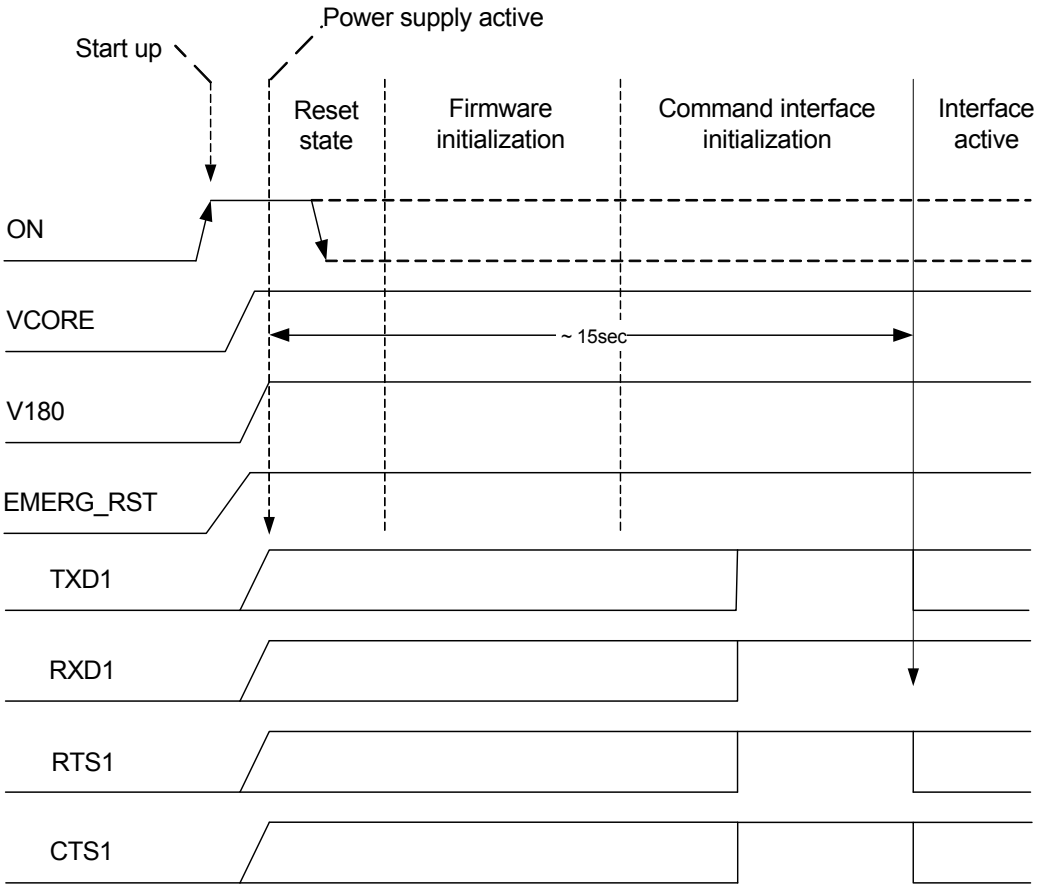


Figure 8: Serial interface ASC1

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 4800 bps to 921600 bps.
- Supports RTS1/CTS1 hardware flow control. Communication is possible by using only RXD and TXD lines, if RTS1 is pulled low.
- Wake up from SLEEP mode by RTS0 activation (high to low transition; see Section 3.3.2).

AT commands for signaling are not supported on ASC1 interface. ASC1 is intended only for data transfer in a Linux environment.

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



*) For pull-down values see Table 15.

Figure 9: ASC1 startup behavior

2.1.6 UICC/SIM/USIM Interface

ELS31-VA/ELS51-VA has an integrated UICC/SIM/USIM interface compatible with the 3GPP 31.102 and ETSI 102 221. This is wired to the host interface in order to be connected to an external SIM card holder. Five pads on the SMT application interface are reserved for the SIM interface.

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

The CCIN signal serves to detect whether a tray (with SIM card) is present in the card holder. The CCIN 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 CCIN signal is mandatory for compliance with the GSM 11.11 recommendation if the mechanical design of the host application allows the user to remove the SIM card during operation. To take advantage of this feature, an appropriate SIM card detect switch is required on the card holder. For example, this is true for the model supplied by Molex, which has been tested to operate with ELS31-VA/ELS51-VA 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.
CCCLK	Chipcard clock
CCVCC	SIM supply voltage.
CCIO	Serial data line, input and output.
CCRST	Chipcard reset
CCIN	Input on the baseband processor for detecting a SIM card tray in the holder. If the SIM is removed during operation the SIM interface is shut down immediately to prevent destruction of the SIM. The CCIN signal is by default low and will change to high level if a SIM card is inserted. The CCIN signal is mandatory for applications that allow the user to remove the SIM card during operation. The CCIN signal is solely intended for use with a SIM card. It must not be used for any other purposes. Failure to comply with this requirement may invalidate the type approval of ELS31-VA/ELS51-VA.

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 ELS31-VA/ELS51-VA.

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

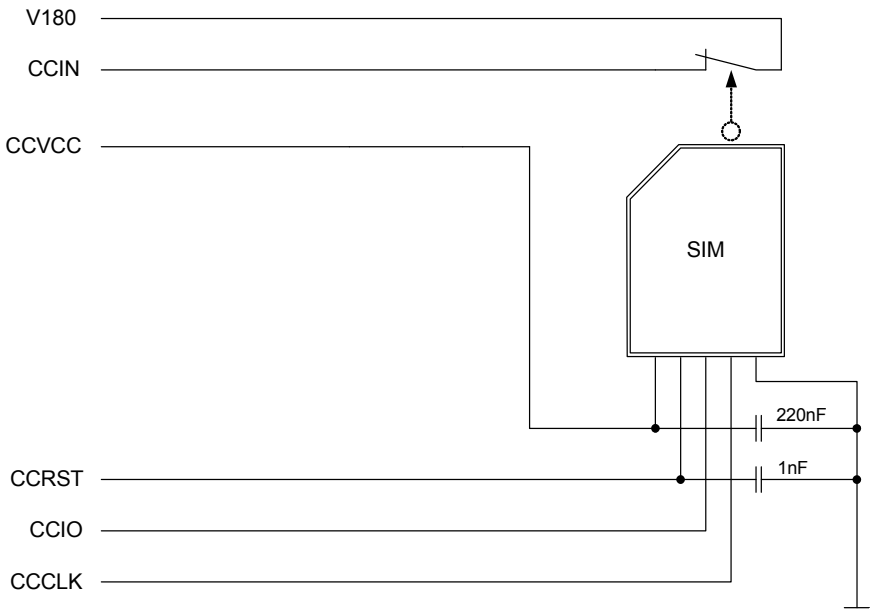


Figure 10: External UICC/SIM/USIM card holder circuit

The total cable length between the SMT application interface pads on ELS31-VA/ELS51-VA and the pads of the external SIM card holder must not exceed 100mm in order to meet the specifications of 3GPP TS 51.010-1 and to satisfy the requirements of EMC compliance.

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

The ELS31-VA/ELS51-VA includes embedded ESD protection for the SIM interface that complies to ETSI EN 301 489-1/7: Contact discharge: ± 4kV, air discharge: ± 8kV.

2.1.7 Digital Audio Interface

ELS31-VA/ELS51-VA supports a digital audio interface that can be employed either as pulse code modulation interface (see Section 2.1.8) or as inter IC sound interface (see Section 2.1.9). Operation of these interface variants is mutually exclusive, and can be configured by AT command (see [1])). Default setting is pulse code modulation.

2.1.8 Pulse Code Modulation Interface (PCM)

Note: ELS31-VA/ELS51-VA's PCM interface is reserved for future use. Usage as digital audio interface is currently not supported.

ELS31-VA/ELS51-VA's PCM interface can be used to connect audio devices capable of pulse code modulation. The PCM functionality is limited to the use of covers the use of narrowband codecs with 8kHz sample rate and wideband codecs with 16kHz sample rate onlyas well. Configured for wideband the The PCM interface runs at 16 kHz sample rate (62.5µs frame length), while the signal processing maintains this rate in a wideband AMR call or samples automatically down to 8kHz in a narrowband call. Therefore, the PCM sample rate is independent of the audio bandwidth of the call.

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

For the PCM configuration the AT^SAIC command parameters <clock>, <mode>, <frame_mode>, <ext_clk_mode> and <sample_rate> (see [1]) cannot be configured in any combination. The **following notes**, must be considered while configuring the PCM interface:

ELS31-VA/ELS51-VA’s digital audio interface can only be operated in slave mode. Therefore, the <mode> parameter must be set to <1>, and the <ext_clk_mode> be set to not permanent resp. off. Further, while in slave mode the <clock>, <frame_mode> and <sample_rate> must be set according to the characteristics of the external master. There is no automatic detection of the received clock frequency, frame length and sample rate.

Four GPIOs can be configured by AT command as PCM signals: GPIO20 --> PCM_I2S_OUT, GPIO21--> PCM_I2S_IN, GPIO22 --> PCM_I2S_FSC and GPIO23 --> PCM_I2S_CLK. The setting is non-volatile and becomes active after a module restart (see also [1]).

Table 5 describes the available DAI/PCM lines at the digital audio interface. For electrical details see Section 2.1.2.

Table 5: Overview of PCM pin functions

Signal name on B2B connector SMT application interface	Signal configuration inactive	Signal direction: Slave	Description
PCM_I2S_OUT	PD	O	PCM data from ELS31-VA/ELS51-VA to external codec
PCM_I2S_IN	PD	I	PCM data from external codec to ELS31-VA/ ELS51-VA
PCM_I2S_FSC	PD	I	Frame synchronization signal from external codec
PCM_I2S_CLK	PD	I	Bit clock from external codec

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

The timing of a PCM short frame is shown in Figure 11.

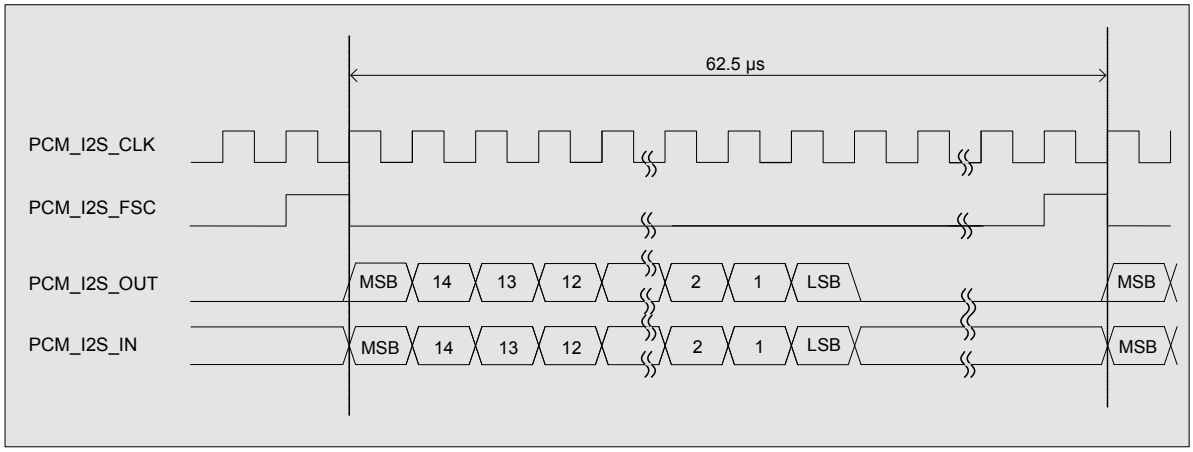


Figure 11: PCM timing short frame (4096KHz, 16kHz sample rate)

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

Characteristics of Audio Modes

ELS31-VA/ELS51-VA has various audio modes selectable with AT^SNFS (for details on AT^SNFS see [1]).

Audio mode 1 with its default settings is used for type approval with the Votronic handset via the DSB75 codec adapter. The handset is adjusted for the type 3.2 low-leakage ear simulator for narrowband and wideband calls.

The other modes are customer specific modes, and can as such be prepared for specific requirements.

2.1.9 Inter IC Sound Interface (I²S)

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

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

The I²S interface has the following characteristics:
- Bit clock mode: Slave, requires external master clock input
- Sampling rate: 8KHz (narrowband), 16KHz (wideband)
- 256kHz bit clock at 8kHz sample rate
- 512kHz bit clock at 16kHz sample rate
- Frame length: 32 bit stereo voice signal (16 bit word length)

The digital audio interface lines available for the PCM interface are also available for the I²S interface. In I²S mode they have the same electrical characteristics.

Table 6 lists the available I²S interface signals, Figure 12 shows the I²S timing.

Table 6: Overview of I²S pin functions

Signal name on SMT application interface	Signal configuration inactive	Signal direction: Slave	Description
PCM_I2S_OUT	PD	O	I²S data from ELS31-VA/ELS51-VA to external codec
PCM_I2S_IN	PD	I	I²S data from external codec to ELS31-VA/ELS51-VA
PCM_I2S_FSC	PD	I	Frame synchronization signal from external codec Word alignment (WS)
PCM_I2S_CLK	PD	I	Bit clock from external codec

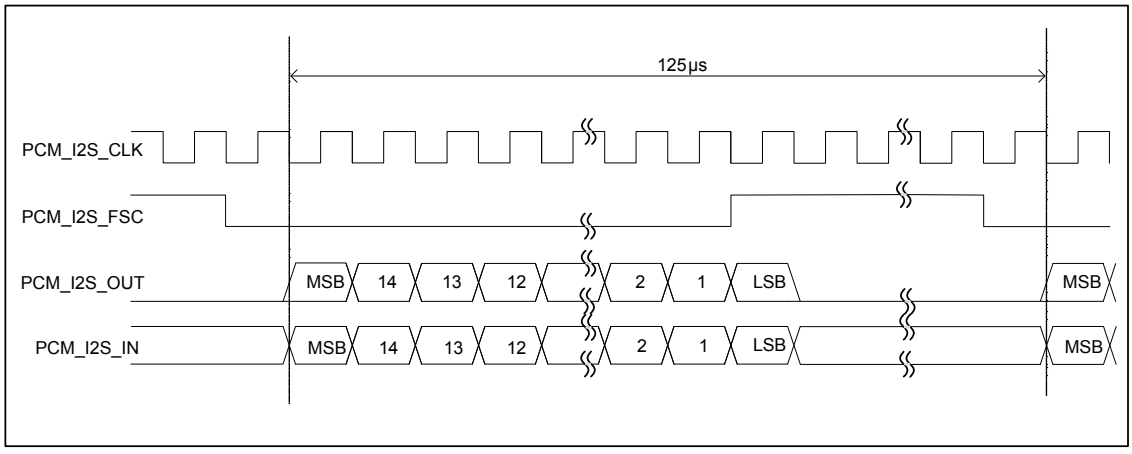


Figure 12: I²S timing (slave mode)

2.1.10 GPIO Interface

ELS31-VA/ELS51-VA offers a GPIO interface with 17 GPIO and 3 GPO lines. The lines are shared with other interfaces or functions: Fast shutdown (see Section 2.1.16.4), status LED (see Section 2.1.16.1), a pulse counter (see Section 2.1.13), ASC0 (see Section 2.1.4), ASC1 (see Section 2.1.5), SPI (see Section 2.1.12), HSIC (see Section 2.1.14), and digital audio interface (DAI; see Section 2.1.7).

The following table shows the configuration variants for the GPIO pads. All variants are mutually exclusive, i.e. a pad configured for instance as Status LED is locked for alternative usage.

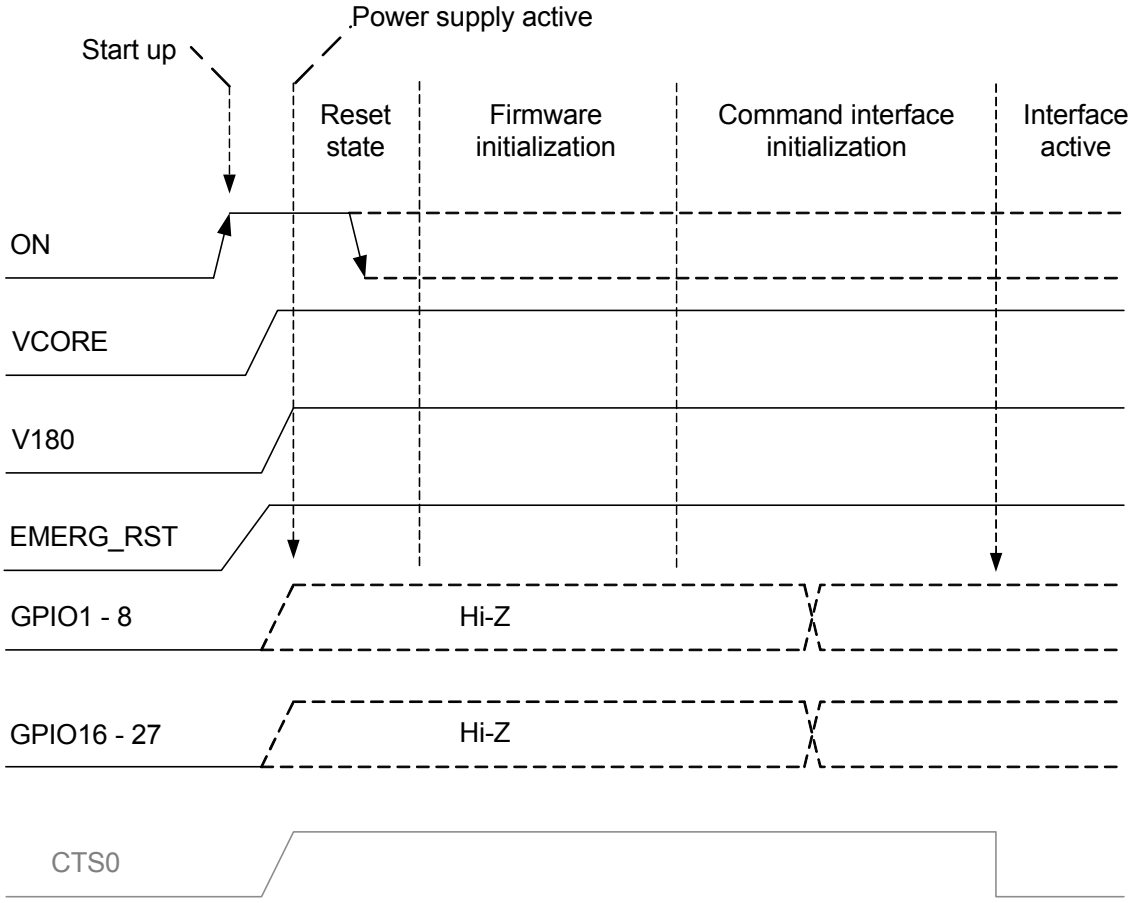
Table 7: GPIO lines and possible alternative assignment

GPIO	Fast Shutdown	Status LED	Pulse Counter	ASC0	ASC1	SPI	HSIC	PCM
GPIO1				DTR0				
GPIO2				DCD0				
GPIO3				DSR0				
GPIO4	FST_SHDN							
GPO5		LED						
GPIO6								
GPIO7								
GPIO8			COUNTER					
GPIO16					RXD1		AP_WAKEUP	
GPIO17					TXD1		HOST_ACTIVE	
GPIO18					RTS1		CP_WAKEUP	
GPIO19					CTS1		SUSPEND	
GPIO20								PCM_I2S_OUT
GPIO21								PCM_I2S_IN
GPIO22								PCM_I2S_FSC
GPO23								PCM_I2S_CLK
GPIO24				RING0				
GPIO25								
GPO26						SPI_CS1		
GPIO27						SPI_CS2		

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.

