SERCOMM 中磊電子

***TPB23***

# Hardware Guide

## Version 1.0

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**SerComm Corporation**

8F,No.3-1,YuanQu St.,NanKang,Taipei 115,Taiwan,R.O.C

Tel: 886-2-26553988

Fax: 886-2-26553966

http://www.sercomm.com

**SerComm (Suzhou) R&D Center**

NO, 26, Xinghai Street, Suzhou Industrial Park, Jiangsu, China

Tel: 86-512-67612332

Fax: 86-512-67612331

http://www.sercomm.com

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# Table of Contents

# 1. About This Document

## Purpose

This document describes the TPB23 module from the following aspects: overall introduction, hardware ports, port specifications, electrical characteristics, and related product information, helping you have quick overview of application scenarios, hardware specifications, and design suggestions of the TPB23 module.

## Intended Audience

This document is intended for hardware engineers.

## Draft A (2017-10-28)

This is the draft of *TPB23 Module Hardware Guide*.

# 2. Introduction

## 2.1. Product Description

The TPB23 module is used on Narrow-band Internet ofThings (NB-IoT) networks, and it communicates with mobile network operator (MNO) devices in compliance with the NB-IoT wireless communication protocol. Figure 2-1 illustrates the position of the TPB23 module on NB-IoT networks.

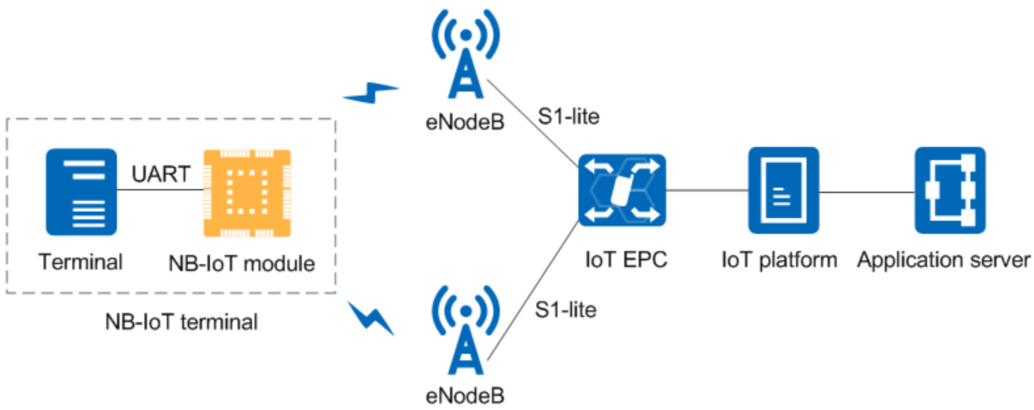



Figure 2-1 Network architecture

The following part details each item in the network architecture:

- NB-IoT terminal, such as smart water meter and gas meter

  Consists of terminals and NB-IoT modules and uses NB-IoT modules to communicate with an eNodeB over the Uu interface.
- NB-IoT module

  Lets terminals communicate with NB-IoT networks in compliance with the NB-IoT wireless communication protocol.
- Terminal, such as smart water meters and gas meters

  Communicates with NB-IoT modules in compliance with the universal asynchronous receiver/transmitter (UART).
- eNodeB

  Processes network access messages over the Uu interface, manages cells, and forwards non-access stratum (NAS) data to a higher-layer network element (NE) for processing. An eNodeB is connected to the IoT EPC over the S1-lite interface.
- IoT EPC

  Exchanges information with NB-IoT terminals at the NAS layer and forwards data related to NB-IoT services to the IoT platform for processing.
- IoT platform, referred to the IoT platform in this document

  Converges different types of IoT data from diversified radio access networks and forwards such data to a required service application for processing based on the data type.
- Application server

Functions as an IoT data convergence point and processes data based on customer requirements.

## 2.2. Function Description

The TPB23 module provides the interconnection between NB-IoT networks and terminals.

- Interconnection with NB-IoT eNodeBs
  - The TPB23 module receives signals sent from NB-IoT networks, processes then, and sends commands or data to terminals, to perform the operation and maintenance (O&M) for terminals.
  - The TPB23 module receives data and commands from terminals, transfers those data and commands to NB-IoT networks through NB-IoT eNodeBs, and then delivers them to application servers (ASs).
- Interconnection with terminals
  - The TPB23 module reads terminal data and uploads it to the NB-IoT platform.
  - The TPB23 module receives commands from the NB-IoT platform and performs O&M for terminals.

## 2.3. Block Circuit Diagram

The TPB23 module is based on the NB-IoT module developed by Boudica 150 chip. Figure 2-2 shows the module block circuit diagram.

