Cinterion® ELS81-US

Hardware Interface Description

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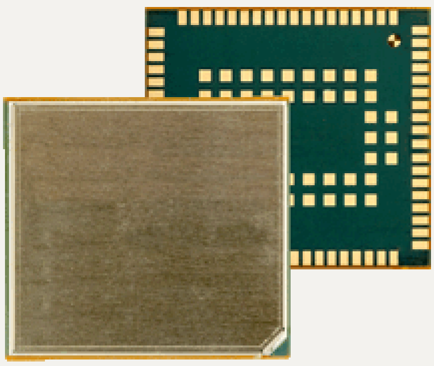

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1 Introduction

This document[1] describes the hardware of the Cinterion® ELS81-US module. It helps you quickly retrieve interface specifications, electrical and mechanical details and information on the requirements to be considered for integrating further components.

1.1 Key Features at a Glance

Feature	Implementation
General	
Frequency bands	UMTS/HSPA+: Triple band, 850 (BdV) / AWS (BdIV) / 1900MHz (BdII) LTE: Quad band, 700 (Bd12) / 850 (Bd5) / AWS (Bd4) / 1900MHz (Bd2)
Output power (according to Release 99)	Class 3 (+23.5dBm +1.5/-2.5dB) for UMTS 1900,WCDMA FDD BdII Class 3 (+23.5dBm +1.5/-2.5dB) for UMTS AWS, WCDMA FDD BdIV Class 3 (+23.5dBm +1.5/-2.5dB) for UMTS 850, WCDMA FDD BdV
Output power (according to Release 8)	Class 3 (+23dBm ±2dB) for LTE 1900,LTE FDD Bd2 Class 3 (+23dBm ±2dB) for LTE AWS, LTE FDD Bd4 Class 3 (+23dBm ±2dB) for LTE 850, LTE FDD Bd5 Class 3 (+23dBm ±2dB) for LTE 700, LTE FDD Bd12
Power supply	3.0V to 4.5V
Operating temperature (board temperature)	Normal operation: -30°C to +85°C Extended operation: -40°C to +90°C
Physical	Dimensions: 27.6mm x 25.4mm x 2.2mm Weight: approx. 4g
RoHS	All hardware components fully compliant with EU RoHS Directive
LTE features	
3GPP Release 9	UE CAT 4 supported DL 150Mbps, UL 50Mbps
HSPA features	
3GPP Release 8	DL 7.2Mbps, UL 5.7Mbps HSDPA Cat.10 / HSUPA Cat.6 data rates Compressed mode (CM) supported according to 3GPP TS25.212
UMTS features	
3GPP Release 4	PS data rate – 384 kbps DL / 384 kbps UL CS data rate – 64 kbps DL / 64 kbps UL
SMS	Point-to-point MT and MO Cell broadcast Text and PDU mode Storage: SIM card plus SMS locations in mobile equipment

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

Feature	**Implementation**
Software	
AT commands	Hayes 3GPP TS 27.007, TS 27.005, Thales AT commands for RIL compatibility
Java™ Open Platform	Java™ Open Platform with • Java™ profile IMP-NG & CLDC 1.1 HI • Secure data transmission via HTTPS/SSL[1] • Multi-threading programming and multi-application execution Major benefits: seamless integration into Java applications, ease of programming, no need for application microcontroller, extremely cost-efficient hardware and software design – ideal platform for industrial applications. The memory space available for Java programs is 30MB in the flash file system and 18MB RAM. Application code and data share the space in the flash file system and in RAM.
Microsoft™ compatibility	RIL for Pocket PC and Smartphone
SIM Application Toolkit	SAT letter classes b, c, e; with BIP
Firmware update	Generic update from host application over ASC0 or USB modem.
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 additional SMT application development equipment.
USB	USB 2.0 High Speed (480Mbit/s) device interface, Full Speed (12Mbit/s) compliant
2 serial interfaces	ASC0 (shared with GPIO lines): • 8-wire modem interface with status and control lines, unbalanced, asynchronous • Adjustable baud rates: 1,200bps to 3Mbps • Autobauding: 1,200bps to 230,400bps • Supports RTS0/CTS0 hardware flow control. ASC1 (shared with GPIO lines): • 4-wire, unbalanced asynchronous interface • Adjustable baud rates: 1,200bps to 921,60bps • Autobauding: 1,200bps to 230,400bps • Supports RTS1/CTS1 hardware flow control
UICC interface	Supported SIM/USIM cards: 3V, 1.8V
GPIO interface	22 GPIO lines comprising: 13 lines shared with ASC0, ASC1 and SPI lines, with network status indication, PWM functionality, fast shutdown and pulse counter 9 GPIO lines not shared
I^2C interface	Supports I^2C serial interface
SPI interface	Serial peripheral interface, shared with GPIO lines
Antenna interface pads	50Ω. UMTS/LTE main antenna, UMTS/UMTS/LTE RX Diversity/MIMO(for LTE Cat4) 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 FST_SHDN instead of AT command Automatic switch-off in case of critical temperature or voltage conditions
Reset	Orderly shutdown and reset by AT command Emergency reset by hardware signal EMERG_RST
Special features	
Real time clock	Timer functions via AT commands
Evaluation kit	
Evaluation module	ELS81-US module soldered onto a dedicated PCB that can be connected to an adapter in order to be mounted onto the DSB75.
DSB75	DSB75 Development Support Board designed to test and type approve Thales modules and provide a sample configuration for application engineering. A special adapter is required to connect the ELS81-US evaluation module to the DSB75.

1. HTTP/SecureConnection over SSL version 3.0 and TLS versions 1.0, 1.1, and 1.2 are supported. For details please refer to Java User’s Guide for Cinterion ® ELS81-US.

1.2 ELS81-US System Overview

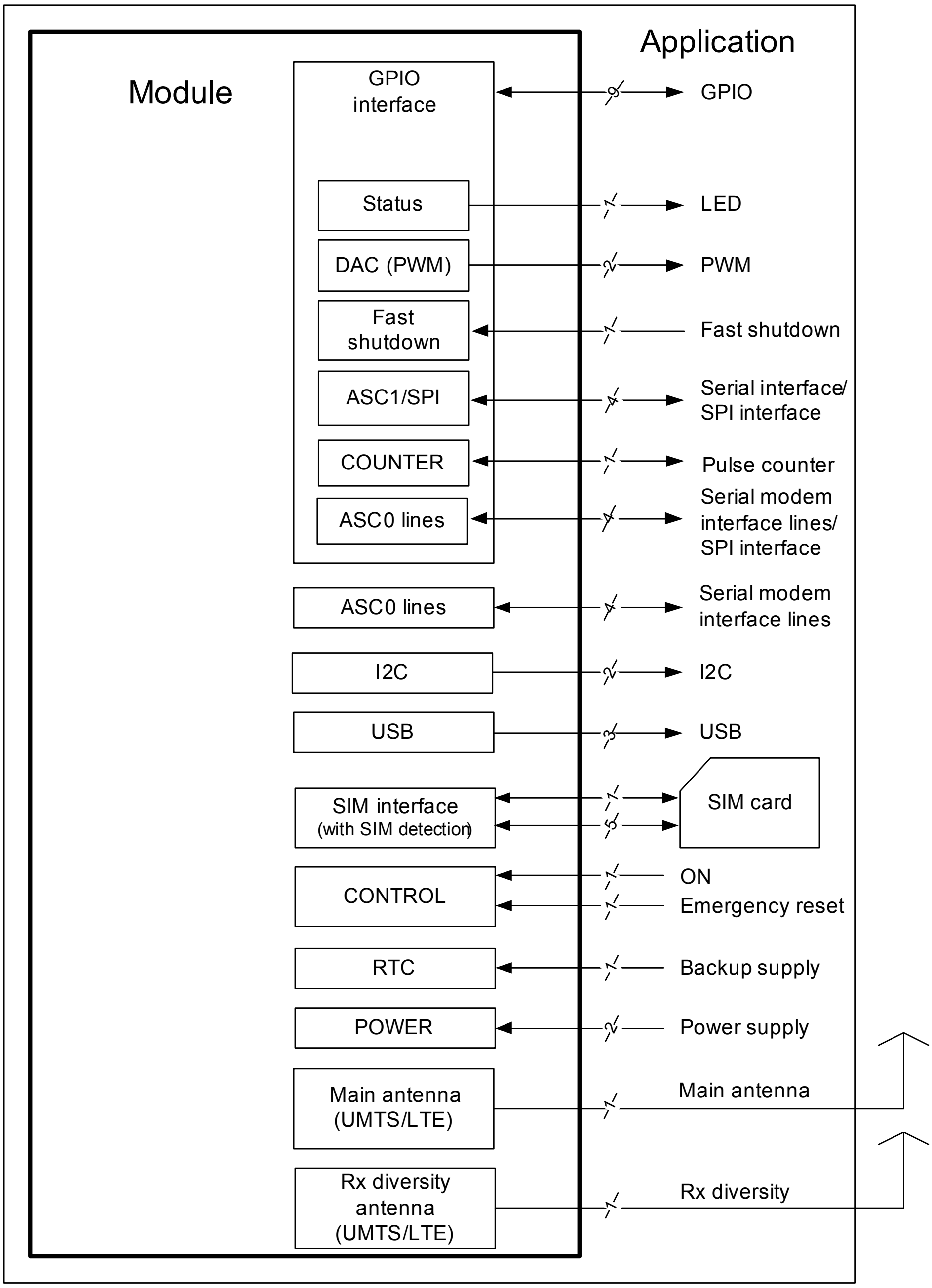


Figure 1: ELS81-US system overview

1.3 Circuit Concept

Figure 2 and Figure 3 show block diagrams of the ELS81-US module and illustrate the major functional components:

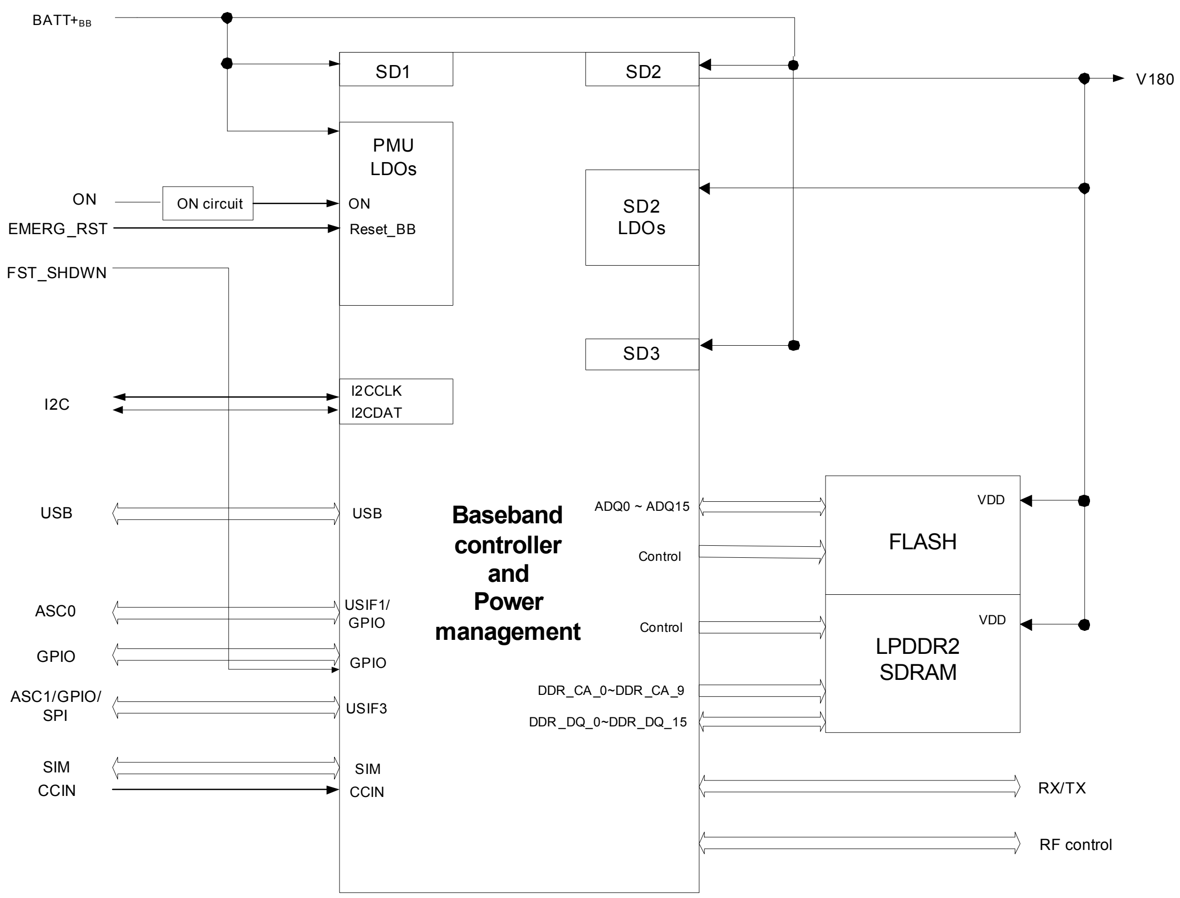


Figure 2: ELS81-US block diagram

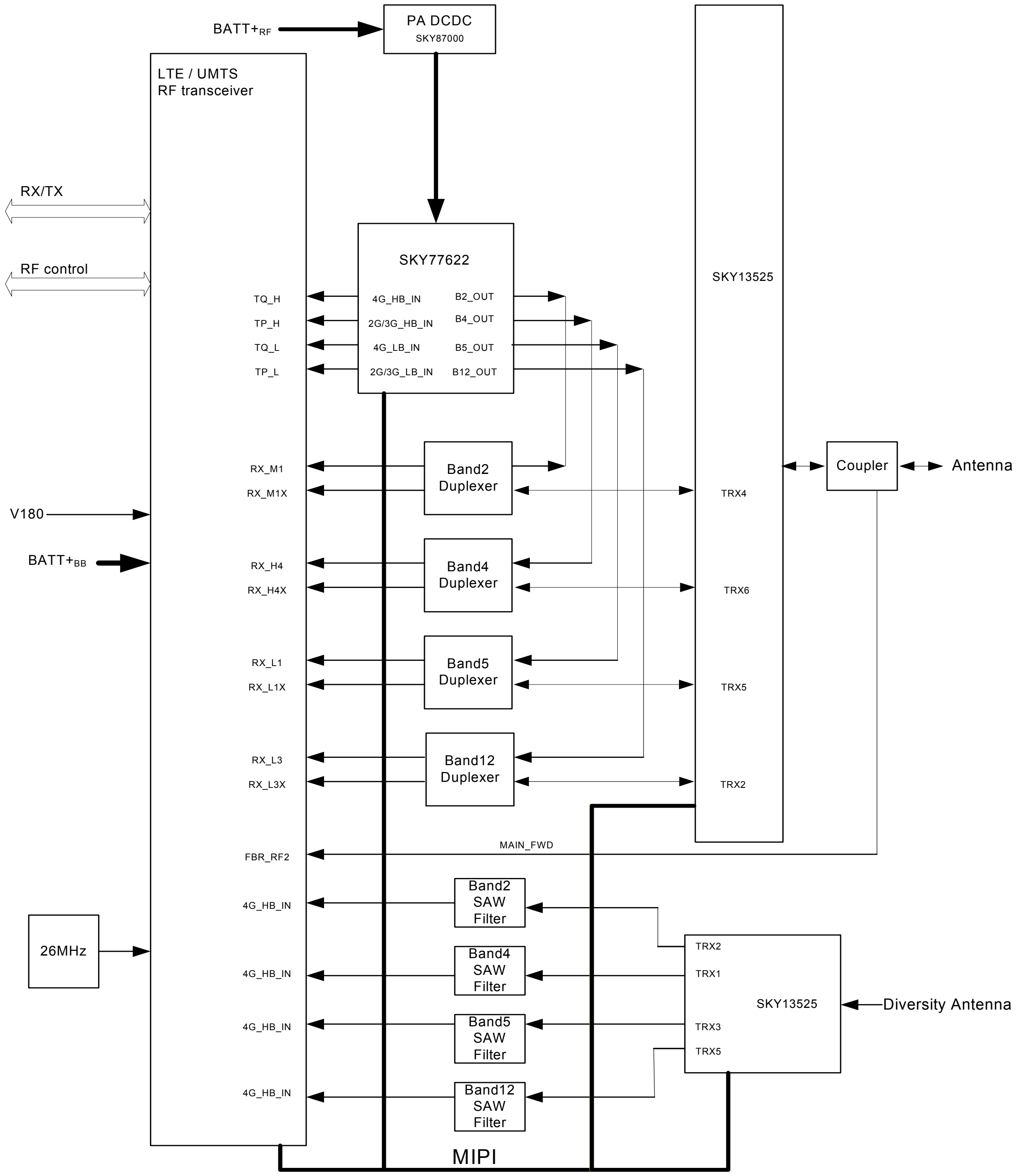


Figure 3: ELS81-US RF section block diagram

2 Interface Characteristics

ELS81-US is equipped with an SMT application interface that connects to the external application. The SMT application interface incorporates the various application interfaces as well as the RF antenna interface.

2.1 Application Interface

2.1.1 Pad Assignment

The SMT application interface on the ELS81-US provides connecting pads to integrate the module into external applications. Figure 4 shows the connecting pads' numbering plan, the following Table 1 lists the pads' assignments.

Figure 4: Numbering plan for connecting pads (bottom view)

Table 1: Pad assignments

Pad no.	Signal name	Pad no.	Signal name	Pad no.	Signal name
201	Not connected	24	GPIO22	235	USB_DN
202	Not connected	25	GPIO21	236	Not connected
203	GND	26	GPIO23	237	Not connected
204	$BATT+_{BB}$	27	I2CDAT	238	GND
205	GND	28	I2CCLK	239	GPIO5/LED
206	ADC1	29	GPIO17/TXD1/MISO	240	GPIO6/PWM2
207	ON	30	GPIO16/RXD1/MOSI	241	GPIO7/PWM1
208	GND	31	GPIO18/RTS1	242	GPIO8/COUNTER
209	V180	32	GPIO19/CTS1/SPI_CS	53	$BATT+_{RF}$
210	RXD0	33	EMERG_RST	54	GND
211	CTS0	221	GPIO12	55	GND
212	TXD0	222	GPIO11	56	ANT_DRX
213	GPIO24/RING0	223	GND	57	GND
214	RTS0	224	Not connected	58	GND
215	VDDLP	225	GND	59	ANT_MAIN
216	CCRST	226	Not connected	60	GND
217	CCIN	227	GND	61	GND
218	CCIO	228	Not connected	62	GND
219	GPIO14	229	GPIO4/FST_SHDN	63	GND
220	GPIO13	230	GPIO3/DSR0/SPI_CLK	64	Not connected
20	CCVCC	231	GPIO2/DCD0	65	Not connected
21	CCCLK	232	GPIO1/DTR0	66	Not connected
22	VCORE	233	VUSB	243	Not connected
23	GPIO20	234	USB_DP	244	GPIO15
Centrally located pads					
67	Not connected	83	GND	99	GND
68	Not connected	84	GND	100	GND
69	Not connected	85	GND	101	GND
70	Not connected	86	GND	102	GND
71	Not connected	87	Not connected	103	GND
72	Not connected	88	GND	104	Not connected
73	Not connected	89	GND	105	Not connected
74	Do not use	90	GND	106	Not connected
75	Do not use	91	Not connected	245	GND
76	Do not use	92	GND	246	Not connected
77	Do not use	93	GND	247	Not connected
78	Do not use	94	GND	248	Not connected
79	Not connected	95	GND	249	Not connected
80	Do not use	96	GND	250	GND
81	GND	97	GND	251	GND
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 ELS81-US module. They do not apply to the accessories connected.

2.1.2 Signal Properties

Table 2: Signal properties

Function	Signal name	IO	Signal form and level	Comment
Power supply	BATT+$_{BB}$ BATT+$_{RF}$	I	WCDMA activated: $V_I$max = 4.5V $V_I$norm = 3.8V $V_I$min = 3.0V during Transmit active. Imax = 900mA during Tx LTE activated: $V_I$max = 4.5V $V_I$norm = 3.8V $V_I$min = 3.0V during Transmit active.	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 3.0V including drop, ripple, spikes and not rise above 4.5V. BATT+$_{BB}$ and BATT+$_{RF}$ require an ultra low ESR capacitor: BATT+$_{BB}$ --> 150µF BATT+$_{RF}$ --> 150µF If using Multilayer Ceramic Chip Capacitors (MLCC) please take DC-bias into account. Note that minimum ESR value is advised at <70mΩ.
Power supply	GND		Ground	Application Ground
External supply voltage	V180	O	Normal operation: $V_O$norm = 1.80V ±3% $I_O$max = -10mA SLEEP mode Operation: V_OSleep = 1.80V ±5% $I_O$max = -10mA CLmax = 100µF	V180 should be used to supply level shifters at the interfaces or to supply external application circuits. VCORE and V180 may be used for the power indication circuit. **Vcore and V180 are sensitive against back-powering by other signals. While switched off these voltage domains must have <0.2V.** If unused keep lines open.
	VCORE	O	$V_O$norm = 1.2V ±2.5% $I_O$max = -10mA CLmax = 100nF SLEEP mode Operation: V_OSleep = 0.90V...1.2V ±4% $I_O$max = -10mA	
Ignition	ON[1]	I	V_{IH}max = 5V tolerant V_{IH}min = 1.3V V_{IL}max = 0.5V Slew rate ≤ 1ms ON ___|~~~~	This signal switches the module on, and is rising edge sensitive triggered. Internal pull down value for this signal is 100kΩ.

