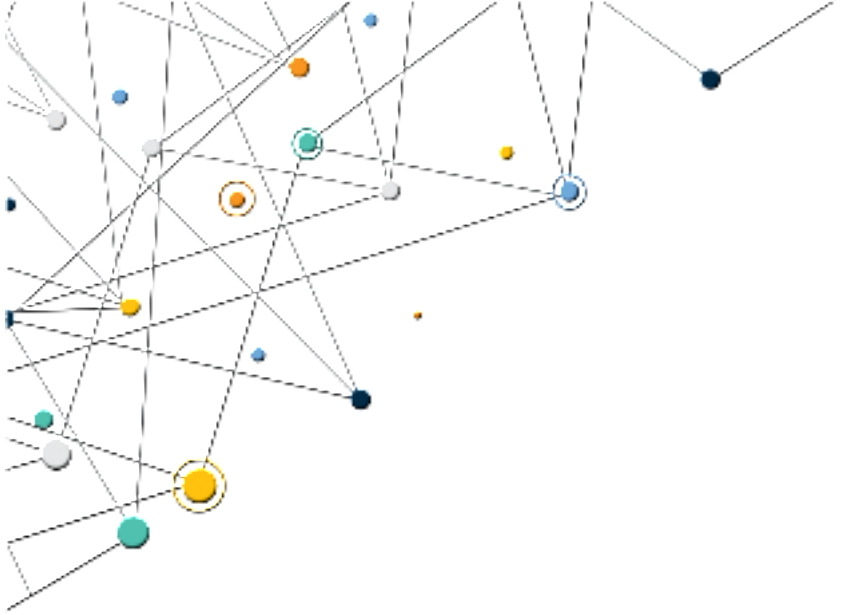
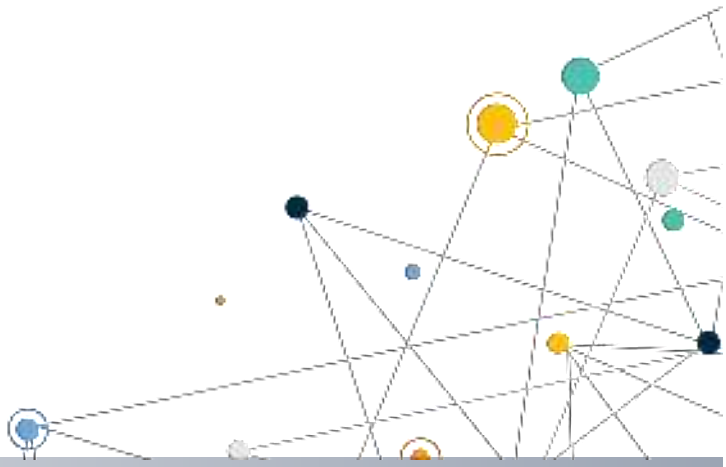


ML865G1

HW Design Guide

1VV0301632 Rev. 5 – 2021-07-26



Telit Technical Documentation

APPLICABILITY TABLE

PRODUCTS
ML865G1-WW

CONTENTS

1. INTRODUCTION

1.1. Scope

This document describes electrical specifications, mechanical information, interfaces application, and manufacturing information about the Telit ML865G1 module. With the help of this document and other application notes or user guides, users can understand the Telit ML865G1 module well and develop various products quickly.

1.2. Audience

This document is intended for system integrators who use the Telit ML865G1 module in their products.

1.3. Contact Information, Support

For technical queries, support services, and to share documentation feedback, contact Telit Technical Support at:

- *TS-EMEA@telit.com*
- *TS-AMERICAS@telit.com*
- *TS-APAC@telit.com*
- *TS-SRD@telit.com*

Alternatively, use:

http://www.telit.com/support

For detailed information about where you can buy the Telit modules or for recommendations on accessories and components visit:

http://www.telit.com

1.4. Symbol Conventions

	**Danger:** This information MUST be followed or catastrophic equipment failure or personal injury may occur.
	**Warning:** Alerts the user on important steps about the module integration.
	**Note/Tip:** Provides advice and suggestions that may be useful when integrating the module.
	**Electro-static Discharge:** Notifies the user to take proper grounding precautions before handling the product.

Table 1: Symbol Conventions

All dates are in ISO 8601 format, i.e. YYYY-MM-DD.

1.5. Related Documents

- 80000NT10001A - SIM INTEGRATION DESIGN GUIDES Application Note
- 80529NT11661A - Cat M/NB-IoT Quick Start Guide
- 1VV0300989 - SSL/TLS User Guide
- 80000NT10001A - SIM Integration Design Guide
- 80000NT10003A - Rework procedure for BGA modules
- 80000NT10028A - Event Monitor Application Note

2. GENERAL PRODUCT DESCRIPTION

2.1. Overview

The ML865G1 module is a CATM / NBIoT / 2G communication product which allows integrators to plan on availability for even the longest lifecycle applications, highly recommended for new designs specified for worldwide coverage.

The ML865G1 operates with 1.8 V GPIOs, minimizing power consumption and making it even more ideal for applications with battery power and wearable device.

2.2. Product Variants and Frequency Bands

Product	2G Band (MHz)	LTE CATM1	NBIoT	Region
ML865G1-WW	850, 900, 1800, 1900	B1, B2, B3, B4, B5, B8, B12, B13, B18, B19, B20, B25, B26, B27, B28, B66, B85	B1, B2, B3, B4, B5, B8, B12, B13, B18, B19, B20, B25, B26, B28, B66, B71, B85	Worldwide

Table 2: Product Variants and their Frequency Bands

Refer to "RF Section" for details information about frequencies.

Note: Cellular technologies and frequency bands that are enabled may vary based on firmware version and firmware configuration used.

2.3. Target Market

ML865G1 can be used for telematics applications where tamper-resistance, confidentiality, integrity, and authenticity of end-user information are required, for example:

- Telematics services
- Road pricing
- Pay-as-you-drive insurance
- Stolen vehicles tracking
- Internet connectivity

2.4. Main features

Function	Features
Modem	• CATM, NBIoT, 2G technologies • SMS support (text and PDU) • Alarm management • Real Time Clock
Interfaces	• Main UART for AT command access • AUX UART used for diagnostic monitoring and debugging • USB • SPI • 8 GPIOs • Antenna port

Table 3: Functional Features

2.5. TX Output Power

ML865G1-WW

Band	Mode	Class	RF power (dBm)
850/900MHz	GPRS	4	33
	EGPRS	E2	27
1800/1900MHz	GPRS	1	30
	EGPRS	E2	26
B1, B2, B3, B4, B5, B8, B12, B13, B18, B19, B20, B25, B26, B27, B28, B66, B85	(LTE) CAT-M1	3	23
B1, B2, B3, B4, B5, B8, B12, B13, B18, B19, B20, B25, B26, B28, B66, B85	(LTE) CAT-NB2	3	23
B71	(LTE) CAT-NB2	5	20

Table 4: Transmission Output Power

2.6. RX Sensitivity

2.6.1. L865G1-WW

Band	REFsens (dBm) Typical	3GPP REFsens (dBm)*
CATM1 / Band1	-106.2	-102.7
CAT M1 / Band2	-107.4	-100.3
CAT M1 / Band3	-106.1	-99.3
CAT M1 / Band4	-107.1	-102.3
CAT M1 / Band5	-106.4	-100.8
CAT M1 / Band8	-105.9	-99.8
CAT M1 / Band12	-103.7	-99.3
CAT M1 / Band13	-107.0	-99.3
CAT M1 / Band18	-107.1	-102.3
CAT M1 / Band19	-105.5	-102.3
CAT M1 / Band20	-106.1	-99.8
CAT M1 / Band25	-107.2	-
CAT M1 / Band26	-106.6	-100.3
CAT M1 / Band27	-107.2	-100.8
CAT M1 / Band28	-106.4	-100.8
CAT M1 / Band66	-106.8	-
CAT M1 / Band85	-102.2	-
CAT NB2 / Band1	-116.2	-108.2
CAT NB2 / Band2	-116.4	-108.2
CAT NB2 / Band3	-116.2	-108.2
CAT NB2 / Band4	-116.0	-
CAT NB2 / Band5	-116.0	-108.2
CAT NB2 / Band8	-110.6	-108.2
CAT NB2 / Band12	-115.5	-108.2

Band	REFsens (dBm) Typical	3GPP REFsens (dBm)*
CAT NB2 / Band13	-115.9	-108.2
CAT NB2 / Band18	-116.1	-108.2
CAT NB2 / Band19	-115.7	-108.2
CAT NB2 / Band20	-115.4	-108.2
CAT NB2 / Band25	-116.4	-
CAT NB2 / Band26	-115.9	-108.2
CAT NB2 / Band28	-115.9	-108.2
CAT NB2 / Band66	-116.4	-108.2
CAT NB2 / Band71	-104.7	-
CAT NB2 / Band85	-115.9	-

Table 5: Reception Sensitivity ML865G1-WW ** 3GPP TS 36.521-1 Release 15*

2.7. Mechanical Specifications

2.7.1. Dimensions

The overall dimensions of ML865G1-WW are:

- Length: 24.0 mm
- Width: 24.0 mm
- Thickness: 2.6 mm

2.7.2. Weight

The nominal weight of the ML865G1-WW is 2 grams.

2.8. Temperature Range

Temperature Range		Note
Operating Temperature Range	–40°C to +85°C	The module is fully functional (*) and compliant according to regulatory standards.
Storage Temperature Range	–40°C to +105°C	The module is not powered and not connected to power supply

Table 6: Temperature Range

Note: (*) Functional: if applicable, the module is able to make and receive voice calls, data calls, send and receive SMS and data traffic.

3. PINS ALLOCATION

3.1. Pin-out

Pin	Signal	I/O	Function	Type	Comment
USB HS 2.0 COMMUNICATION PORT					
20	USB_D+	I/O	USB differential Data (+)	3V	
19	USB_D-	I/O	USB differential Data (-)	3V	
18	VUSB	I	Power sense for the internal USB transceiver.	3-5V	Internal PD (100K)
Asynchronous Serial Port (USIF0) - Prog. / Data + HW Flow Control					
1	C109/DCD	O	Output for Data carrier detect signal (DCD) to DTE	CMOS 1.8V	
2	C125/RING	O	Output for Ring indicator signal (RI) to DTE	CMOS 1.8V	
3	C107/DSR	O	Output for Data set ready signal (DSR) to DTE	CMOS 1.8V	
4	C108/DTR	I	Input for Data terminal ready signal (DTR) from DTE	CMOS 1.8V	Internal PU (100K)
5	C105/RTS	I	Input for Request to send signal (RTS) from DTE	CMOS 1.8V	Internal PU (100K)
6	C106/CTS	O	Output for Clear to send signal (CTS) to DTE	CMOS 1.8V	
9	C103/TXD	I	Serial data input (TXD) from DTE	CMOS 1.8V	Internal PU (100K)
10	C104/RXD	O	Serial data output to DTE	CMOS 1.8V	
SIM card interface					
11	SIMVCC	-	External SIM signal – Power supply for the SIM	1.8V	Only 1.8V simcard are supported
12	SIMRST	O	External SIM signal – Reset	1.8V	
13	SIMCLK	O	External SIM signal – Clock	1.8V	
14	SIMIO	I/O	External SIM signal – Data I/O	1.8V	Internal pull-up 20K
ADC					

Pin	Signal	I/O	Function	Type	Comment
15	ADC_IN1	I	Analog/Digital converter input		
Auxiliary (USIF1)					
52	RXD_AUX /SPI_MISO	I/O	Auxiliary UART (RX Data)/SPI_MISO	CMOS 1.8V	
53	TXD_AUX / SPI_MOSI	I/O	Auxiliary UART (TX Data)/SPI_MOSI	CMOS 1.8V	Internal PU (100K)
Miscellaneous					
7	ON_OFF/WAKE	I	Input Command for Power ON/OFF and to wake from deep sleep mode (PSM)		1.8V Active High
55	HW_SHUTDOWN*	I	UNCONDITIONAL SHUTDOWN	VBATT	
51	V_AUX/PWRMON	O		1.8V	
56	FORCED_USB_BOOT	I		CMOS 1.8V	
40	ANTENNA	I/O	Antenna pad – 50 Ω	RF	
37	GNSS_ANT	I	GNSS receiver input - 50 Ω	RF	
GPIO					
48	GPIO_01 / DVI_WA0	I/O	GPIO01 Configurable GPIO / Digital Audio Interface (WA0)	CMOS 1.8V	
47	GPIO_02 /DVI_RX	I/O	GPIO02 I/O pin Digital Audio Interface (RX)	CMOS 1.8V	
46	GPIO_03 / DVI_TX	I/O	GPIO03 GPIO I/O pin/ Digital Audio Interface (TX)	CMOS 1.8V	
45	GPIO_04 / DVI_CLK	I/O	GPIO04 Configurable GPIO/ Digital Audio Interface (CLK)	CMOS 1.8V	
33	GPIO_05/ GNSS_LNA_EN	I/O	GPIO05 Configurable GPIO	CMOS 1.8V	
32	GPIO_06 / SPI_CS	I/O	GPIO06 Configurable GPIO /SPI_CS	CMOS 1.8V	
31	GPIO_07	I/O	GPIO07 Configurable GPIO	CMOS 1.8V	
30	GPIO_08	I/O	GPIO08 Configurable GPIO	CMOS 1.8V	STAT_LED alternate function

Pin	Signal	I/O	Function	Type	Comment
29	SPI_CLK	I/O	SPI_CLK	CMOS 1.8V	
Power Supply					
44	VBATT	-	Main power supply (Baseband)	Power	
43	VBATT_PA	-	Main power supply (Radio PA)	Power	
42	GND	-	Ground	Power	
41	GND	-	Ground	Power	
39	GND	-	Ground	Power	
38	GND	-	Ground	Power	
35	GND	-	Ground	Power	
27	GND	-	Ground	Power	
23	GND	-	Ground	Power	
21	GND	-	Ground	Power	
54	GND	-	Ground	Power	
Reserved					
8		-	RFU		
16		-	RFU		
17		-	RFU		
22		-	RFU		
24		-	RFU		
25		-	RFU		
26			RFU		
28		-	RFU		
34		-	RFU		
36		-	RFU		
49		-	RFU		
50		-	RFU		

Table 7: Pin-out Information

Warning: ML865G1 is adopting a modified 56-pin xL865 Form Factor, pin to pin compatible with the previous 48-pin xL865 FF and with 8 additional pads.

Pins numbering has been changed accordingly and care should be paid when comparing to the previous 48-pin xL865 FF design.

3.2. Pin Layout

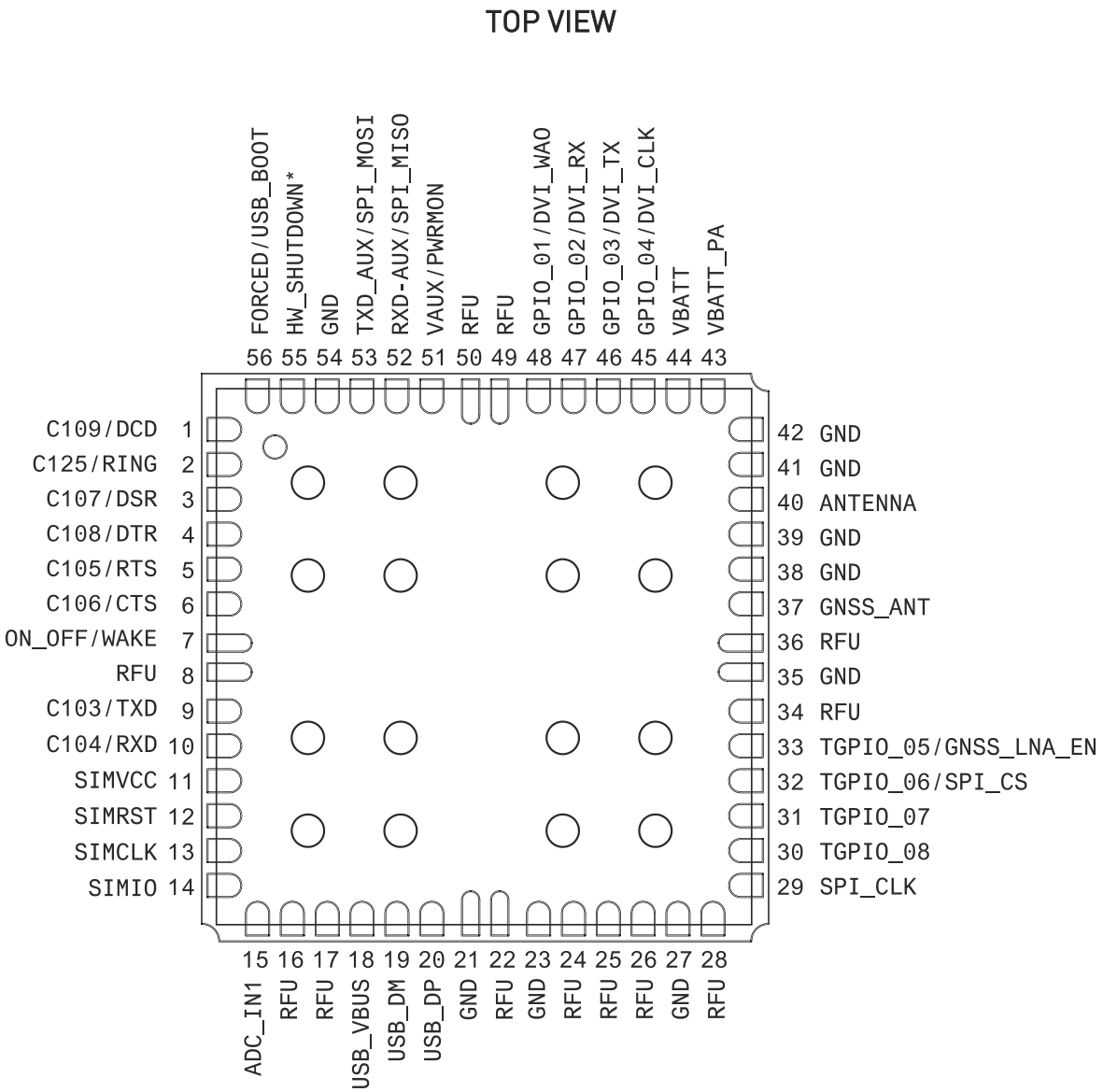


Figure 1: Pin Layout

Warning: The pins defined as NC/RFU are to be considered RESERVED and must not be connected to any pin in the application.