Notes:
- GPO5, GPO23 and GPO26 are GPOs only.

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 down values see Table 15.

Figure 13: GPIO startup behavior

2.1.11 I²C Interface

I²C is a serial, 8-bit oriented data transfer bus for bit rates up to 100kbps. It consists of two lines, the serial data line I2CDAT and the serial clock line I2CCLK. The module acts as a single master device, e.g. the clock I2CCLK is driven by the module. I2CDAT is a bi-directional line. Each device connected to the bus is software addressable by a unique 7-bit address, and simple master/slave relationships exist at all times. The module operates as master-transmitter or as master-receiver. The customer application transmits or receives data only on request of the module.

To configure and activate the I2C bus use the AT^SSPI command. Detailed information on the AT^SSPI command as well explanations on the protocol and syntax required for data transmission can be found in [1].

The I²C interface can be powered via the V180 line of ELS31-VA/ELS51-VA. If connected to the V180 line, the I²C interface will properly shut down when the module enters the Power Down mode.

In the application I2CDAT and I2CCLK lines need to be connected to a positive supply voltage via a pull-up resistor. For electrical characteristics please refer to Table 2.

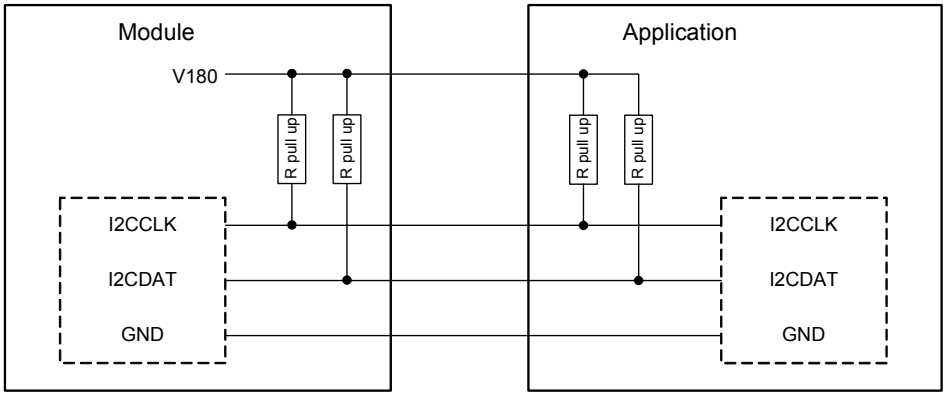


Figure 14: I²C interface connected to V180

Note: Good care should be taken when creating the PCB layout of the host application: The traces of I2CCLK and I2CDAT should be equal in length and as short as possible.

The following figure shows the startup behavior of the I²C interface. With an active state of the ASC0 interface (i.e. CTS0 is at low level) the initialization of the I²C interface is also finished.

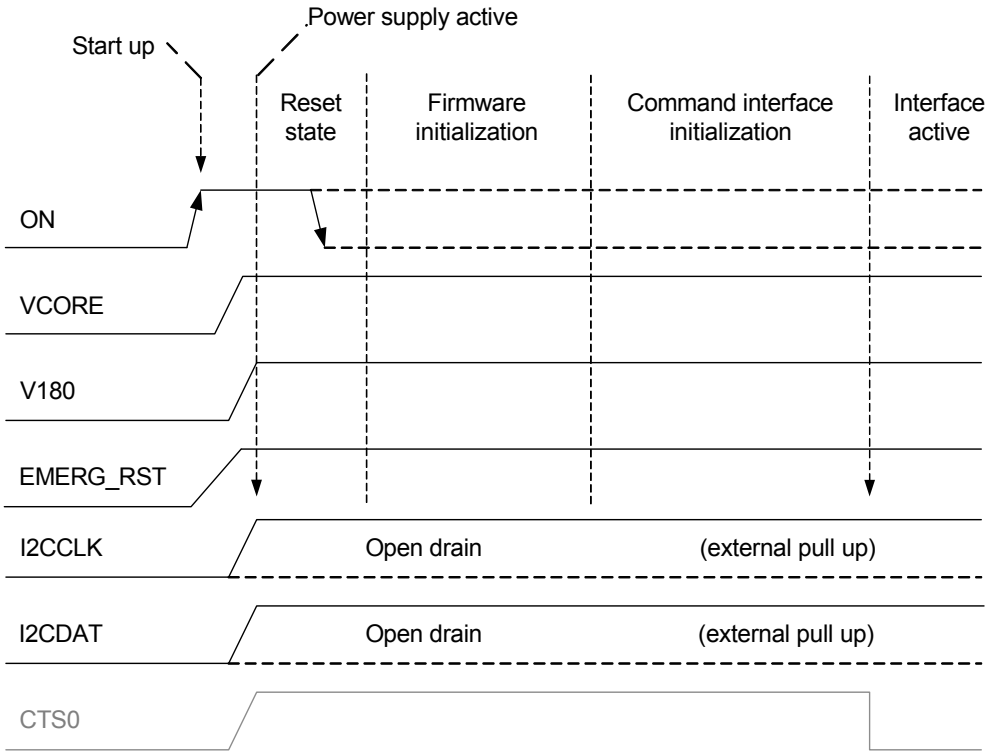


Figure 15: I²C startup behavior

2.1.12 SPI Interface

The ELS31-VA/ELS51-VA GPIO interface lines can be configured as Serial Peripheral Interface (SPI). The SPI is a synchronous serial interface for control and data transfer between ELS31-VA/ELS51-VA and the external application. Only one application can be connected to the SPI and the interface supports only master mode. The transmission rates are up to 6.5Mbit/s. The SPI interface comprises the two data lines SPI_MOSI and SPI_MISO, the clock line SPI_CLK a well as the chip select lines SPI_CS1 and SPI_CS2.

These two GPIO lines can be configured as SPI interface signals as follows: GPO26 --> SPI_CS1 and GPIO27 --> SPI_CS2. The configuration is done by AT command (see [1]). It is non-volatile and becomes active after a module restart.

To configure and activate the SPI interface use the AT^SSPI command. Detailed information on the AT^SSPI command as well explanations on the SPI modes required for data transmission can be found in [1].

In general, SPI supports four operation modes. The modes are different in clock phase and clock polarity. The module's SPI mode can be configured by using the AT command AT^SSPI. Make sure the module and the connected slave device works with the same SPI mode.

Figure 16 shows the characteristics of the four SPI modes. The SPI modes 0 and 3 are the most common used modes. For electrical characteristics please refer to Table 2.

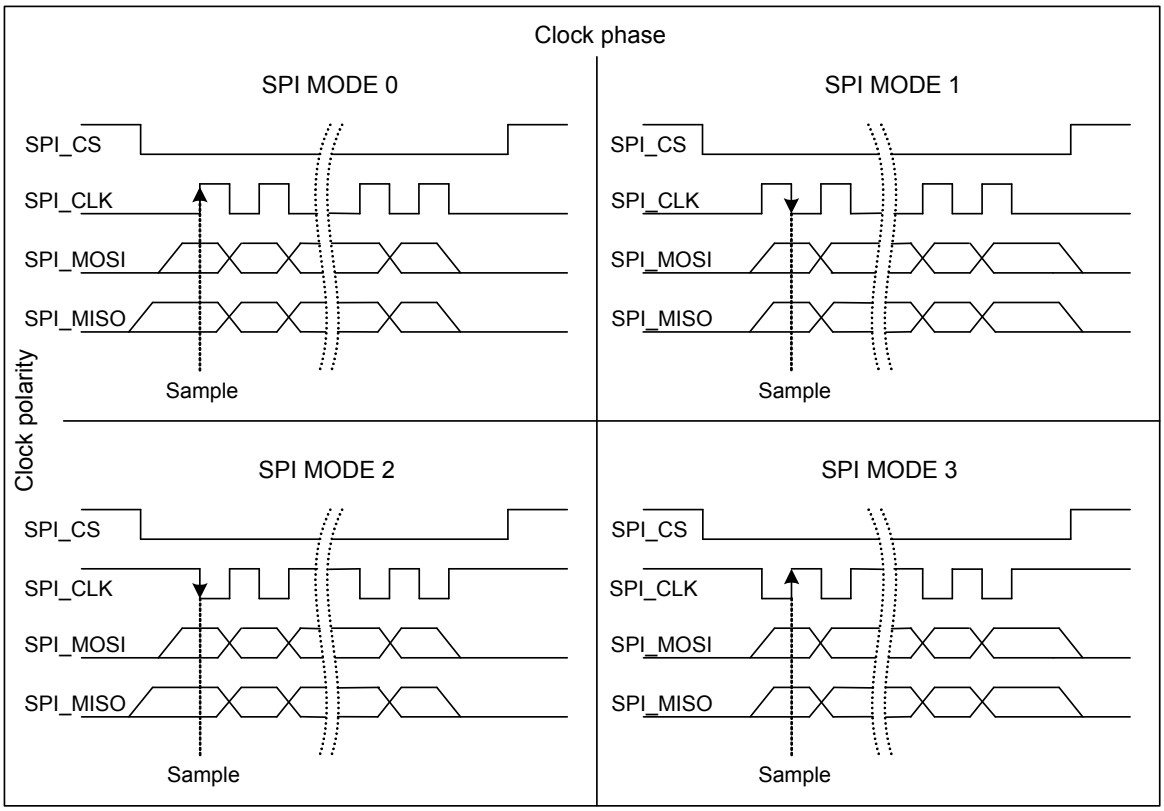


Figure 16: Characteristics of SPI modes

2.1.13 Pulse Counter

The GPIO8 line can be configured as pulse counter line COUNTER (for GPIOs see Section 2.1.10). The pulse counter interface can be used, for example, as a clock - it is designed to measure signals from 0 to 1000 pulses per second. Note that the pulse counter works in batches of 8 pulses, i.e., the URC indicates the number of pulses counted in batches of 8 pulses. For more information on how to use this feature see [1].

2.1.14 HSIC Interface (ELS51-VA Only)

The (USB) High Speed Inter Chip (HSIC) interface can be used between the module and an external application processor, and is compliant to the High Speed USB 2.0 interface with 480Mbit/s. The maximum distance between module processor and external application processor should not exceed 100mm.

The HSIC interface comprises two signal lines (strobe - HSIC_STRB - and data - HSIC_DATA) used in a source synchronous serial interface with a 240MHz clock to provide a 480Mbps USB interface. The HSIC_STRB and HSIC_DATA lines are high-speed signals and should be routed as 50Ohm impedance traces. The trace length of these signals should be balanced to minimize timing skew and be no longer than 100mm.

The HSIC interface implementation complies with the USB HSIC standard “High-Speed Inter-Chip USB Electrical Specification”, Version 1, September 23, 2007[1].

2.1.15 SDIO Interface (ELS51-VA Only)

The Secure Digital Input Output (SDIO) interface can be used to for instance connect an SD card. The SDIO interface has the following features:

Table 8: SDIO interface features

Feature	Description/Value
Interface Type	SDIO/SD1 (1 data line), SDIO/SD4 (4 data lines), MMC4 (4 data lines)
Voltage	1.8 V
DMA Mode	SDMA / ADMA1 / ADMA2
Number of SLOTs	1
Implement DDR mode	Yes
Card inserted status	Yes
SDIOCLK frequency	Default Mode: 23 MHz maximum High Speed Mode: 46 MHz maximum UHS-I Mode: 92 MHz
Max block length	2048 bytes
SDIO interrupt support	Yes, support SDIO/SD1, SDIO/SD4 mode interrupts

1. The USB specifications are ready for download on http://www.usb.org/developers/docs/usb20_docs/

Table 9 lists the six SDIO interface lines:

Table 9: SDIO interface lines

Signal	Direction	Description
SDIOCLK	Out	SD master clock output to SD/MMC/SDIO device.
SDIOCMD	I/O	Command line.
SDIO0	I/O	Data lines. Only SDIO0 carries data in 1-bit SD mode, SDIO0..3 carry data in 4-bits mode. SDIO interrupt is multiplexed with SDIO1.
SDIO1	I/O	
SDIO2	I/O	
SDIO3	I/O	

Figure 17 illustrates the SDIO timings for data input and output, whereas the below Table 10 gives the actual timing values for the various speed modes.

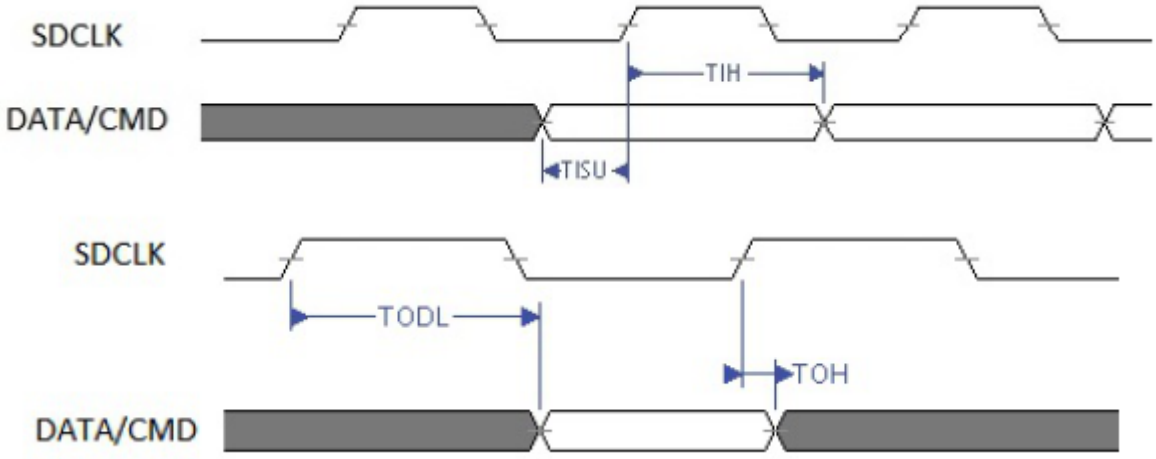


Figure 17: SDIO interface timing diagrams (Input/Output)

Table 10: SDIO timings

Mode	Parameter	Minimum	Maximum
Normal speed	T_{ISU} Input set-up time	5ns	
	T_{IH} Input hold time	5ns	
	T_{ODL} Output delay time during Date Transfer Mode	0ns	14ns
	T_{ODL} Output delay time during Identification Mode	0ns	50ns

Table 10: SDIO timings

Mode	Parameter	Minimum	Maximum
High speed	T_{ISU} Input set-up time	6ns	
	T_{IH} Input hold time	2ns	
	T_{ODLY} Output delay time during Date Transfer Mode	0ns	14ns
	T_{OH} Output hold time	2.5ns	
USH-1	T_{ISU} Input set-up time	3ns	
	T_{IH} Input hold time	0.8ns	
	T_{ODLY} Output delay time during Date Transfer Mode (SDR12, SDR25)	0ns	14ns
	T_{ODLY} Output delay time during Date Transfer Mode (SDR50)	0ns	7.5ns
	T_{OH} Output hold time	1.5ns	

2.1.16 Control Signals

2.1.16.1 Status LED

The LED line can also be configured as GPO5 line, and can be used to drive a status LED that indicates different operating modes of the module (for GPOs see Section 2.1.10). LED and GPO functionality are mutually exclusive.

To take advantage of this function connect an LED to the LED/GPO5 line as shown in Figure 18.

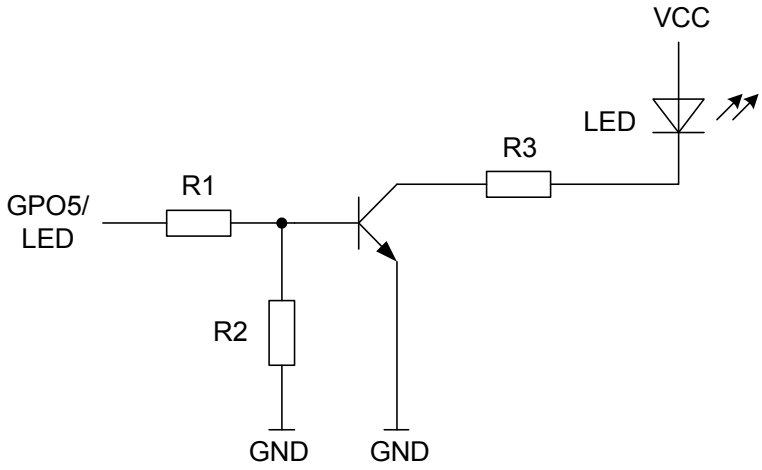


Figure 18: Status signaling with LED driver

2.1.16.2 Power Indication Circuit

In Power Down mode the maximum voltage at any digital or analog interface line must not exceed +0.3V (see also Section 2.1.2.1). Exceeding this limit for any length of time might cause permanent damage to the module.

It is therefore recommended to implement a power indication signal that reports the module's power state and shows whether it is active or in Power Down mode. 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 19 denotes the module's active state with a low signal and the module's Power Down mode with a high signal or high impedance state.

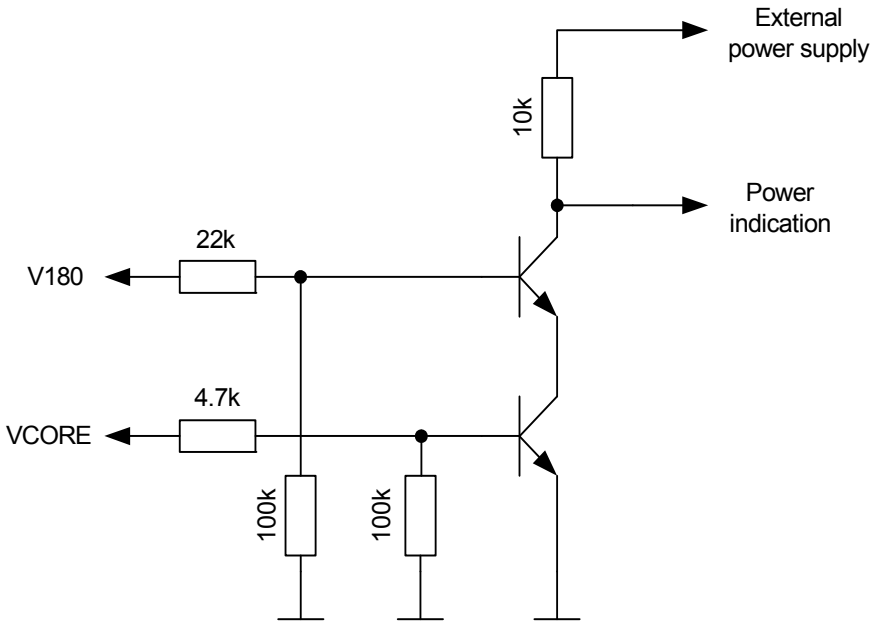


Figure 19: Power indication circuit

2.1.16.3 Host Wakeup

If no call, data or message transfer is in progress, the host may shut down its own USB interface to save power. If a call or other request (URC'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. This functionality should only be used with legacy USB applications not supporting the recommended USB suspend and resume mechanism as described in [5] (see also Section 2.1.3.2). For more information on how to configure the RING0 line by AT^SCFG command see [1].