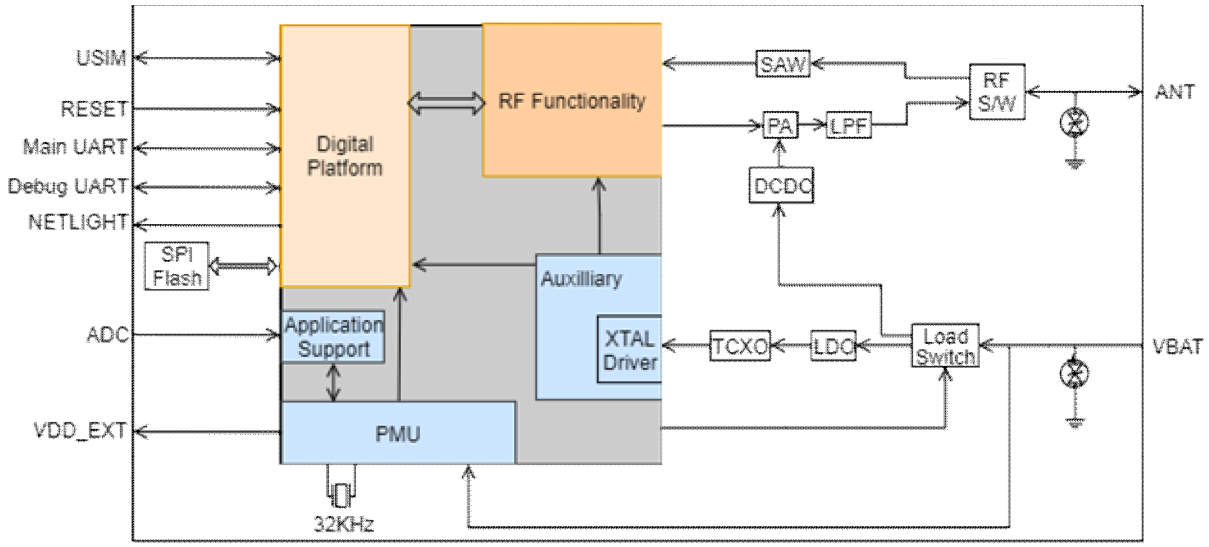



Figure 2-2 TPB23 module hardware overview diagram

## 2.4. EVK Board

Sercomm develops the Evaluation Kit (EVK) of the TPB23 module to help you easily use the TPB23 module, and quickly understand and control or test the TPB23 module. For details about how to use the EVK, see *TPB23 Module EVK User Guide*.

# 3. Application Port

## 3.1. Module Pin Definition

The TPB23 module provides 94-pin ports for external usage.

The pin define from TOP side as Figure 3-1 shows:

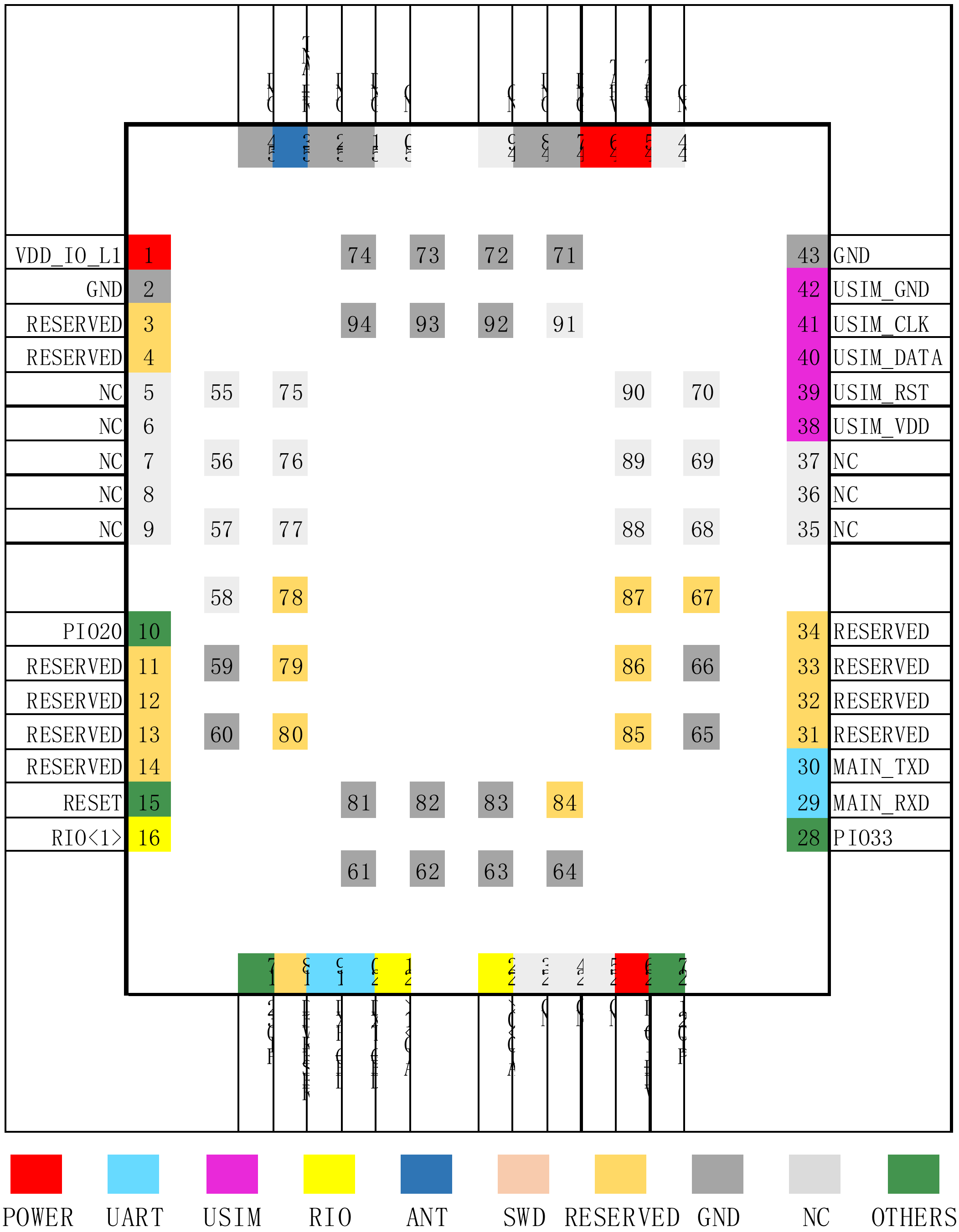



**Figure 3-1** Sequence of TPB23 module pins

**Table 3-1** I/O Parameters Definition

| Type | Description |
|---|---|
| DI | Digital input |
| DO | Digital output |
| I/O | Bidirectional input/output |
| AI | Analog input |
| AO | Analog output |
| PO | Power output |
| PI | Power input |
| OD | Open drain |