4. POWER SUPPLY

The power supply circuitry and the board layout are a very important part in the full product design and they strongly reflect on the product overall performances, so the requirements and the guidelines that will follow should be read carefully for a proper design.

4.1. Power Supply Requirements

The external power supply must be connected to VBATT & VBATT_PA signals and must fulfill the following requirements:

Power Supply	Value
Nominal Supply Voltage	3.8V
Operating Voltage Range	3.20 V - 4.20 V
Extended Voltange Range	2.60 V - 4.50 V
$VBATT_{min}$	2.7V

Table 8: Power Supply Requirements

Warning: The range 2.60V - 3.20V can be used only if both USB and 2G are disabled.

Warning: The supply voltage of the modem must never exceed the Extended Operating Voltage Range.

The wrong implementation of power supply guidelines described in this document may result in module fault.

Note:

The application's power supply section must be designed with care to avoid an excessive voltage drop during transmission peak current absorptions. If the voltage drops beyond the limits of the Extended Operating Voltage range, an unintentional module power off can occur.The voltage must be at least $VBATT_{min}$ to power on the module.

.

Note: For PTCRB approval on the final products the power supply is required to be within the "Normal Operating Voltage Range".

Note/Tip: HW User Guide specifications shall be fully acknowledged and correctly implemented to use the module in its "Extended Operating Voltage Range".

4.2. Power Consumption

4.2.1. Idle mode

Mode	Measure (Typical)			Mode Description
IDLE mode	CATM (mA)	NBIoT (mA)	2G (MA)	
AT+CFUN=1	9.5	9.2	9.0	Normal mode: full functionality of the module
AT+CFUN=4	7.5			Disabled TX and RX; module is not registered on the network
AT+CFUN=5	1.20	0.95	-	Paging cycle #256 frames (2.56s DRx cycle)
	0.60	0.60	-	81.92s eDRx cycle length (PTW=2.56s, DRX=1.28s)
	0.18[1]	0.18[1]	-	327.68s eDRx cycle length (PTW=2.56s, DRX=1.28s)
	0.10[1]	0.10[1]	-	655.36s eDRx cycle length (PTW=2.56s, DRX=1.28s)
	0.05[1]	0.05[1]	-	1310.72s eDRx cycle length (PTW=2.56s, DRX=1.28s)
	0.03[1]	0.03[1]	-	2621.44s eDRx cycle length (PTW=2.56s, DRX=1.28s)
	-	-	0.90	Paging Multiframe 9
PSM mode	Typical (mA)			
AT+CPSMS=1	3uA			No current source or sink by any connected pin

Table 9: Idle and PSM Mode *[1]PSM in between eDRX*

Mode		Measure* (Typical)	Mode Description
GPS		(mA)	
Active State (GNSS ON, CFUN=4)	Acquisition	69.3	GPS+GLO, DPO off
	Navigation	22	GPS+GLO, DPO on DWELL=280ms

		55.9	GPS+GLO, DPO off
Active State (GNSS ON, CFUN=5 eDRX)	Acquisition	68.5	GPS+GLO, DPO off
	Navigation	15.7	GPS+GLO, DPO on DWELL=280ms
		54	GPS+GLO, DPO off

Table 10: GPS Mode **reference signal @-130 dbm with static scenario*

Note: The reported LTE CAT M1 and LTE CAT NB1 values are an average among all the product variants and bands for each network wireless technology.

The support of specific network wireless technology depends on the product variant configuration.

4.2.2. ML865G1-WW Connected Mode

Mode	Measure (Typical)		Mode Description
Connected mode	Average (mA)	Peak (mA)	
CATM	380	1100	1 RB, RMC, TBS=5, QPSK, 23dBm, Band 85, 28, 12
	320	900	1 RB, RMC, TBS=5, QPSK,23dBm, Band 13, 26, 5, 18, 19, 20, 8
	305	800	1 RB, RMC, TBS=5, QPSK, 23dBm, Band 3, 2, 25, 4, 1, 66
NBIoT	240	335	3.75KHz, 1 SC, RU 32ms, TBS=0, BPSK, 20dBm, Band 71
	600	1000	3.75KHz, 1 SC, RU 32ms, TBS=0, BPSK, 23dBm, Band 85, 28, 12
	500	850	3.75KHz, 1 SC, RU 32ms, TBS=0, BPSK, 23dBm, Band 13, 26, 5, 18, 19, 20, 8
	430	750	3.75KHz, 1 SC, RU 32ms, TBS=0, BPSK, 23dBm, Band 3, 2, 25, 4, 1, 66
	68	300	15KHz, 12 SC, RU 1ms, TBS=5, QPSK, 21dBm, Band 71
	88	950	15KHz, 12 SC, RU 1ms, TBS=5, QPSK, 23dBm, Band 85, 28, 12
	78	800	15KHz, 12 SC, RU 1ms, TBS=5, QPSK, 23dBm, Band 13, 26, 5, 18, 19, 20, 8

	77	730	15KHz, 12 SC, RU 1ms, TBS=5, QPSK, 23dBm, Band 3, 2, 25, 4, 1, 66
GPRS	300	2000	1TX + 1RX, CS1, GMSK, Band 850, 900
	170	1000	1TX + 1RX, CS1, GMSK, Band 1800, 1900

Table 11: ML865G1-WW Connected Mode

4.3. General Design Rules

The main guidelines for the Power Supply Design include three different design steps:

- the electrical design
- the thermal design
- the PCB layout

4.3.1. Electrical Design Guidelines

The electrical design of the power supply strongly depends on the power source where this power is drained. We will distinguish them into three categories:

- +5V input (typically PC internal regulator output)
- +12V input (typically automotive)
- Battery

4.3.1.1. +5V Source Power Supply Design Guidelines

- The desired output for the power supply is 3.8V, so there's not a big difference between the input source and the desired output and a linear regulator can be used. A switching power supply will not be suitable due to the low drop out requirements.
- When using a linear regulator, a proper heat sink shall be provided in order to dissipate the power generated.
- A Bypass low ESR capacitor of adequate capacity must be provided in order to cut the current absorption peaks close to the Module, a 100µF capacitor is usually suitable.
- Make sure the low ESR capacitor on the power supply output rated at least 10V.

An example of linear regulator with 5V input is:

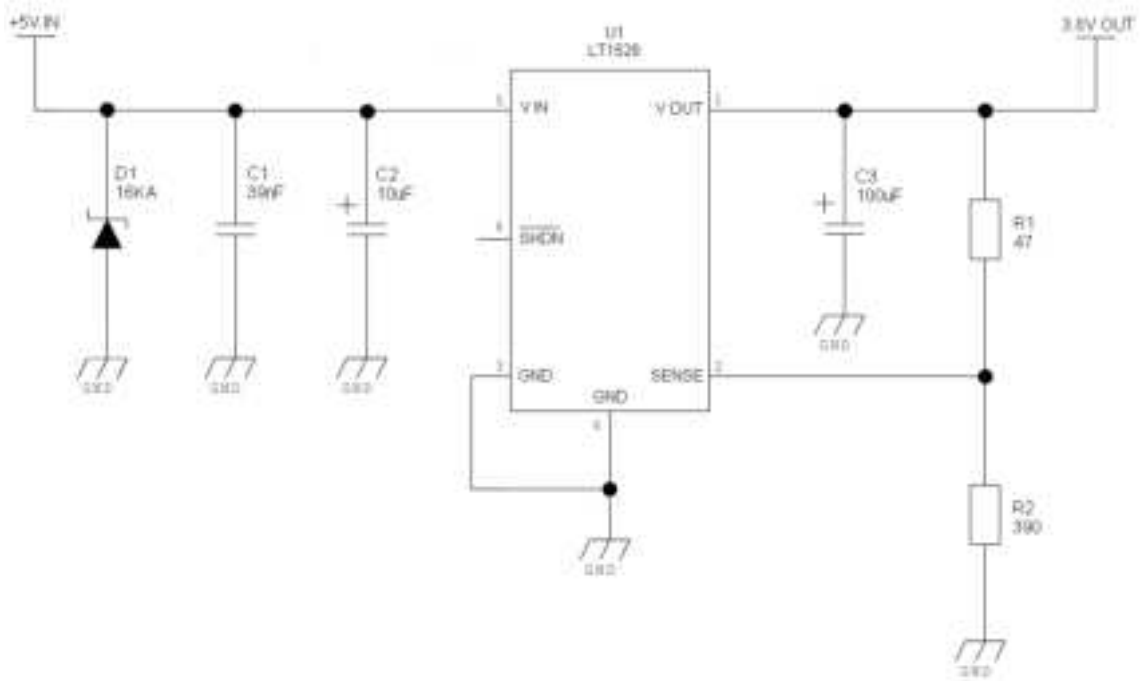


Figure 2: An example of linear regulator with 5V input

4.3.1.2. +12V Source Power Supply Design Guidelines

- The desired output for the power supply is 3.8V, so due to the big difference between the input source and the desired output, a linear regulator is not suitable and shall not be used. A switching power supply will be preferable because of its better efficiency.
- When using a switching regulator, a 500kHz or more switching frequency regulator is preferable because of its smaller inductor size and its faster transient response. This allows the regulator to respond quickly to the current peaks absorption.
- In any case the frequency and Switching design selection is related to the application to be developed since the switching frequency could also generate EMC interferences.
- For car PB battery the input voltage can rise up to 15,8V and this should be kept in mind when choosing components: all components in the power supply must withstand this voltage.
- A Bypass low ESR capacitor of adequate capacity must be provided in order to cut the current absorption peaks, a 100µF capacitor is usually suitable.
- Make sure the low ESR capacitor on the power supply output is rated at least 10V.
- For Car applications a spike protection diode should be inserted close to the power input, in order to clean the supply from the spikes.

An example of switching regulator with 12V input is in the below schematic:

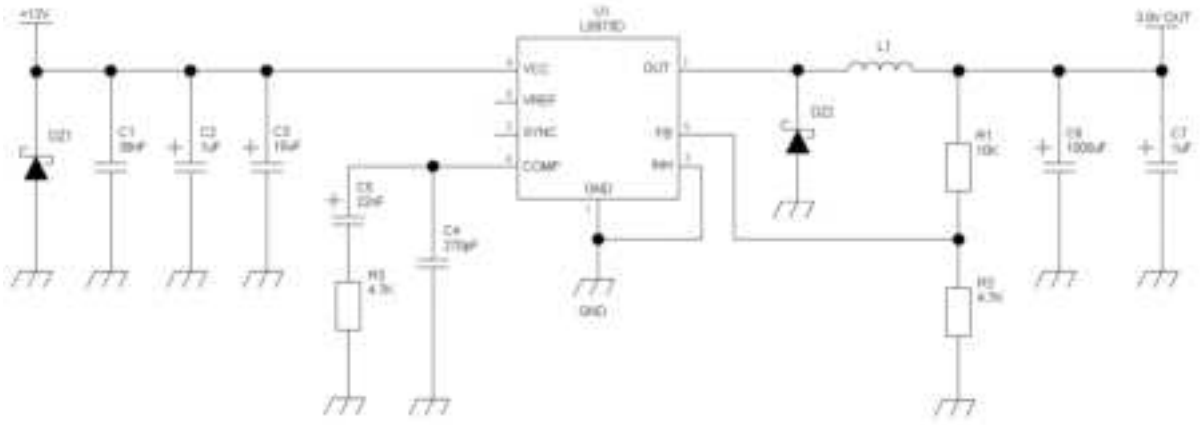


Figure 3: An example of switching regulator with 12V input

4.3.1.3. Battery Source Power Supply Design Guidelines

The desired nominal output for the power supply is 3.8V and the maximum voltage allowed is 4.2V, hence a single 3.7V Li-Ion cell battery type is suitable for supplying the power to the Telit ML865G1 module.

- A Bypass low ESR capacitor of adequate capacity must be provided in order to cut the current absorption peaks, a 100µF tantalum capacitor is usually suitable.
- Make sure the low ESR capacitor (usually a tantalum one) is rated at least 10V.
- A protection diode should be inserted close to the power input, in order to save the ML865G1 from power polarity inversion. Otherwise the battery connector should be done in a way to avoid polarity inversions when connecting the battery.
- The battery must be rated to supply peaks of current up to 2A.

Note: DON'T USE any Ni-Cd, Ni-MH, and Pb battery types directly connected with ML865G1. Their use can lead to overvoltage on the ML865G1 and damage it. USE ONLY Li-Ion battery types

4.3.2. Thermal Design Guidelines

This section will be available in next document revisions.

4.3.3. Power Supply PCB layout Guidelines

As seen on the guidelines for electrical design, the power supply shall have a low ESR capacitor on the output to cut the current peaks on the input to protect the supply from spikes. The placement of this component is crucial for the correct working of the circuitry. A misplaced component can be useless or can even decrease the power supply performance.

- The Bypass low ESR capacitor must be placed close to the Telit ML865G1 power input pads or in the case the power supply is a switching type it can be placed close to the inductor to cut the ripple provided the PCB trace from the capacitor to the ML865G1 is wide enough to ensure a dropless connection even during an 2A current peak.
- The protection diode must be placed close to the input connector where the power source is drained.
- The PCB traces to the ML865G1 and the Bypass capacitor must be wide enough to ensure no significant voltage drops occur. This is for the same reason as previous point. Try to keep this trace as short as possible.
- To reduce the EMI due to switching, it is important to keep the mesh involved very small; therefore the input capacitor, the output diode (if not embodied in the IC) and the regulator shall form a very small loop.This is done in order to reduce the radiated field (noise) at the switching frequency (100-500 kHz usually).
- A dedicated ground for the Switching regulator separated by the common ground plane is suggested.
- The placement of the power supply on the board should be done in such a way to guarantee that the high current return paths in the ground plane are not overlapped to any noise sensitive circuitry as the microphone amplifier/buffer or earphone amplifier.
- The power supply input cables should be kept separate from noise sensitive lines such as microphone/earphone cables.
- The insertion of EMI filter on VBATT pins is suggested in those designs where antenna is placed close to battery or supply lines. A ferrite bead like Murata BLM18EG101TN1 or Taiyo Yuden P/N FBMH1608HM101 can be used for this purpose.

The below figure shows the recommended circuit:

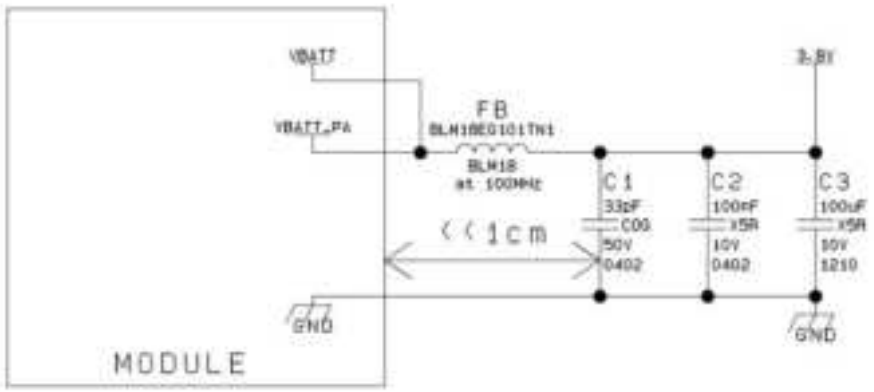


Figure 4: Recommended Circuit

4.4. RTC supply

RTC is functional when ML865G1 is in PSM state and VBATT pin is supplied.

RTC settings are erased if VBATT supply is temporary disconnected.

4.5. VAUX Power Output

A regulated power supply output is provided on pin 51 to supply small devices from the module, like: level translators, audio codec, sensors, and others.