Possible RING0 line states are listed in Table 11.

Table 11: Host wakeup line

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

Figure 20 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

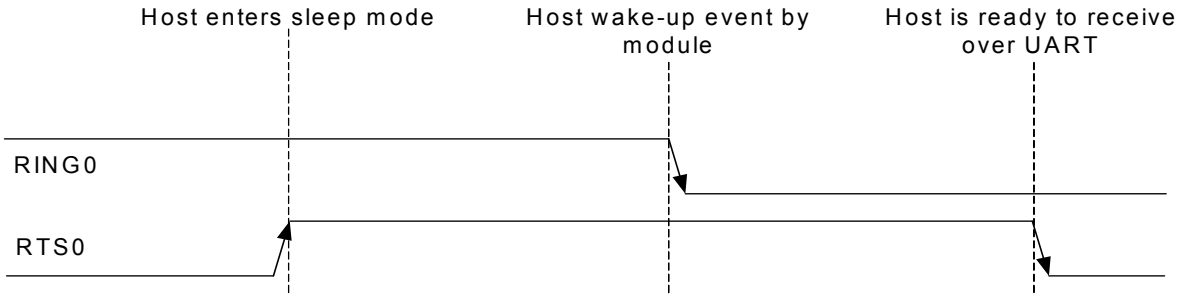


Figure 20: Wake-up via RING0

2.1.16.4 Fast Shutdown

The GPIO4 interface line can be configured as fast shutdown signal line FST_SHDN. The configured FST_SHDN line is an active low control signal. Before setting the FST_SHDN line to low, the ON signal should be set to low (see Figure 21).

By default, the fast shutdown feature is disabled. It has to be enabled using the AT command AT^SCFG "MEShutdown/Fso". For details see [1].

If enabled, a low impulse of 10 milliseconds on the FST_SHDN line starts the fast shutdown procedure.The fast shutdown procedure still finishes any data activities on the module's flash file system, thus ensuring data integrity, but the module will no longer deregister gracefully from the network. On-going flash access cycles (writing/deleting) will be finalized within less than 200 milliseconds. If the module is in power sleep mode, the 200 milliseconds maximum shutdown time will start after the module wakes up from sleep mode.

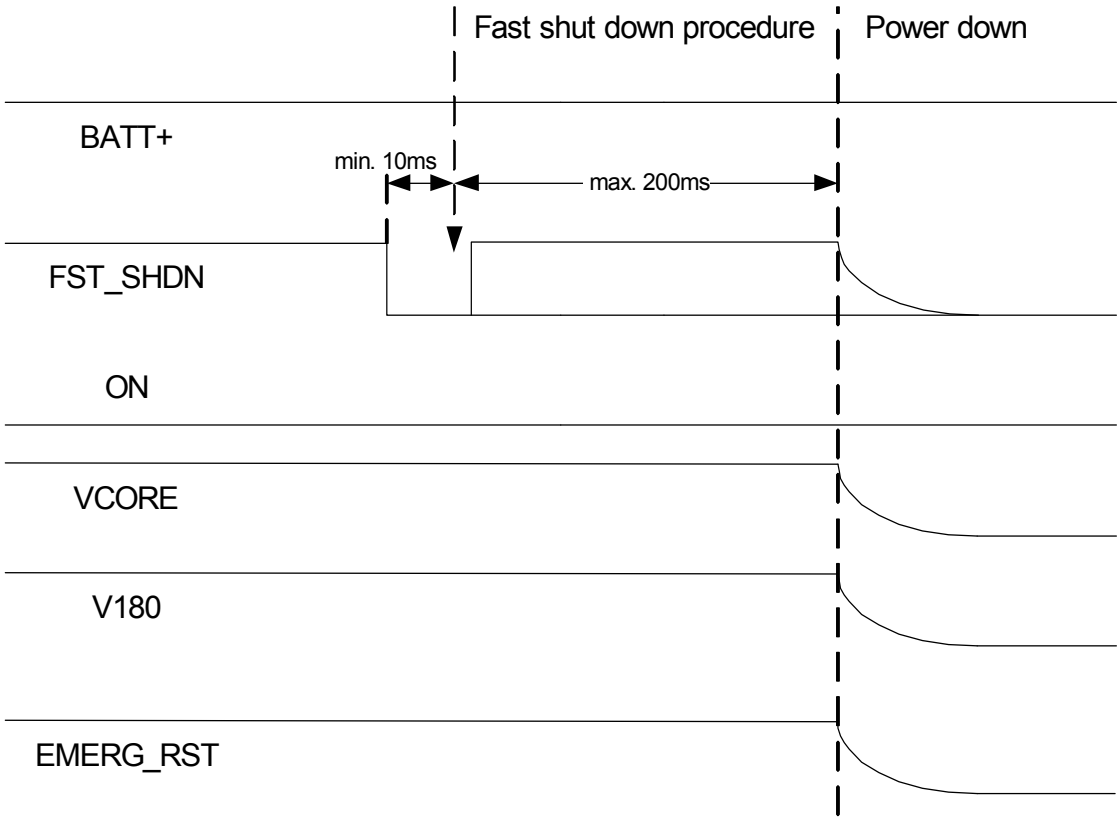


Figure 21: Fast shutdown timing

Please note that if enabled, the normal software controlled shutdown using AT^SMSO will also be a fast shutdown, i.e., without network deregistration. However, in this case no URCs including shutdown URCs will be provided by the AT^SMSO command.

2.2 RF Antenna Interface

The RF interface has an impedance of 50Ω. ELS31-VA/ELS51-VA is capable of sustaining a total 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 ELS31-VA/ELS51-VA module and should be placed in the host application if the antenna does not have an impedance of 50Ω.

Regarding the return loss ELS31-VA/ELS51-VA provides the following values in the active band:

Table 12: 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 Specifications

ELS31-VA/ELS51-VA is equipped with two receiver ports. The sensitivity results according to Table 13 are verified by using both antenna ports according to the recommendation given in 3GPP TS 36.521-1, Chapter 7.2. The sensitivity results also depend on the selected bandwidth.

Table 13: RF Antenna interface LTE

Parameter	Conditions	Min.	Typical	Max.	Unit
LTE connectivity	Band 4 and 13				
Static Receiver input Sensitivity @ ARP (ch. bandwidth 5MHz)	LTE Band 4	-99.3	-103	--	dBm
	LTE Band 13	-99.3	-101	--	dBm
RF Power @ ARP with 50Ω Load	LTE Band 4	21	23	25	dBm
	LTE Band 13	21	23	25	dBm

2.2.2 Antenna Installation

The antenna is connected by soldering the antenna pads (RF_OUT, pad #59 and DIV_ANT, pad 56) its neighboring ground pads (GND, i.e., pads #55, #57, #58 and #60) directly to the application's PCB. The antenna pad is the antenna reference point (ARP) for ELS31-VA/ELS51-VA. All RF data specified throughout this document is related to the ARP.

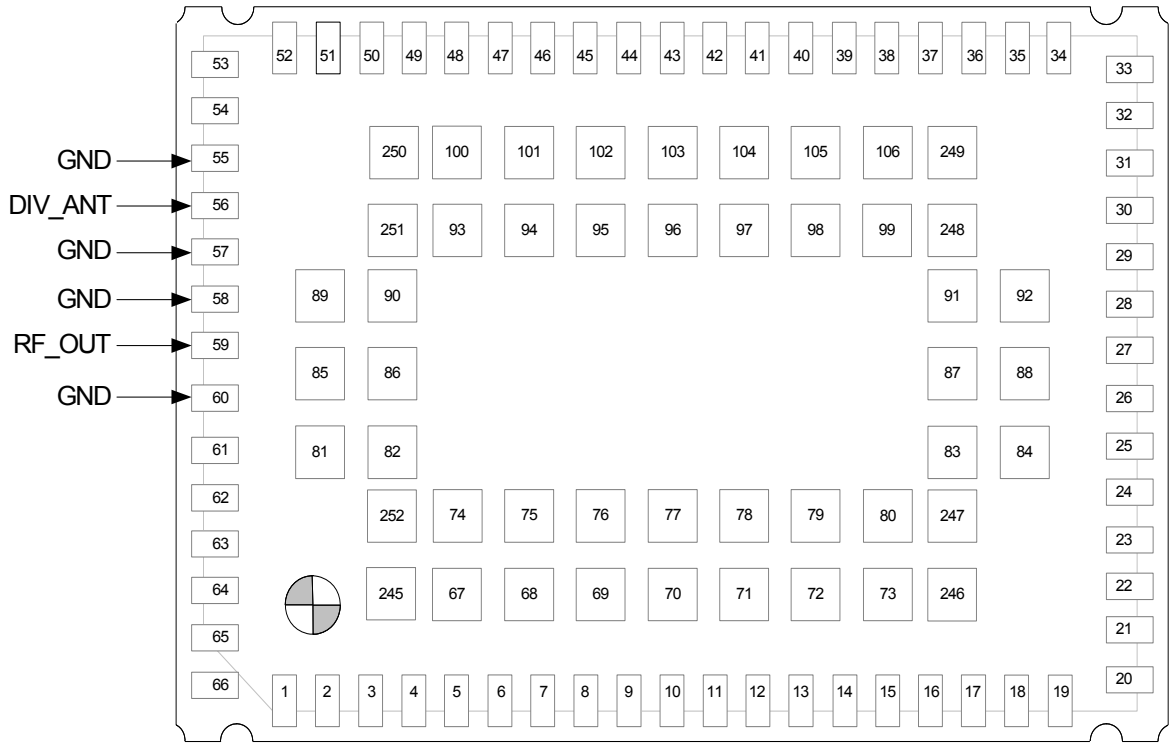


Figure 22: Antenna pads (bottom view)

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 Micro-Stripline technology. Please see Section 2.2.3.2 for an example.

For type approval purposes, the use of a 50Ω coaxial antenna connector (U.FL-R-SMT) might be necessary. In this case the U.FL-R-SMT connector should be placed as close as possible to ELS31-VA/ELS51-VA's antenna pad.

2.2.3 RF Line Routing Design

2.2.3.1 RF Interface Signals Circuit Diagram Example

Figure 23 is a topology reference, and it is recommended not to deviate from this circuit for your external application.

The RF inter-connects called RF Port 1 and RF Port 2 are examples only. Depending on the RF antenna, the interfacing system will dictate the RF inter-connects.

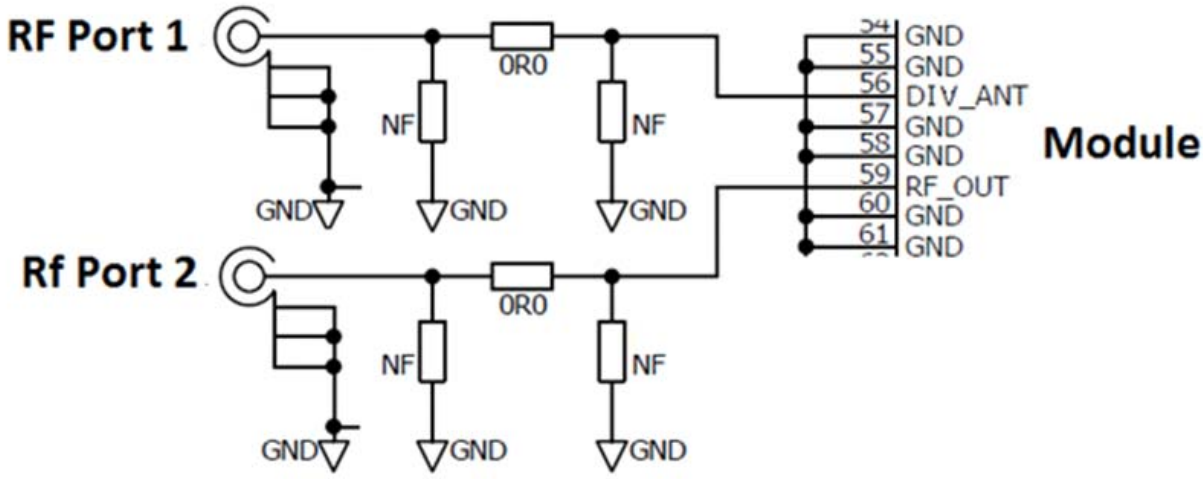


Figure 23: RF interface signals example

Please be also aware of ESD protection required on the RF interface lines. ESD protection might be utilized through the above pi-network (primarily intended for managing any additional RF optimization needs), or by additional components in series with the pi-network illustrated above. Please see Section 3.6.1 for further details.

2.2.3.2 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).