**Table 3-2** TPB23 module pin definition

| Pin Name | Pin No. | I/O Type | Description | PU/PD |
|---|---|---|---|---|
| VDD_IO_L1 | 1 | PO | IO_L1 power supply, default value is 0V, if this pin is not used, please floating. | -- |
| GND | 2, 43, 47, 48, 51, 52, 54, 59, 60, 61, 62, 63, 64, 65, 66, 71, 72, 73, 74, 81, 82, 83, 92, 93, and 94 | N/A | Used for grounding | -- |
| NC | 5, 6, 7, 8, 9, 23, 24, 25, 35, 36, 37, 44, 49, 50, 55, 56, 57, 58, 68, 69, 70, 75, 76, 77, 88, 89, 90 and 91 | N/A | Unconnected | -- |
| RESERVED | 11, 12, 13, 14, 18, 31, 32, 33, 34, 67, 78, 79, 80, 84, 85, 86 and 87 | N/A | Reserved pins, please floating. | -- |
| SWD_DATA | 3 | DI/DO | Serial wire data signal, | -- |

| Pin Name | Pin No. | I/O Type | Description | PU/PD |
|---|---|---|---|---|
| SWD_CLK | 4 | DI | Serial wire clock signal | -- |
| PIO20 | 10 | I/O | PIO20 for external use, voltage can configured from 1.5V to 3.3V by software, step is 0.3V. | -- |
| RESET | 15 | DI | Module Boudica reset, active low (pull-up is always enabled) | -- |
| RIO<1> | 16 | I/O | For future use | -- |
| PIO32 | 17 | I/O | PIO32 for external use, voltage can configured from 1.5V to 3.3V by software, step is 0.3V. | -- |
| DBG_RXD | 19 | DI | UART1: data receiving | -- |
| DBG_TXD | 20 | DO | UART1: data transmission | -- |
| AIO<1> | 21 | AI | Analog peripheral input/output lines | -- |
| AIO<0> | 22 | AI | Analog peripheral input/output lines | -- |
| VDD_IO_D | 26 | PO | IO_D power supply, default value is 3.3V, and max current is 10mA, if this pin is not used, please floating. | -- |
| PIO21 | 27 | I/O | PIO21 for external use, voltage can configured from 1.5V to 3.3V by software, step is 0.3V. | -- |
| PIO33 | 28 | I/O | PIO33 for external use, voltage can configured from 1.5V | -- |

| Pin Name | Pin No. | I/O Type | Description | PU/PD |
|---|---|---|---|---|
| | | | to 3.3V by software, step is 0.3V. | |
| MAIN_RXD | 29 | DI | UART: data receiving | -- |
| MAIN_TXD | 30 | DO | UART: data transmission | -- |
| USIM_VDD | 38 | PO | Power supply for USIM card | -- |
| USIM_RST | 39 | DO | USIM reset | -- |
| USIM_DATA | 40 | I/O | USIM data | -- |
| USIM_CLK | 41 | DO | USIM clock | -- |
| USIM_GND | 42 | N/A | USIM ground | -- |
| VBAT | 45 and 46 | PI | Main power supply of module: VBAT = 3.1 V to 4.2 V | -- |
| RF_ANT | 53 | I/O | RF antenna pad | -- |

## 3.2. Power Port

The power ports in the TPB23 module include:

- Port VBAT for power supply
- Port VDD_IO_L1 and VDD_IO_D for IO power level
- Port USIM_VDD for USIM power output

### 3.2.1. Pin Definition

Table 3-3 defines power port pins.

**Table 3-3** Definition of power port pins

| Pin Name | Pin No. | I/O Type | Description |
|---|---|---|---|
| VBAT | 45 and 46 | PI | Main power supply |

| Pin Name | Pin No. | I/O Type | Description |
|---|---|---|---|
| | | | of module:<br>VBAT = 3.1 V to 4.2 V |
| VDD_IO_L1 | 1 | PO | IO_L1 power supply for external use, default value is 0V, if not used, please let it floating. |
| VDD_IO_D | 26 | PO | Power supply for external use, default value is 3.3V, and max current is 10mA. |
| GND | 2, 43, 47, 48, 51, 52, 54, 59, 60, 61, 62, 63, 64, 65, 66, 71, 72, 73, 74, 81, 82, 83, 92, 93, and 94 | N/A | Ground |

### 3.2.2. Reference Design

You are advised to use the Low Dropout Regulator (LDO) or battery as the power supply. It is recommended that the LDO power current be greater than or equal to 500 mA. Energy storage capacitance must be included in the LDO output to ensure that the voltage sag in case of large current is less than 0.1 V.

