WIRELESS

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# TOBY-L1 series

## LTE modules

## System Integration Manual


### Abstract

This document describes the features and the system integration of TOBY-L1 series LTE wireless modules.

These modules are a complete and cost efficient 4G solution offering 100 Mb/s download, 50 Mb/s upload, and covering up to 3 LTE Bands in the compact TOBY form factor.



35.6 x 24.8 x 2.6 mm

| Document Information | |
|---|---|
| **Title** | TOBY-L1 series |
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| Document status information | |
|---|---|
| Objective Specification | This document contains target values. Revised and supplementary data will be published later. |
| Advance Information | This document contains data based on early testing. Revised and supplementary data will be published later. |
| Preliminary | This document contains data from product verification. Revised and supplementary data may be published later. |
| Released | This document contains the final product specification. |

**This document applies to the following products:**

| Name | Type number | Firmware version | PCN / IN |
|---|---|---|---|
| TOBY-L100 | TOBY-L100-00S-00 | G0.V.00.00.08 | |
| TOBY-L110 | TOBY-L110-00S-00 | G0.EE.00.00.08 | |

# Preface

## u-blox Technical Documentation

As part of our commitment to customer support, u-blox maintains an extensive volume of technical documentation for our products. In addition to our product-specific technical data sheets, the following manuals are available to assist u-blox customers in product design and development.

**AT Commands Manual:** This document provides the description of the supported AT commands by the TOBY-L1 series modules to verify all implemented functionalities.

**System Integration Manual:** This manual provides hardware design instructions and information on how to set up production and final product tests.

**Application Note:** document provides general design instructions and information that applies to all u-blox Wireless modules. See Related documents section for a list of Application Notes related to your Wireless Module.

## How to use this Manual

The TOBY-L1 series System Integration Manual provides the necessary information to successfully design and configure the u-blox wireless modules.

This manual has a modular structure. It is not necessary to read it from the beginning to the end.

The following symbols are used to highlight important information within the manual:

☞ An index finger points out key information pertaining to module integration and performance.

⚠ **A warning symbol indicates actions that could negatively impact or damage the module.**

## Questions

If you have any questions about u-blox Wireless Integration:

- Read this manual carefully.
- Contact our information service on the homepage http://www.u-blox.com
- Read the questions and answers on our FAQ database on the homepage http://www.u-blox.com

## Technical Support

### Worldwide Web

Our website (www.u-blox.com) is a rich pool of information. Product information, technical documents and helpful FAQ can be accessed 24h a day.

### By E-mail

Contact the closest Technical Support office by email. Use our service pool email addresses rather than any personal email address of our staff. This makes sure that your request is processed as soon as possible. You will find the contact details at the end of the document.

### Helpful Information when Contacting Technical Support

When contacting Technical Support, have the following information ready:

- Module type (e.g. TOBY-L100) and firmware version
- Module configuration
- Clear description of your question or the problem
- A short description of the application
- Your complete contact details

# Contents

# 1 System description

## 1.1 Overview

The TOBY-L1 series comprises LTE-only modules in the very small LGA form-factor (35.6 x 24.8 x 2.6 mm) that are easy to integrate in compact designs.

TOBY-L1 series wireless modules provide 4G LTE-only data communication supports up to three LTE-FDD bands:

- TOBY-L100 is designed for operation on the LTE Verizon network in North America (LTE bands 4, 13), and meets the requirements of Verizon network certification for LTE only devices.
- TOBY-L110 is designed for operation on the LTE European networks (LTE bands 3, 7, 20), and meets the requirements of European networks certification for LTE only devices.

LTE-only modules offer cost advantages compared to multi-mode (LTE/3G/2G) modules and are optimized for applications using only LTE networks. Additionally, the TOBY-L1 series modules are form-factor compatible with the popular u-blox wireless module families: this allows customers to take the maximum advantage of their hardware and software investments, and provides very short time-to-market.

The modules are dedicated for data transfer, supporting a high-speed USB 2.0 interface. With LTE Category 3 data rates of 100 Mb/s (downlink) and 50 Mb/s (uplink), the modules are ideal for applications requiring the highest data-rates and high-speed internet access. TOBY-L1 series modules are the perfect choice for consumer fixed-wireless terminals, mobile routers and gateways, and applications requiring video streaming. They are also optimally suited for industrial (M2M) applications, such as remote access to video cameras, digital signage, telehealth, security and surveillance systems.

TOBY-L1 series main features and interface are summarized in Table 1.

| Module | Region / Operator | LTE | | UMTS | GSM | GNSS | | Interfaces | | | | | | | | Audio | | Features | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LTE category | LTE bands | UMTS bands | GSM bands | GNSS receiver | CellLocate™ | UART | USB 2.0 | USB HSIC | RMII | SDIO | GPIO | Audio | MIMO 2x2 | CSFB | VoLTE | Embedded TCP/UDP stack | Embedded HTTP, FTP, SSL | FOTA |
| **TOBY-L100** | Verizon | 3 | 4, 13 | | | | | | 1 | | | | 6 | | • | | | | | • |
| **TOBY-L110** | Europe | 3 | 3, 7, 20 | | | | | | 1 | | | | 6 | | • | | | | | • |

**Table 1: TOBY-L1 series main features summary**

☞ GPIOs are not supported by initial FW release. Check FW release schedule.

Table 2 reports a summary of LTE characteristics of TOBY-L1 series modules.

| 4G LTE Characteristics |
|---|
| 3GPP Release 9 - Long Term Evolution (LTE)<br>Evolved Universal Terrestrial Radio Access (E-UTRA)<br>Frequency Division Duplex (FDD)<br>Multi-Input Multi-Output (MIMO) 2 x 2 antenna support |
| Band support:<br>• TOBY-L100:<br>o Band 4: 1710 - 1755MHz (Tx), 2110 - 2155 MHz (Rx)<br>o Band 13: 777 - 787 MHz (Tx), 746 - 756 MHz (Rx)<br>• TOBY-L110:<br>o Band 3: 1710 - 1785 MHz (Tx), 1805 - 1880 MHz (Rx)<br>o Band 7: 2500 - 2570 MHz (Tx), 2620 - 2690 MHz (Rx)<br>o Band 20: 832 - 862 MHz (Tx), 791 - 821 MHz (Rx) |
| Channel bandwidth:<br>• TOBY-L100<br>o Band 4: 1.4MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz<br>o Band 13: 10 MHz<br>• TOBY-L110:<br>o Band 3: 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz<br>o Band 7: 5 MHz, 10 MHz, 15 MHz, 20 MHz<br>o Band 20: 5 MHz, 10 MHz, 15 MHz, 20 MHz |
| Power class:<br>• Class 3 (+23 dBm) |
| Data rate:<br>• LTE category 3: up to 50 Mb/s Up-Link, 100 Mb/s Down-Link |
| Short Message Service (SMS):<br>• SMS via embedded IMS (IP Multimedia Subsystem) |

**Table 2: TOBY-L1 series LTE characteristics summary**

## 1.2 Architecture

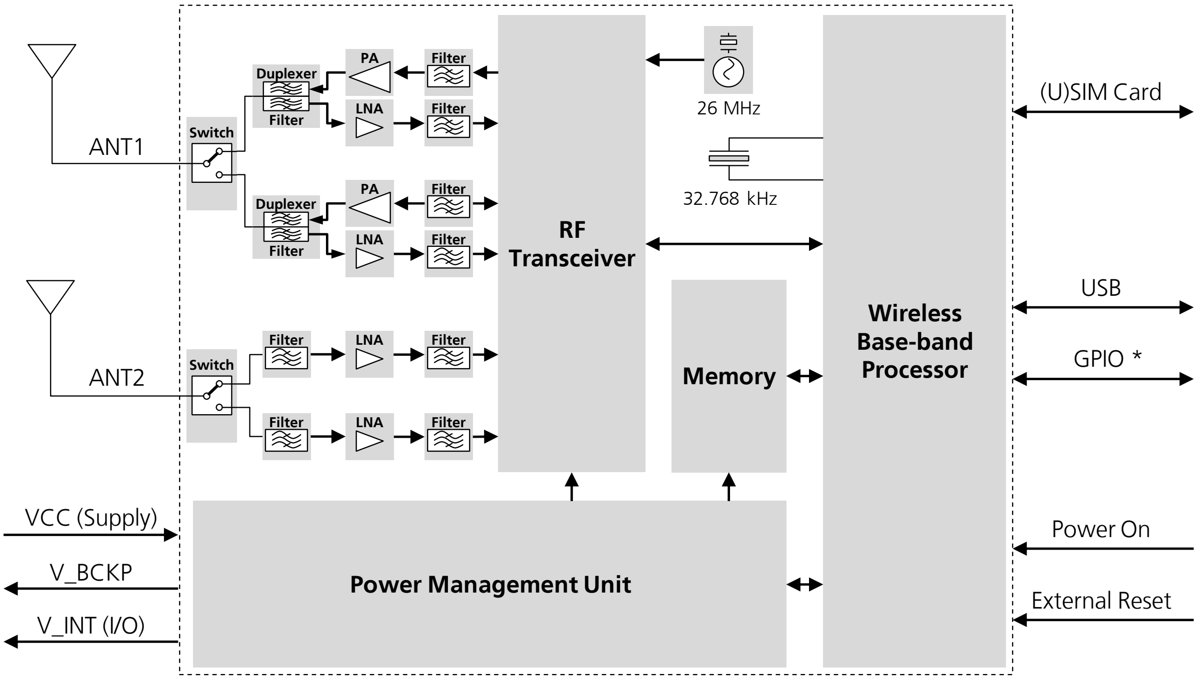


**Figure 1: TOBY-L100 block diagram**

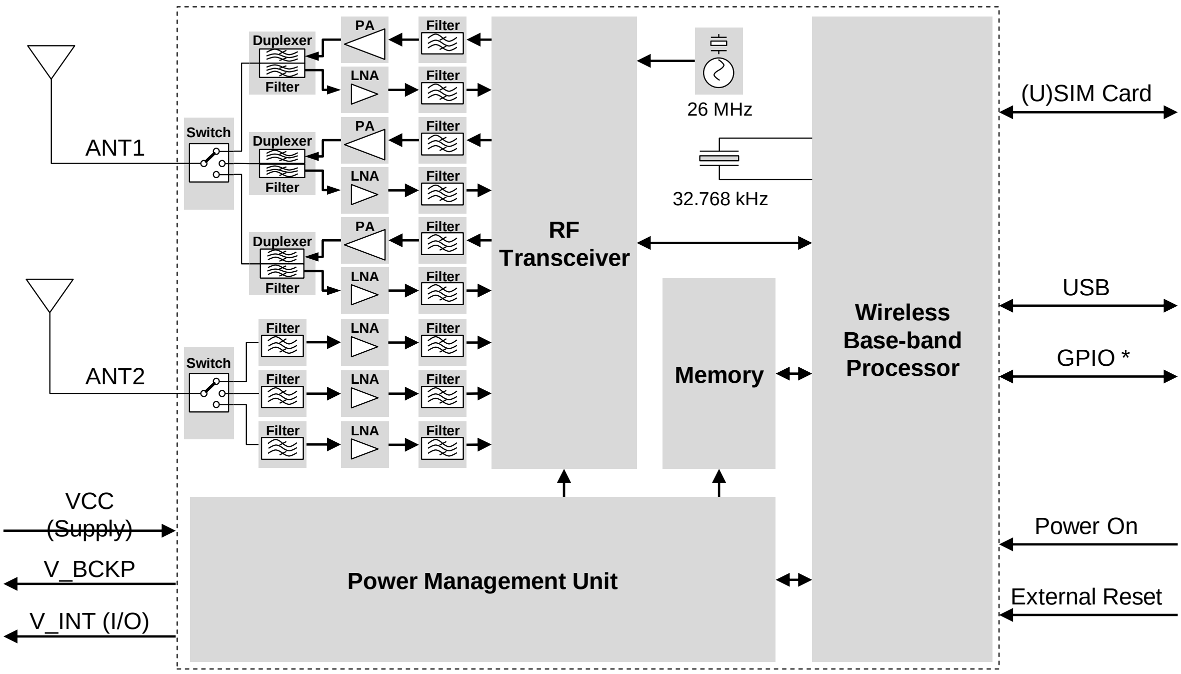


**Figure 2: TOBY-L110 block diagram**

☞ * = GPIOs are not supported by initial FW release.

### 1.2.1 Internal blocks

TOBY-L1 series modules consist of the following internal sections: RF, Baseband and Power Management.

**RF section**

The RF section is composed of RF transceiver, filters, LNAs, PAs, duplexers and antenna switches.

- FDD (frequency division duplex)RF transceiver performs modulation, up-conversion of the baseband I/Q signals for TX, down-conversion and demodulation of the dual RF signals received. The RF transceiver contains:
  - automatically gain controlled direct conversion Zero-IF receiver,
  - highly linear RF demodulator / modulator capable QPSK/16QAM/64QAM,
  - Fractional-N Sigma-Delta RF synthesizer,
  - VCO.

Tx signal is pre-amplified by RF transceiver, then connected to the primary antenna input/output port (**ANT1**) of the module via power amplifier (PA), band specific duplexer and antenna switch.

- Dual receiving paths are connected respectively to the primary (**ANT1**) and secondary (**ANT2**) antenna ports via duplexer SAW (band pass) filters
- 26 MHz crystal oscillator generates the clock reference in active-mode or connected-mode.

**Baseband section**

The Baseband section is composed of the following main elements:

- Baseband processors in a mixed signal ASIC, which integrates
  - microprocessor for control functions,
  - DSP core for LTE Layer 1 and digital processing of Rx and Tx signal paths,
  - memory interface controller,
  - dedicated peripheral blocks for control of the USB, USIM and GPIO digital interfaces,
  - analog front end interfaces to RF transceiver ASIC.
- Memory system, which includes NAND flash and LPDDR.

**Power Management section**

The Power Management section is composed of the following elements:

- Voltage regulators to derive all the system supply voltages from the module supply input **VCC**
- Voltage sources for external use: **V_BCKP** and **V_INT**
- Hardware power on
- Hardware reset
- Low power idle-mode support

TOBY-L1 series modules are provided with an internal 32.768 kHz crystal oscillator to provide the clock reference in the low power idle-mode, which can be set with power saving configuration enabled by the AT+UPSV command.

## 1.3 Pin-out

Table 3 lists the pin-out of the TOBY-L1 series modules, with pins grouped by function.

| Function | Pin Name | Module | Pin No | I/O | Description | Remarks |
|---|---|---|---|---|---|---|
| **Power** | **VCC** | All | 70,71,72 | I | Module supply input | **VCC** pins are internally connected each other.<br>**VCC** supply circuit affects the RF performance and compliance of the device integrating the module with applicable required certification schemes.<br>See section 1.5.1 for functional description and requirements for the **VCC** module supply.<br>See section 2.1.1 for external circuit design-in. |
| | **GND** | All | 2, 30, 32, 44, 46, 69, 73, 74, 76, 78, 79, 80, 82, 83, 85, 86, 88-90, 92-152 | N/A | Ground | **GND** pins are internally connected each other.<br>External ground connection affects the RF and thermal performance of the device.<br>See section 1.5.1 for functional description.<br>See section 2.1.1 for external circuit design-in. |
| | **V_BCKP** | All | 3 | O | RTC supply output | **V_BCKP** = 2.5 V (typical) generated by internal regulator when valid **VCC** supply is present.<br>See section 1.5.2 for functional description.<br>See section 2.1.2 for external circuit design-in. |
| | **V_INT** | All | 5 | O | Digital Interfaces supply output | **V_INT** = 1.8 V (typical) generated by internal regulator when the module is switched on.<br>See section 1.5.3 for functional description.<br>See section 2.1.3 for external circuit design-in. |
| **System** | **PWR_ON** | All | 20 | I | Power-on input | High impedance input: input voltage level has to be properly fixed, e.g. adding an external pull-up resistor to the **V_BCKP** output pin<br>See section 1.6.1 for functional description.<br>See section 2.2.1 for external circuit design-in. |
| | **RESET_N** | All | 23 | I | External reset input | It is internally pulled up to **V_BCKP** with a 10 kΩ resistor.<br>See section 1.6.3 for functional description.<br>See section 2.2.2 for external circuit design-in. |
| **RF** | **ANT1** | All | 81 | I/O | Primary antenna | Main Tx / Rx antenna interface.<br>50 Ω nominal characteristic impedance.<br>Antenna circuit affects the RF performance and compliance of the device integrating the module with applicable required certification schemes.<br>See section 1.7 for functional description and requirements for the antenna RF interface.<br>See section 2.3 for external circuit design-in. |
| | **ANT2** | All | 87 | I | Secondary antenna | Rx only for the MIMO 2x2 configuration.<br>50 Ω nominal characteristic impedance.<br>Antenna circuit affects the RF performance and compliance of the device integrating the module with applicable required certification schemes.<br>See section 1.7 for functional description and requirements for the antenna RF interface.<br>See section 2.3 for external circuit design-in. |

| Function | Pin Name | Module | Pin No | I/O | Description | Remarks |
|---|---|---|---|---|---|---|
| **SIM** | **VSIM** | All | 59 | O | SIM supply output | **VSIM** = 1.8 V / 3 V automatically generated according to the connected SIM type.<br>See section 1.8 for functional description.<br>See section 2.4 for external circuit design-in. |
| | **SIM_IO** | All | 57 | I/O | SIM data | Data input/output for 1.8 V / 3 V SIM<br>Internal 4.7 kΩ pull-up to **VSIM**.<br>See section 1.8 for functional description.<br>See section 2.4 for external circuit design-in. |
| | **SIM_CLK** | All | 56 | O | SIM clock | 5 MHz clock output for 1.8 V / 3 V SIM<br>See section 1.8 for functional description.<br>See section 2.4 for external circuit design-in. |
| | **SIM_RST** | All | 58 | O | SIM reset | Reset output for 1.8 V / 3 V SIM<br>See section 1.8 for functional description.<br>See section 2.4 for external circuit design-in. |
| **USB** | **USB_D-** | All | 27 | I/O | USB Data Line D- | 90 Ω nominal differential impedance ($Z_0$)<br>30 Ω nominal common mode impedance ($Z_{CM}$)<br>Pull-up or pull-down resistors and external series resistors as required by the USB 2.0 high-speed specification [4] are part of the USB pad driver and need not be provided externally.<br>See section 1.9.1 for functional description.<br>See section 2.5.1 for external circuit design-in. |
| | **USB_D+** | All | 28 | I/O | USB Data Line D+ | 90 Ω nominal differential impedance ($Z_0$)<br>30 Ω nominal common mode impedance ($Z_{CM}$)<br>Pull-up or pull-down resistors and external series resistors as required by the USB 2.0 high-speed specification [4] are part of the USB pad driver and need not be provided externally.<br>See section 1.9.1 for functional description.<br>See section 2.5.1 for external circuit design-in. |
| **GPIO** | **GPIO1** | All | 21 | I/O | GPIO | 1.8 V GPIO by default configured as pad disabled.<br>See section 1.10 for functional description.<br>See section 2.6 for external circuit design-in. |
| | **GPIO2** | All | 22 | I/O | GPIO | 1.8 V GPIO by default configured as pad disabled.<br>See section 1.10 for functional description.<br>See section 2.6 for external circuit design-in. |
| | **GPIO3** | All | 24 | I/O | GPIO | 1.8 V GPIO by default configured as pad disabled.<br>See section 1.10 for functional description.<br>See section 2.6 for external circuit design-in. |
| | **GPIO4** | All | 25 | I/O | GPIO | 1.8 V GPIO by default configured as pad disabled.<br>See section 1.10 for functional description.<br>See section 2.6 for external circuit design-in. |
| | **GPIO5** | All | 60 | I/O | GPIO | 1.8 V GPIO by default configured as pad disabled.<br>See section 1.10 for functional description.<br>See section 2.6 for external circuit design-in. |
| | **GPIO6** | All | 61 | I/O | GPIO | 1.8 V GPIO by default configured as pad disabled.<br>See section 1.10 for functional description.<br>See section 2.6 for external circuit design-in. |
| **Reserved** | **RSVD** | All | 1, 4, 6-19, 26, 29, 31, 33-43, 45, 47-55, 62-68, 75, 77, 84, 91 | N/A | RESERVED pin | Leave unconnected.<br>See section 2.7 |

**Table 3: TOBY-L1 series modules pin definition, grouped by function**

## 1.4 Operating modes

TOBY-L1 modules have several operating modes. The operating modes are defined in Table 4 and described in details in Table 5, providing general guidelines for operation.

| General Status | Operating Mode | Definition |
|---|---|---|
| **Power-down** | **Not-Powered Mode** | **VCC** supply not present or below operating range: module is switched off. |
| | **Power-Off Mode** | **VCC** supply within operating range and module is switched off. |
| **Normal Operation** | **Low Power-Mode** | Module processor core runs with 32 kHz reference, that is generated by:<br>• The internal 32 kHz oscillator |
| | **Idle-Mode** | Module processor core runs with 26 MHz reference generated by the internal oscillator. |
| | **Connected-Mode** | Data Connection enabled and processor core runs with 26 MHz reference. |

**Table 4: Module operating modes definition**

| Operating Mode | Description | Transition between operating modes |
|---|---|---|
| **Not-Powered Mode** | Module is switched off.<br>USB interface is not accessible. | When **VCC** supply is removed, the module enters not-powered mode.<br>When in not-powered mode, the module cannot be switched on by a low level on **PWR_ON** input.<br>When in not-powered mode, the module can be switched on after applying **VCC** supply (refer to 2.2.1) so that the module switches from not-powered to idle-mode. |
| **Power-Off Mode** | Module is switched off: normal shutdown by an appropriate power-off event (refer to 1.6.2).<br>USB interface is not accessible. | When the module is switched off by an appropriate power-off event (refer to 1.6.2), the module enters power-off mode from idle-mode.<br>When in power-off mode, the module can be switched on by a low level on **PWR_ON** input from power-off to idle-mode.<br>When **VCC** supply is removed, the module switches from power-off mode to not-powered mode. |
| **Idle-Mode** | The module is ready to communicate with an external device by means of the USB interface unless power saving configuration is enabled by the AT+UPSV command<br><br>Power saving configuration is not enabled by default: it can be enabled by the AT+UPSV command (see TOBY-L1xx AT Commands Manual [2]). | When the module is switched on by an appropriate power-on event (refer to 2.2.1), the module enters idle-mode from not-powered or power-off mode.<br><br>If power saving is enabled the module can transition from Idle-Mode to Power save-mode (refer to the TOBY-L1xx AT Commands Manual [2], AT+UPSV).<br><br>When a data Connection is initiated, the module switches from idle-mode to connected-mode. |
| **Power Save-Mode** | The module is ready to communicate with an external device by means of the USB interface<br><br>Power saving configuration is not enabled by default: it can be enabled by the AT+UPSV command (see TOBY-L1xx AT Commands Manual [2]). | When the module is commanded to enter power save-mode from idle-mode by AT+UPSV=1<br><br>When the module is commanded to disable power save-mode by AT+UPSV=0 |
| **Connected-Mode** | A data connection is in progress.<br>The module is ready to communicate with an external device by means of the USB interface unless power saving configuration is enabled by the AT+UPSV command (TOBY-L1xx AT Commands Manual [2]). | When a data connection is initiated, the module enters connected-mode from idle-mode.<br>When a data connection is terminated, the module returns to the idle-mode. |

| Operating Mode | Description | Transition between operating modes |
|---|---|---|
| **Airplane-Mode** | The module is ready to communicate with an external device by means of the USB interface. | When the module is commanded to enter airplane-mode from idle-mode by AT+CFUN=0 |
| | The module cannot register or connect to network. Purpose is to inhibit RF reception and transmission. | When the module is commanded to leave airplane-mode by AT+CFUN=1 |

**Table 5: Module operating modes description**

Figure 3 describes the transition between the different operating modes.

