Specifications for

WisTrio IoT Modular Boards

RAK5010

Version V1.4 | August 2019

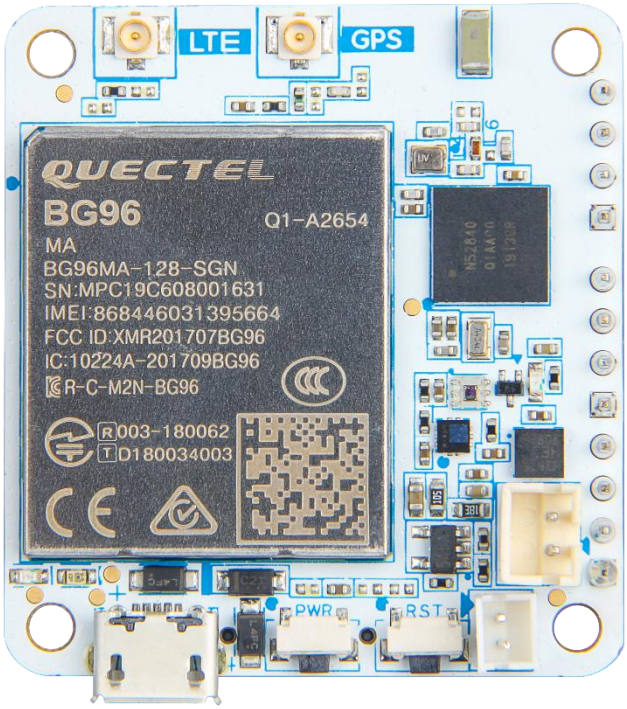

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Table of Contents

1 Overview

1.1 Introduction

The RAK5010 is a tracker, which integrates LTE CAT M1&NB1, GPS, BLE and sensors. It is built on the Quectel BG96 LTE CAT M1&NB1 module, which has an integrated GPS receiver. The MCU running the board is a Nordic nRF52840 controller.

As it has both GPS and BLE it can be used for outdoor and indoor scenarios, where location based services need be present.

It integrates four kinds of sensors: humidity and temperature sensor, pressure sensor, 3-axis motion sensor, and ambient light sensor. The extension IOs allow adding more sensors in addition to the on-board ones.

This board is particularly suitable to be used as a quick testing and prototyping tool for applications requiring Nb-IoT connectivity. Application development environments that are supported are CooCox IDE and Keil.

The main features are listed below:

- Quectel BG96, with LTE CAT M1, LTE NB1 and GNSS
- Nordic nRF52840, with BLE5.0 and long range BLE.
- nRF52840 integrates the ultra-low power microcontroller ARM Cortex-M4 (64Mhz)
- Built-in humidity and temperature sensor, pressure sensor, 3-axis motion sensor, and ambient light sensor.
- iPEX connectors for the LTE and GPS antenna and an on-board ceramic antenna for the BLE.
- nano SIM and ESIM options.
- Can be powered by either Micro USB, 3.7V rechargeable battery or a 5V Solar Panel Port
- Multiple interfaces: I2C, UART, GPIO and AD.

1.2 Package Contents

GPS Antenna (1x)

LTE Antenna (1x)

RAK5010 Board (1x)

Micro USB Cable (1x)

2 RAK5010 IoT Modular Boards

2.1 Overview

Figure 1 below shows the top view and the interfaces of the RAK5010 IoT Modular Boards board.

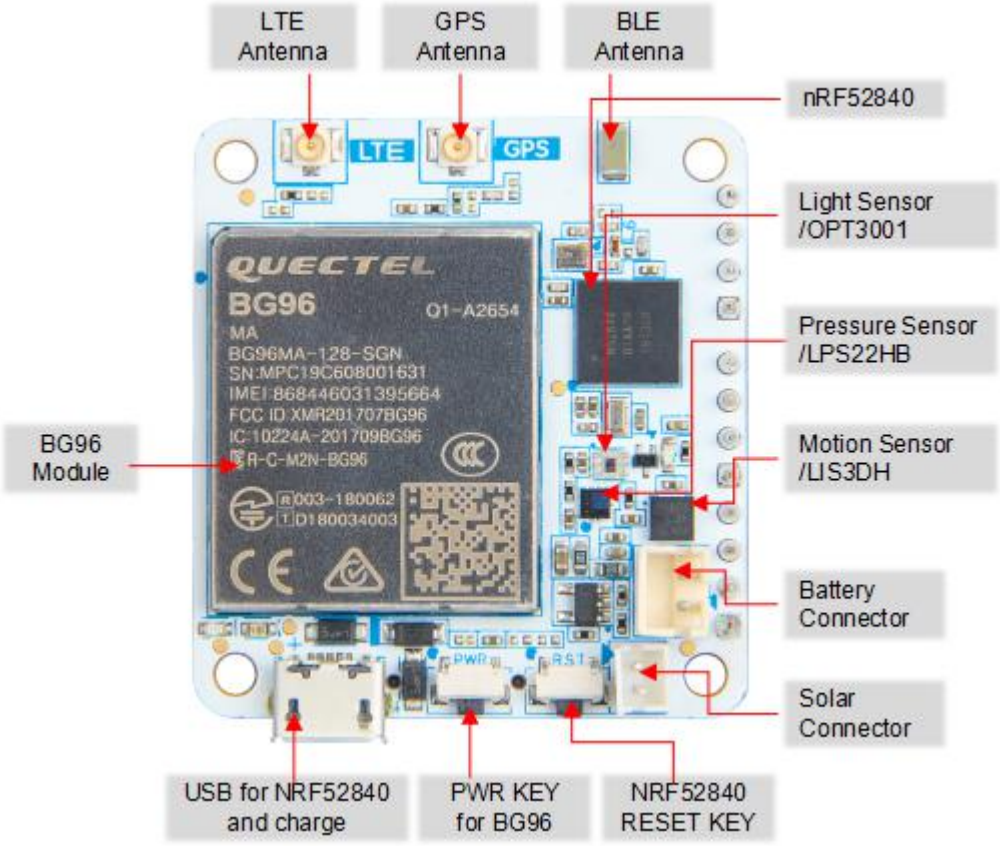


***Figure 1** | Top view of the board with interfaces*

Figure 2 shows the bottom of the board, where Figure 3, the dimensions of the board, and Figure 4 shows the header pin spacing.