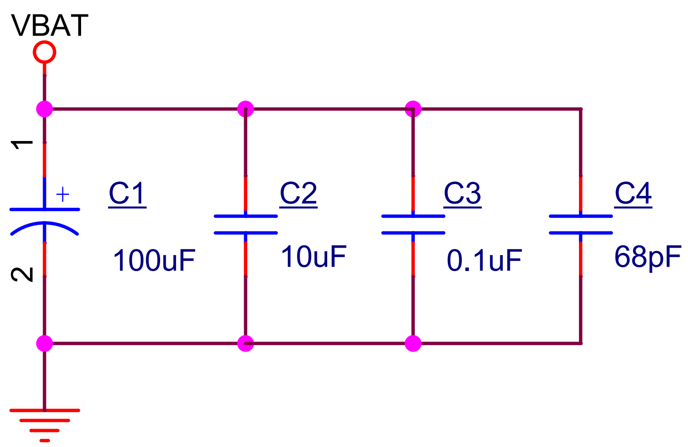



**Figure 3-2** Recommended power supply circuit diagram

## 3.3. UART Port

The TPB23 module provides two serial ports. One port is for data interconnection with terminals (for receiving and sending AT commands), and the other one is for monitoring Boudica chip Operation status. The default voltage level of the UART port is 3.3V.

**Table 3-4** UART_AT pin definition

| Pin Name | Pin No. | I/O Type | Description |
|---|---|---|---|
| MAIN_RXD | 29 | DI | UART: data receiving |
| MAIN_TXD | 30 | DO | UART: data transmission |

**Table 3-5** UART_Log pin definition

| Pin Name | Pin No. | I/O Type | Description |
|---|---|---|---|
| DBG_RXD | 19 | DI | Secondary UART: data receiving |
| DBG_TXD | 20 | DO | Secondary UART: data transmission |

## 3.4. USIM Port

Figure 3-3 shows the reference design diagram of the SIM port circuit.

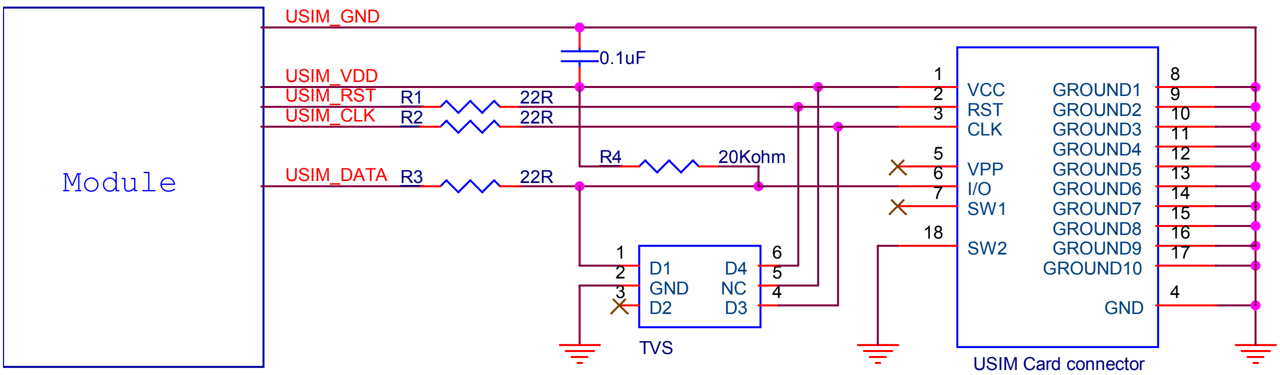



**Figure 3-3** Reference circuit diagram of the SIM port

### 3.4.1. Pin Definition

**Table 3-6** USIM port pin definition on the module side

| Pin Name | Pin No. | I/O Type | Description |
|---|---|---|---|
| USIM_VDD | 38 | PO | Power supply for USIM card |
| USIM_RST | 39 | DO | USIM reset |
| USIM_DATA | 40 | I/O | USIM data, need add 20Kohm pull up register |
| USIM_CLK | 41 | DO | USIM clock |
| USIM_GND | 42 | N/A | USIM ground |

## 3.5. AIO Port

The TPB23 module provides a 10-bit ADC. This ADC is available in Active and Standby modes of operation and is accessible via AIO<1:0> and as per Table 3-7 programmable-gain input buffer provides six ADC sensitivity settings. The ADC is capable of performing single measurements as well as continuous sampling with a programmable sampling rate.

**Table 3-7** Application ADC characteristics

| PMU ADC Characteristics<br>ADC Full-Scale Range (FSR): | Min | Typ | Max | Unit |
|---|---|---|---|---|
| Gain = 0 | -- | 1.45 | -- | V |
| Gain = 1 | -- | 2.0 | -- | V |
| Gain = 2 | -- | 2.5 | -- | V |
| Gain = 3 | -- | 3.0 | -- | V |
| Gain = 4 | -- | 3.5 | -- | V |
| Gain = 5 | -- | 4.0 | -- | V |
| Sampling frequency | 0 | -- | 25 | MHz |

# 4. Antenna Port

## 4.1. Pin Definition

**Table 4-1** Definition of antenna port pins

| Pin Name | Pin No. | I/O Type | Description |
|---|---|---|---|
| RF_ANT | 53 | I/O | RF antenna pad |
| GND | 52,54 | N/A | Ground |