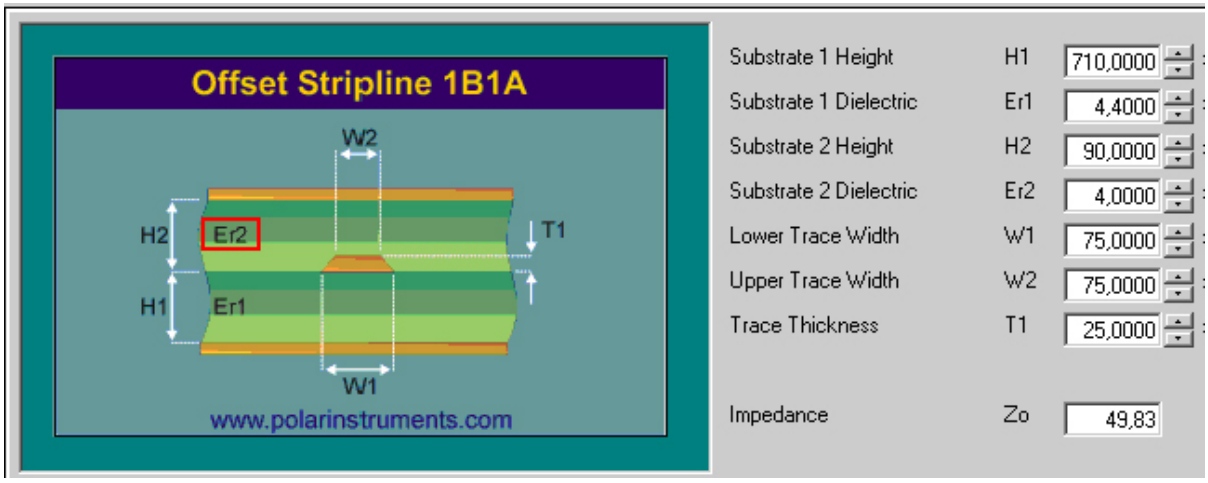


Figure 24: Embedded Stripline with 65µm prepreg (1080) and 710µm core

Micro-Stripline

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

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

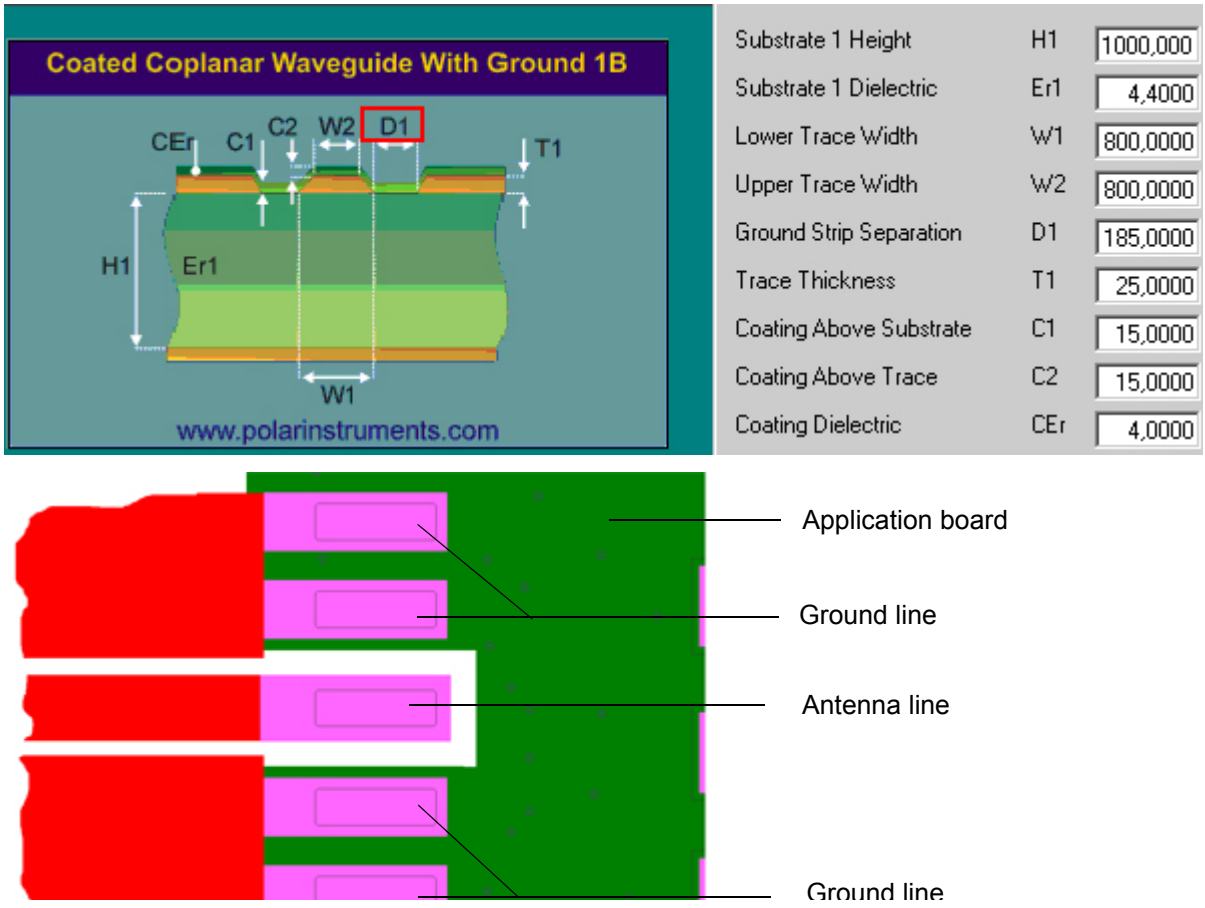


Figure 25: Micro-Stripline on 1.0mm standard FR4 2-layer PCB - example 1

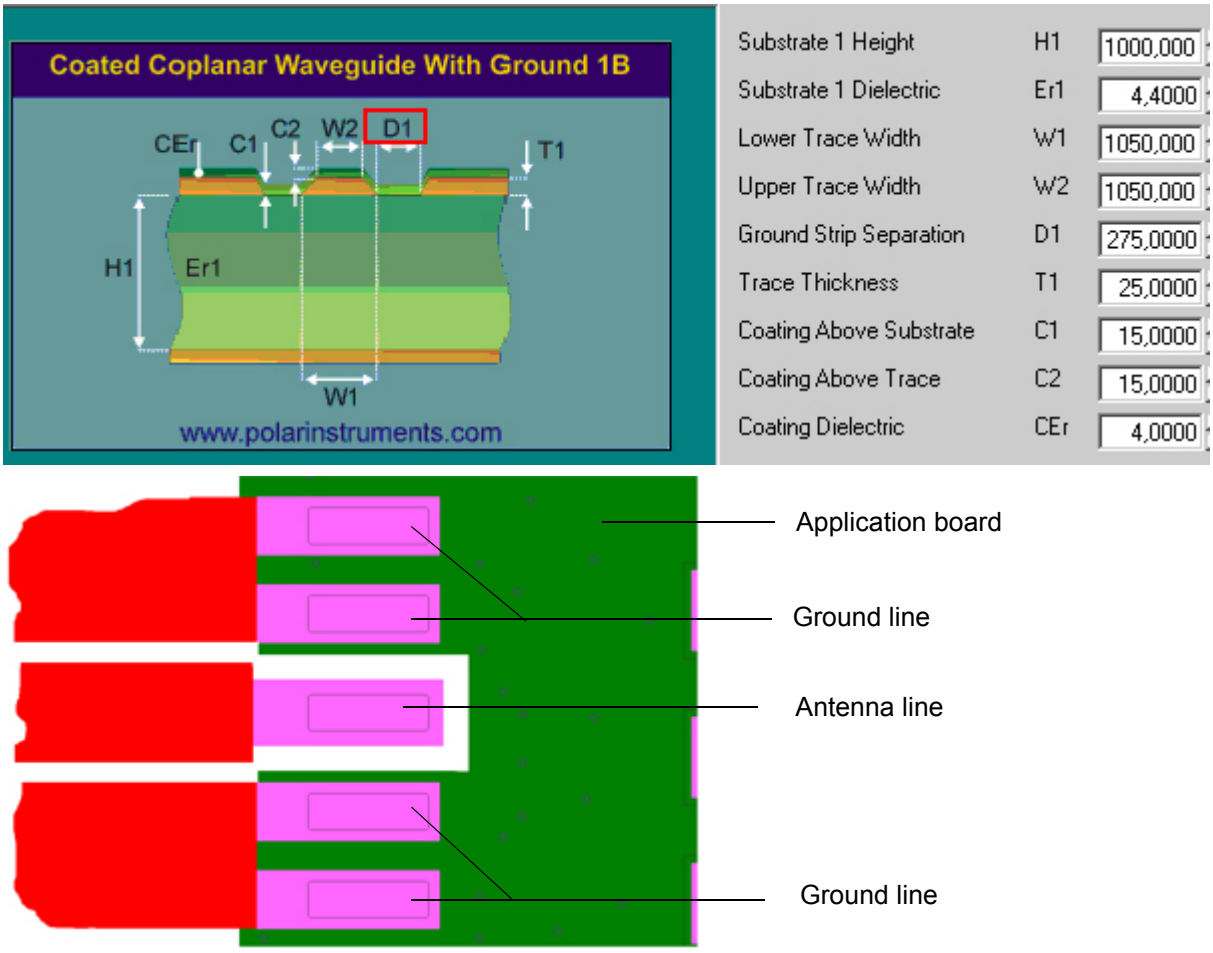


Figure 26: Micro-Stripline on 1.0mm Standard FR4 PCB - example 2

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

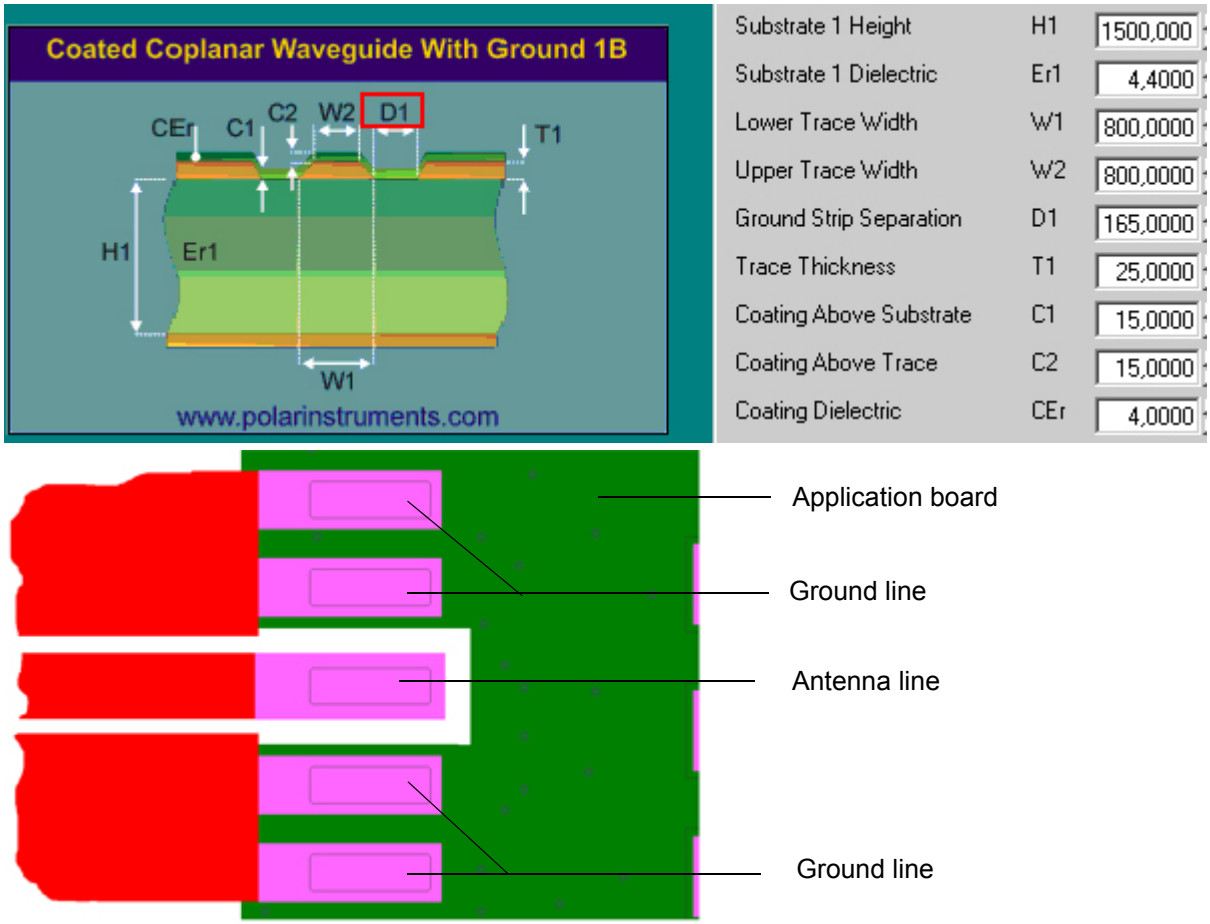


Figure 27: Micro-Stripline on 1.5mm Standard FR4 PCB - example 1

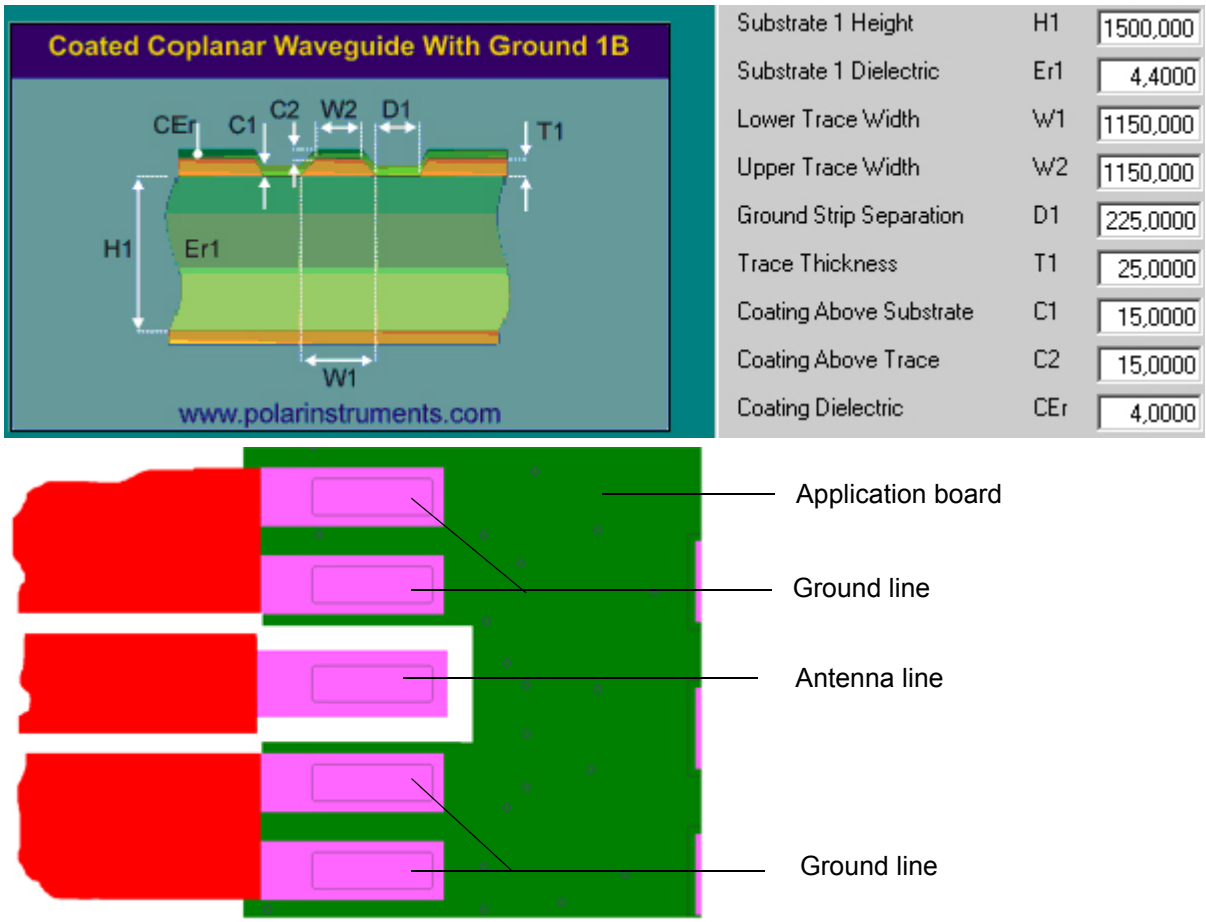


Figure 28: Micro-Stripline on 1.5mm Standard FR4 PCB - example 2

2.3 Sample Application

Figure 29 shows a typical example of how to integrate a ELS31-VA/ELS51-VA 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 [4].

The EMC measures are best practice recommendations. In fact, an adequate EMC strategy for an individual application is very much determined by the overall layout and, especially, the position of components. For example, mounting the internal acoustic transducers directly on the PCB eliminates the need to use the ferrite beads shown in the sample schematic.

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: ELS31-VA/ELS51-VA 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 29 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 ELS31-VA/ELS51-VA modules.

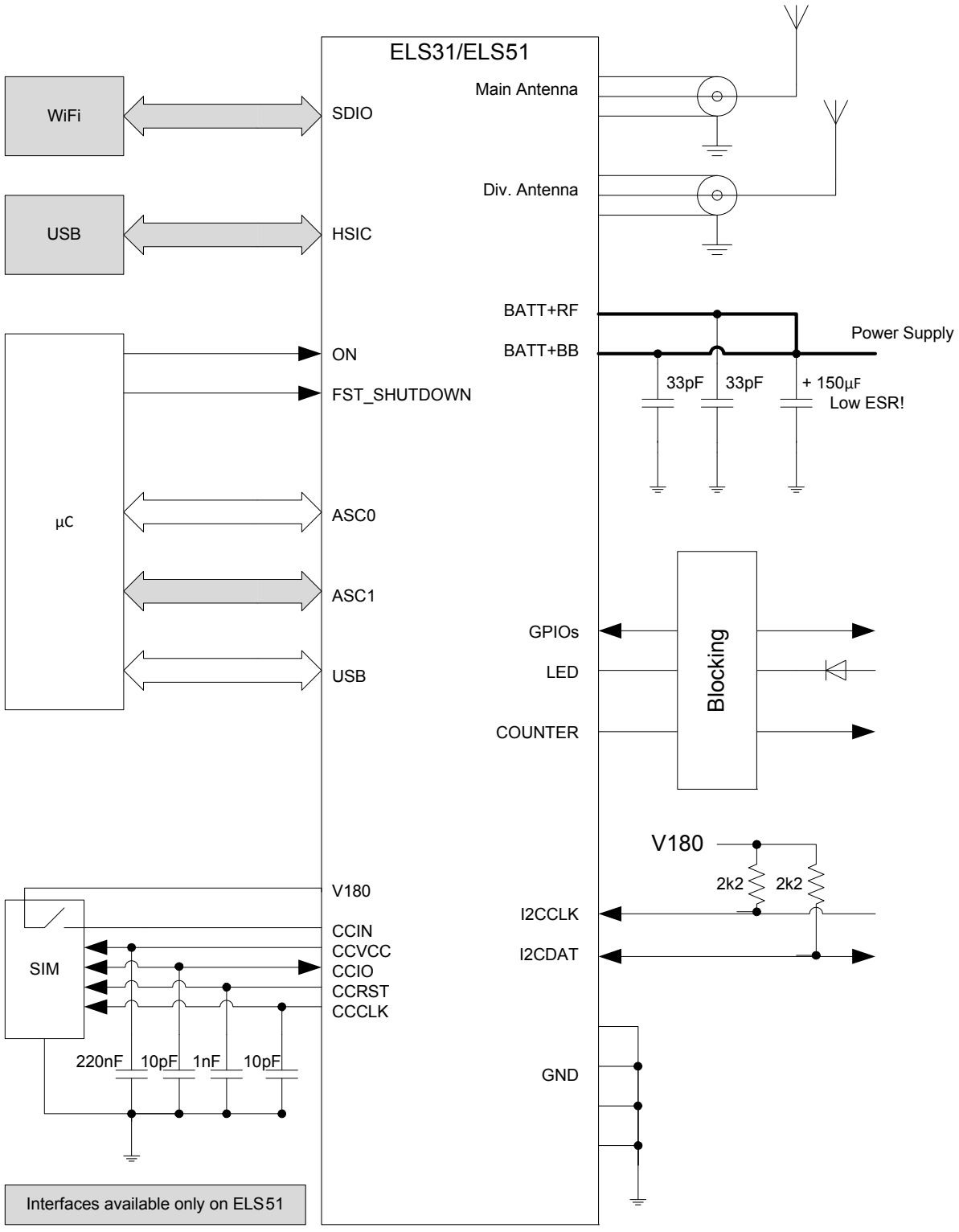


Figure 29: Schematic diagram of ELS31-VA/ELS51-VA sample application

2.3.1 Prevent 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. 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 30 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 fed back by the application interface - recognizing such a fault state is possible by V180.

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 30 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.

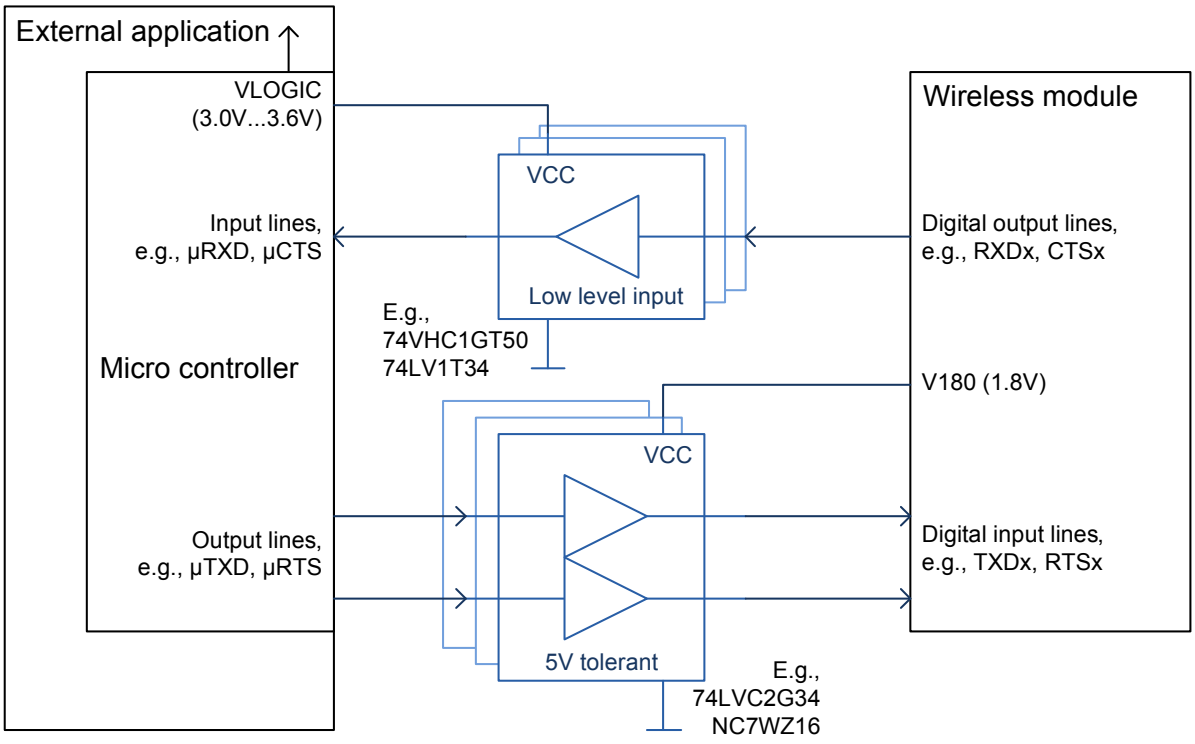


Figure 30: Sample level conversion circuit

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.

3 Operating Characteristics

3.1 Operating Modes

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

Table 14: Overview of operating modes

Mode	Function	
Normal operation	LTE IDLE	No data transfer is in progress and the USB connection is suspended by host (or is not present) and no active communication via ASC0/ ASC1. For power saving issues see Section 3.3. In IDLE mode, the software can be active or in SLEEP state.
	LTE DATA	LTE data transfer in progress. Power consumption depends on network settings and data transfer rate.
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]). In Airplane mode, the software can be active or in SLEEP state.	