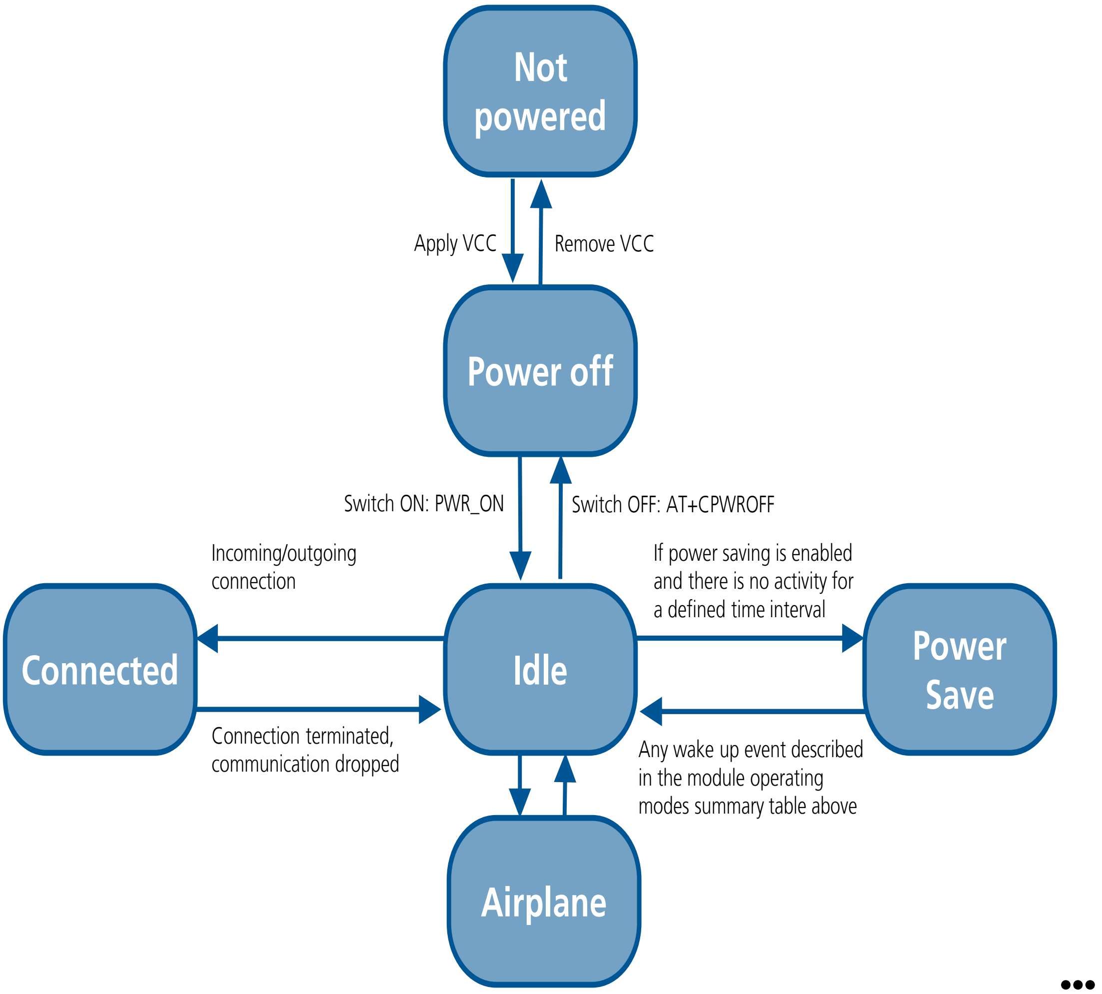


**Figure 3: Operating modes transition**

## 1.5 Supply interfaces

### 1.5.1 Module supply input (VCC)

TOBY-L1 modules must be supplied via the three **VCC** pins that represent the module power supply input.

The **VCC** pins are internally connected to the integrated Power Management Unit. All supply voltages needed by the module are generated from the **VCC** supply by integrated voltage regulators, including **V_BCKP** supply, **V_INT** digital interface supply and **VSIM** SIM card supply.

During operation, the current drawn by the TOBY-L1 series modules through the **VCC** pins can vary by several orders of magnitude. This range from the high peak of current consumption during LTE transmission bursts at maximum power level in connected-mode (as described in the chapter 1.5.1.2), to the low current consumption during low power save-mode with power saving enabled (as described in the chapter 1.5.1.3).

#### 1.5.1.1 VCC supply requirements

Table 6 summarizes the requirements for the **VCC** module supply. Refer to chapter 2.1.1 for all the suggestions to properly design a **VCC** supply circuit compliant to the requirements listed in Table 6.

⚠ **The VCC supply circuit affects the RF compliance of the device integrating TOBY-L1 series module with applicable required certification schemes as well as antenna circuit design. Compliance is guaranteed if the VCC requirements summarized in the Table 6 are fulfilled.**

| Item | Requirement | Remark |
|---|---|---|
| **VCC** nominal voltage | Within **VCC** normal operating range:<br>3.4 V min. / 4.50 V max. | The module cannot be switched on if **VCC** voltage value is below the normal operating range minimum limit.<br>Ensure that the input voltage at **VCC** pins is above the minimum limit of the normal operating range for at least 1 second before the module switch-on. |
| **VCC** average current | Considerably withstand maximum average current consumption value in connected-mode conditions specified in TOBY-L1 series Data Sheet [1]. | The maximum average current consumption can be greater than the specified value according to the actual antenna mismatching, temperature and **VCC** voltage.<br>Chapter 1.5.1.2 describes connected-mode current. |

**Table 6: Summary of VCC supply requirements**

#### 1.5.1.2 VCC current consumption in connected-mode

When a LTE connection is established, the **VCC** consumption is determined by the current consumption profile typical of the LTE transmitting and receiving bursts.

The current consumption peak during a transmission slot is strictly dependent on the transmitted power, which is reflected by the network conditions.

Figure 4 shows an example of the module current consumption profile versus time in LTE connected-mode.

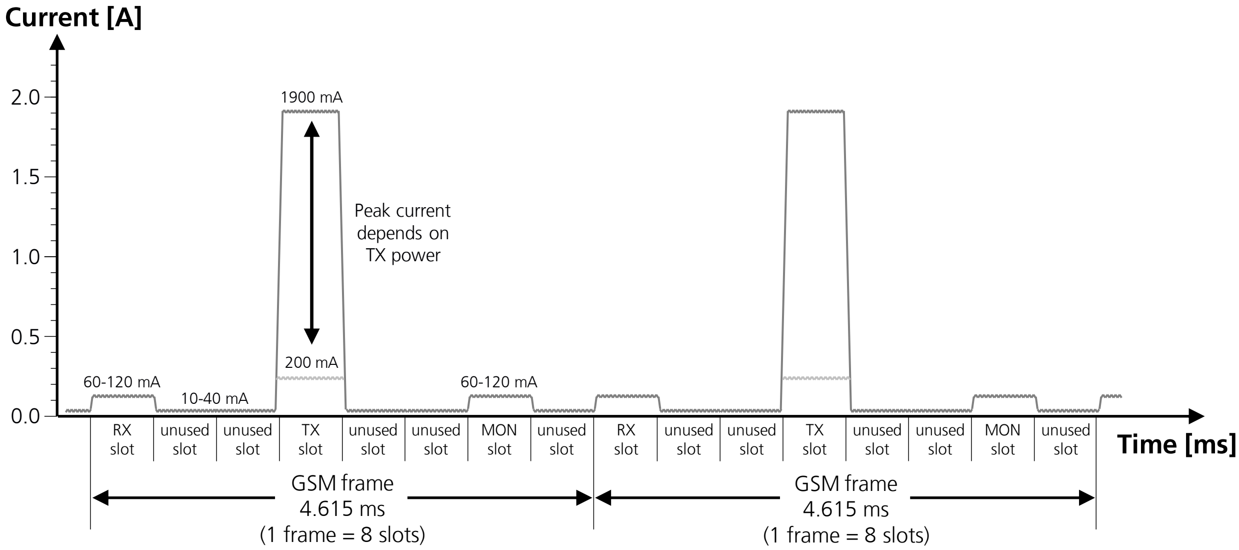


**Figure 4: VCC current consumption profile versus time during a LTE Connection (1 TX slot, 1 RX slot)**

### 1.5.1.3 VCC current consumption in power save-mode (power saving enabled)

The power saving configuration is by default disabled, but it can be enabled using the appropriate AT command (refer to TOBY-L1xx AT Commands Manual [2], AT+UPSV command). When power saving is enabled, the module automatically enters power save-mode whenever possible, reducing current consumption.

During power save-mode, the module processor runs with 32 kHz reference clock frequency.

When power saving is enabled, the module is registered or attached to a network and a data Connection is not enabled, the module automatically enters power save-mode whenever possible, but it must periodically monitor the paging channel of the current base station (paging block reception), in accordance to LTE system requirements. When the module monitors the paging channel, it wakes up to idle-mode, to enable the reception of paging block. In between, the module switches to power save-mode..

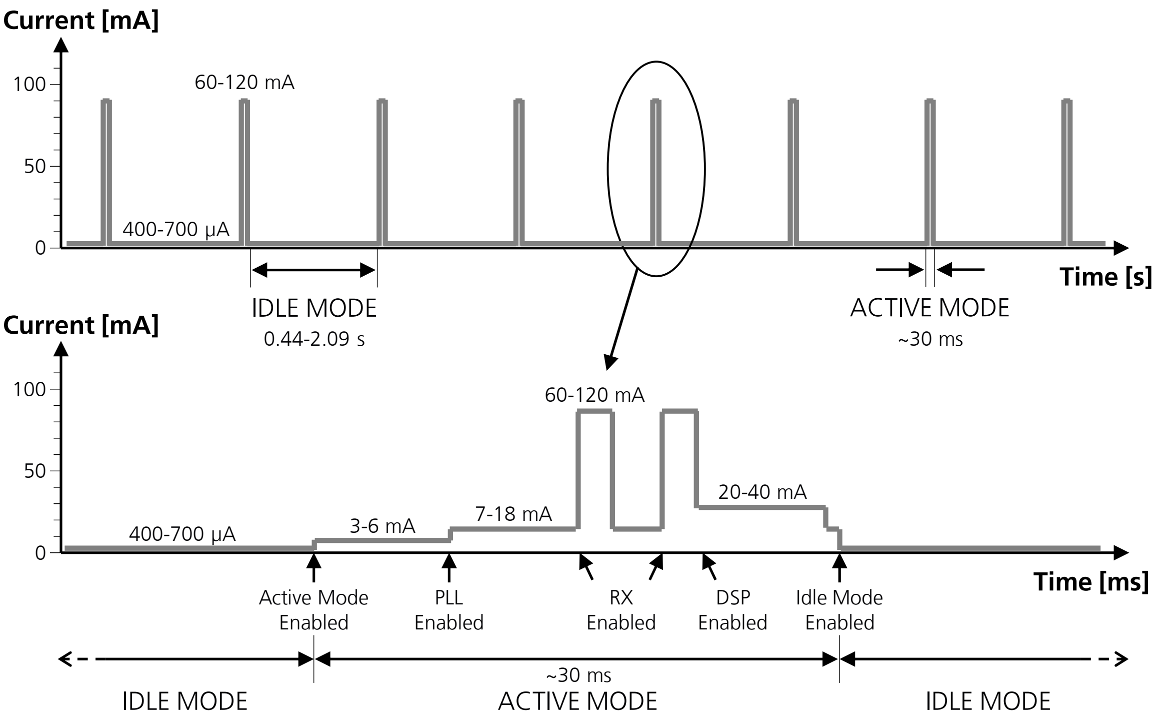


**Figure 5: Description of VCC current consumption profile versus time when the module is registered the network: the module is in idle-mode and periodically wakes up to active-mode to monitor the paging channel for paging block reception**

### 1.5.1.4 VCC current consumption in fixed active-mode (power saving disabled)

Power saving configuration is by default disabled, or it can be disabled using the appropriate AT command (refer to TOBY-L1xx AT Commands Manual [2], AT+UPSV command). When power saving is disabled, the module does not automatically enter power save-mode whenever possible: the module remains in idle-mode.

The module processor core is activated during idle-mode, and the 26 MHz reference clock frequency is used.

Figure 6 shows an example of the module current consumption profile when power saving is disabled: the module is registered with the network, idle-mode is maintained, and the receiver and the DSP are periodically activated to monitor the paging channel for paging block reception.

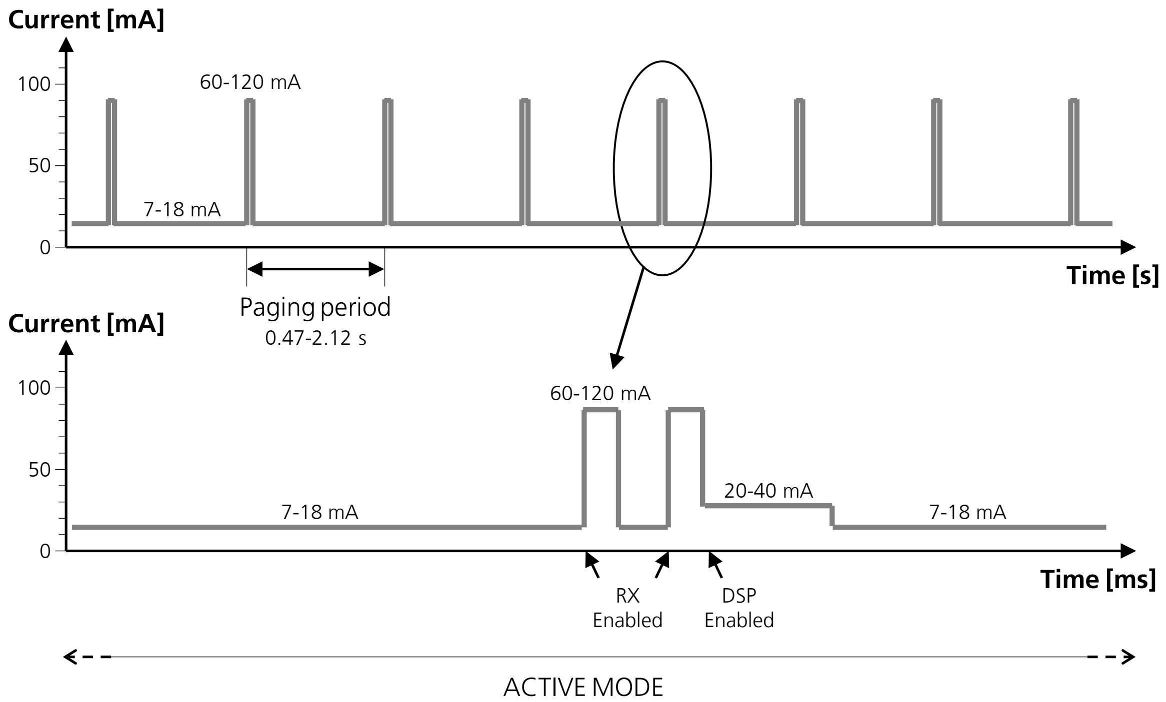


**Figure 6: Description of the VCC current consumption profile versus time when power saving is disabled: the active-mode is always held, and the receiver and the DSP are periodically activated to monitor the paging channel for paging block reception**

### 1.5.2 2.5V Supply Output (V_BCKP)

The **V_BCKP** pin of TOBY-L1 modules connected to internal 2.5v supply for customer use. This supply is internally generated by a linear LDO regulator integrated in the Power Management Unit, as shown in Figure 7. The output of this linear regulator is always enabled when the main voltage supply provided to the module through the **VCC** pins is within the valid operating range.

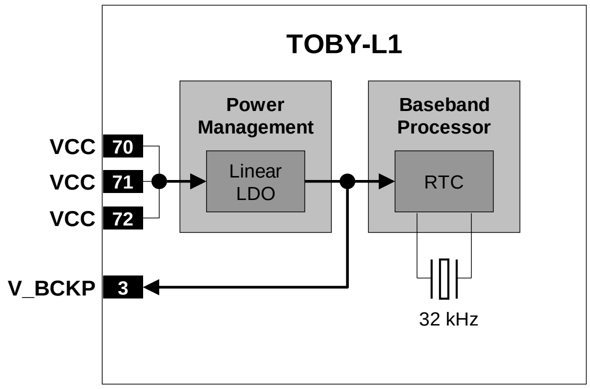


**Figure 7: TOBY-L1 series (V_BCKP) simplified block diagram**

### 1.5.3 1.8V Supply Output (V_INT)

The 1.8 V voltage supply used internally to source the digital interfaces of TOBY-L1 modules is also available on the **V_INT** supply output pin, as described in Figure 8.

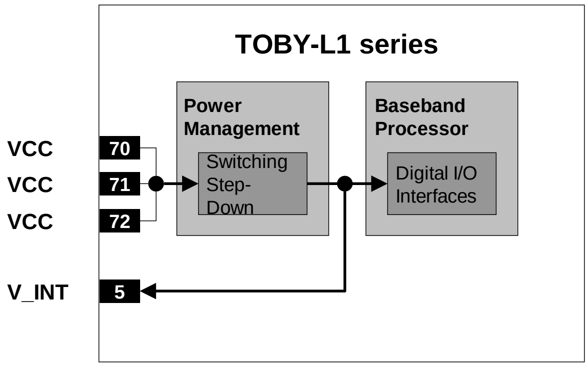


**Figure 8: TOBY-L1 series interfaces supply output (V_INT) simplified block diagram**

The internal regulator that generates the **V_INT** supply is a switching step-down converter that is directly supplied from **VCC**. The voltage regulator output is set to 1.8 V (typical) when the module is switched on and it is disabled when the module is switched off.

The switching regulator operates in Pulse Width Modulation (PWM) for greater efficiency at high output loads when the module is in connected-mode. When the module is in low power save-mode between paging periods and with power saving configuration enabled by the appropriate AT command, it automatically switches to a power save mode for greater efficiency at low output loads. Refer to the TOBY-L1xx AT Commands Manual [2], +UPSV command.

## 1.6 System function interfaces

### 1.6.1 Module power-on

The power-on sequence of TOBY-L1 series modules is initiated by

- Low level on the **PWR_ON** pin (normally high with external pull-up) for an appropriate time period.

#### 1.6.1.1 Low level on PWR_ON

When a TOBY-L1 module is in the power-off mode (i.e. switched off with valid **VCC** supply maintained), the module can be switched on by forcing a low level on the **PWR_ON** input pin for at least 5 seconds.

The input voltage thresholds are tolerant of voltages up to the module supply level. The detailed electrical characteristics are described in TOBY-L1 series Data Sheet [1].

There is no internal pull-up resistor on the **PWR_ON** pin: the pin has high input impedance and is weakly pulled to the high level by the internal circuit. Therefore the external circuit must be able to hold the high logic level stable, e.g. providing an external pull-up resistor (for further design-in guidelines refer to chapter 2.2.1).

#### 1.6.1.2 Additional considerations

The module can be switched on from power-off mode by forcing a proper start-up event (e.g. **PWR_ON** low). After the detection of a start-up event, all the module digital pins are held in tri-state until all the internal LDO voltage regulators are turned on in a defined power-on sequence. Anyway it is highly suggested to not force any logical state at pins input to avoid latch-up situations before the module is operational.

Then, as described in Figure 9, the baseband core is still held in reset state for a time interval: the internal reset signal (which is not available on a module pin) is still low and all the digital pins of the module are held in reset state. The reset state of all the digital pins is reported in the pin description table of TOBY-L1 Series Data Sheet [1]. When the internal signal is released, the configuration of the module interfaces starts: during this phase any digital pin is set in a proper sequence from the reset state to the default operational configuration.

After the internal reset is at high level, interface configuration sequence starts at that time we have to ensure low level on the **PWR_ON** for 5 seconds (worst case). Finally, the module is fully ready to operate when all interfaces are configured.

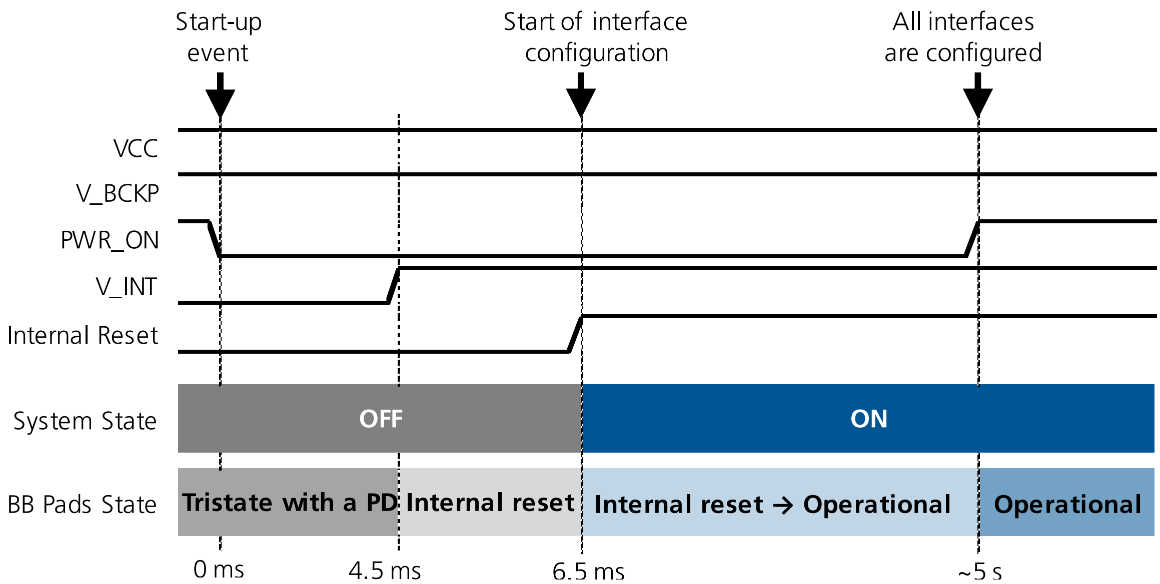


**Figure 9: TOBY-L1 series power-on sequence description**

☞ The Internal Reset signal is available as soon as low level on **PWR_ON** pin is applied, you can also monitor the **V_INT** pin to sense start of the TOBY-L1 series power-on sequence.

### 1.6.2 Module power-off

An under-voltage shutdown occurs on TOBY-L1 modules when the **VCC** supply is removed, but in this case the current parameter settings are not saved in the module's non-volatile memory and a proper network detach cannot be performed.

Figure 10 describes the power-off sequence by means of low level on **RESET_N** pin (normally high by internal pull-up). At the end of the switch-off routine, all digital pins are locked in tri-state by the module and all the internal LDO voltage regulators except **V_BCKP** are turned off in a defined power-off sequence. The module remains in power off mode as long as a switch on event does not occur (i.e. applying a low level on the **PWR_ON** pin), and enters not-powered mode if the supply is removed from the **VCC** pin.

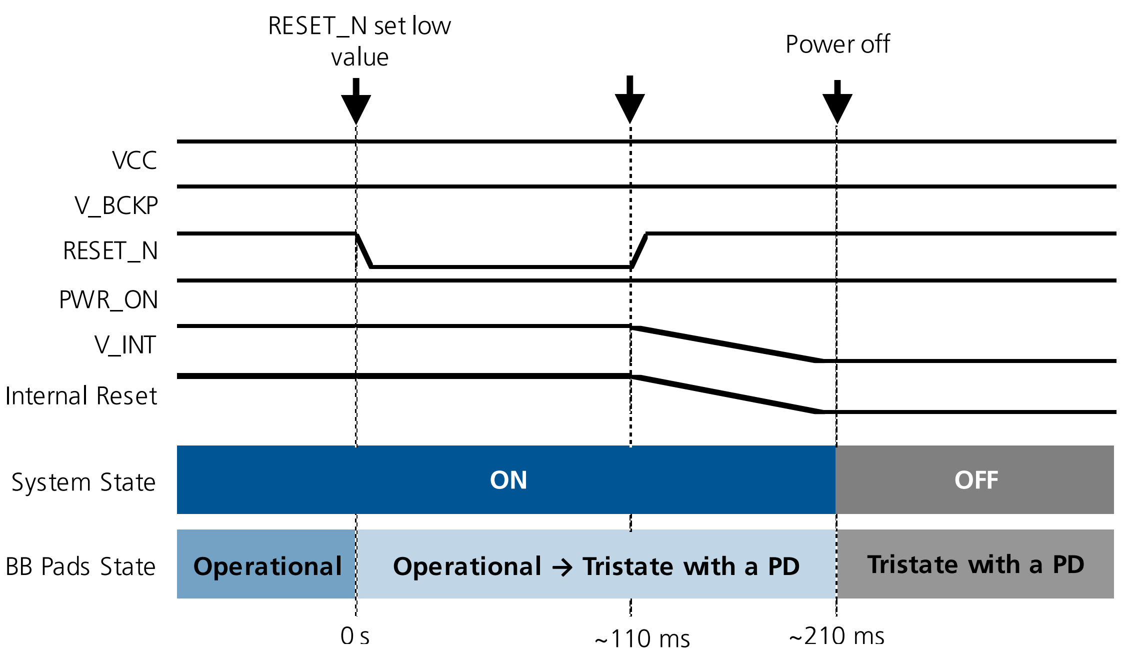


**Figure 10: TOBY-L1 series power-off sequence description**

### 1.6.3 Module reset

A TOBY-L1 module reset can be performed in one of two ways.