## 4.2. Operation Band

**Table 4-2** Antenna Operation band

| Band | Up-link | Down-link |
|---|---|---|
| Band 1 | 1920 MHz to 1980 MHz | 2110 MHz to 2170 MHz |
| Band 2 | 1850 MHz to 1910 MHz | 1930 MHz to 1990 MHz |
| Band 3 | 1710 MHz to 1785 MHz | 1805 MHz to 1880 MHz |
| Band 5 | 824 MHz to 849 MHz | 869 MHz to 894 MHz |
| Band 8 | 880 MHz to 915 MHz | 925 MHz to 960 MHz |
| Band 12 | 699MHz to 716 MHz | 729 MHz to 746 MHz |
| Band 13 | 777 MHz to 787 MHz | 746 MHz to 756 MHz |
| Band 17 | 704 MHz to 716 MHz | 815 MHz to 830 MHz |
| Band 18 | 815 MHz to 830 MHz | 860 MHz to 875 MHz |
| Band 19 | 830 MHz to 845 MHz | 875 MHz to 890 MHz |
| Band 20 | 832 MHz to 862 MHz | 791 MHz to821 MHz |
| Band 26 | 814 MHz to 849 MHz | 859 MHz to 894 MHz |
| Band 28 | 703 MHz to 748 MHz | 758 MHz to 803 MHz |
| Band 66 | 1710 MHz to 1780 MHz | 2110 MHz to 2200 MHz |

## 4.3. Reference Design

### 4.3.1. Matching Circuit

The matching circuit is located between the passive antenna and radio frequency (RF) cable, and is used to optimize antenna standing wave parameters, to ensure that energies are effectively radiated. Figure 4-1

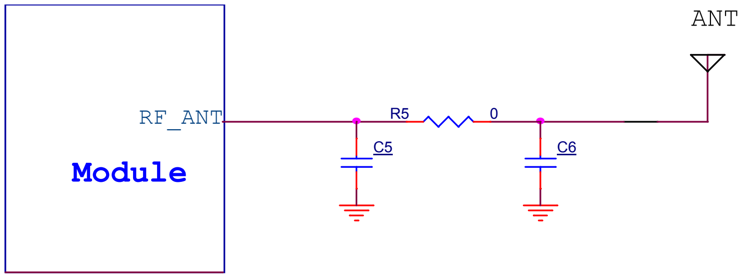


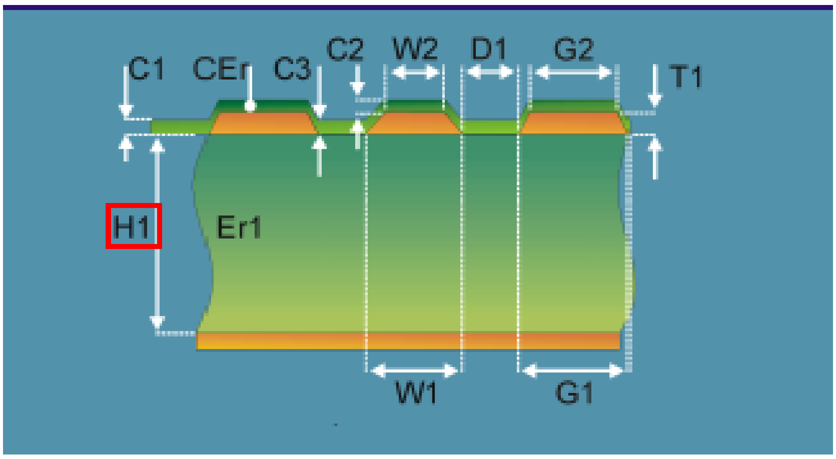

Figure 4-1 Common PI model

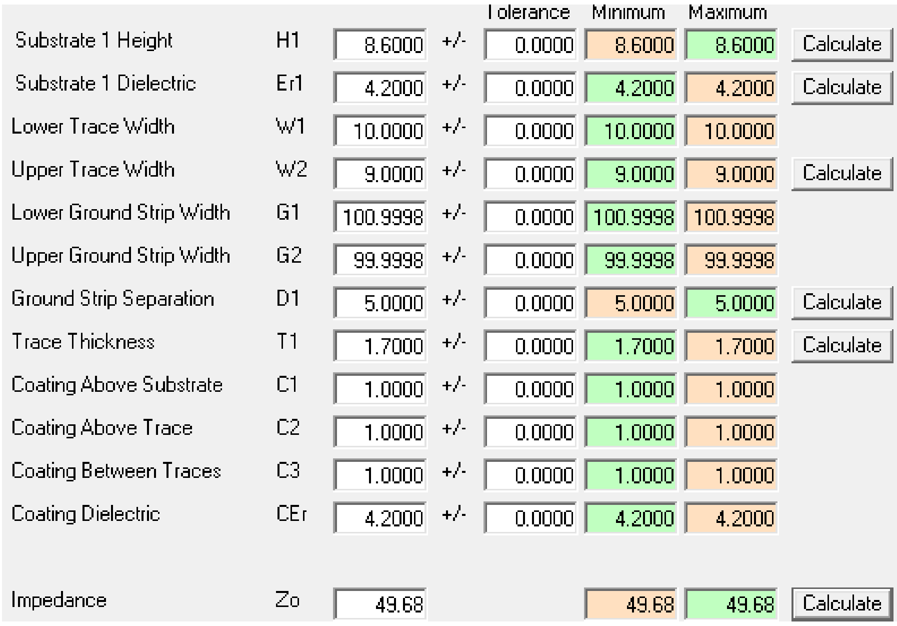
### 4.3.2. RF_ANT to antenna RF trace PCB Design

The following lists the printed circuit board (PCB) layout design rules:

- The characteristic impedance of the transmission line must be 50 ohm.
- The PCB cable must be as short as possible to reduce antenna cable loss.
- The PCB cable must be routed as straight as possible, and right-angle cable layout is not allowed. The PCB cable would better not be connected to different layers through a via hole.
- The PCB cable must have a good reference ground around, to avoid other signal lines close to the antenna cable without ground isolated.