Table 2: Signal properties

Function	Signal name	IO	Signal form and level	Comment
Emer- gency restart	EMERG_RST	I	R_I ≈ 1kΩ, C_I ≈ 1nF V_{OH}max = VDDLP max V_{IH}min = 1.35V V_{IL}max = 0.3V at ~200µA ~~|___|~~ low impulse width > 10ms	This line must be driven low by an open drain or open collector driver con-nected to GND. If unused keep line open.
RTC backup	VDDLP	I/O	$V_O$norm = 1.8V ±5% $I_O$max = -25mA $V_I$max = 1.9V $V_I$min = 1.0V $I_I$typ < 1µA	It is recommended to use a serial resistor between VDDLP and a possible capacitor (bigger than 1µF). If unused keep line open.
USB	VUSB_IN	I	$V_I$min = 3V $V_I$max = 5.25V Active and suspend current: I_{max} < 100µA	All electrical characteris-tics according to USB Implementers' Forum, USB 2.0 Specification. If unused keep lines open.
	USB_DN	I/O	Full and high speed signal characteris-tics according USB 2.0 Specification.	
	USB_DP			
Serial Interface ASC0	RXD0	O	V_{OL}max = 0.25V at I = 1mA V_{OH}min = 1.55V at I = -1mA V_{OH}max = 1.85V	If unused keep lines open. Note that some ASC0 lines are originally avail-able as GPIO lines. If configured as ASC0 lines, the GPIO lines are assigned as follows: GPIO1 --> DTR0 GPIO2 --> DCD0 GPIO3 --> DSR0 GPIO24 --> RING0 The DSR0 line is also shared with the SPI inter-face's SPI_CLK signal. Note that DCD0/GPIO2 must not be driven low during startup
	CTS0	O		
	DSR0	O		
	DCD0	O		
	RING0	O		
	TXD0	I	V_{IL}max = 0.35V V_{IH}min = 1.30V V_{IH}max = 1.85V	
	RTS0	I	Pull down resistor active V_{IL}max = 0.35V at > 50µA V_{IH}min = 1.30V at < 240µA V_{IH}max = 1.85V at < 240µA	
	DTR0	I	Pull up resistor active V_{IL}max = 0.35V at < -200µA V_{IH}min = 1.30V at > -50µA V_{IH}max = 1.85V	

Table 2: Signal properties

Function	Signal name	IO	Signal form and level	Comment
Serial Interface ASC1	RXD1	O	V_{OL}max = 0.25V at I = 1mA V_{OH}min = 1.55V at I = -1mA V_{OH}max = 1.85V V_{IL}max = 0.35V V_{IH}min = 1.30V V_{IH}max = 1.85V	If unused keep line open. Note that 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 GPIO19 --> CTS1
	TXD1	I		
	RTS1	I		
	CTS1	O		
SIM card detection	CCIN	I	$R_I \approx$ 110kΩ V_{IH}min = 1.45V at I = 15µA, V_{IH}max= 1.9V V_{IL}max = 0.3V	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_{OL}max = 0.30V at I = 1mA V_{OH}min = 2.45V at I = -1mA V_{OH}max = 2.90V	Maximum cable length or copper track to SIM card holder should not exceed 100mm.
	CCIO	I/O	V_{IL}max = 0.50V V_{IH}min = 2.05V V_{IH}max = 2.90V V_{OL}max = 0.25V at I = 1mA V_{OH}min = 2.50V at I = -1mA V_{OH}max = 2.90V	
	CCCLK	O	V_{OL}max = 0.25V at I = 1mA V_{OH}min = 2.40V at I = -1mA V_{OH}max = 2.90V	
	CCVCC	O	$V_O$min= 2.70V $V_O$typ = 2.90V $V_O$max = 3.30V $I_O$max = -30mA	

Table 2: Signal properties

Function	Signal name	IO	Signal form and level	Comment
1.8V SIM Card Interface	CCRST	O	V_{OL}max = 0.25V at I = 1mA V_{OH}min = 1.45V at I = -1mA V_{OH}max = 1.90V	Maximum cable length or copper track to SIM card holder should not exceed 100mm.
	CCIO	I/O	V_{IL}max = 0.35V V_{IH}min = 1.25V V_{IH}max = 1.85V V_{OL}max = 0.25V at I = 1mA V_{OH}min = 1.50V at I = -1mA V_{OH}max = 1.85V	
	CCCLK	O	V_{OL}max = 0.25V at I = 1mA V_{OH}min = 1.50V at I = -1mA V_{OH}max = 1.85V	
	CCVCC	O	$V_O$min = 1.75V $V_O$typ = 1.80V $V_O$max = 1.85V $I_O$max = -30mA	
I^2C	I2CCLK	IO	Open drain IO V_{OL}min = 0.35V at Imax = 4mA (Imax = Imax external + I pull-up) V_{OH}max = 1.85V R external pull up min = 560Ω V_{IL}max = 0.35V V_{IH}min = 1.3V 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. 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 4mA. I^2C interface of the module already has internal 1KOhm pull up resistor to V180 inside the module. Please take this into consideration during application design. If lines are unused keep lines open.
	I2CDAT	IO		

Table 2: Signal properties

Function	Signal name	IO	Signal form and level	Comment
SPI	SPI_CLK	O	V_{OL}max = 0.25V at I = 1mA V_{OH}min = 1.55V at I = -1mA V_{OH}max = 1.85V V_{IL}max = 0.35V V_{IH}min = 1.30V V_{IH}max = 1.85V	If lines are unused keep lines open. Note that the SPI interface lines are originally available as GPIO lines. If configured as SPI lines, the GPIO lines are assigned as follows: GPIO3 --> SPI_CLK GPIO16 --> MOSI GPIO17 --> MISO GPIO19 --> SPI_CS
	MOSI	O		
	MISO	I		
	SPI_CS	O		
GPIO interface	GPIO1-GPIO3	IO	V_{OL}max = 0.25V at I = 1mA V_{OH}min = 1.55V at I = -1mA V_{OH}max = 1.85V V_{IL}max = 0.35V V_{IH}min = 1.30V V_{IH}max = 1.85V Imax = ±5mA	If unused keep line open. Please note that most GPIO lines can be configured by AT command for alternative functions: GPIO1-GPIO3: ASC0 control lines DTR0, DCD0 and DSR0 GPIO4: Fast shutdown GPIO5: Status LED line GPIO6/GPIO7: PWM GPIO8: Pulse Counter GPIO16-GPIO19: ASC1 or SPI GPIO24: ASC0 control line RING0
	GPIO4	IO		
	GPIO5	IO		
	GPIO6	IO		
	GPIO7	IO		
	GPIO8	IO		
	GPIO11-GPIO15	IO		
	GPIO16-GPIO19	IO		
	GPIO20-GPIO23	IO		
	GPIO24	IO		
Fast shutdown	FST_SHDN	I	V_{IL}max = 0.35V V_{IH}min = 1.30V V_{IH}max = 1.85V ~~|___|~~ low impulse width > 1ms	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
Status LED	LED	O	V_{OL}max = 0.25V at I = 1mA V_{OH}min = 1.55V at I = -1mA V_{OH}max = 1.85V	If unused keep line open. Note that the LED line is originally available as GPIO line. If configured as LED line, the GPIO line is assigned as follows: GPIO5 --> LED

Table 2: Signal properties

Function	Signal name	IO	Signal form and level	Comment
PWM	PWM1	O	V_{OL}max = 0.25V at I = 1mA V_{OH}min = 1.55V at I = -1mA V_{OH}max = 1.85V	If unused keep lines open. Note that the PWM lines are originally available as GPIO lines. If configured as PWM lines, the GPIO lines are assigned as follows: GPIO7 --> PWM1 GPIO6 --> PWM2
	PWM2	O		
Pulse counter	COUNTER	I	Internal up resistor active V_{IL}max = 0.35V at < -200µA V_{IH}min = 1.30V at > -50µA V_{IH}max = 1.85V	If unused keep line open. Note that the COUNTER line is originally available as GPIO line. If configured as COUNTER line, the GPIO line is assigned as follows: GPIO8 --> COUNTER
ADC (Analog-to-Digital Converter)	ADC1	I	R_I = 1MΩ V_I = 0V ... 1.2V (valid range) V_{IH} max = 1.2V Resolution 1024 steps Tolerance 0.3%	ADC can be used as input for external measurements. If unused keep line open.

1. After the operating voltage is applied, it is required to wait at least 1 second to trigger the ON signal.

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 ELS81-US.

Table 3: Absolute maximum ratings[1]

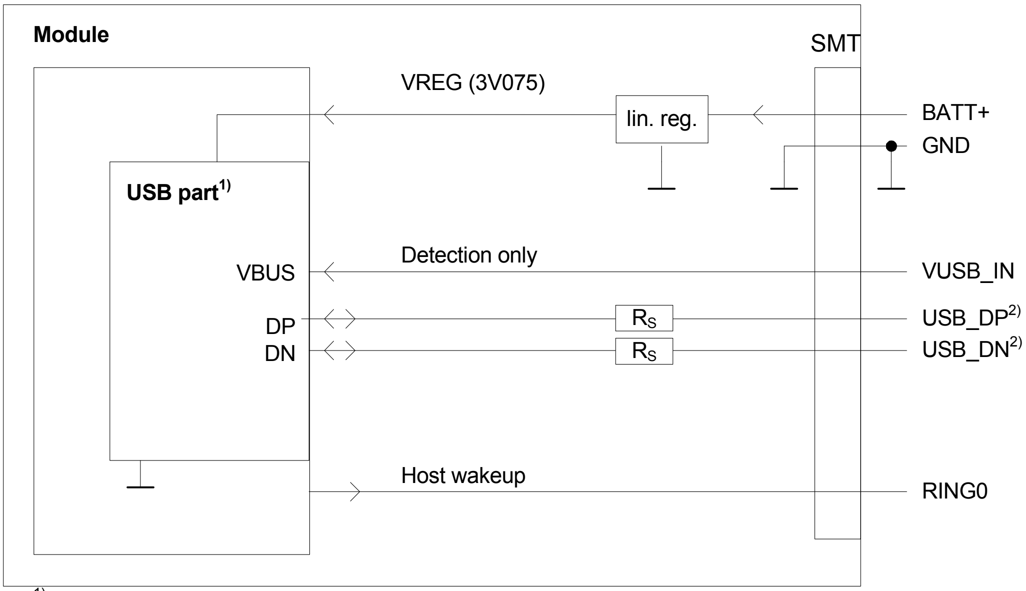
Parameter	Min	Max	Unit
Supply voltage $BATT+_{BB}$, $BATT+_{RF}$	-0.5	+5.5	V
Voltage at all signal lines in Power Down mode	-0.3	+0.3	V
Voltage at digital lines in normal operation	-0.2	V180 + 0.2	V
Voltage at SIM/USIM interface, CCVCC in normal operation	-0.5	+3.3	V
VDDLP input voltage	-0.15	2.0	V
Voltage at ADC line in normal operation	0	1.2	V
V180 in normal operation	+1.7	+1.9	V
Current at V180 in normal operation	-0	+50	mA
VCORE in normal operation	+0.85	+1.25	V
Current at VCORE in normal operation	-0	+50	mA
Voltage at ON signal	-0.5	+6.5	V
Current at single GPIO	-5	+5	mA
Current at all GPIO	-50	+50	mA
Voltage at VCORE, V180 in power down mode	-0.2	+0.2	V

1. Positive noted current means current sourcing from ELS81-US. Negative noted current means current sourcing towards ELS81-US.

2.1.3 USB Interface

ELS81-US 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 external application is responsible for supplying the VUSB_IN line. This line is used for cable detection only. The USB part (driver and transceiver) is supplied by means of BATT+. This is because ELS81-US is designed as a self-powered device compliant with the “Universal Serial Bus Specification Revision 2.0”[1].



1) All serial (including R_S) and pull-up resistors for data lines are implemented.
2) If the USB interface is operated in High Speed mode (480MHz), it is recommended to take special care routing the data lines USB_DP and USB_DN. Application layout should in this case implement a differential impedance of 90 ohms for proper signal integrity.

Figure 5: 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 ELS81-US needs to be installed.

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

2.1.3.1 Reducing Power Consumption

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

- **Recommended implementation of USB Suspend/Resume/Remote Wakeup:**
  The USB host should be able to bring its USB interface into the Suspended state as described in the “Universal Serial Bus Specification Revision 2.0“[1]. For this functionality to work, the VUSB_IN line should always be kept enabled. On incoming calls and other events ELS81-US will then generate a Remote Wakeup request to resume the USB host controller.

  See also [6] (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 2.1.13.3. To prevent existing data call connections from being disconnected while the USB interface is in detached state (i.e., VUSB_IN=0) it is possible to call AT&D0, thus ignoring the status of the DTR line (see also [1]).

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

2.1.4 Serial Interface ASC0

ELS81-US 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.

ELS81-US is designed for use as a DCE. Based on the conventions for DCE-DTE connections it communicates with the customer application (DTE) using the following signals:
- Port TXD @ application sends data to the module's TXD0 signal line
- Port RXD @ application receives data from the module's RXD0 signal line

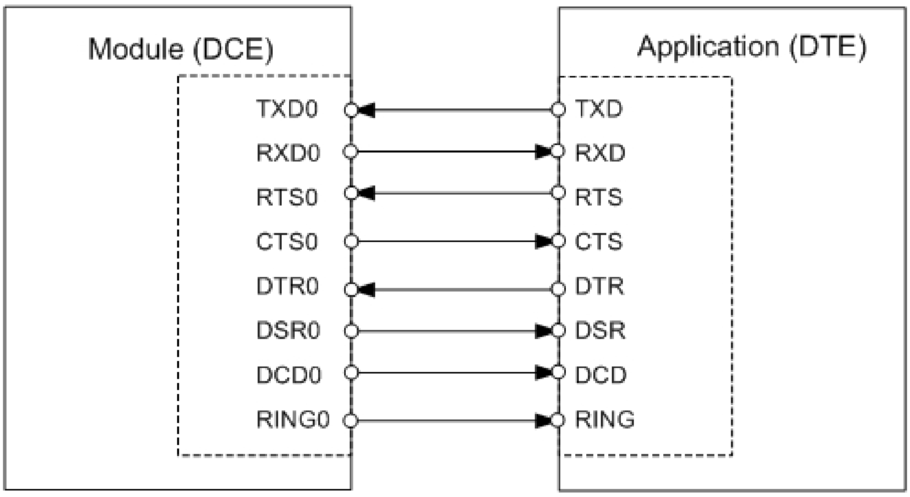
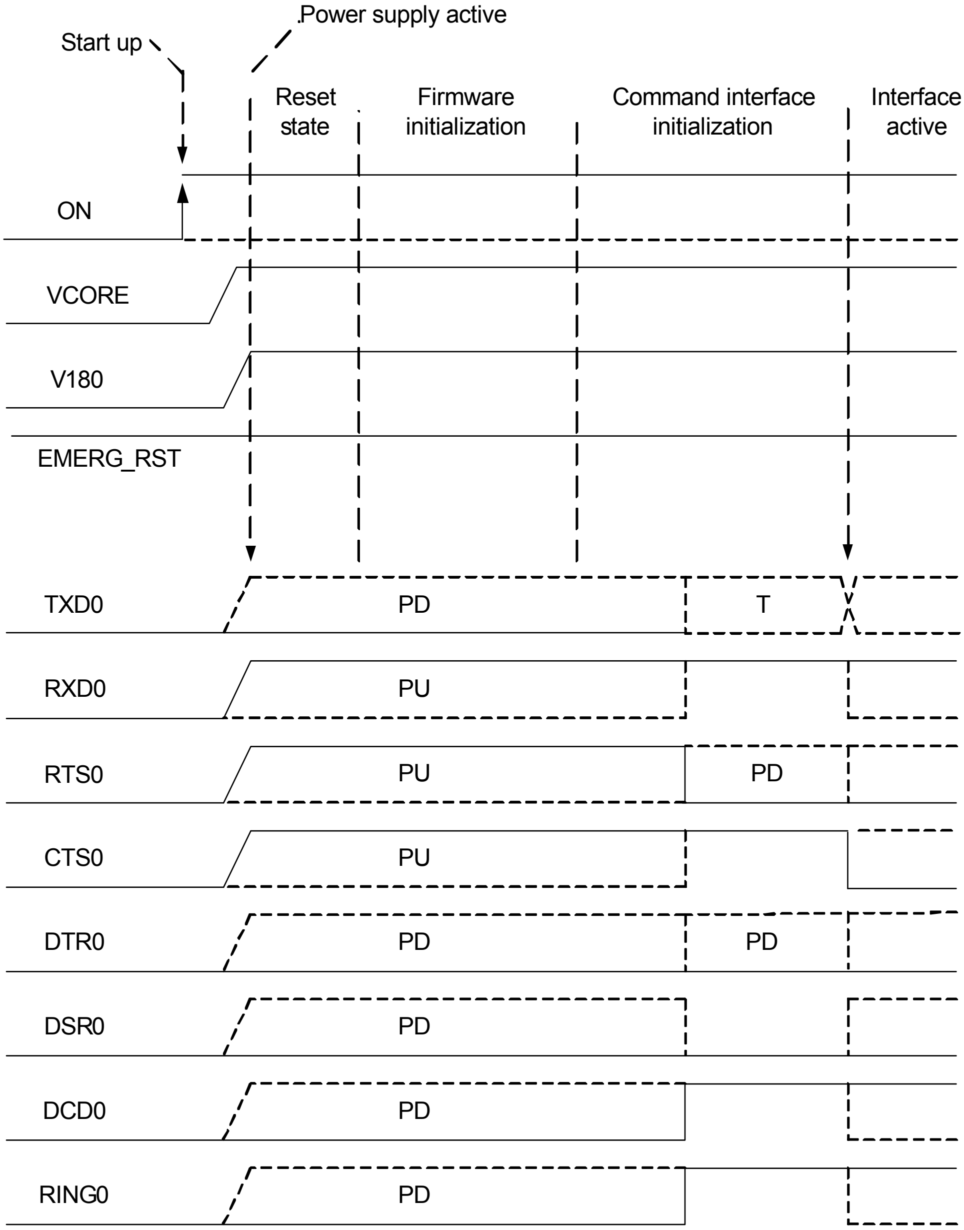


Figure 6: Serial interface ASC0

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.
- The RING0 signal serves to indicate incoming calls and other types of URCs (Unsolicited Result Code). It can also be used to send pulses to the host application, for example to wake up the application from power saving state.
- Configured for 8 data bits, no parity and 1 stop bit.
- ASC0 can be operated at fixed bit rates from 1,200bps up to 3Mbps.
- Autobauding supports bit rates from 1,200bps up to 230,400bps.
- Supports RTS0/CTS0 hardware flow control. The hardware hand shake line RTS0 has an internal pull down resistor causing a low level signal, if the line is not used and open. Although hardware flow control is recommended, this allows communication by using only RXD and TXD lines.
- Wake up from SLEEP mode by RTS0 activation (high to low transition; see Section 3.3.2).

Note: The ASC0 modem control lines DTR0, DCD0, DSR0 and RING0 are originally available as GPIO lines. If configured as ASC0 lines, these GPIO lines are assigned as follows: GPIO1 --> DTR0, GPIO2 --> DCD0, GPIO3 --> DSR0 and GPIO24 --> RING0. Also, DSR0 is shared with the SPI_CLK line of the SPI interface and may be configured as such. Configuration is done by AT command (see [1]). The configuration is non-volatile and becomes active after a module restart.

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



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

Figure 7: ASC0 startup behavior

Notes:
During startup the DTR0 signal is driven active low for 500µs. It is recommended to provide a 470Ω serial resistor for the DTR0 line to prevent shorts (high current flow).

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

An external pull down to ground on the DCD0 line during the startup phase activates a special mode for ELS81-US. In this special mode the AT command interface is not available and the module may therefore no longer behave as expected.

2.1.5 Serial Interface ASC1

Four ELS81-US GPIO lines can be configured as ASC1 interface signals to provide a 4-wire unbalanced, asynchronous modem interface ASC1 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 9.

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.

ELS81-US is designed for use as a DCE. Based on the conventions for DCE-DTE connections it communicates with the customer application (DTE) using the following signals:

- Port TXD @ application sends data to module's TXD1 signal line
- Port RXD @ application receives data from the module's RXD1 signal line

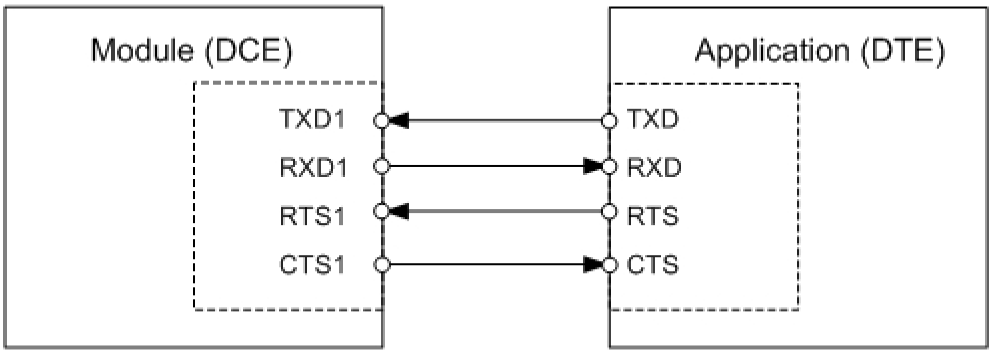
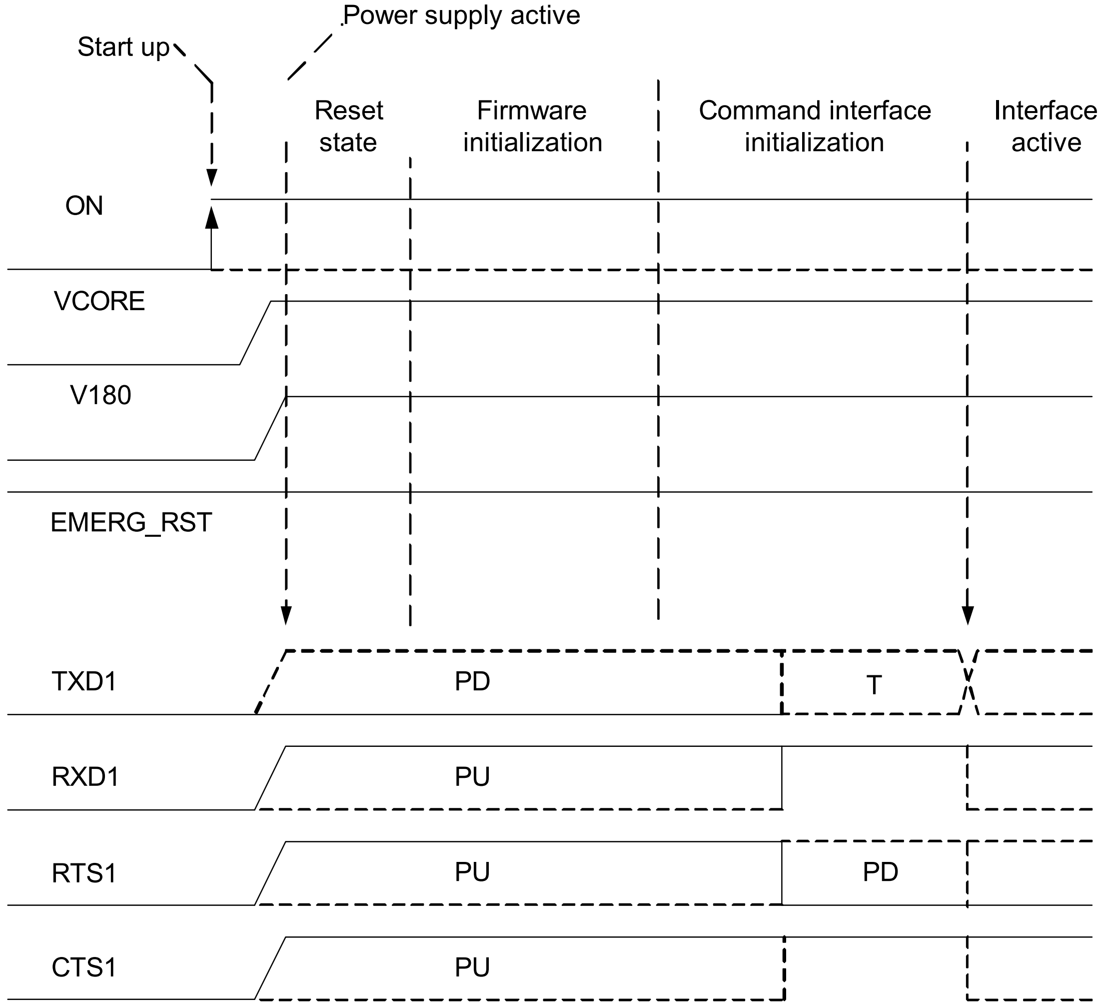


Figure 8: Serial interface ASC1

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 1,200 bps to 921,600 bps.
- Autobauding supports bit rates from 1,200bps up to 230,400bps.
- Supports RTS1/CTS1 hardware flow. The hardware hand shake line RTS0 has an internal pull down resistor causing a low level signal, if the line is not used and open. Although hardware flow control is recommended, this allows communication by using only RXD and TXD lines.

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



*) For pull-down values see Table 10.

Figure 9: ASC1 startup behavior

2.1.6 UICC/SIM/USIM Interface

ELS81-US 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. 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 ELS81-US and is part of the Thales 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 ELS81-US.

Note [1]: 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 ELS81-US.

Note [2]: On the evaluation board, the CCIN signal is inverted, thus the CCIN signal is by default high and will change to a low level if a SIM card is inserted.

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

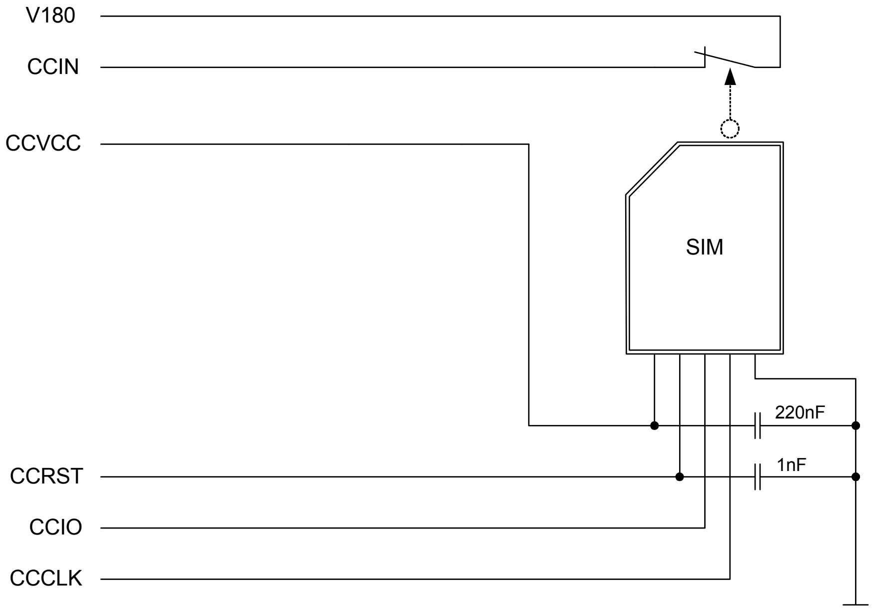


Figure 10: External UICC/SIM/USIM card holder circuit

The total cable length between the SMT application interface pads on ELS81-US and the pads of the external SIM card holder must not exceed 100mm in order to meet the specifications of 3GPP TS 51.010-1 and to satisfy the requirements of EMC compliance.

To avoid possible cross-talk from the 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.

An example for an optimized ESD protection for the SIM interface is shown in Section 2.1.6.1.