**RESET_N input pin**: Forces a low level on the **RESET_N** input pin, causing an "external" or "hardware" reset. This must be low for at least xx ms. This causes an asynchronous reset of the module baseband processor, excluding the integrated Power Management Unit. The **V_INT** interfaces supply is enabled and each digital pin is set in its reset state, the **V_BCKP** supply is enabled. Forcing an "external" or "hardware" reset, the current parameter settings are not saved in the module's non-volatile memory and a proper network detach is not performed.

**AT+CFUN command** (refer to the TOBY-L1xx AT Commands Manual [2] for more details): This command causes an "internal" or "software" reset, which is an asynchronous reset of the module baseband processor. The electrical behavior is the same as that of the "external" or "hardware" reset, but in an "internal" or "software" reset the current parameter settings are saved in the module's non-volatile memory and a proper network detach is performed.

After either reset, when **RESET_N** is released from the low level, the module automatically starts its power-on sequence from the reset state.

☞ The reset state of all digital pins is reported in the pin description table in TOBY-L1 series Data Sheet [1].

As described in Figure 11, the module has an internal pull-up resistor which pulls the line to the high logic level when the **RESET_N** pin is not forced low from the external. Detailed electrical characteristics are described in TOBY-L1 series Data Sheet [1].

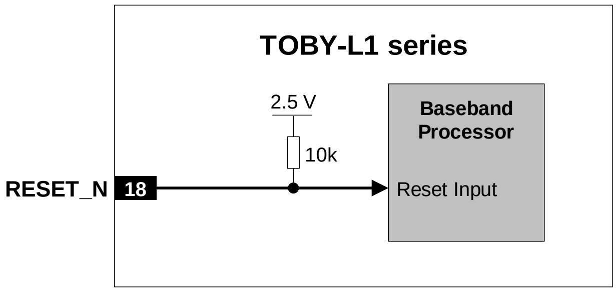


**Figure 11: TOBY-L1 series reset input (RESET_N) description**

## 1.7 Antenna interface

### 1.7.1 Antenna RF interfaces (ANT1 / ANT2)

The **ANT** pins of TOBY-L1 modules represents the RF input/output for transmission and reception of the LTE RF signals. The **ANT** pin has a nominal characteristic impedance of 50 Ω and must be connected to the antenna through a 50 Ω transmission line to allow proper RF transmission and reception in operating bands.

#### 1.7.1.1 Antenna RF interface requirements

Table 7 summarizes the requirements for the antenna RF interface (**ANT**). Refer to section 2.3.1 for suggestions to properly design an antenna circuit compliant to these requirements.

**The antenna circuit affects the RF compliance of the device integrating TOBY-L1 series module with applicable required certification schemes. Compliance is guaranteed if the antenna RF interface (ANT1 / ANT2 ) requirements summarized in Table 7 are fulfilled.**

| Item | Requirements | Remarks |
|---|---|---|
| **Impedance** | 50 Ω nominal characteristic impedance | The impedance of the antenna RF connection must match the 50 Ω impedance of the **ANT** pin. |
| **Frequency Range** | Module dependent | The required frequency range of the antenna depends on the operating bands of the used TOBY-L1 module and the used Mobile Network. |
| **V.S.W.R**<br>**Return Loss** | < 2:1 recommended, < 3:1 acceptable<br>$S_{11}$ < -10 dB recommended, $S_{11}$ < -6 dB acceptable | The impedance of the antenna termination must match as much as possible the 50 Ω impedance of the **ANT** pin over the operating frequency range. |
| **Input Power** | > 1 W peak | The antenna termination must withstand the maximum peak of power transmitted by TOBY-L1 modules. |
| **Gain** | Below the levels reported in the chapter 4.2.2 | The antenna gain must not exceed the herein specified value to comply with regulatory agencies radiation exposure limits. |

**Table 7: Summary of antenna RF interface (ANT) requirements**

## 1.8 SIM interface

### 1.8.1 SIM card interface

TOBY-L1 modules provide high-speed SIM/ME interface including automatic detection and configuration of the voltage required by the connected SIM card or chip.

Both 1.8 V and 3 V SIM types are supported: activation and deactivation with automatic voltage switch from 1.8 V to 3 V is implemented, according to ISO-IEC 7816-3 specifications. The **VSIM** supply output pin provides internal short circuit protection to limit start-up current and protect the device in short circuit situations.

The SIM driver supports the PPS (Protocol and Parameter Selection) procedure for baud-rate selection, according to the values determined by the SIM Card.

SIM Application Toolkit (R99) is supported.

### 1.8.2 SIM card detection

The SIM card detection function determined via firmware after power on of module.

## 1.9 Serial interfaces

TOBY-L1 series modules provide the following serial communication interface:

- USB interface: 4-wire

### 1.9.1 USB

TOBY-L1 modules provide a high-speed USB interface at 480 Mb/s compliant with the Universal Serial Bus Revision 2.0 specification [4]. It acts as a USB device and can be connected to any USB host such as a PC or other Application Processor.

The USB-device shall look for all upper-SW-layers like any other serial device. This means that TOBY-L series modules emulate all serial control logical lines.

| Name | Description | Remarks |
|---|---|---|
| **USB_D+** | USB Data Line D+ | 90 Ω nominal differential characteristic impedance ($Z_0$)<br>30 Ω nominal common mode characteristic impedance ($Z_{CM}$)<br>Pull-up or pull-down resistors and external series resistors as required by the USB 2.0 high-speed specification [4] are part of the USB pad driver and need not be provided externally. |
| **USB_D-** | USB Data Line D- | 90 Ω nominal differential characteristic impedance ($Z_0$)<br>30 Ω nominal common mode characteristic impedance ($Z_{CM}$)<br>Pull-up or pull-down resistors and external series resistors as required by the USB 2.0 high-speed specification [4] are part of the USB pad driver and need not be provided externally. |

**Table 8: USB pins**

☞ The USB interface pins ESD sensitivity rating is 1 kV (Human Body Model according to JESD22-A114F). Higher protection level could be required if the lines are externally accessible on the application board. Higher protection level can be achieved by mounting a very low capacitance (i.e. less or equal to 1 pF) ESD protection (e.g. Tyco Electronics PESD0402-140 ESD protection device) on the lines connected to these pins, close to accessible points.

#### 1.9.1.1 USB features

TOBY-L1 modules simultaneously supports 3 USB CDC (Communications Device Class) that assure multiple functionalities to the USB physical interface. The 3 available CDCs are configured as described in the following list:

- USB1: Remote NDIS based Internet Sharing Device ( Ethernet connection )
- USB2: Gadget Serial ( AT Commands )
- USB3: Multifunction Gadget with multiple configurations

The module firmware can be upgraded over the USB interface using the u-blox EasyFlash tool Firmware Update Application Note [11]).

USB CDC/ACM drivers are available for the following operating system platforms:

- Windows XP
- Windows 7
- Standard Linux/Android USB kernel drivers

TOBY-L1 module identifies itself by its VID (Vendor ID) and PID (Product ID) combination, included in the USB device descriptor.

VID and PID of TOBY-L1 modules are the following:

- VID = 0x1546
- PID = 0x1131 for TOBY-L100 series
- PID = 0x1131 for TOBY-L110 series

#### 1.9.1.2 USB and power saving

If power saving is enabled by AT command (AT+UPSV=1), the TOBY-L1 module automatically enters the USB suspended state when the device has observed no bus traffic for a specified period (refer to the Universal Serial Bus Revision 2.0 specification [4]). In suspended state, the module maintains any internal status as USB device, including its address and configuration. In addition, the module enters the suspended state when the hub port it is attached to is disabled: this is referred to as USB selective suspend. The module exits suspend mode when there is bus activity.

TOBY-L1 module is capable of USB remote wake-up signaling: i.e. may request the host to exit suspend mode or selective suspend by using electrical signaling to indicate remote wake-up. This notifies the host that it should resume from its suspended mode, if necessary, and service the external event that triggered the suspended USB device to signal the host. Remote wake-up is accomplished using electrical signaling described in the Universal Serial Bus Revision 2.0 specification [4].

When the USB enters suspended state, the average **VCC** module current consumption of TOBY-L1 module is ~400 µA higher then when the USB is not attached to a USB host.

If power saving is disabled by AT+UPSV=0 and the TOBY-L1 module is attached to a USB host as USB device, is configured and is not suspended, the average **VCC** module current consumption in fixed active mode is increased to ~40 mA.

## 1.10 General Purpose Input/Output (GPIO)

☞ TOBY-L1 modules may support functionality in future software release.

## 1.11 Reserved pins (RSVD)

TOBY-L1 modules have pins reserved for future use: they can all be left unconnected on the application board.

## 1.12 System features

### 1.12.1 Network indication

☞ Not supported by TOBY-L1 modules.

### 1.12.2 TCP/IP and UDP/IP

Via the AT commands it is possible to access the TCP/IP and UDP/IP functionalities over the Packet Switched data connection. For more details about AT commands see the TOBY-L1xx AT Commands Manual [2].

Using the embedded TCP/IP or UDP/IP stack, only 1 IP instance (address) is supported. The IP instance supports up to 7 sockets. Using an external TCP/IP stack (on the application processor), it is possible to have 3 IP instances (addresses).

Direct Link mode for TCP and UDP sockets is supported. Sockets can be set in Direct Link mode to establish a transparent end-to-end communication with an already connected TCP or UDP socket via serial interface. In Direct Link mode, data sent to the serial interface from an external application processor is forwarded to the network and vice-versa.

To avoid data loss while using Direct Link, enable HW flow control on the serial interface.

### 1.12.3 FTP

TOBY-L1 modules support the File Transfer Protocol functionalities via AT commands. Files are read and stored in the local file system of the module. For more details about AT commands see the TOBY-L1xx AT Commands Manual [2].

### 1.12.4 HTTP

HTTP client is implemented in TOBY-L1 modules: HEAD, GET, POST, DELETE and PUT operations are available. The file size to be uploaded / downloaded depends on the free space available in the local file system (FFS) at the moment of the operation. Up to 4 HTTP client contexts can simultaneously be used.

For more details about AT commands see the TOBY-L1xx AT Commands Manual [2].

### 1.12.5 SMTP

☞ Not supported by TOBY-L1 modules.

### 1.12.6 Firmware upgrade Over The Air (FOTA)

This feature allows upgrading the module Firmware over the air, i.e. over the LTE network. The main idea with updating Firmware over the air is to reduce the amount of data required for transmission to the module. This is achieved by downloading only a “delta file” instead of the full firmware. The delta contains only the differences between the two firmware versions (old and new), and is compressed.

For more details, refer to the Firmware Update Application Note [11].

### 1.12.7 Power saving

The power saving configuration is by default disabled, but it can be enabled using the AT+UPSV command. When power saving is enabled, the module automatically enters the low power save-mode whenever possible, reducing current consumption.

During low power save-mode, the module is not ready to communicate with an external device by means of the USB interface, since it is configured to reduce power consumption. It can be woken up from power save-mode to idle-mode by the connected application processor or by network activities, as described in the Table 5.

During power save-mode, the module processor core runs on the 32 kHz reference clock.

For the complete description of the AT+UPSV command, refer to the TOBY-L1xx AT Commands Manual [2].

For the definition and the description of TOBY-L1 series modules operating modes, including the events forcing transitions between the different operating modes, refer to the chapter 1.4.

For the description of current consumption in idle and active operating modes, refer to chapters 1.5.1.2, 1.5.1.4.

# 2 Design-in

For an optimal integration of TOBY-L1 modules in the final application board follow the design guidelines stated in this chapter.

Every application circuit must be properly designed to guarantee the correct functionality of the relative interface, however a number of points require high attention during the design of the application device.

The following list provides a ranking of importance in the application design, starting from the highest relevance:

1. Module antenna connection: **ANT1** and **ANT2** pins. Antenna circuit directly affects the RF compliance of the device integrating TOBY-L1 module with applicable certification schemes. Very carefully follow the suggestions provided in the relative chapter 2.3 for schematic and layout design.
2. Module supply: **VCC** and **GND** pins. The supply circuit affects the RF compliance of the device integrating TOBY-L1 module with applicable required certification schemes as well as antenna circuit design. Very carefully follow the suggestions provided in the relative chapter 2.1.1 for schematic and layout design.
3. SIM card interface: **VSIM**, **SIM_CLK**, **SIM_IO**, **SIM_RST** pins. Accurate design is required to guarantee SIM card functionality reducing the risk of RF coupling. Carefully follow the suggestions provided in the relative chapter 2.4 for schematic and layout design.
4. System functions: **RESET_N**, **PWR_ON** pins. Accurate design is required to guarantee that the voltage level is well defined during operation. Carefully follow the suggestions provided in the relative chapter 2.2 for schematic and layout design.
5. Other supplies: the **V_BCKP** supply output and the **V_INT** digital interfaces supply output. Accurate design is required to guarantee proper functionality. Follow the suggestions provided in the relative chapters 2.1.2 and 2.1.3 for schematic and layout design.

## 2.1 Supply interfaces

### 2.1.1 Module supply (VCC)

#### 2.1.1.1 General guidelines for VCC supply circuit selection and design

**VCC** pins are internally connected, but connect all the available pads to the external supply to minimize the power loss due to series resistance.

**GND** pins are internally connected but connect all the available pads to solid ground on the application board, since a good (low impedance) connection to external ground can minimize power loss and improve RF and thermal performance.

TOBY-L1 modules must be supplied through the **VCC** pins by a proper DC power supply that should meet the following prerequisites to comply with the module **VCC** requirements summarized in Table 6.

The proper DC power supply can be selected according to the application requirements (see Figure 12) between the different possible supply sources types, which most common ones are the following:

- Switching regulator
- Low Drop-Out (LDO) linear regulator
- Rechargeable Lithium-ion (Li-Ion) or Lithium-ion polymer (Li-Pol) battery
- Primary (disposable) battery

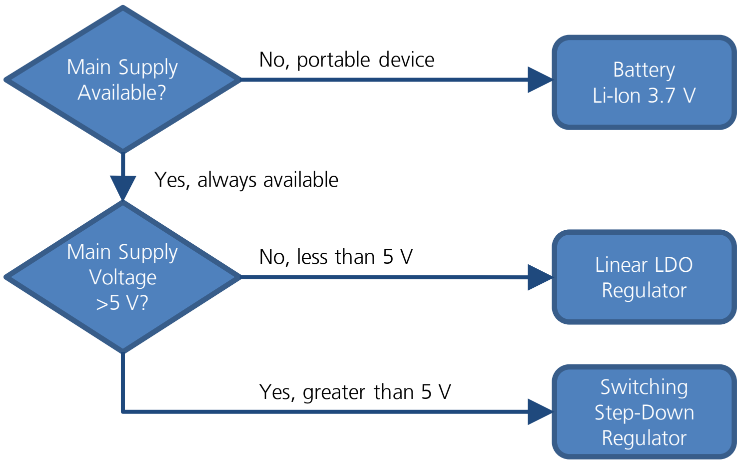


**Figure 12: VCC supply concept selection**

The switching step-down regulator is the typical choice when the available primary supply source has a nominal voltage much higher (e.g. greater than 5 V) than the TOBY-L1 modules operating supply voltage. The use of switching step-down provides the best power efficiency for the overall application and minimizes current drawn from the main supply source.

The use of an LDO linear regulator becomes convenient for a primary supply with a relatively low voltage (e.g. less than 5 V). In this case the typical 90% efficiency of the switching regulator diminishes the benefit of voltage step-down and no true advantage is gained in input current savings. On the opposite side, linear regulators are not recommended for high voltage step-down as they dissipate a considerable amount of energy in thermal power.

If TOBY-L1 modules are deployed in a mobile unit where no permanent primary supply source is available, then a battery will be required to provide **VCC**. A standard 3-cell Li-Ion or Li-Pol battery pack directly connected to **VCC** is the usual choice for battery-powered devices. During charging, batteries with Ni-MH chemistry typically reach a maximum voltage that is above the maximum rating for **VCC**, and should therefore be avoided.

The use of primary (not rechargeable) battery is uncommon, since the most cells available are seldom capable of delivering the burst peak current for a LTE Connection due to high internal resistance.

Keep in mind that the use of batteries requires the implementation of a suitable charger circuit (not included in TOBY-L1 modules). The charger circuit should be designed in order to prevent over-voltage on **VCC** beyond the upper limit of the absolute maximum rating.

The usage of more than one DC supply at the same time should be carefully evaluated: depending on the supply source characteristics, different DC supply systems can result as mutually exclusive.

The usage of a regulator or a battery not able to withstand the maximum peak current consumption specified in the TOBY-L1 series Data Sheet [1] is generally not recommended. However, if the selected regulator or battery is not able to withstand the maximum peak current of the module, it must be able to considerably withstand at least the maximum average current consumption value specified in the TOBY-L1 series Data Sheet [1], and the additional energy required by the module during a LTE Tx slot (when the current consumption can rise up to 1.9 A in the worst case, as described in section 1.5.1.2) could be provided by a proper bypass tank capacitor with very large capacitance and very low ESR (depending on the actual capability of the selected regulator or battery, the required capacitance can be considerably larger than 1 mF) placed close to the module **VCC** pins. Carefully evaluate the implementation of this solution since the aging and temperature conditions highly affects the actual capacitors characteristics.

The following sections highlight some design aspects for each of the supplies listed above providing application circuit design-in compliant with the module **VCC** requirements summarized in Table 6.

#### 2.1.1.2 Guidelines for VCC supply circuit design using a switching regulator

The use of a switching regulator is suggested when the difference from the available supply rail to the **VCC** value is high: switching regulators provide good efficiency transforming a 12 V or greater voltage supply to the typical 3.8 V value of the **VCC** supply.

The characteristics of the switching regulator connected to **VCC** pins should meet the following prerequisites to comply with the module **VCC** requirements summarized in Table 6:

- **Power capability**: the switching regulator with its output circuit must be capable of providing a voltage value to the **VCC** pins within the specified operating range and must be capable of delivering 1.9 A current pulses with 1/8 duty cycle to the **VCC** pins
- **Low output ripple**: the switching regulator together with its output circuit must be capable of providing a clean (low noise) **VCC** voltage profile
- **High switching frequency:** for best performance and for smaller applications select a switching frequency ≥ 600 kHz (since L-C output filter is typically smaller for high switching frequency). The use of a switching regulator with a variable switching frequency or with a switching frequency lower than 600 kHz must be carefully evaluated since this can produce noise in the **VCC** voltage profile and therefore negatively impact LTE modulation spectrum performance. An additional L-C low-pass filter between the switching regulator output to **VCC** supply pins can mitigate the ripple on **VCC**, but adds extra voltage drop due to resistive losses on series inductors
- **PWM mode operation**: it is preferable to select regulators with Pulse Width Modulation (PWM) mode. While in connected-mode Pulse Frequency Modulation (PFM) mode and PFM/PWM mode, transitions must be avoided to reduce the noise on the **VCC** voltage profile. Switching regulators that are able to switch between low ripple PWM mode and high efficiency burst or PFM mode can be used, provided the mode transition occurs when the module changes status from idle/active-mode to connected-mode (where current consumption increases to a value greater than 100 mA): it is permissible to use a regulator that switches from the PWM mode to the burst or PFM mode at an appropriate current threshold (e.g. 60 mA)
- **Output voltage slope**: the use of the soft start function provided by some voltage regulators should be carefully evaluated, since the **VCC** pins voltage must ramp from 2.5 V to 3.2 V within 4 ms to switch on the module that otherwise can be switched on by a low level on **PWR_ON** pin

Figure 13 and the components listed in Table 9 show an example of a high reliability power supply circuit, where the module **VCC** is supplied by a step-down switching regulator capable of delivering 1.9 A current pulses with low output ripple and with fixed switching frequency in PWM mode operation greater than 1 MHz.

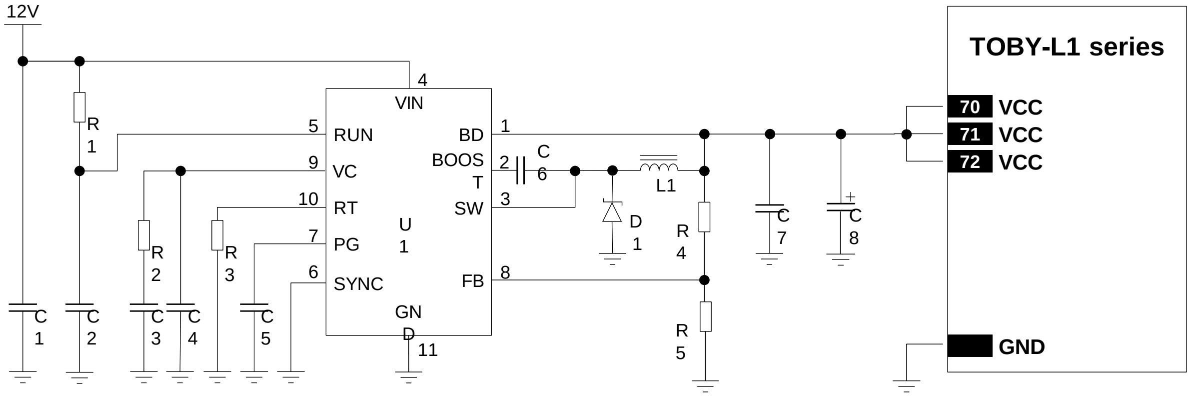


**Figure 13: Suggested schematic design for the VCC voltage supply application circuit using a step-down regulator**

| Reference | Description | Part Number - Manufacturer |
|---|---|---|
| C1 | 10 µF Capacitor Ceramic X7R 5750 15% 50 V | C5750X7R1H106MB - TDK |
| C2 | 10 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R71C103KA01 - Murata |
| C3 | 680 pF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R71H681KA01 - Murata |
| C4 | 22 pF Capacitor Ceramic C0G 0402 5% 25 V | GRM1555C1H220JZ01 - Murata |
| C5 | 10 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R71C103KA01 - Murata |
| C6 | 470 nF Capacitor Ceramic X7R 0603 10% 25 V | GRM188R71E474KA12 - Murata |
| C7 | 22 µF Capacitor Ceramic X5R 1210 10% 25 V | GRM32ER61E226KE15 - Murata |
| C8 | 330 µF Capacitor Tantalum D_SIZE 6.3 V 45 mΩ | T520D337M006ATE045 - KEMET |
| D1 | Schottky Diode 40 V 3 A | MBRA340T3G - ON Semiconductor |
| L1 | 10 µH Inductor 744066100 30% 3.6 A | 744066100 - Wurth Electronics |
| R1 | 470 kΩ Resistor 0402 5% 0.1 W | 2322-705-87474-L - Yageo |
| R2 | 15 kΩ Resistor 0402 5% 0.1 W | 2322-705-87153-L - Yageo |
| R3 | 22 kΩ Resistor 0402 5% 0.1 W | 2322-705-87223-L - Yageo |
| R4 | 390 kΩ Resistor 0402 1% 0.063 W | RC0402FR-07390KL - Yageo |
| R5 | 100 kΩ Resistor 0402 5% 0.1 W | 2322-705-70104-L - Yageo |
| U1 | Step-Down Regulator MSOP10 3.5 A 2.4 MHz | LT3972IMSE#PBF - Linear Technology |

**Table 9: Suggested components for the VCC voltage supply application circuit using a step-down regulator**

Figure 14 and the components listed in Table 10 show an example of a low cost power supply circuit, where the **VCC** module supply is provided by a step-down switching regulator capable of delivering 1.9 A current pulses, transforming a 12 V supply input.