Pin 51 can be used also as PWRMON (module powered ON indication) function, because is always active when the module is powered ON and cannot be set to LOW level by any AT command.

Host can only detect deep sleep mode (PSM) by monitoring of VAUX/PWRMON output pin, since there is no pin dedicated to PSM status indicator.

The operating range characteristics of the supply are:

Item	Min	Typical	Max
Output voltage	1.78V	1.80V	1.82V
Output current	-	-	60mA
Output bypass capacitor (inside the module)		1uF	

Table 12: Operating range characteristics of the supply

Note: VAUX during PSM period is OFF (PSM has to be enabled previously by AT+CPSMS command)

Note: The Output Current MUST never be exceeded; care must be taken when designing the application section to avoid an excessive current consumption.

5. DIGITAL SECTION

ML865G1 has four main operation states:

- **OFF state:** Vbatt is applied and only RTC is running. Baseband is switched OFF and the only change possible is the ON state.
- **ON state:** baseband is fully switched on and ML865G1 is ready to accept AT commands. ML865G1 can be idle or connected.
- **Sleep mode state:** main baseband processor is intermittently switched ON and AT commands can be processed with some latency. ML865G1 is idle with low current consumption.
- **Deep sleep mode state:** PSM defined in 3GPP Release 12. Baseband is switched OFF most of the time.

5.1. Logic Levels

Parameter	Min	Max
ABSOLUTE MAXIMUM RATINGS – NOT FUNCTIONAL		
Input level on any digital pin (CMOS 1.8) with respect to ground	-0.3V	2.1V
Operating Range - Interface levels (1.8V CMOS)		
Input high level	1.5V	1.9V
Input low level	0V	0.35V
Output high level	1.6V	1.9V
Output low level	0V	0.2V

Table 13: Logic levels Minimum and maximum

Parameter	AVG
Current characteristics:	
Output Current	1mA
Input Current	1uA

Table 14: Logic levels average

5.2. Power On

To turn on the ML865G1 the pad ON_OFF/WAKE must be set HIGH level for at 5 seconds and then released.

ON_OFF/WAKE pad can make also an asynchronous wakeup of the system from the PSM Mode, before the scheduled event of timer T3412 expired. To make asynchronous exit from PSM mode ON_OFF/WAKE pin must be set HIGH level for 5 seconds.

The signal ON_OFF/WAKE can be directly connected to any GPIO (1.8V) of Application Processor with a totem pole output. A level shifter is not required.

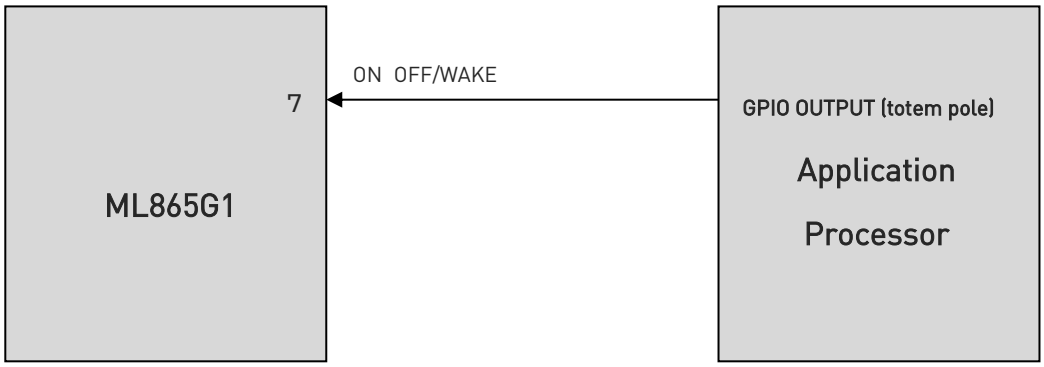


Figure 5: ON_OFF/WAKE connection

The typical current consumption of the input ON_OFF/WAKE pad is 0.25mA@1.8V.

Note: Do not use any pull down resistor on the ON_OFF/WAKE line, it is internally pulled down.

The VAUX/PWRMON pin can be monitored by application processor to check if the device is powered ON.

A flow chart showing the proper turn on procedure is displayed below:

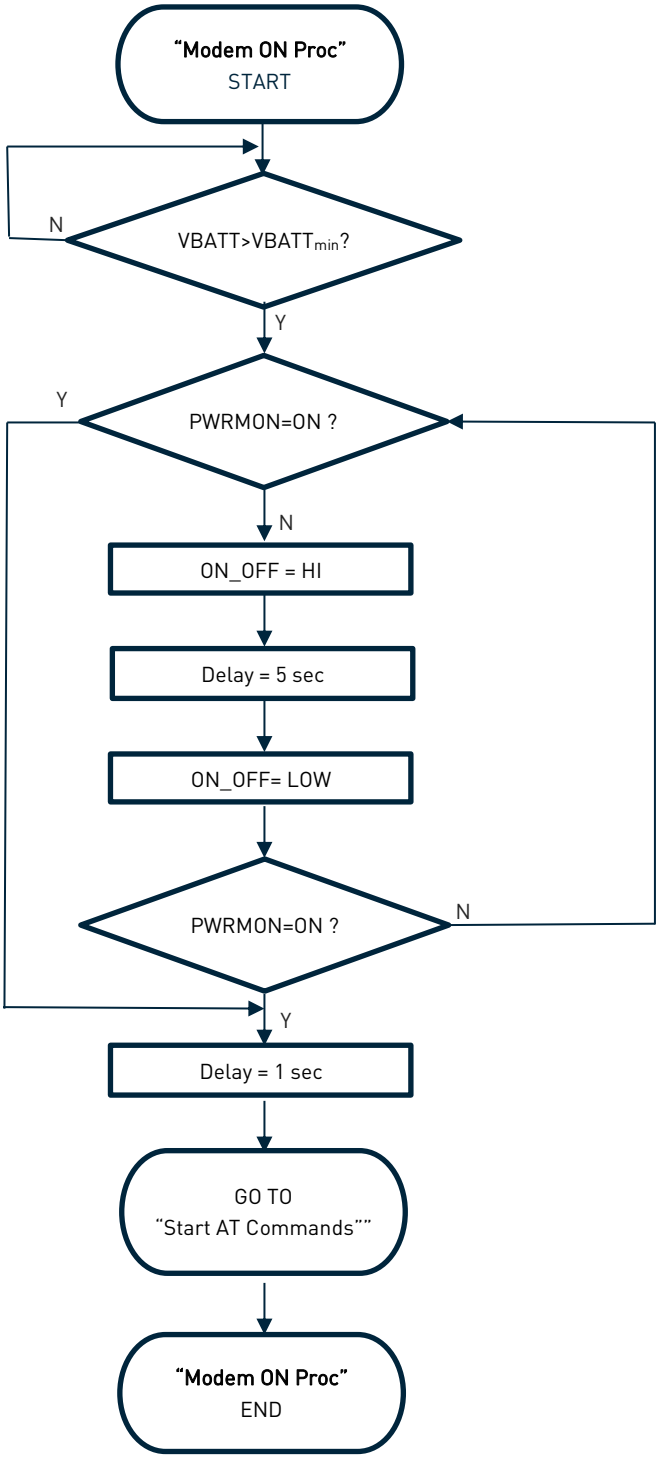


Figure 6: Turn on procedure flow chart

A flow chart showing the AT commands managing procedure is displayed below:

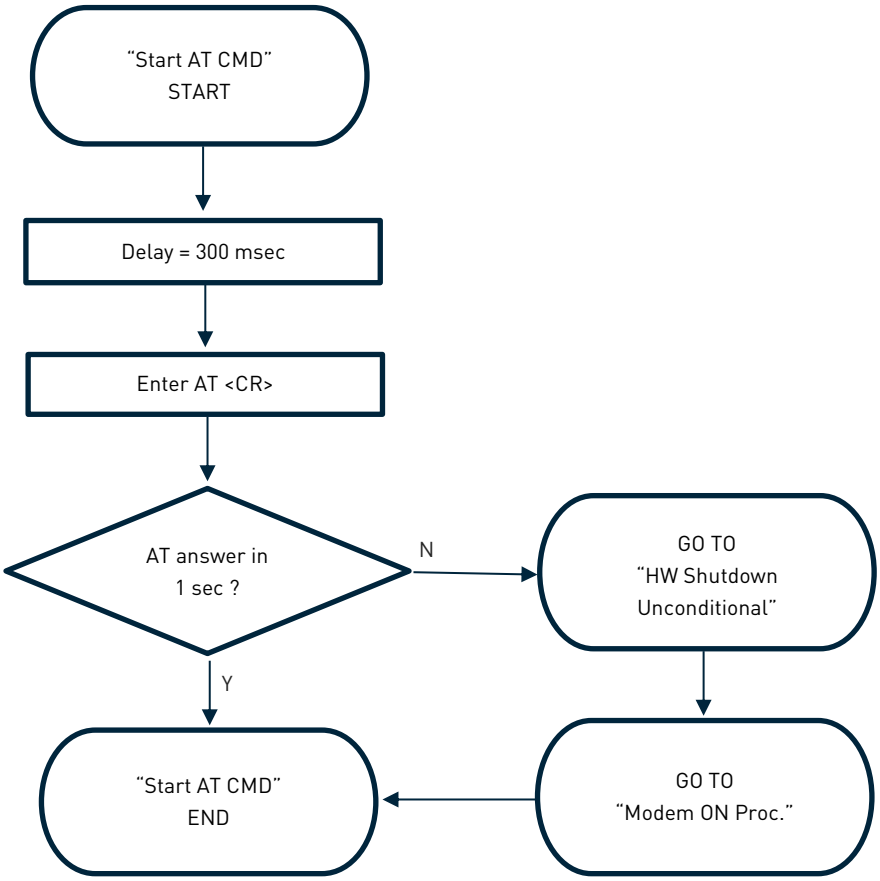


Figure 7: AT commands managing procedure flow chart

Note: In order to avoid a back powering effect it is recommended to prevent any HIGH logic level signal from being applied to the digital pins of the ML865G1 when the module is powered off or during an ON-OFF transition.

Warning: It is recommended to set the ON_OFF/WAKE line HIGH to power on the module only after VBATT is higher than 3.20V.

In case this condition is not satisfied, you could use the HW_SHUTDOWN* line to recover it and then restart the power on activity using the ON_OFF/WAKE line.

After HW_SHUTDOWN* is released you could again use the ON_OFF/WAKE line to power on the module.

5.3. Auto Power On

ML865G1 module can be switched on with ON_OFF/WAKE pin 7 permanently fixed to HI level (1.8V).

In the configuration there are two limitations:

- the asynchronous PSM wake-up cannot be implemented.
- Power Off can be only implemented via AT command (see ML865G1 Software User Guide, AT#SHDN)

5.4. Power Off

Turning off of the device can be done in two ways:

- via AT command (see ML865G1 Software User Guide, AT#SHDN)
- pin ON_OFF/WAKE asserted (HIGH) for at least 3 seconds

Either ways, the device issues a detach request to network informing that the device will not be reachable any more.

Note: To check if the device has been powered off or in PSM mode, the hardware line PWRMON must be monitored. The device is powered off when PWRMON goes low.

VBATT can be removed when PWRMON is in LOW state.

In order to avoid a back powering effect it is recommended to prevent any HIGH logic level signal from being applied to the digital pins of the ML865G1 when the module is powered off or during an ON-OFF transition.

Warning: Not following the recommended shut-down procedures might damage the device and consequently void the warranty..

The following flow chart shows the proper turn off procedure:

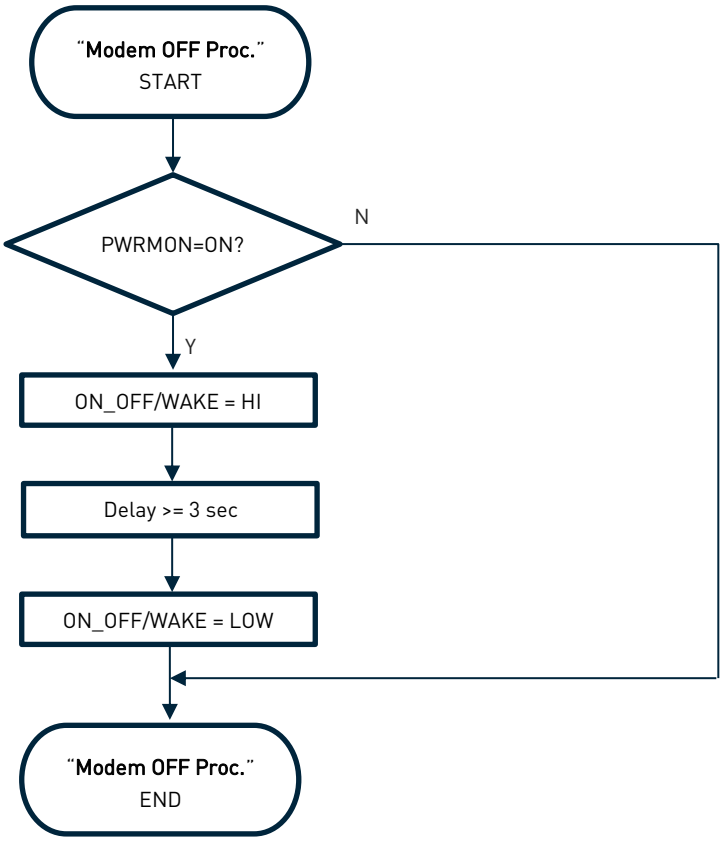


Figure 8: turn off procedure flow chart

5.5. Unconditional Shutdown

HW_SHUTDOWN* is used to unconditionally shutdown the ML865G1. Whenever this signal is pulled low, the ML865G1 is reset. When the device is reset it stops any operation. After the release of the line, the ML865G1 is unconditionally shut down, without performing any disconnection from the network where it is registered. This behaviour is not a proper shut down because any cellular device is requested to issue a detach request on turn off. The HW_SHUTDOWN* is internally controlled on start-up to always achieve a proper power-on reset sequence, so there's no need to control this pin at start-up.

To unconditionally shutdown the ML865G1, the pad HW_SHUTDOWN* must be tied low for at least 200 milliseconds and then released.

The signal is internally pulled up so the pin can be left floating if not used.

If used, then it **must always be connected with an open collector transistor**, to permit to the internal circuitry the power on reset and under voltage lockout functions.

During PSM mode, HW_SHUTDOWN toggle has no effect. The use of HW_SHUTDOWN* pin is valid only when ML865G1 has VAUX/PWRMON output HI.

PIN DESCRIPTION

Signal	Function	I/O	Pin
HW_SHUTDOWN*	Unconditional Shutdown of the Module	I	55

Table 15: HW_SHUTDOWN signal*

Warning: The hardware unconditional Shutdown must not be used during normal device operation as it does not disconnect the device from the network and can damage the memory content. It shall be kept as an emergency exit procedure.