The recommended PCB design about 4-Layer as Figure 4-2 follow:





| | | | | Tolerance | Minimum | Maximum | |
|---|---|---|---|---|---|---|---|
| Substrate 1 Height | H1 | 8.6000 | +/- | 0.0000 | 8.6000 | 8.6000 | Calculate |
| Substrate 1 Dielectric | Er1 | 4.2000 | +/- | 0.0000 | 4.2000 | 4.2000 | Calculate |
| Lower Trace Width | W1 | 10.0000 | +/- | 0.0000 | 10.0000 | 10.0000 | |
| Upper Trace Width | W2 | 9.0000 | +/- | 0.0000 | 9.0000 | 9.0000 | Calculate |
| Lower Ground Strip Width | G1 | 100.9998 | +/- | 0.0000 | 100.9998 | 100.9998 | |
| Upper Ground Strip Width | G2 | 99.9998 | +/- | 0.0000 | 99.9998 | 99.9998 | |
| Ground Strip Separation | D1 | 5.0000 | +/- | 0.0000 | 5.0000 | 5.0000 | Calculate |
| Trace Thickness | T1 | 1.7000 | +/- | 0.0000 | 1.7000 | 1.7000 | Calculate |
| Coating Above Substrate | C1 | 1.0000 | +/- | 0.0000 | 1.0000 | 1.0000 | |
| Coating Above Trace | C2 | 1.0000 | +/- | 0.0000 | 1.0000 | 1.0000 | |
| Coating Between Traces | C3 | 1.0000 | +/- | 0.0000 | 1.0000 | 1.0000 | |
| Coating Dielectric | CEr | 4.2000 | +/- | 0.0000 | 4.2000 | 4.2000 | |
| Impedance | Zo | 49.68 | | | 49.68 | 49.68 | Calculate |

Units: mil

Figure 4-2 Recommended PCB design

# 5. Operation Modes

The TPB23 module has three Operation modes, which can determine availability of functions for different levels of power-saving.

**Table 5-1** Operation modes

| Mode | Function | Description |
|---|---|---|
| Operation Modes | Active | In active mode, all functions of the module are available and all process are active. Radio transmission and reception can be performed.<br>Transitions powers also can changed by software for different application for power save in active mode. |
| | Idle | In Idle mode, all processors are inactive, but all peripherals can be active. The system clock is active and power consumption is reduced via clock gating and power gating. Idle mode is entered when all processors are executing a wait-for-interrupt (WFI) instruction. |
| | Power Slave Mode(PSM) | In PSM mode, only the 32kHz RTC is working, which means the module can be moved to active state by an RTC interrupt or by an external event through the peripherals that are using the RTC. This mode is entered by all processors setting the "sleep-deep" bit and then executing a WFI |

| Mode | Function | Description |
|---|---|---|
| | | instruction. |

# 6. Power on and off sequence

## 6.1. Power on sequence

The module can be automatically turned on by supplied power source to VBAT pins.

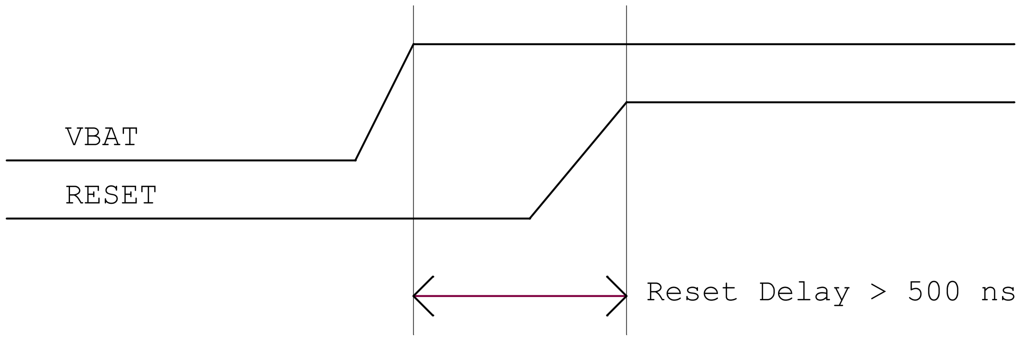



Figure 6-1 Power on sequence

## 6.2. Power off sequence

The module can be automatically turned off by shut down the VBAT power supply.

# 7. Electrical Power, Reliability, and RF Characteristics

## 7.1. Operation and Storage Environment

**Table 7-1** Operation and Storage Environment

| Item | Minimum Value | Typical Value | Maximum Value | Unit |
|---|---|---|---|---|
| Operation temperature | –30 | 25 | 75 | ˚C |
| Storage temperature | –40 | 25 | 85 | ˚C |
| VBAT | 3.1 | 3.6 | 4.2 | V |

## 7.2. VBAT power consumption

**Table 7-2** VBAT power consumption (With 3.6V typical VBAT power supply)

| Item | Band | TX Power | Minimum Value | Typical Value | Maximum Value | Unit |
|---|---|---|---|---|---|---|
| Module Boot | 3 | -- | -- | -- | 60 | mA |
| PSM | 3 | -- | -- | 4 | -- | uA |
| Idle | 3 | -- | -- | 6 | -- | mA |
| Rx-mode | 3 | -- | -- | 65 | -- | mA |
| Power off | 3 | -- | -- | 5 | 6000 | uA |
| Connected Mode (TX/RX call enabled) | 3 | -10dBm | -- | 60 | -- | mA |
| | 3 | 0dBm | -- | 88 | -- | mA |
| | 3 | 10dBm | -- | 100 | -- | mA |
| | 3 | 23dBm | -- | 260-300 | -- | mA |

## 7.3. ESD and EMC Characteristics

### 7.3.1. ESD

The TPB23 module has no electrostatic discharge (ESD) protection measures, and its sensitive pins needs external ESD protection. Appropriate ESD measures need to be taken during the overall manufacturing, transporting, and Operation stages.