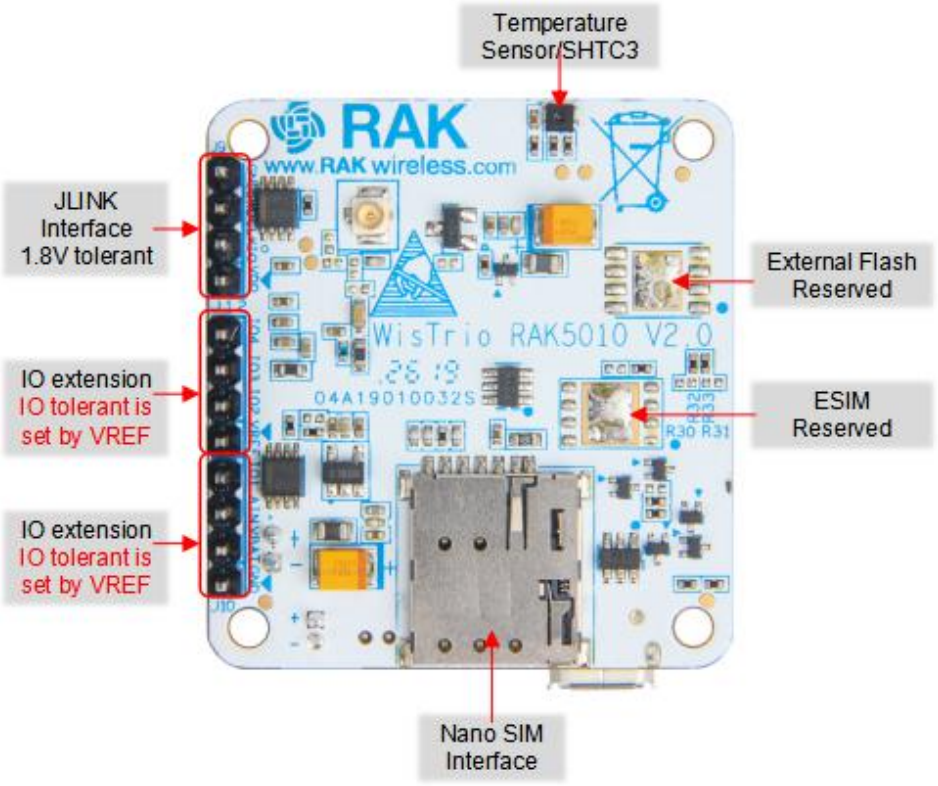


***Figure 2** | Bottom view of the board with interfaces*

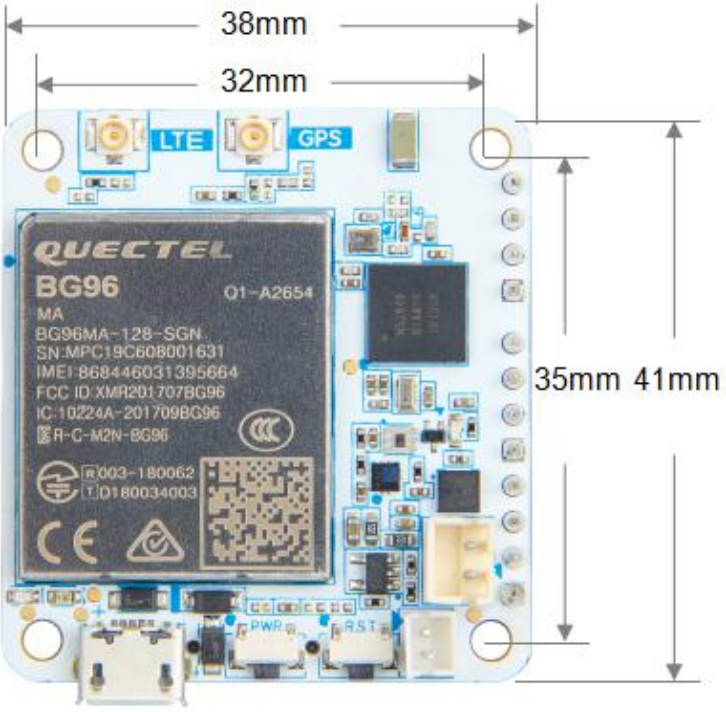


***Figure 3** | Board dimensions*

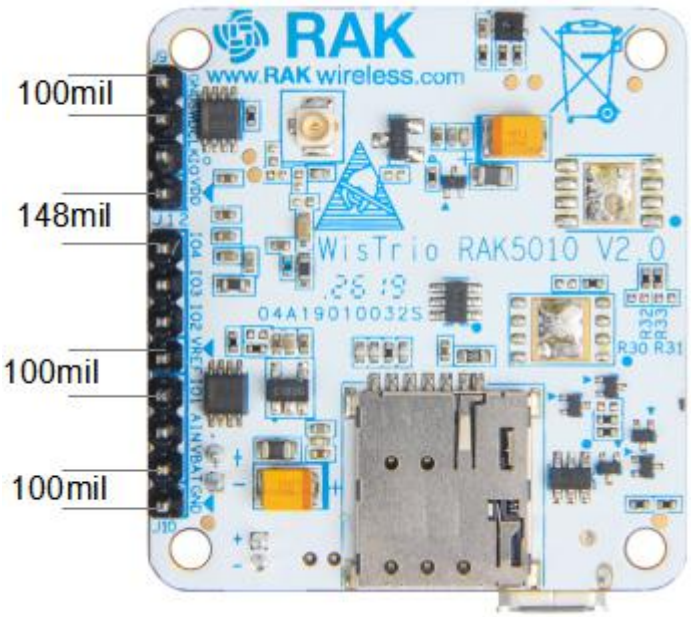


***Figure 4** | Header Spacing*

2.2 Functional Diagram

The block diagram below shows the internal architecture and external interfaces of the RAK5010 board.

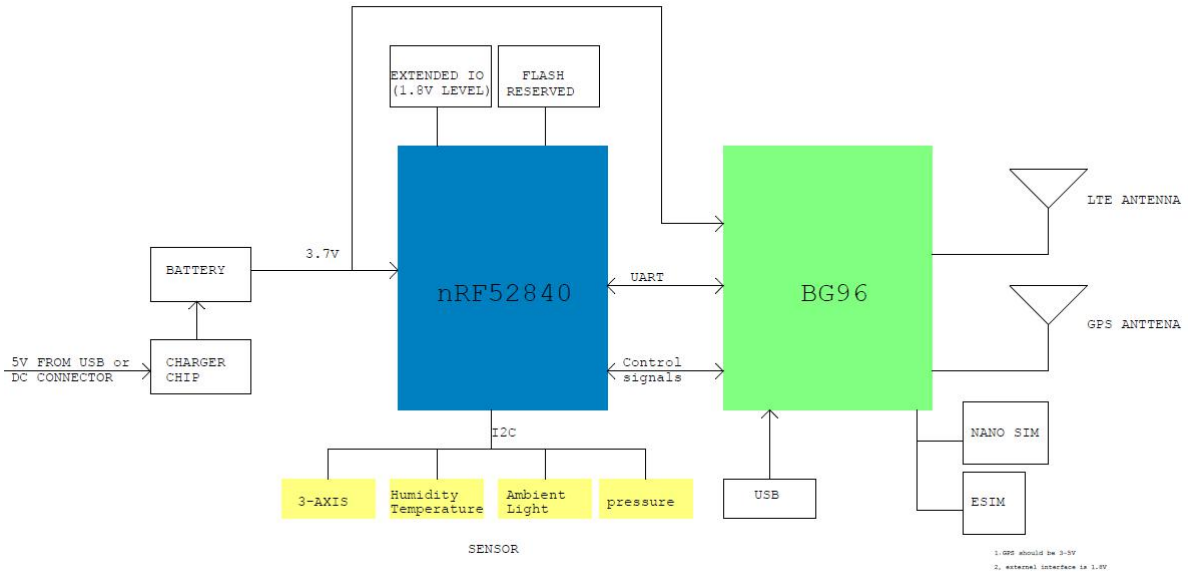


***Figure 5** | Block diagram*

2.3 Interfaces

The node is built around the BG96 module and the nRF52840 BLE chip. It provides the following interfaces, headers, jumpers, buttons and connectors:

- Micro USB
- 2 sets of 4-pin 2.54mm Headers (UART, GPIOS, I2C, power)
- 4-pin Jlink header
- 2-pin Battery female interface
- 2-pin Solar Panel female interface
- LEDs
- Reset Button
- PWR Button for the BG96

There are two Antenna connectors:

- LTE Antenna with iPEX connector
- GPS Antenna with iPEX connector

2.4 Board Pin Out

There are the two connectors on the board:

2.4.1 P1

Solar panel interface.