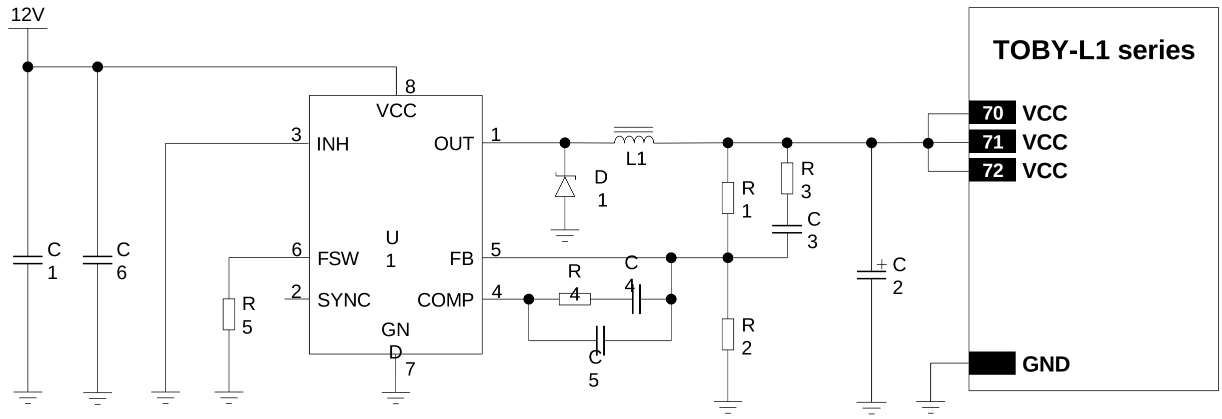


**Figure 14: Suggested low cost solution for the VCC voltage supply application circuit using step-down regulator**

| Reference | Description | Part Number - Manufacturer |
|---|---|---|
| C1 | 22 µF Capacitor Ceramic X5R 1210 10% 25 V | GRM32ER61E226KE15 – Murata |
| C2 | 100 µF Capacitor Tantalum B_SIZE 20% 6.3V 15mΩ | T520B107M006ATE015 – Kemet |
| C3 | 5.6 nF Capacitor Ceramic X7R 0402 10% 50 V | GRM155R71H562KA88 – Murata |
| C4 | 6.8 nF Capacitor Ceramic X7R 0402 10% 50 V | GRM155R71H682KA88 – Murata |
| C5 | 56 pF Capacitor Ceramic C0G 0402 5% 50 V | GRM1555C1H560JA01 – Murata |
| C6 | 220 nF Capacitor Ceramic X7R 0603 10% 25 V | GRM188R71E224KA88 – Murata |
| D1 | Schottky Diode 25V 2 A | STPS2L25 – STMicroelectronics |
| L1 | 5.2 µH Inductor 30% 5.28A 22 mΩ | MSS1038-522NL – Coilcraft |
| R1 | 4.7 kΩ Resistor 0402 1% 0.063 W | RC0402FR-074K7L – Yageo |
| R2 | 910 Ω Resistor 0402 1% 0.063 W | RC0402FR-07910RL – Yageo |
| R3 | 82 Ω Resistor 0402 5% 0.063 W | RC0402JR-0782RL – Yageo |
| R4 | 8.2 kΩ Resistor 0402 5% 0.063 W | RC0402JR-078K2L – Yageo |
| R5 | 39 kΩ Resistor 0402 5% 0.063 W | RC0402JR-0739KL – Yageo |
| U1 | Step-Down Regulator 8-VFQFPN 3 A 1 MHz | L5987TR – ST Microelectronics |

**Table 10: Suggested components for low cost solution VCC voltage supply application circuit using a step-down regulator**

### 2.1.1.3 Guidelines for VCC supply circuit design using a Low Drop-Out (LDO) linear regulator

The use of a linear regulator is suggested when the difference from the available supply rail and the **VCC** value is low: linear regulators provide high efficiency when transforming a 5 V supply to a voltage value within the module **VCC** normal operating range.

The characteristics of the LDO linear regulator connected to the **VCC** pins should meet the following prerequisites to comply with the module **VCC** requirements summarized in Table 6:

- **Power capabilities**: the LDO linear regulator with its output circuit must be capable of providing a proper voltage value to the **VCC** pins and of delivering 1.9 A current pulses with 1/8 duty cycle
- **Power dissipation**: the power handling capability of the LDO linear regulator must be checked to limit its junction temperature to the maximum rated operating range (i.e. check the voltage drop from the max input voltage to the min output voltage to evaluate the power dissipation of the regulator)

- **Output voltage slope**: the use of the soft start function provided by some voltage regulator should be carefully evaluated, since the **VCC** pins voltage must ramp from 2.5 V to 3.2 V within 4 ms to switch-on the module that otherwise can be switched on by a low level on **PWR_ON** pin

Figure 15 and the components listed in Table 11 show an example of a power supply circuit, where the **VCC** module supply is provided by an LDO linear regulator capable of delivering 1.9 A current pulses, with proper power handling capability.

It is recommended to configure the LDO linear regulator to generate a voltage supply value slightly below the maximum limit of the module VCC normal operating range (e.g. ~4.1 V as in the circuit described in Figure 15 and Table 11). This reduces the power on the linear regulator and improves the thermal design of the supply circuit.

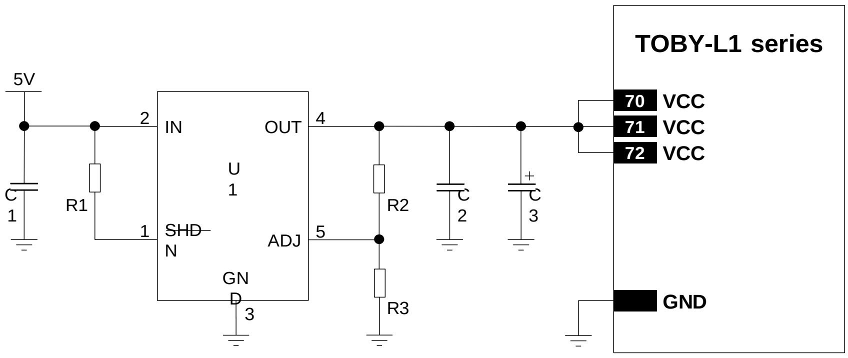


**Figure 15: Suggested schematic design for the VCC voltage supply application circuit using an LDO linear regulator**

| Reference | Description | Part Number - Manufacturer |
|---|---|---|
| C1, C2 | 10 µF Capacitor Ceramic X5R 0603 20% 6.3 V | GRM188R60J106ME47 - Murata |
| C3 | 330 µF Capacitor Tantalum D_SIZE 6.3 V 45 mΩ | T520D337M006ATE045 - KEMET |
| R1 | 47 kΩ Resistor 0402 5% 0.1 W | RC0402JR-0747KL - Yageo Phycomp |
| R2 | 9.1 kΩ Resistor 0402 5% 0.1 W | RC0402JR-079K1L - Yageo Phycomp |
| R3 | 3.9 kΩ Resistor 0402 5% 0.1 W | RC0402JR-073K9L - Yageo Phycomp |
| U1 | LDO Linear Regulator ADJ 3.0 A | LT1764AEQ#PBF - Linear Technology |

**Table 11: Suggested components for VCC voltage supply application circuit using an LDO linear regulator**

#### 2.1.1.4 Guidelines for VCC supply circuit design using a rechargeable Li-Ion or Li-Pol battery

Rechargeable Li-Ion or Li-Pol batteries connected to the **VCC** pins should meet the following prerequisites to comply with the module **VCC** requirements summarized in Table 6:

- **Maximum pulse and DC discharge current**: the rechargeable Li-Ion battery with its output circuit must be capable of delivering 1.9 A current pulses with 1/8 duty-cycle to the **VCC** pins and must be capable of delivering a DC current greater than the module maximum average current consumption to **VCC** pins. The maximum pulse discharge current and the maximum DC discharge current are not always reported in battery data sheets, but the maximum DC discharge current is typically almost equal to the battery capacity in Amp-hours divided by 1 hour
- **DC series resistance**: the rechargeable Li-Ion battery with its output circuit must be capable of avoiding a VCC voltage drop greater than 400 mV during transmit bursts

#### 2.1.1.5 Guidelines for VCC supply circuit design using a primary (disposable) battery

The characteristics of a primary (non-rechargeable) battery connected to **VCC** pins should meet the following prerequisites to comply with the module **VCC** requirements summarized in Table 6:

- **Maximum pulse and DC discharge current**: the non-rechargeable battery with its output circuit must be capable of delivering 1.9 A current pulses with 1/8 duty-cycle to the **VCC** pins and must be capable of delivering a DC current greater than the module maximum average current consumption at the **VCC** pins. The maximum pulse and the maximum DC discharge current is not always reported in battery data sheets, but the maximum DC discharge current is typically almost equal to the battery capacity in Amp-hours divided by 1 hour
- **DC series resistance**: the non-rechargeable battery with its output circuit must be capable of avoiding a VCC voltage drop greater than 400 mV during transmit bursts

#### 2.1.1.6 Additional guidelines for VCC supply circuit design

To reduce voltage drops, use a low impedance power source. The resistance of the power supply lines (connected to the **VCC** and **GND** pins of the module) on the application board and battery pack should also be considered and minimized: cabling and routing must be as short as possible to minimize power losses.

Three pins are allocated for **VCC** supply. Another twenty pins are designated for **GND** connection. Even if all the **VCC** pins and all the **GND** pins are internally connected within the module, it is recommended to properly connect all of them to supply the module to minimize series resistance losses.

To avoid voltage drop undershoot and overshoot at the start and end of a transmit burst during a LTE Connection (when current consumption on the **VCC** supply can rise up to as much as 1.9 A in the worst case), place a bypass capacitor with large capacitance (more than 100 µF) and low ESR near the **VCC** pins, for example:

- 330 µF capacitance, 45 mΩ ESR (e.g. KEMET T520D337M006ATE045, Tantalum Capacitor)

The use of very large capacitors (i.e. greater then 1000 µF) on the **VCC** line should be carefully evaluated, since the voltage at the **VCC** pins must ramp from 2.5 V to 3.2 V within 4 ms to switch on the module that otherwise can be switched on by a low level on **PWR_ON** pin.

To reduce voltage ripple and noise, especially if the application device integrates an internal antenna, place the following bypass capacitors near the **VCC** pins:

- 100 nF capacitor (e.g Murata GRM155R61C104K) to filter digital logic noise from clocks and data sources
- 10 nF capacitor (e.g. Murata GRM155R71C103K) to filter digital logic noise from clocks and data sources
- 56 pF capacitor with Self-Resonant Frequency in 800/900 MHz range (e.g. Murata GRM1555C1E560J) to filter transmission EMI in the LTE/ELTE bands
- 15 pF capacitor with Self-Resonant Frequency in 1800/1900 MHz range (e.g. Murata GRM1555C1E150J) to filter transmission EMI in the DCS/PCS bands

☞ Figure 16 shows the complete configuration but the mounting of each single component depends on the application design: it is recommended to provide all the **VCC** bypass capacitors as described in Figure 16 and Table 12 if the application device integrates an internal antenna.

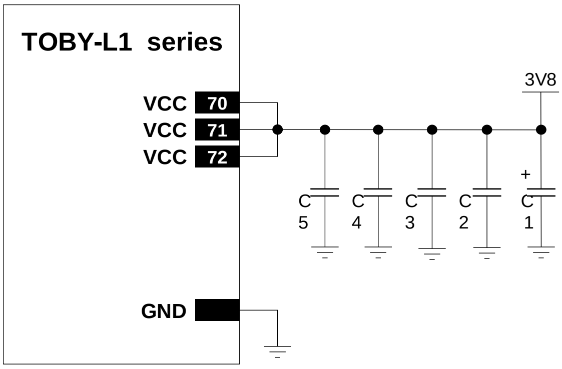


**Figure 16: Suggested schematic and layout design for the VCC bypass capacitors to reduce ripple / noise on VCC voltage profile and to avoid undershoot / overshoot on VCC voltage drops**

| Reference | Description | Part Number - Manufacturer |
|---|---|---|
| C1 | 330 µF Capacitor Tantalum D_SIZE 6.3 V 45 mΩ | T520D337M006ATE045 - KEMET |
| C2 | 100 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R71C104KA01 - Murata |
| C3 | 10 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R71C103KA01 - Murata |
| C4 | 56 pF Capacitor Ceramic C0G 0402 5% 25 V | GRM1555C1E560JA01 - Murata |
| C5 | 15 pF Capacitor Ceramic C0G 0402 5% 25 V | GRM1555C1E150JA01 - Murata |

**Table 12: Suggested components to reduce ripple / noise on VCC and to avoid undershoot/ overshoot on VCC voltage drops**

☞ ESD sensitivity rating of the **VCC** supply pins is 1 kV (Human Body Model according to JESD22-A114). Higher protection level can be required if the line is externally accessible on the application board, e.g. if accessible battery connector is directly connected to **VCC** pins. Higher protection level can be achieved by mounting an ESD protection (e.g. EPCOS CA05P4S14THSG varistor array) close to accessible point.

#### 2.1.1.7 Guidelines for external battery charging circuit

TOBY-L1 modules do not have an on-board charging circuit. Figure 17 provides an example of a battery charger design, suitable for applications that are battery powered with a Li-Ion (or Li-Polymer) cell.

In the application circuit, a rechargeable Li-Ion (or Li-Polymer) battery cell, that features proper pulse and DC discharge current capabilities and proper DC series resistance, is directly connected to the **VCC** supply input of TOBY-L1 module. Battery charging is completely managed by the STMicroelectronics L6924U Battery Charger IC that, from a USB power source (5.0 V typ.), charges as a linear charger the battery, in three phases:

- **Pre-charge constant current** (active when the battery is deeply discharged): the battery is charged with a low current, set to 10% of the fast-charge current
- **Fast-charge constant current**: the battery is charged with the maximum current, configured by the value of an external resistor to a value suitable for USB power source (~500 mA)
- **Constant voltage**: when the battery voltage reaches the regulated output voltage (4.2 V), the L6924U starts to reduce the current until the charge termination is done. The charging process ends when the charging current reaches the value configured by an external resistor to ~15 mA or when the charging timer reaches the value configured by an external capacitor to ~9800 s

Using a battery pack with an internal NTC resistor, the L6924U can monitor the battery temperature to protect the battery from operating under unsafe thermal conditions.

Alternatively the L6924U, providing input voltage range up to 12 V, can charge from an AC wall adapter. When a current-limited adapter is used, it can operate in quasi-pulse mode, reducing power dissipation.

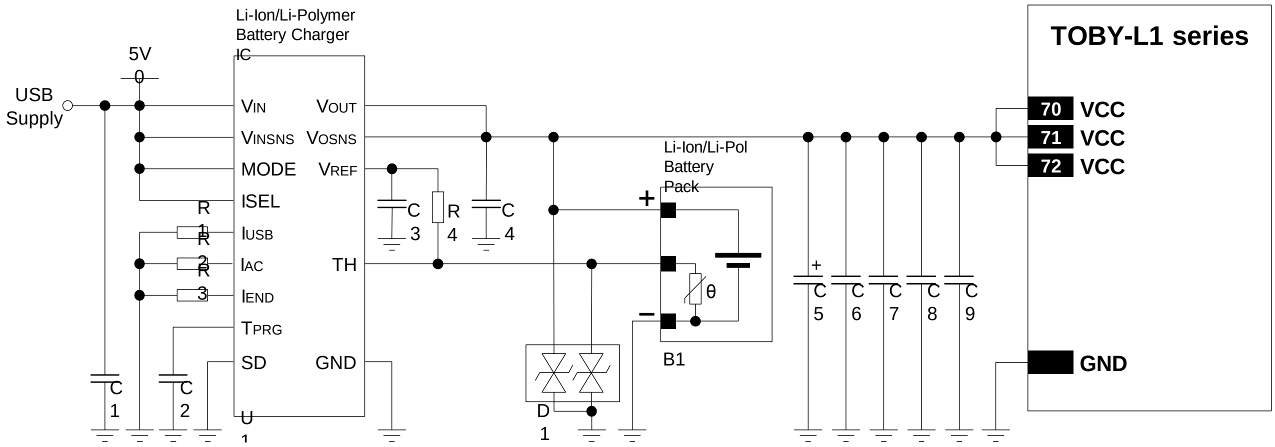


**Figure 17: Li-Ion (or Li-Polymer) battery charging application circuit**

| Reference | Description | Part Number - Manufacturer |
|---|---|---|
| B1 | Li-Ion (or Li-Polymer) battery pack with 470 Ω NTC | Various manufacturer |
| C1, C4 | 1 µF Capacitor Ceramic X7R 0603 10% 16 V | GRM188R71C105KA12 - Murata |
| C2, C6 | 10 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R71C103KA01 - Murata |
| C3 | 1 nF Capacitor Ceramic X7R 0402 10% 50 V | GRM155R71H102KA01 - Murata |
| C5 | 330 µF Capacitor Tantalum D_SIZE 6.3 V 45 mΩ | T520D337M006ATE045 - KEMET |
| C7 | 100 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R61A104KA01 - Murata |
| C8 | 56 pF Capacitor Ceramic C0G 0402 5% 25 V | GRM1555C1E560JA01 - Murata |
| C9 | 15 pF Capacitor Ceramic C0G 0402 5% 25 V | GRM1555C1E150JA01 - Murata |
| D1 | Low Capacitance ESD Protection | USB0002RP or USB0002DP - AVX |
| R1, R2 | 24 kΩ Resistor 0402 5% 0.1 W | RC0402JR-0724KL - Yageo Phycomp |
| R3 | 3.3 kΩ Resistor 0402 5% 0.1 W | RC0402JR-073K3L - Yageo Phycomp |
| R4 | 1.0 kΩ Resistor 0402 5% 0.1 W | RC0402JR-071K0L - Yageo Phycomp |
| U1 | Single Cell Li-Ion (or Li-Polymer) Battery Charger IC for USB port and AC Adapter | L6924U - STMicroelectronics |

**Table 13: Suggested components for Li-Ion (or Li-Polymer) battery charging application circuit**

#### 2.1.1.8 Guidelines for VCC supply layout design

Good connection of the module **VCC** pins with DC supply source is required for correct RF performance. Guidelines are summarized in the following list:

- All the available **VCC** pins must be connected to the DC source
- **VCC** connection must be as wide as possible and as short as possible
- Any series component with Equivalent Series Resistance (ESR) greater than few milliohms must be avoided
- **VCC** connection must be routed through a PCB area separated from sensitive analog signals and sensitive functional units: it is good practice to interpose at least one layer of PCB ground between **VCC** track and other signal routing
- Coupling between **VCC** and audio lines (especially microphone inputs) must be avoided, because the typical LTE burst has a periodic nature of approx. 217 Hz, which lies in the audible audio range
- The tank bypass capacitor with low ESR for current spikes smoothing described in Figure 16 and Table 12 should be placed close to the **VCC** pins. If the main DC source is a switching DC-DC converter, place the large capacitor close to the DC-DC output and minimize the **VCC** track length. Otherwise consider using separate capacitors for DC-DC converter and TOBY-L1 module tank capacitor
- The bypass capacitors in the pF range described in Figure 16 and Table 12 should be placed as close as possible to the **VCC** pins. This is highly recommended if the application device integrates an internal antenna

- Since **VCC** is directly connected to RF Power Amplifiers, voltage ripple at high frequency may result in unwanted spurious modulation of transmitter RF signal. This is more likely to happen with switching DC-DC converters, in which case it is better to select the highest operating frequency for the switcher and add a large L-C filter before connecting to the TOBY-L1 series modules in the worst case
- If **VCC** is protected by transient voltage suppressor to ensure that the voltage maximum ratings are not exceeded, place the protecting device along the path from the DC source toward the TOBY-L1 module, preferably closer to the DC source (otherwise protection functionality may be compromised)

#### 2.1.1.9 Guidelines for grounding layout design

Good connection of the module **GND** pins with application board solid ground layer is required for correct RF performance. It significantly reduces EMC issues and provides a thermal heat sink for the module.

- Connect each **GND** pin with application board solid GND layer. It is strongly recommended that each **GND** pad surrounding **VCC** pins have one or more dedicated via down to the application board solid ground layer
- The **VCC** supply current flows back to main DC source through GND as ground current: provide adequate return path with suitable uninterrupted ground plane to main DC source
- If the application board is a multilayer PCB, then it is required to connect together each GND area with complete via stack down to main board ground layer
- It is recommended to implement one layer of the application board as ground plane as wide as possible
- Good grounding of **GND** pads also ensures thermal heat sink. This is critical during Connection connection, when the real network commands the module to transmit at maximum power: proper grounding helps prevent module overheating

### 2.1.2 2.5V supply (V_BCKP)

#### 2.1.2.1 Guidelines for V_BCKP circuit design

On TOBY-L100 and TOBY-L110 modules, the **V_BCKP** supply output can be used to for external customer use.

☞ The internal regulator for **V_BCKP** is optimized for low leakage current and very light loads. Do not apply loads which might exceed the limit for maximum available current from **V_BCKP** supply, as this can cause malfunctions in the module. TOBY-L1 series Data Sheet [1] describes the detailed electrical characteristics.

**V_BCKP** supply output pin provides internal short circuit protection to limit start-up current and protect the device in short circuit situations. No additional external short circuit protection is required.

☞ ESD sensitivity rating of the **V_BCKP** supply pin is 1 kV (Human Body Model according to JESD22-A114). Higher protection level can be required if the line is externally accessible on the application board, e.g. if an accessible back-up battery connector is directly connected to **V_BCKP** pin. Higher protection level can be achieved by mounting an ESD protection (e.g. EPCOS CA05P4S14THSG varistor array) close to the accessible point.

#### 2.1.2.2 Guidelines for V_BCKP layout design

**V_BCKP** supply requires careful layout: avoid injecting noise on this voltage domain as it may affect the stability of the internal circuitry.

### 2.1.3 1.8V supply (V_INT)

#### 2.1.3.1 Guidelines for V_INT circuit design

The **V_INT** digital interfaces 1.8 V supply output can be mainly used to:

- Supply voltage translators to connect digital interfaces of the module to a 3.0 V device (see section 2.5.1)
- Indicate when the module is switched on

☞ Do not apply loads which might exceed the limit for maximum available current from **V_INT** supply, as this can cause malfunctions in internal circuitry supplies to the same domain. TOBY-L1 series Data Sheet [1] describes the detailed electrical characteristics.

☞ **V_INT** can only be used as an output; do not connect any external regulator on **V_INT**.

Since the **V_INT** supply is generated by an internal switching step-down regulator, the **V_INT** voltage ripple can range from 15 mVpp during active-mode or connected-mode (when the switching regulator operates in PWM mode), to 90 mVpp in idle-mode (when the switching regulator operates in PFM mode).

☞ It is not recommended to supply sensitive analog circuitry without adequate filtering for digital noise.

**V_INT** supply output pin provides internal short circuit protection to limit start-up current and protect the device in short circuit situations. No additional external short circuit protection is required.

☞ ESD sensitivity rating of the **V_INT** supply pin is 1 kV (Human Body Model according to JESD22-A114). Higher protection level could be required if the line is externally accessible on the application board. Higher protection level can be achieved by mounting an ESD protection (e.g. EPCOS CA05P4S14THSG varistor array) close to accessible point.

☞ If the **V_INT** supply output is not required by the customer application, since DDC ($I^2C$) interface and SIM detection functions are not used and voltage translation of digital interfaces are not needed, the **V_INT** pin can be left unconnected to external components, but it is recommended providing direct access on the application board by means of accessible testpoint directly connected to the **V_INT** pin.

#### 2.1.3.2 Guidelines for V_INT layout design

**V_INT** digital interfaces supply output is generated by an integrated switching step-down converter, used internally to supply the digital interfaces. Because of this, it can be a source of noise: avoid coupling with sensitive signals.

## 2.2 System functions interfaces

### 2.2.1 Module power-on (PWR_ON)

#### 2.2.1.1 Guidelines for PWR_ON circuit design

2.2.1.2 Pull-up resistor (e.g. 100 kΩ) biased by the **V_BCKP** supply pin of the module, as described in Figure 18 and Table 14. Connecting the **PWR_ON** input to a push button, the pin will be externally accessible on the application device: according to EMC/ESD requirements of the application, provide an additional ESD protection (e.g. EPCOS CA05P4S14THSG varistor array) on the line connected to this pin, close to accessible point.