INCORRECT SHUTDOWN Procedure can void the warranty

A typical circuit is the following:

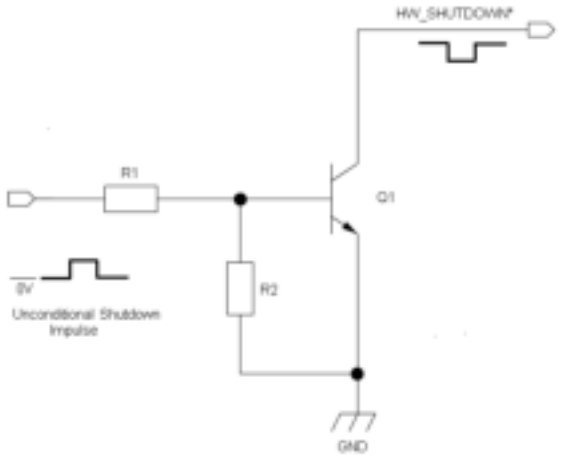


Figure 9: typical circuit

For example: Let us assume you need to drive the HW_SHUTDOWN* pad with a totem pole output of a +3/5 V microcontroller:

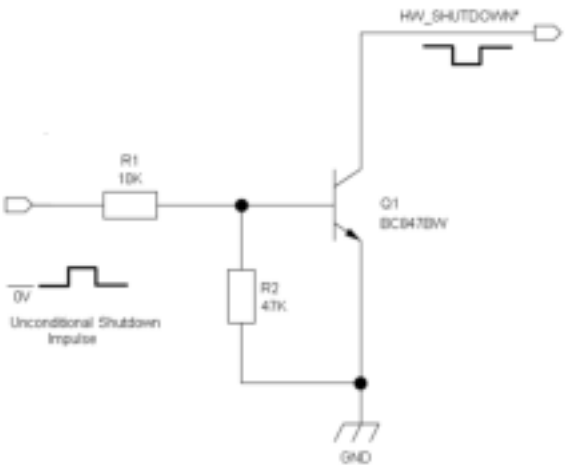


Figure 10: typical circuit

In the following flow chart the proper Unconditional Shutdown procedure is described:

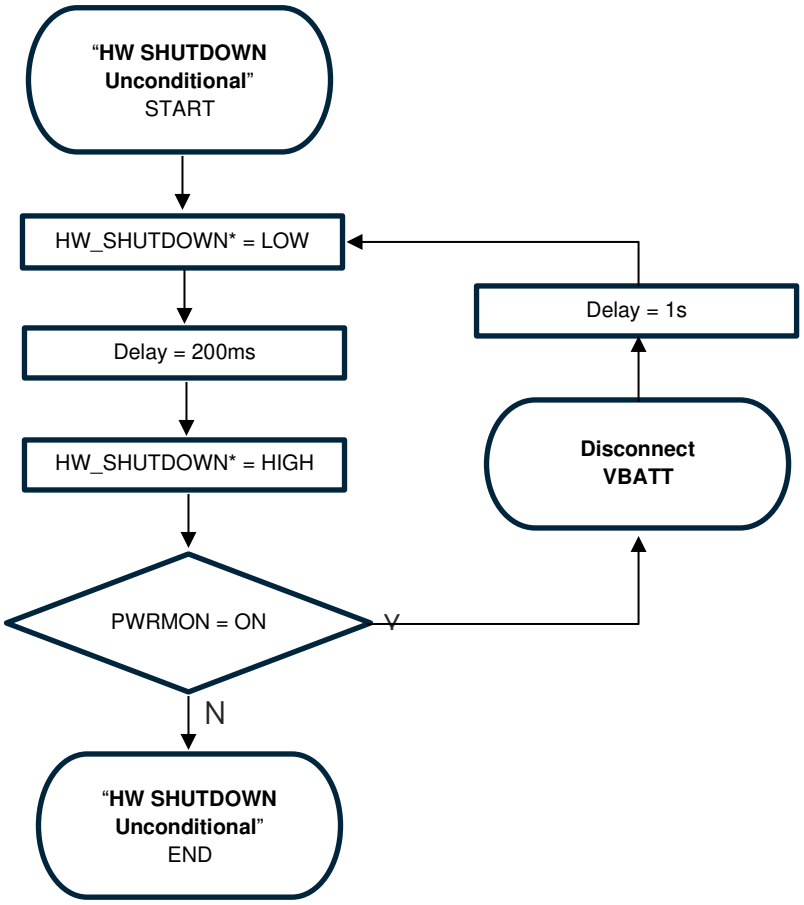


Figure 11: restart procedure flow chart

Note: In order to avoid a back powering effect it is recommended to prevent any HIGH logic level signal from being applied to the digital pins of the ML865G1 when the module is powered off or during an ON-OFF transition.

5.6. Wake from deep sleep mode

ML865G1 supports Power Saving Mode (PSM) functionality defined in 3GPP Release 12. When Periodic Update Timer expires, ML865G1 power off until the next scheduled wake-up time.

Asynchronous event controlled by host can wake up from deep sleep mode by asserting ON_OFF/WAKE pin HIGH level for at least 5 seconds.

Host can detect deep sleep mode by polling VAUX/PWRMON pin if previously configured in the user schematic for this purpose.

Note: Do not use any pull up resistor on the HW_SHUTDOWN* line nor any totem pole digital output. Using pull up resistor may bring to latch up problems on the ML865G1 power regulator and improper functioning of the module.

To correctly restart the module please refer to the related paragraph ("Power ON").The unconditional hardware shutdown must always be implemented on the boards and should be used only as an emergency exit procedure.

5.7. Fast power down

The procedure to power off ML865G1 described in Chapter 5.4 normally takes more than 1 second to detach from the network and make ML865G1internal filesystem properly closed. In case of unwanted supply voltage loss the system can be switched off without any risk of filesystem data corruption by implementing Fast Shut Down feature.

Fast Shut Down feature permits to reduce the current consumption and the time-to-poweroff to minimum values.

Note: Refer to ML865G1 series AT command reference guide (Fast power down - #FASTSHDN) in order to set up detailed AT command.

5.7.1. Fast Shut Down by Hardware

The Fast Power Down can be triggered by configuration of any GPIO. HI level to LOW level transition of GPIO commands fast power down.

Example circuit:

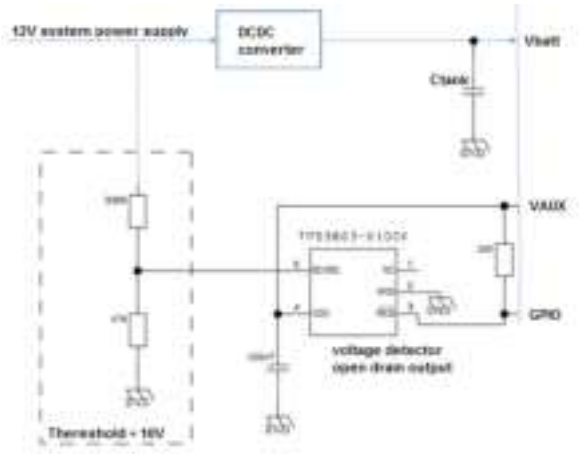


Figure 12: example circuit

Note: Consider voltage drop under max current conditions when defining the voltage detector thereshold in order to avoid unwanted shutdown.

The capacitor is rated with the following formula:

$$C = I \frac{\Delta t}{\Delta V}$$

Tip: Make check of timings and voltage discharge during system verification.

5.7.2. Fast Shut Down by Software

The Fast Power Down can be triggered by AT command.

5.8. Communication ports

5.8.1. USB 2.0 HS

The ML865G1 includes one integrated universal serial bus (USB 2.0 HS) transceiver.

The following table is listing the available signals:

PAD	Signal	I/O	Function	NOTE
20	USB_D+	I/O	USB differential Data (+)	
19	USB_D-	I/O	USB differential Data (-)	

PAD	Signal	I/O	Function	NOTE
18	VUSB	AI	Power sense for the internal USB transceiver.	Accepted range: 3.0V to 5.5V 100K pull down

Table 16: Available Signals

The USB_DPLUS and USB_DMINUS signals have a clock rate of 480 MHz, therefore signal traces should be routed carefully. Trace lengths, number of vias and capacitive loading should be minimized. The characteristic impedance value should be as close as possible to 90 Ohms differential.

ESD protection can be added to USB D+/D- lines in case of external connector for cable connection.

Proper components for USB 2.0 must be used.

Note: Disconnect or assert to GND the VUSB pin before activating the Power Saving Mode.

5.8.2. SPI

The ML865G1 Module is provided by a standard 3-wire master or slave SPI interface with chip select control.

The following table lists the available signals:

PAD	Signal	I/O	Function	Type	NOTE
29	SPI_CLK	I/O	SPI Clock	CMOS 1.8V	
52	SPI_MISO	I/O	SPI MISO	CMOS 1.8V	Shared with RX_AUX
53	SPI_MOSI	I/O	SPI MOSI	CMOS 1.8V	Shared with TX_AUX
32	SPI_CS	I/O	SPI Chip Select	CMOS 1.8V	

Table 17: Available Signals

Tip: Due to the shared functions, SPI port and TX_AUX/RX_AUX port cannot be used simultanously.

5.8.2.1. SPI Connections

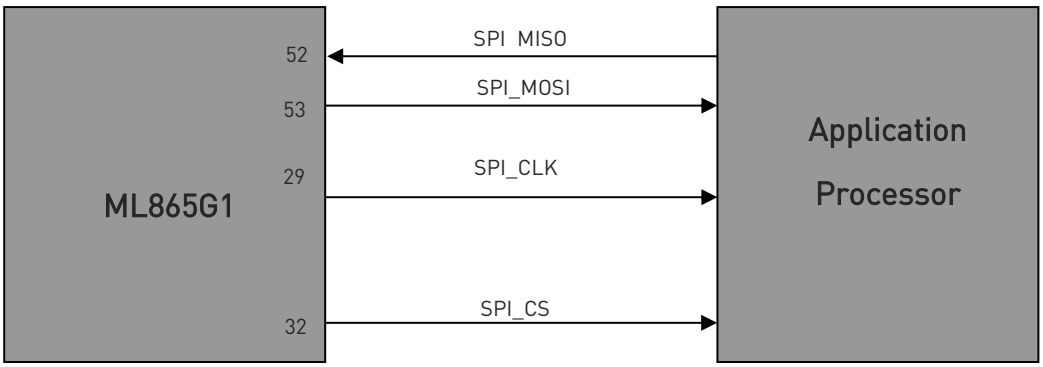


Figure 13: SPI Connections

5.8.3. Serial Ports

The ML865G1 module is equipped with by 2 Asynchronous serial ports:

- MODEM SERIAL PORT 1 (Main)
- MODEM SERIAL PORT 2 (Auxiliary)

Several configurations can be designed for the serial port on the OEM hardware, but the most common are:

- RS232 PC com port
- microcontroller UART @ 1.8V (Universal Asynchronous Receive Transmit)
- microcontroller UART @ 5V or other voltages different from 1.8V

Depending on the type of serial port on the OEM hardware a level translator circuit may be needed to make the system work. On the ML865G1 the ports are CMOS 1.8.

5.8.3.1. Modem serial port 1 (USIF0)

The serial port 1 on the ML865G1 is a +1.8V UART with all the 7 RS232 signals. It differs from the PC-RS232 in the signal polarity (RS232 is reversed) and levels.

The following table lists the available signals:

RS232 Pin	Signal	ML865G1 PAD	Name	Usage
1	C109/DCD	1	Data Carrier Detect	Output from the ML865G1 that indicates the carrier presence
2	C104/RXD	10	Transmit line *see Note	Output transmit line of ML865G1 UART

3	C103/TXD	9	Receive line *see Note	Input receive of the ML865G1 UART
4	C108/DTR	4	Data Terminal Ready	Input to the ML865G1 that controls the DTE READY condition
6	C107/DSR	3	Data Set Ready	Output from the ML865G1 that indicates the module is ready
7	C105/RTS	5	Request to Send	Input to the ML865G1 that controls the Hardware flow control
8	C106/CTS	6	Clear to Send	Output from the ML865G1 that controls the Hardware flow control
9	C125/RING	2	Ring Indicator	Output from the ML865G1 that indicates the incoming call condition

Table 18: Available Signals

Note: According to V.24, some signal names are referred to the application side, therefore on the ML865G1 side these signal are on the opposite direction:

TXD on the application side will be connected to the receive line (here named C103/TXD)

RXD on the application side will be connected to the transmit line (here named C104/RXD)

For a minimum implementation, only the TXD, RXD lines can be connected, the other lines can be left open provided a software flow control is implemented.

In order to avoid a back powering effect it is recommended to prevent any HIGH logic level signal from being applied to the digital pins of the ML865G1 when the module is powered off or during an ON/OFF transition.

5.8.3.2. Modem serial port 2 (USIF1)

The secondary serial port on the ML865G1 is a CMOS1.8V with only the RX and TX signals.

The signals of the ML865G1 serial port are:

PAD	Signal	I/O	Function	Type	NOTE
53	TX_AUX	O	Auxiliary UART (TX Data to DTE)	CMOS 1.8V	Shared with SPI_MOSI
52	RX_AUX	I	Auxiliary UART (RX Data from DTE)	CMOS 1.8V	Shared with SPI_MISO

Table 19: ML865G1serial port signals

Note: Due to the shared functions, TX_AUX/RX_AUX port and SPI port cannot be used simultanously.

In order to avoid a back powering effect it is recommended to prevent any HIGH logic level signal from being applied to the digital pins of the ML865G1 when the module is powered off or during an ON/OFF transition.

Refer to ML865G1 series AT command reference guide for port configuration.

5.8.3.3. RS232 level translation

In order to interface the ML865G1 with a PC com port or a RS232 (EIA/TIA-232) application a level translator is required. This level translator must:

- invert the electrical signal in both directions;
- Change the level from 0/1.8V to +15/-15V.

Actually, the RS232 UART 16450, 16550, 16650 & 16750 chipsets accept signals with lower levels on the RS232 side (EIA/TIA-562), allowing a lower voltage-multiplying ratio on the level translator. Note that the negative signal voltage must be less than 0V and therefore some sort of level translation is always required.

The simplest way to translate the levels and invert the signal is by using a single chip level translator. There are a multitude of them, differing in the number of drivers and receivers and in the levels (be sure to get a true RS232 level translator not a RS485 or other standards).

By convention the driver is the level translator from the 0-1.8V UART to the RS232 level. The receiver is the translator from the RS232 level to 0-1.8V UART.

To translate the whole set of control lines of the UART you will need:

- 5 drivers
- 3 receivers

An example of RS232 level adaptation circuitry could be done using a MAXIM transceiver (MAX218)

In this case the chipset is capable to translate directly from 1.8V to the RS232 levels (Example done on 4 signals only).

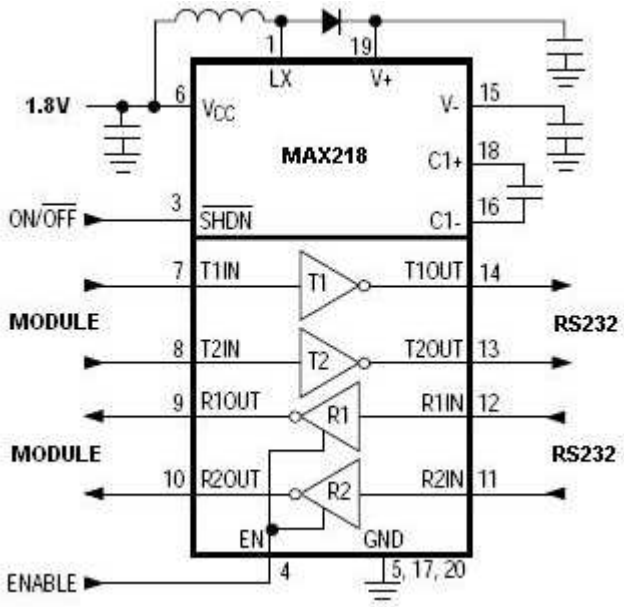


Figure 14: example circuitry

The RS232 serial port lines are usually connected to a DB9 connector with the following layout:

Figure 15: example RS232 serial port lines

5.9. General purpose I/O

The ML865G1 module is provided by a set of Configurable Digital Input / Output pins (CMOS 1.8V). Input pads can only be read; they report the digital value (high or low) present on the pad at the time of reading. Output pads can only be written or queried and set the value of the pad output.

An alternate function pad is internally controlled by the ML865G1 firmware and acts depending on the implemented function.

The following table shows the available GPIO on the ML865G1:

PAD	Signal	I/O	Output Drive Strength	Default State	NOTE
48	GPIO_01	I/O	1mA	INPUT – PD (100K)	
47	GPIO_02	I/O	1mA	INPUT – PD (100K)	
46	GPIO_03	I/O	1mA	INPUT – PD (100K)	
45	GPIO_04	I/O	1mA	INPUT – PD (100K)	
33	GPIO_05	I/O	1mA	INPUT – PD (100K)	
32	GPIO_06	I/O	1mA	INPUT – PD (100K)	
31	GPIO_07	I/O	1mA	INPUT – PD (100K)	
30	GPIO_08	I/O	1mA	INPUT – PD (100K)	

Table 20: ML865G1 available GPIO

5.9.1. Using a GPIO as INPUT

The GPIO pads, when used as inputs, can be connected to a digital output of another device and report its status, provided this device has interface levels compatible with the 1.8V CMOS levels of the GPIO.

Input current (@1.8V) is about 18uA (corrisponding to 100K pulldown value) in all GPIO pin. This value is present since ML865 poweron.

If the digital output of the device to be connected with the GPIO input pad has interface levels different from the 1.8V CMOS, then it can be buffered with an open collector transistor with a 47K pull up to 1.8V supplied by VAUX/POWERMON (pin 51).

Note: In order to avoid a back powering effect it is recommended to prevent any HIGH logic level signal from being applied to the digital pins of the ML865G1 when the module is powered off or during an ON/OFF transition.

Refer to ML865G1 series AT command reference guide for GPIO pins configuration

5.9.2. Using a GPIO as OUTPUT

The GPIO pads, when used as outputs, can drive 1.8V CMOS digital devices or compatible hardware. When set as outputs, the pads have a push-pull output and therefore the pull-up resistor may be omitted.

5.9.3. Indication of network service availability

The STAT_LED pin status shows information on the network service availability and Call status.

The function is available as alternate function of GPIO_08 (to be enabled using the AT#GPIO=8,0,2 command).

In the ML865G1 modules, the STAT_LED needs an external transistor to drive an external LED and its voltage level is defined accordingly to the table below:.