Pin	Pin Name	Description
1	C0NN_5V	Positive of solar panel
2	GND	GND

***Table 1** | Solar Panel pinout*

Note: The output of the solar panel cannot exceed 5.5V, otherwise it may cause permanent damage to the board.

2.4.2 P2

Li-ion battery connector.

Pin	Pin Name	Description
1	GND	GND
2	VBAT	Positive of the battery

Table 2 | Battery pinout

2.4.3 J9

J9 is J-LINK connector, with J-LINK debugger, you can program and debug nRF52840.

Pin	Pin Name	Description
1	VDD	1.8V default. Reference voltage for J-LINK, note 1
2	SWDIO	SWD data signal(3.3V tolerant)
3	SWDCLK	SWD clock signal(3.3V tolerant)
4	GND	GND

Table 3 | J-LINK Connector pinout

Note: VDD of J9 should connect to the PIN1 of SEGGER J-LINK(Figure 6) debugger for SWDIO/SWDCLK's reference voltage. If this pin is not connect correctly, the J-LINK' logic level may not set to VDD of nrf52840, it may damage the nrf52840.

Below is the definition of 20PIN segger J-LINK connector:

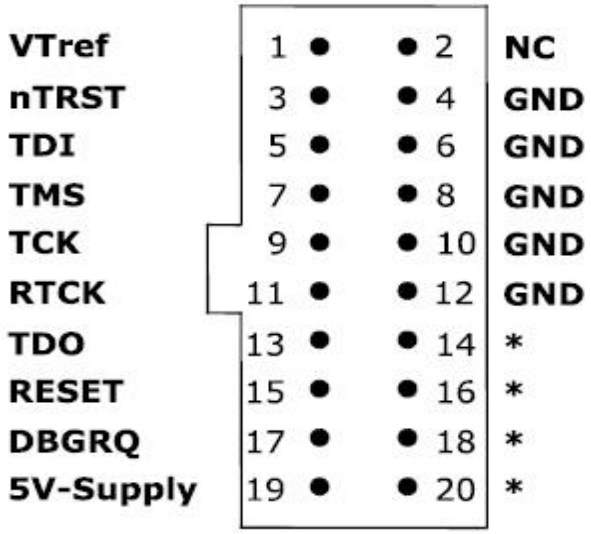


Figure 6 | J-LINK Pinout

Pin	Signal	Type	Description
1	VTref	Input	This is the target reference voltage. It is used to check if the target has power, to create the logic-level reference for the input comparators and to control the output logic levels to the target. It is normally fed from VDD of the target board and must not have a series resistor

Table 4 | *Reference voltage*

2.4.4 J10 and J12

J10 and J12 are IO extension headers. Those are bridged from the nRF52840 IOs, through logical level shift circuits. Thus, the IOs level is set by the VREF pin. The function of these IOs is configurable. They can work as UART, I2C， general GPIO or AD.

Definition of J10

Pin	Pin Name	Description
1	GND	GND
2	VBAT	Connected to the battery
3	AIN	Configurable IO, connected to AIN3 (P0.05) on nRF52840. If used as AD, the input range is configurable, please refer to the manual of nrf52840, if used as general IO, the logic level is 1.8V and there no level shift on it.
4	NRF_IO1	Configurable IO, connected to P0.19 on the nRF52840. There is a level shift circuit between this pin and the nRF52840

Table 5 | *J10 Header pinout*

Definition of J12

Pin	Pin Name	Description
1	EXT_VREF	Reference level for the IO extensions
2	NRF_IO2	Configurable IO, connect to P0.20 on the nRF52840. There is a level shift circuit between this pin and the nRF52840
3	NRF_IO3	Configurable IO, connect to P1.02 on the nRF52840. There is a level shift circuit between this pin and the nRF52840
4	NRF_IO4	Configurable IO, connect to P1.01 on the nRF52840. There is a level shift circuit between this pin and the nRF52840

Table 6 | *J12 Header pinout*

The logic level shift circuit on the RAK5010 board connects EXT_VREF to your extension board's power and equalizes it to the logical level of the IO on your extension board.

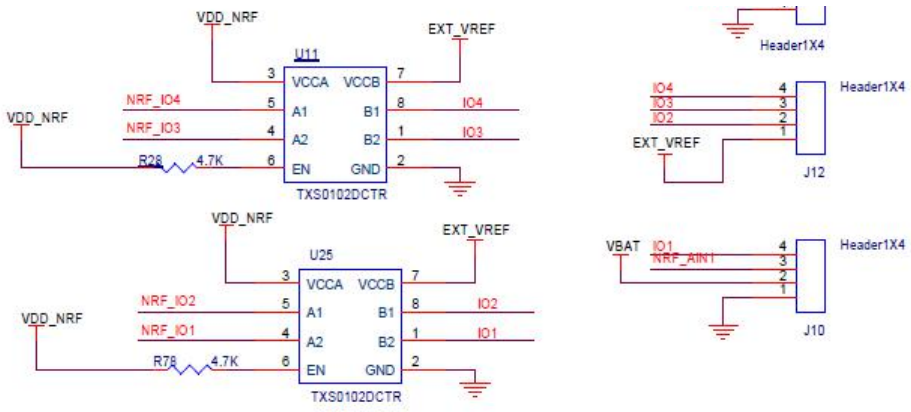


***Figure 7** | Typical Converter circuitry*

2.5 Micro-B USB Interface

A Standard Micro-B USB compliant with USB 2.0 standard specification. This USB interface is connected to the USB port of NRF52840 for default. It also can connect to BG96 by reworking some resistor on the board. If this USB port is connected to the BG96, BG96's AT command port GNSS port and debug port can be accessed through this USB. It is also used as charge input port for battery. The Micro-B USB pin definition is shown below:

Pin	Description
1	USB_VBUS (+5V)
2	USB_DM
3	USB_DP
4	NC
5	GND

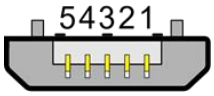


***Table 7** | USB Connector pinout*

This USB port is also used as battery charge port.

2.6 LEDs

Three LEDs are used to indicate operating status, here are their functions:

LED Color	Function	LED Status	Description
Green	connected to the nRF52840	/	Defined by the user.
Blue	BG96 Status LED	ON	The BG96 module is powered on.
		OFF	The BG96 module is powered off.
Red	BG96 NETLIGHT	Flicker slowly (200ms High/1800ms Low)	Network searching
		Flicker slowly (1800ms High/200ms Low)	Idle
		Flicker quickly (125ms High/125ms Low)	Data transfer is ongoing
		Always high	Voice calling

***Table 8** | LED Status*

2.7 RESET Push Button

Reset Push Button is used to reset the nRF52840. You can control the BG96 reset with by the firmware of the nRF52840.