2.1.6.1 Enhanced ESD Protection for SIM Interface

To optimize ESD protection for the SIM interface it is possible to add ESD diodes to the SIM interface lines as shown in the example given in Figure 11.[1]

The example was designed to meet ESD protection according ETSI EN 301 489-1/52: Contact discharge: ± 4kV, air discharge: ± 8kV.

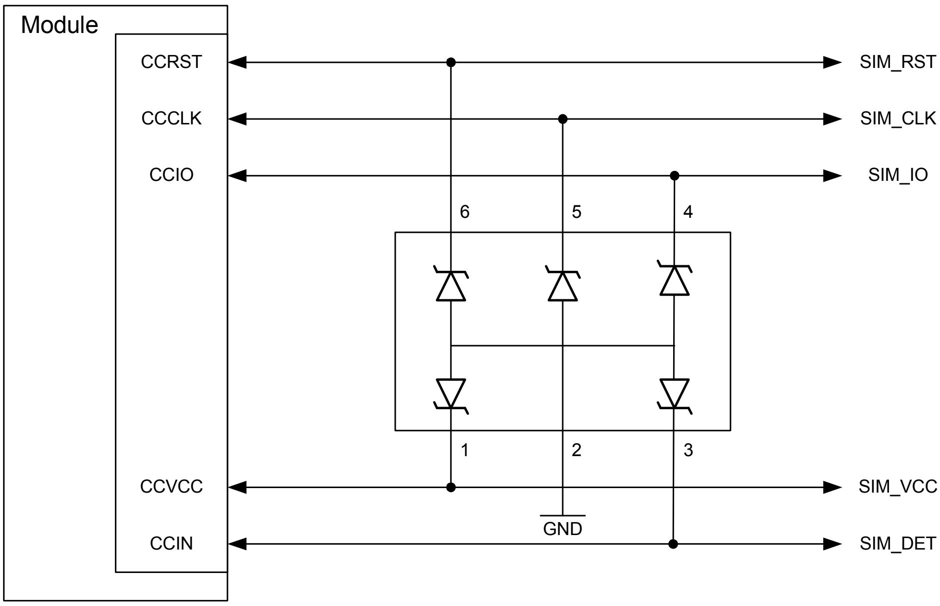


Figure 11: SIM interface - enhanced ESD protection

1. Note that the protection diode shall have low internal capacitance less than 5pF for IO and CLK.

2.1.7 RTC Backup

The internal Real Time Clock of ELS81-US is supplied from a separate voltage regulator in the power supply component which is also active when ELS81-US is in Power Down mode and BATT+ is available. An alarm function is provided that allows to wake up ELS81-US without logging on to the RF network.

In addition, you can use the VDDLP pad to backup the RTC from an external capacitor. The capacitor is charged from the internal LDO of ELS81-US. If the voltage supply at BATT+ is disconnected the RTC can be powered by the capacitor. The size of the capacitor determines the duration of buffering when no voltage is applied to ELS81-US, i.e. the greater the capacitor the longer ELS81-US will save the date and time. The RTC can also be supplied from an external battery (rechargeable or non-chargeable). In this case the electrical specification of the VDDLP pad (see Section 2.1.2) has to be taken in to account.

Figure 12 shows an RTC backup configuration. A serial 1kΩ resistor has to be placed on the application next to VDDLP. It limits the input current of an empty capacitor or battery.

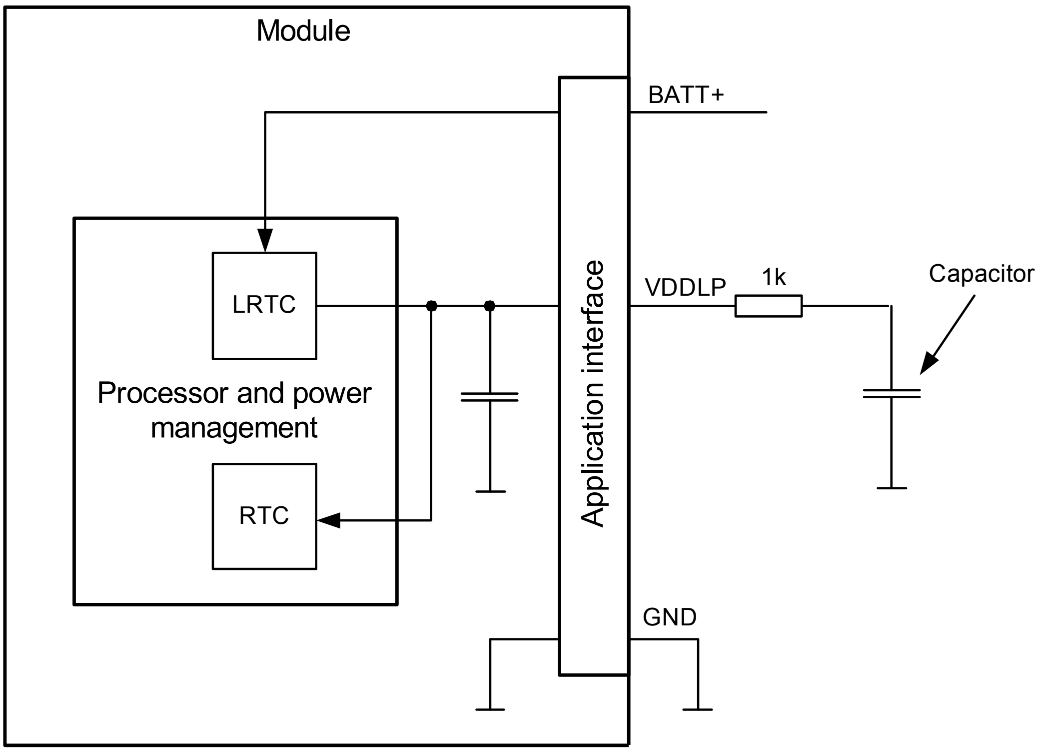


Figure 12: RTC supply variants

2.1.8 GPIO Interface

ELS81-US offers a GPIO interface with 22 GPIO lines. The GPIO lines are shared with other interfaces or functions: Fast shutdown (see Section 2.1.13.4), status LED (see Section 2.1.13.1), the PWM functionality (see Section 2.1.11), an pulse counter (see Section 2.1.12), ASC0 (see Section 2.1.4), ASC1 (see Section 2.1.5), an SPI interface (see Section 2.1.10).

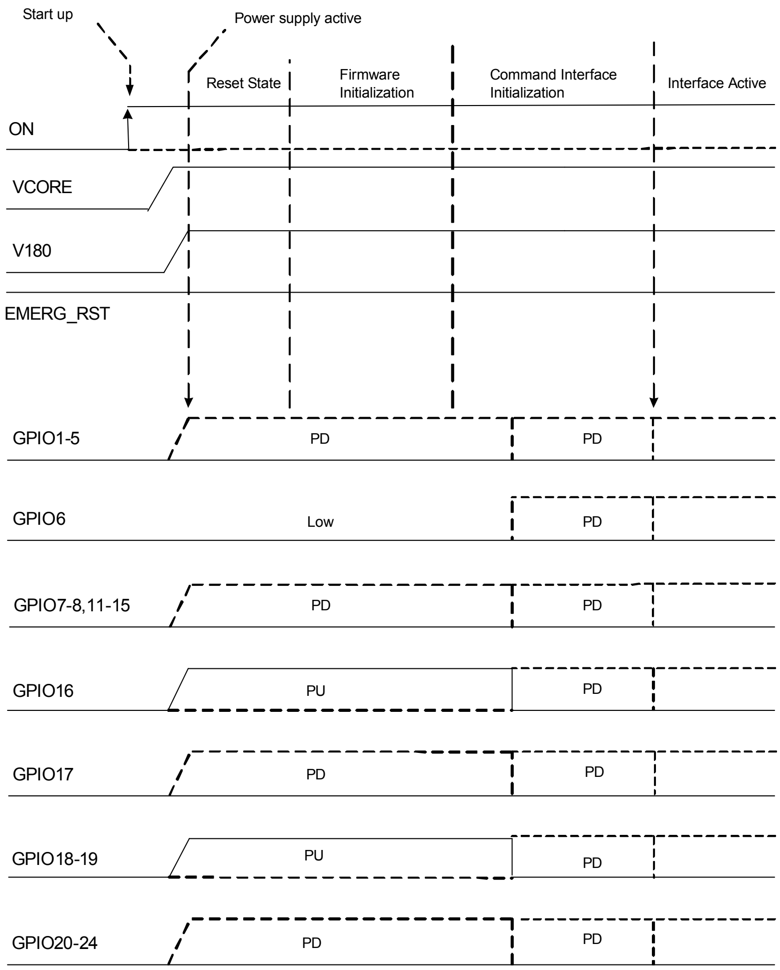
The following table shows the configuration variants for the GPIO pads. All variants are mutually exclusive, i.e. a pad configured for instance as Status LED is locked for alternative usage.

Table 5: GPIO lines and possible alternative assignment

GPIO	Fast Shutdown	Status LED	PWM	Pulse Counter	ASC0	ASC1	SPI
GPIO1					DTR0		
GPIO2					DCD0		
GPIO3					DSR0		SPI_CLK
GPIO4	FST_SHDN						
GPIO5		Status LED					
GPIO6			PWM2				
GPIO7			PWM1				
GPIO8				COUNTER			
GPIO11							
GPIO12							
GPIO13							
GPIO14							
GPIO15							
GPIO16						RXD1	MOSI
GPIO17						TXD1	MISO
GPIO18						RTS1	
GPIO19						CTS1	SPI_CS
GPIO20							
GPIO21							
GPIO22							
GPIO23							
GPIO24					RING0		

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

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



*) For pull down values see Table 10.

Figure 13: GPIO startup behavior

2.1.9 I²C Interface

I^2C is a serial, 8-bit oriented data transfer bus for bit rates up to 400kbps in Fast mode. 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 I^2C interface can be powered via the V180 line of ELS81-US. If connected to the V180 line, the I^2C 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.

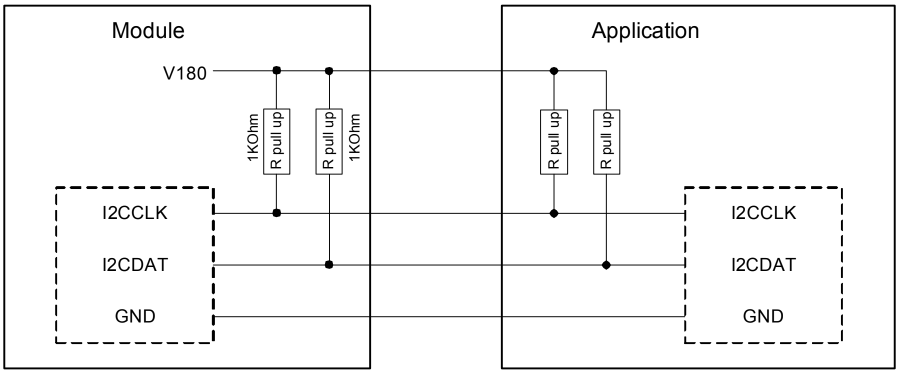


Figure 14: I^2C interface connected to V180

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 I^2C interface. With an active state of the ASC0 interface (i.e. CTS0 is at low level) the initialization of the I^2C interface is also finished.

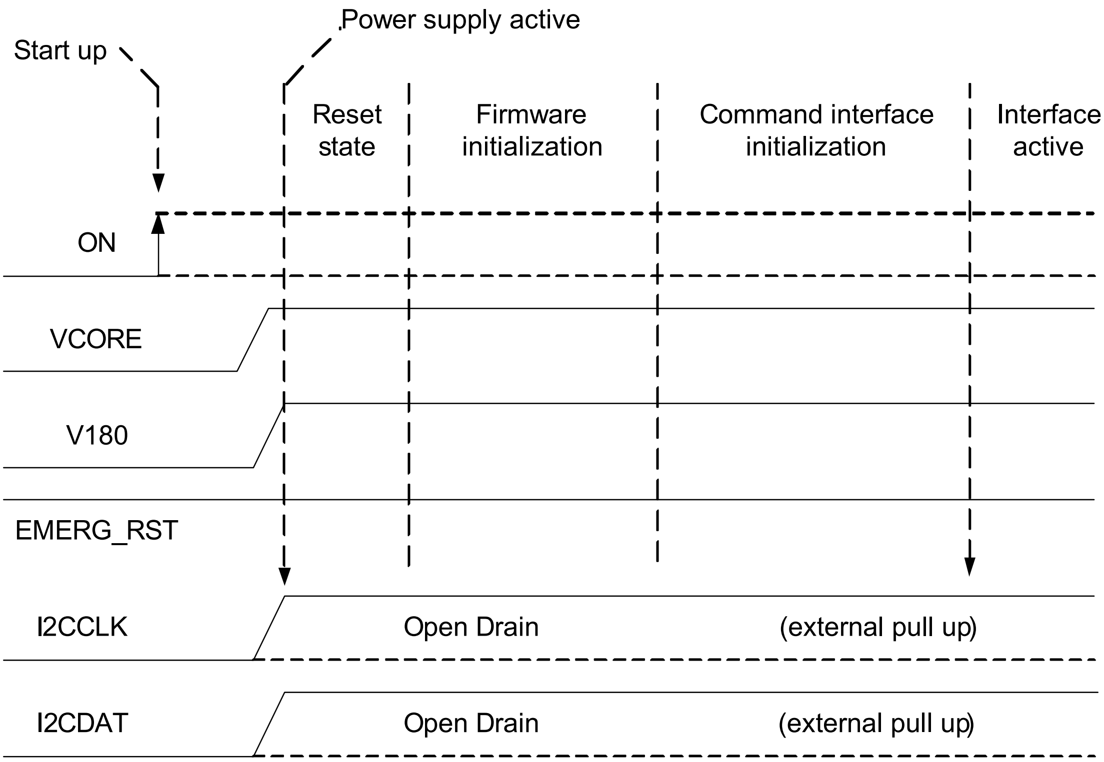


Figure 15: I^2C startup behavior

2.1.10 SPI Interface

Four ELS81-US GPIO interface lines can be configured as Serial Peripheral Interface (SPI). The SPI is a synchronous serial interface for control and data transfer between ELS81-US 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 MOSI and MISO, the clock line SPI_CLK a well as the chip select line SPI_CS.

The four GPIO lines can be configured as SPI interface signals as follows: GPIO3 --> SPI_CLK, GPIO16 --> MOSI, GPIO17 --> MISO and GPIO19 --> SPI_CS. The configuration is done by AT command (see [1]). It is non-volatile and becomes active after a module restart.

The GPIO lines are also shared with the ASC1 signal lines and the ASC0 modem status signal line DSR0.

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.

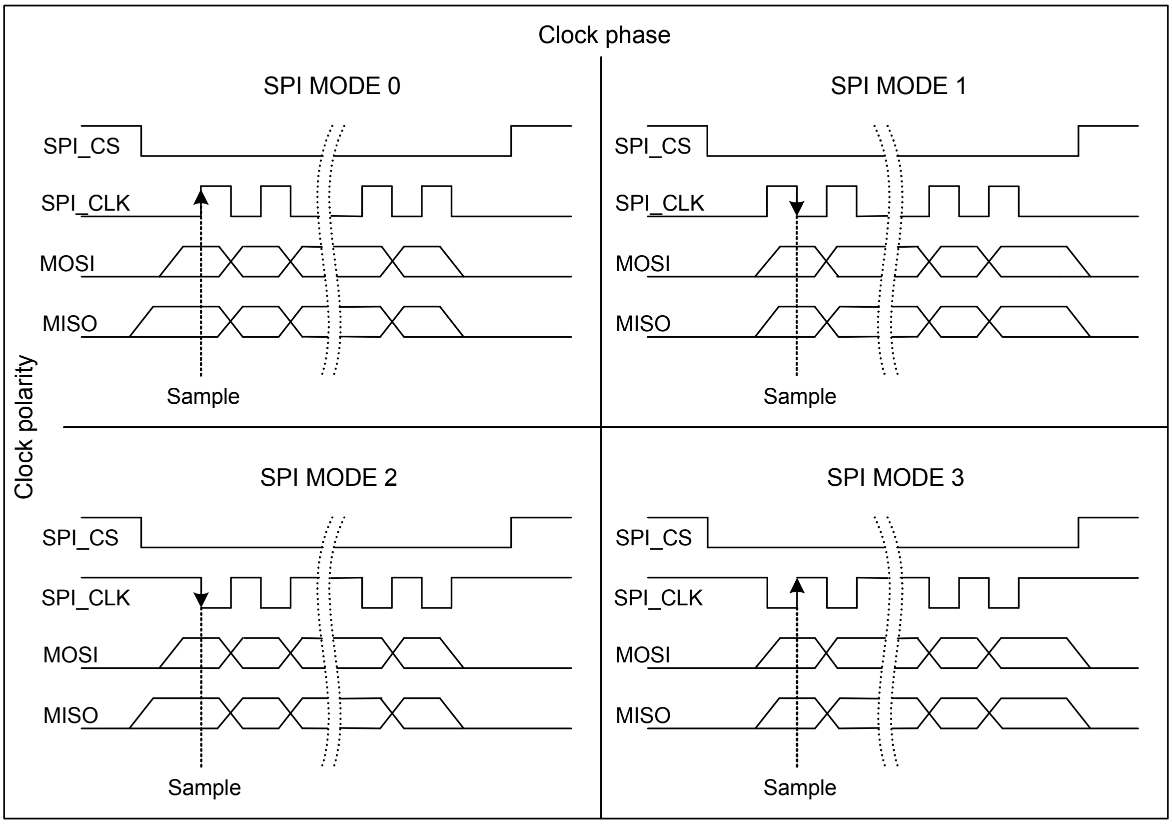


Figure 16: Characteristics of SPI modes

2.1.11 PWM Interfaces

The GPIO6 and GPIO7 interface lines can be configured as Pulse Width Modulation interface lines PWM1 and PWM2. The PWM interface lines can be used, for example, to connect buzzers. The PWM1 line is shared with GPIO7 and the PWM2 line is shared with GPIO6 (for GPIOs see Section 2.1.8). GPIO and PWM functionality are mutually exclusive.

The startup behavior of the lines is shown in Figure 13.

2.1.12 Pulse Counter

The GPIO8 line can be configured as pulse counter line COUNTER. The pulse counter interface can be used, for example, as a clock (for GPIOs see Section 2.1.8).

2.1.13 Control Signals

2.1.13.1 Status LED

The GPIO5 interface line can be configured to drive a status LED that indicates different operating modes of the module (for GPIOs see Section 2.1.8). GPIO and LED functionality are mutually exclusive.

To take advantage of this function connect an LED to the GPIO5/LED line as shown in Figure 17.

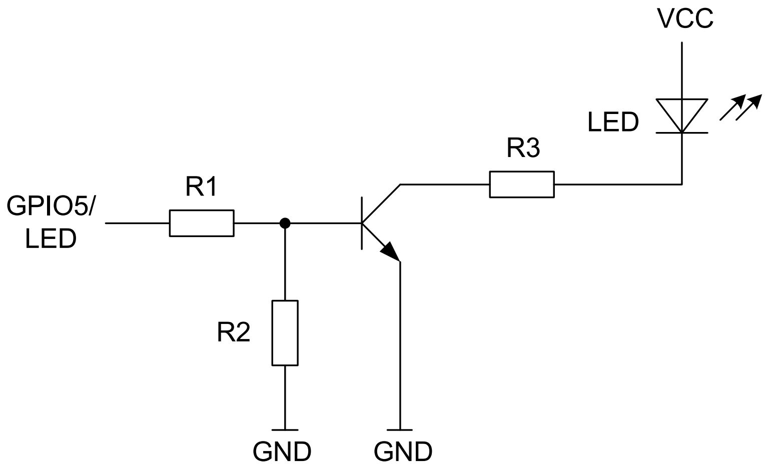


Figure 17: Status signaling with LED driver

2.1.13.2 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 18 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.

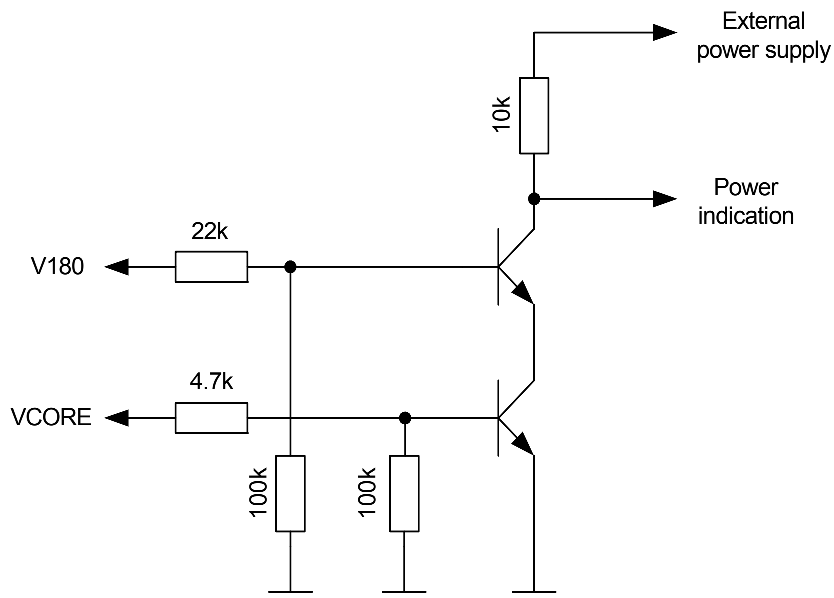


Figure 18: Power indication circuit

2.1.13.3 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 [6] (see also Section 2.1.3.1). For more information on how to configure the RING0 line by AT^SCFG command see [1].

Possible RING0 line states are listed in Table 6.

Table 6: Host wakeup lines

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

2.1.13.4 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 and must be applied for at least 1 milliseconds. If unused this line can be left open because of a configured internal pull-up resistor. Before setting the FST_SHDN line to low, the ON signal should be set to low (see Figure 19). Otherwise there might be back powering at the ON line in Power Down mode.

The fast shutdown feature can be triggered using the AT command AT^SMSO=<fso>. For details see [1].

If triggered, a low impulse >1 milliseconds on the FST_SHDN line starts the fast shutdown. The fast shutdown procedure still finishes any data activities on the module's flash file system, thus ensuring data integrity, but will no longer deregister gracefully from the network, thus saving the time required for network deregistration.

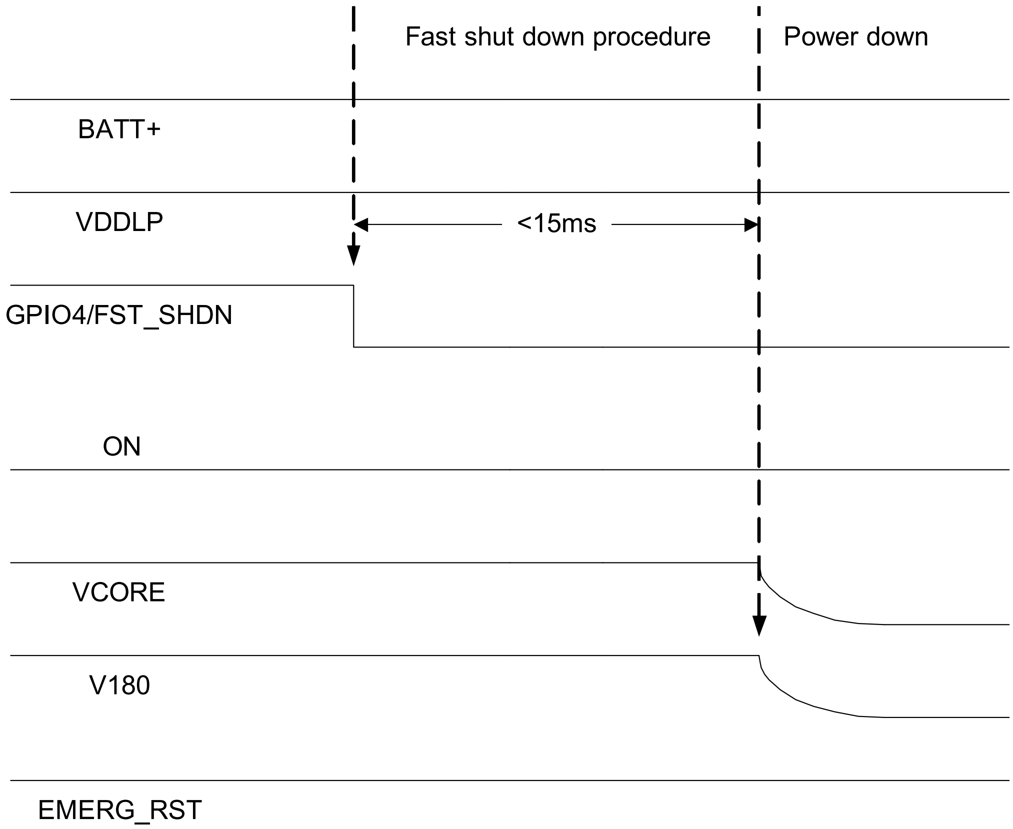


Figure 19: Fast shutdown timing

Please note that the normal software controlled shutdown using AT^SMSO will allow option for a fast shutdown by parameter <fso>, i.e., without network deregistration. However, in this case no URCs including shutdown URCs will be provided by the AT^SMSO command.