Device Status	Led Status
Device off	Permanently off
Not Registered	Permanently on
Registered in idle	Blinking 1sec on + 2 sec off
Registered in idle + power saving	It depends on the event that triggers the wakeup (In sync with network paging)
Connecting	Blinking 1 sec on + 2 sec off

Table 21: LED and its voltage level

The reference schematic for LED indicator, R3 must be calculated taking in account VBATT value and LED type. :

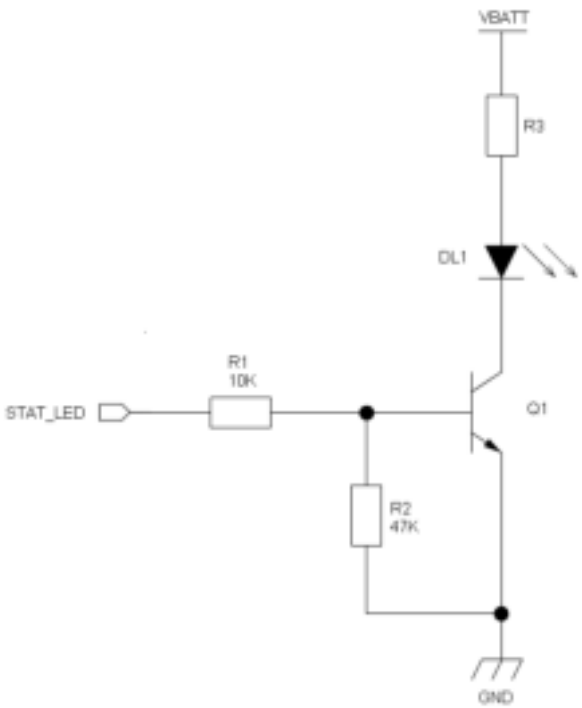


Figure 16: LED indicator reference schematic

5.10. External SIM Holder

Please refer to the related User Guide (SIM Holder Design Guides, 80000NT10001a).

5.11. ADC Converter

The ML865G1 is provided by one AD converters. It is able to read a voltage level in the range of 0÷1.8 volts applied on the ADC pin input, store and convert it into 10 bit word.

The input lines are named as ADC_IN1 and they are available on Pin 15.

The following table is showing the ADC characteristics:

Item	Min	Typical	Max	Unit
Input Voltage range	0	-	1.8	Volt
AD conversion	-	-	10	bits
Input Resistance	1	-	-	Mohm
Input Capacitance	-	1	-	pF

Table 22: ADC characteristics

5.11.1. Using ADC Converter

Available in a next document revision.

5.12. Forced USB boot

In some case of firmware upgrade FORCED_USB_BOOT pin must be set to 1.8V during poweron of ML865G1.

The input current is very low so 10K resistor to 1.8V supply can be used to keep this pin in HI state.

FORCED_USB_BOOT pin must be connected only during firmware upgrade operation and normally it has to be left open.

FORCED_USB_BOOT pin must be available in the user application circuit throught test points for easy connection of 10K resistor and 1.8V supply.

6. RF SECTION

6.1. Bands Variants

See section Product Variants and Frequency Bands

6.2. TX Output power

See section TX Output Power

6.3. RX Sensitivity

This information will be available in a next document revision.

6.4. Antenna requirements

The antenna connection and board layout design are the most important aspect in the full product design as they strongly affect the product overall performances, so read carefully and follow the requirements and the guidelines for a proper design.

The antenna and antenna transmission line on PCB for a Telit ML865G1-WW device shall fulfil the following requirements:

Item	Value
Frequency range	Depending on frequency band(s) provided by the network operator, the customer shall use the most suitable antenna for that/those band(s)
Bandwidth	250 MHz in LTE Band 1 140 MHz in LTE Band 2, PCS1900 170 MHz in LTE Band 3, DCS1800 445 MHz in LTE Band 4 70 MHz in LTE Band 5, GSM850 80 MHz in LTE Band 8, GSM900 47 MHz in LTE Band 12 41 MHz in LTE Band 13 60 MHz in LTE Band 18 60 MHz in LTE Band 19 71 MHz in LTE Band 20 145 MHz in LTE Band 25 80 MHz in LTE Band 26 62 MHz in LTE Band 27 100 MHz in LTE Band 28 490 MHz in LTE Band 66 81 MHz in LTE Band 71 48 MHz in LTE Band 85
Impedance	50 ohm
Input power	ML865G1-WW: > 33dBm Average power

Item	Value
VSWR absolute max	≤ 10:1 (limit to avoid permanent damage)
VSWR recommended	≤ 2:1 (limit to fulfill all regulatory requirements)

Table 23: ML865G1-WW Antenna and Antenna transmission line on PCB

6.4.1. PCB Design guidelines

When using the ML865G1, since there's no antenna connector on the module, the antenna must be connected to the ML865G1 antenna pad (K1) by means of a transmission line implemented on the PCB.

This transmission line shall fulfil the following requirements:

Item	Value
Characteristic Impedance	50 ohm (+-10%)
Max Attenuation	0,3 dB
Coupling	Coupling with other signals shall be avoided
Ground Plane	Cold End (Ground Plane) of antenna shall be equipotential to the ML865G1 ground pins

Table 24: ML865G1-WW Antenna pad requirements

The transmission line should be designed according to the following guidelines:

- make sure that the transmission line's characteristic impedance is 50ohm ;
- keep line on the PCB as short as possible, since the antenna line loss shall be less than about 0,3 dB;
- the line geometry should have uniform characteristics, constant cross section, avoid meanders and abrupt curves;
- any kind of suitable geometry / structure (Microstrip, Stripline, Coplanar, Grounded Coplanar Waveguide...) can be used to implement the printed transmission line afferent the antenna;
- if a Ground plane is required in the line geometry, this must be continuous and sufficiently extended, so that the geometry can be as similar as possible to the related canonical model;
- keep, if possible, at least one layer of the PCB used only for the Ground plane; If possible, use this layer as reference Ground plane for the transmission line;
- it is advisable to surround (on both sides) the PCB transmission line with Ground, avoiding that other signal tracks face directly the antenna line track.

- avoid crossing any un-shielded transmission line footprint with other signal tracks on different layers;
- the ground surrounding the antenna line on PCB has to be strictly connected to the main Ground Plane by means of via holes (at least once per 2mm), placed close to the ground edges facing the line track;
- place EM noisy devices as far as possible from ML865G1 antenna line;
- keep the antenna line far away from the ML865G1 power supply lines;
- if EM noisy devices (such as fast switching ICs, LCD and so on) are present on the PCB hosting the ML865, take care of the shielding of the antenna line by burying it in an inner layer of PCB and surround it with Ground planes, or shield it with a metal frame cover.
- If EM noisy devices are not present around the line, the use of geometries such as Microstrip or Grounded Coplanar Waveguide is preferable, since they typically ensure less attenuation if compared to a Stripline of the same length;

The following image shows the suggested layout for the Antenna pad connection:

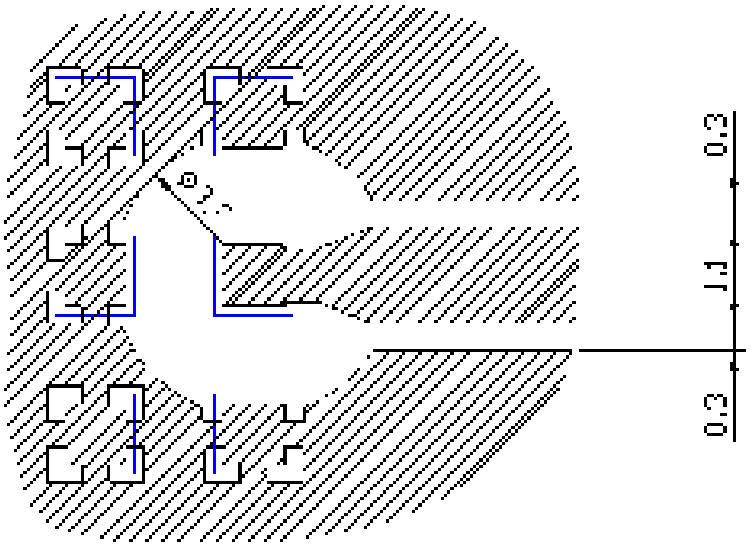


Figure 17: Layout for the Antenna pad connection

6.4.2. PCB Guidelines in case of FCC Certification

In the case FCC certification is required for an application using ML865G1, according to FCC KDB 996369 for modular approval requirements, the transmission line must be similar to the one implemented on ML865G1 interface board and described in the following chapter.

6.4.2.1. Transmission line design

When designing the ML865G1 interface board, the placement of components has been chosen properly, in order to keep the length of the line as short as possible, thus leading to the lowest power losses possible. A Grounded Coplanar Waveguide (G-CPW) line has been chosen, since this kind of transmission line ensures good impedance control and can be implemented in an outer PCB layer as needed in this case. A SMA female connector has been used to feed the line.

The interface board is made on a FR4, 4-layers PCB. The substrate material is characterized by relative permittivity εr = 4.6 ± 0.4 @ 1 GHz, TanD= 0.019 ÷ 0.026 @ 1 GHz.

A characteristic impedance of nearly 50 Ω is achieved using trace width = 1.1 mm, clearance from coplanar ground plane = 0.3 mm each side. The line uses reference ground plane on layer 3, while copper is removed from layer 2 underneath the line. The height of trace above ground plane is 1.335 mm. The calculated characteristic impedance is 51.6 Ω, estimated line loss is less than 0.1 dB.

The line geometry is shown below:

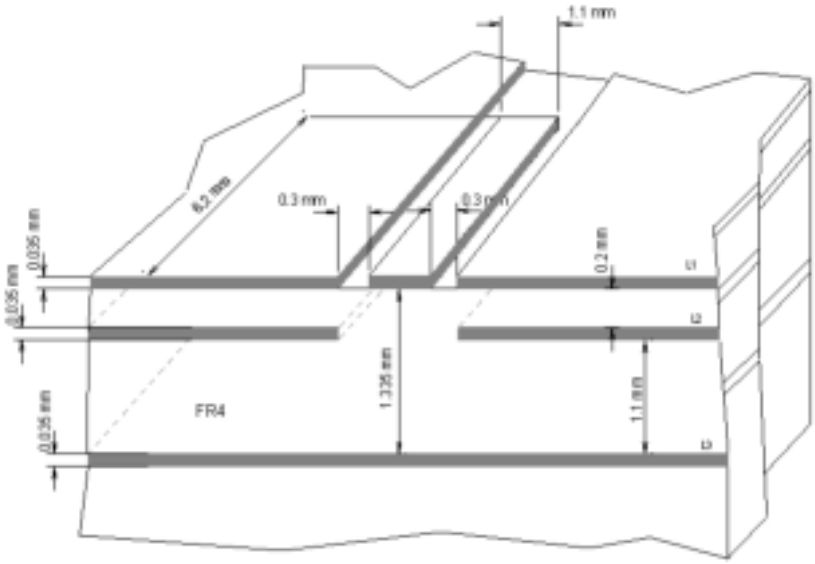


Figure 18: Line geometry

6.4.2.2. Transmission Line Measurements

An HP8753E VNA (Full-2-port calibration) was used in this measurement session.

A calibrated coaxial cable was soldered at the pad corresponding to RF output; a SMA connector was soldered to the board in order to characterize the losses of the transmission line including the connector itself. During Return Loss / impedance measurements, the transmission line has been terminated to 50 Ω load.

Return Loss plot of line under test is shown below:

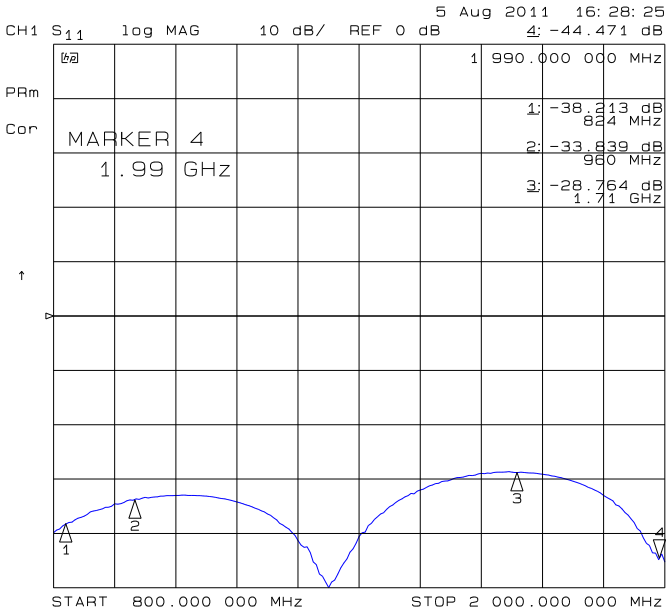


Figure 19: Return Loss plot of line under test

Line input impedance (in Smith Chart format, once the line has been terminated to 50 Ω load) is shown in the following figure:

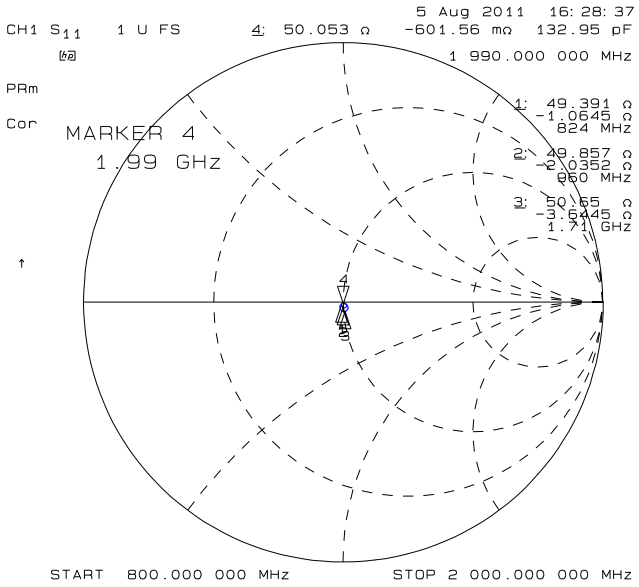


Figure 20: Line input impedance

Insertion Loss of G-CPW line plus SMA connector is shown below:

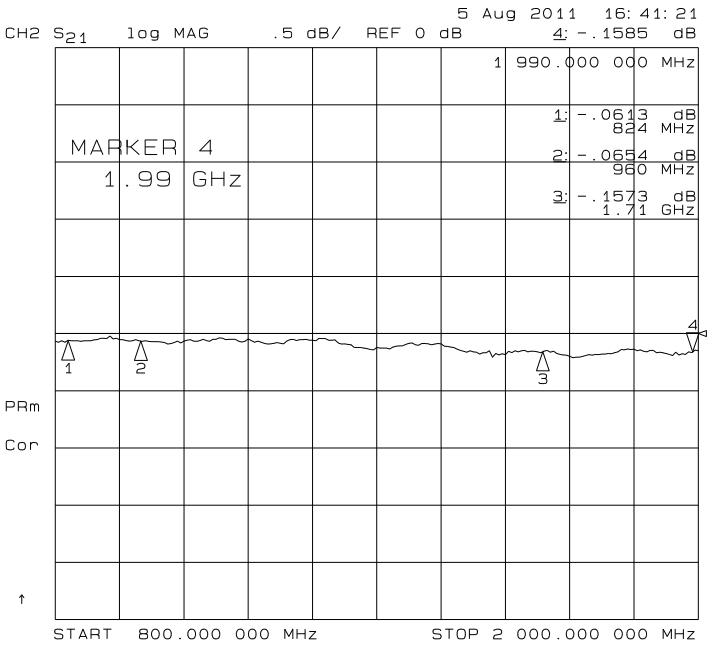


Figure 21: Insertion Loss of G-CPW line plus SMA connector

6.4.2.3. Antenna Installation Guidelines

- Install the antenna in a place covered by the LTE signal with CAT-M1 support.
- The antenna must not be installed inside metal cases.
- The antenna must be installed according to the Antenna manufacturer instructions.
- The antenna integration should optimize the Radiation Efficiency. Efficiency values > 50% are recommended on all frequency bands
- The antenna integration should not perturb the radiation pattern described in the antenna manufacturer documentation.
- It is preferable to get an omnidirectional radiation pattern.
- The antenna Gain must not exceed values indicated in regulatory requirements, where applicable, in order to meet the related EIRP limitations. Typical antenna Gain in most M2M applications does not exceed 2dBi
- If the device antenna is located farther than 20cm from the human body and there are no co-located transmitter then the Telit FCC/IC approvals can be re-used by the end product
- If the device antenna is located closer than 20cm from the human body or there are co-located transmitter then the additional FCC/IC testing may be required for the end product (Telit FCC/IC approvals cannot be reused)

7. AUDIO SECTION

The Telit digital audio interface (DVI) of the ML865G1 Module is based on the I^2S serial bus interface standard. The audio port can be connected to end device using digital interface, or via one of the several compliant codecs (in case an analog audio is needed).

7.1. Electrical Characteristics

The product is providing the DVI on the following pins:

Pin	Signal	I/O	Function	Internal Pull Up	Type
48	DVI_WA0	O	Digital Audio Interface (Word Alignment / LRCLK)		CMOS 1.8V
47	DVI_RX	I	Digital Audio Interface (RX)		CMOS 1.8V
46	DVI_TX	O	Digital Audio Interface (TX)		CMOS 1.8V
45	DVI_CLK	O	Digital Audio Interface (BCLK)		CMOS 1.8V

Table 25: Pins DVI

7.2. Codec examples

Please refer to the Digital Audio Application note.

8. GNSS SECTION

ML865G1 module includes a state-of-art receiver capable of simultaneously searching and tracking satellite signals from multiple satellite constellations. This multi-GNSS receiver uses the entire spectrum of GNSS systems available: GPS, GLONASS, BeiDou, Galileo, and QZSS.