2.8 PWRKEY Push Button

When the BG96 is in power off mode, it can be turned back on to normal mode by holding the PWRKEY button for at least 100ms. Holding the PWRKEY button for at least 650ms, the module will execute the power-down procedure, after the PWRKEY is released.

2.9 IO Connections between the BG96 and the nRF52840

The nRF52840 communicates with the BG96 primarily though the UART interface. There is however additional signaling between the two modules. This is for the purpose of auto monitoring of status indicators and control. The pin mapping is shown below:

Function of BG96	PIN definition on nRF52840

TX of UART	P0.08 (RX for the nRF52840)
RX of UART	P0.06 (TX for the nRF52840)
BG96_CTS	P0.11
BG96_RTS	P0.07
BG96_RI	P0.27
BG96_STATUS	P0.31
BG96_RESET	P0.28
BG96_PWRKEY	P0.02
BG96_WDISABLE	P0.29
BG96_DTR	P0.26
BG96_AP READY	P0.30
BG96_PSM	P0.03

***Table 9** | BG96 Pin mapping*

If BG96_RESET, BG96_PWRKEY, and BG96_WDISABLE are not set correctly, the BG96 module will not boot up normally. When powering up, the BG96_RESET should be retained at a low-level voltage, the BG96_WDISABLE should be retained at low level voltage, and the BG96_PWRKEY should be given a pulse with a high level and at least 100ms width in order to turn the BG96 normally.

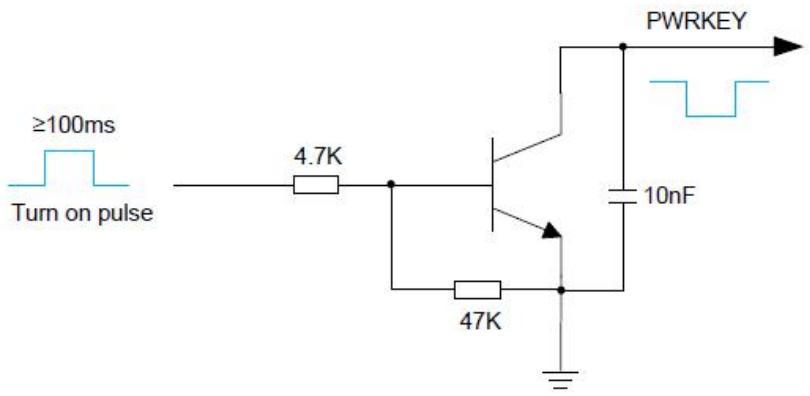


***Figure 8** | Turning on the BG96 via the PWRKEY*

2.10 Antenna Connector

The connectors for both the GPS and LTE antennas are iPEX.

Make sure that the LTE antenna is tuned to work at the operational frequency of your LTE provider, corresponding to your region.

2.11 Power Requirements

The RAK5010 tracker board can be powered by a battery, connected to the P2. The nominal operational voltage of the battery should be within the range in the table:

Min.	Typ.	Max.	Unit
3.3	3.7	4.3	V

***Table 10** | Power requirements*

If a rechargeable battery is used, the USB connector is used as a charging port. The voltage and current fed to the battery through the port should not exceed the ones in the table below.

Parameter	Value
Charging voltage	4.5-5.5V
Charging current	500mA

***Table 11** | Battery charging limits*

A suitable Li-Ion battery would have the following parameters:

Parameter	Value
Standard voltage	3.7V
Charging voltage	4.2V
Capacity	As required
Discharge current	2A

***Table 12** | Battery parameters*

Note: If a non-rechargeable battery is connected to the RAK5010, please never power USB port, it will damage the battery, might damage the board and is considered a fire hazard.

A 5V Solar panel can be connected to the board via the P1 connector to serve for the purpose of charging the battery.

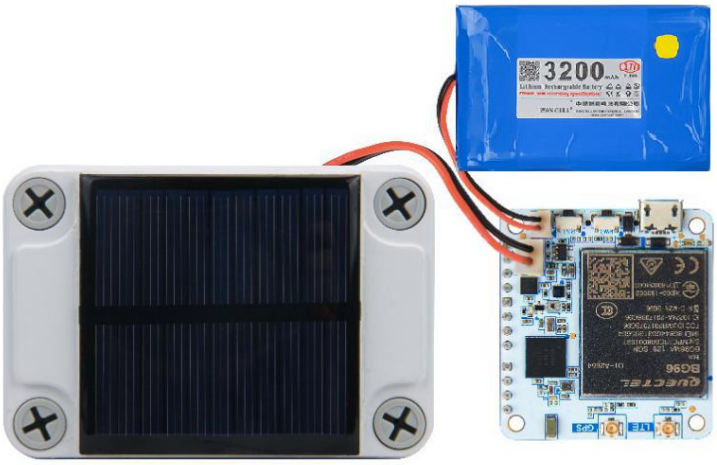


***Figure 10** | Battery charging via s Solar Panel*

3 Electrical and Mechanical Specifications

3.1 Absolute Maximum Ratings

Stresses above those listed as “absolute maximum ratings” may cause permanent damage to the device. This is a stress rating, functional operation of the device under these conditions is not advised. Exposure to maximum rating conditions may affect device reliability.

Ratings	Maximum value	Unit
Vbus, power supply on UBS port	-0.3 - 5.5	V
Vbat, battery voltage	-0.3 - 4.3	V
Vconn solar panel voltage	-0.3 - 5.5	V
IOs of J-link (J9)	-0.3 - 1.9	V
IOs of BG96, nRF52840 - J10 and J12	-0.3 -VREF	V
ESD	2000	V

***Table 13** | Absolute Maximum ratings*

Note: The RAK5010, as any electronic equipment is sensitive to electrostatic discharge (ESD), improper handling can cause permanent damage to module.

3.2 Environmental Requirements

The table below lists the operation and storage temperature requirements:

Parameter	Min.	Typical	Max.
Operational Temp. Range	-35 ºC	+25 ºC	+75 ºC
Extended Temp. Range	-40 ˚C	+25 ºC	+80 ˚C
Storage Temp. Range	-40 ˚C	+25 ºC	+80 ˚C

Table 14 | *Temperature requirements*

3.3 Current Consumption

Conditions	Current	Unit
The nRF52840 is Running, the BG96 transmits data @ NB1, 23dBm	200	mA
BLE transmits @ 0dBm, the BG96 is in power saving mode	7	mA
The nRF52840 is in sleep mode, the BG96 is in power saving mode	13	μA

Table 15 | *Current consumption*

Note: For the above results to be reached, the nRF52840's regulator has to be in DC-DC mode and all the sensors have to be in sleep mode.