Please also note that the fast shutdown operation does not allow the module deregister from the network, therefore, this practice is not recommended, and should not be conducted on regular basis. If it is used for energy saving reason, for instance, used in battery-driven solutions that require prompt system shutdown before battery depletion, discretion is advised in such case.

2.2 RF Antenna Interface

The ELS81-US UMTS/LTE antenna interface comprises a UMTS/LTE main antenna as well as a UMTS/LTE Rx diversity antenna to improve signal reliability and quality[1]. The RF interface has an impedance of 50Ω. ELS81-US 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 ELS81-US module and should be placed in the host application if the antenna does not have an impedance of 50Ω.

Regarding the return loss ELS81-US provides the following values in the active band:

Table 7: Return loss in the active band

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

2.2.1 Antenna Interface Specifications

The LTE Cat.1 standard is designed for two antennas. It is mandatory to connect/apply the Rx diversity antenna to an existing antenna. The minimum efficiency shall be better than 50%.

Table 8: RF Antenna interface UMTS/LTE (at operating temperature range[1])

Parameter	Conditions	Min.	Typical	Max.	Unit
LTE connectivity[2]	Band 2, 4, 5,12				
Receiver Input Sensitivity @ ARP (Dual Antenna; ch. bandwidth 5MHz)	LTE 700 Band 12 (ch. bandwidth 5MHz)	-97	-103.5		dBm
	LTE 850 Band 5 (ch. bandwidth 10MHz)	-98	-104.5		dBm
	LTE AWS Band 4 (ch. bandwidth 10MHz)	-100	-103		dBm
	LTE 1900 Band 2 (ch. bandwidth 10MHz)	-98	-102.5		dBm

1. By delivery default the UMTS/LTE Rx diversity antenna is configured as available for the module since its usage is mandatory for LTE. Please refer to [1] for details on how to configure antenna settings.

Table 8: RF Antenna interface UMTS/LTE (at operating temperature range[1])

Parameter	Conditions	Min.	Typical	Max.	Unit
RF Power @ ARP with 50Ω Load (Board temperature < 85°C, BW:5MHz RB:25 (DL), 1 (UL) QPSK)	LTE 700 Band 12 (ch. bandwidth 5MHz; 1RB, position low)	+21	+23		dBm
	LTE 850 Band 5 (ch. bandwidth 5MHz; 1RB, position low)	+21	+23		dBm
	LTE AWS Band 4 (ch. bandwidth 5MHz; 1RB, position low)	+21	+23		dBm
	LTE 1900 Band 2 (ch. bandwidth 5MHz; 1RB, position low)	+21	+23		dBm
UMTS/HSPA connectivity[2]	Band II, IV, V				
Receiver Input Sensitivity @ ARP	UMTS 850 Band V	-104.7	-110		dBm
	UMTS AWS Band IV	-106.7	-108.5		dBm
	UMTS 1900 Band II	-104.7	-110		dBm
RF Power @ ARP with 50Ω Load (Board temperature < 85°C)	UMTS 850 Band V	+21	+23.5		dBm
	UMTS AWS Band IV	+21	+23.5		dBm
	UMTS 1900 Band II	+21	+23.5		dBm

1. No active power reduction is implemented - any deviations are hardware related.
2. Applies also to UMTS/LTE Rx diversity antenna.

2.2.2 Antenna Installation

The antenna is connected by soldering the antenna pad (ANT_MAIN or ANT_DRX) and its neighboring ground pads (GND) directly to the application's PCB. The antenna pads are the antenna reference points (ARP) for ELS81-US. All RF data specified throughout this document is related to the ARP.

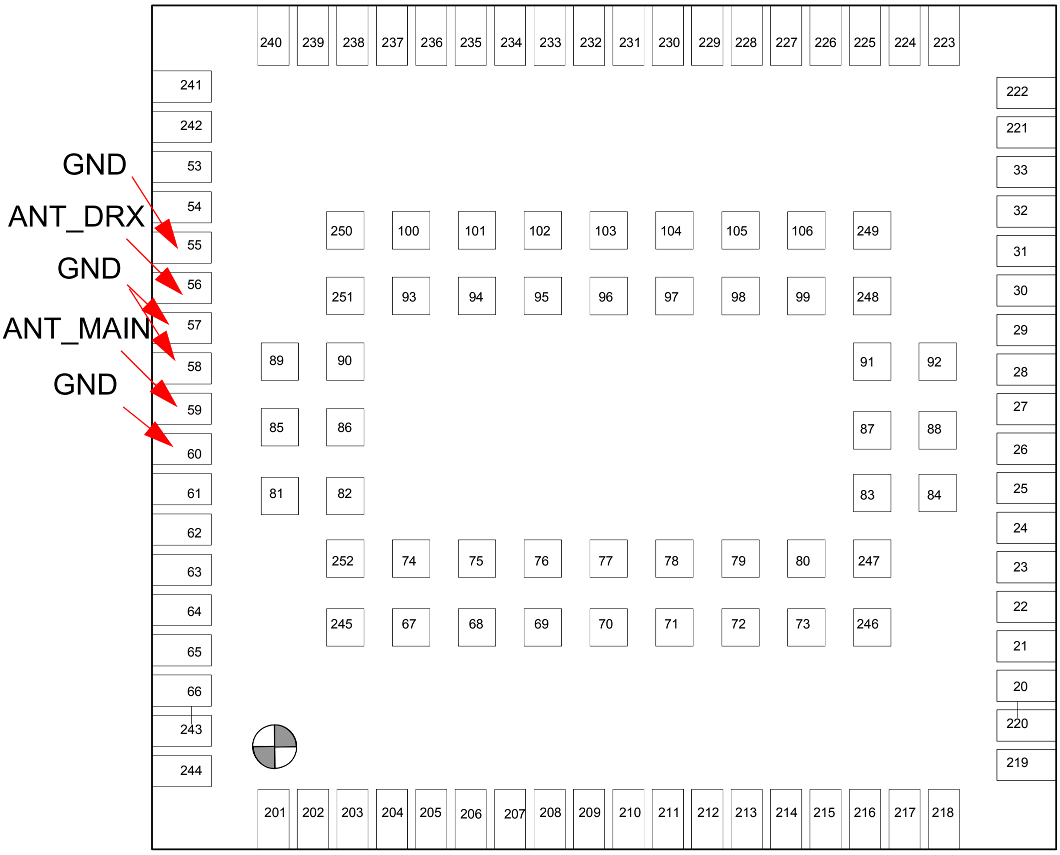


Figure 20: Antenna pads (bottom view)

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

The wiring of the antenna connection, starting from the antenna pad to the application's antenna should result in a 50Ω line impedance. Line width and distance to the GND plane 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 external application PCB, it is recommended to realize the antenna connection line using embedded Stripline rather than Micro-Stripline technology. Please see Section 2.2.3.1 for examples of how to design the antenna connection in order to achieve the required 50Ω line impedance.

For type approval purposes, the use of a 50Ω coaxial antenna connector (U.FL-R-SMT) might be necessary. In this case the U.FL-R-SMT connector should be placed as close as possible to ELS81-US's antenna pad.

2.2.3 RF Line Routing Design

2.2.3.1 Line Arrangement Examples

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

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

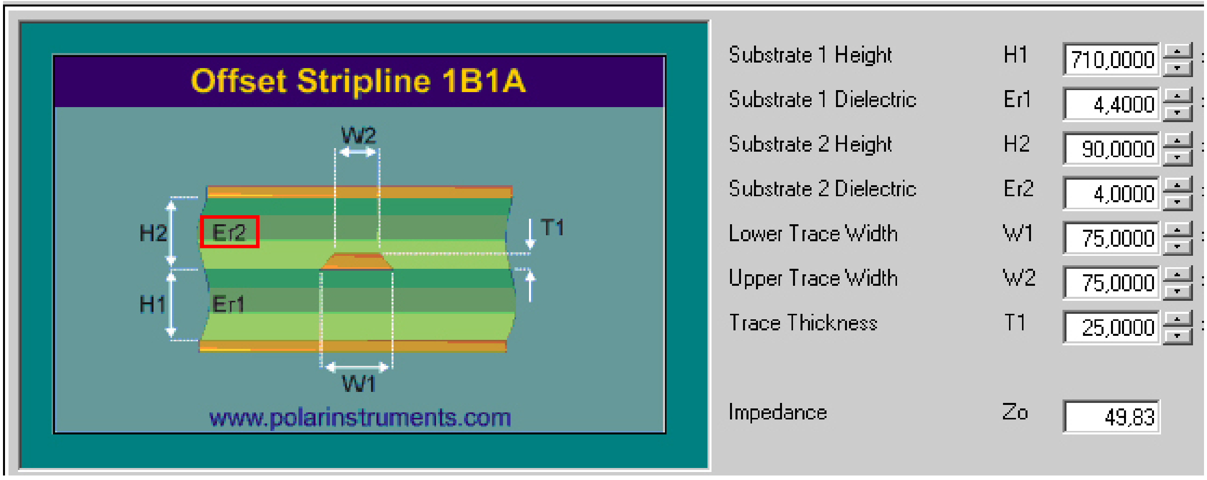


Figure 21: Embedded Stripline with 65µm prepreg (1080) and 710µm core

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).

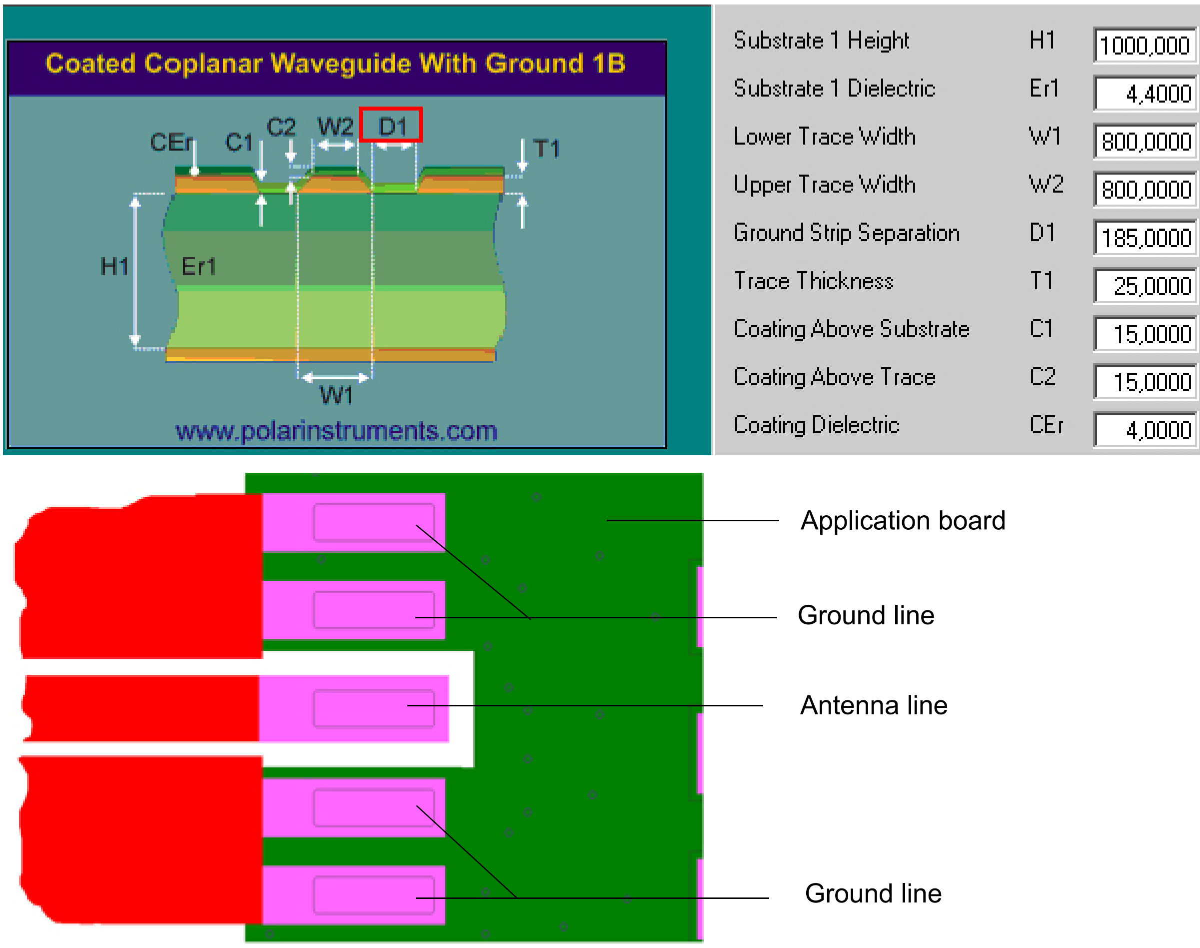


Figure 22: Micro-Stripline on 1.0mm standard FR4 2-layer PCB - example 1

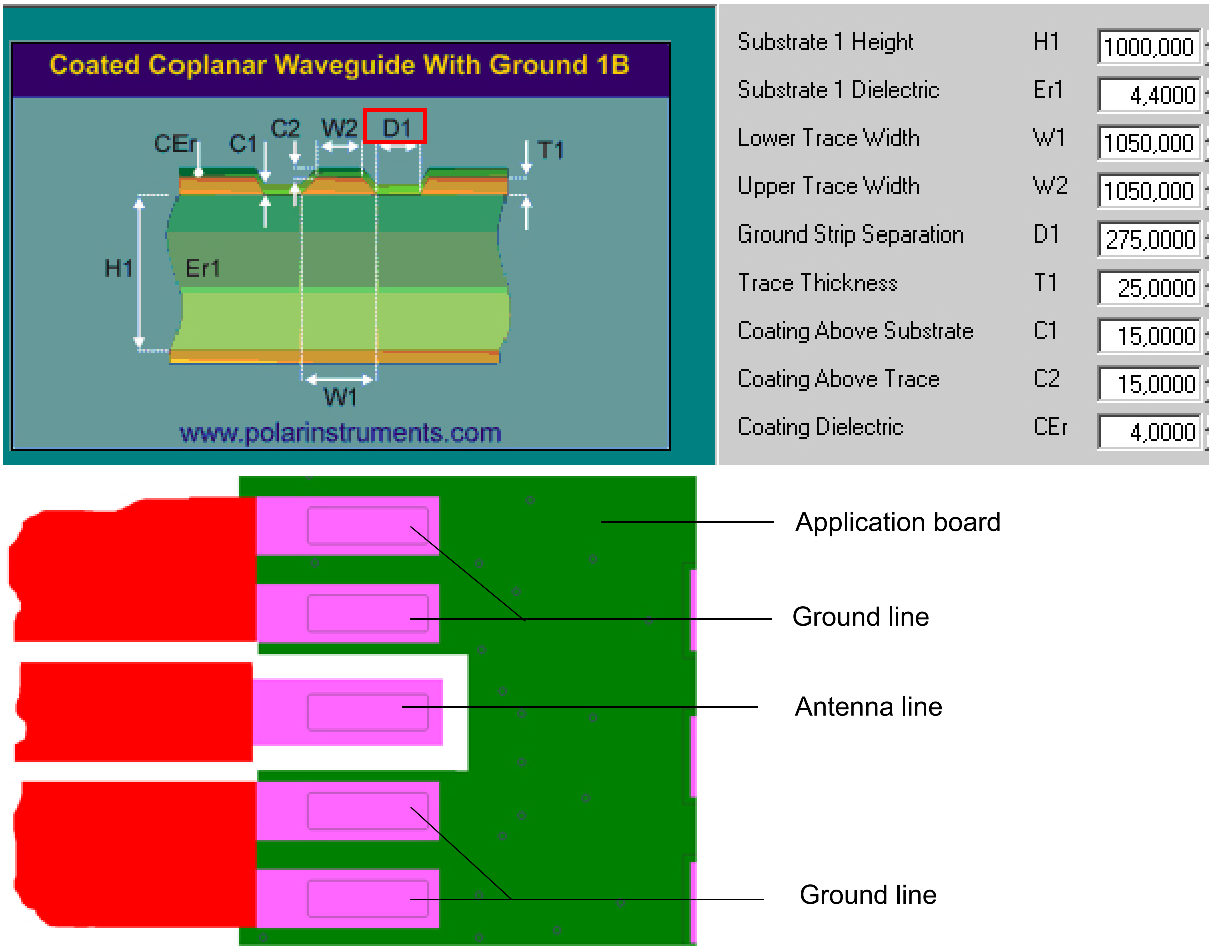


Figure 23: Micro-Stripline on 1.0mm Standard FR4 PCB - example 2

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

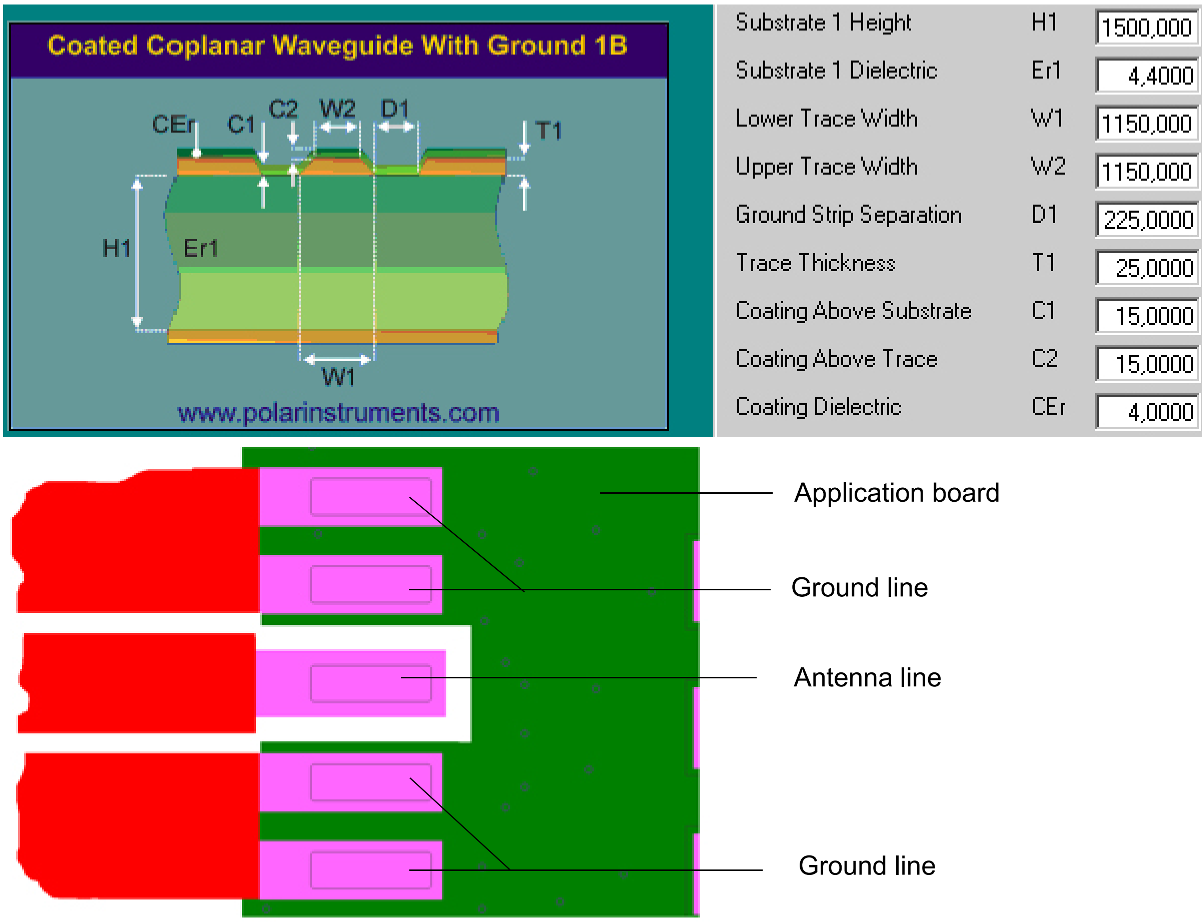


Figure 25: Micro-Stripline on 1.5mm Standard FR4 PCB - example 2

2.2.3.2 Routing Example

Interface to RF Connector

Figure 26 shows the connection of the module's antenna pad with an application PCB's coaxial antenna connector. Please note that the ELS81-US bottom plane appears mirrored, since it is viewed from ELS81-US top side. By definition the top of customer's board shall mate with the bottom of the ELS81-US module.

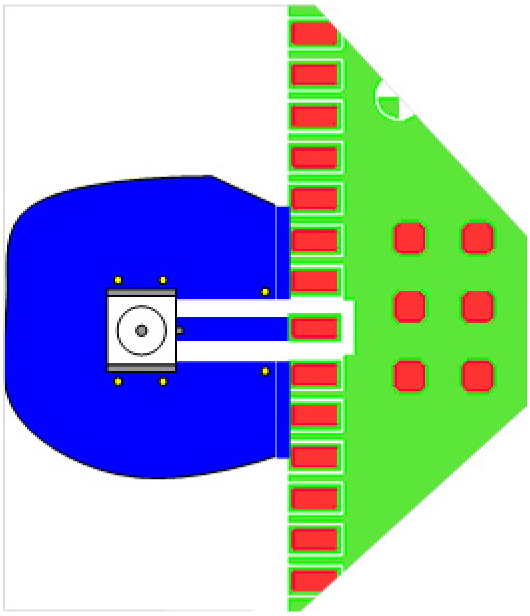


Figure 26: Routing to application's RF connector - top view

2.3 Sample Application

Figure 27 shows a typical example of how to integrate a ELS81-US module with an application. Usage of the various host interfaces depends on the desired features of the application.

Because of the very low power consumption design, current flowing from any other source into the module circuit must be avoided, for example reverse current from high state external control lines. 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.

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, VDDLP, and 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.

Depending on the micro controller used by an external application ELS81-US‘s digital input and output lines may require level conversion. Section 2.3.1 shows a possible sample level conversion circuit.

Note: ELS81-US is not intended for use with cables longer than 3m.

Disclaimer
No warranty, either stated or implied, is provided on the sample schematic diagram shown in Figure 27 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 ELS81-US modules.

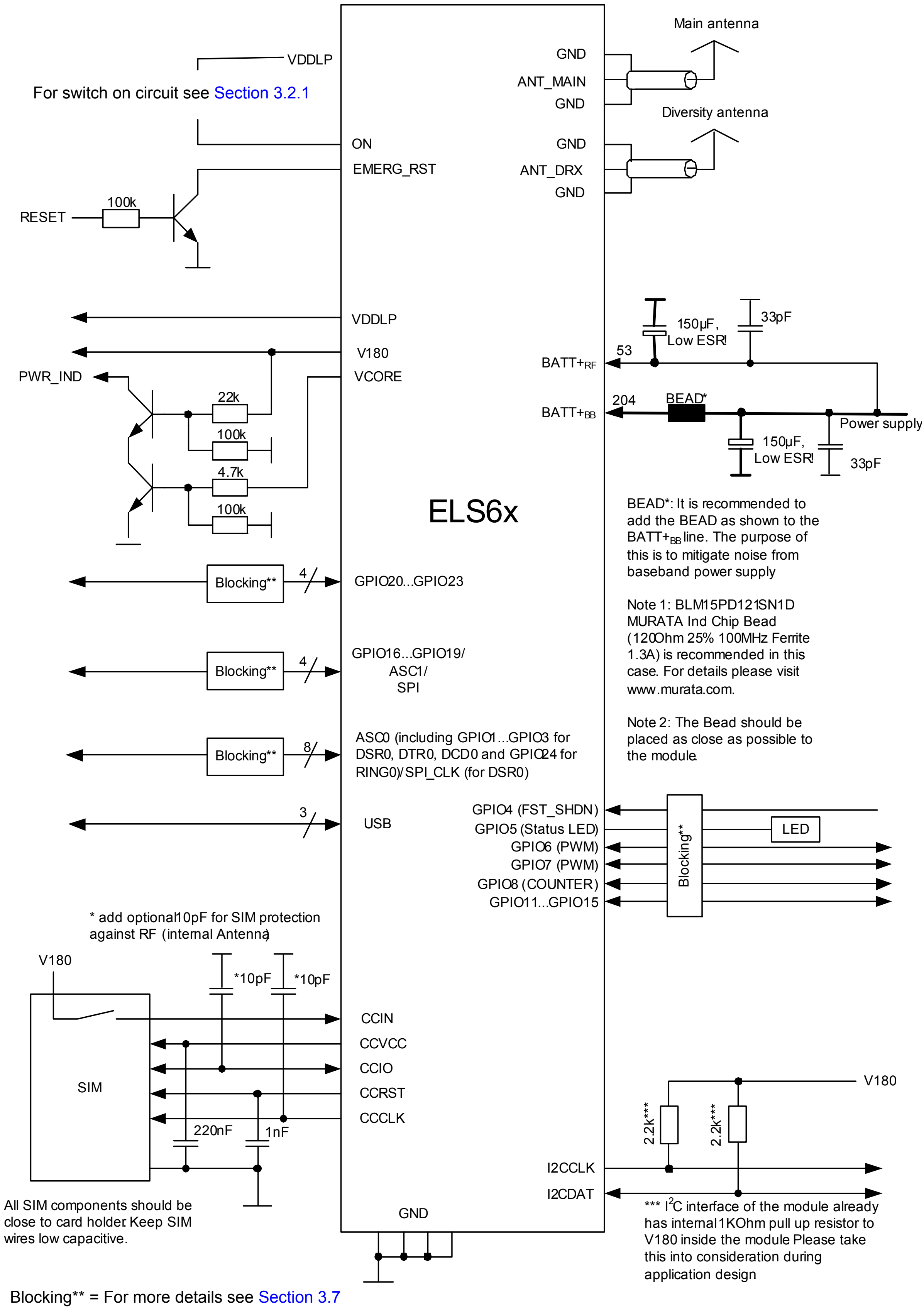


Figure 27: Schematic diagram of ELS81-US sample application

2.3.1 Sample Level Conversion Circuit

Depending on the micro controller used by an external application ELS81-US's digital input and output lines (i.e., ASC0, ASC1 and GPIO lines) may require level conversion. The following Figure 28 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.