8.1. GNSS Signals Pin-out

Pin	Signal	I/O	Function	Type
37	ANT_GNSS	I	GNSS Antenna (50 ohm)	CMOS 1.8V
33	GNSS_LNA_EN	O	GNSS External LNA Enable	

Table 26: GNSS Signals Pin-out

8.2. RF Front End Design

The ML865G1 Module doesn't contain the LNA necessary to achieve the maximum sensitivity. The active antenna (antenna with a built-in low noise amplifier) must be used and must be supplied with a proper bias-tee circuit.

8.2.1. Guidelines of PCB line for GNSS Antenna

- Make sure that the antenna line impedance is 50ohm.
- Keep the antenna line on the PCB as short as possible to reduce the loss.
- The antenna line must have uniform characteristics, constant cross section, avoid meanders and abrupt curves.
- If possible, keep one layer of the PCB used only for the Ground plane.
- Surround (on both the sides, above and below) the antenna line on PCB with Ground, avoid having other signal tracks facing directly the antenna line of track.
- The ground around the antenna line on PCB must be strictly connected to the Ground Plane by placing vias once per 2mm at least.
- Place EM noisy devices as far as possible from antenna line.
- Keep the antenna line far away from power supply lines.
- Keep the antenna line far away from GSM RF lines.
- If there are EM noisy devices around the PCB hosting the module, such as fast switching ICs, take care of the shielding of the antenna line by burying it inside the

layers of PCB and surrounding it with Ground planes, or shielding it with a metal frame cover.

- If you do not have EM noisy devices around the PCB hosting the module, use a strip-line on the superficial copper layer for the antenna line. The line attenuation will be lower than a buried one.

8.2.2. Hardware-based solution for GNSS and LTE coexistence

When a stand-alone GNSS receiver is present in the user application, the LTE transmission may desensitize the GNSS receiver in particular if the decoupling between LTE and GNSS antennas is low. A SAW filter can be added on LTE side, to protect GNSS receiver from LTE out-of-band emissions, as described in the schematic below.

When the GNSS receiver embedded in the ML865G1 module is used, there is no condition for degradation, because LTE part and GNSS part are never active simultaneously, therefore the filtering on the LTE side is not needed.

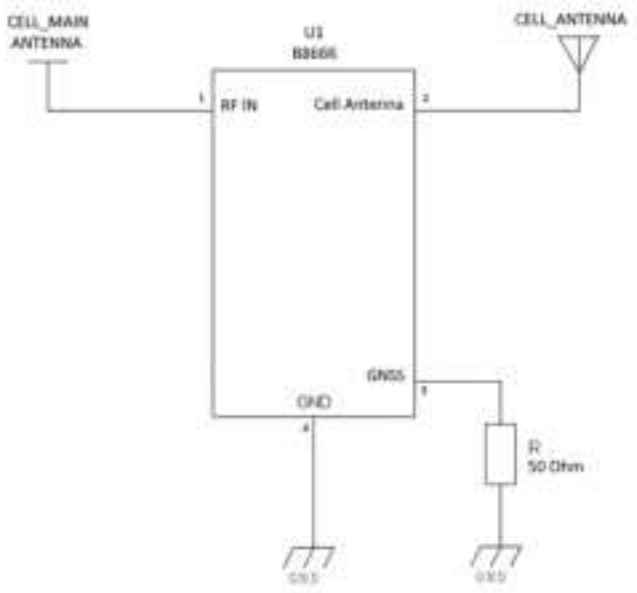


Figure 22: Reference schematic

8.3. GNSS Antenna Requirements

GNSS active antenna must be used or integrated in the application.

8.3.1. GNSS Antenna specification

Item	Value
Frequency range	1559.0 ~ 1610.0 MHz
Gain	20 ~ 30dB
Impedance	50 ohm
Noise Figure of LNA	< 1.5 (recommended)
DC supply voltage	DC 1.8 ~ 3.3V
VSWR	≤ 3:1 (recommended)

Table 27: GNSS Antenna specification

8.3.2. GNSS Antenna – Installation Guidelines

- The antenna must be installed according to the antenna manufacturer's instructions to obtain the maximum performance from the GNSS receiver.
- The position of the antenna must be carefully evaluated if operating in conjunction with any other antenna or transmitter.
- The antenna must not be installed inside metal cases or near any obstacle that may degrade features like antenna lobes and gain.

8.3.3. Powering the External LNA (active antenna)

The LNA of active antenna needs a source of power because 1.8V or 3V DC voltage required by the active antenna is not supplied by the ML865G1 module, but can be easily included in the user application circuit.

The electrical characteristics of the GPS_LNA_EN signal are:

Level	Min	Max
Output High Level	1.6V	1.9V
Output Low Level	0V	0.3V

Table 28: GPS_LNA_EN signal characteristics

Example of external antenna bias circuitry:

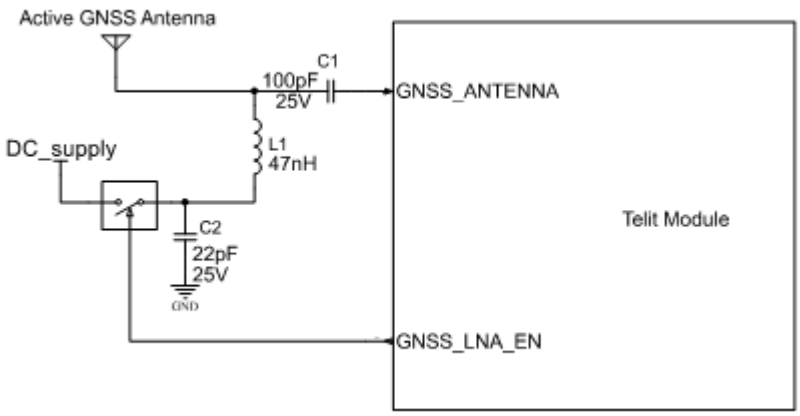


Figure 23: Antenna bias circuitry example

Pay attention to the maximum bias current in case of unwanted short on the antenna cable, since the decoupling inductor may be damaged.

In case of LNA with 1.8V supply, VAUX/POWERMON pin can be used to supply active GNSS antenna

8.4. GNSS Characteristics

The table below specifies the GNSS characteristics and expected performance:

Parameters		Typical Measurement
Sensitivity	Tracking Sensitivity	-159 dBm
	Navigation	-155 dBm
	Cold Start	-144 dBm
Min Navigation update rate		1Hz

Table 29: GNSS Characteristics

9. MECHANICAL DESIGN

9.1. Drawing

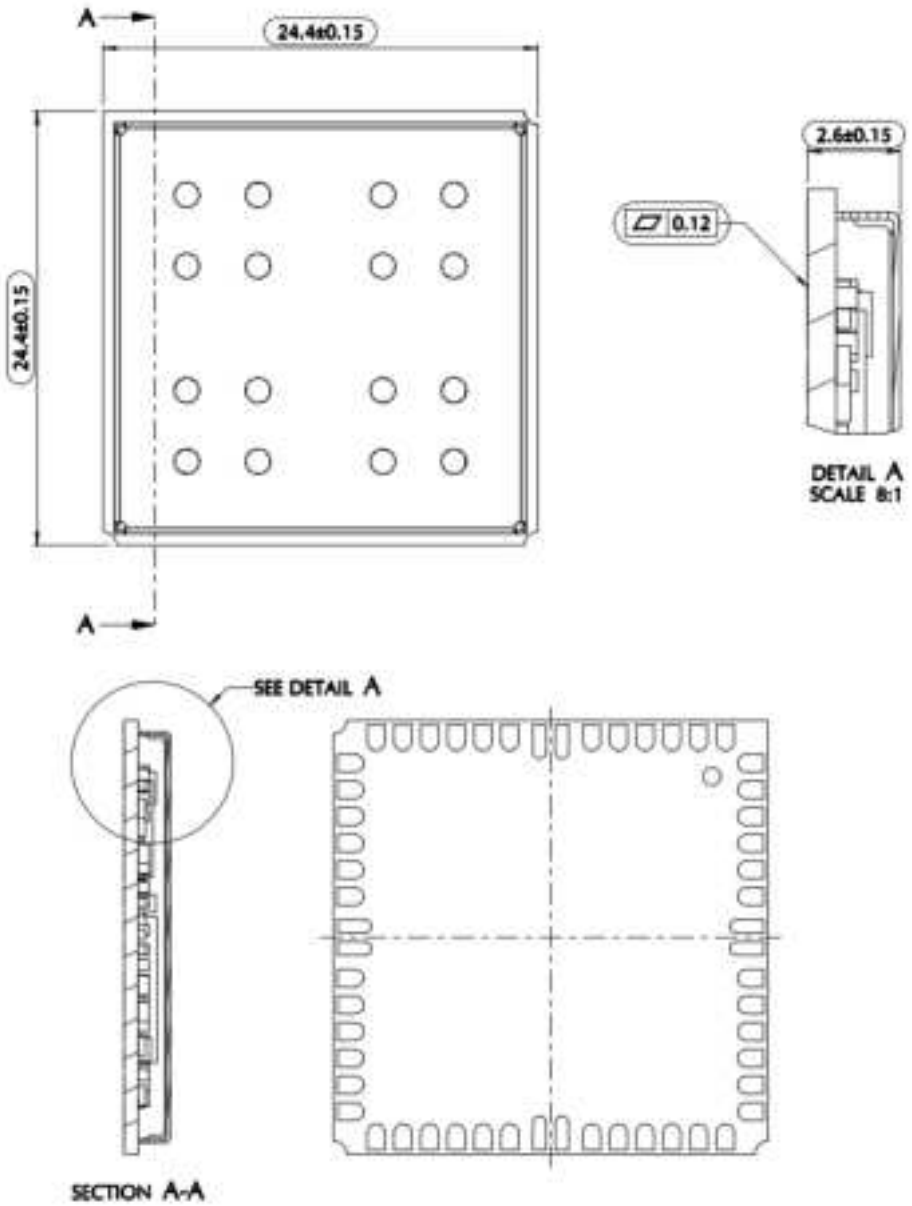


Figure 24: Mechanical Design Drawing

Note: Dimensions in mm.

General Tolerance ±0.1, Angular Tolerance ±1°, The tolerance is not cumulative.

10. APPLICATION PCB DESIGN

10.1. General

The ML865G1 modules have been designed to be compliant with a standard lead-free SMT process.

10.2. Recommended Footprint for the application

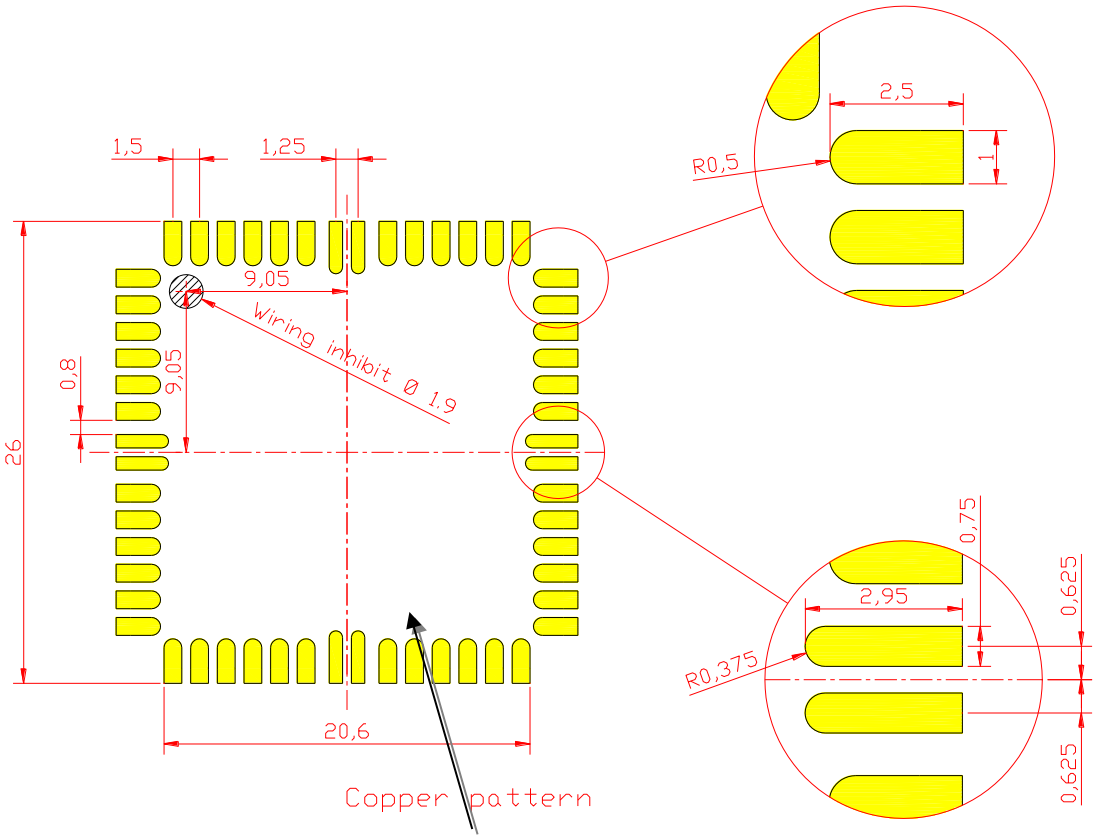


Figure 25: Coppert pattern

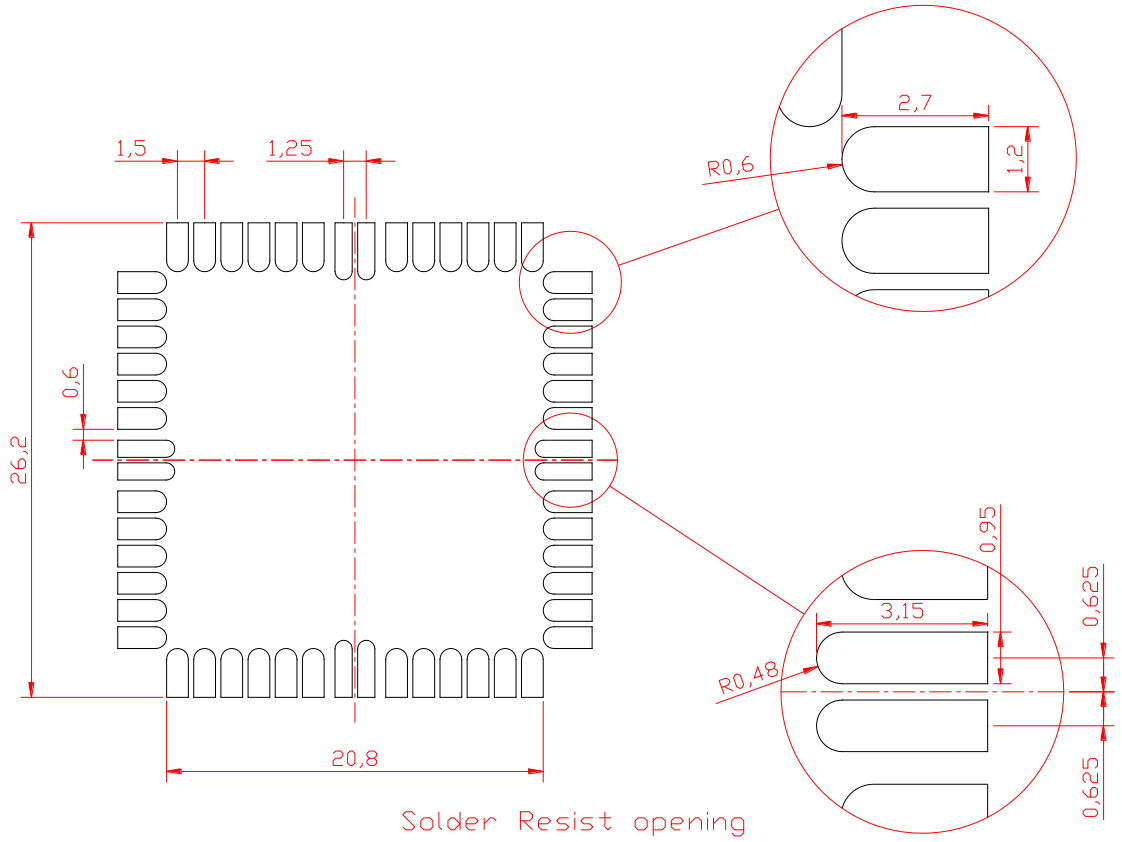


Figure 26: Solder resist openings

In order to easily rework the ML865G1 it is recommended to consider on the application a 1.5 mm placement inhibit area around the module.

It is also suggested, as common rule for an SMT component, to avoid having a mechanical part of the application in direct contact with the module.

Note: In the customer application, the region under WIRING INHIBIT (see figure above) must be clear from signal or ground paths.

10.3. PCB pad design

Non solder mask defined (NSMD) type is recommended for the solder pads on the PCB.