4 SoCs and Sensors

4.1 BG96 Module

4.1.1 Frequency Bands

LTE Bands	GSM	Rx-diversity	GNSS
Cat M1 & NB1:			
LTE-FDD: B1/B2/B3/B4/B5/B8/B12/B13/B18/ B19/B20/B26/B28	GSM850/GSM900	Not Supported	GPS, GLONASS, BeiDou/Compass, Galileo, QZSS
LTE-TDD: B39 (for Cat M1 only)	DCS1800/PCS1900		

***Table 16** | Frequency bands of operation for BG96*

4.1.2 Key Feature of BG96 Module

Feature	Details
Power Supply	Supply Voltage: 3.3V – 4.3V Typical supply voltage: 3.8V
Transmitting Power	Class: 3 (23dBm±2dB) for LTE-FDD bands Class: 3 (23dBm±2dB) for LTE-TDD bands Class: 4 (33dBm±2dB) for GSM850 Class: 4 (33dBm±2dB) for GSM900 Class: 1 (30dBm±2dB) for DCS1800 Class: 1 (30dBm±2dB) for PCS1900 Class: E2 (27dBm±3dB) for GSM850 8-PSK Class: E2 (27dBm±3dB) for GSM900 8-PSK Class: E2 (26dBm±3dB) for DCS1800 8-PSK Class: E2 (26dBm±3dB) for PCS1900 8-PSK
LTE Features	Supports LTE Cat M1 and LTE Cat NB1 Supports 1.4MHz RF bandwidth for LTE Cat M1 Supports 200KHz RF bandwidth for LTE Cat NB1 Supports SISO in the DL direction Cat M1: Max. 300Kbps (DL)/375Kbps (UL) Cat NB1: Max. 32Kbps (DL)/70Kbps (UL)
GSM Features	**GPRS:** Supports GPRS multi-slot class 33 (33 by default) Coding scheme: CS-1, CS-2, CS-3, and CS-4 Max. 107Kbps (DL), Max. 85.6Kbps (UL) **EDGE:** Supports Edge multi-slot class 33 (33 by default) Supports GMSK and 8-PSK for different MCS Downlink Coding Schemes: CS 1-4 and MCS 1-9 Uplink Coding Schemes: CS 1-4 and MCS 1-9 Max. 296Kbps (DL), 236.8Kbps (UL)

***Table 17** | BG96 Features*

4.2 nRF52840 Module

Parameter	Detail
CPU	ARM® Cortex®-M4 32-bit processor with FPU, 64 MHz
Flash	1MB
RAM	256KB
BLE Protocol	BLE5.0
BLE Tx Power	8dBm max
BLE Rx Sensitivity	-95dBm @ 1Mbps BLE mode
BLE Data Rate	2Mbps,1Mbps, 500Kbps,125Kbps
Current Consumption	4.8mA in Tx, 4.6mA in Rx and 1.5uA in Sleep Mode

***Table 18** | nRF52840 parameters*

4.3 Humidity and Temperature Sensors

The Temperature and Humidity Sensor is an SHTC3 from Sensirion.

Temperature

Parameter	Conditions	Value	Units
Accuracy Tolerance	Typ.	±2.0	°C
	Max.	See Figure 3	°C
Repeatability	-	0.1	°C
Resolution	-	0.01	°C
Specified Range	-	-40 to +125	°C
Response Time	τ 63%	<5 to 30	s
Long-term Drift	Typ.	<0.2	°C/y

***Table 19** | Temperature parameters*

Note: When in charging, the heat emitted by the charging chip will affect the accuracy of temperature and other sensors and the heat emitted by BG96 module and other chips working for a long time will also affect the accuracy of sensors, so the system should work in the sleep mode when data is not transmitted.

Humidity

Parameter	Conditions	Value	Units
Accuracy Tolerance	Typ.	±2.0	%RH
	Max.	See Figure 2	%RH
Repeatability	-	0.1	%RH
Resolution	-	0.01	%RH
Hysteresis	-	±1	%RH
Specified Range	extended	0 to 100	%RH
Response Time	τ 63%	8	s
Long-term Drift	Typ.	<0.25	%RH/y

Table 20 | Humidity parameters

4.4 Pressure Sensor

The Pressure Sensor is an LPS22HB from ST:

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
PT_{op}	Operating Temperature Range		-40		+85	°C
PT_{full}	Full Accuracy Temperature Range		0		+65	°C
P_{op}	Operating Pressure Range		260		1260	hPa
P_{bits}	Pressure Output Data			24		bits
P_{sens}	Pressure Sensitivity			4096		LSB/hPa
P_{AccRel}	Relative Accuracy over Pressure	P = 800 – 1100 hPa T = 25 °C		±0.1		hPa
P_{AccT}	Absolute Accuracy over Temperature	P_{op} = 0 to 65 °C after OPC P_{op} = 0 to 65 °C no OPC		±0.1 ±1		hPa
P_{noise}	RMS Pressure Sensing Noise	with embedded filtering		0.0075		hPa RMS
ODR_{Pres}	Pressure Output Data Rate			1/10/25/50/75		Hz

Table 21 | Pressure sensor parameters

4.5 3-axis Motion Sensor

The 3-axis Motion Sensor is an LIS3DH from ST:

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
FS	Measurement Range	FS bit set to 00		±2.0		g
		FS bit set to 01		±4.0		
		FS bit set to 10		±8.0		
		FS bit set to 11		±16.0		
So	Sensitivity	FS bit set to 00; High-resolution mode		1		mg/digit
		FS bit set to 00; Normal mode		4		
		FS bit set to 00; Low-power mode		16		
		FS bit set to 01; High-resolution mode		2		mg/digit
		FS bit set to 01; Normal mode		8		
		FS bit set to 01; Low-power mode		32		
		FS bit set to 10; High-resolution mode		4		mg/digit
		FS bit set to 10; Normal mode		16		
		FS bit set to 10; Low-power mode		64		
		FS bit set to 11; High-resolution mode		12		mg/digit
		FS bit set to 11; Normal mode		48		
		FS bit set to 11; Low-power mode		192		

***Table 22** | Motion sensor parameters*

4.6 Ambient Light Sensor

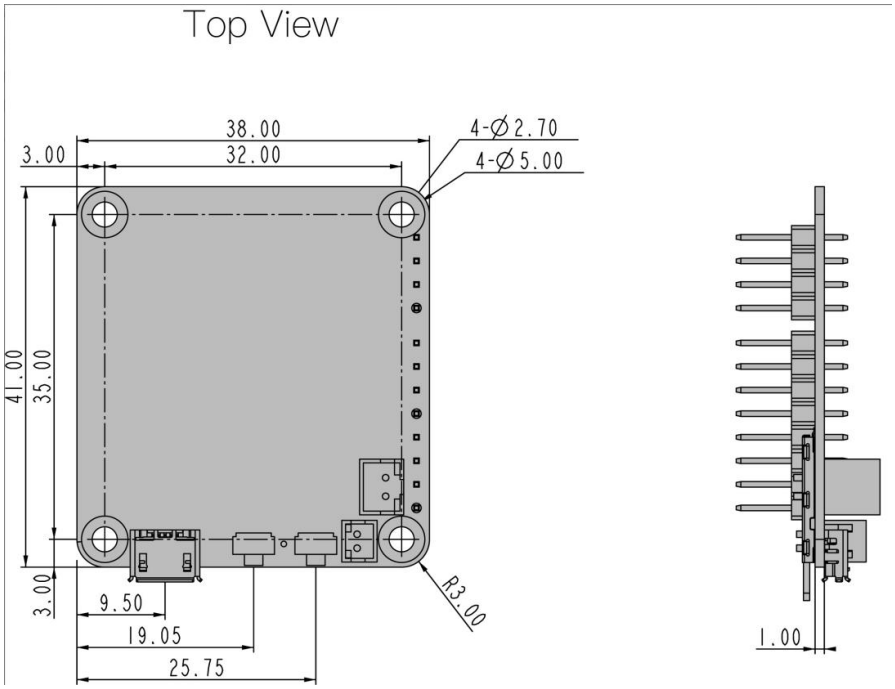
The Ambient Light Sensor is an OPT3001 from TI:

Parameter	Test Condition	Min.	Typ.	Max.	Unit
Peak irradiance spectral responsibility			550		nm
Resolution (LSB)	Lowest full-scale range, RN[3:0] = 0000b		0.01		lux
Full-scale illuminance			83865.6		lux
Measurement output result	0.64 lux per ADC code, 2620.90 lux full-scale (RN[3:0] = 0110) , 2000 lux input	2812	3125	3437	ADC codes
		1800	2000	2200	lux
Relative accuracy between gain ranges			0.2%		
Infrared response (850 nm)			0.2%		
Light source variation (incandescent, halogen, fluorescent)	Bare device, no cover glass		4%		
Linearity	Input luminance > 40 lux		2%		
	Input luminance < 40 lux		5%		
Measured drift across temperature	Input luminance = 2000 lux		0.01		%/°C
Dark condition, ADC output	0.01 lux per ADC code		0	3	ADC codes
			0	0.03	lux
Half-power angle	50% of full-power reading		47		degrees

***Table 23** | Light sensor parameters*

4.7 Mechanical Dimensions

Here are the detailed dimensions of the RAK5010 tracker:



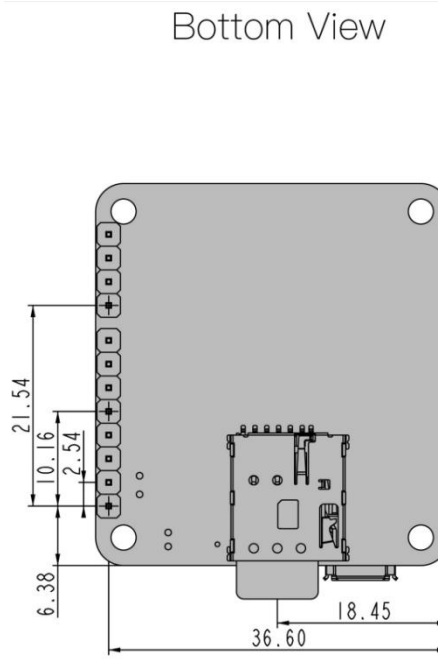


Figure 11 | Mechanical dimensions

5 Antennas

5.1 LTE Antenna

The LTE antenna connector is shown below.

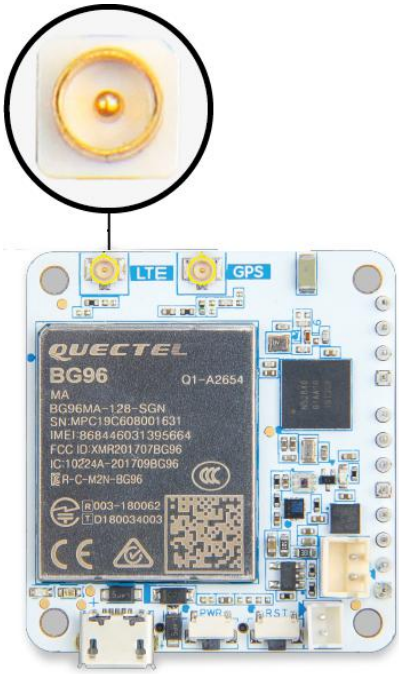


Figure 12 | iPEX onboard connector for the LTE antenna

A PCB antenna as the one in Figure 9 is included with the board. In case you want to use another antenna keep in mind that you need to have the proper connector (iPEX) and have it tuned to the frequency band of operation in your region.

Figure 13 | PCB LTE antenna with pigtail

The antenna environmental requirements are listed in the table below:

Conditions	Temperature	Humidity
Working	-40 ºC ~ +75 ºC	0% ~ 95%
Storage	-40 ºC ~ +85 ºC	0% ~ 95%

Table 24 | LTE Antenna Environmental Requirements

The antenna specifications are listed in the table below:

Item	Specifications
Range of Frequency	806-960/1710-2700MHz
VSWR	≤1.5
Gain	1.0
Polarization	Linear
Impedance (Ω)	50
Antenna Type	PCB

Table 25 | LTE Antenna Parameters

5.2 GPS Antenna

The GPS antenna connector is shown below (same as the LTE one):

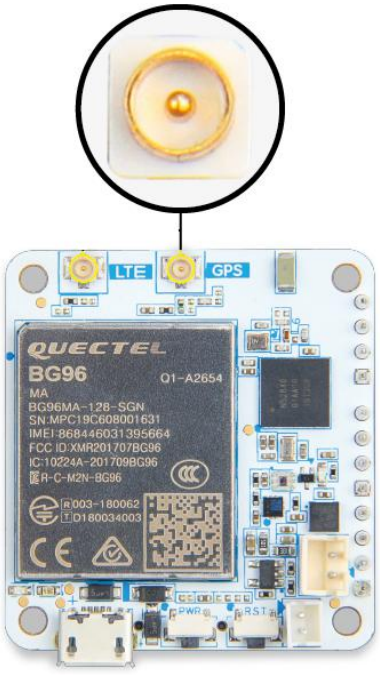
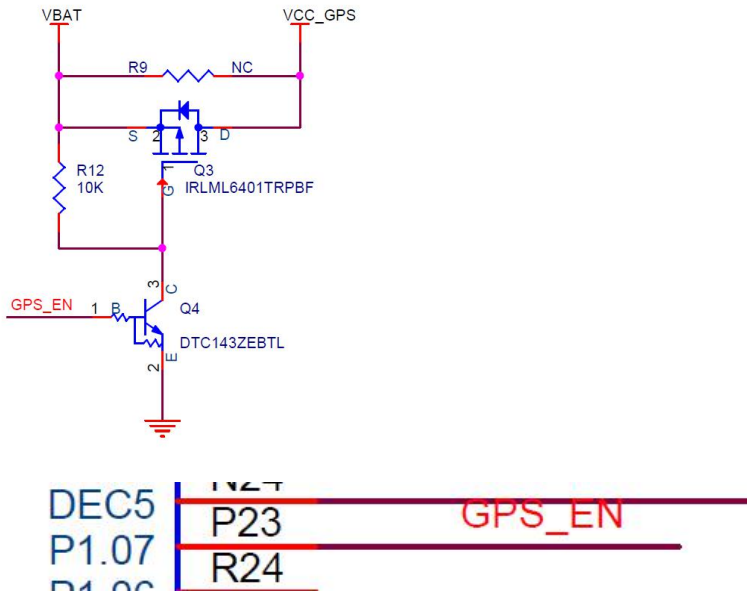


Figure 14 | iPEX onboard connector for the GPS antenna

5.2.1 GPS Antenna Power Supply Control

In order to support low power and long battery life, the active GPS antenna's power supply should be shut down when system don't access the data from GPS module. The GPS power supply is controlled by nRF52840 with

MOSFET, The pin map of GPS_EN on Nrf52840 is P1.09, and the circuit is below:



nrf52840

set P1.07=1, GPS antenna power is on;

set P1.07=0, GPS antenna power is off;