3.2 Power Up/Power Down Scenarios

Do not turn on the ELS31-VA/ELS51-VA while it is beyond the safety limits of voltage and temperature stated in Section 2.1.2.1. ELS31-VA/ELS51-VA 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 ELS31-VA/ELS51-VA

ELS31-VA/ELS51-VA can be turned on as described in the following sections:
- Connecting the operating voltage BATT_BB and BATT_RF (see Section 3.2.1.1).
- Hardware driven switch on by 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 ELS31-VA/ELS51-VA BATT Lines

Figure 31 shows sample external application circuits that allow to connect (and also to temporarily disconnect) the module's BATT_BB and BATT_RF lines from the external application's power supply.

Figure 31 illustrates the application of power using an externally controlled microcontroller. The transistor T2 mentioned in Figure 31 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_BB and BATT_RF lines the module can then be (re-)started as described in Section 3.2.1.2.

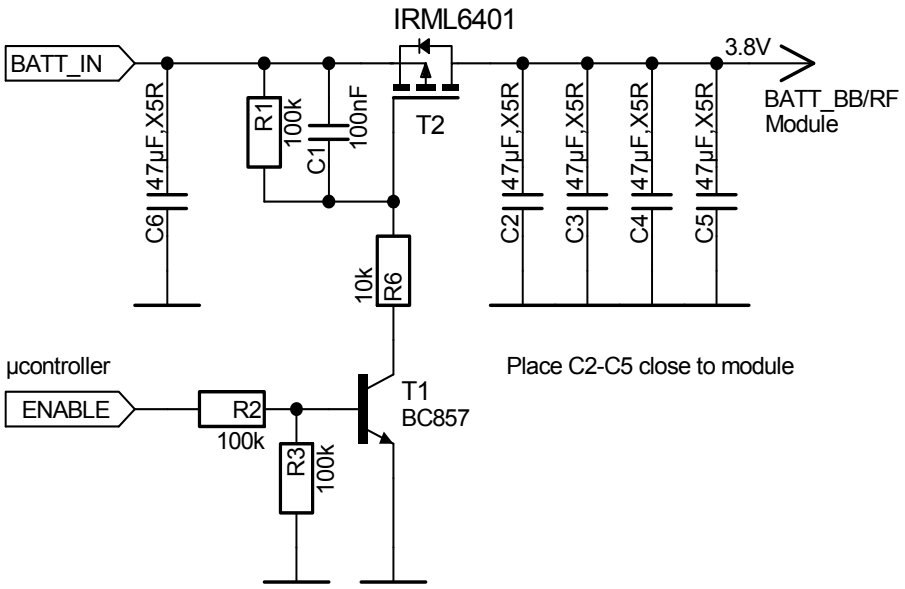


Figure 31: Sample circuit for applying power using an external µC

3.2.1.2 Switch on ELS31-VA/ELS51-VA Using ON Signal

When the operating voltage BATT_BB is applied, ELS31-VA/ELS51-VA can be switched on by means of the ON signal.

The ON signal is an edge triggered signal. The module starts into normal mode on detecting a rising edge at the ON signal. The subsequent high level at the ON signal should last for at least 100µs. Note that if the ON signal is set to high before BATT_BB is applied, ELS31-VA/ELS51-VA may not start up correctly.

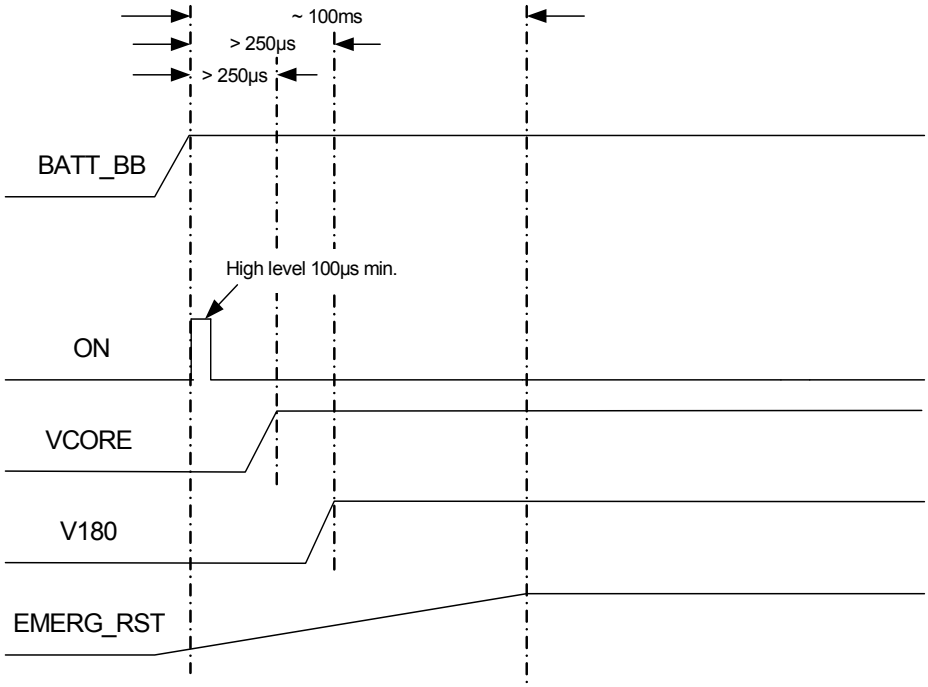


Figure 32: ON timing

The module can also start automatically and immediately after applying the VBATT by connecting the ON pad to BATT_BB for a so-called auto start mode. If ON is connected to BATT_BB, and the module is switched off (e.g. by calling AT^SMSO), it will immediately restart.

For the auto start mode, it is recommended to set a pull-up resistor of maximum TBD.kOhm between the ON circuit and the BATT_BB power supply.

Note: If during a power cycle or voltage drop the BATT_BB voltage level does not drop below 0.5V, it may happen that the module can no longer start up properly, because its reset condition was not reached. This scenario can happen, if the BATT_BB supply is decoupled by big capacitors – with a slow discharge after a sudden power drop. So, please make sure to keep the power off state long enough for the capacitors to discharge below 0.5V. As a workaround it is recommended to reset the module with EMERG_RST after startup (see also Section 3.2.2.2). If an automatic module startup is configured for the module, i.e., the ON signal is connected to BATT_BB, then the EMERG_RST signal may be generated automatically – using an external voltage detector - when the BATT_BB voltage does reach the valid operating voltage range.

3.2.2 Restart ELS31-VA/ELS51-VA

After startup ELS31-VA/ELS51-VA 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 ELS31-VA/ELS51-VA via AT+CFUN Command

To reset and restart the ELS31-VA/ELS51-VA module use the command AT+CFUN. See [1] for details.

3.2.2.2 Restart ELS31-VA/ELS51-VA Using EMERG_RST

The EMERG_RST signal is internally connected to the central GSM processor. A low level for more than 10 milliseconds sets the processor and with it all the other 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.

After releasing the EMERG-RST line, i.e., with a change of the signal level from low to high, the module restarts. The other signals continue from their reset state as if the module was switched on by the ON signal.

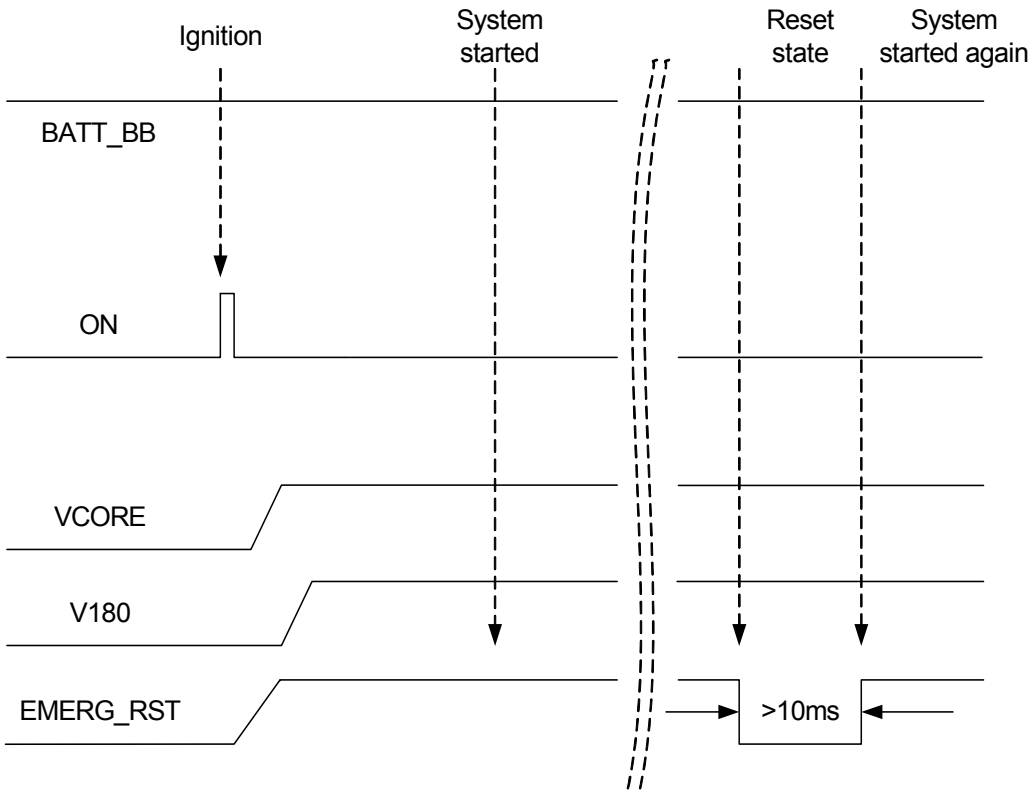


Figure 33: Emergency restart timing

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

Note: It is necessary to trigger EMERG_RST after a module turn off by a sudden (incomplete) power drop, and before using ON to restart the module (see also Section 3.2.1.2).

Caution: Generally, 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 ELS31-VA/ELS51-VA does not respond, if restart or shutdown via AT command fails.

3.2.3 Signal States after First Startup

Table 15 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 with the rising edge of an internal reset line - either with a normal module startup after about 26 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 2.1.4). Now, the module is ready to receive and transmit data.

Table 15: Signal states

Signal name	Default functionality	Reset state	First start up configuration
CCIO		I	O / L
CCRST		I	O / L
CCCLK		O / L	O / L
CCIN		I	I / PD
RXD0		I / PU	O / H
TXD0		I	I
CTS0		I	O / H
RTS0		I	I / PD
GPIO1/DTR0	DTR0	T / PD	I / PU
GPIO2/DCD0	DCD0	T / PD	O
GPIO3/DSR0	DSR0	T / PD	O
GPIO4/FST_SHDN	GPIO4	I / PD	I / PU
GPO5/LED	LED	I / PD	O
GPIO6	GPIO6	I / PD	I / PD
GPIO7	GPIO7	I / PU	I / PD
GPIO8/COUNTER	GPIO8	I	I / PD
GPIO16/RXD1	GPIO16	I	I / PU
GPIO17/TXD1	GPIO17	I /PU	I / PU
GPIO18/RTS1	GPIO18	I /PU	I / PU
GPIO19/CTS1	GPIO19	I /PU	I / PU
GPIO20/PCM_I2S_OUT	GPIO20	I	I / PD
GPIO21/PCM_I2S_IN	GPIO21	I	I / PD
GPIO22/PCM_I2S_FSC	GPIO22	I	I / PD
GPO23/PCM_I2S_CLK	GPO23	I	O / L
GPIO24/RING0	RING0	T / PD	O
GPIO25	GPIO25	I	I / PD
GPO26/SPI_CS1	GPO26	I	O
GPIO27/SPI_CS2	GPIO27	I	I / PD
I2CCLK		I / PD	T / OD
I2CDAT		I / PD	T / OD

Abbreviations used in above Table 15:

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 ELS31-VA/ELS51-VA

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.
- *Hardware controlled shutdown procedure*: Hardware controlled by employing the FST_SHDN line. See Section 2.1.16.4.
- *Automatic shutdown (software controlled)*: See Section 3.2.5
  - Takes effect if ELS31-VA/ELS51-VA board temperature exceeds a critical limit.

3.2.4.1 Switch off ELS31-VA/ELS51-VA Using AT Command

The best and safest approach to powering down ELS31-VA/ELS51-VA is to issue the appropriate AT command. This procedure lets ELS31-VA/ELS51-VA 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 issueing the switch off AT command, the ON signal should be set to low (see Figure 34). Otherwise there might be back powering at the ON line in Power Down mode.

While ELS31-VA/ELS51-VA 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.

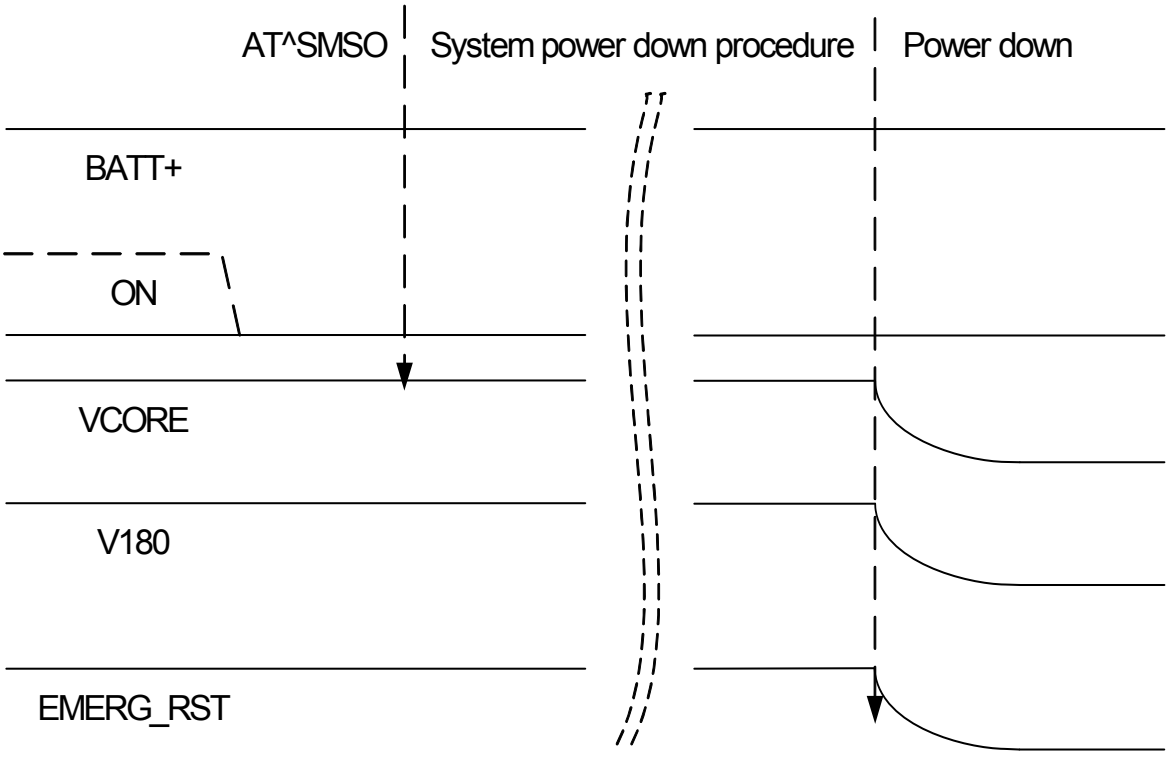


Figure 34: Switch off behavior

3.2.5 Automatic Shutdown

Automatic shutdown takes effect if the following event occurs:
- The ELS31-VA/ELS51-VA 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. ELS31-VA/ELS51-VA 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, ELS31-VA/ELS51-VA 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 ELS31-VA/ELS51-VA. 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 16 for the associated URCs.

Table 16: Temperature dependent behavior

Sending temperature alert (2min 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. ELS31-VA/ELS51-VA switches off.
^SCTM_B: -2	Alert: Board equal or below undertemperature limit. ELS31-VA/ELS51-VA 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 ELS31-VA/ELS51-VA 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 the specified maximum supply voltage V_{BATT+} given in Table 2. When the average supply voltage measured by ELS31-VA/ELS51-VA 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 ELS31-VA/ELS51-VA. Especially the power amplifier linked to $BATT+_{RF}$ is very sensitive to high voltage and might even be destroyed.

3.3 Power Saving

ELS31-VA/ELS51-VA can be configured in two ways to control power consumption:

- Being set by configuration, it is possible to specify a so-called power saving mode for the module (for details on the command see [1]). The module's UART interfaces (ASC0 and ASC1) are then deactivated and will only periodically be activated to be able to listen to network paging messages as described in Section 3.3.1. See Section 3.3.2 for a description of how to immediately wake up ELS31-VA/ELS51-VA again using RTS0.
  Note: RTS0/RTS1 must to be set to high before the ELS31-VA/ELS51-VA can change into power saving mode. Also note that the AT^SPOW setting has no effect on the USB interface. As long as the USB connection is active, the module will not change into its SLEEP state to reduce its functionality to a minimum and thus minimizing its current consumption. To enable switching into SLEEP mode, the USB connection must therefore either not be present at all or the USB host must bring its USB interface into Suspend state. Also, VUSB_IN should always be kept enabled for this functionality. See “Universal Serial Bus Specification Revision 2.0”[1] for a description of the Suspend state.
- 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 paging timing cycle of the base station.

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

t = DRX Cycle Value* 10 ms

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

In the pauses between listening to paging messages, the module resumes power saving, as shown in Figure 35.

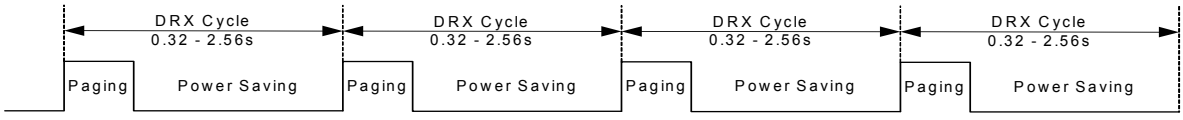


Figure 35: Power saving and paging in LTE networks

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

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

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

3.3.2 Wake-up via RTS0/RTS1

RTS0/RTS1 can be used to wake up ELS31-VA/ELS51-VA 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 36 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.