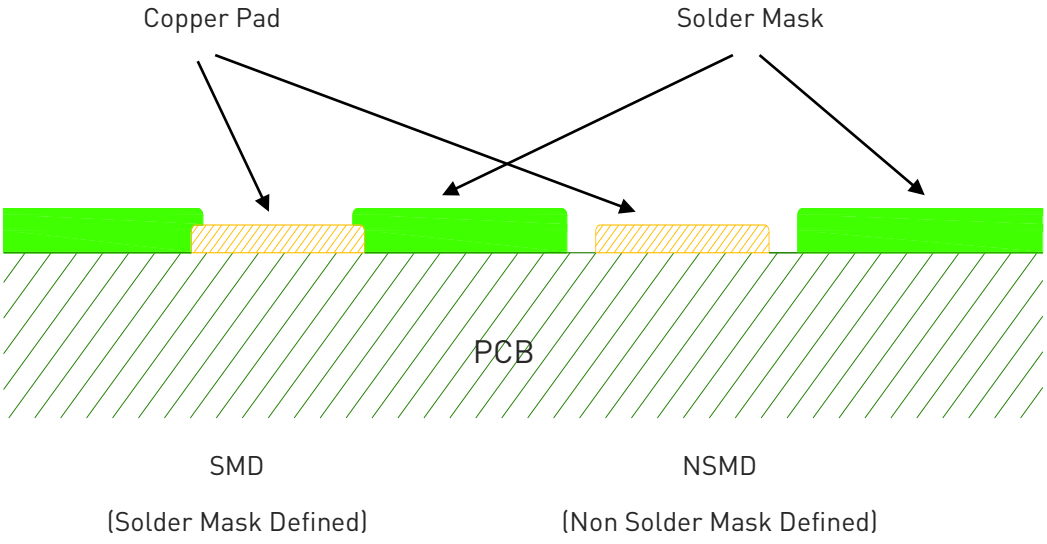


Figure 27: PCB solder pad recommendations

10.4. Recommendations for PCB pad dimensions

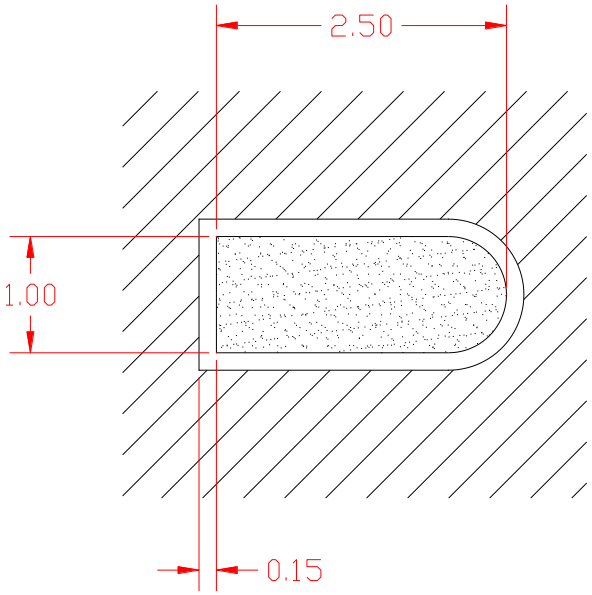


Figure 28: Pad dimensions

It is not recommended to place via or micro-via not covered by solder resist in an area of 0.3 mm around the pads unless it carries the same signal of the pad itself (see the figure below).

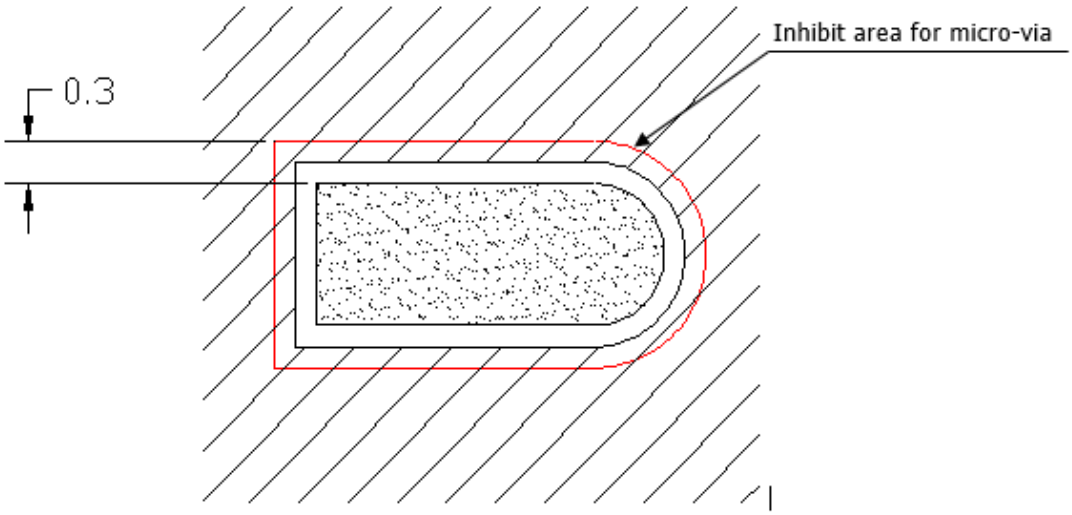


Figure 29: Inhibit area for micro-via

Holes in pad are allowed only for blind holes and not for through holes.

Recommendations for PCB pad surfaces:

Finish	Layer Thickness (um)	Properties
Electro-less Ni / Immersion Au	3 –7 / 0.03 – 0.15	good solder ability protection, high shear force values

Table 30: Recommendations for PCB pad surfaces

The PCB must be able to resist the higher temperatures which are occurring during the lead-free process. This issue should be discussed with the PCB-supplier. Generally, the wettability of tin-lead solder paste on the described surface plating is better than compared to lead-free solder paste.

It is not necessary to panel the application's PCB, however in that case it is suggested to use milled contours and predrilled board breakouts; scoring or v-cut solutions are not recommended.

10.5. Stencil

The stencil opening can be the same as the recommended footprint (1:1), we suggest a thickness of stencil foil ≥ 120 µm.

10.6. Solder paste

Item	Lead Free
Solder Paste	Sn/Ag/Cu

Table 31: Solder paste table

We recommend using only "no clean" solder paste in order to avoid the cleaning of the modules after assembly

10.7. Solder Reflow

Recommended solder reflow profile:

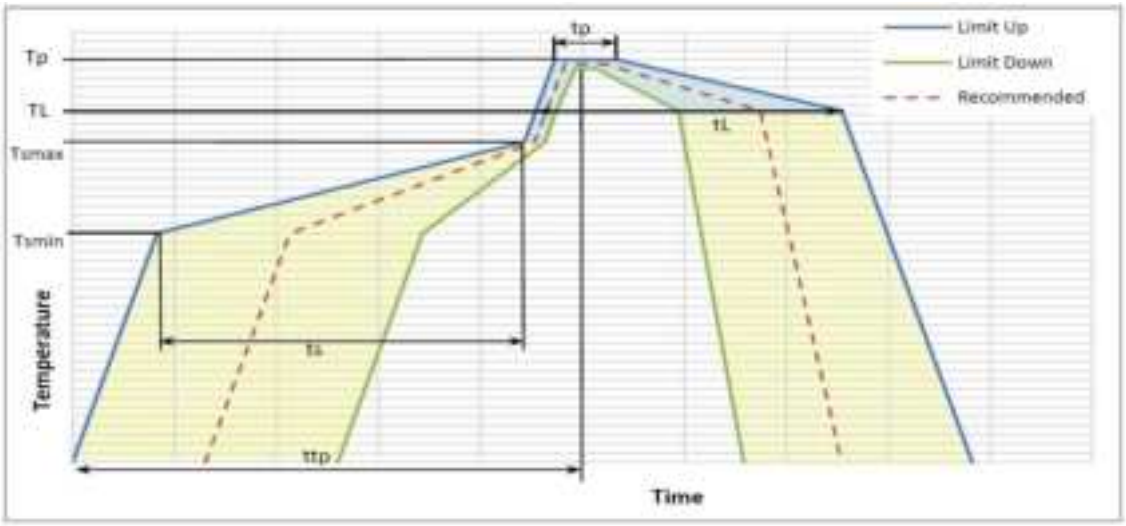


Figure 30: Recommended solder reflow profile

Warning: The above solder reflow profile represents the typical SAC reflow limits and does not guarantee adequate adherence of the module to the customer application throughout the temperature range. Customer must optimize the reflow profile depending on the overall system taking into account such factors as thermal mass and warpage.

Profile Feature	Pb-Free Assembly Free
Average ramp-up rate (T_L to T_P)	3°C/second max
Preheat **– Temperature Min (Tsmin)** **– Temperature Max (Tsmax)** **– Time (min to max) (ts)**	 150°C 200°C 60-180 seconds

Profile Feature	Pb-Free Assembly Free
Tsmax to TL – Ramp-up Rate	3°C/second max
Time maintained above: – Temperature (TL) – Time (tL)	217°C 60-150 seconds
Peak Temperature (Tp)	245 +0/-5°C
Time within 5°C of actual Peak Temperature (tp)	10-30 seconds
Ramp-down Rate	6°C/second max.
Time 25°C to Peak Temperature	8 minutes max.

Table 32: Profile feature recommendations

Note: All temperatures refer to topside of the package, measured on the package body surface.

Warning: THE ML865G1 MODULE WITHSTANDS ONE REFLOW PROCESS ONLY.

11. PACKAGING

It is possible to order in two packaging system:

- Package on tray
- Package on reel

11.1. Tray

The ML865G1 modules are packaged on trays of 40 pieces each. These trays can be used in SMT processes for pick & place handling.

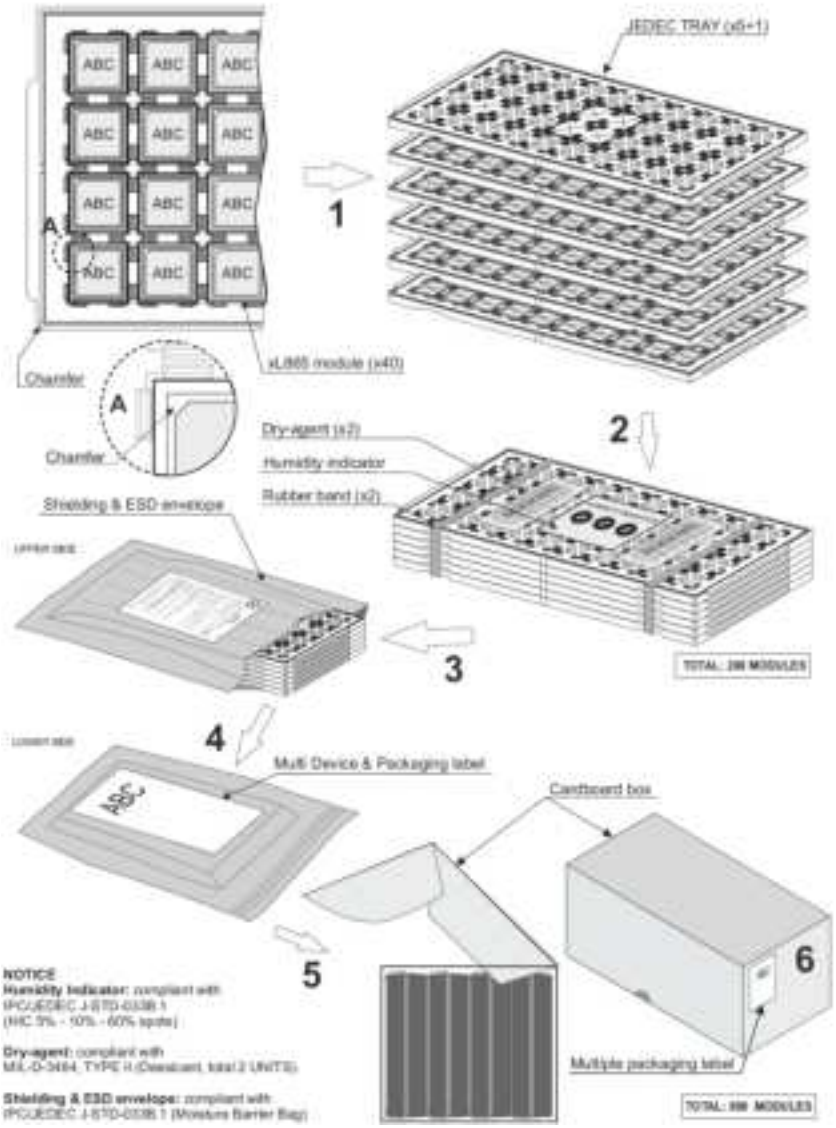


Figure 31: Tray packaging

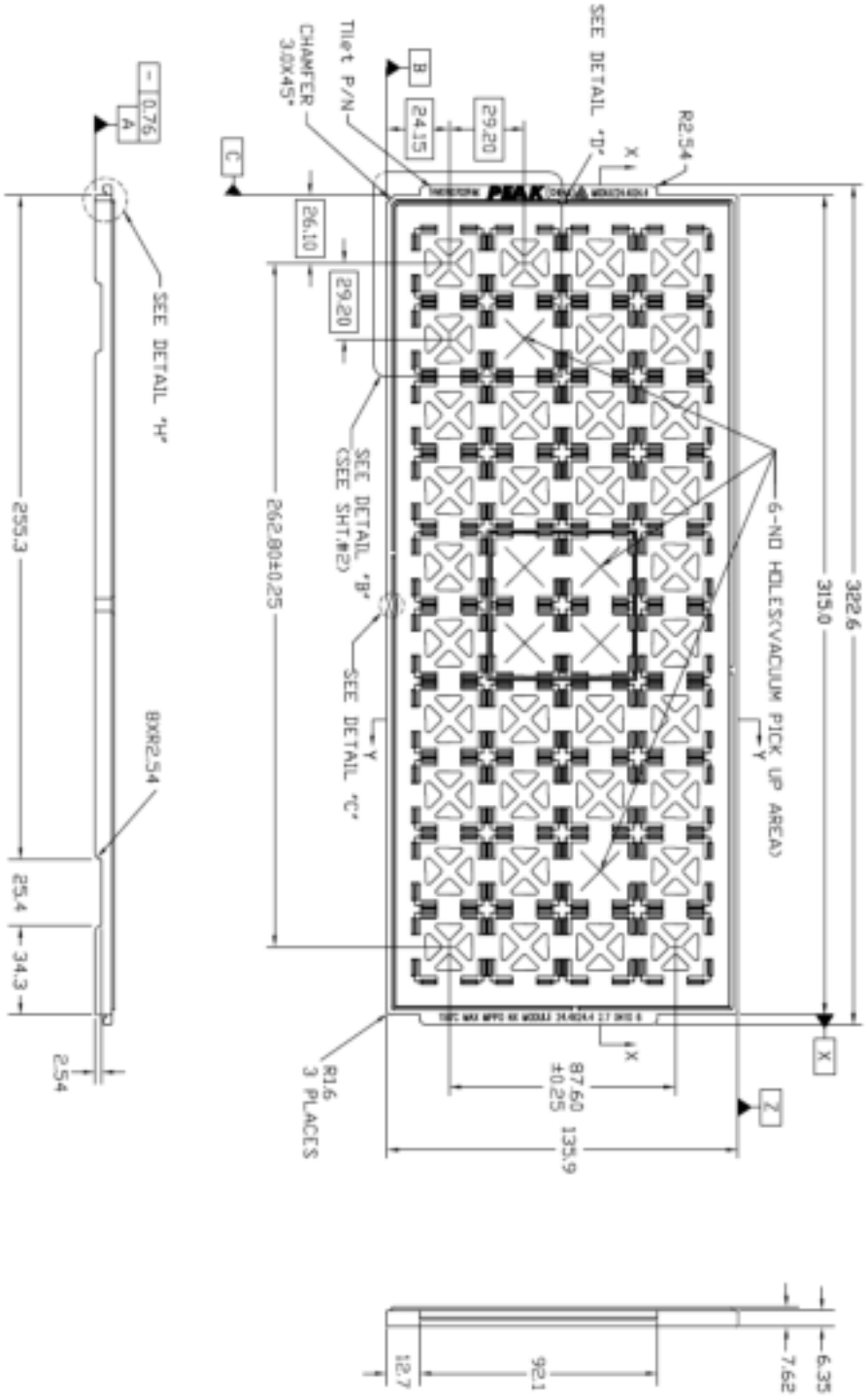


Figure 32: Tray dimensions

11.2. Reel

The ML865G1 can be packaged on reels of 200 pieces each.

See figure for module positioning into the carrier.