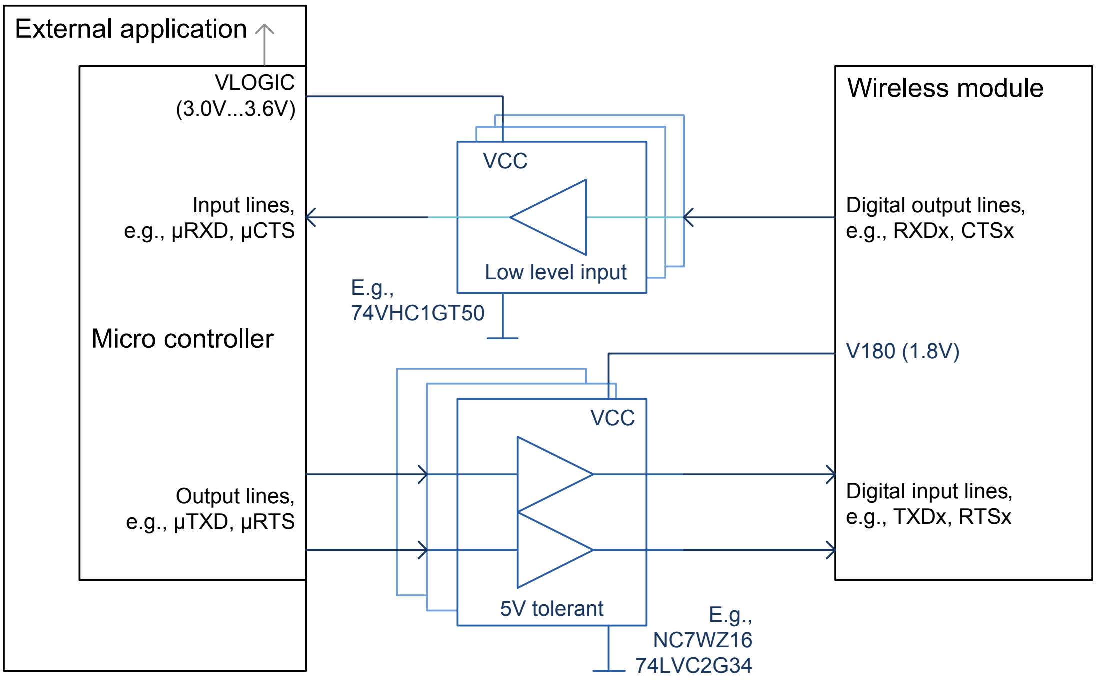


Figure 28: Sample level conversion circuit

3 Operating Characteristics

3.1 Operating Modes

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

Table 9: Overview of operating modes

Mode	Function	
Normal operation	UMTS / HSPA / LTE SLEEP	Power saving set automatically when no call is in progress and the USB connection is suspended by host or not present and no active communication via ASC0.
	UMTS / HSPA / LTE IDLE	Power saving disabled or an USB connection not suspended, but no call in progress.
	UMTS DATA	UMTS data transfer in progress. Power consumption depends on network settings (e.g. TPC Pattern) and data transfer rate.
	HSPA DATA	HSPA data transfer in progress. Power consumption depends on network settings (e.g. TPC Pattern) and data transfer rate.
	LTE DATA	LTE data transfer in progress. Power consumption depends on network settings (e.g. TPC Pattern) and data transfer rate.
Power Down	Normal shutdown after sending the power down command. Only a voltage regulator is active for powering the RTC. 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 network and disables all AT commands whose execution requires a radio connection. Airplane mode can be controlled by AT command (see [1]).	
Alarm mode	Restricted operation launched by RTC alert function when the module is in Power Down mode. In Alarm mode, the module remains deregistered from the network. Limited number of AT commands is accessible.	

3.2 Power Up/Power Down Scenarios

In general, be sure not to turn on ELS81-US while it is beyond the safety limits of voltage and temperature stated in Section 2.1.2.1. ELS81-US immediately switches off after having started and detected these inappropriate conditions. In extreme cases this can cause permanent damage to the module.

3.2.1 Turn on ELS81-US

ELS81-US can be turned on as described in the following sections:
- Connecting the operating voltage BATT+ (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 ELS81-US BATT+ Lines

Figure 29 shows sample external application circuits that allow to connect (and also to temporarily disconnect) the module‘s BATT+ lines from the external application‘s power supply.

Figure 29 illustrates the application of power employing an externally controlled microcontroller. The voltage supervisory circuit ensures that the power is disconnected and applied again depending on given thresholds.

The transistor T2 mentioned in Figure 29 should have an R_{DS_ON} value $\leq$ 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+ lines the module can then be (re-)started as described in Section 3.2.1.2 and Section 3.2.2.

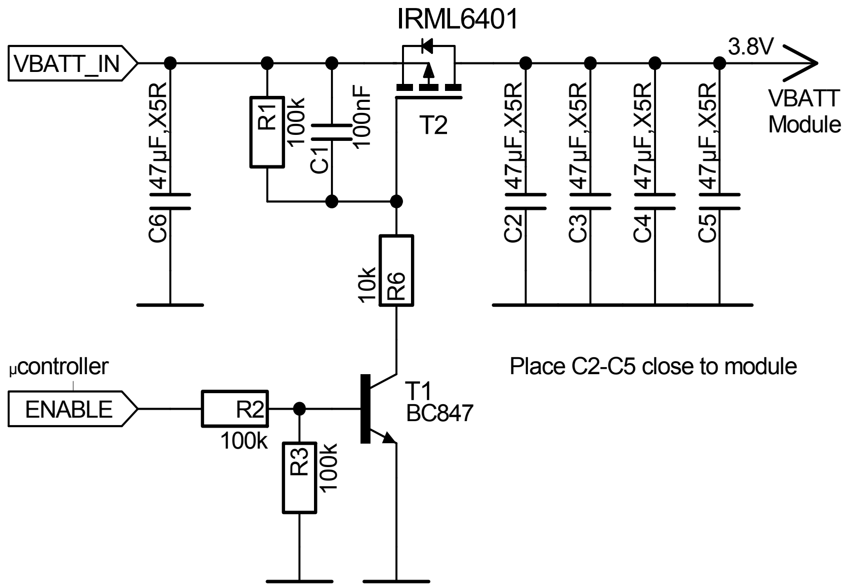


Figure 29: Sample circuit for applying power using an external µC

3.2.1.2 Switch on ELS81-US Using ON Signal

After the operating voltage BATT+ is applied, ELS81-US can be switched on by means of the ON signal.

The ON signal is an edge triggered signal and allows the input voltage level up to 5V. The module starts into normal mode on detecting the rising edge of the ON signal. The rising edge of ON signal must be applied at least 100 milliseconds later than BATT+. See Figure 31.

The following Figure 30 shows recommendations for possible switch-on circuits.

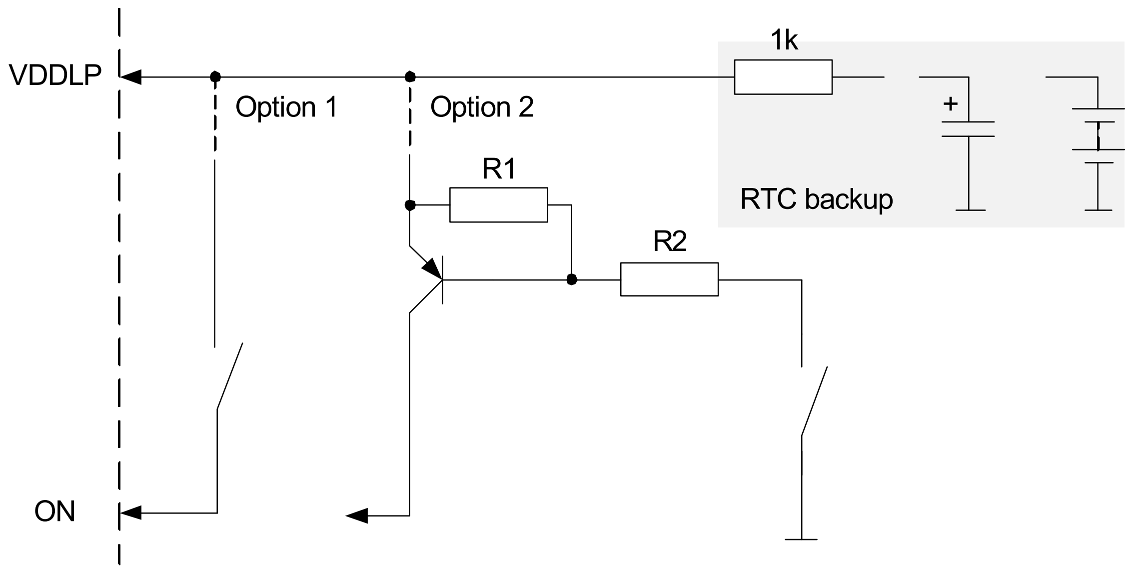


Figure 30: ON circuit options

It is recommended to set a serial 1kOhm resistor between the ON circuit and the external capacitor or battery at the VDDLP power supply (i.e., RTC backup circuit). This serial resistor protection is necessary in case the capacitor or battery has low power (is empty).With Option 2 the typical resistor values are: R1 = 150k and R2 = 3k. But the resistor values depend on the current gain from the employed PNP resistor.

Please note that the ON signal is an edge triggered signal. This implies that a micro-second high pulse on the signal line suffices to almost immediately switch on the module, as shown in Figure 31. After module startup the ON signal should always be set to low to prevent possible back powering at this pad.[1]

1. Please take due discretion when designing the filtering circuit, especially ESD, which may cause unintended switch on.

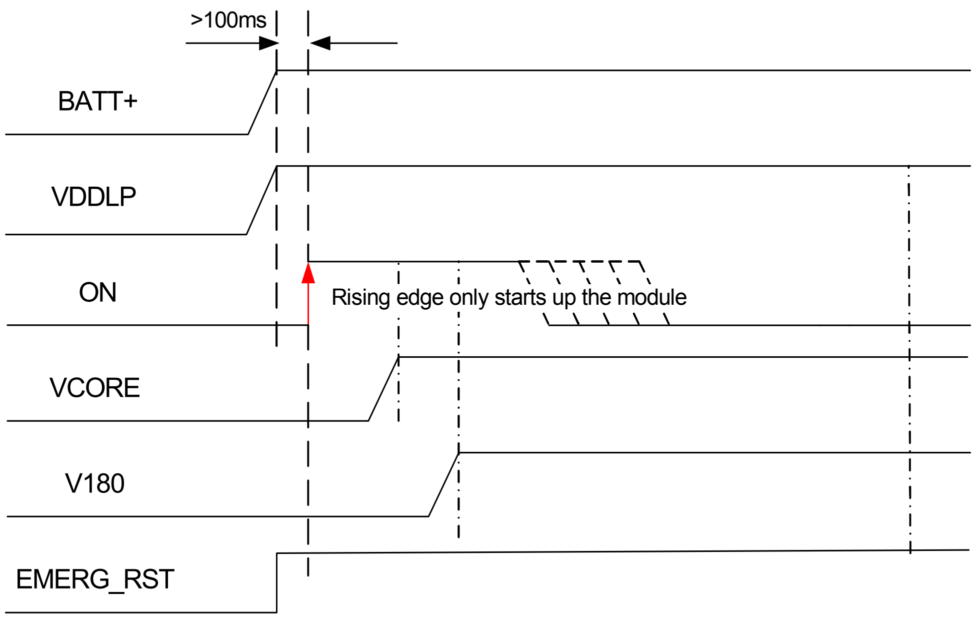


Figure 31: ON timing

3.2.1.3 Automatic Power On

In case an automatic power on function is required for an external module application, circuits such as shown in either Figure 32 or - if based on a voltage detector - Figure 33 and Figure 34 are recommended.

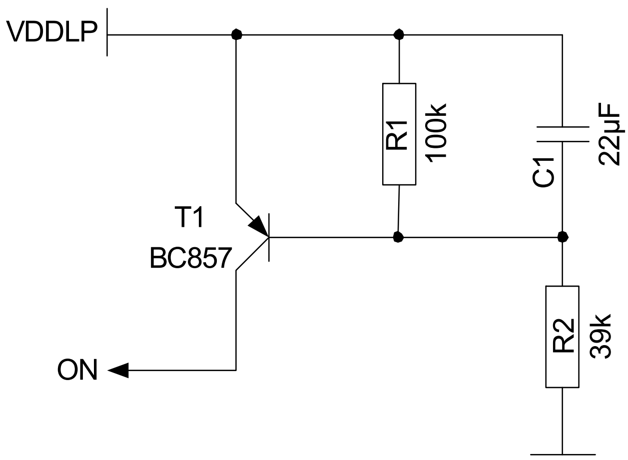


Figure 32: Automatic ON circuit

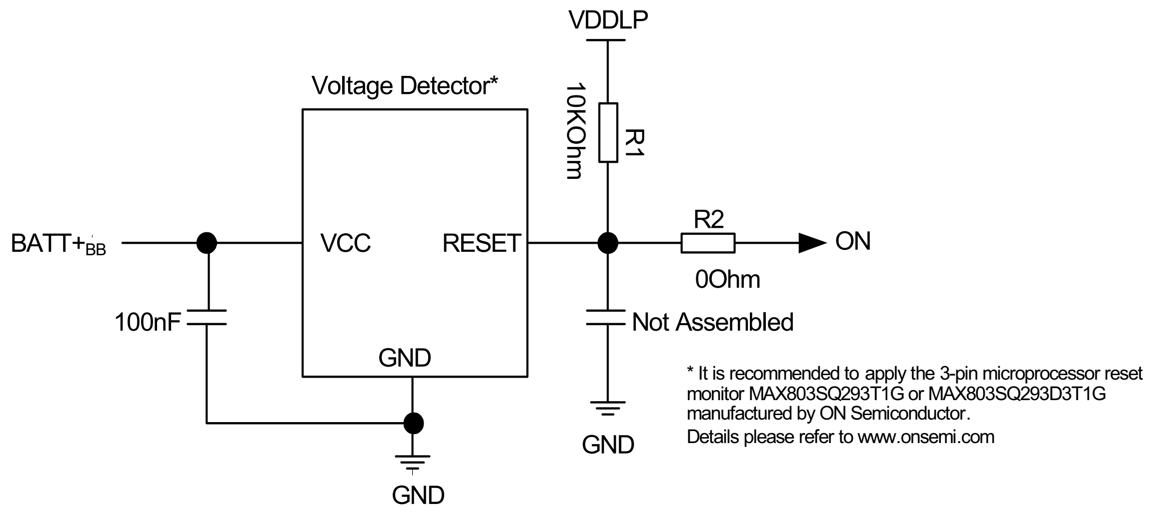


Figure 33: Automatic ON circuit based on voltage detector - option 1

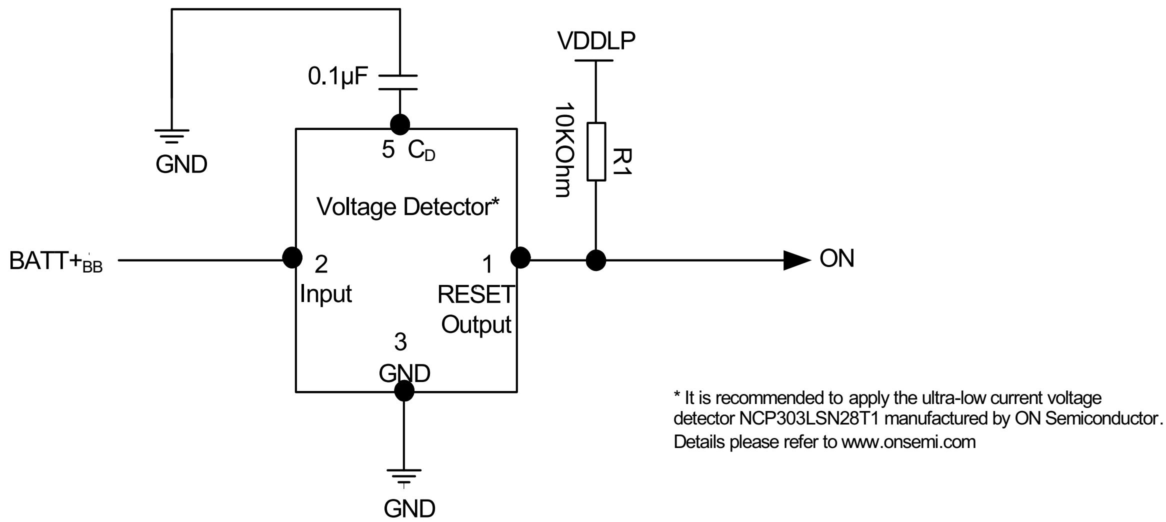


Figure 34: Automatic ON circuit based on voltage detector - option 2

3.2.2 Restart ELS81-US

After startup ELS81-US can be re-started as described in the following sections:

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

3.2.2.1 Restart ELS81-US via AT+CFUN Command

To reset and restart the ELS81-US module use the command AT+CFUN. See [1] for details.

3.2.2.2 Restart ELS81-US Using EMERG_RST

The EMERG_RST signal is internally connected to the main module processor. A low level for more than 10ms 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.

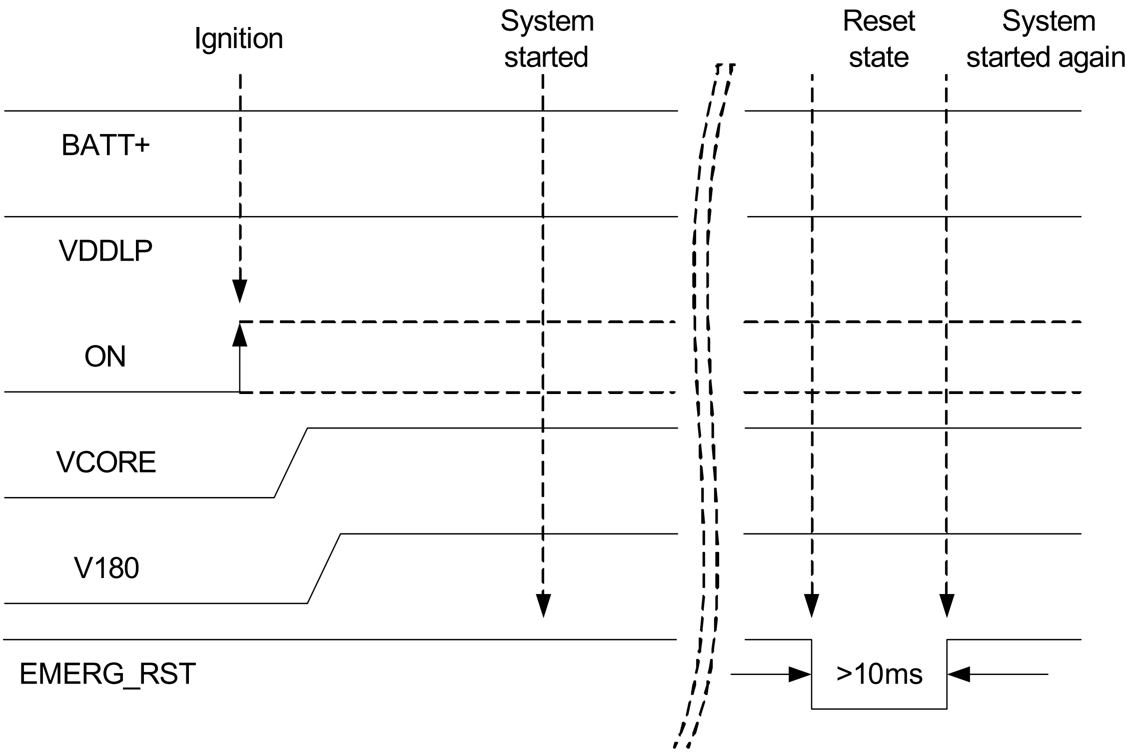


Figure 35: Emergency restart timing

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

Caution: Use the EMERG_RST line only when, due to serious problems, the software is not responding for more than 5 seconds. Pulling the EMERG_RST line causes the loss of all information stored in the volatile memory. Therefore, this procedure is intended only for use in case of emergency, e.g. if ELS81-US does not respond, if reset or shutdown via AT command fails.

3.2.3 Signal States after Startup

Table 10 lists the states each interface signal passes through during reset phase and the 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 the EMERG_RST signal - either after a normal module startup (see Section 3.2.1.2) or after a reset (see Section 3.2.2.2). After the reset state has been reached the firmware initialization state begins. The firmware initialization is completed as soon as the ASC0 interface lines CTS0, DSR0 and RING0 as well as the ASC1 interface line CTS1 have turned low (see Section 2.1.4 and Section 2.1.5). Now, the module is ready to receive and transmit data.

Table 10: Signal states

Signal name	Reset state	First start up configuration
CCIO	L	O / L
CCRST	L	O / L
CCCLK	L	O / L
CCIN	T / 100k PD	I / PD
RXD0	T / PU	O / H
TXD0	T / PD	I
CTS0	T / PU	O / H
RTS0	T / PU	I / PD
GPIO1	T / PD	T / PD
GPIO2	T / PD	T / PD
GPIO3	T / PD	T / PD
GPIO4	T / PD	T / PD
GPIO5	T / PD	T / PD
GPIO6	T / PD	T / PD
GPIO7	T / PD	T / PD
GPIO8	T / PD	T / PD
GPIO11-GPIO15	T / PD	T / PD
GPIO16	T / PD	T / PD
GPIO17	T / PD	T / PD
GPIO18	T / PD	T / PD
GPIO19	T / PD	T / PD
GPIO20	T / PD	T / PD
GPIO21	T / PD	T / PD
GPIO22	T / PD	T / PD
GPIO23	T / PD	T / PD
GPIO24	T / PD	T / PD
I2CCLK	T / PU	OD / PU
I2CDAT	T / PU	OD / PU

Abbreviations used in above Table 10:

L = Low level H = High level T = Tristate I = Input	O = Output OD = Open Drain PD = Pull down, 200µA at 1.9V PU = Pull up, -240µA at 0V

3.2.4 Turn off ELS81-US

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

- *Software controlled shutdown procedure*: Software controlled by sending an AT command over the serial application interface. See Section 3.2.4.1.
- *Hardware controlled shutdown procedure*: Hardware controlled by disconnecting the module‘s power supply lines BATT+ (see Section 3.2.1.1).
- *Automatic shutdown (software controlled)*: See Section 3.2.5
  - Takes effect if ELS81-US board temperature or voltage levels exceed a critical limit.

3.2.4.1 Switch off ELS81-US Using AT Command

The best and safest approach to powering down ELS81-US is to issue the appropriate AT command. This procedure lets ELS81-US log off from the network and allows the software to enter into a secure state and safe data before disconnecting the power supply. The mode is referred to as Power Down mode. In this mode, only the RTC stays active. After sending the switch off command AT^SMSO, be sure not to enter any further AT commands until the module was restarted.

CAUTION: Be sure not to disconnect the operating voltage V_{BATT+} before V180 pad has gone low. Otherwise you run the risk of losing data, or in some rare cases even to render the module inoperable.

To monitor the V180 line, it is recommended to implement a power indication circuit as described in Section 2.1.13.2.