The **PWR_ON** pin has high input impedance and is weakly pulled to the high level on the module. Avoid keeping it floating in a noisy environment. To hold the high logic level stable, the **PWR_ON** pin must be connected to a pull-up resistor (e.g. 100 kΩ) biased by the **V_BCKP** supply pin of the module.

ESD sensitivity rating of the **PWR_ON** pin is 1 kV (Human Body Model according to JESD22-A114). Higher protection level can be required if the line is externally accessible on the application board, e.g. if an accessible push button is directly connected to **PWR_ON** pin. Higher protection level can be achieved by mounting an ESD protection (e.g. EPCOS CA05P4S14THSG varistor array) close to accessible point.

Connecting the **PWR_ON** input to an external device (e.g. application processor), use an open drain output on the external device with an external pull-up resistor (e.g. 100 kΩ) biased by the **V_BCKP** supply pin of the module, as described in Figure 18 and Table 14.

A compatible push-pull output of an application processor can also be used: in this case the pull-up can be provided to pull the **PWR_ON** level high when the application processor is switched off. If the high-level voltage of the push-pull output pin of the application processor is greater than the maximum input voltage operating range of the **V_BCKP** pin (refer to TOBY-L1 series Data Sheet [1]), the **V_BCKP** supply cannot be used to bias the pull-up resistor: the supply rail of the application processor or the module **VCC** supply could be used, but this increases the **V_BCKP** current consumption when the module is in not-powered mode (**VCC** supply not present). Using a push-pull output of the external device, take care to fix the proper level in all the possible scenarios to avoid an inappropriate module switch-on.

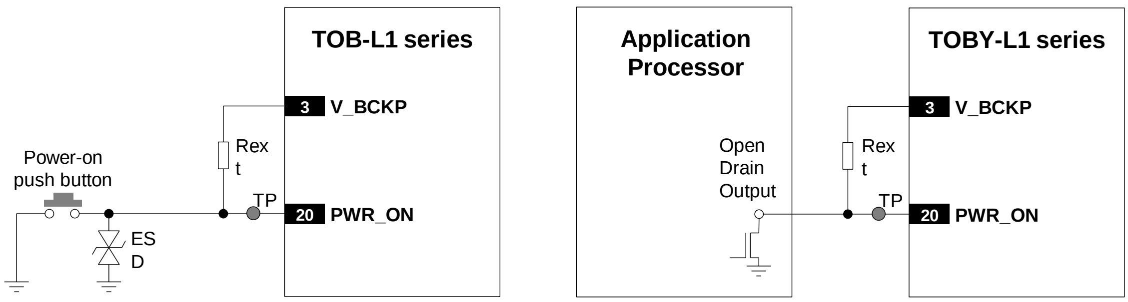


**Figure 18: PWR_ON application circuits using a push button and an open drain output of an application processor**

| Reference | Description | Remarks |
|---|---|---|
| Rext | 100 kΩ Resistor 0402 5% 0.1 W | External pull-up resistor |
| ESD | CT0402S14AHSG - EPCOS | Varistor array for ESD protection |

**Table 14: Example of pull-up resistor and ESD protection for the PWR_ON application circuit**

It is recommended to provide direct access to the **PWR_ON** pin on the application board by means of accessible testpoint directly connected to the **PWR_ON** pin.

#### 2.2.1.3 Guidelines for PWR_ON layout design

The power-on circuit (**PWR_ON**) requires careful layout since it is the sensitive input available to switch on the TOBY-L1 modules until a valid **VCC** supply is provided after that the module has been switched off by means of the AT+CPWROFF command: ensure that the voltage level is well defined during operation and no transient noise is coupled on this line, otherwise the module might detect a spurious power-on request.

### 2.2.2 Module reset (RESET_N)

#### 2.2.2.1 Guidelines for RESET_N circuit design

As described in Figure 11, the module has an internal pull-up resistor on the reset input line: an external pull-up is not required on the application board.

Connecting the **RESET_N** input to a push button that shorts the **RESET_N** pin to ground, the pin will be externally accessible on the application device: according to EMC/ESD requirements of the application, provide an additional ESD protection (e.g. EPCOS CA05P4S14THSG varistor array) on the line connected to this pin, close to accessible point, as described in Figure 19 and Table 15.

☞ ESD sensitivity rating of the **RESET_N** pin is 1 kV (Human Body Model according to JESD22-A114). Higher protection level can be required if the line is externally accessible on the application board, e.g. if an accessible push button is directly connected to **RESET_N** pin. Higher protection level can be achieved by mounting an ESD protection (e.g. EPCOS CA05P4S14THSG varistor array) close to accessible point.

Connecting the **RESET_N** input to an external device (e.g. application processor), an open drain output can be directly connected without any external pull-up, as described in Figure 19 and Table 15: the internal pull-up resistor provided by the module pulls the line to the high logic level when the **RESET_N** pin is not forced low by the application processor. A compatible push-pull output of an application processor can be used too.

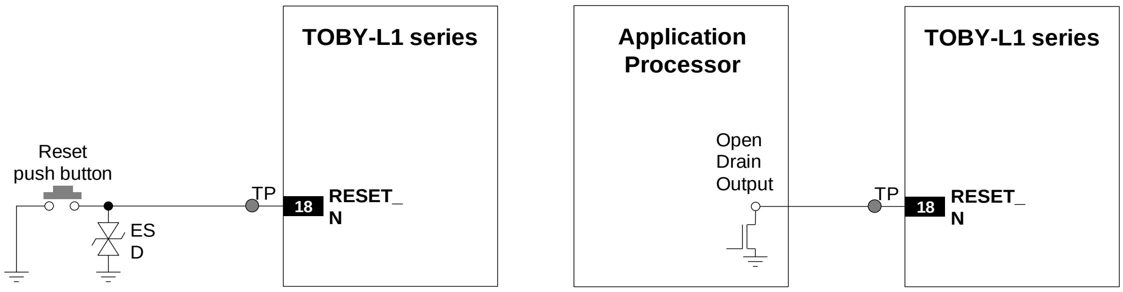


**Figure 19: RESET_N application circuits using a push button and an open drain output of an application processor**

| Reference | Description | Remarks |
|---|---|---|
| ESD | Varistor for ESD protection | CT0402S14AHSG - EPCOS |

**Table 15: Example of ESD protection component for the RESET_N application circuit**

☞ If the external reset function is not required by the customer application, the **RESET_N** input pin can be left unconnected to external components, but it is recommended providing direct access on the application board by means of accessible testpoint directly connected to the **RESET_N** pin.

#### 2.2.2.2 Guidelines for RESET_N layout design

The reset circuit (**RESET_N**) requires careful layout due to the pin function: ensure that the voltage level is well defined during operation and no transient noise is coupled on this line, otherwise the module might detect a spurious reset request. It is recommended to keep the connection line to **RESET_N** as short as possible.

## 2.3 Antenna interface

The **ANT1 ANT2** pins, provided by all TOBY-L1 modules, represent the main RF inputs/output used to transmit and receive the LTE RF signals. The primary antenna must be connected. The **ANT** pin has a nominal characteristic impedance of 50 Ω and must be connected to the antenna through a 50 Ω transmission line to allow transmission and reception of radio frequency (RF) signals in operating bands.

### 2.3.1 Antenna RF interface (ANT)

#### 2.3.1.1 General guidelines for antenna selection and design

The LTE antenna is the most critical component to be evaluated. Designers must take care of the antenna from all perspective at the very start of the design phase when the physical dimensions of the application board are under analysis/decision, since the RF compliance of the device integrating TOBY-L1 module with all the applicable required certification schemes depends from antenna radiating performance.

LTE antennas are typically available in the typies of linear monopole and path antenna.

- Linear monopole - External antenna
  - External antenna basically does not imply physical restriction to the design of the PCB where the TOBY-L1 series module is mounted.
  - The radiation performance mainly depends on the antenna. It is required to select the antenna with optimal radiating performance in the operating bands.
  - An RF cable should be selected with minimum insertion loss due to the additional insertion loss introduced by low quality or long cable. Large insertion loss reduces radiation performance.
  - A high quality 50 Ω RF connector provides proper PCB-to-RF-cable transition. It is recommended to strictly follow the layout guidelines provided by the connector manufacturer.
- Patch-like antenna - Integrated antenna:
  - Internal integrated antenna implies physical restriction to the design of the PCB. The ground plane can be reduced down to a minimum size that must be similar to the quarter of the wavelength of the minimum frequency that has to be radiated. As numerical example:

    Frequency = 1 GHz → Wavelength = 30 cm → Minimum GND plane size = 7.5 cm
  - The radiation performance depends on the whole PCB and antenna system design, including product mechanical design and usage. The antenna should be selected with optimal radiating performance in the operating bands according to the mechanical specifications of the PCB and the whole product.
  - It is recommended to select a complete custom antenna designed by an antenna manufacturer if the required ground plane dimensions are very small (e.g. less than 6.5 cm long and 4 cm wide). The antenna design process should begin at the start of the whole product design process
  - It is highly recommended to strictly follow the detailed and specific guidelines provided by the antenna manufacturer regarding correct installation and deployment of the antenna system, including PCB layout and matching circuitry
  - Further to the custom PCB and product restrictions, the antenna may require a tuning to comply with all the applicable required certification schemes. It is recommended to consult the antenna manufacturer for the design-in guidelines for antenna matching relative to the custom application

In both cases, selecting an external or an internal antenna, these recommendations should be observed:

- Select an antenna providing optimal return loss (or V.S.W.R.) figure over all the operating frequencies,
- Select an antenna providing optimal efficiency figure over all the operating frequencies,

- Select an antenna providing appropriate gain figure (i.e. combined antenna directivity and efficiency figure) so that the electromagnetic field radiation intensity do not exceed the regulatory limits specified in some countries (e.g. by FCC in the United States, as reported in the chapter 4.2.2).

#### 2.3.1.2 Guidelines for antenna RF interface design

**Guidelines for ANT pin RF connection design**

Proper transition between the **ANT** pad and the application board PCB must be provided, implementing the following design-in guidelines for the layout of the application PCB close to the **ANT** pad:

- On a multi layer board, the whole layer stack below the RF connection should be free of digital lines
- Increase GND keep-out (i.e. clearance, a void area) around the **ANT** pad, on the top layer of the application PCB, to at least 250 µm up to adjacent pads metal definition and up to 400 µm on the area below the module, to reduce parasitic capacitance to ground, as described in the left picture in Figure 20
- Add GND keep-out (i.e. clearance, a void area) on the buried metal layer below the **ANT** pad if the top-layer to buried layer dielectric thickness is below 200 µm, to reduce parasitic capacitance to ground, as described in the right picture in Figure 20

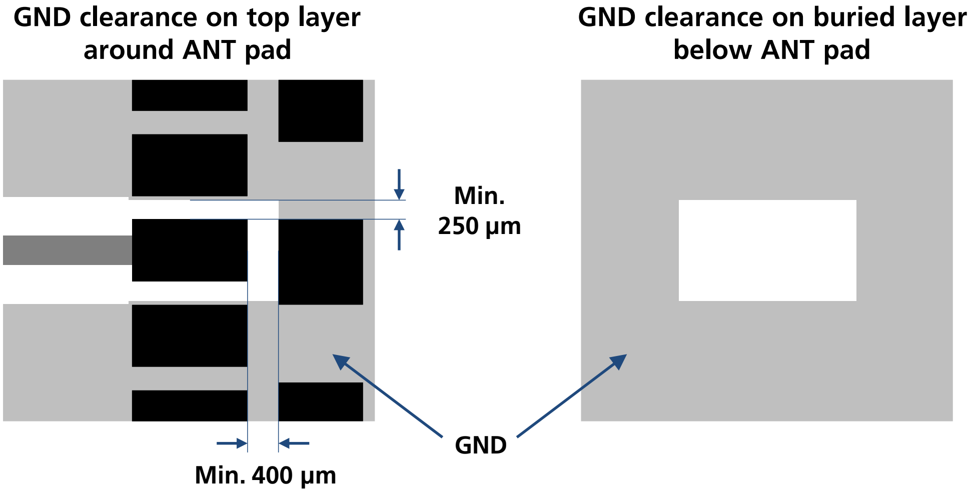


**Figure 20: GND keep-out area on the top layer around ANT pad and on the very close buried layer below ANT pad**

**Guidelines for RF transmission line design**

The transmission line from the **ANT** pad up to antenna connector or up to the internal antenna pad must be designed so that the characteristic impedance is as close as possible to 50 Ω.

The transmission line can be designed as a micro strip (consists of a conducting strip separated from a ground plane by a dielectric material) or a strip line (consists of a flat strip of metal which is sandwiched between two parallel ground planes within a dielectric material). The micro strip, implemented as a coplanar waveguide, is the most common configuration for printed circuit board.

Figure 21 and Figure 22 provide two examples of proper 50 Ω coplanar waveguide designs: the first transmission line can be implemented in case of 4-layer PCB stack-up herein described, the second transmission line can be implemented in case of 2-layer PCB stack-up herein described.

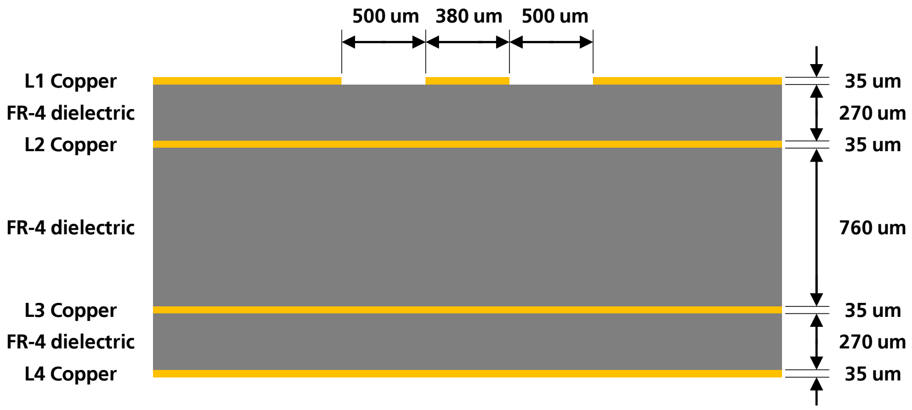


**Figure 21: Example of 50 Ω coplanar waveguide transmission line design for the described 4-layer board layup**

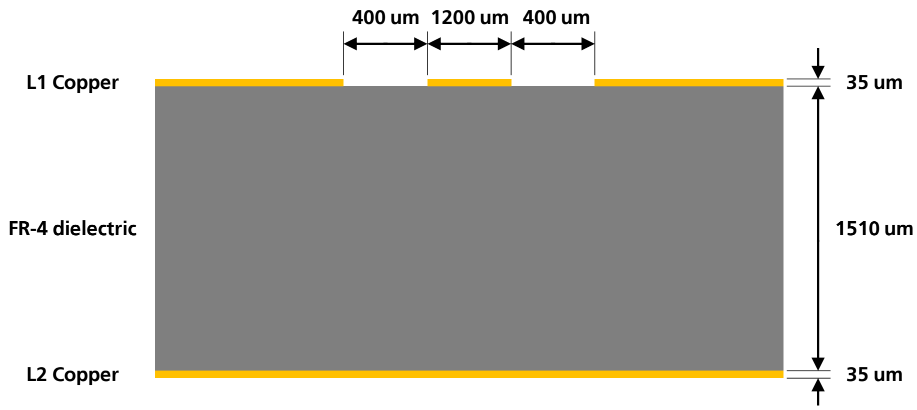


**Figure 22: Example of 50 Ω coplanar waveguide transmission line design for the described 2-layer board layup**

If the two examples do not match the application PCB stack-up the 50 Ω characteristic impedance calculation can be made using the HFSS commercial finite element method solver for electromagnetic structures from Ansys Corporation, or using freeware tools like AppCAD from Agilent or TXLine from Applied Wave Research, taking care of the approximation formulas used by the tools for the impedance computation.

To achieve a 50 Ω characteristic impedance, the width of the transmission line must be chosen depending on:

- the thickness of the transmission line itself (e.g. 35 µm in the example of Figure 21 and Figure 22)
- the thickness of the dielectric material between the top layer (where the transmission line is routed) and the inner closer layer implementing the ground plane (e.g. 270 µm in Figure 21, 1510 µm in Figure 22)
- the dielectric constant of the dielectric material (e.g. dielectric constant of the FR-4 dielectric material in Figure 21 and Figure 22)
- the gap from the transmission line to the adjacent ground plane on the same layer of the transmission line (e.g. 500 µm in Figure 21, 400 µm in Figure 22)

If the distance between the transmission line and the adjacent GND area (on the same layer) does not exceed 5 times the track width of the micro strip, use the "Coplanar Waveguide" model for the 50 Ω calculation.

Additionally to the 50 Ω impedance, the following guidelines are recommended for the transmission line design:

- Minimize the transmission line length: the insertion loss should be minimized as much as possible, in the order of a few tenths of a dB,
- Add GND keep-out (i.e. clearance, a void area) on buried metal layers below any pad of component present on the RF transmission line, if top-layer to buried layer dielectric thickness is below 200 µm, to reduce parasitic capacitance to ground,
- The transmission line width and spacing to GND must be uniform and routed as smoothly as possible: avoid abrupt changes of width and spacing to GND,
- Add GND stitching vias around transmission line, as described in Figure 23,
- Ensure solid metal connection of the adjacent metal layer on the PCB stack-up to main ground layer, providing enough on the adjacent metal layer, as described in Figure 23,
- Route RF transmission line far from any noise source (as switching supplies and digital lines) and from any sensitive circuit (as analog audio lines),
- Avoid stubs on the transmission line,
- Avoid signal routing in parallel to transmission line or crossing the transmission line on buried metal layer,
- Do not route microstrip line below discrete component or other mechanics placed on top layer

An example of proper RF circuit design is reported in the Figure 23. In this case, the **ANT** pin is directly connected to an SMA connector by means of a proper 50 Ω transmission line, designed with proper layout.

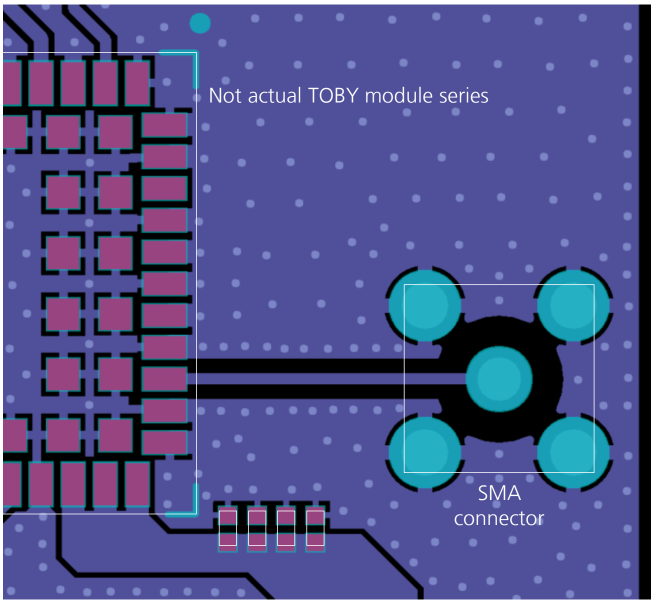


**Figure 23: Suggested circuit and layout for antenna RF circuit on application board, if antenna detection is not required**

### Guidelines for RF termination design

The RF termination must provide a characteristic impedance of 50 Ω as well as the RF transmission line up to the RF termination itself, to match the characteristic impedance of the **ANT** pin of TOBY-L1 modules.

However, real antennas have no perfect 50 Ω load on all the supported frequency bands. Therefore, to reduce as much as possible performance degradation due to antenna mismatch, the RF termination must provide optimal return loss (or V.S.W.R.) figure over all the operating frequency bands, as summarized in Table 7.

If an external antenna is used, the antenna connector represents the RF termination on the PCB:

- Use a suitable 50 Ω connector providing proper PCB-to-RF-cable transition
- Strictly follow the connector manufacturer's recommended layout, for example:
  - SMA Pin-Through-Hole connectors require GND keep-out (i.e. clearance, a void area) on all the layers around the central pin up to annular pads of the four GND posts, as shown in Figure 23
  - UFL surface mounted connectors require no conductive traces (i.e. clearance, a void area) in the area below the connector between the GND land pads.
- Cut out the GND layer under RF connectors and close to buried vias, to remove stray capacitance and thus keep the RF line 50 Ω, e.g. the active pad of UFL connectors needs to have a GND keep-out (i.e. clearance, a void area) at least on first inner layer to reduce parasitic capacitance to ground.

If an integrated antenna is used, the RF termination is represented by the integrated antenna itself. The following guidelines should be followed.

- Use an antenna designed by an antenna manufacturer, providing the best possible return loss (or V.S.W.R.).
- Provide a ground plane large enough according to the relative integrated antenna requirements. The ground plane of the application PCB can be reduced down to a minimum size that must be similar to one quarter of wavelength of the minimum frequency that has to be radiated. As numerical example,

  Frequency = 1 GHz → Wavelength = 30 cm → Minimum GND plane size = 7.5 cm
- It is highly recommended to strictly follow the detailed and specific guidelines provided by the antenna manufacturer regarding correct installation and deployment of the antenna system, including PCB layout and matching circuitry.
- Further to the custom PCB and product restrictions, the antenna may require a tuning to comply with all the applicable required certification schemes. It is recommended to consult the antenna manufacturer for the design-in guidelines for the antenna matching relative to the custom application

Additionally, these recommendations regarding the antenna system placement must be followed:

- Do not include antenna within closed metal case.
- Do not place the antenna in close vicinity to end user since the emitted radiation in human tissue is limited by regulatory requirements.
- Place the antenna far from sensitive analog systems or employ countermeasures to reduce electromagnetic compatibility issues.
- Take care of interaction between co-located RF systems since the LTE transmitted power may interact or disturb the performance of companion systems.

## 2.4 SIM interface

#### 2.4.1.1 Guidelines for SIM circuit design

**Guidelines for SIM cards, SIM connectors and SIM chips selection**

The ISO/IEC 7816, the ETSI TS 102 221 and the ETSI TS 102 671 specifications define the physical, electrical and functional characteristics of Universal Integrated Circuit Cards (UICC) which contains the Subscriber Identification Module (SIM) integrated circuit that securely stores all the information needed to identify and authenticate subscribers over the LTE network.

Removable UICC / SIM card contacts mapping is defined by ISO/IEC 7816 and ETSI TS 102 221as follows:

- Contact C1 = VCC (Supply) → It must be connected to **VSIM**
- Contact C2 = RST (Reset) → It must be connected to **SIM_RST**
- Contact C3 = CLK (Clock) → It must be connected to **SIM_CLK**
- Contact C4 = AUX1 (Auxiliary contact) → It must be left not connected
- Contact C5 = GND (Ground) → It must be connected to **GND**
- Contact C6 = VPP (Programming supply) → It must be left not connected
- Contact C7 = I/O (Data input/output) → It must be connected to **SIM_IO**
- Contact C8 = AUX2 (Auxiliary contact) → It must be left not connected

A removable SIM card can have 6 contacts (C1 = VCC, C2 = RST, C3 = CLK, C5 = GND, C6 = VPP, C7 = I/O) or 8 contacts, providing also the auxiliary contacts C4 = AUX1 and C8 = AUX2 for USB interfaces and other uses. Only 6 contacts are required and must be connected to the module SIM card interface as described above, since TOBY-L1 modules do not support the additional auxiliary features (contacts C4 = AUX1 and C8 = AUX2).

Removable SIM card are suitable for applications where the SIM changing is required during the product lifetime.

A SIM card holder can have 6 or 8 positions if a mechanical card presence detector is not provided, or it can have 6+2 or 8+2 positions if two additional pins relative to the normally-open mechanical switch integrated in the SIM connector for the mechanical card presence detection are provided: select a SIM connector providing 6+2 or 8+2 positions if the optional SIM detection feature is required by the custom application, otherwise a connector without integrated mechanical presence switch can be selected.