Consider ESD measures for critical output and input ports, and place protection components near ports. Table 7-2 shows the ESD requirements for the TPB23 module.

**Table 7-3** ESD requirements for the TPB23 module

| Pin | Contact Discharge | Air Discharge | Unit |
|---|---|---|---|
| VBAT | ±5 | ±10 | KV |
| ANT | ±4 | ±8 | KV |
| Other ports | ±0.5 | ±1 | KV |

### 7.3.2. EMC

The signal integrity and power integrity issues caused by electromagnetic compatibility (EMC) need to be considered when you use the TPB23 module to design. The following part lists some suggestions:

- The coupling of the TPB23 module and other digital chips must be deployed remotely as far as possible, to avoid mutual interference.
- The power supply (CSS), clock, high-speed digital signals, EMI components, and RF simulation parts must be deployed remotely as far as possible.
- The CSS, clock, high-speed digital signals, EMI components, and antennas must be coupled remotely as far as possible in space.
- During cabling routing, the RF reference ground is complete, digital and analog areas are separated, and all cables are routed in compliance with specified requirements to avoid mutual coupling between lines.

The decoupling capacitor is placed near pins.

## 7.4. RF Characteristics

RF parameters are defined at Module pins.

### 7.4.1. RF transmitter characteristics

**Table 7-4** RF transmitter characteristics

| Item | Min | Typ | Max | Unit | Comments |
|---|---|---|---|---|---|
| Maximum Transmit Power | / | 23 | / | dBm | See "Operating Licensed Spectrum" Bands |

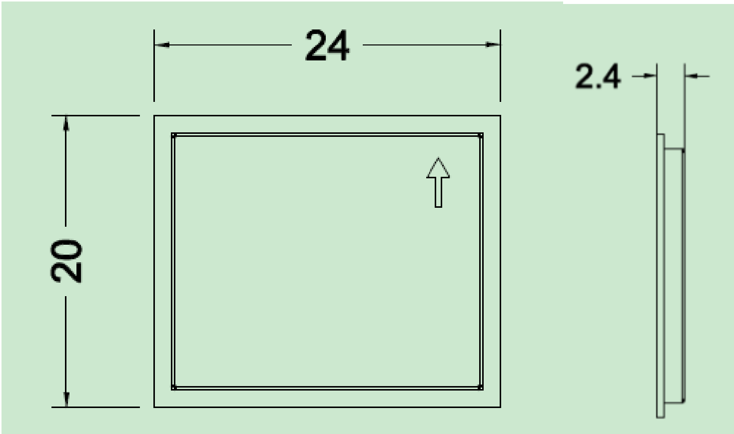
### 7.4.2. RF receiver characteristics

**Table 7-5** RF receiver characteristics

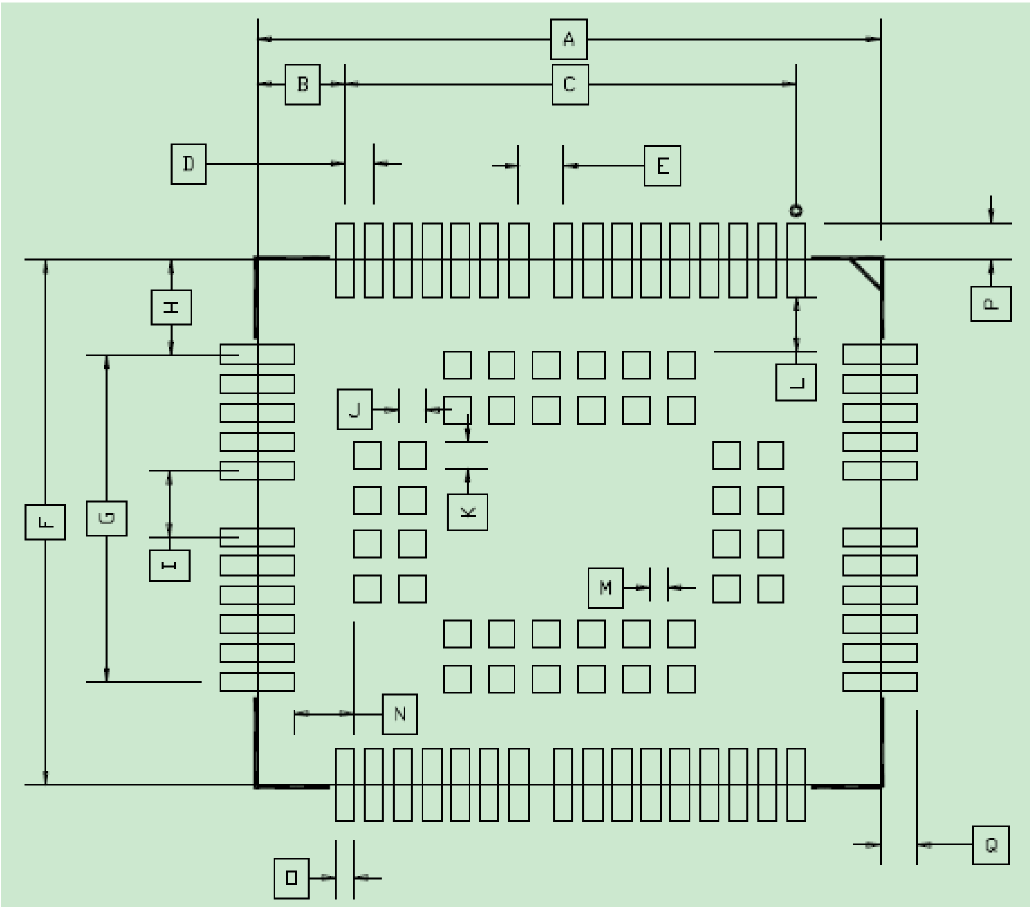
| Item | Min | Typ | Max | Unit | Comments |
|---|---|---|---|---|---|
| Max receivable input | / | / | 10 | dBm | See "Operating Licensed Spectrum" Bands |
| Sensitivity | / | -129 | / | dBm | At rep_128. And ant rep_1 is -109dBm. |