While ELS81-US is in Power Down mode the application interface is switched off and must not be fed from any other voltage source. **Therefore, your application must be designed to avoid any current flow into any digital pads of the application interface.**

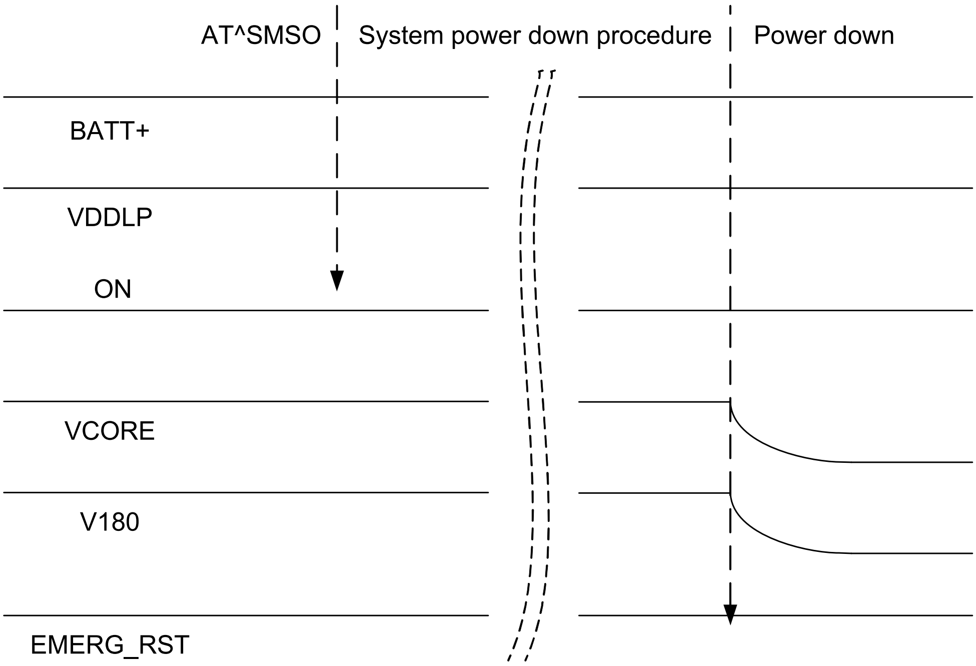


Figure 36: Switch off behavior

3.2.5 Automatic Shutdown

Automatic shutdown takes effect if the following event occurs:
- ELS81-US board is exceeding the critical limits of overtemperature or undertemperature (see Section 3.2.5.1)
- Undervoltage or overvoltage is detected (see Section 3.2.5.2 and Section 3.2.5.3)

The automatic shutdown procedure is equivalent to the power-down initiated with an AT command, i.e. ELS81-US logs off from the network and the software enters a secure state avoiding loss of data.

3.2.5.1 Thermal Shutdown

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

Each time the board temperature goes out of range or back to normal, ELS81-US instantly displays an alert (if enabled).
- URCs indicating the level "1" or "-1" allow the user to take appropriate precautions, such as protecting the module from exposure to extreme conditions. The presentation of the URCs depends on the settings selected with the AT^SCTM write command (for details see [1]):
  AT^SCTM=1: Presentation of URCs is always enabled.
  AT^SCTM=0 (default): Presentation of URCs is enabled during the 2 minute guard period after start-up of ELS81-US. After expiry of the 2 minute guard period, the presentation of URCs will be disabled, i.e. no URCs with alert levels "1" or "-1" will be generated.
- URCs indicating the level "2" or "-2" are instantly followed by an orderly shutdown. The presentation of these URCs is always enabled, i.e. they will be output even though the factory setting AT^SCTM=0 was never changed.

The maximum temperature ratings are stated in Section 3.5. Refer to Table 11 for the associated URCs.

Table 11: Temperature dependent behavior

Sending temperature alert (2min after ELS81-US 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. ELS81-US switches off.
^SCTM_B: -2	Alert: Board equal or below undertemperature limit. ELS81-US switches off.

3.2.5.2 Undervoltage Shutdown

The undervoltage shutdown threshold is the specified minimum supply voltage V_{BATT+} given in Table 2. When the average supply voltage measured by ELS81-US approaches the undervoltage shutdown threshold (i.e., 0.05V offset) the module will send the following URC:

^SBC: Undervoltage Warning

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

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

^SBC: Undervoltage Shutdown

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

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

Note: For battery powered applications it is strongly recommended to implement a BATT+ connecting circuit as described in Section 3.2.1.1 in order to not only be able save power, but also to restart the module after an undervoltage shutdown where the battery is deeply discharged. Also note that the undervoltage threshold is calculated for max. 400mV voltage drops during transmit burst. Power supply sources for external applications should be designed to tolerate 400mV voltage drops without crossing the lower limit of 3.0 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 ELS81-US approaches the overvoltage shutdown threshold (i.e., 0.05V offset) the module will send the following URC:

^SBC: Overvoltage Warning

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

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

^SBC: Overvoltage Shutdown

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

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

Keep in mind that several ELS81-US components are directly linked to BATT+ and, therefore, the supply voltage remains applied at major parts of ELS81-US. Especially the power amplifier linked to $BATT+_{RF}$ is very sensitive to high voltage and might even be destroyed.

3.3 Power Saving

ELS81-US can be configured to control power consumption:

- Using the AT command AT^SPOW it is possible to specify a so-called power saving mode for the module (<mode> = 2; 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 and Section 3.3.2. See Section 3.3.3 for a description on how to immediately wake up ELS81-US again using RTS0.

  Please 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.

3.3.1 Power Saving while Attached to WCDMA Networks

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

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

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

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

In the pauses between listening to paging messages, the module resumes power saving, as shown in Figure 37.

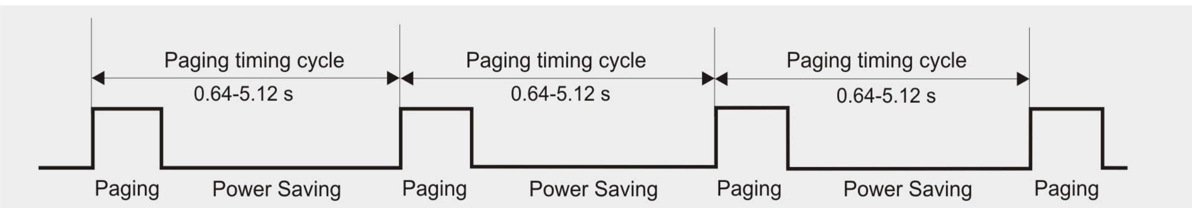


Figure 37: Power saving and paging in WCDMA networks

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

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

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

3.3.2 Power Saving while Attached to LTE Networks

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

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

t = DRX Cycle Value * 10 ms

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

In the pauses between listening to paging messages, the module resumes power saving, as shown in Figure 38.

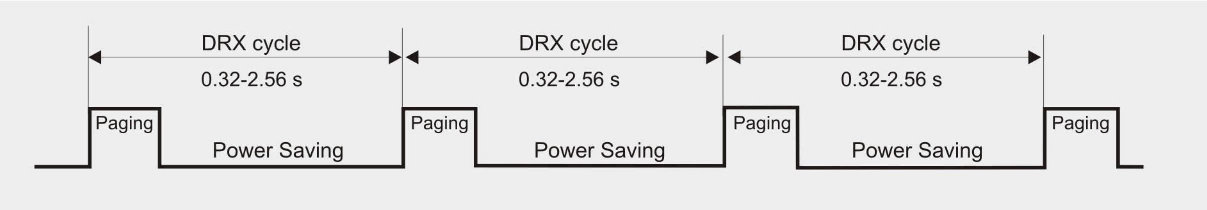


Figure 38: Power saving and paging in LTE networks

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

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

3.3.3 Wake-up via RTS0

RTS0 can be used to wake up ELS81-US from SLEEP mode configured with AT^SPOW. Assertion of RTS0 (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 assertion, the CTS0 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 39 shows the described RTS0 wake up mechanism.

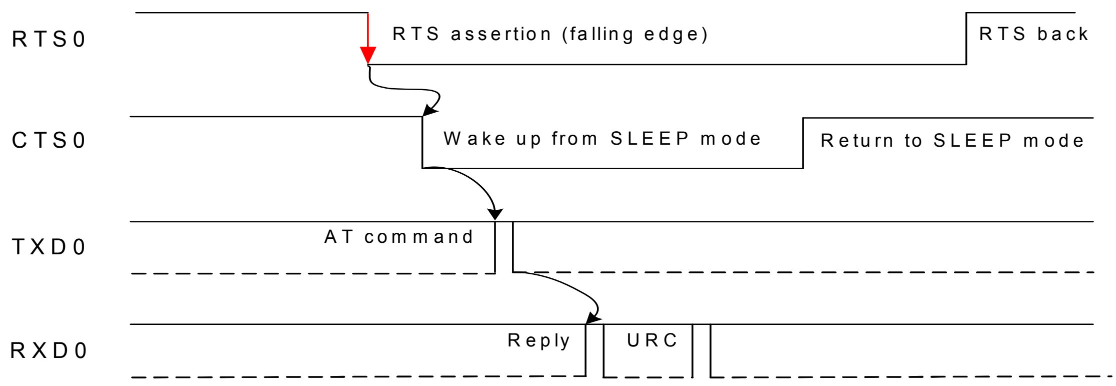


Figure 39: Wake-up via RTS0

3.4 Power Supply

ELS81-US needs to be connected to a power supply at the SMT application interface - 2 lines BATT+, 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 UMTS/LTE 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 ELS81-US has to be a single voltage source at $BATT+_{BB}$ and $BATT+_{RF}$. It must be able to provide the peak current during the uplink transmission.

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

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

3.4.1 Power Supply Ratings

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

Table 12: Voltage supply ratings

	Description	Conditions	Min	Typ	Max	Unit
BATT+	Supply voltage	Directly measured at Module. Voltage must stay within the min/max values, including voltage drop, ripple, spikes.	3.0		4.5	V
	Maximum allowed voltage drop during transmit burst	Normal condition, power control level for Pout max			400	mV

Table 13: Current consumption ratings[1]

	Description	Conditions		Typical rating	Unit
I_{VDDLP} @ 1.8V	OFF State supply current	RTC backup @ BATT+ = 0V		0.1	µA
I_{BATT+}[2] (i.e., sum of $BATT+_{BB}$ and $BATT+_{RF}$)	OFF State supply current	Power Down		82	µA
	Average UMTS supply current Data transfer @ maximum Pout	SLEEP[3] @ DRX=9 (UART deactivated)	USB disconnected	1.7	mA
			USB suspended	1.7	mA
		SLEEP[3] @ DRX=8 (UART deactivated)	USB disconnected	1.7	mA
			USB suspended	1.7	mA
		SLEEP[3] @ DRX=6 (UART deactivated)	USB disconnected	2.5	mA
			USB suspended	2.4	mA
		IDLE[4] @ DRX=6 (UART active, but no communication)	USB disconnected	13	mA
			USB active	32	mA
		UMTS Data transfer Band II		580	mA
		UMTS Data transfer Band IV		610	mA
		UMTS Data transfer Band V		400	mA
		HSPA Data transfer Band II		580	mA
		HSPA Data transfer Band IV		610	mA
		HSPA Data transfer Band V		400	mA

Table 13: Current consumption ratings[1]

	Description	Conditions		Typical rating	Unit
I_{BATT+}[2] (i.e., sum of $BATT+_{BB}$ and $BATT+_{RF}$)	Average LTE supply current Data transfer @ maximum Pout	SLEEP[3] @ "Paging Occasions" = 256	USB disconnected	2.1	mA
			USB suspended	2.0	mA
		SLEEP[3] @ "Paging Occasions" = 128	USB disconnected	2.5	mA
			USB suspended	2.3	mA
		SLEEP[3] @ "Paging Occasions" = 64	USB disconnected	3.2	mA
			USB suspended	3.2	mA
		SLEEP[3] @ "Paging Occasions" = 32	USB disconnected	4.6	mA
			USB suspended	4.7	mA
		IDLE[4] @ DRX=6 (UART active, but no communication)	USB disconnected	20	mA
			USB active	40	mA
		LTE[5] Data transfer Band 2		660	mA
		LTE[5] Data transfer Band 4		685	mA
		LTE[5] Data transfer Band 5		530	mA
		LTE[5] Data transfer Band 12		660	mA

1. Note: Current consumption ratings are based on measurements done in a laboratory test environment, and deviations may occur from the given typical ratings. Under real life conditions however, with e.g., varying network quality, location changes, or changing supply currents, the deviations from these typical ratings may be even bigger, and will have to be taken into account for actual power supply solutions. For more details on power supply design see [3].
2. With an impedance of Z_{LOAD}=50Ω at the antenna connector.Measured at 25°C at 3.8V - except for Power Down ratings that were measured at 3.0V.
3. Measurements start 6 minutes after switching ON the module,
   Averaging times:
   SLEEP mode - 3 minutes, transfer modes - 1.5 minutes
   Communication tester settings: no neighbour cells, no cell reselection etc., RMC (reference measurement channel). Note that SLEEP mode is enabled via AT command AT^SPOW=2, 1000, 3
4. The power save mode is disabled via AT command AT^SPOW=1,0,0
5. Communication tester settings:
   Channel Bandwidth: 5MHz
   Number of Resource Blocks: 25 (DL), 1 (UL)
   Modulation: QPSK

3.4.2 Measuring the Supply Voltage (V_{BATT+})

To measure the supply voltage V_{BATT+} it is possible to define two reference points GND and BATT+. GND should be the module's shielding, while BATT+ should be a test pad on the external application the module is mounted on. The external BATT+ reference point has to be connected to and positioned close to the SMT application interface's BATT+ pads 53 ($BATT+_{RF}$) or 204 ($BATT+_{BB}$) as shown in Figure 40.

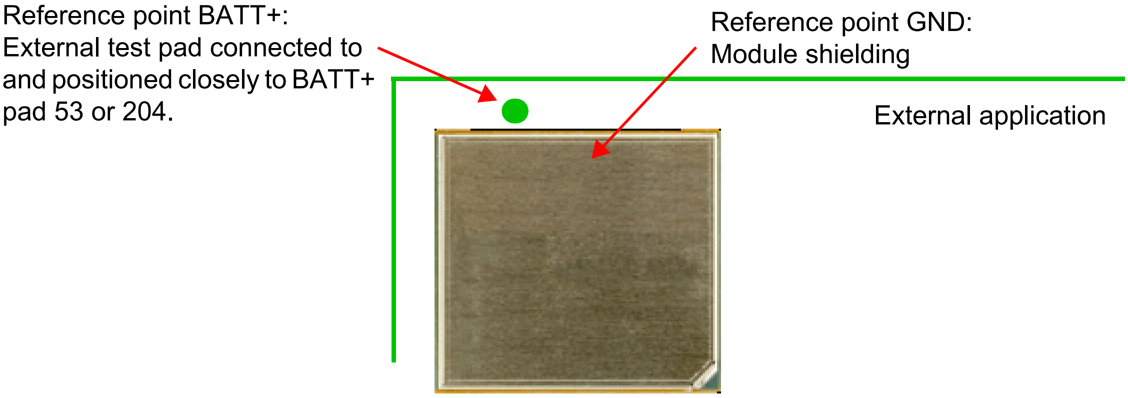


Figure 40: Position of reference points BATT+ and GND

3.4.3 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+ 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 ELS81-US is in IDLE mode or Limited Service (deregistered). The displayed voltage (in mV) is averaged over the last measuring period before the AT^SBV command was executed.

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

3.5 Operating Temperatures

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

Table 14: Board temperature

Parameter	Min	Typ	Max	Unit
Normal operation	-30	+25	+85	°C
Extended operation[1]	-40		+90	°C
Automatic shutdown[2] Temperature measured on ELS81-US 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 [5].

3.6 Electrostatic Discharge

The module is not protected against Electrostatic Discharge (ESD) in general. Consequently, it is subject to ESD handling precautions that typically apply to ESD sensitive components. Proper ESD handling and packaging procedures must be applied throughout the processing, handling and operation of any application that incorporates a ELS81-US module.

An example for an enhanced ESD protection for the SIM interface is given in Section 2.1.6.1.

ELS81-US has been tested according to group standard ETSI EN 301 489-1 (see Table 22) and test standard EN 61000-4-2. Electrostatic values can be gathered from the following table.

Table 15: Electrostatic values

Specification/Requirements	Contact discharge	Air discharge
EN 61000-4-2		
Antenna interfaces	±1kV	n.a.
Antenna interfaces with ESD protection (see Section 3.6.1)	±4kV	±8kV
BATT+	±4kV	±8kV
JEDEC JESD22-A114D (Human Body Model, Test conditions: 1.5 kΩ, 100 pF)		
All other interfaces	±1kV	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 Thales reference application described in Chapter 5.

3.6.1 ESD Protection for Antenna Interfaces

The following Figure 41 shows how to implement an external ESD protection for the RF antenna interfaces (ANT_MAIN and ANT_DRX) with either a T pad or PI pad attenuator circuit (for RF line routing design see also Section 2.2.3).

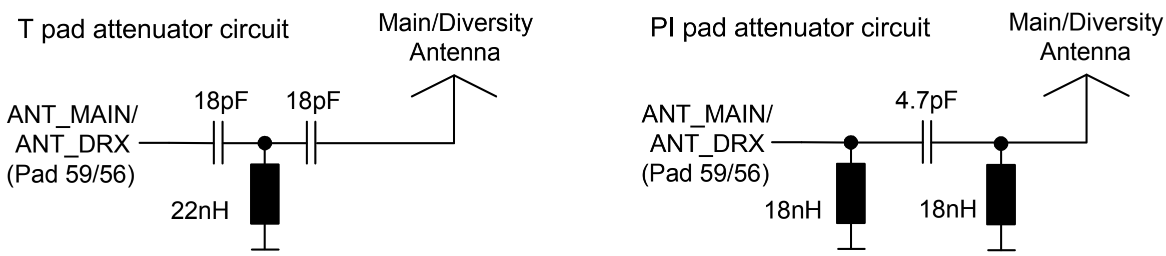


Figure 41: ESD protection for RF antenna interface

Recommended inductor types for the above sample circuits: Size 0402 SMD from Panasonic ELJRF series (22nH and 18nH inductors) or Murata LQW15AN18NJ00 (18nH inductors only).

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-E) that may be implemented between module and external application depending on the signal line (see Figure 42 and Table 16). Pay attention not to exceed the maximum input voltages and prevent voltage overshots if using inductive EMC measures.

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

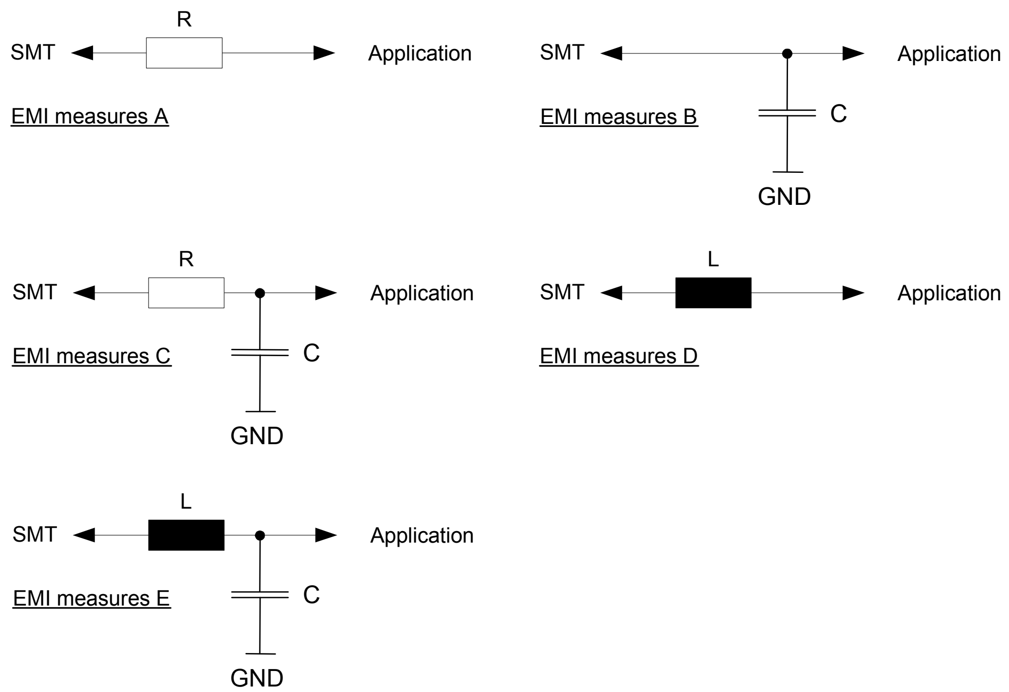


Figure 42: EMI circuits

Note: In case the application uses an internal RF antenna that is implemented close to the ELS81-US module, Thales strongly recommends sufficient EMI measures, e.g. of type B or C, for each digital input or output.

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

Table 16: EMI measures on the application interface

Signal name	EMI measures					Remark
	A	B	C	D	E	
CCIN	x			x		
CCRST		x				The external capacitor should be not higher than 30pF. The value of the capacitor depends on the external application.
CCIO		x				
CCCLK		x				
RXD0	x	x	x	x	x	
TXD0	x	x	x	x	x	
CTS0	x	x	x	x	x	
RTS0	x	x	x	x	x	
GPIO1/DTR0	x	x	x	x	x	
GPIO2/DCD0	x	x	x	x	x	
GPIO3/DSR0/SPI_CLK	x	x	x	x	x	
GPIO4/FST_SHDN	x	x	x	x	x	
GPIO5/LED	x	x	x	x	x	
GPIO6/PWM2	x	x	x	x	x	
GPIO7/PWM1	x	x	x	x	x	
GPIO8/COUNTER	x	x	x	x	x	
GPIO11-GPIO15	x	x	x	x	x	
GPIO16/RXD1/MOSI	x	x	x	x	x	
GPIO17/TXD1/MISO	x	x	x	x	x	
GPIO18/RTS1	x	x	x	x	x	
GPIO19/CTS1/SPI_CS	x	x	x	x	x	
GPIO20	x	x	x	x	x	
GPIO21	x	x	x	x	x	
GPIO22	x	x	x	x	x	
GPIO23	x	x	x	x	x	
GPIO24/RING0	x	x	x	x	x	
I2CDAT		x		x		The rising signal edge is reduced with an additional capacitor.
I2CCLK		x		x		
V180		x		x	x	
VCORE		x		x	x	
BATT+$_{RF}$ (pad 53)		x	x			Measures required if BATT+$_{RF}$ is close to internal RF antenna - e.g., 39pF blocking capacitor to ground
BATT+$_{BB}$ (pad 204)		x	x			
VUSB		x		x	x	
USB_DP						It is not allowed to use any external ESD or EMI components at this interface signal lines.
USB_DN						

3.8 Reliability Characteristics

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

Table 17: Summary of reliability test conditions

Type of test	**Conditions**	**Standard**
Vibration	Frequency range: 10-20Hz; acceleration: 5g Frequency range: 20-500Hz; acceleration: 20g Duration: 20h per axis; 3 axes	DIN IEC 60068-2-6[1]
Shock half-sinus	Acceleration: 500g Shock duration: 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

4.1 Mechanical Dimensions of ELS81-US

Figure 43 shows the top and bottom view of ELS81-US and provides an overview of the board's mechanical dimensions. For further details see Figure 44.