Solderable UICC / SIM chip contacts mapping (M2M UICC Form Factor) is defined by ETSI TS 102 671 as follows:

- Package Pin 8 = UICC Contact C1 = VCC (Supply) → It must be connected to **VSIM.**
- Package Pin 7 = UICC Contact C2 = RST (Reset) → It must be connected to **SIM_RST.**
- Package Pin 6 = UICC Contact C3 = CLK (Clock) → It must be connected to **SIM_CLK.**
- Package Pin 5 = UICC Contact C4 = AUX1 (Auxiliary contact) → It must be left not connected.
- Package Pin 1 = UICC Contact C5 = GND (Ground) → It must be connected to **GND.**
- Package Pin 2 = UICC Contact C6 = VPP (Programming supply) →It must be connected to **VSIM.**
- Package Pin 3 = UICC Contact C7 = I/O (Data input/output) →It must be connected to **SIM_IO.**
- Package Pin 4 = UICC Contact C8 = AUX2 (Auxiliary contact) →It must be left not connected.

A solderable SIM chip has 8 contacts and can provide also the auxiliary contacts C4 = AUX1 and C8 = AUX2 for USB interfaces and other uses, but only 6 contacts are required and must be connected to the module SIM card interface as described above, since TOBY-L1 modules do not support the additional auxiliary features (contacts C4 = AUX1 and C8 = AUX2).

Solderable SIM chips are suitable for M2M applications where it is not required to change the SIM once installed.

### Guidelines for single SIM card connection without detection

A removable SIM card placed in a SIM card holder must be connected the SIM card interface of TOBY-L1 modules as described in Figure 24, where the optional SIM detection feature is not implemented (refer to the circuit described in **Error! Reference source not found.** if the SIM detection feature is not required).

Follow these guidelines connecting the module to a SIM connector without SIM presence detection:

- Connect the UICC / SIM contacts C1 (VCC) and C6 (VPP) to the **VSIM** pin of the module
- Connect the UICC / SIM contact C7 (I/O) to the **SIM_IO** pin of the module
- Connect the UICC / SIM contact C3 (CLK) to the **SIM_CLK** pin of the module
- Connect the UICC / SIM contact C2 (RST) to the **SIM_RST** pin of the module
- Connect the UICC / SIM contact C5 (GND) to ground
- Provide a 100 nF bypass capacitor (e.g. Murata GRM155R71C104K) at the SIM supply line (**VSIM**), close to the relative pad of the SIM connector, to prevent digital noise
- Provide a bypass capacitor of about 22 pF to 47 pF (e.g. Murata GRM1555C1H470J) on each SIM line (**VSIM**, **SIM_CLK**, **SIM_IO**, **SIM_RST**), very close to each relative pad of the SIM connector, to prevent RF coupling especially in case the RF antenna is placed closer than 10 - 30 cm from the SIM card holder
- Provide a very low capacitance (i.e. less than 10 pF) ESD protection (e.g. Tyco Electronics PESD0402-140) on each externally accessible SIM line, close to each relative pad of the SIM connector: ESD sensitivity rating of the SIM interface pins is 1 kV (Human Body Model according to JESD22-A114), so that, according to the EMC/ESD requirements of the custom application, higher protection level can be required if the lines are externally accessible on the application device
- Limit capacitance and series resistance on each SIM signal (**SIM_CLK**, **SIM_IO**, **SIM_RST**) to match the requirements for the SIM interface (27.7 ns is the maximum allowed rise time on the **SIM_CLK** line, 1.0 µs is the maximum allowed rise time on the **SIM_IO** and **SIM_RST** lines)

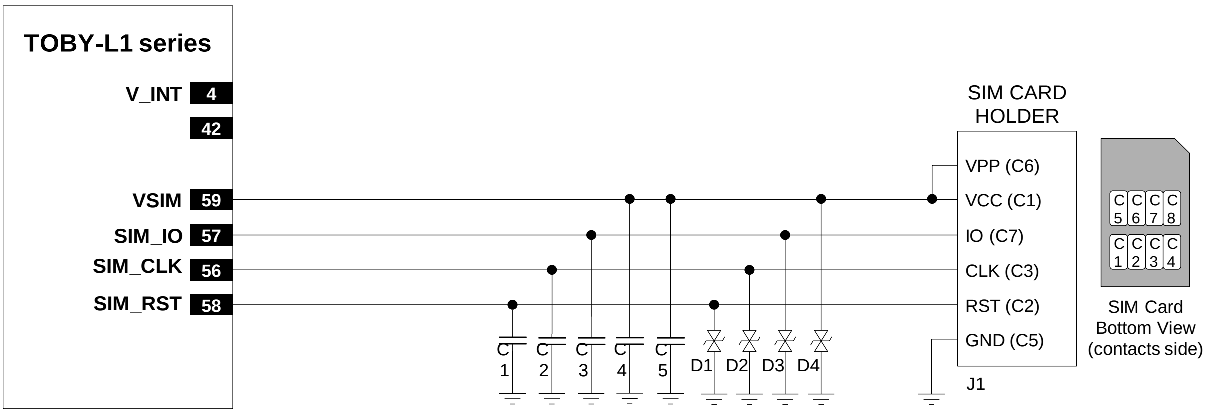


**Figure 24: Application circuit for the connection to a single removable SIM card, with SIM detection not implemented**

| Reference | Description | Part Number - Manufacturer |
|---|---|---|
| C1, C2, C3, C4 | 47 pF Capacitor Ceramic C0G 0402 5% 50 V | GRM1555C1H470JA01 - Murata |
| C5 | 100 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R71C104KA01 - Murata |
| D1, D2, D3, D4 | Very Low Capacitance ESD Protection | PESD0402-140 - Tyco Electronics |
| J1 | SIM Card Holder<br>6 positions, without card presence switch | Various Manufacturers,<br>C707 10M006 136 2 - Amphenol |

**Table 16: Example of components for the connection to a single removable SIM card, with SIM detection not implemented**

### Guidelines for single SIM chip connection

A solderable SIM chip (M2M UICC Form Factor) must be connected the SIM card interface of TOBY-L1 modules as described in Figure 25, where the optional SIM detection feature is not implemented (refer to the circuit described in **Error! Reference source not found.** if the SIM detection feature is not required).

Follow these guidelines connecting the module to a solderable SIM chip without SIM presence detection:

- Connect the UICC / SIM contacts C1 (VCC) and C6 (VPP) to the **VSIM** pin of the module
- Connect the UICC / SIM contact C7 (I/O) to the **SIM_IO** pin of the module
- Connect the UICC / SIM contact C3 (CLK) to the **SIM_CLK** pin of the module
- Connect the UICC / SIM contact C2 (RST) to the **SIM_RST** pin of the module
- Connect the UICC / SIM contact C5 (GND) to ground
- Provide a 100 nF bypass capacitor (e.g. Murata GRM155R71C104K) at the SIM supply line (**VSIM**) close to the relative pad of the SIM chip, to prevent digital noise
- Provide a bypass capacitor of about 22 pF to 47 pF (e.g. Murata GRM1555C1H470J) on each SIM line (**VSIM**, **SIM_CLK**, **SIM_IO**, **SIM_RST**), to prevent RF coupling especially in case the RF antenna is placed closer than 10 - 30 cm from the SIM card holder
- Limit capacitance and series resistance on each SIM signal (**SIM_CLK**, **SIM_IO**, **SIM_RST**) to match the requirements for the SIM interface (27.7 ns is the maximum allowed rise time on the **SIM_CLK** line, 1.0 µs is the maximum allowed rise time on the **SIM_IO** and **SIM_RST** lines)

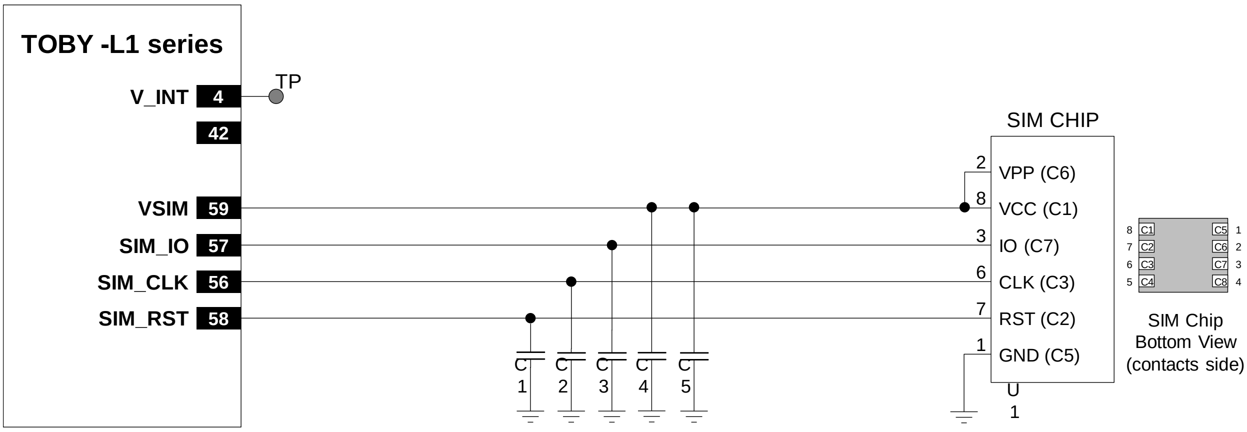


**Figure 25: Application circuit for the connection to a single solderable SIM chip, with SIM detection not implemented**

| Reference | Description | Part Number - Manufacturer |
|---|---|---|
| C1, C2, C3, C4 | 47 pF Capacitor Ceramic C0G 0402 5% 50 V | GRM1555C1H470JA01 - Murata |
| C5 | 100 nF Capacitor Ceramic X7R 0402 10% 16 V | GRM155R71C104KA01 - Murata |
| U1 | SIM chip (M2M UICC Form Factor) | Various Manufacturers |

**Table 17: Example of components for the connection to a single solderable SIM chip, with SIM detection not implemented**

#### 2.4.1.2 Guidelines for SIM layout design

The layout of the SIM card interface lines (**VSIM**, **SIM_CLK**, **SIM_IO**, **SIM_RST**) may be critical if the SIM card is placed far away from the TOBY-L1 series modules or in close proximity to the RF antenna: these two cases should be avoided or at least mitigated as described below.

In the first case, the long connection can cause the radiation of some harmonics of the digital data frequency as any other digital interface: keep the traces short and avoid coupling with RF line or sensitive analog inputs.

In the second case, the same harmonics can be picked up and create self-interference that can reduce the sensitivity of LTE receiver channels whose carrier frequency is coincidental with harmonic frequencies: placing the RF bypass capacitors suggested in **Error! Reference source not found.** near the SIM connector will mitigate the problem.

In addition, since the SIM card is typically accessed by the end user, it can be subjected to ESD discharges: add adequate ESD protection as suggested in **Error! Reference source not found.** to protect module SIM pins near the SIM connector.

Limit capacitance and series resistance on each SIM signal to match the SIM specifications: the connections should always be kept as short as possible.

Avoid coupling with any sensitive analog circuit, since the SIM signals can cause the radiation of some harmonics of the digital data frequency

## 2.5 Serial interfaces

### 2.5.1 USB interface

#### 2.5.1.1 Guidelines for USB circuit design

The **USB_D+** and **USB_D-** lines carry the USB serial data and signaling. The lines are used in single ended mode for full speed signaling handshake, as well as in differential mode for high speed signaling and data transfer.

USB pull-up or pull-down resistors on pins **USB_D+** and **USB_D-** as required by the Universal Serial Bus Revision 2.0 specification [4] are part of the USB pad driver and do not need to be externally provided.

External series resistors on pins **USB_D+** and **USB_D-** as required by the Universal Serial Bus Revision 2.0 specification [4] are also integrated and do not need to be externally provided.

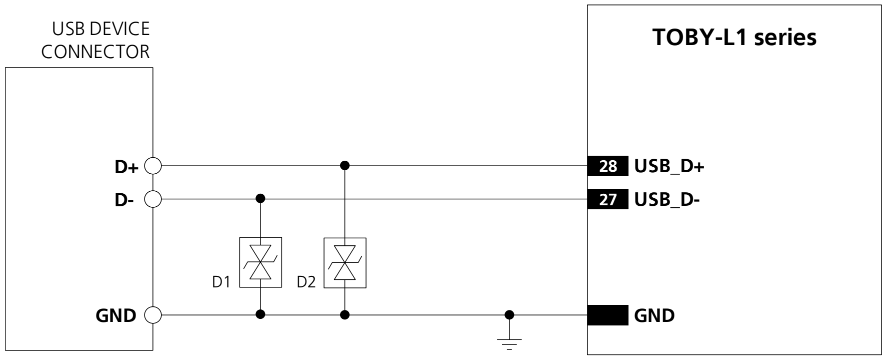


**Figure 26: USB Interface application circuit**

| Reference | Description | Part Number - Manufacturer |
|---|---|---|
| D1, D2 | Very Low Capacitance ESD Protection | PESD0402-140 - Tyco Electronics |

**Table 18: Component for USB application circuit**

### 2.5.1.2 Guidelines for USB layout design

The **USB_D+** / **USB_D-** lines require accurate layout design to achieve reliable signaling at the high speed data rate (up to 480 Mb/s) supported by the USB serial interface.

The characteristic impedance of the **USB_D+** / **USB_D-** lines is specified by the Universal Serial Bus Revision 2.0 specification [4]. The most important parameter is the differential characteristic impedance applicable for the odd-mode electromagnetic field, which should be as close as possible to 90 Ω differential: signal integrity may be degraded if PCB layout is not optimal, especially when the USB signaling lines are very long.

Use the following general routing guidelines to minimize signal quality problems:

- Route **USB_D+** / **USB_D-** lines as a differential pair
- Route **USB_D+** / **USB_D-** lines as short as possible
- Ensure the differential characteristic impedance ($Z_0$) is as close as possible to 90 Ω
- Ensure the common mode characteristic impedance ($Z_{CM}$) is as close as possible to 30 Ω
- Consider design rules for **USB_D+** / **USB_D-** similar to RF transmission lines, being them coupled differential micro-strip or buried stripline: avoid any stubs, abrupt change of layout, and route on clear PCB area

Figure 27 and Figure 28 provide two examples of coplanar waveguide designs with differential characteristic impedance close to 90 Ω and common mode characteristic impedance close to 30 Ω. The first transmission line can be implemented in case of 4-layer PCB stack-up herein described, the second transmission line can be implemented in case of 2-layer PCB stack-up herein described.

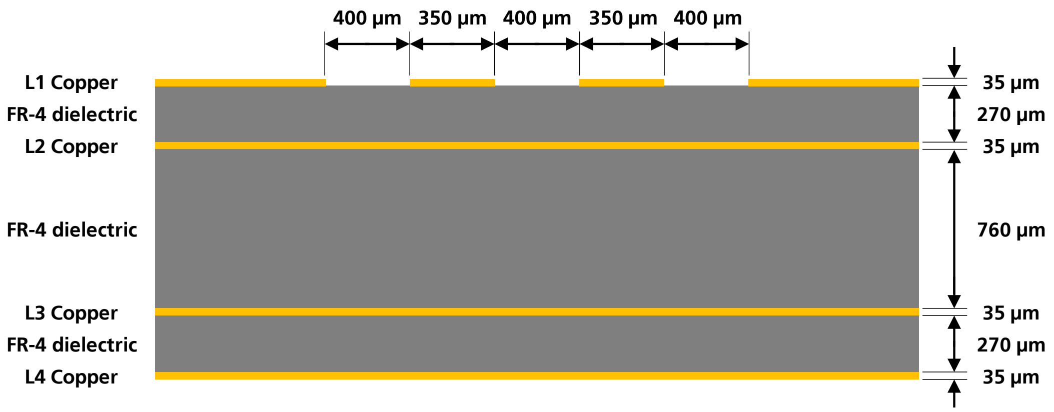


**Figure 27: Example of USB line design, with $Z_0$ close to 90 Ω and $Z_{CM}$ close to 30 Ω, for the described 4-layer board layup**

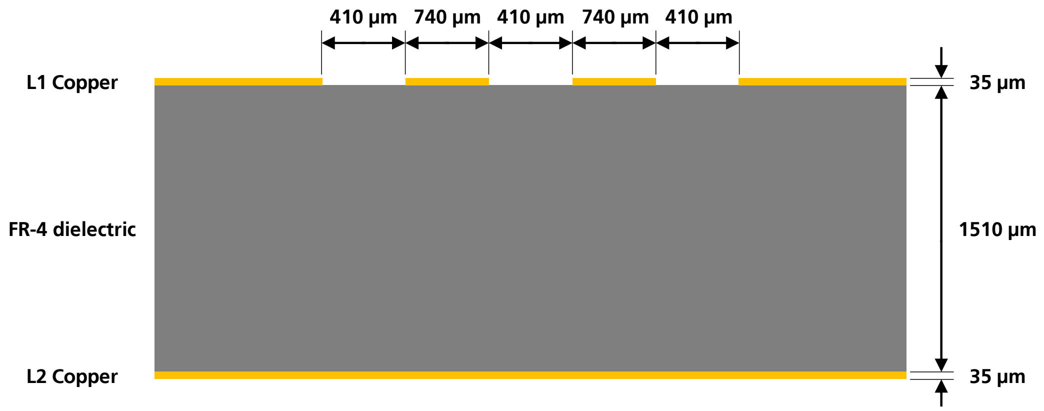


**Figure 28: Example of USB line design, with $Z_0$ close to 90 Ω and $Z_{CM}$ close to 30 Ω, for the described 2-layer board layup**

## 2.6 General Purpose Input/Output (GPIO)

#### 2.6.1.1 Guidelines for GPIO circuit design

The following application circuits are suggested as general guideline for the usage of the GPIO pins available with the TOBY-L1 modules, according to the relative custom function.

- **Network status indication**:

  The pin configured to provide the "Network status indication" function, e.g. the **GPIO1**, can be connected on the application board to an input pin of an application processor or can drive a LED by a transistor with integrated resistors to indicate network status.

## 2.7 Reserved pins (RSVD)

TOBY-L1 series modules have pins reserved for future use. All the **RSVD** pins are to be left unconnected on the application board.

## 2.8 Module placement

Optimize placement for minimum length of RF line and closer path from DC source for **VCC**.

Make sure that RF and analog circuits are clearly separated from any other digital circuits on the system board.

Provide enough clearance between the module and any external part.

☞ The heat dissipation during continuous transmission at maximum power can significantly raise the temperature of the application base-board below the TOBY-L1 modules: avoid placing temperature sensitive devices close to the module.

## 2.9 Module footprint and paste mask

Figure 29 and Table 19 describe the suggested footprint (i.e. copper mask) and paste mask layout for TOBY-L1 modules: the proposed land pattern layout reflects the modules' pads layout, while the proposed stencil apertures layout is slightly different (see the F'', H'', I'', J'', O'' parameters compared to the F', H', I', J', O' ones).

The Non Solder Mask Defined (NSMD) pad type is recommended over the Solder Mask Defined (SMD) pad type, implementing the solder mask opening 50 µm larger per side than the corresponding copper pad.

The recommended solder paste thickness is 150 µm, according to application production process requirements.

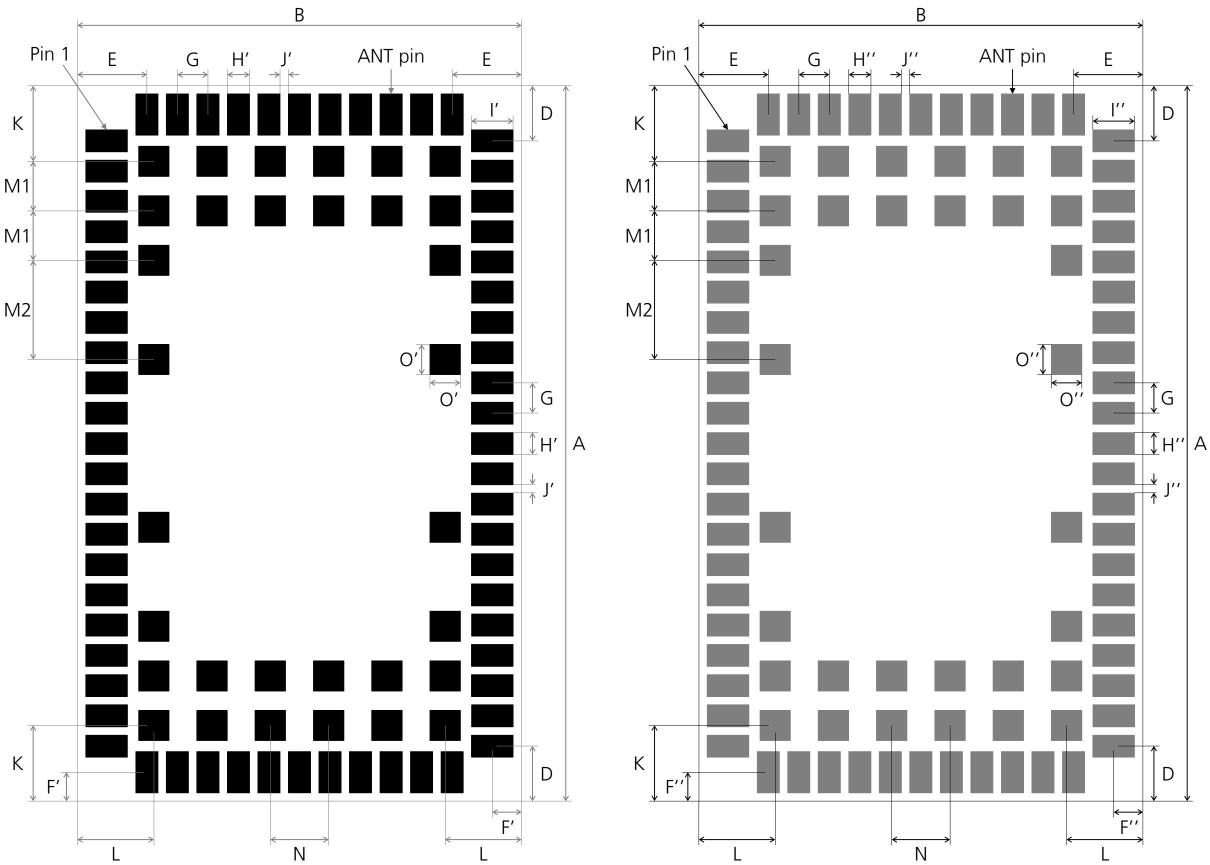


**Figure 29: TOBY-L1 series modules suggested footprint and paste mask (application board top view)**

| Parameter | Value | Parameter | Value | Parameter | Value |
|---|---|---|---|---|---|
| A | 26.0 mm | G | 1.10 mm | K | 2.75 mm |
| B | 16.0 mm | H' | 0.80 mm | L | 2.75 mm |
| C | 3.00 mm | H'' | 0.75 mm | M1 | 1.80 mm |
| D | 2.00 mm | I' | 1.50 mm | M2 | 3.60 mm |
| E | 2.50 mm | I'' | 1.55 mm | N | 2.10 mm |
| F' | 1.05 mm | J' | 0.30 mm | O' | 1.10 mm |
| F'' | 1.00 mm | J'' | 0.35 mm | O'' | 1.05 mm |

**Table 19: TOBY-L1 series modules suggested footprint and paste mask dimensions**

☞ These are recommendations only and not specifications. The exact copper, solder and paste mask geometries, distances, stencil thicknesses and solder paste volumes must be adapted to the specific production processes (e.g. soldering etc.) of the customer.

## 2.10 Thermal guidelines

☞ TOBY-L1 series module operating temperature range and module thermal resistance are specified in the TOBY-L1 series Data Sheet [1].

The most critical condition concerning module thermal performance is the uplink transmission at maximum power (data upload in connected-mode), when the baseband processor runs at full speed, radio circuits are all active and the RF power amplifier is driven to higher output RF power. This scenario is not often encountered in real networks; however the application should be correctly designed to cope with it.

During transmission at maximum RF power the TOBY-L1 series modules generate thermal power that can exceed 1 W: this is an indicative value since the exact generated power strictly depends on operating condition such as the number of allocated TX slot, transmitting frequency band, etc. The generated thermal power must be adequately dissipated through the thermal and mechanical design of the application.

The spreading of the Module-to-Ambient thermal resistance ($R_{th,M-A}$) depends on the module operating condition. The overall temperature distribution is influenced by the configuration of the active components during the specific mode of operation and their different thermal resistance toward the case interface.