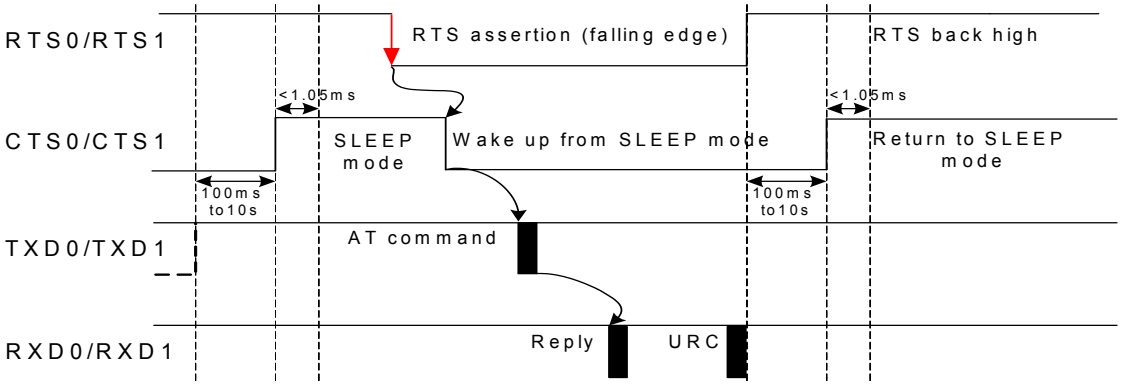


Figure 36: Wake-up via RTS0/RTS1

Note: RTS0/RTS1 has to be high for ELS31-VA/ELS51-VA to be able to change into SLEEP mode.

3.4 Power Supply

ELS31-VA/ELS51-VA needs to be connected to a power supply at the SMT application interface - 2 BATT lines and GND. There are two separate voltage domains for BATT:
- BATT_BB with a line mainly for the baseband power supply.
- BATT_RF with a line for the RF power amplifier supply.

Please note that throughout the document BATT refers to both voltage domains and power supply lines - BATT_BB and BATT_RF.

The power supply of ELS31-VA/ELS51-VA has to be a single voltage source at BATT_BB and BATT_RF. 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 17 and Table 18 assemble various voltage supply and current consumption ratings of the module.

Table 17: Voltage supply ratings

	Description	Conditions	Min	Typ	Max	Unit
BATT_BB BATT_RF	Supply voltage	Directly measured at Module. Voltage must stay within the min/max values, including voltage drop, ripple, spikes	3.3		4.5	V
	Voltage ripple	Normal condition, power control level for Pout max @ f <= 250 kHz @ f > 250 kHz			 110 30	 mV_{pp} mV_{pp}

Table 18: Current consumption ratings

	Description	Conditions		Power [mW]	Typical rating @ 3.8V [mA]
I_{BATT+}	Power Down Mode				<15µA
	Aiplane Mode			9.2	2.4
	LTE Idle	RRC Paging cycle @ 2.56 s		15.2	4.0
		RRC Paging cycle @ 1.28 s		20.9	5.5
	LTE Data	LTE cDRX mode No traffic	cDRX period 320ms	238	62.5
		Cell search		38	10

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_BB/BATT_RF never drops below 3.3V on the ELS31-VA/ELS51-VA board.

3.4.3 Measuring the Supply Voltage (BATT_BB)

To measure the supply voltage of BATT_BB/BATT_RF it is possible to define three reference points GND ,BATT_BB and BATT_RF. GND should be the module's shielding, while BATT_BB/BATT_RF should be a test pad on the external application the module is mounted on. The external BATT_BB/NBATT_RF reference points have to be connected to and positioned close to the SMT application interface's BATT pads 5 (BATT_BB) or 53 (BATT_RF) as shown in Figure 37.

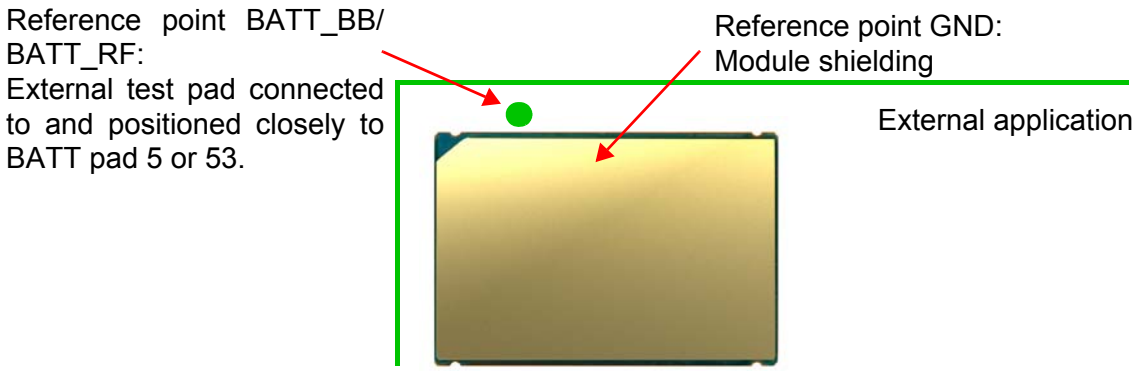


Figure 37: Position of reference points BATT_BB/BATT_RF and GND

3.4.4 Monitoring Power Supply by 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_BB 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 ELS31-VA/ELS51-VA 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 19: Board temperature

Parameter	Min	Typ	Max	Unit
Normal operation	-30	+25	+85	°C
Extended operation[1]	-40		+90	°C
Automatic shutdown[2] Temperature measured on ELS31-VA/ELS51-VA board	<-40	---	>+90	°C

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

For more information regarding the module's thermal behavior please refer to [3].

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 ELS31-VA/ELS51-VA module.

Special ESD protection complying to ETSI EN 301 489-01/-07 is provided for the SIM interface as also mentioned in Section 2.1.6.

The remaining interfaces of ELS31-VA/ELS51-VA with the exception of the antenna interface are not accessible to the user of the final product (since they are installed within the device) and are therefore only protected according to the ANSI/ESDA/JEDEC JS-001-2011 requirements.

ELS31-VA/ELS51-VA has been tested according to following standards. Electrostatic values can be gathered from the following table.

Table 20: Electrostatic values

Specification/Requirements	Contact discharge	Air discharge
ETSI EN 301 489-01/-07		
SIM interface	± 4kV	± 8kV
ANSI/ESDA/JEDEC JS-001-2011		
All other SMT interfaces	± 1kV Human Body Model	n.a.
JEDEC JESD22-A114D (Human Body Model, Test conditions: 1.5 kΩ, 100 pF)		
All other 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 Chapter 5.3.

3.6.1 ESD Protection for Antenna Interface

The following Figure 38 shows how to implement an external ESD protection for the RF antenna interface with either a T pad or PI pad attenuator circuit (for RF line routing design see also Section 2.2.3).

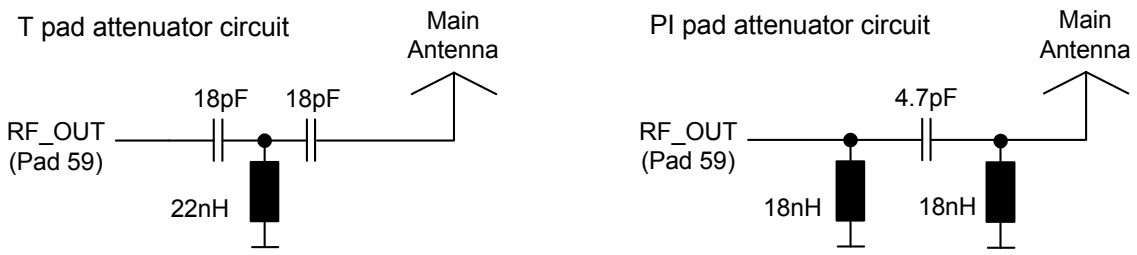


Figure 38: ESD protection for RF antenna interface

Possible inductors: Murata LQG15HS22NJ02D (22nH), and LQW15AN18NJ00 (18nH)

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 (cp. 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 five possible variants of EMI measures (A-C) that may be implemented between module and external application depending on the signal line (see Figure 39 and Table 21). 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.

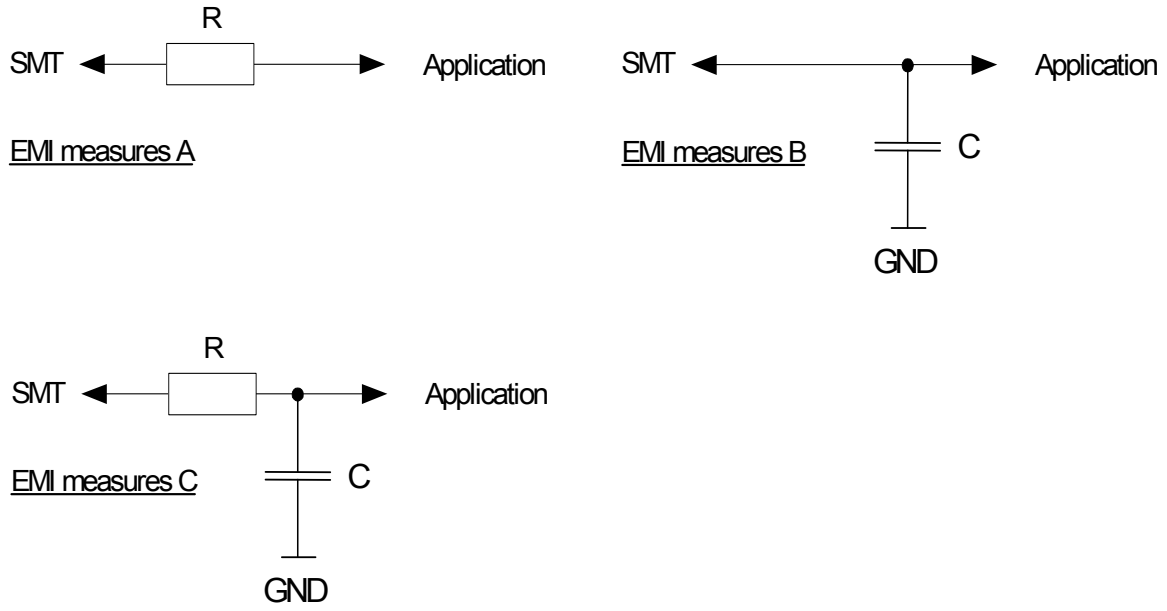


Figure 39: EMI circuits

Note: In case the application uses an internal antenna that is implemented close to the ELS31-VA/ELS51-VA / ELS51-VA module, Gemalto strongly recommends sufficient EMI measures, e.g. of type B or C, for each digital input or output.

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

Table 21: 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	
GPO5/LED	x	x	x	
GPIO6	x	x	x	
GPIO7	x	x	x	
GPIO8/COUNTER	x	x	x	
GPIO16/RXD1/AP_WAKEUP	x	x	x	
GPIO17/TXD1/HOST_ACTIVE	x	x	x	
GPIO18/RTS1/CP_WAKEUP	x	x	x	
GPIO19/CTS1/SUSPEND	x	x	x	
GPIO20/PCM_I2S_OUT	x	x	x	
GPIO21/PCM_I2S_IN	x	x	x	
GPIO22/PCM_I2S_FSC	x	x	x	
GPO23/PCM_I2S_CLK	x	x	x	
GPIO24/RING0	x	x	x	
GPIO25	x	x	x	
GPO26/SPI_CS1	x	x	x	
GPIO27/SPI_CS2	x	x	x	
I2CDAT		x		The rising signal edge is reduced with an additional capacitor.
I2CCLK		x		
V180		x		
VCORE		x		

Table 21: EMI measures on the application interface

Signal name	EMI measures			Remark
	A	B	C	
BATT_RF		x		Measures required if $BATT+_{RF}$ is close to internal LTE antenna - e.g., 39pF blocking capacitor to ground
BATT_BB		x		
SDIOCMD	x	x	x	
SDIOCLK	x	x	x	
SDIO0	x	x	x	
SDIO1	x	x	x	
SDIO2	x	x	x	
SDIO3	x	x	x	
HSIC_DATA	x	x	x	
HSIC_STRB	x	x	x	

3.8 Reliability Characteristics

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

Table 22: Summary of reliability test conditions

Type of test	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 ELS31-VA/ELS51-VA and give recommendations for integrating ELS31-VA/ELS51-VA into the host application.

4.1 Mechanical Dimensions of ELS31-VA/ELS51-VA

Figure 40 shows the top and bottom view of ELS31-VA/ELS51-VA and provides an overview of the board's mechanical dimensions. For further details see Figure 41.

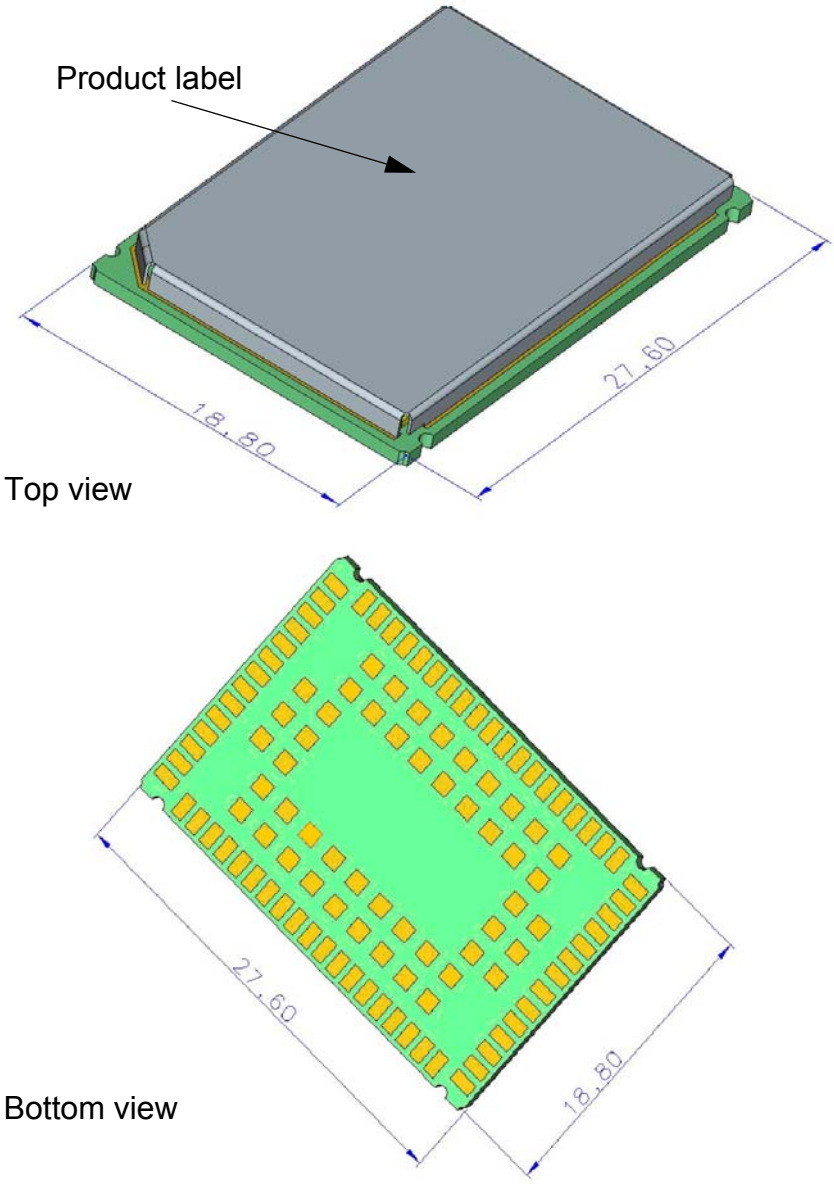


Figure 40: ELS31-VA/ELS51-VA– top and bottom view

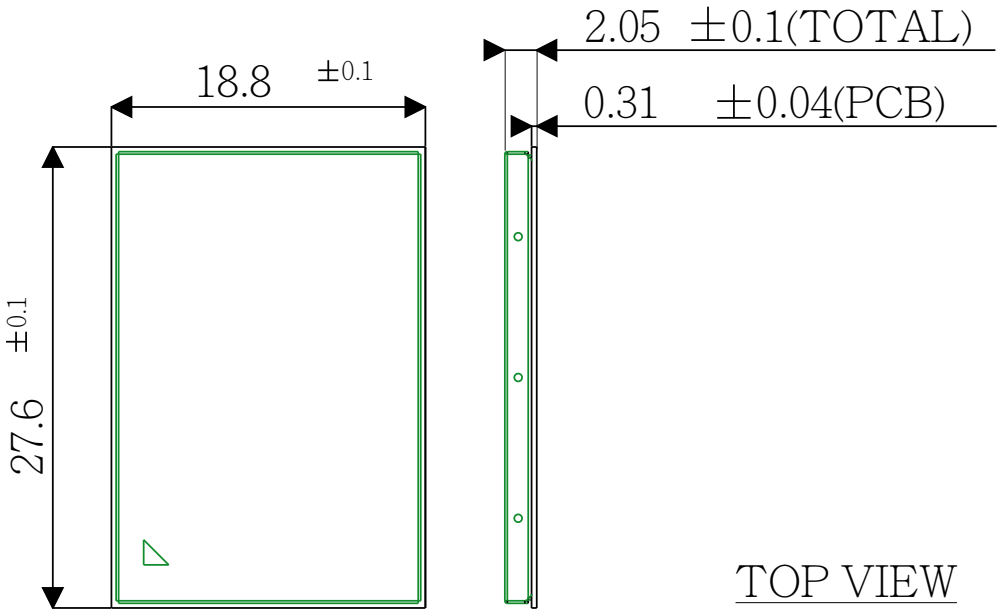


Figure 41: Dimensions of ELS31-VA/ELS51-VA (all dimensions in mm)

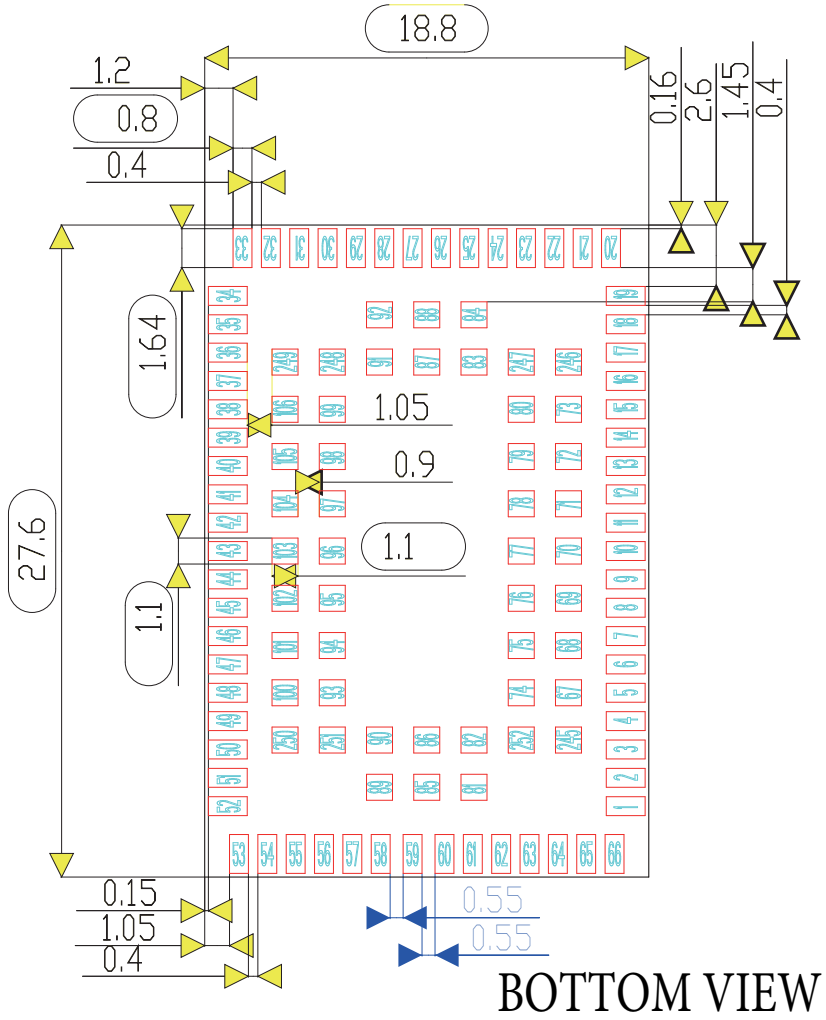


Figure 42: Dimensions of ELS31-VA/ELS51-VA (all dimensions in mm) - bottom view

4.2 Mounting ELS31-VA/ELS51-VA onto the Application Platform

This section describes how to mount ELS31-VA/ELS51-VA onto the PCBs (=printed circuit boards), including land pattern and stencil design, board-level characterization, soldering conditions, durability and mechanical handling. For more information on issues related to SMT module integration see also [4].