5.2.2 GPS Antenna Specifications

***Figure 15** | GPS antenna*

The antenna environmental requirements are listed in the table below:

Conditions	Temperature	Humidity
Working	-35 ºC ~ +80 ºC	0% ~ 95%
Storage	-35 ºC ~ +80 ºC	0% ~ 95%

***Table 26** | GPS Antenna Environmental Requirements*

Antenna specifications are listed in the table below:

Item	Specifications	PET
Range of Receiving Frequency	1575.42±1.1	±2.5
Center Frequency (MHz) w/ 30mm2 GND plane	1575.42	±3.0
Bandwidth (MHz) (Return Loss ≤ -10dB)	≥10	±0.5
VSWR (in Center Frequency)	≤1.5	±0.5
Gain (Zenith) (dBi Typ.) w/ 70mm2 GND Plane	4.5	±0.5
Axial Ratio (dB) w/ 70mm2 GND Plane	3.0	±0.2
Polarization	Right-Handed Circular	-
Impedance (Ω)	50	-
Frequency Temperature Coefficient (ppm/ºC)	0±10	-

***Table 27** | GPS antenna Parameters*

Amplifier Specifications are listed in the table below:

Item	Specifications
Frequency Range	1575.42 MHz
Gain	27 dB
VSWR	≤ 2.0 V
Noise Coefficient	≤ 2.0 dB
DC Voltage	3 ~ 5 V
DC Current	10 mA

***Table 28** | Amplifier Specifications*

Environmental test performance specifications are listed below:

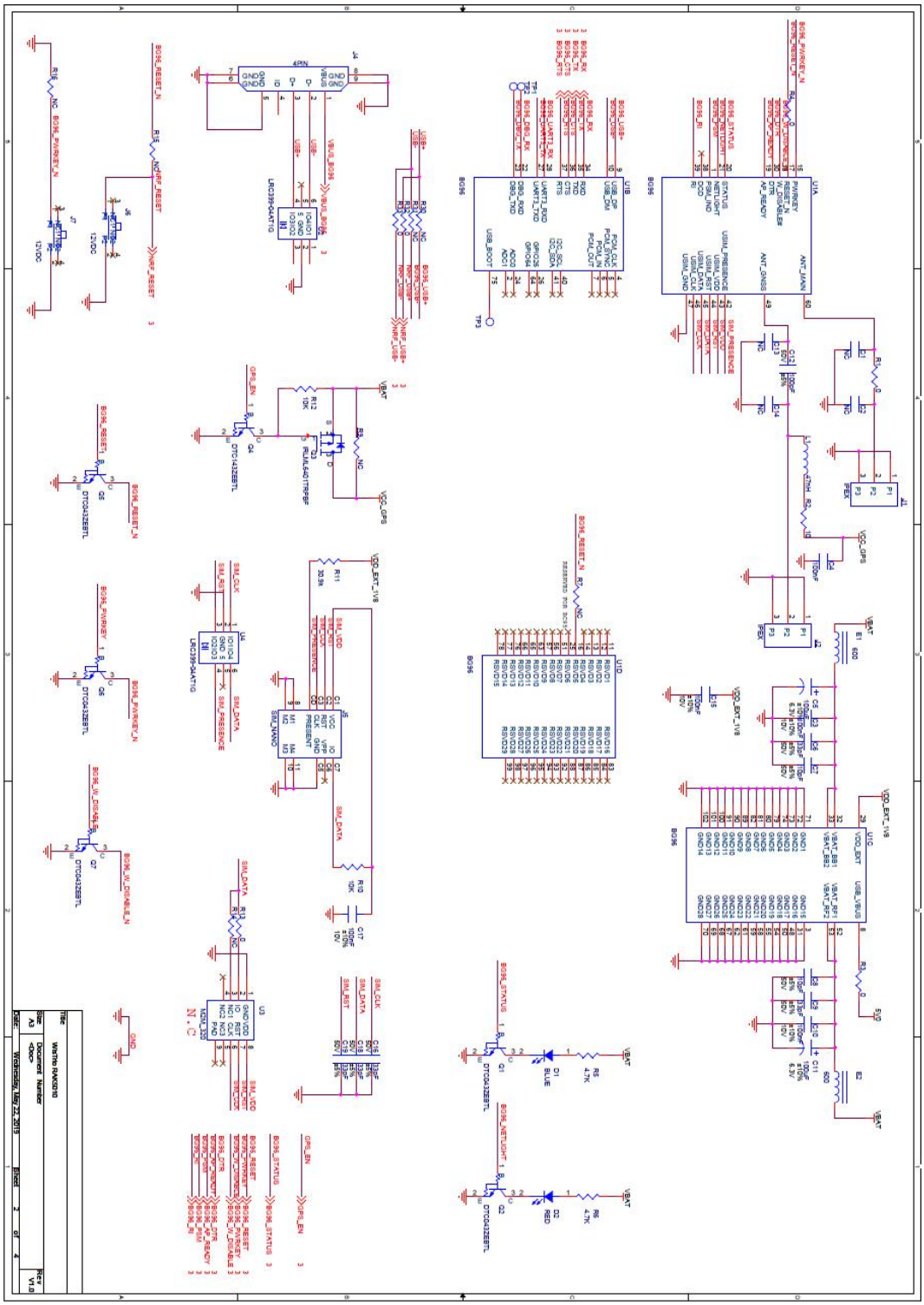
Item	Normal Temp.	High Temp.[1]	Low Temp.[2]
Amplifier Gain	27dB ± 2.0	27dB ± 2.0	27dB ± 2.0
VSWR	≤ 2.0	≤ 2.0	≤ 2.0
Noise Coefficient	≤ 2.0	≤ 2.0	≤ 2.0