Mounting a TOBY-L1 series module on a 79 mm x 62 mm x 1.41 mm 4-Layers PCB with a high coverage of copper in still air conditions[1], the increase of the module temperature[2] in different modes of operation, referred to idle state initial condition[3], can be summarized as following:

- ~8 °C during a LTE connection (1 TX slot, 1 RX slot) at max TX power
- ~12 °C during a GPRS data transfer (2 TX slots, 3 RX slots) at max TX power

☞ The Module-to-Ambient thermal resistance value and the relative increase of module temperature will be different for other mechanical deployments of the module, e.g. PCB with different dimensions and characteristics, mechanical shells enclosure, or forced air flow.

The increase of thermal dissipation, i.e. the Module-to-Ambient thermal resistance reduction, will decrease the temperature for internal circuitry of TOBY-L1 series modules for a given operating ambient temperature. This improves the device long-term reliability for applications operating at high ambient temperature.

A few hardware techniques may be used to reduce the Module-to-Ambient thermal resistance in the application:

- Connect each **GND** pin with solid ground layer of the application board and connect each ground area of the multilayer application board with complete thermal via stacked down to main ground layer.
- Provide a ground plane as wide as possible on the application board.
- Optimize antenna return loss, to optimize overall electrical performance of the module including a decrease of module thermal power.
- Optimize the thermal design of any high-power components included in the application, such as linear regulators and amplifiers, to optimize overall temperature distribution in the application device.
- Select the material, the thickness and the surface of the box (i.e. the mechanical enclosure of the application device that integrates the module) so that it provides good thermal dissipation.
- Force ventilation air-flow within mechanical enclosure.
- Provide a heat sink component attached to the module top side, with electrically insulated / high thermal conductivity adhesive, or on the backside of the application board, below the wireless module.

[1] Refer to TOBY-L1 series Data Sheet [1] for the $R_{th,M-A}$ value in this application condition
[2] Temperature is measured by internal sensor of wireless module
[3] Steady state thermal equilibrium is assumed. The module's temperature in idle state can be considered equal to ambient temperature

For example, after the installation of a robust aluminum heat-sink with forced air ventilation on the back of the same application board described above, the Module-to-Ambient thermal resistance ($R_{th,M-A}$) is reduced up to the Module-to-Case thermal resistance ($R_{th,M-C}$) defined in the TOBY-L1 series Data Sheet [1]. The effect of lower $R_{th,M-A}$ can be seen from the module temperature increase, which now can be summarized as following:

- ~1 °C during a LTE connection (1 TX slot, 1 RX slot) at the maximum TX power

Beside the reduction of the Module-to-Ambient thermal resistance implemented by the hardware design of the application device integrating a TOBY-L1 series module, the increase of module temperature can be moderated by the software implementation of the application.

Since the most critical condition concerning module thermal power occurs when module connected-mode is enabled, the actual module thermal power depends, as module current consumption, on the radio access mode,the operating band and the average TX power.

## 2.11 ESD guidelines

### 2.11.1 ESD immunity test overview

The immunity of devices integrating TOBY-L1 series modules to Electro-Static Discharge (ESD) is part of the Electro-Magnetic Compatibility (EMC) conformity which is required for products bearing the CE marking, compliant with the R&TTE Directive (99/5/EC), the EMC Directive (89/336/EEC) and the Low Voltage Directive (73/23/EEC) issued by the Commission of the European Community.

Compliance with these directives implies conformity to the following European Norms for device ESD immunity: ESD testing standard CENELEC EN 61000-4-2 [6] and the radio equipment standards ETSI EN 301 489-1 [7], ETSI EN 301 489-7 [8], ETSI EN 301 489-24 [9], which requirements are summarized in Table 20.

The ESD immunity test is performed at the enclosure port, defined by ETSI EN 301 489-1 [7] as the physical boundary through which the electromagnetic field radiates. If the device implements an integral antenna, the enclosure port is seen as all insulating and conductive surfaces housing the device. If the device implements a removable antenna, the antenna port can be separated from the enclosure port. The antenna port includes the antenna element and its interconnecting cable surfaces.

The applicability of ESD immunity test to the whole device depends on the device classification as defined by ETSI EN 301 489-1 [7]. Applicability of ESD immunity test to the relative device ports or the relative interconnecting cables to auxiliary equipment, depends on device accessible interfaces and manufacturer requirements, as defined by ETSI EN 301 489-1 [7].

Contact discharges are performed at conductive surfaces, while air discharges are performed at insulating surfaces. Indirect contact discharges are performed on the measurement setup horizontal and vertical coupling planes as defined in CENELEC EN 61000-4-2 [6].

☞ For the definition of integral antenna, removable antenna, antenna port, device classification refer to ETSI EN 301 489-1 [7].

☞ CENELEC EN 61000-4-2 [6] defines the contact and air discharges.

| Application | Category | Immunity Level |
|---|---|---|
| All exposed surfaces of the radio equipment and ancillary equipment in a representative configuration | Contact Discharge | 4 kV |
| | Air Discharge | 8 kV |

**Table 20: Electro-Magnetic Compatibility ESD immunity requirements as defined by CENELEC EN 61000-4-2, ETSI EN 301 489-1, ETSI EN 301 489-7, ETSI EN 301 489-24**

### 2.11.2 ESD immunity test of TOBY-L1 series reference designs

Although Electro-Magnetic Compatibility (EMC) certification is required for customized devices integrating TOBY-L1 series modules for R&TTED and European Conformance CE mark, EMC certification (including ESD immunity) has been successfully performed on TOBY-L1 series modules reference design according to CENELEC EN 61000-4-2 [6], ETSI EN 301 489-1 [7], ETSI EN 301 489-7 [8], ETSI EN 301 489-24 [9] European Norms.

The EMC / ESD approved u-blox reference designs consist of a TOBY-L1 series module soldered onto a motherboard which provides supply interface, SIM card, headset and communication port. An external antenna is connected to an SMA connector provided on the motherboard for the LTE antenna.

Since an external antenna is used, the antenna port can be separated from the enclosure port. The reference design is not enclosed in a box so that the enclosure port is not identified with physical surfaces. Therefore, some test cases cannot be applied. Only the antenna port is identified as accessible for direct ESD exposure.

☞ u-blox TOBY-L1 series reference design implement all the ESD precautions described in section 2.11.3.

Table 21 reports the u-blox TOBY-L1 series reference designs ESD immunity test results, according to test requirements stated in the CENELEC EN 61000-4-2 [6], ETSI EN 301 489-1 [7], ETSI EN 301 489-7 [8] and ETSI EN 301 489-24 [9].

| Category | Application | Immunity Level | Remarks |
|---|---|---|---|
| Contact Discharge to coupling planes (indirect contact discharge) | Enclosure | +4 kV / -4 kV | |
| Contact Discharges to conducted surfaces (direct contact discharge) | Enclosure port | Not Applicable | Test not applicable to u-blox reference design because it does not provide enclosure surface.<br>The test is applicable only to equipment providing conductive enclosure surface. |
| | Antenna port | +4 kV / -4 kV | Test applicable to u-blox reference design because it provides antenna with conductive & insulating surfaces.<br>The test is applicable only to equipment providing antenna with conductive surface. |
| Air Discharge at insulating surfaces | Enclosure port | Not Applicable | Test not applicable to the u-blox reference design because it does not provide an enclosure surface.<br>The test is applicable only to equipment providing insulating enclosure surface. |
| | Antenna port | +8 kV / -8 kV | Test applicable to u-blox reference design because it provides antenna with conductive & insulating surfaces.<br>The test is applicable only to equipment providing antenna with insulating surface. |

**Table 21: Enclosure ESD immunity level of u-blox TOBY-L1 series modules reference designs**

## 2.11.3 ESD application circuits

The application circuits described in this section are recommended and should be implemented in the device integrating TOBY-L1 series modules, according to the application board classification (see ETSI EN 301 489-1 [7]), to satisfy the requirements for ESD immunity test summarized in Table 20.

### Antenna interface

The **ANT** pin of TOBY-L1 series modules provides ESD immunity up to ±4 kV for direct Contact Discharge and up to ±8 kV for Air Discharge: no further precaution to ESD immunity test is needed, as implemented in the EMC / ESD approved reference design of TOBY-L1 series modules.

The antenna interface application circuit implemented in the EMC / ESD approved reference designs of TOBY-L1 series modules is described in Figure 23

### RESET_N pin

The following precautions are suggested for the **RESET_N** line of TOBY-L1 series modules, depending on the application board handling, to satisfy ESD immunity test requirements:

- It is recommended to keep the connection line to **RESET_N** as short as possible

Maximum ESD sensitivity rating of the **RESET_N** pin is 1 kV (Human Body Model according to JESD22-A114). Higher protection level could be required if the **RESET_N** pin is externally accessible on the application board. The following precautions are suggested to achieve higher protection level:

- A general purpose ESD protection device (e.g. EPCOS CA05P4S14THSG varistor array or EPCOS CT0402S14AHSG varistor) should be mounted on the **RESET_N** line, close to accessible point

The **RESET_N** application circuit implemented in the EMC / ESD approved reference designs of TOBY-L1 series modules is described in Figure 19 and Table 15 (section 2.2.2).

### SIM interface

The following precautions are suggested for TOBY-L1 series modules SIM interface (**VSIM**, **SIM_RST**, **SIM_IO**, **SIM_CLK** pins), depending on the application board handling, to satisfy ESD immunity test requirements:

- A 47 pF bypass capacitor (e.g. Murata GRM1555C1H470J) must be mounted on the lines connected to **VSIM**, **SIM_RST**, **SIM_IO** and **SIM_CLK** pins to assure SIM interface functionality when an electrostatic discharge is applied to the application board enclosure
- It is suggested to use as short as possible connection lines at SIM pins

Maximum ESD sensitivity rating of SIM interface pins is 1 kV (Human Body Model according to JESD22-A114). Higher protection level could be required if SIM interface pins are externally accessible on the application board. The following precautions are suggested to achieve higher protection level:

- A low capacitance (i.e. less than 10 pF) ESD protection device (e.g. Tyco Electronics PESD0402-140) should be mounted on each SIM interface line, close to accessible points (i.e. close to the SIM card holder)

The SIM interface application circuit implemented in the EMC / ESD approved reference designs of TOBY-L1 series modules is described in **Error! Reference source not found.** and **Error! Reference source not found.** (section 2.4).

### Other pins and interfaces

All the module pins that are externally accessible on the device integrating TOBY-L1 series module should be included in the ESD immunity test since they are considered to be a port as defined in ETSI EN 301 489-1 [7]. Depending on applicability, to satisfy ESD immunity test requirements according to ESD category level, all the module pins that are externally accessible should be protected up to ±4 kV for direct Contact Discharge and up to ±8 kV for Air Discharge applied to the enclosure surface.

The maximum ESD sensitivity rating of all the other pins of the module is 1 kV (Human Body Model according to JESD22-A114). Higher protection level could be required if the relative pin is externally accessible on the application board. The following precautions are suggested to achieve higher protection level:

- A general purpose ESD protection device (e.g. EPCOS CA05P4S14THSG or EPCOS CT0402S14AHSG varistor) should be mounted on the relative line, close to accessible point

## 2.12 Schematic for TOBY-L1 series module integration

Figure 30 is an example of a schematic diagram where a TOBY-L100 module is integrated into an application board, using all the available interfaces and functions of the module.

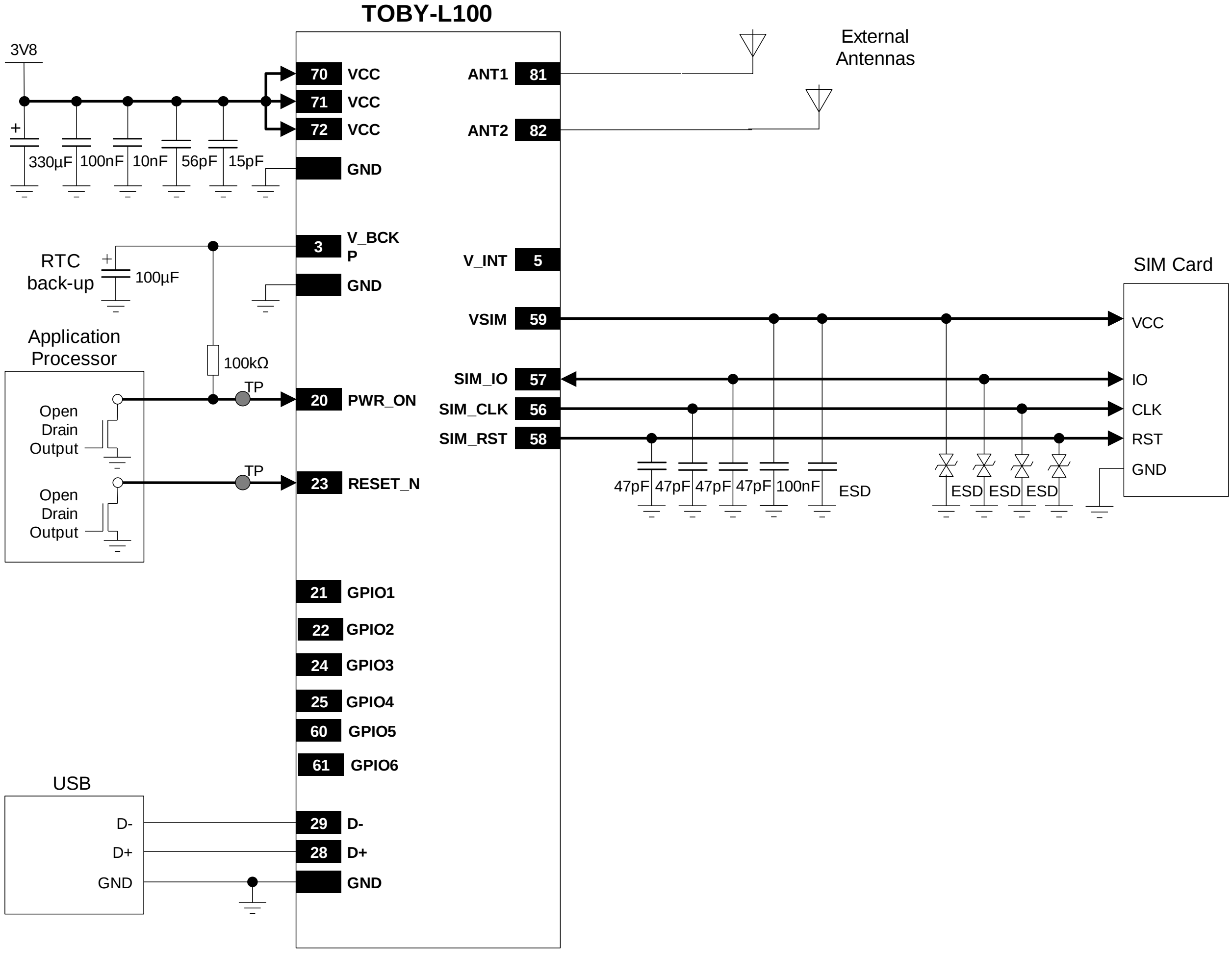


**Figure 30: Example of schematic diagram to integrate TOBY-L100 module in an application board, using all the interfaces**

## 2.13 Design-in checklist

This section provides a design-in checklist.

### 2.13.1 Schematic checklist

The following are the most important points for a simple schematic check:

- ☑ DC supply must provide a nominal voltage at **VCC** pin above the minimum operating range limit.
- ☑ DC supply must be capable of providing 1.0 A current pulses, providing a voltage at **VCC** pin above the minimum operating range limit and with a maximum 400 mV voltage drop from the nominal value.
- ☑ **VCC** supply should be clean, with very low ripple/noise: provide the suggested bypass capacitors, in particular if the application device integrates an internal antenna.
- ☑ Do not leave **PWR_ON** floating: fix properly the level, e.g. adding a proper pull-up resistor to **V_BCKP**.
- ☑ Do not apply loads which might exceed the limit for maximum available current from **V_INT** supply.
- ☑ Check that voltage level of any connected pin does not exceed the relative operating range.
- ☑ Capacitance and series resistance must be limited on each SIM signal to match the SIM specifications.
- ☑ Insert the suggested capacitors on each SIM signal and low capacitance ESD protections if accessible.
- ☑ Provide accessible testpoints directly connected to the following pins: **V_INT** pin, **PWR_ON** and/or **RESET_N** pins, to allow the module firmware upgrade using the u-blox EasyFlash tool and to allow the trace log capture (debug purpose).
- ☑ Provide proper precautions for ESD immunity as required on the application board.
- ☑ All unused pins can be left unconnected except the **PWR_ON** pin (its level must be properly fixed, e.g. adding a 100 kΩ pull-up to **V_BCKP**).

### 2.13.2 Layout checklist

The following are the most important points for a simple layout check:

☑ Check 50 Ω nominal characteristic impedance of the RF transmission line connected to the **ANT** pad (antenna RF input/output interface).

☑ Ensure no coupling occurs between the RF interface and noisy or sensitive signals (primarily analog audio input/output signals, SIM signals, high-speed digital lines).

☑ **VCC** line should be wide and short.

☑ Route **VCC** supply line away from sensitive analog signals.

☑ Ensure proper grounding.

☑ Optimize placement for minimum length of RF line and closer path from DC source for **VCC**.

☑ Keep routing short and minimize parasitic capacitance on the SIM lines to preserve signal integrity.

### 2.13.3 Antenna checklist

☑ Antenna termination should provide 50 Ω characteristic impedance with V.S.W.R at least less than 3:1 (recommended 2:1) on operating bands in deployment geographical area.

☑ Follow the recommendations of the antenna producer for correct antenna installation and deployment (PCB layout and matching circuitry).

☑ Follow the additional guidelines for products marked with the FCC logo (United States only) reported in chapter 2.3.1.2 and 4.2.2

☑ Follow the guidelines**Error! Reference source not found.** to get proper antenna detection functionality, if required.

# 3 Handling and soldering

☞ No natural rubbers, no hygroscopic materials or materials containing asbestos are employed.

## 3.1 Packaging, shipping, storage and moisture preconditioning

For information pertaining to reels and tapes, Moisture Sensitivity levels (MSD), shipment and storage information, as well as drying for preconditioning see the TOBY-L1 series Data Sheet [1] and the u-blox Package Information Guide **Error! Reference source not found.**.

The TOBY-L1 series modules are Electro-Static Discharge (ESD) sensitive devices.

⚠ **Ensure ESD precautions are implemented during handling of the module.**

## 3.2 Soldering

### 3.2.1 Soldering paste

Use of "No Clean" soldering paste is strongly recommended, as it does not require cleaning after the soldering process has taken place. The paste listed in the example below meets these criteria.

| | |
|---|---|
| Soldering Paste: | OM338 SAC405 / Nr.143714 (Cookson Electronics) |
| Alloy specification: | 95.5% Sn / 3.9% Ag / 0.6% Cu (95.5% Tin / 3.9% Silver / 0.6% Copper) |
| | 95.5% Sn / 4.0% Ag / 0.5% Cu (95.5% Tin / 4.0% Silver / 0.5% Copper) |
| Melting Temperature: | 217 °C |
| Stencil Thickness: | 150 µm for base boards |

The final choice of the soldering paste depends on the approved manufacturing procedures.

The paste-mask geometry for applying soldering paste should meet the recommendations in section 2.9

☞ The quality of the solder joints on the connectors ('half vias') should meet the appropriate IPC specification.

### 3.2.2 Reflow soldering

**A convection type-soldering oven is strongly recommended** over the infrared type radiation oven. Convection heated ovens allow precise control of the temperature and all parts will be heated up evenly, regardless of material properties, thickness of components and surface color.

Consider the "IPC-7530 Guidelines for temperature profiling for mass soldering (reflow and wave) processes, published 2001".

Reflow profiles are to be selected according to the following recommendations.

⚠ **Failure to observe these recommendations can result in severe damage to the device!**

### Preheat phase

Initial heating of component leads and balls. Residual humidity will be dried out. Note that this preheat phase will not replace prior baking procedures.

- Temperature rise rate: max 3 °C/s — If the temperature rise is too rapid in the preheat phase it may cause excessive slumping.
- Time: 60 – 120 s — If the preheat is insufficient, rather large solder balls tend to be generated. Conversely, if performed excessively, fine balls and large balls will be generated in clusters.
- End Temperature: 150 - 200 °C — If the temperature is too low, non-melting tends to be caused in areas containing large heat capacity.

### Heating/ reflow phase

The temperature rises above the liquidus temperature of 217 °C. Avoid a sudden rise in temperature as the slump of the paste could become worse.

- Limit time above 217 °C liquidus temperature: 40 - 60 s
- Peak reflow temperature: 245 °C

### Cooling phase

A controlled cooling avoids negative metallurgical effects (solder becomes more brittle) of the solder and possible mechanical tensions in the products. Controlled cooling helps to achieve bright solder fillets with a good shape and low contact angle.

- Temperature fall rate: max 4 °C/s

☞ To avoid falling off, modules should be placed on the topside of the motherboard during soldering.

The soldering temperature profile chosen at the factory depends on additional external factors like choice of soldering paste, size, thickness and properties of the base board, etc.

⚠ **Exceeding the maximum soldering temperature and the maximum liquidus time limit in the recommended soldering profile may permanently damage the module.**

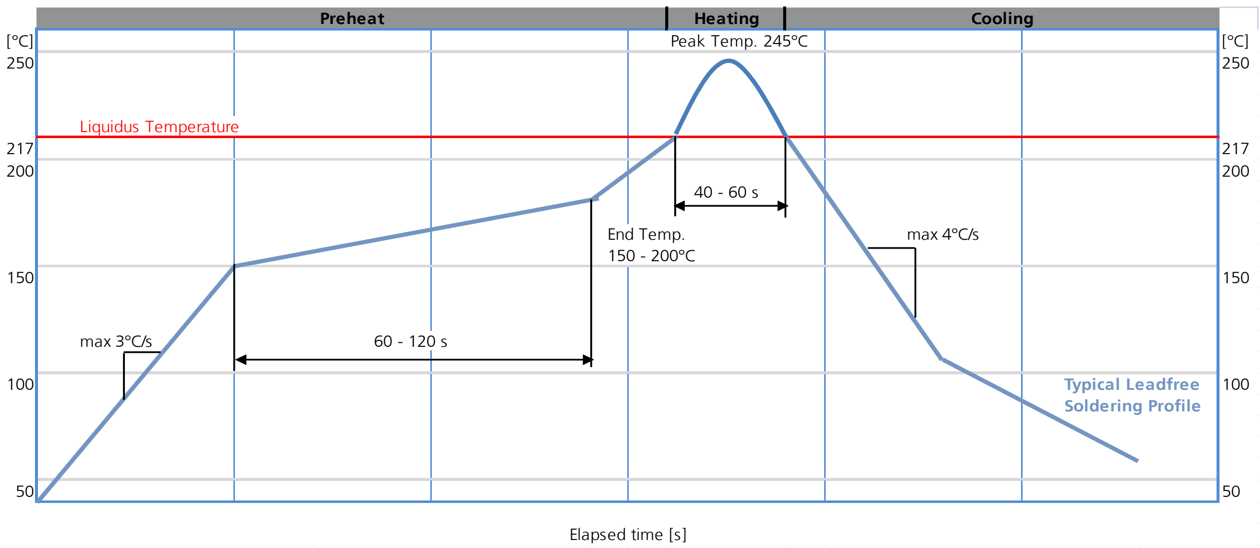


**Figure 31: Recommended soldering profile**

☞ TOBY-L1 series modules must not be soldered with a damp heat process.

### 3.2.3 Optical inspection

After soldering the TOBY-L1 series modules, inspect the modules optically to verify that the module is properly aligned and centered.

### 3.2.4 Cleaning

Cleaning the soldered modules is not recommended. Residues underneath the modules cannot be easily removed with a washing process.

- Cleaning with water will lead to capillary effects where water is absorbed in the gap between the baseboard and the module. The combination of residues of soldering flux and encapsulated water leads to short circuits or resistor-like interconnections between neighboring pads. Water will also damage the sticker and the ink-jet printed text.
- Cleaning with alcohol or other organic solvents can result in soldering flux residues flooding into the two housings, areas that are not accessible for post-wash inspections. The solvent will also damage the sticker and the ink-jet printed text.
- Ultrasonic cleaning will permanently damage the module, in particular the quartz oscillators.

For best results use a "no clean" soldering paste and eliminate the cleaning step after the soldering.