Note: 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 120 micron thick stencil.

The land pattern given in Figure 43 reflects the module‘s pad layout, including signal pads and ground pads (for pad assignment see Section 2.1.1).

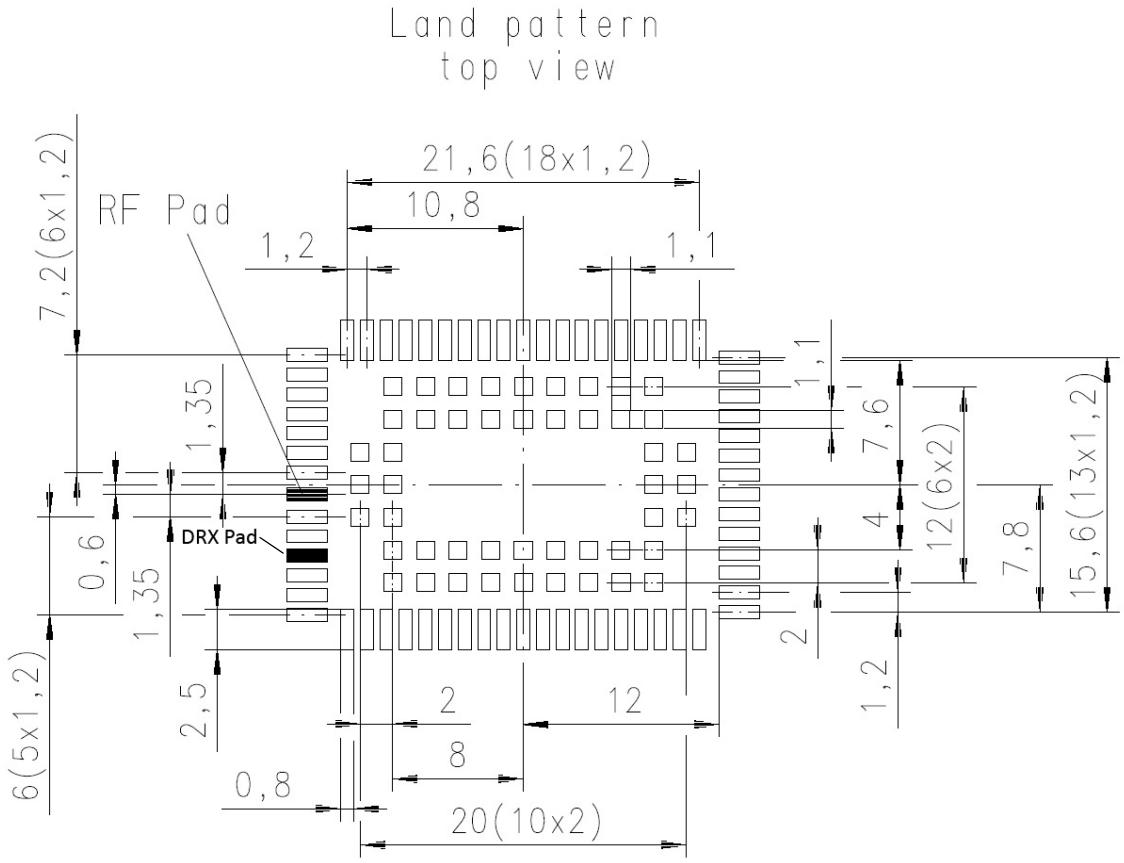


Figure 43: Land pattern (top view)

The stencil design illustrated in Figure 44 is recommended by Gemalto M2M as a result of extensive tests with Gemalto M2M Daisy Chain modules.

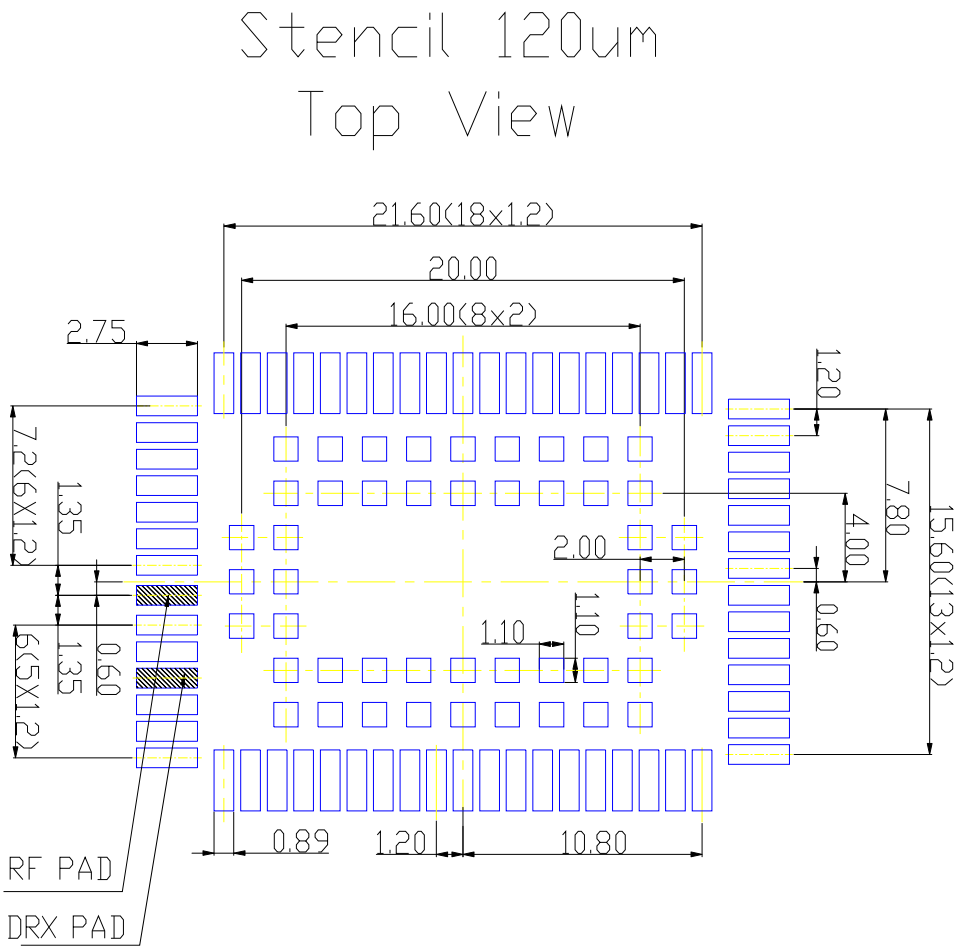


Figure 44: Recommended design for 120 micron thick stencil (top view, dual design)

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. Sample surface mount checks are described in [4].

It is recommended to characterize land patterns before an actual PCB production, taking individual processes, materials, equipment, stencil design, and reflow profile into account. For land and stencil pattern design recommendations see also Section 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 [4].

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

ELS31-VA/ELS51-VA comprises components that are susceptible to damage induced by absorbed moisture.

Gemalto M2M's ELS31-VA/ELS51-VA 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

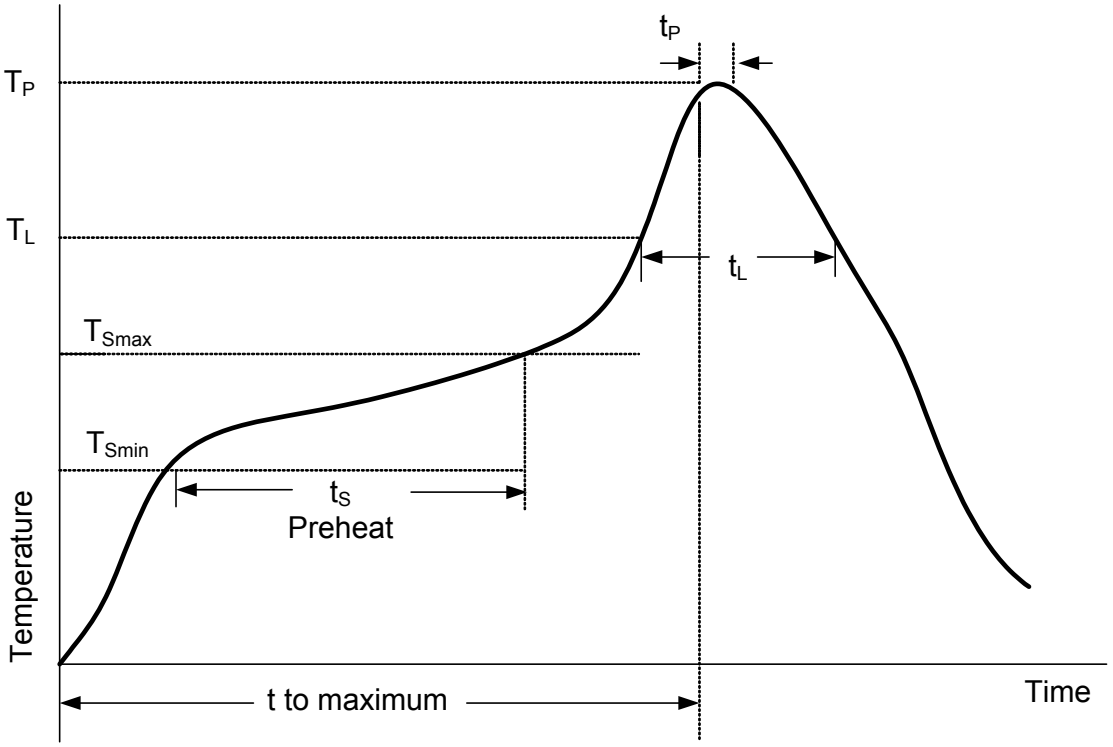


Figure 45: Reflow Profile

Table 23: Reflow temperature ratings[1]

Profile Feature	Pb-Free Assembly
Preheat & Soak Temperature Minimum (T_{Smin}) Temperature Maximum (T_{Smax}) Time (t_{Smin} to t_{Smax}) (t_S)	 150°C 200°C 60-120 seconds
Average ramp up rate (T_{Smax} to T_P)	3K/second max.
Liquidous temperature (T_L) Time at liquidous (t_L)	217°C 60-90 seconds
Peak package body temperature (T_P)	245°C +0/-10°C
Time (t_P) within 5 °C of the peak package body temperature (T_P)	20 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 [4].

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 240°C. This specifies the temperature as measured at the module's top side.
- A maximum duration of 15 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.

ELS31-VA/ELS51-VA is specified for one soldering cycle only. Once ELS31-VA/ELS51-VA 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

ELS31-VA/ELS51-VA 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 24: 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

ELS31-VA/ELS51-VA 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 50 for details):

- It is *not necessary* to bake ELS31-VA/ELS51-VA, if the conditions specified in Section 4.2.4.1 and Section 4.2.4.2 were not exceeded.
- It is *necessary* to bake ELS31-VA/ELS51-VA, 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 irreversable 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 further information on electrostatic discharge.

4.3 Packaging

4.3.1 Tape and Reel

The single-feed tape carrier for ELS31-VA/ELS51-VA is illustrated in Figure 46. The figure also shows the proper part orientation. The tape width is 44 mm and the ELS31-VA/ELS51-VA 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

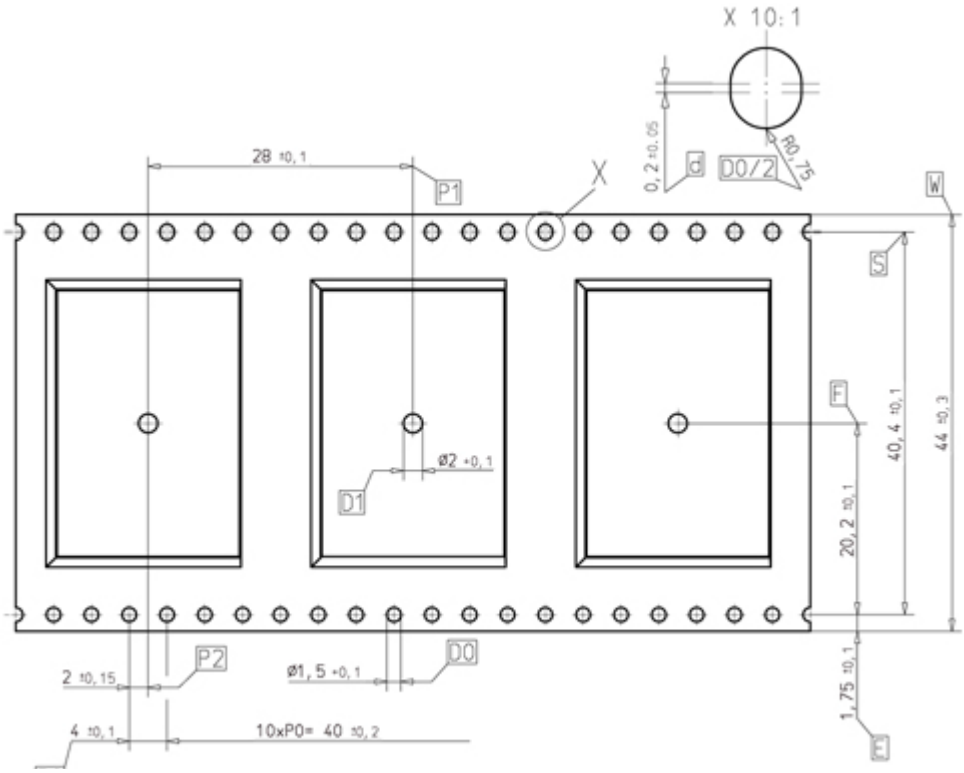


Figure 46: Carrier tape

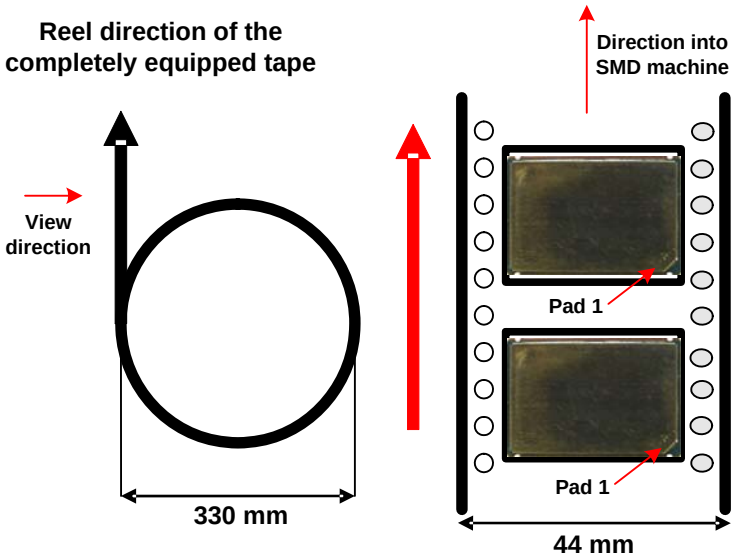


Figure 47: Reel direction

4.3.1.2 Barcode Label

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

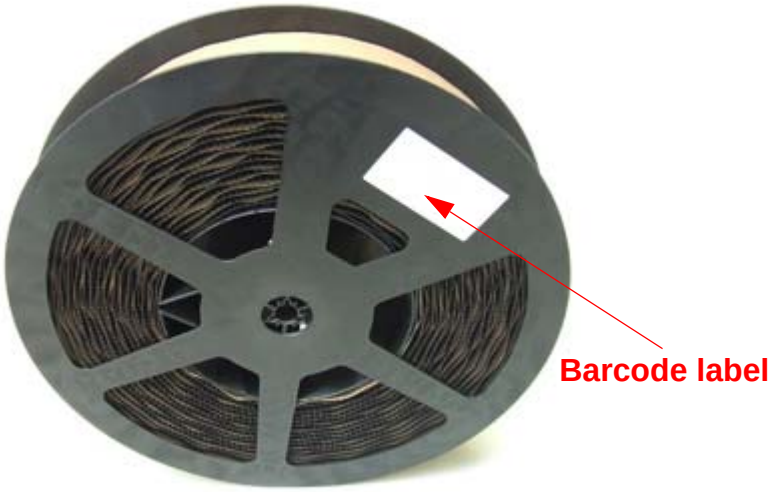


Figure 48: Barcode label on tape reel

4.3.2 Shipping Materials

ELS31-VA/ELS51-VA is distributed in tape and reel carriers. The tape and reel carriers used to distribute ELS31-VA/ELS51-VA 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 49. 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 ELS31-VA/ELS51-VA modules from moisture exposure. It should not be opened until the devices are ready to be soldered onto the application.

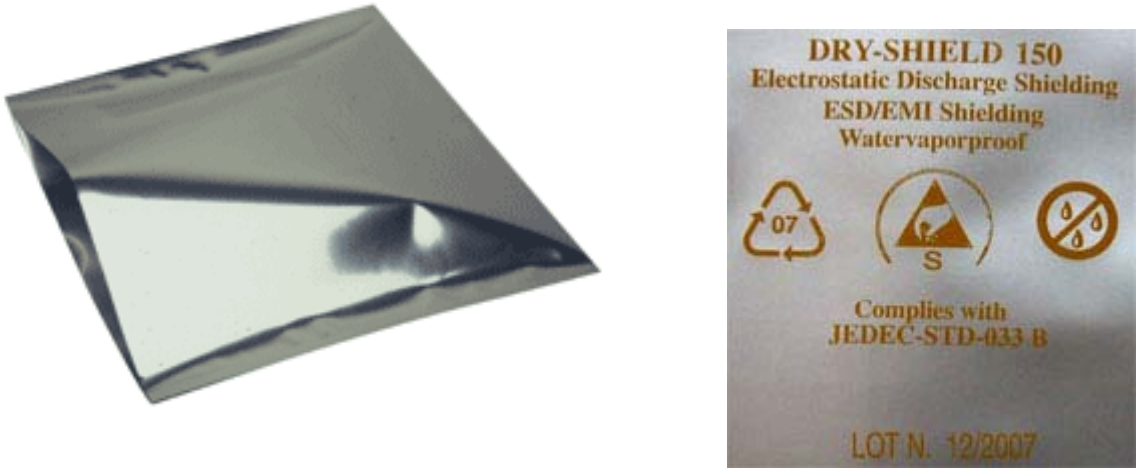


Figure 49: Moisture barrier bag (MBB) with imprint

The label shown in Figure 50 summarizes requirements regarding moisture sensitivity, including shelf life and baking requirements. It is attached to the outside of the moisture barrier bag.