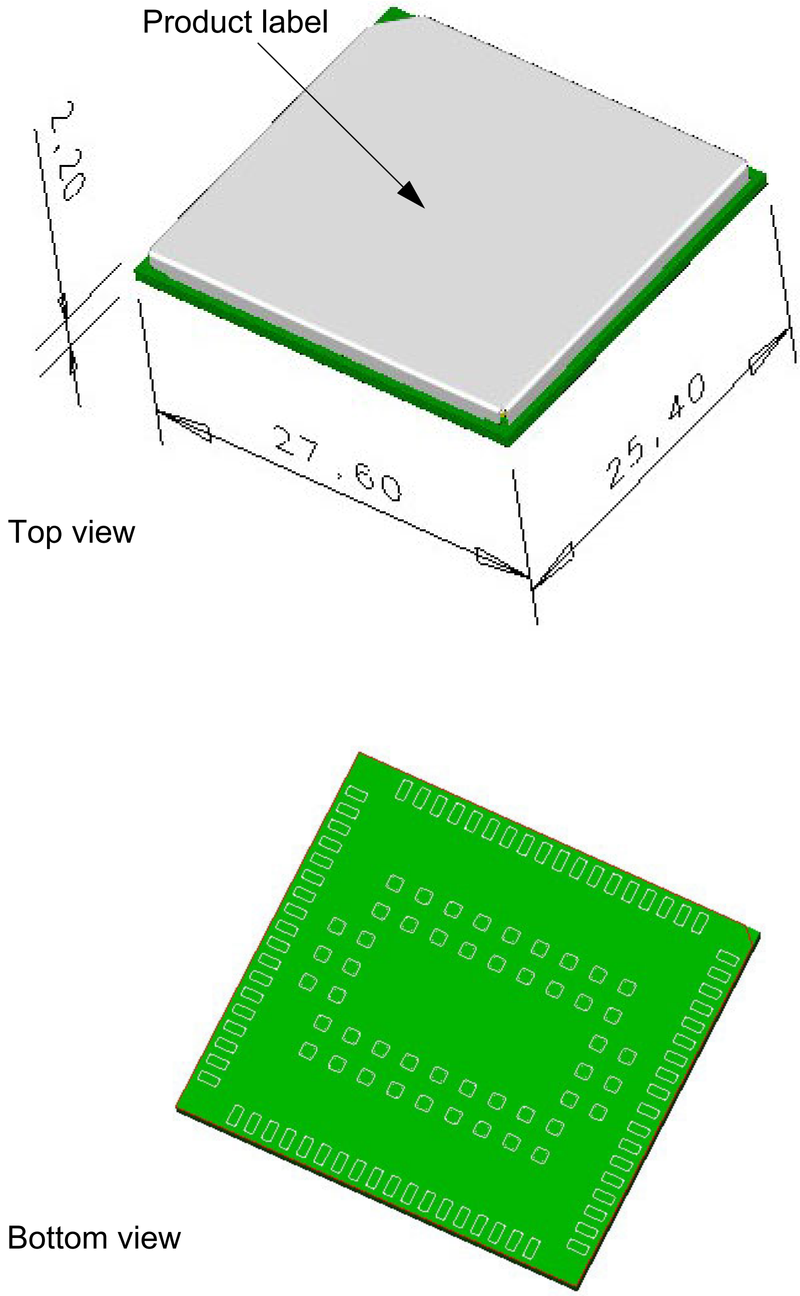


Figure 43: ELS81-US– top and bottom view

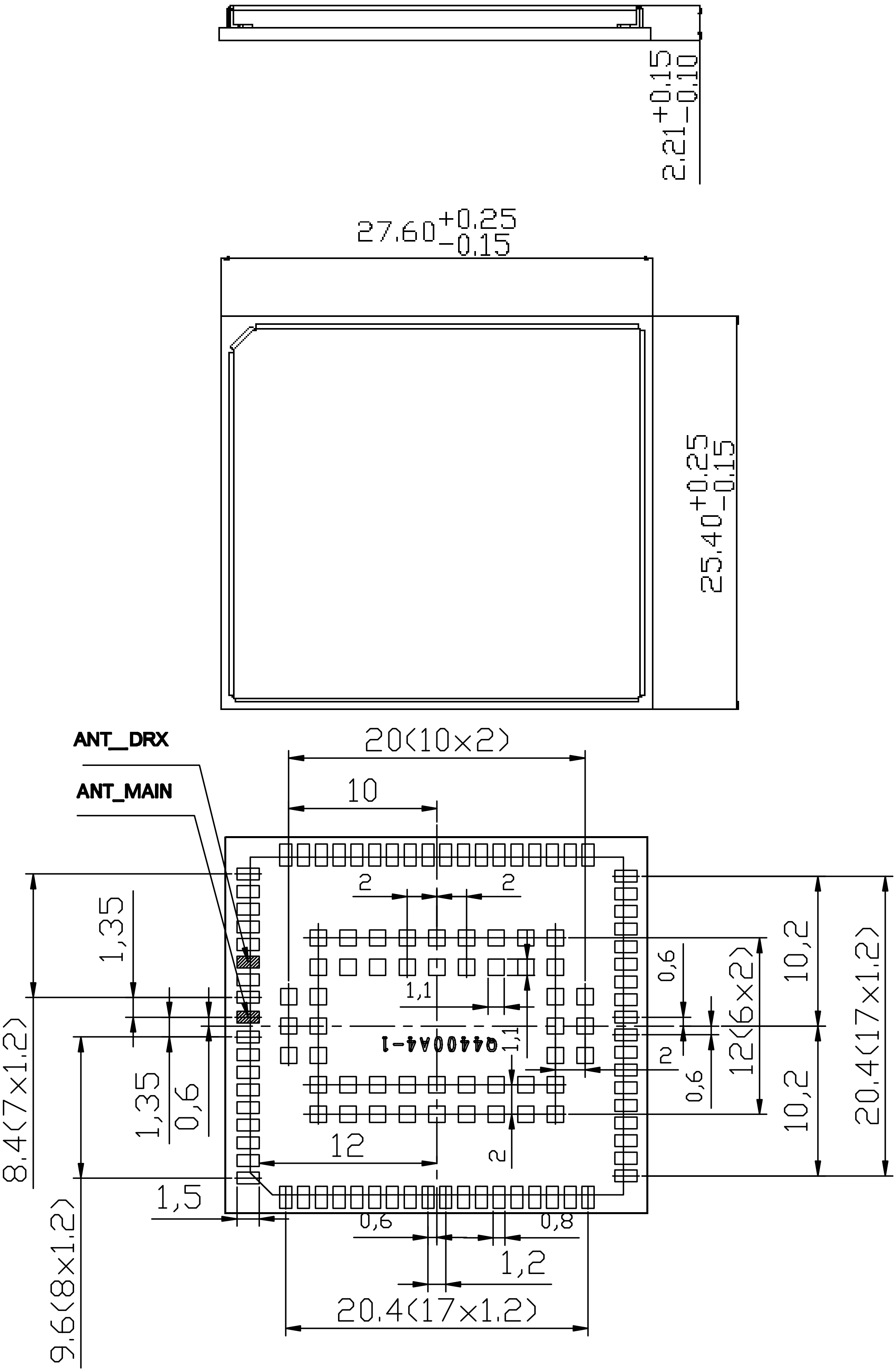


Figure 44: Dimensions of ELS81-US (all dimensions in mm)

4.2 Mounting ELS81-US onto the Application Platform

This section describes how to mount ELS81-US onto the PCBs, including land pattern and stencil design, board-level characterization, soldering conditions, durability and mechanical handling. For more information on issues related to SMT module integration see also [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 Thales characterizations for lead-free solder paste on a four-layer test PCB and a respectively 110 µm and 150 µm thick stencil.

The land pattern given in Figure 45 reflects the module's pad layout, including signal pads and ground pads (for pad assignment see Section 2.1.1).

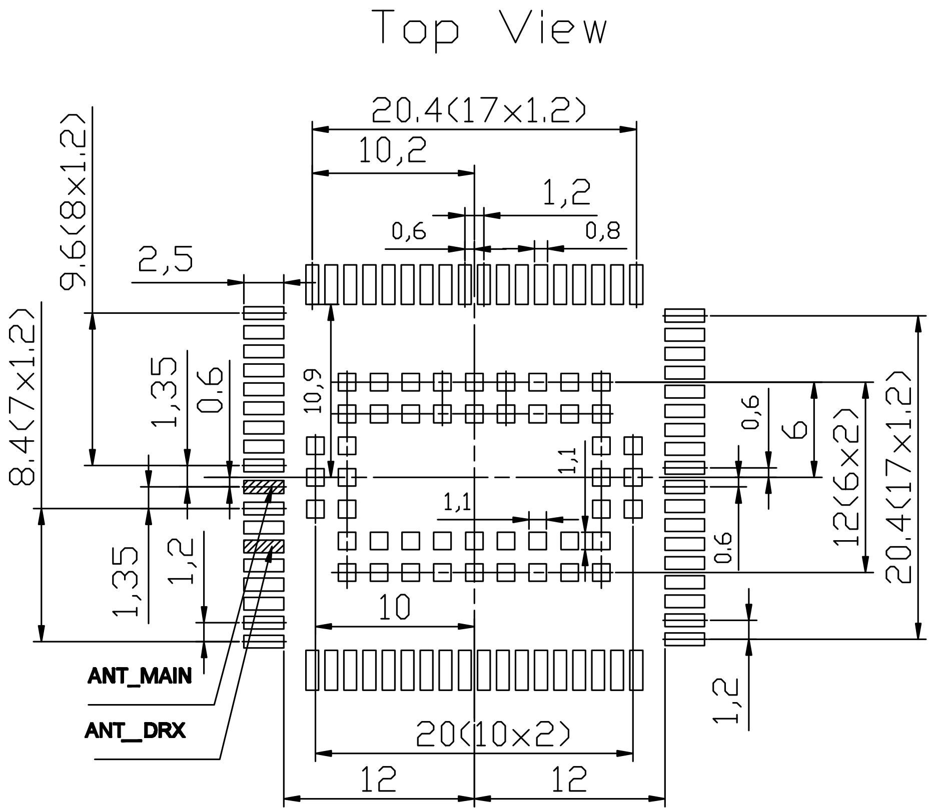


Figure 45: Land pattern (top view)

The stencil design illustrated in Figure 46 and Figure 47 is recommended by Thales as a result of extensive tests with Thales Daisy Chain modules.

The central ground pads are primarily intended for stabilizing purposes, and may show some more voids than the application interface pads at the module's rim. This is acceptable, since they are electrically irrelevant.

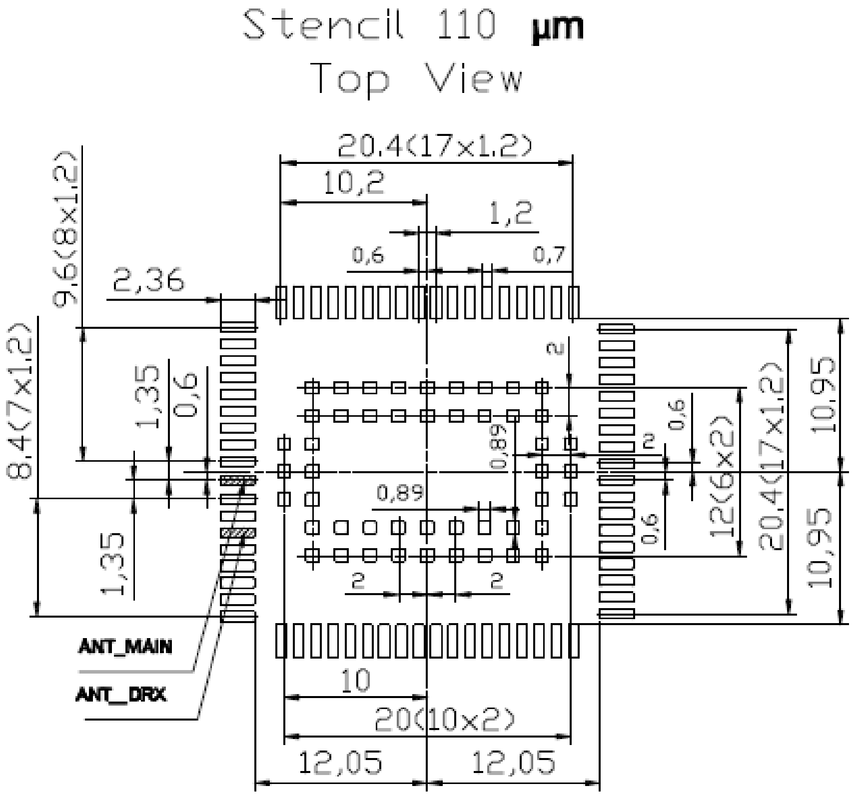


Figure 46: Recommended design for 110µm thick stencil (top view)

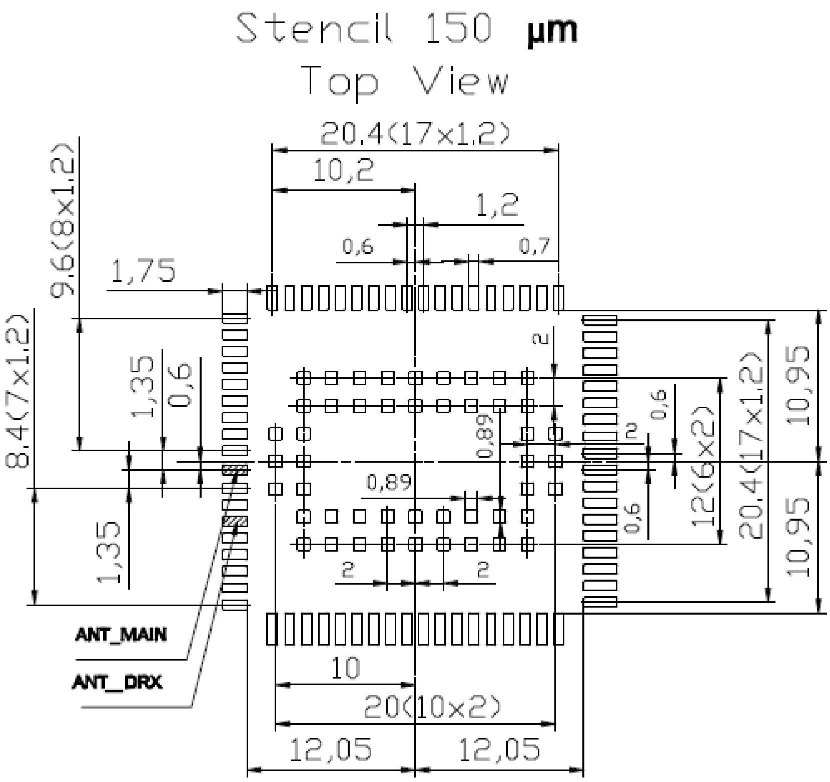


Figure 47: Recommended design for 150µm thick stencil (top view)

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

ELS81-US comprises components that are susceptible to damage induced by absorbed moisture.

Thales' ELS81-US module complies with the latest revision of the IPC/JEDEC J-STD-020 Standard for moisture sensitive surface mount devices and is classified as MSL 4.

For additional moisture sensitivity level (MSL) 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

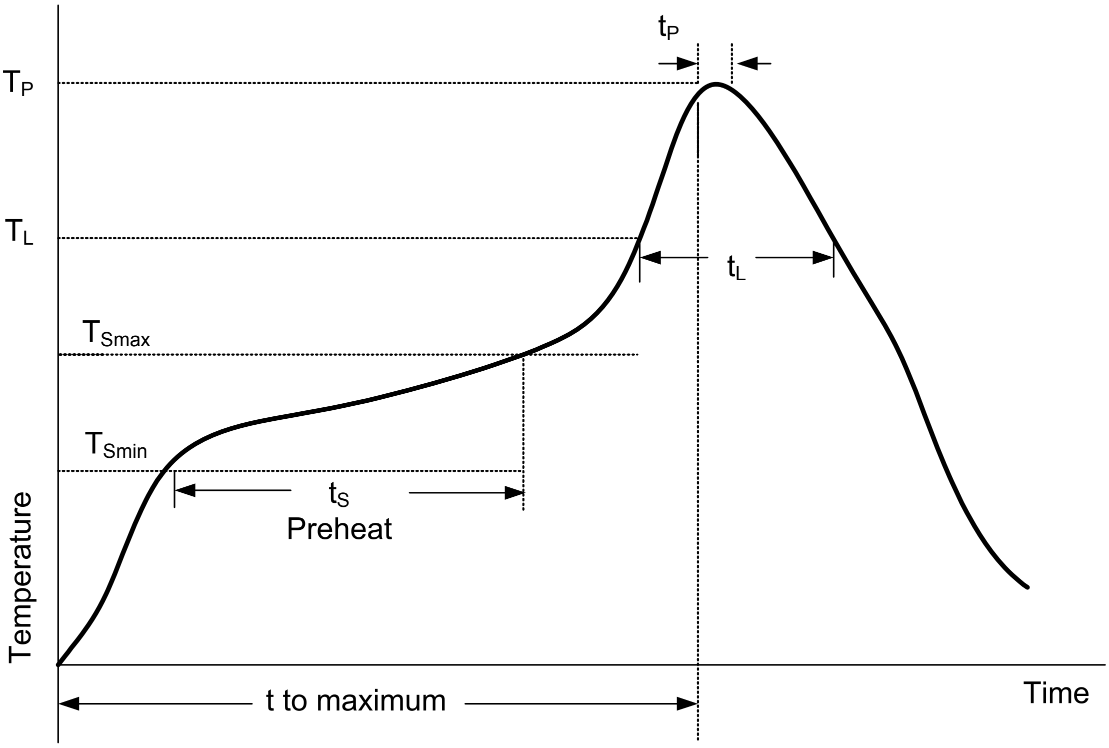
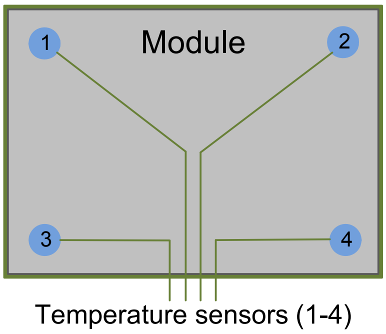


Figure 48: Reflow Profile

Table 18: Reflow temperature ratings[1]

Profile Feature	Pb-Free Assembly
Preheat & Soak Temperature Minimum (T_{Smin}) Temperature Maximum (T_{Smax}) Time (t_{Smin} to t_{Smax}) (t_S)	150°C 200°C 60-120 seconds
Average ramp up rate (T_L to T_P)	3K/second max. [2]
Liquidous temperature (T_L) Time at liquidous (t_L)	217°C 50-90 seconds
Peak package body temperature (T_P)	245°C +0/-5°C
Time (t_P) within 5 °C of the peak package body temperature (T_P)	30 seconds max.
Average ramp-down rate	3 K/second max. [2]
Time 25°C to maximum temperature	8 minutes max.

1. Please note that the reflow profile features and ratings listed above are based on the joint industry standard IPC/JEDEC J-STD-020D.1, and are as such meant as a general guideline. For more information on reflow profiles and their optimization please refer to [4].
2. Temperatures measured on shielding at each corner. See also [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 245°C. This specifies the temperature as measured at the module’s top side.
- A maximum duration of 30 seconds at this temperature.

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

ELS81-US is specified for one soldering cycle only. Once ELS81-US is removed from the application, the module will very likely be destroyed and cannot be soldered onto another application.

4.2.4 Durability and Mechanical Handling

4.2.4.1 Storage Conditions

ELS81-US modules, as delivered in tape and reel carriers, must be stored in sealed, moisture barrier anti-static bags. The conditions stated below are only valid for modules in their original packed state in weather protected, non-temperature-controlled storage locations. Normal storage time under these conditions is 12 months maximum.

Table 19: Storage conditions

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

4.2.4.2 Processing Life

ELS81-US must be soldered to an application within 72 hours after opening the moisture barrier bag (MBB) it was stored in.

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

4.2.4.3 Baking

Baking conditions are specified on the moisture sensitivity label attached to each MBB (see Figure 53 for details):
- It is *not necessary* to bake ELS81-US, if the conditions specified in Section 4.2.4.1 and Section 4.2.4.2 were not exceeded.
- It is *necessary* to bake ELS81-US, if any condition specified in Section 4.2.4.1 and Section 4.2.4.2 was exceeded.

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

4.2.4.4 Electrostatic Discharge

Electrostatic discharge (ESD) 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 ELS81-US is illustrated in Figure 49. The figure also shows the proper part orientation. The tape width is 44mm and the ELS81-US modules are placed on the tape with a 32-mm pitch. The reels are 330mm in diameter with a core diameter of 100mm. Each reel contains 500 modules.

4.3.1.1 Orientation

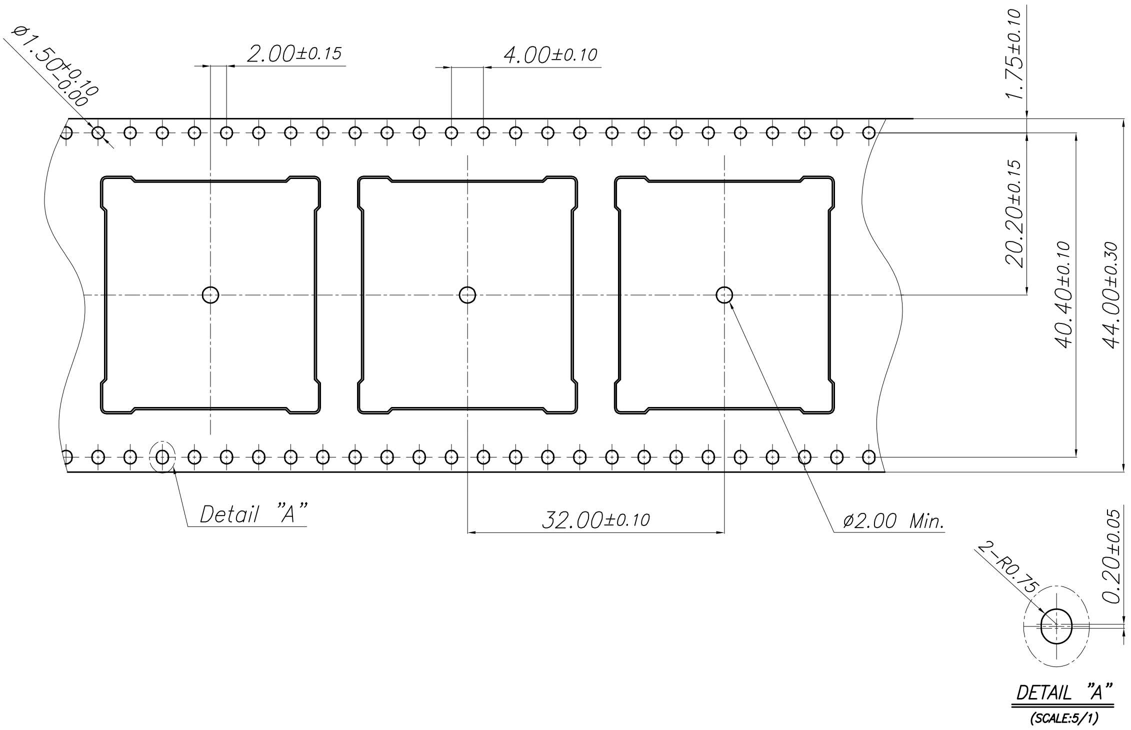


Figure 49: Carrier tape

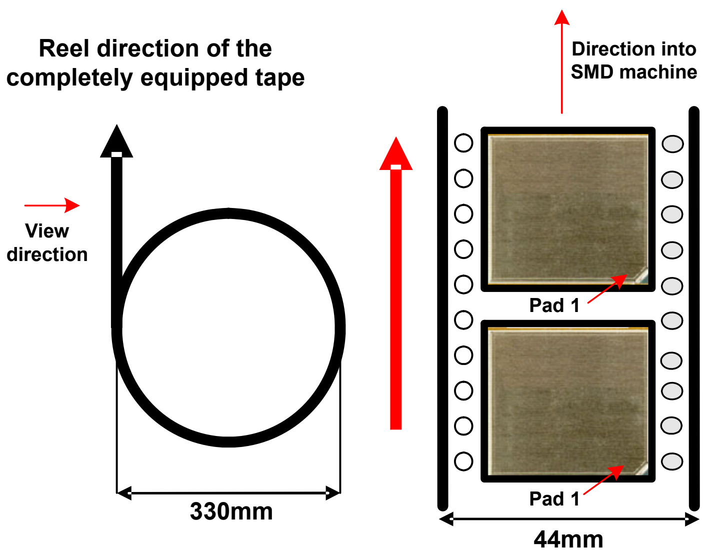


Figure 50: Reel direction

4.3.1.2 Barcode Label

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

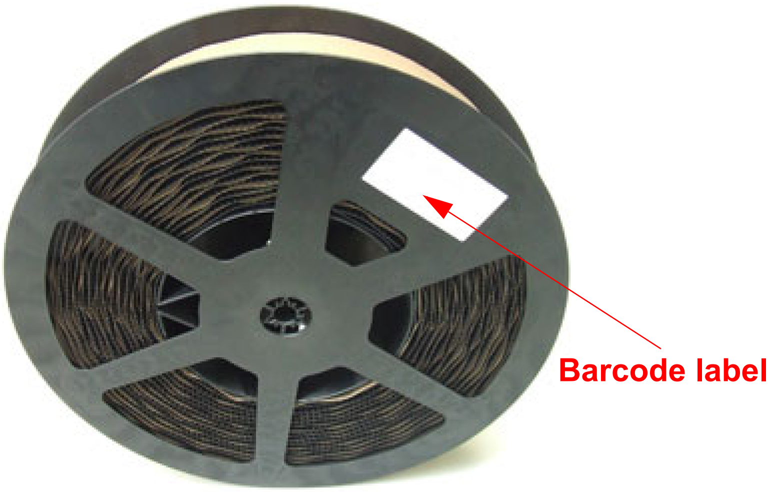


Figure 51: Barcode label on tape reel

4.3.2 Shipping Materials

ELS81-US is distributed in tape and reel carriers. The tape and reel carriers used to distribute ELS81-US are packed as described below, including the following required shipping materials:

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

4.3.2.1 Moisture Barrier Bag

The tape reels are stored inside a moisture barrier bag (MBB), together with a humidity indicator card and desiccant pouches - see Figure 52. 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 ELS81-US modules from moisture exposure. It should not be opened until the devices are ready to be soldered onto the application.