### 3.2.5 Repeated reflow soldering

Only a single reflow soldering process is encouraged for boards with a TOBY-L1 series module populated on it. The reason for this is the risk of the module falling off due to high weight in relation to the adhesive properties of the solder.

### 3.2.6 Wave soldering

Boards with combined through-hole technology (THT) components and surface-mount technology (SMT) devices require wave soldering to solder the THT components. Only a single wave soldering process is encouraged for boards populated with TOBY-L1 series modules.

### 3.2.7 Hand soldering

Hand soldering is not recommended.

### 3.2.8 Rework

Rework is not recommended.

☞ Never attempt a rework on the module itself, e.g. replacing individual components. Such actions immediately terminate the warranty.

### 3.2.9 Conformal coating

Certain applications employ a conformal coating of the PCB using HumiSeal® or other related coating products.

These materials affect the HF properties of the TOBY-L1 series modules and it is important to prevent them from flowing into the module.

The RF shields do not provide 100% protection for the module from coating liquids with low viscosity, therefore care is required in applying the coating.

☞ Conformal Coating of the module will void the warranty.

### 3.2.10 Casting

If casting is required, use viscose or another type of silicon pottant. The OEM is strongly advised to qualify such processes in combination with the TOBY-L1 series modules before implementing this in the production.

☞ Casting will void the warranty.

### 3.2.11 Grounding metal covers

Attempts to improve grounding by soldering ground cables, wick or other forms of metal strips directly onto the EMI covers is done at the customer's own risk. The numerous ground pins should be sufficient to provide optimum immunity to interferences and noise.

☞ u-blox gives no warranty for damages to the TOBY-L1 series modules caused by soldering metal cables or any other forms of metal strips directly onto the EMI covers.

### 3.2.12 Use of ultrasonic processes

TOBY-L1 series modules contain components which are sensitive to Ultrasonic Waves. Use of any Ultrasonic Processes (cleaning, welding etc.) may cause damage to the module.

☞ u-blox gives no warranty against damages to the TOBY-L1 series modules caused by any Ultrasonic Processes.

# 4 Approvals

☞ For the complete list of all the certification schemes approvals of TOBY-L1 series modules and the corresponding declarations of conformity, refer to the u-blox web-site (http://www.u-blox.com).

## 4.1 Product certification approval overview

Product certification approval is the process of certifying that a product has passed all tests and criteria required by specifications, typically called "certification schemes" that can be divided into three distinct categories:

- Regulatory certification
  - Country specific approval required by local government in most regions and countries, as:
    - CE (Conformité Européenne) marking for European Union
    - FCC (Federal Communications Commission) approval for United States
- Industry certification
  - Telecom industry specific approval verifying the interoperability between devices and networks:
    - GCF (Global Certification Forum), partnership between European device manufacturers and network operators to ensure and verify global interoperability between devices and networks
    - PTCRB (PCS Type Certification Review Board), created by United States network operators to ensure and verify interoperability between devices and North America networks
- Operator certification
  - Operator specific approval required by some mobile network operator, as:
    - AT&T network operator in United States

Even if TOBY-L1 modules are approved under all major certification schemes, the application device that integrates TOBY-L1 modules must be approved under all the certification schemes required by the specific application device to be deployed in the market.

The required certification scheme approvals and relative testing specifications differ depending on the country or the region where the device that integrates TOBY-L1 series modules must be deployed, on the relative vertical market of the device, on type, features and functionalities of the whole application device, and on the network operators where the device must operate.

☞ The certification of the application device that integrates a TOBY-L1 module and the compliance of the application device with all the applicable certification schemes, directives and standards are the sole responsibility of the application device manufacturer.

TOBY-L1 modules are certified according to all capabilities and options stated in the Protocol Implementation Conformance Statement document (PICS) of the module. The PICS, according to 3GPP TS 51.010-2 [5], is a statement of the implemented and supported capabilities and options of a device.

☞ The PICS document of the application device integrating a TOBY-L1 module must be updated from the module PICS statement if any feature stated as supported by the module in its PICS document is not implemented or disabled in the application device, as for the following cases:

- if the automatic network attach is disabled by AT+COPS command

## 4.2 Federal Communications Commission and Industry Canada notice

Federal Communications Commission (FCC) ID:

- R5Q-TOBYL100
-

Industry Canada (IC) Certification Number:

- 8595A-TOBYL100

### 4.2.1 Safety Warnings review the structure

- Equipment for building-in. The requirements for fire enclosure must be evaluated in the end product
- The clearance and creepage current distances required by the end product must be withheld when the module is installed
- The cooling of the end product shall not negatively be influenced by the installation of the module
- Excessive sound pressure from earphones and headphones can cause hearing loss
- No natural rubbers, no hygroscopic materials nor materials containing asbestos are employed

### 4.2.2 Declaration of Conformity – United States only

This device complies with Part 27 of the FCC rules. Operation is subject to the following two conditions:

- this device may not cause harmful interference
- this device must accept any interference received, including interference that may cause undesired operation

⚠ **Radiofrequency radiation exposure Information: this equipment complies with FCC radiation exposure limits prescribed for an uncontrolled environment for fixed and mobile use conditions. This equipment should be installed and operated with a minimum distance of 20 cm between the radiator and the body of the user or nearby persons. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter except as authorized in the certification of the product.**

⚠ **The gain of the system antenna(s) used for the TOBY-L1 series modules (i.e. the combined transmission line, connector, cable losses and radiating element gain) must not exceed 10.7 dBi (for LTE band 13) and 6.57 dBi (for LTE band 4) for mobile and fixed or mobile operating configurations.**

### 4.2.3 Modifications

The FCC requires the user to be notified that any changes or modifications made to this device that are not expressly approved by u-blox could void the user's authority to operate the equipment.

⚠ **Manufacturers of mobile or fixed devices incorporating the TOBY-L1 series modules are authorized to use the FCC Grants and Industry Canada Certificates of the TOBY-L1 series modules for their own final products according to the conditions referenced in the certificates.**

⚠ **The FCC Label shall in the above case be visible from the outside, or the host device shall bear a second label stating:**

**"Contains FCC ID: R5Q-TOBYL100" resp.**

⚠ **The IC Label shall in the above case be visible from the outside, or the host device shall bear a second label stating:**

**"Contains IC: 8595A-TOBYL100" resp.**

⚠ **Canada, Industry Canada (IC) Notices**

**This Class B digital apparatus complies with Canadian ICES-003 and RSS-210.**

**Operation is subject to the following two conditions:**

- **this device may not cause interference**
- **this device must accept any interference, including interference that may cause undesired operation of the device**

**Radio Frequency (RF) Exposure Information**

**The radiated output power of the u-blox Wireless Module is below the Industry Canada (IC) radio frequency exposure limits. The u-blox Wireless Module should be used in such a manner such that the potential for human contact during normal operation is minimized.**

**This device has been evaluated and shown compliant with the IC RF Exposure limits under mobile exposure conditions (antennas are greater than 20cm from a person's body).**

**This device has been certified for use in Canada. Status of the listing in the Industry Canada's REL (Radio Equipment List) can be found at the following web address: http://www.ic.gc.ca/app/sitt/reltel/srch/nwRdSrch.do?lang=eng**

**Additional Canadian information on RF exposure also can be found at the following web address: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08792.html**

⚠ **IMPORTANT: Manufacturers of portable applications incorporating the TOBY-L1 series 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 device. This is mandatory to meet the SAR requirements for portable devices.**

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

⚠ **Canada, avis d'Industrie Canada (IC)**

**Cet appareil numérique de classe B est conforme aux normes canadiennes ICES-003 et RSS-139.**

**Son fonctionnement est soumis aux deux conditions suivantes:**

- **cet appareil ne doit pas causer d'interférence**
- **cet appareil doit accepter toute interférence, notamment les interférences qui peuvent affecter son fonctionnement**

**Informations concernant l'exposition aux fréquences radio (RF)**

**La puissance de sortie émise par l'appareil de sans fil u-blox Wireless Module est inférieure à la limite d'exposition aux fréquences radio d'Industrie Canada (IC). Utilisez l'appareil de sans fil u-blox Wireless Module de façon à minimiser les contacts humains lors du fonctionnement normal.**

**Ce périphérique a été évalué et démontré conforme aux limites d'exposition aux fréquences radio (RF) d'IC lorsqu'il est installé dans des produits hôtes particuliers qui fonctionnent dans des conditions d'exposition à des appareils mobiles (les antennes se situent à plus de 20 centimètres du corps d'une personne).**

**Ce périphérique est homologué pour l'utilisation au Canada. Pour consulter l'entrée correspondant à l'appareil dans la liste d'équipement radio (REL - Radio Equipment List) d'Industrie Canada rendez-vous sur:**

**http://www.ic.gc.ca/app/sitt/reltel/srch/nwRdSrch.do?lang=fra**

**Pour des informations supplémentaires concernant l'exposition aux RF au Canada rendez-vous sur: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08792.html**

⚠ **IMPORTANT: les fabricants d'applications portables contenant les modules TOBY-L1 series doivent faire certifier leur produit final et déposer directement leur candidature pour une certification FCC ainsi que pour un certificat Industrie Canada délivré par l'organisme chargé de ce type d'appareil portable. Ceci est obligatoire afin d'être en accord avec les exigences SAR pour les appareils portables.**

**Tout changement ou modification non expressément approuvé par la partie responsable de la certification peut annuler le droit d'utiliser l'équipement.**

## 4.3 R&TTED and European Conformance CE mark

This device has been evaluated against the essential requirements of the 1999/5/EC Directive.

In order to satisfy the essential requirements of 1999/5/EC Directive, the module is compliant with the following standards:

- Radio Frequency spectrum use (R&TTE art. 3.2):
  - EN 301 511 V9.0.2
- Electromagnetic Compatibility (R&TTE art. 3.1b):
  - EN 301 489-1 V1.9.2
  - EN 301 489-7 V1.4.1
- Health and Safety (R&TTE art. 3.1a)
  - EN 60950-1:2006 + A11:2009 + A1:2010 + A12:2011 + AC:2011
  - EN 62311:2008

The conformity assessment procedure referred to in Article 10 and detailed in Annex IV of Directive 1999/5/EC has been followed with the involvement of the following Notified Body No: 1909

Thus, the following marking is included in the product:

**CE 1909**

There is no restriction for the commercialisation of this device in all the countries of the European Union.

# 5 Product Testing

## 5.1 u-blox in-series production test

u-blox focuses on high quality for its products. All units produced are fully tested. Defective units are analyzed in detail to improve the production quality.

This is achieved with automatic test equipment, which delivers a detailed test report for each unit. The following measurements are done:

- Digital self-test (firmware download, Flash firmware verification, IMEI programming)
- Measurement of voltages and currents
- Adjustment of ADC measurement interfaces
- Functional tests (USB  interface communication, SIM card communication)
- Digital tests (GPIOs)
- Measurement and calibration of RF characteristics in all supported bands (Receiver S/N verification, frequency tuning of reference clock, calibration of transmitter and receiver power levels)
- Verification of RF characteristics after calibration (modulation accuracy, power levels and spectrum performance are checked to be within tolerances when calibration parameters are applied)

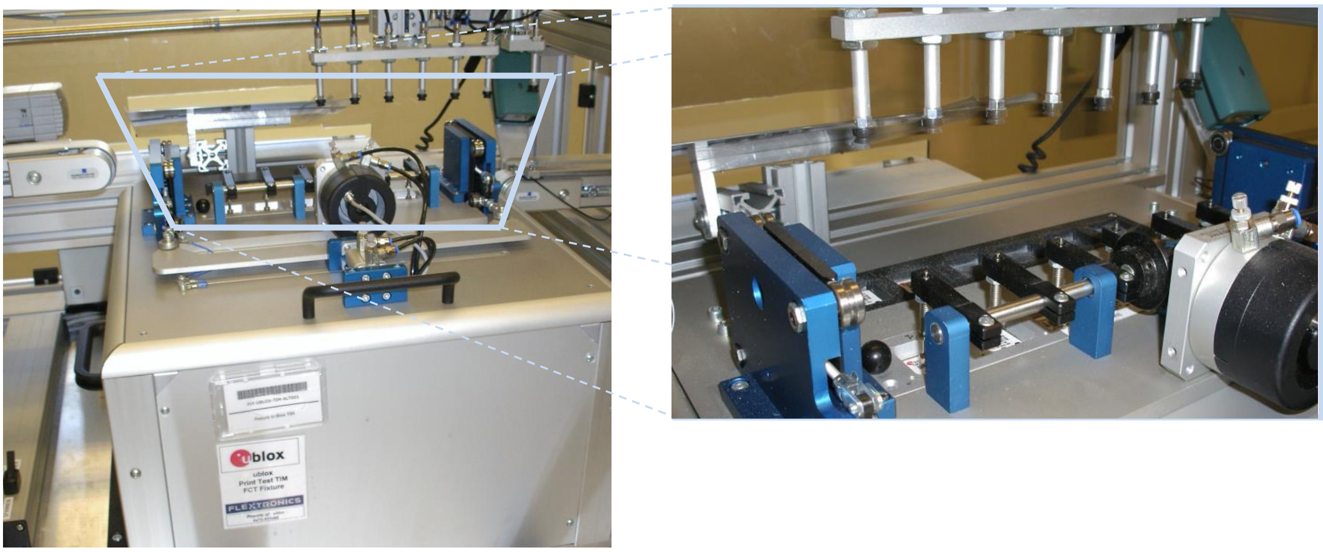

**Figure 32: Automatic test equipment for module tests**

## 5.2 Test parameters for OEM manufacturer

Because of the testing done by u-blox (with 100% coverage), an OEM manufacturer does not need to repeat firmware tests or measurements of the module RF performance or tests over analog and digital interfaces in their production test.

An OEM manufacturer should focus on:

- Module assembly on the device; it should be verified that:
  - Soldering and handling process did not damaged the module components
  - All module pins are well soldered on device board
  - There are no short circuits between pins

- Component assembly on the device; it should be verified that:
    - Communication with host controller can be established
    - The interfaces between module and device are working
    - Overall RF performance test of the device including antenna

Dedicated tests can be implemented to check the device. For example, the measurement of module current consumption when set in a specified status can detect a short circuit if compared with a "Golden Device" result.

Module AT commands are used to perform functional tests (communication with host controller, check SIM card interface, check communication between module and GPIOs, etc.) and to perform RF performance tests.

### 5.2.1 "Go/No go" tests for integrated devices

A 'Go/No go' test is to compare the signal quality with a "Golden Device" in a position with excellent network coverage and after having established a data connection (refer to TOBY-L1xx AT Commands Manual [2], AT+CSQ command: <rssi>, <ber> parameters).

☞ These kinds of test may be useful as a 'go/no go' test but not for RF performance measurements.

This test is suitable to check the communication with host controller and SIM card, the audio and power supply functionality and verify if components at antenna interface are well soldered.

### 5.2.2 Functional tests providing RF operation

Overall RF performance test of the device including antenna can be performed with basic instruments such as a spectrum analyzer (or an RF power meter) and a signal generator using AT+UTEST command over AT interface.

The AT+UTEST command gives a simple interface to set the module to Rx and Tx test modes ignoring LTE signaling protocol. The command can set the module:

- In transmitting mode in a specified channel and power level in all supported modulation schemes (single slot GMSK) and bands
- In receiving mode in a specified channel to returns the measured power level in all supported bands

☞ Refer to the TOBY-L1xx AT Commands Manual [2], for AT+UTEST command syntax description.

☞ Refer to the End user test Application Note **Error! Reference source not found.**, for AT+UTEST command user guide, limitations and examples of use.

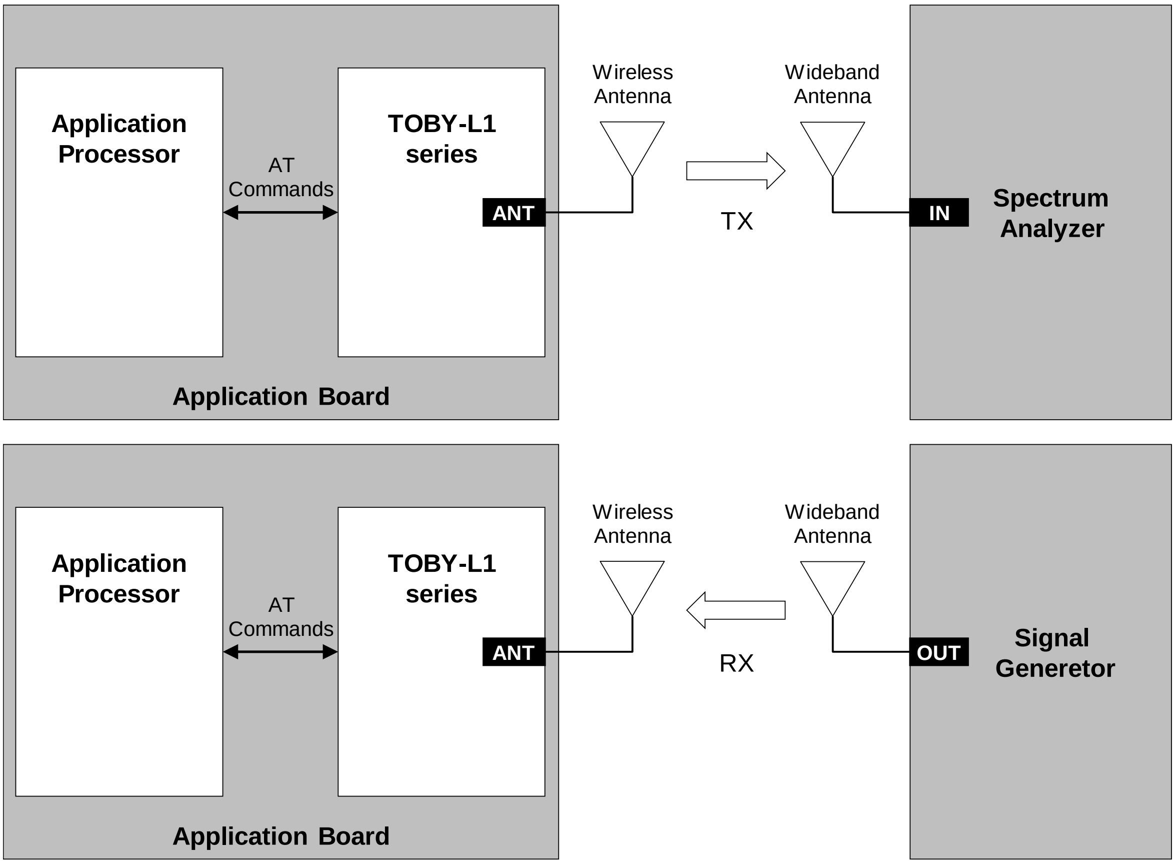


**Figure 33: Setup with spectrum analyzer and signal generator for radiated measurement**

This feature allows the measurement of the transmitter and receiver power levels to check component assembly related to the module antenna interface and to check other device interfaces from which depends the RF performance.

⚠ **To avoid module damage during transmitter test, a proper antenna according to module specifications or a 50 Ω termination must be connected to ANT pin.**

⚠ **To avoid module damage during receiver test the maximum power level received at ANT pin must meet module specifications.**

☞ The AT+UTEST command sets the module to emit RF power ignoring LTE signalling protocol. This emission can generate interference that can be prohibited by law in some countries. The use of this feature is intended for testing purpose in controlled environments by qualified user and must not be used during the normal module operation. Follow instructions suggested in u-blox documentation. u-blox assumes no responsibilities for the inappropriate use of this feature.

# Appendix

# A Glossary

| | |
|---|---|
| 3GPP | 3rd Generation Partnership Project |
| ADC | Analog to Digital Converter |
| AP | Application Processor |
| AT | AT Command Interpreter Software Subsystem, or attention |
| CS | Coding Scheme |
| CSD | Circuit Switched Data |
| CTS | Clear To Send |
| DC | Direct Current |
| DCD | Data Carrier Detect |
| DCE | Data Communication Equipment |
| DCS | Digital Cellular System |
| DDC | Display Data Channel interface |
| DL | Down-link (Reception) |
| DRX | Discontinuous Reception |
| DSP | Digital Signal Processing |
| DSR | Data Set Ready |
| DTE | Data Terminal Equipment |
| DTM | Dual Transfer Mode |
| DTR | Data Terminal Ready |
| EMC | Electro-magnetic Compatibility |
| EMI | Electro-magnetic Interference |
| ESD | Electro-static Discharge |
| ESR | Equivalent Series Resistance |
| FEM | Front End Module |
| FOAT | Firmware Over AT commands |
| FTP | File Transfer Protocol |
| FTPS | FTP Secure |
| FW | Firmware |
| QPSK / 16-QAM | Gaussian Minimum Shift Keying modulation |
| GND | Ground |
| GNSS | Global Navigation Satellite System |
| GPIO | General Purpose Input Output |
| GPRS | General Packet Radio Service |
| GPS | Global Positioning System |
| LTE | Global System for Mobile Communication |
| HF | Hands-free |
| HTTP | HyperText Transfer Protocol |
| HTTPS | Hypertext Transfer Protocol over Secure Socket Layer |
| HW | Hardware |
| I/Q | In phase and Quadrature |

| | |
|---|---|
| $I^2C$ | Inter-Integrated Circuit interface |
| $I^2S$ | Inter IC Sound interface |
| IP | Internet Protocol |
| LCC | Leadless Chip Carrier |
| LDO | Low-Dropout |
| LGA | Land Grid Array |
| LNA | Low Noise Amplifier |
| M2M | Machine-to-Machine |
| MCS | Modulation Coding Scheme |
| N/A | Not Applicable |
| N.A. | Not Available |
| PA | Power Amplifier |
| PCM | Pulse Code Modulation |
| PCN / IN | Product Change Notification / Information Note |
| PCS | Personal Communications Service |
| PFM | Pulse Frequency Modulation |
| PMU | Power Management Unit |
| PSRAM | Pseudo-Static RAM |
| PWM | Pulse Width Modulation |
| RF | Radio Frequency |
| RI | Ring Indicator |
| RTC | Real Time Clock |
| RTS | Request To Send |
| SAW | Surface Acoustic Wave |
| SIM | Subscriber Identification Module |
| SMS | Short Message Service |
| SMTP | Simple Mail Transfer Protocol |
| SPI | Serial Peripheral Interface |
| SRF | Self Resonant Frequency |
| TBD | To Be Defined |
| TCP | Transmission Control Protocol |
| FDMA | Frequency Division Multiple Access |
| TP | Test-Point |
| UART | Universal Asynchronous Receiver-Transmitter |
| UDP | User Datagram Protocol |
| UICC | Universal Integrated Circuit Card |
| UL | Up-link (Transmission) |
| UMTS | Universal Mobile Telecommunications System |
| USB | Universal Serial Bus |
| UTRA | UMTS Terrestrial Radio Access |
| VCO | Voltage Controlled Oscillator |
| VSWR | Voltage Standing Wave Ratio |

# Related documents


[1] u-blox TOBY-L1 series Data Sheet, Docu No UBX-13000868

[2] u-blox TOBY-L1 series AT Commands Manual, Docu No UBX-13002211

[3] 3GPP TS 27.007 – AT command set for User Equipment (UE) (Release 1999)

[4] Universal Serial Bus Revision 2.0 specification, http://www.usb.org/developers/docs/

[5] 3GPP TS 51.010-2 – Technical Specification Group GSM/EDGE Radio Access Network; Mobile Station (MS) conformance specification; Part 2: Protocol Implementation Conformance Statement (PICS)

[6] CENELEC EN 61000-4-2 (2001): "Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test".

[7] ETSI EN 301 489-1 V1.8.1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements"

[8] ETSI EN 301 489-7 V1.3.1 "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 7: Specific conditions for mobile and portable radio and ancillary equipment of digital cellular radio telecommunications systems"

[9] ETSI EN 301 489-24 V1.4.1 "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 24: Specific conditions for IMT-2000 CDMA Direct Spread (UTRA) for Mobile and portable (UE) radio and ancillary equipment"

[10] Multiplexer Implementation Application Note, Docu No WLS-CS-11002

[11] Firmware Update Application Note, Docu No WLS-CS-11001


Some of the above documents can be downloaded from u-blox web-site (http://www.u-blox.com).

# Revision history

| Revision | Date | Name | Status / Comments |
|---|---|---|---|
| - | 02 May 2013 | rcam | Initial Release |
| | | | |

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