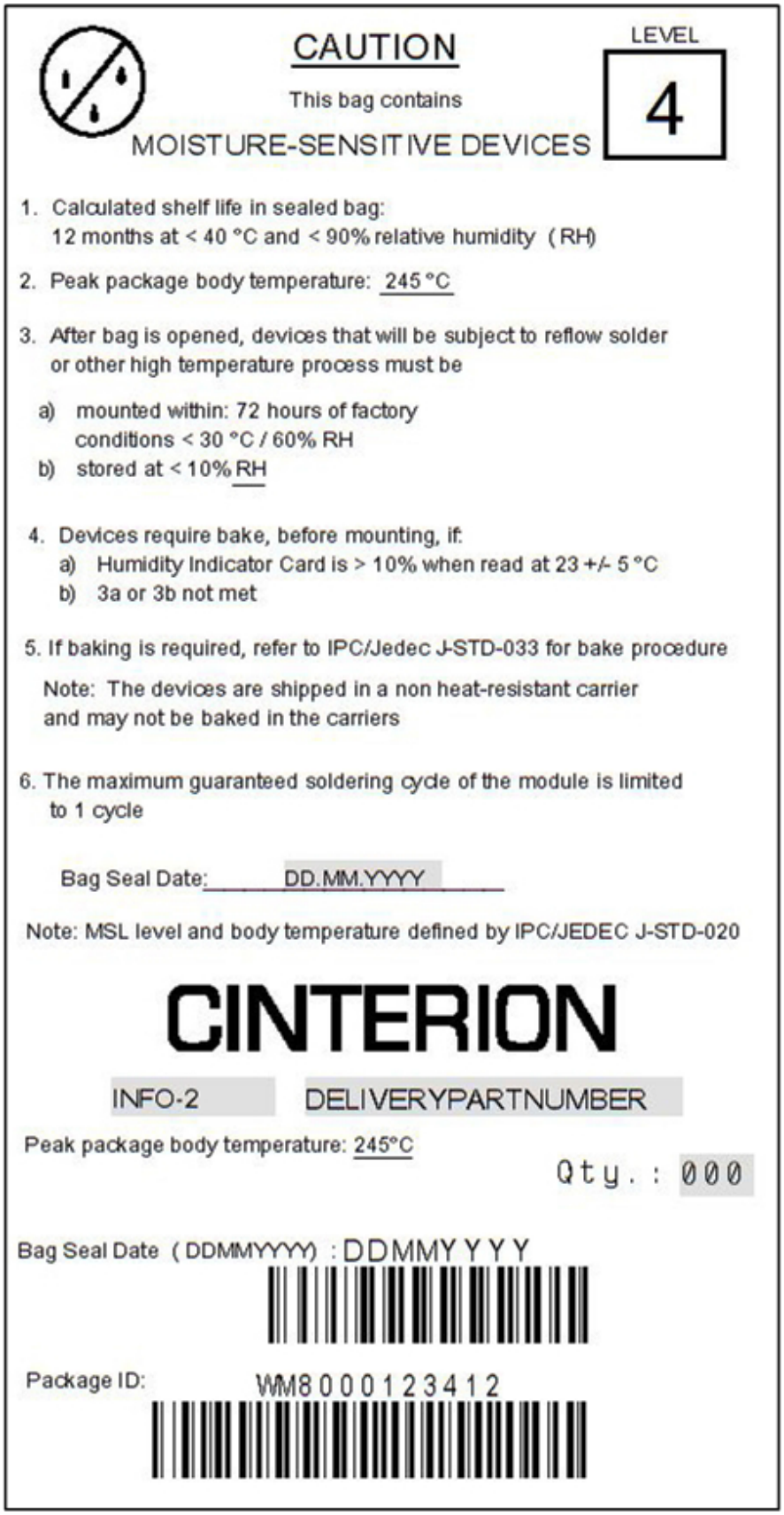


Figure 50: Moisture Sensitivity Label

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 51. If the components have been exposed to moisture above the recommended limits, the units will have to be rebaked.

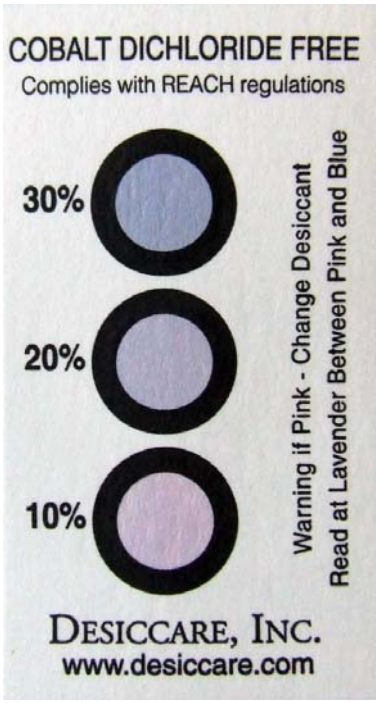


Figure 51: Humidity Indicator Card - HIC

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, ELS31-VA/ELS51-VA may be distributed in trays (for dimensions see Figure 55). 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 information on hand soldering see [4]).

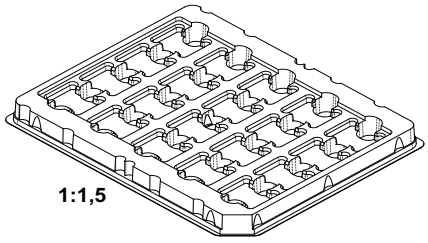


Figure 52: Small quantity tray

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 4.3.2).

Figure 53: Tray to ship odd module amounts

Figure 54: Trays with packaging materials

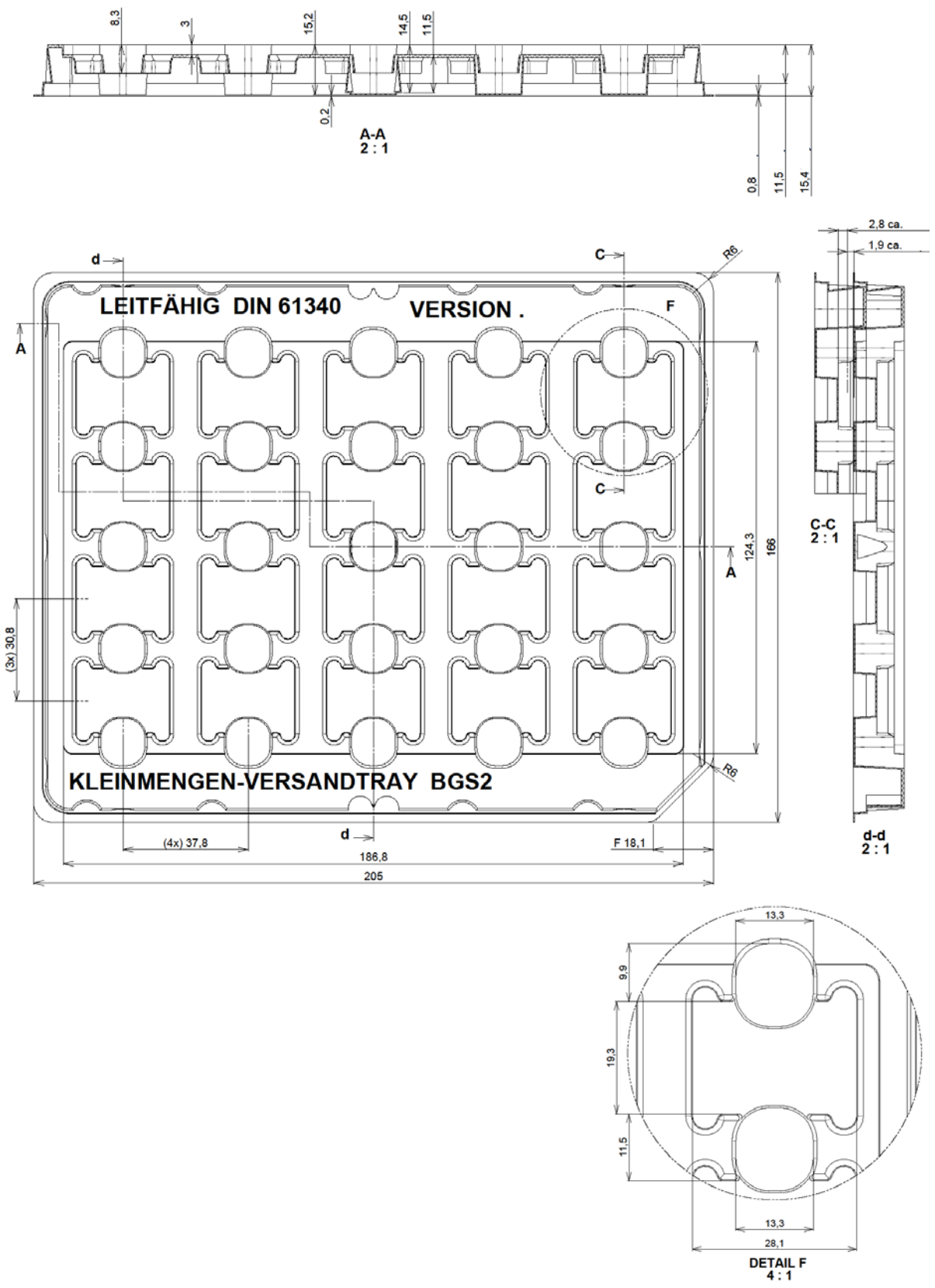


Figure 55: Tray dimensions

5 Regulatory and Type Approval Information

5.1 Directives and Standards

ELS31-VA/ELS51-VA 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 "ELS31-VA/ELS51-VA Hardware Interface Description".

Table 25: 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 26: 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
RSS132 (Issue2) RSS133 (Issue5)	Canadian Standard

Table 27: Standards of Verizon type approval

Verizon Wireless Unified Module Process for Compliance Testing and Approval, October 2014	
Verizon Wireless Device Requirements LTE 3GPP Band 13 Network Access, October 2014	
Verizon Wireless Device Requirements LTE 3GPP Band 4 Network Access, October 2014	
3GPP2 C.S0015-A v1.0	Short Message Service for spread spectrum systems

Table 28: Standards of GCF type approval

3GPP TS 51.010-1	Digital cellular telecommunications system (Release 10); Mobile Station (MS) conformance specification;
GCF-CC V3.58	Global Certification Forum - Certification Criteria

Table 29: Requirements of quality

IEC 60068	Environmental testing
DIN EN 60529	IP codes

Table 30: 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 31 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 31: 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 ELS31-VA/ELS51-VA 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 ELS31-VA/ELS51-VA (including a special approval adapter for the DSB75) is shown in the following figure[1]:

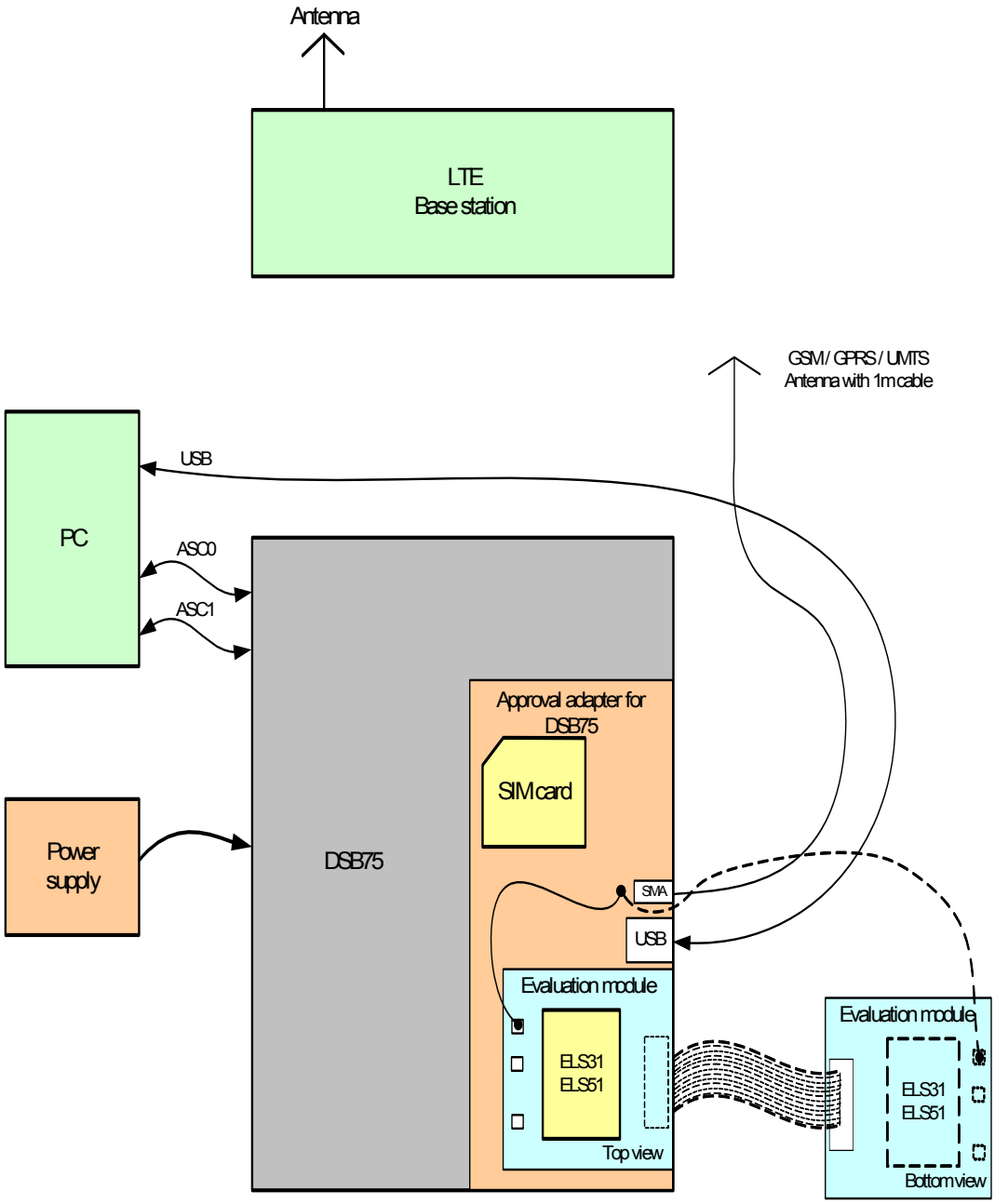


Figure 56: Reference equipment for Type Approval

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 GSM/UMTS test equipment instead of employing the SMA antenna connectors on the ELS31-VA/ELS51-VA-DSB75 adapter as shown in Figure 56. 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 IC 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:

- *ELS31-VA:*
  FCC Identifier: QIPELS31-VA
  Industry Canada Certification Number: 7830A-ELS31VA
  Granted to Gemalto M2M GmbH

- *ELS51-VA:*
  FCC Identifier: QIPELS51-VA (not yet granted)
  Industry Canada Certification Number: 7830A-ELS51VA (not yet granted)
  Granted to Gemalto M2M GmbH

Manufacturers of mobile or fixed devices incorporating ELS31-VA/ELS51-VA modules are authorized to use the FCC Grants and Industry Canada Certificates of the ELS31-VA/ELS51-VA modules for their own final products according to the conditions referenced in these documents. In this case, an FCC/ IC label of the module shall be visible from the outside, or the host device shall bear a second label stating "Contains FCC ID: QIPELS31-VA" / "Contains FCC ID: QIPELS51-VA", and accordingly “Contains IC: 7830A-ELS31VA“ / “Contains IC: 7830A-ELS51-VA“. 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 28 for FCC and IC.

Table 32: Antenna gain limits for FCC and IC

Operating band	FCC limit	IC limit	Unit
Maximum gain in lower operating bands with f< 1GHz (LTE Bd13)	10.4	7.4	dBi
Maximum gain in higher operating bands with f=1700MHz (LTE Bd4)	6.5	6.5	dBi

IMPORTANT:
Manufacturers of portable applications incorporating ELS31-VA/ELS51-VA modules are required to have their final product certified and apply for their own FCC Grant and Industry Canada Certificate related to the specific portable mobile. This is mandatory to meet the SAR requirements for portable mobiles (see Section 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: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules and with Industry Canada license-exempt RSS standard(s). These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference

will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

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

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

If Canadian approval is requested for devices incorporating ELS31VA / ELS51-VA modules the above note will have to be provided in the English and French language in the final user documentation. 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 (IC):
(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 Industry Canada (IC) 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 IC 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‘Industry Canada (IC). 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'IC 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® ELS31-VA/ELS51-VA Hardware Interface Description" v**01.000**

Chapter	What is new
--	Initial document setup.

6.2 Related Documents

[1] ELS31-VA/ELS51-VA AT Command Set
[2] ELS31-VA/ELS51-VA Release Note
[3] Application Note 40: Thermal Solutions
[4] Application Note 48: SMT Module Integration
[5] 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
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
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
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
NTC	Negative Temperature Coefficient
OEM	Original Equipment Manufacturer

Abbreviation	Description
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
PSK	Phase Shift Keying
PSU	Power Supply Unit
R&TTE	Radio and Telecommunication Terminal Equipment
RAM	Random Access Memory
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
UART	Universal asynchronous receiver-transmitter
URC	Unsolicited Result Code
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 ELS31-VA/ELS51-VA. 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 33: List of parts and accessories

Description	Supplier	Ordering information
ELS31-VA	Gemalto M2M	Standard module Gemalto M2M IMEI: Packaging unit (ordering) number: L30960-N4580-A300 Module label number: L30960-N4580-A300-1[1]
ELS51-VA	Gemalto M2M	Standard module Gemalto M2M IMEI: Packaging unit (ordering) number: L30960-N4590-A300 Module label number: L30960-N4590-A300-1[1]
ELS31-VA Evaluation Module	Gemalto M2M	Ordering number: L30960-N4581-A300
ELS51-VA Evaluation Module	Gemalto M2M	Ordering number: L30960-N4591-A300
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 ELS31-VA/ELS51-VA evaluation modules onto DSB75	Gemalto M2M	Ordering number: L30960-N0010-A100
Approval adapter for mounting ELS31-VA/ELS51-VA 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 34.

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 34: 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

Gemalto (Euronext NL0000400653 GTO) is the world leader in digital security with 2015 annual revenues of €3.1 billion and blue-chip customers in over 180 countries. Our 14,000+ employees operate out of 118 offices, 45 personalization and data centers, and 27 research and software development centers located in 49 countries.

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

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

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

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