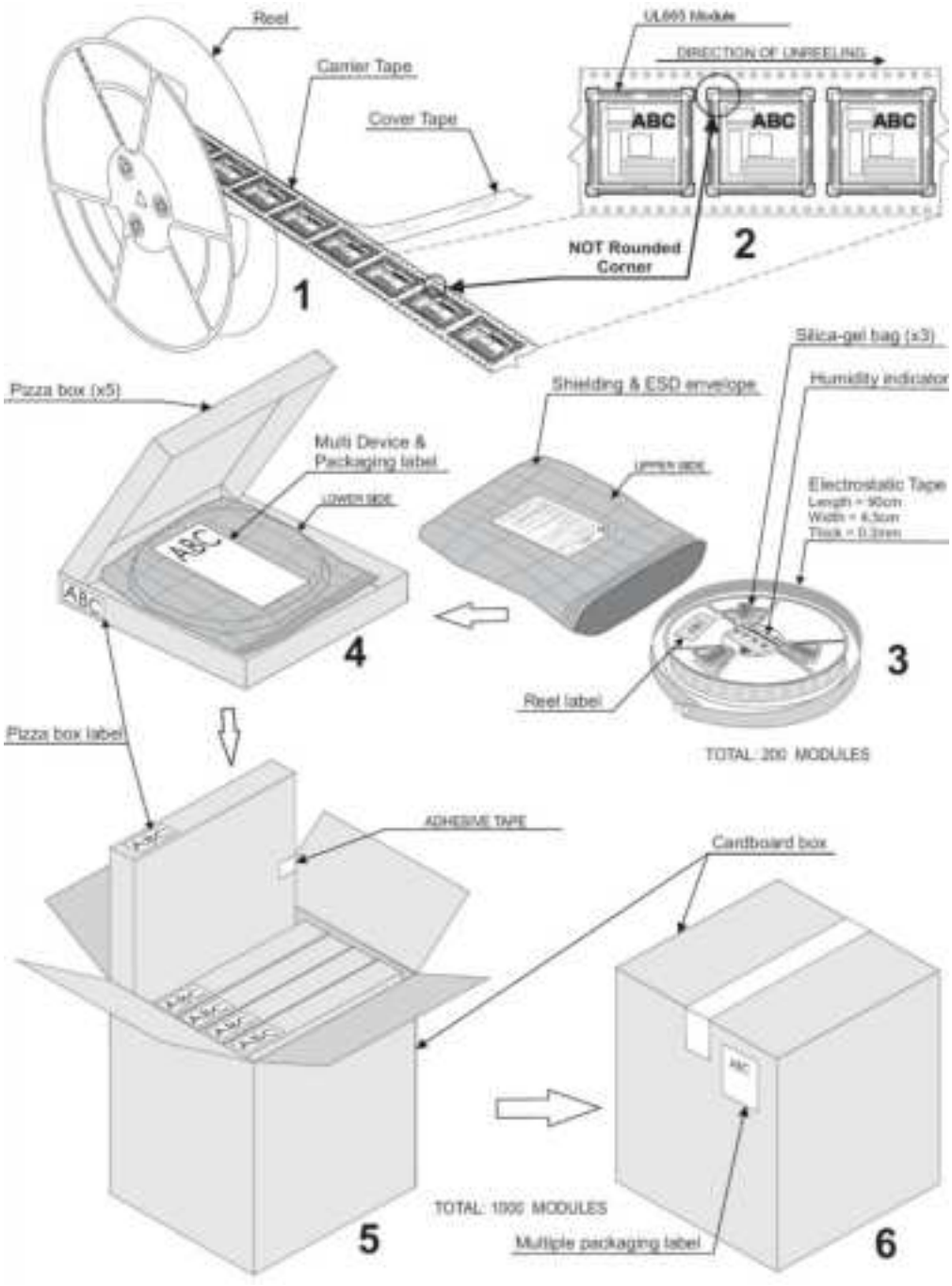


Figure 33: Module positioning into the carrier

11.3. Moisture sensitivity

The moisture sensitivity level of the Product is "3" according to the standard IPC/JEDEC J-STD-020, please take care of all related requirements for using this type of components.

Moreover, the customer must take care of the following conditions:

a) The shelf life of the Product inside of the dry bag is 12 months from the date the bag is sealed.

b) when stored in a non-condensing atmospheric environment of < 40°C and < 90% RH.

c) Environmental condition during production: <= 30°C / 60% RH according to

d) IPC/JEDEC J-STD-033B.

e) The maximum time between the opening the sealed bag and the reflow process must be

f) 168 hours if condition b) "IPC/JEDEC J-STD-033B paragraph 5.2" is respected.

g) Baking is required if conditions b) or c) are not respected

h) Baking is required if the humidity indicator inside the bag indicates 10% RH or more.

12. CONFORMITY ASSESSMENT ISSUES

12.1. Approvals summary

Module	EU RED	BR ANATEL	US FCC	CA ISED
ML865G1-WW	Yes	Yes	Yes	Yes

Table 33: Approvals summary

12.2. RED approval

12.2.1. RED Declaration of Conformity

Hereby, Telit Communications S.p.A declares that the ML865G1-WW Module is in compliance with Directive 2014/53/EU.

The full text of the EU declaration of conformity is available at the following internet address: *http://www.telit.com\red*

Text of 2014/53/EU Directive (RED) can be found here:

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0053

12.2.2. Antennas

This radio transmitter has been approved under RED to operate with the antenna types listed below with the maximum permissible gain indicated. The usage of a different antenna in the final hosting device may need a new assessment of host conformity to RED.

Model	Antenna Type
ML865G1-WW	Omnidirectional Antenna Gain 2.14 dBi

Table 34: RED Antenna Type

Band	ML865G1-WWV
GPRS/EGPRS 900	4.47
GPRS/EGPRS 1800	10.34
FDD 1	11.84
FDD 3	11.33

Band	ML865G1-WWV
FDD 8	8.45
FDD 20	8.20
FDD 28	7.47

Table 35: Max gain for RED (dBi)

12.3. FCC and ISED approval/*FCC et ISDE approbation*

12.3.1. FCC certificates

The FCC Certificate is available here:

https://www.fcc.gov/oet/ea/fccid

12.3.2. ISED Certificate/*ISDE certificates*

The ISED Certificate is available here / *Le certificat ISDE est disponible ici*:

https://sms-sgs.ic.gc.ca/equipmentSearch/searchRadioEquipments?execution=e1s1&lang=en

12.3.3. Applicable FCC and ISED rules/*Liste des règles FCC et ISDE applicables*

Model *Modèle*	Applicable FCC Rules	Applicable ISED Rules *Règles ISDE applicables*
ML865G1-WW	47 CFR Part 2, 22, 24, 27, 90	RSS: 132 Issue3, 133 Issue 6, 130 Issue 2, 139 Issue 3; RSS-Gen Issue 5

Table 36: Applicable FCC and ISED rules

12.3.4. FCC and ISED Regulatory notices/*Avis réglementaires de FCC et ISDE*

Modification statement / *Déclaration de modification*

Telit does not approve any changes or modifications to this device by the user. Any changes or modifications could void the user's authority to operate the equipment.

Telit n'approuve aucune modification apportée à l'appareil par l'utilisateur, quelle qu'en soit la nature. Tout changement ou modification peuvent annuler le droit d'utilisation de l'appareil par l'utilisateur.

Interference statement / *Déclaration d'interférence*

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

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

Wireless notice / *Wireless avis*

This device complies with FCC/ISED radiation exposure limits set forth for an uncontrolled environment and meets the FCC radio frequency (RF) Exposure Guidelines and RSS-102 of the ISED radio frequency (RF) Exposure rules. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter. The antenna should be installed and operated with minimum distance of 20 cm between the radiator and your body.

Le présent appareil est conforme à l'exposition aux radiations FCC / ISED définies pour un environnement non contrôlé et répond aux directives d'exposition de la fréquence de la FCC radiofréquence (RF) et RSS-102 de la fréquence radio (RF) ISED règles d'exposition. L'émetteur ne doit pas être colocalisé ni fonctionner conjointement avec à autre antenne ou autre émetteur. L'antenne doit être installée de façon à garder une distance minimale de 20 centimètres entre la source de rayonnements et votre corps.

FCC Class B digital device notice (FCC only)

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

CAN ICES-3 (B) / NMB-3 (B) (ISED only) / *(ISDE seulement)*

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

Cet appareil numérique de classe B est conforme à la norme canadienne ICES-003.

12.3.5. Antennas/Antennes

FCC

This radio transmitter has been approved by FCC and ISED to operate with the antenna types listed below with the maximum permissible gain indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Model	Antenna Type
ML865G1-WW	Omnidirectional Antenna Gain 2.14 dBi

Table 37: FCC Antenna Type

Max Gain for FCC (dBi)	
Band	ME910G1-W1
GPRS/EGPRS 850	5.4 / 10.4
GPRS/EGPRS 1900	7.0 / 10.0
FDD 2	8.0
FDD 4	5.0
FDD 5	9.4
FDD 12	8.6
FDD 13	9.1
FDD 25	8.0
FDD 26	9.3
FDD 66	5.0

Max Gain for FCC (dBi)	
FDD 71	11.4
FDD 85	8.6

Table 38: Max Gain for FCC (dBi)

ISED / *ISDE*

This radio transmitter has been approved by ISED to operate with the antenna types listed below with the maximum permissible gain indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Le présent émetteur radio a été approuvé par ISDE pour fonctionner avec les types d'antenne énumérés ci-dessous et ayant un gain admissible maximal. Les types d'antenne non inclus dans cette liste, et dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

Model *Modèle*	Antenna Type *Type d'Antenne*
ML865G1-WW	Omnidirectional Antenna Gain 2.14 dBi *Omnidirectionelle* *Gain de l'antenne 2.14 dBi*

Table 39: ISED Antenna Type

Gain maximum pour ISED (dBi) / *Gain maximum pour ISDE (dBi)*	
Bande	**ML865G1-WW**
GPRS/EGPRS 850	2.1 / 7.1
GPRS/EGPRS 1900	7.0 / 10.0
FDD 2	8.0
FDD 4	5.0
FDD 5	6.1
FDD 12	5.6
FDD 13	5.9
FDD 25	8.0
FDD 26	6.0
FDD 66	5.0

Gain maximum pour ISED (dBi) / *Gain maximum pour ISDE (dBi)*	
FDD 71	8.4
FDD 85	5.6

Table 40: Gain maximum for ISED (dBi)

12.3.6. FCC label and compliance information

The product has a FCC ID label on the device itself. Also, the OEM host end product manufacturer will be informed to display a label referring to the enclosed module The exterior label will read as follows: "Contains Transmitter Module FCC ID: RI7ML865G1WW" or "Contains FCC ID: RI7ML865G1WW".

Below list of all the models and related FCC ID:

Model	FCC ID
ML865G1-WW	RI7ML865G1WW

Table 41: FCC ID

12.3.7. ISED label and compliance information/ *Étiquette et informations de conformité ISDE*

The host product shall be properly labelled to identify the modules within the host product.

The ISED certification label of a module shall be clearly visible at all times when installed in the host product; otherwise, the host product must be labelled to display the ISED certification number for the module, preceded by the word "contains" or similar wording expressing the same meaning, as follows:

Contains IC: XXXXXX-YYYYYYYYYY

In this case, XXXXXX-YYYYYYYYYY is the module's certification number.

Le produit hôte devra être correctement étiqueté, de façon à permettre l'identification des modules qui s'y trouvent.

L'étiquette d'homologation d'un module d'ISDE devra être apposée sur le produit hôte à un endroit bien en vue, en tout temps. En l'absence d'étiquette, le produit hôte doit porter une étiquette sur laquelle figure le numéro d'homologation du module d'ISDE, précédé du mot « contient », ou d'une formulation similaire allant dans le même sens et qui va comme suit :

Contient IC : XXXXXX-YYYYYYYYYY

Dans ce cas, XXXXXX-YYYYYYYYYY est le numéro d'homologation du module.

Model *Modèle*	ISED Certification Number *Num. de certification ISDE*
ML865G1-WW	5131A-ML865G1WW

Table 42: ISED Certification Number

12.3.8. Information on test modes and additional testing requirements / *Informations sur les modes de test et les exigences de test supplémentaires*

The module has been evaluated in mobile stand-alone conditions. For different operational conditions from a stand-alone modular transmitter in a host (multiple, simultaneously transmitting modules or other transmitters in a host), additional testing may be required (collocation, retesting…)

If this module is intended for use in a portable device, you are responsible for separate approval to satisfy the SAR requirements of FCC Part 2.1093 and IC RSS-102.

Le module a été évalué dans des conditions autonomes mobiles. Pour différentes conditions de fonctionnement d'un émetteur modulaire autonome dans un hôte (plusieurs modules émettant simultanément ou d'autres émetteurs dans un hôte), des tests supplémentaires peuvent être nécessaires (colocalisation, retesting…)

Si ce module est destiné à être utilisé dans un appareil portable, vous êtes responsable de l'approbation séparée pour satisfaire aux exigences SAR de la FCC Partie 2.1093 et IC RSS-102.

12.3.9. FCC Additional testing, Part 15 Subpart B disclaimer

The modular transmitter is only FCC authorized for the specific rule parts (i.e., FCC transmitter rules) listed on the grant, and that the host product manufacturer is responsible for compliance to any other FCC rules that apply to the host not covered by the modular transmitter grant of certification. If the grantee markets their product as being Part 15 Subpart B compliant (when it also contains unintentional-radiator digital circuity), then the grantee shall provide a notice stating that the final host product still requires Part 15 Subpart B compliance testing with the modular transmitter installed. The end product with an embedded module may also need to pass the FCC Part 15 unintentional emission testing requirements and be properly authorized per FCC Part 15.

12.4. ANATEL Regulatory Notices

"Este equipamento não tem direito à proteção contra interferência prejudicial e não pode causar interferência em sistemas devidamente autorizados"

"This equipment is not entitled to protection against harmful interference and must not cause interference in duly authorized systems"

ME910G1-WW, ME310G1-WW, ML865G1-WW Homologation #: 08566-20-02618

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13.3. Safety Recommendations

Make sure the use of this product is allowed in your country and in the environment required. The use of this product may be dangerous and has to be avoided in areas where:

- it can interfere with other electronic devices, particularly in environments such as hospitals, airports, aircrafts, etc.
- there is a risk of explosion such as gasoline stations, oil refineries, etc. It is the responsibility of the user to enforce the country regulation and the specific environment regulation.

Do not disassemble the product; any mark of tampering will compromise the warranty validity. We recommend following the instructions of the hardware user guides for correct wiring of the product. The product has to be supplied with a stabilized voltage source and the wiring has to be conformed to the security and fire prevention regulations. The product has to be handled with care, avoiding any contact with the pins because electrostatic discharges may damage the product itself. Same cautions have to be taken for the SIM, checking carefully the instruction for its use. Do not insert or remove the SIM when the product is in power saving mode.

The system integrator is responsible for the functioning of the final product. Therefore, the external components of the module, as well as any project or installation issue, have to be handled with care. Any interference may cause the risk of disturbing the GSM network or external devices or having an impact on the security system. Should there be any doubt, please refer to the technical documentation and the regulations in force. Every module has to be equipped with a proper antenna with specific characteristics. The antenna has to be installed carefully in order to avoid any interference with other electronic devices and has to guarantee a minimum distance from the body (20 cm). In case this requirement cannot be satisfied, the system integrator has to assess the final product against the SAR regulation.

The equipment is intended to be installed in a restricted area location.

The equipment must be supplied by an external specific limited power source in compliance with the standard EN 62368-1:2014.

The European Community provides some Directives for the electronic equipment introduced on the market. All of the relevant information is available on the European Community website:

https://ec.europa.eu/growth/sectors/electrical-engineering_en

14. GLOSSARY

ADC	Analog – Digital Converter
CLK	Clock
CMOS	Complementary Metal – Oxide Semiconductor
CS	Chip Select
DAC	Digital – Analog Converter
DTE	Data Terminal Equipment
ESR	Equivalent Series Resistance
GPIO	General Purpose Input Output
HS	High Speed
HSDPA	High Speed Downlink Packet Access
HSIC	High Speed Inter Chip
HSUPA	High Speed Uplink Packet Access
I/O	Input Output
MISO	Master Input – Slave Output
MOSI	Master Output – Slave Input
MRDY	Master Ready
PCB	Printed Circuit Board
RTC	Real Time Clock
SIM	Subscriber Identification Module
SPI	Serial Peripheral Interface
SRDY	Slave Ready
TTSC	Telit Technical Support Centre
UART	Universal Asynchronous Receiver Transmitter
UMTS	Universal Mobile Telecommunication System
USB	Universal Serial Bus
VNA	Vector Network Analyzer
VSWR	Voltage Standing Wave Radio
WCDMA	Wideband Code Division Multiple Access

15. DOCUMENT HISTORY

Revision	Date	Changes
5	2021-07-26	Manual template update Chapter 12, RED update
4	2020-09-23	Section 2.5, TX Power update Section 2.8, Temperature ranges update
3	2020-07-22	Conformity assessment update with ANATEL
2	2020-07-01	Power consumption section 4.2 update ON/OFF/WAKE pin update, section 5 GNSS section 8 update RX sensitivity table update, section 2.6
1	2020-06-16	In the table of chapter 3.1 the "Auxiliary" section title has been changed in Auxiliary (USIF1). The title of chapter 5.8.4.2 has been changed from "Modem serial port 2" in "Modem serial port 2 (USIF1)". The title of chapter 5.8.4.1 has been changed from "Modem serial port 1" in "Modem serial port 1 (USIF0)".
0	2019-12-06	First issue

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