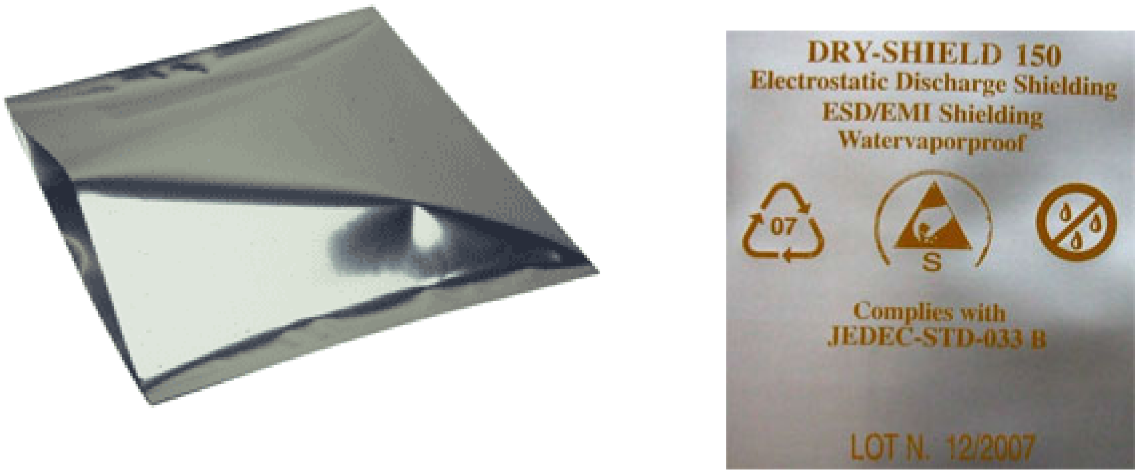


Figure 52: Moisture barrier bag (MBB) with imprint

The label shown in Figure 53 summarizes requirements regarding moisture sensitivity, including shelf life and baking requirements. It is attached to the outside of the moisture barrier bag.

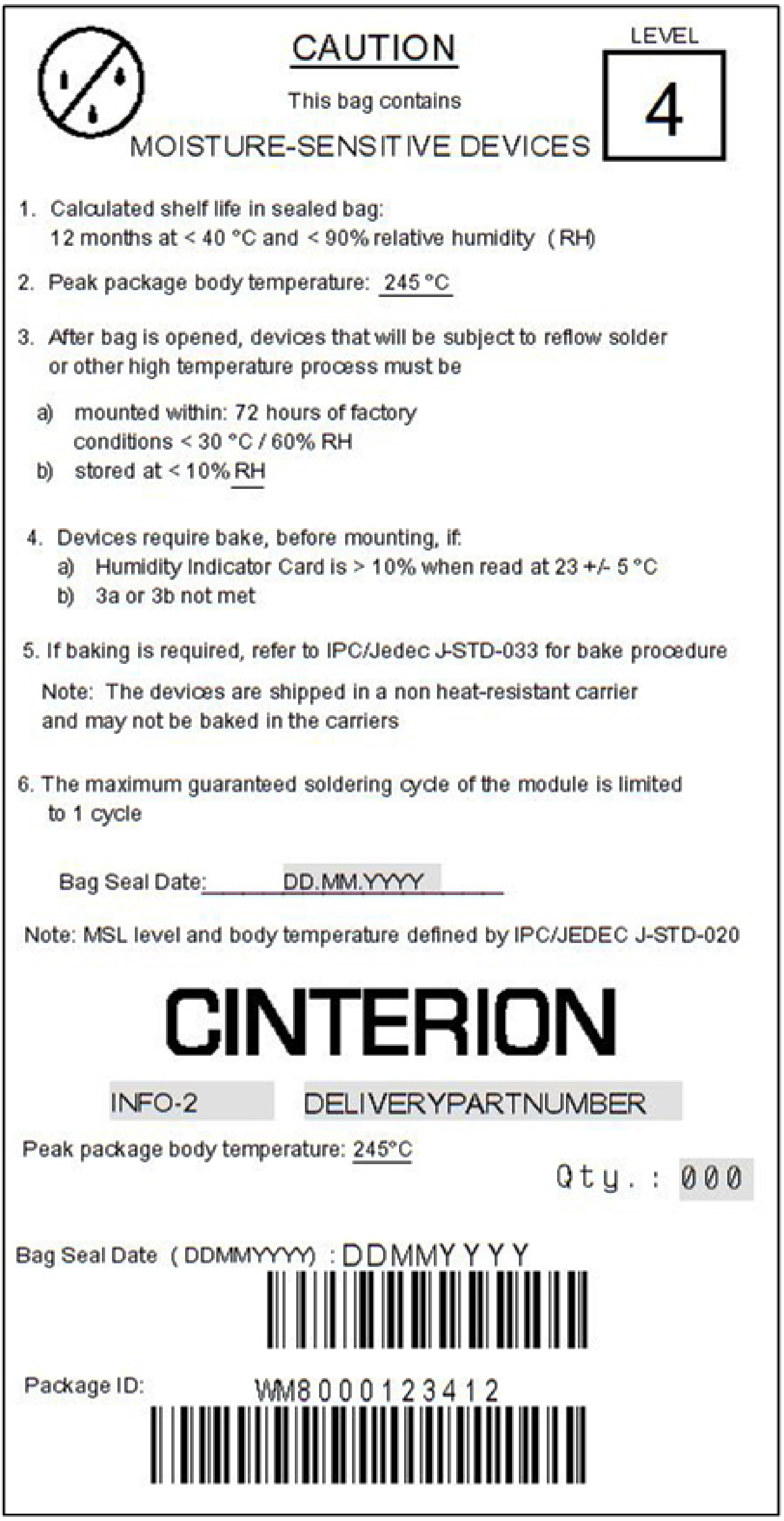


Figure 53: Moisture Sensitivity Label

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

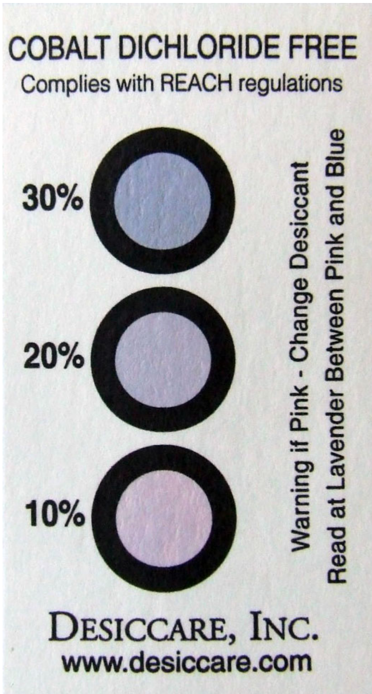


Figure 54: Humidity Indicator Card - HIC

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, ELS81-US 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]).

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).

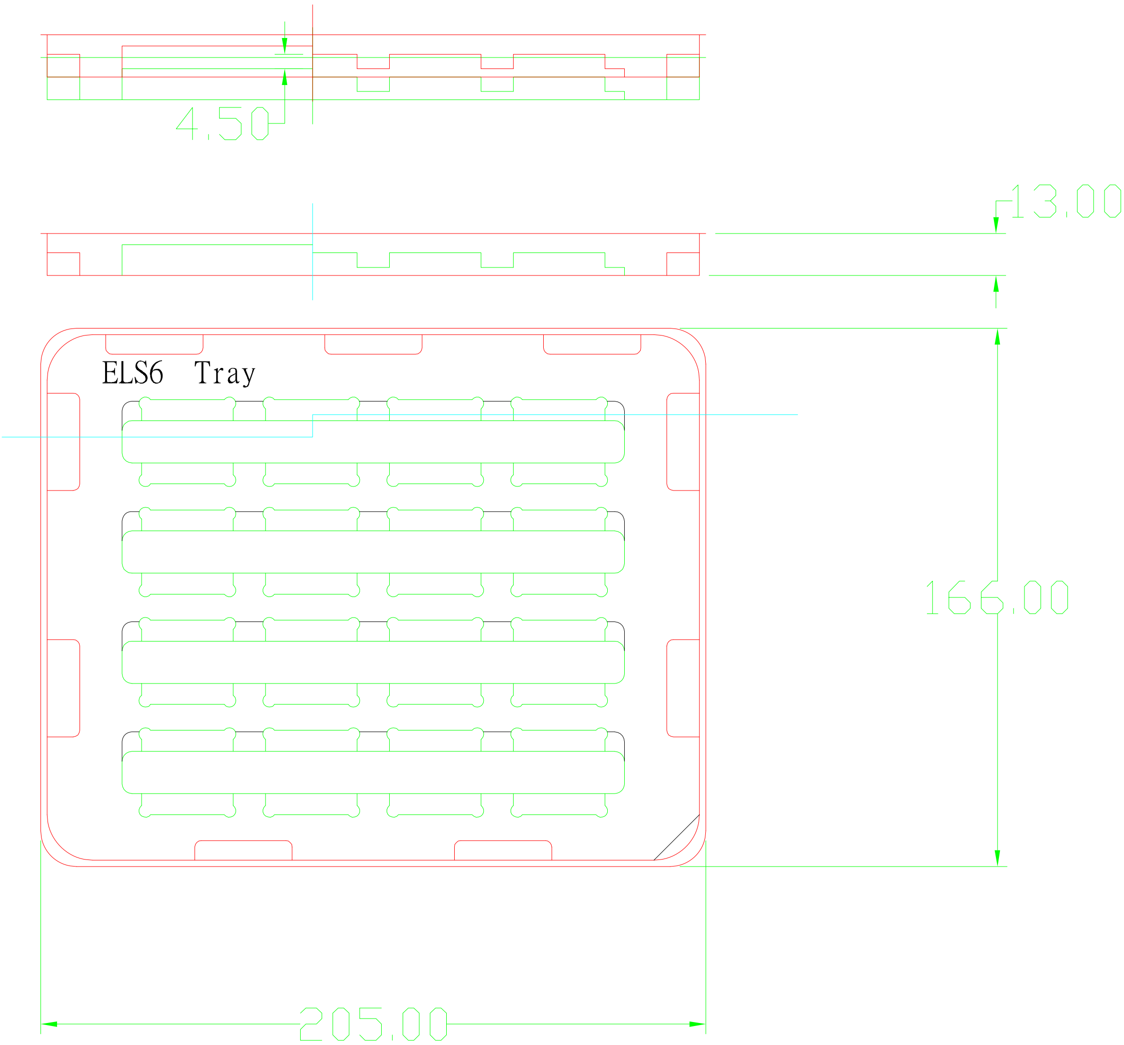


Figure 55: Tray dimensions

5 Regulatory and Type Approval Information

5.1 Directives and Standards

ELS81-US is designed to comply with the directives and standards listed below.

It is the responsibility of the application manufacturer to ensure compliance of the final product with all provisions of the applicable directives and standards as well as with the technical specifications provided in the "ELS81-US Hardware Interface Description".[1]

Table 20: Directives

2014/53/EU	Directive of the European Parliament and of the council of 16 April 2014 on the harmonization of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/05/EC. The product is labeled with the CE conformity mark.
2002/95/EC (RoHS 1) 2011/65/EC (RoHS 2)	Directive of the European Parliament and of the Council of 27 January 2003 (and revised on 8 June 2011) on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)

Table 21: Standards of North American type approval

CFR Title 47	Code of Federal Regulations, Part 22 and Part 24 (Telecommunications, PCS); US Equipment Authorization FCC
OET Bulletin 65 (Edition 97-01)	Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields
UL 60 950-1	Product Safety Certification (Safety requirements)
NAPRD.03 V5.15	Overview of PCS Type certification review board Mobile Equipment Type Certification and IMEI control PCS Type Certification Review board (PTCRB)
RSS132 (Issue2) RSS133 (Issue5)	Canadian Standard

Table 22: Standards of European type approval

3GPP TS 51.010-1	Digital cellular telecommunications system (Release 9); Mobile Station (MS) conformance specification;
GCF-CC V3.61.2	Global Certification Forum - Certification Criteria
ETSI EN 301 511 V12.5.1	Global System for Mobile communications (GSM); Mobile Stations (MS) equipment; Harmonized Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU

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

Table 22: Standards of European type approval

Draft ETSI EN 301 489-01 V2.2.0	Electromagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements; Harmonized Standard covering the essential requirements of article 3.1(b) of Directive 2014/53/EU and the essential requirements of article 6 of Directive 2014/30/EU
Draft ETSI EN 301 489-52 V1.1.0	Electromagnetic Compatibility (EMC) standard for radio equipment and services; Part 52: Specific conditions for Cellular Communication Mobile and portable (UE) radio and ancillary equipment; Harmonized Standard covering the essential requirements of article 3.1(b) of Directive 2014/53/EU
ETSI EN 301 908-1 V11.1.1	IMT cellular networks; Harmonized Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 1: Introduction and common requirements
ETSI EN 301 908-2 V11.1.2	IMT cellular networks; Harmonized Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 2: CDMA Direct Spread (UTRA FDD) User Equipment (UE)
ETSI EN 301 908-13 V11.1.2	IMT cellular networks; Harmonized Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 13: Evolved Universal Terrestrial Radio Access (E-UTRA) User Equipment (UE)
EN 62311:2008	Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz)
EN 60950-1: 2006 +A11:2009+A1:2010+A12:2011+A2:2013	Safety of information technology equipment

Table 23: Requirements of quality

IEC 60068	Environmental testing
DIN EN 60529	IP codes

Table 24: Standards of the Ministry of Information Industry of the People's Republic of China

SJ/T 11363-2006	"Requirements for Concentration Limits for Certain Hazardous Substances in Electronic Information Products" (2006-06).
SJ/T 11364-2006	"Marking for Control of Pollution Caused by Electronic Information Products" (2006-06).  According to the "Chinese Administration on the Control of Pollution caused by Electronic Information Products" (ACPEIP) the EPUP, i.e., Environmental Protection Use Period, of this product is 20 years as per the symbol shown here, unless otherwise marked. The EPUP is valid only as long as the product is operated within the operating limits described in the Thales Hardware Interface Description. Please see Table 25 for an overview of toxic or hazardous substances or elements that might be contained in product parts in concentrations above the limits defined by SJ/T 11363-2006.

Table 25: Toxic or hazardous substances or elements with defined concentration limits

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

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

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

5.2 SAR requirements specific to portable mobiles

Mobile phones, PDAs or other portable transmitters and receivers incorporating a UMTS module must be in accordance with the guidelines for human exposure to radio frequency energy. This requires the Specific Absorption Rate (SAR) of portable ELS81-US based applications to be evaluated and approved for compliance with national and/or international regulations.

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

Products intended for sale on US markets

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

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

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

5.3 Reference Equipment for Type Approval

The Thales reference setup submitted to type approve ELS81-US (including a special approval adapter for the DSB75) is shown in the following figure[1]:

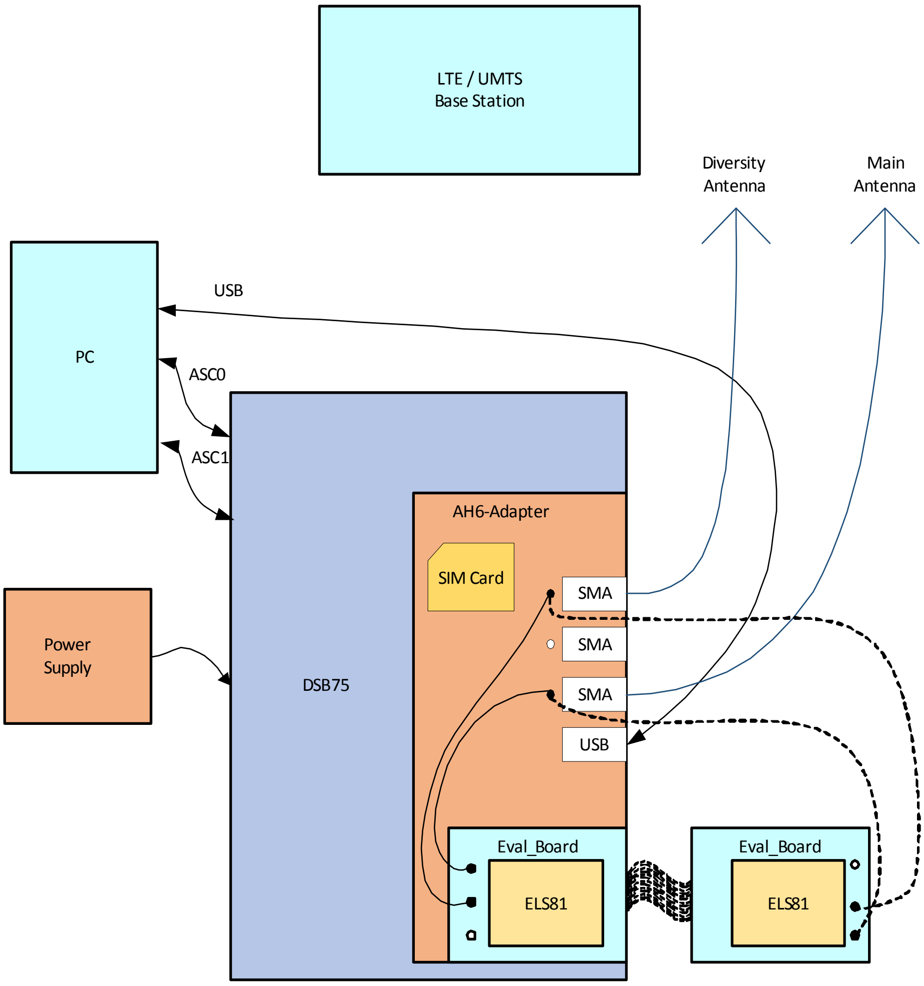


Figure 56: Reference equipment for Type Approval

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 UMTS test equipment instead of employing the SMA antenna connectors on the ELS81-US-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 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 Thales reference application described in Section 5.3 will be registered under the following identifiers:

FCC Identifier: QIPELS81-US
Industry Canada Certification Number: 7830A-ELS81US
Granted to THALES DIS AIS Deutschland GmbH

Manufacturers of mobile or fixed devices incorporating ELS81-US modules are authorized to use the FCC Grants and Industry Canada Certificates of the ELS81-US 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: QIPELS81-US", and accordingly “Contains IC: 7830A-ELS81*US*“. 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 limit 2.15 dBi for 700MHz, 850MHz, 1700MHz and 1900MHz.
IMPORTANT:
Manufacturers of portable applications incorporating ELS81-US 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 ELS81-US modules the below notes 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

Preceding document: "Cinterion® ELS81-US Hardware Interface Description" Version 04.000a
New document: "Cinterion® ELS81-US Hardware Interface Description" Version **04.000b**

Chapter	What is new
---	Layout update.

Preceding document: "Cinterion® ELS81-US Hardware Interface Description" Version 04.000
New document: "Cinterion® ELS81-US Hardware Interface Description" Version 04.000a

Chapter	What is new
3.4.1	Added general note for current consumptions ratings listed in Table 13.

Preceding document: "Cinterion® ELS81-US Hardware Interface Description" Version 01.004b
New document: "Cinterion® ELS81-US Hardware Interface Description" Version 04.000

Chapter	What is new
1.1	Revised antenna interface pads.
2.1	Updated Figure 7: ASC0 startup behavior Updated Figure 9: ASC1 startup behavior Updated Figure 13: GPIO startup behavior
3.4	Updated Table 13, footnote 3

Preceding document: "Cinterion® ELS81-US Hardware Interface Description" Version 01.004a
New document: "Cinterion® ELS81-US Hardware Interface Description" Version 01.004b

Chapter	What is new
2.2.1	Revised note on Rx diversity antenna connection.

Preceding document: "Cinterion® ELS81-US Hardware Interface Description" Version 01.004
New document: "Cinterion® ELS81-US Hardware Interface Description" Version 01.004a

Chapter	What is new
1.1	Revised HSDPA category (Cat.8 --> Cat.10).
2.1.1	Set pads 76-78 and 80 to "Do not use" (instead of "Not connected").
7.1	Updated ordering information.

New document: "Cinterion® ELS81-US Hardware Interface Description" Version 01.004

Chapter	What is new
--	Initial document setup.

6.2 Related Documents

[1] ELS81-US AT Command Set
[2] ELS81-US Release Note
[3] Application Note 26: Power Supply for Wireless Applications
[4] Application Note 48: SMT Module Integration
[5] Application Note 40: Thermal Solutions
[6] Universal Serial Bus Specification Revision 2.0, April 27, 2000

6.3 Terms and Abbreviations

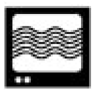
Abbreviation	Description
ADC	Analog-to-digital converter
AGC	Automatic Gain Control
ANSI	American National Standards Institute
ARFCN	Absolute Radio Frequency Channel Number
ARP	Antenna Reference Point
ASC0/ASC1	Asynchronous Controller. Abbreviations used for first and second serial interface of ELS81-US
B	Thermistor Constant
BER	Bit Error Rate
BIP	Bearer Independent Protocol
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
dBm0	Digital level, 3.14dBm0 corresponds to full scale, see ITU G.711, A-law
DCE	Data Communication Equipment (typically modems, e.g. Thales module)
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, UMTS application)

Abbreviation	Description
DTR	Data Terminal Ready
DTX	Discontinuous Transmission
EFR	Enhanced Full Rate
EIRP	Equivalent Isotropic Radiated Power
EMC	Electromagnetic Compatibility
ERP	Effective Radiated Power
ESD	Electrostatic Discharge
ETS	European Telecommunication Standard
ETSI	European Telecommunication Standards Institute
FCC	Federal Communications Commission (U.S.)
FDMA	Frequency Division Multiple Access
FR	Full Rate
GMSK	Gaussian Minimum Shift Keying
GPIO	General Purpose Input/Output
HiZ	High Impedance
HR	Half Rate
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
LPM	Link Power Management
Mbps	Mbits per second
MMI	Man Machine Interface
MO	Mobile Originated
MS	Mobile Station (UMTS module), also referred to as TE
MSISDN	Mobile Station International ISDN number
MT	Mobile Terminated
NTC	Negative Temperature Coefficient
OEM	Original Equipment Manufacturer
PA	Power Amplifier
PAP	Password Authentication Protocol
PBCCH	Packet Switched Broadcast Control Channel

Abbreviation	Description
PCB	Printed Circuit Board
PCL	Power Control Level
PDU	Protocol Data Unit
PLL	Phase Locked Loop
PPP	Point-to-point protocol
PSK	Phase Shift Keying
PSU	Power Supply Unit
PWM	Pulse Width Modulation
R&TTE	Radio and Telecommunication Terminal Equipment
RAM	Random Access Memory
RF	Radio Frequency
RLS	Radio Link Stability
RMS	Root Mean Square (value)
RoHS	Restriction of the use of certain hazardous substances in electrical and electronic equipment.
ROM	Read-only Memory
RTC	Real Time Clock
RTS	Request to Send
Rx	Receive Direction
SAR	Specific Absorption Rate
SAW	Surface Accoustic Wave
SELV	Safety Extra Low Voltage
SIM	Subscriber Identification Module
SMD	Surface Mount Device
SMS	Short Message Service
SMT	Surface Mount Technology
SPI	Serial Peripheral Interface
SRAM	Static Random Access Memory
TA	Terminal adapter (e.g. UMTS 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 ELS81-US. Manufacturers of the cellular terminal are advised to convey the following safety information to users and operating personnel and to incorporate these guidelines into all manuals supplied with the product. Failure to comply with these precautions violates safety standards of design, manufacture and intended use of the product. Thales 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 26: List of parts and accessories

Description	Supplier	Ordering information
ELS81-US	Thales	Standard module Thales IMEI Packaging unit (ordering) number: L30960-N5400-A100 Module label number: L30960-N5400-A100-1[1] Customer IMEI module: Packaging unit (ordering) number: L30960-N5405-A100 Module label number: L30960-N5405-A100-1[1]
ELS81-US Evaluation Module	Thales	Ordering number: L30960-N5401-A100
DSB75 Evaluation Kit	Thales	Ordering number: L36880-N8811-A100
DSB Mini Compact Evaluation Board	Thales	Ordering number: L30960-N0030-A100
Starter Kit B80	Thales	Ordering Number L30960-N0040-A100
Multi-Adapter R1 for mounting ELS81-US evaluation modules onto DSB75	Thales	Ordering number: L30960-N0010-A100
Approval adapter for mounting ELS81-US evaluation modules onto DSB75	Thales	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 27.

1. Note: At the discretion of Thales, 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 27: 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

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