# 8. Mechanical Characteristic

The module size is 24 x 20 x 2.4 mm:




For details about the bottom dimensions of the TPB23 module as follow:

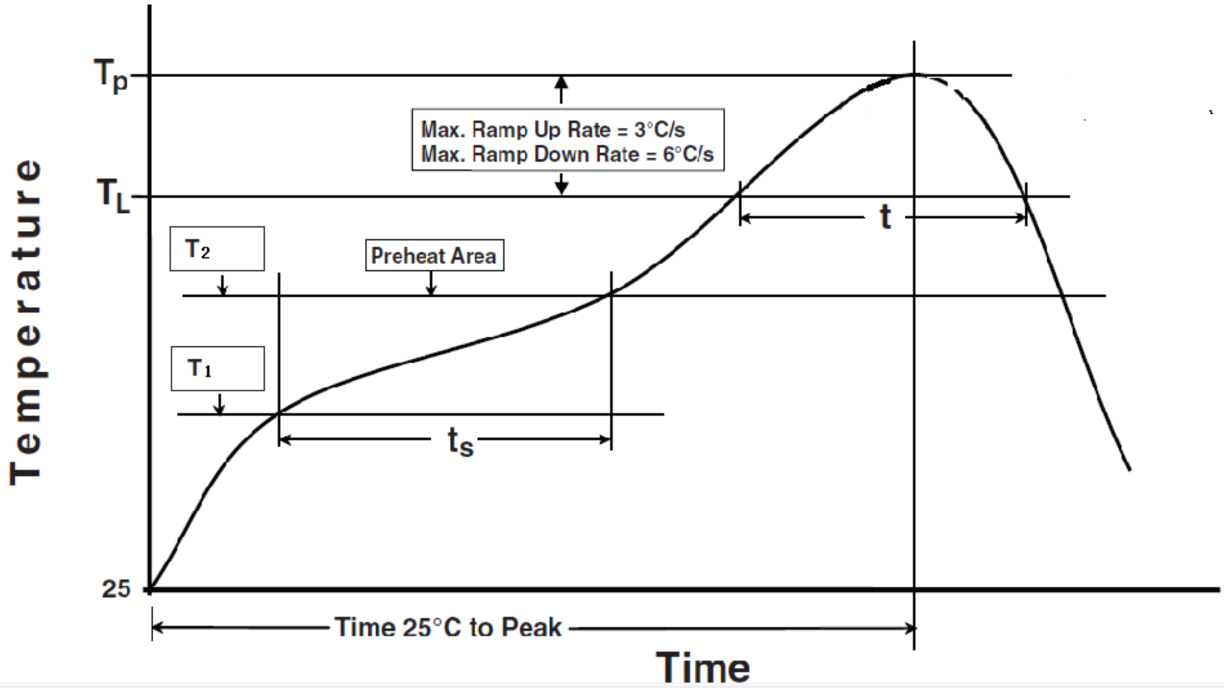



| | Dimension (mm) |
|---|---|
| A | 24.0 |
| B | 3.3 |
| C | 17.1 |
| D | 1.1 |
| E | 1.7 |
| F | 20.0 |
| G | 12.4 |
| H | 3.6 |
| I | 2.5 |
| J | 1.0 |
| K | 1.0 |
| L | 2.1 |
| M | 0.7 |
| N | 2.25 |
| O | 0.7 |
| P | 1.4 |
| Q | 1.4 |

Figure 8-1 The bottom dimensions

# 9. Recommend Re-flow Profile

| TPB-20 reflow profile | Min | Typ | Max | Unit |
|---|---|---|---|---|
| Temperature $T_1$ | 150 | | | ℃ |
| Temperature $T_2$ | | | 200 | ℃ |
| Temperature $T_L$ | | 217 | | ℃ |
| Temperature $T_P$ | | | 260 | ℃ |
| Time ts ($T_1$ to $T_2$) | 60 | | 120 | sec |
| Time t (above $T_L$) | 60 | | 150 | sec |
| Ramp Up Rate $T_L$ to $T_P$ | | | 3 | ℃ |
| Ramp Down Rate $T_P$ to $T_L$ | | | 6 | ℃ |



# 10. Acronyms or Abbreviations

| | |
|---|---|
| **AI** | Analog Input |
| **DI** | Digital Input |
| **DO** | Digital Output |
| **EMC** | Electromagnetic Compatibility |
| **EPC** | Evolved Packet Core |
| **ESD** | Electrostatic Discharge |
| **EVK** | Evaluation Kit |
| **LDO** | Low Dropout Regulator |
| **NB-IoT** | Narrowband Internet of Things |
| **RF** | Radio Rrequency |
| **UART** | Universal Asynchronous Receiver/Transmitter |
| **USIM** | Universal Subscriber Identity Module |