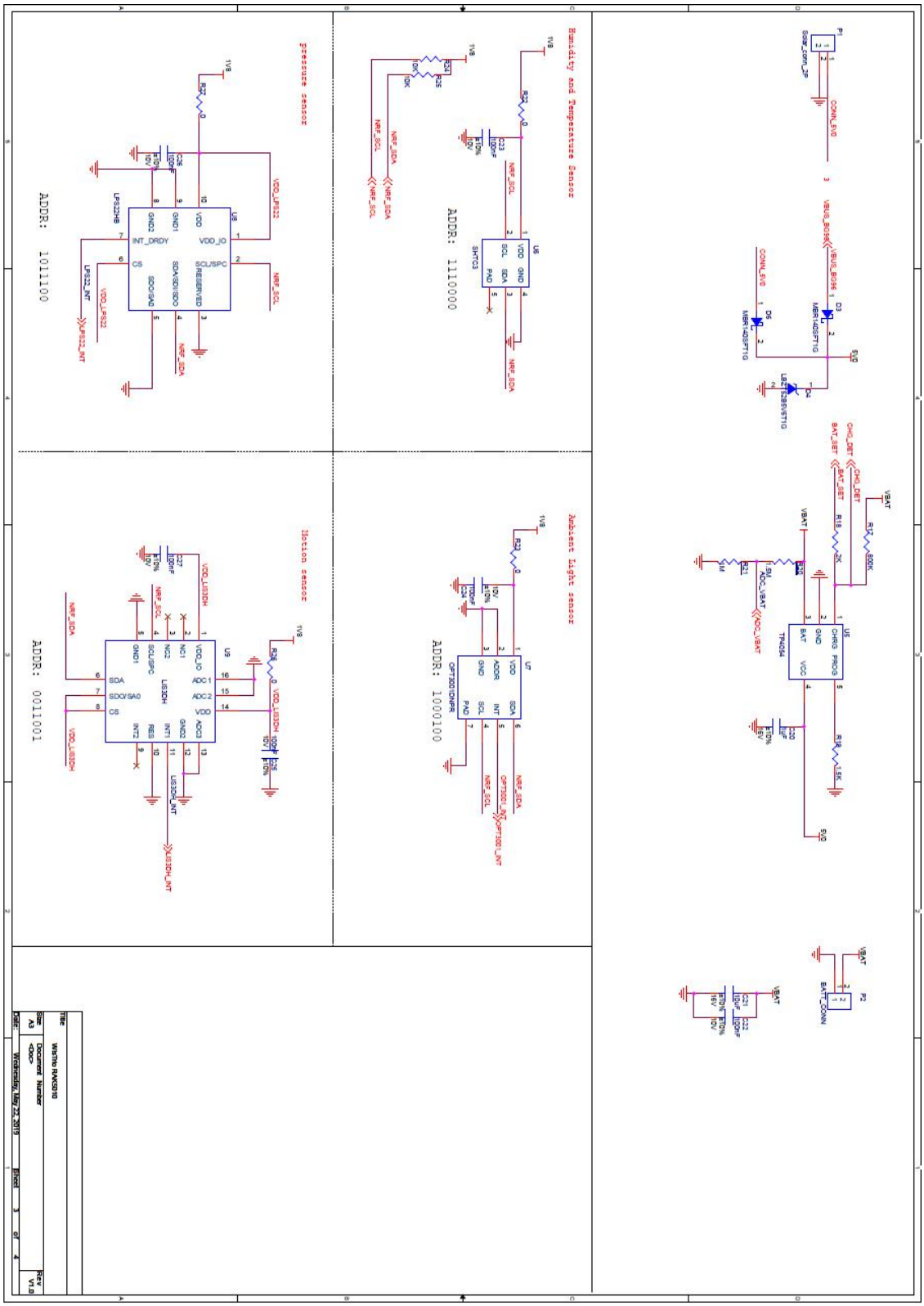
1. High temperature test: soap in temperature (85º C) and humidity (95%) chamber for 24-hour and return to normal temperature (at least for 1-hour) without visual shape change.
2. Low temperature test: soap in temperature (-40º C) chamber for 24-hour and return to normal temperature (at least for 1-hour) without visual shape change.

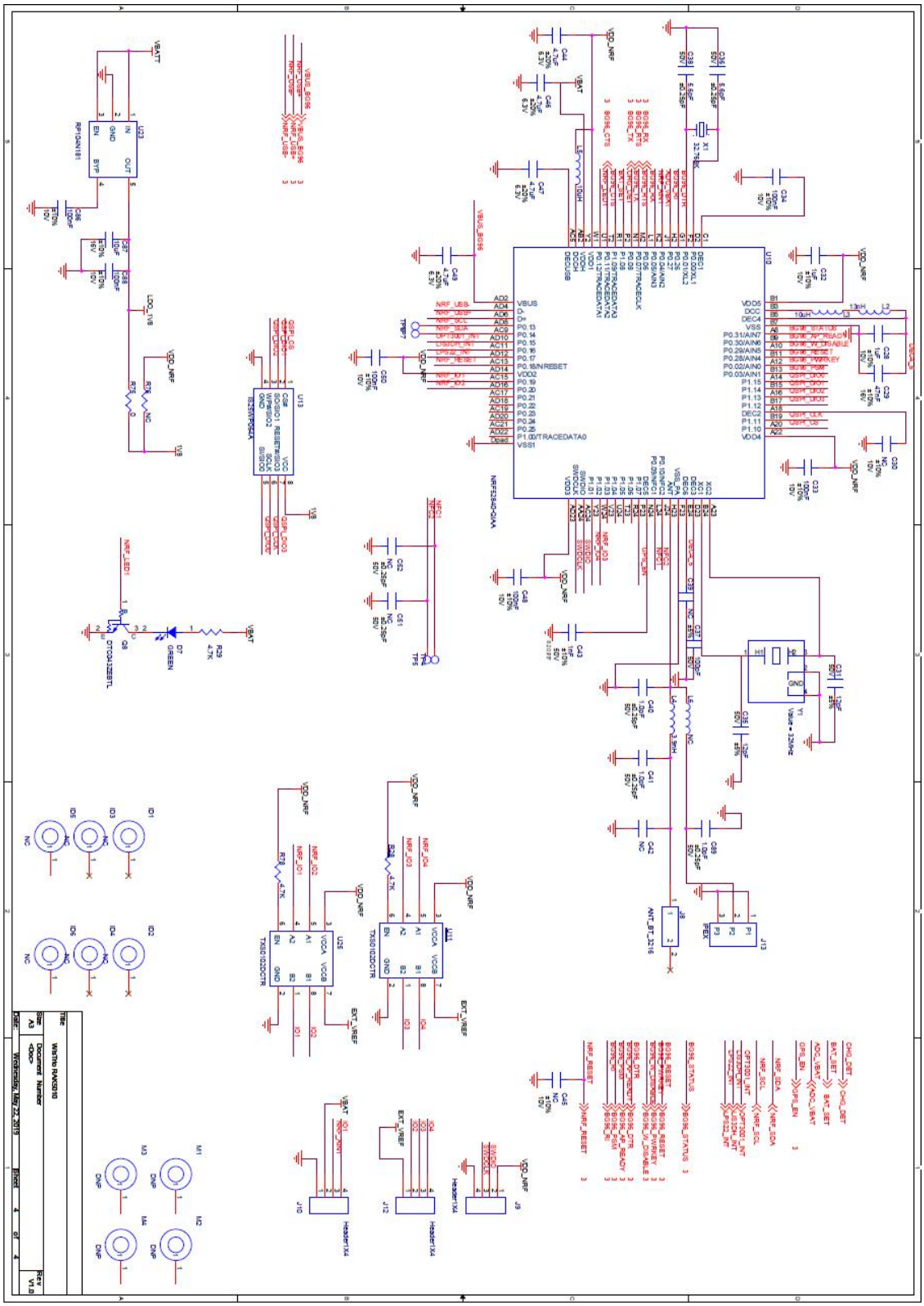
***Table 29** | Environmental Test Performance*

6 Schematics

The Component schematics diagram of the RAK5010 are shown below:







7 Revision History

Revision	Description	Date
1.0	Initial version	2019-07-23
1.1	Update of IO level Reference parameter and signal pinout	2019-07-29
1.2	Modify the interface figures and mechanical dimensions	2019-08-13
1.3	Checked by Vladislav	2019-08-22
1.4	Modify the LED description	2019-09-09

8 Document Summary

Prepared by	Checked by	Approved by
Terry & Penn	Vladislav,Terry	

About RAKwireless:

RAKwireless is the pioneer in providing innovative and diverse cellular and LoRa connectivity solutions for IoT edge devices. It's easy and modular design can be used in different IoT applications and accelerate time-to-market.

For more information, please visit RAKwireless website at www.rakwireless.com.