Nordic Thingy:91

User Guide

v1.4

NORDIC® SEMICONDUCTOR

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Revision history

Date	Version	Description
November 2020	1.4	Updated the following sections with the information needed for Thingy:91 v1.4.0 • Introduction on page 5 • GPS on page 22 • Motion sensors on page 30 • Pin maps on page 27 Added: • Antenna performance on page 20 • Updating the nRF Connect for Cloud certificate on page 15
May 2020	1.3	Updated: • Firmware on page 14 by adding links to relevant documentation Replaced: • Firmware update chapter with Programming Nordic Thingy:91 on page 14
April 2020	1.2	Updated Introduction on page 5
December 2019	1.1	Updated: • Kit content diagram and added a short description • Getting started on page 11 • Connecting LTE Link Monitor on page 13 • Buttons on page 33 • Figures with callouts indicating functionality of components Added the different ways to obtain firmware images for updating firmware, and operating modes: • Firmware on page 14 Updated different firmware update methods and added new update technique using USB (MCUBoot)
August 2019	1.0	First release

1 Introduction

The Nordic Thingy:91™ is a battery-operated prototyping platform for cellular IoT, certified for global operation. It is ideal for rapid development of prototypes for cellular IoT systems and is especially suited for asset tracking applications and environmental monitoring.

Nordic Thingy:91 includes sensors that gather data about its own movements and the surrounding environment. Temperature, humidity, air quality, air pressure, color, and light data can easily be extracted for local or remote analysis. For input, the Nordic Thingy:91 offers a user-programmable button. Visual output is achieved with RGB indicator LEDs, while a buzzer can provide audible output. The standard application firmware on Nordic Thingy:91 extracts the data from the different sensors and relays it securely to the nRF Connect for Cloud, where it is displayed in a user-friendly interface.

The firmware supports concurrent operation with LTE Link Monitor, a tool providing an AT command interface, enabling link and network testing. LTE Link Monitor is an application, which is implemented as part of the nRF Connect for Desktop application. The firmware has been developed using the nRF Connect *Software Development Kit (SDK)*. It is open source and can be leveraged and modified to suit your specific needs. The firmware can be updated and debugged by using an external programmer/debug probe, for example nRF9160 *Development Kit (DK)* or J-Link device supporting Arm Cortex-M33.

Nordic Thingy:91 integrates the nRF9160 *System in Package (SiP)*[1], supporting LTE-M, NB-IoT and *Global Positioning System (GPS)*, and the nRF52840 *System on Chip (SoC)*, supporting *Bluetooth*® Low Energy and *Near Field Communication (NFC)* passive tag.

> **Note:** LTE-M or LTE NB-IoT can operate simultaneously with Bluetooth LE.

Source code for firmware, hardware layout, and schematics are all available on our web site www.nordicsemi.com.

Nordic Thingy:91 has an antenna supporting *GPS*, LTE-M, and NB-IoT that enables it to support a global range of LTE bands. It has two antennas connected to the nRF52840: a 2.4 GHz antenna for Bluetooth LE and an *NFC* passive tag antenna. To connect to cellular network out of the box, Nordic Thingy:91 has a nano/4FF SIM card slot and is bundled with a SIM card from iBasis that comes preloaded with 10 MB. See iBasis IoT network coverage for information on the network coverage in different regions.

NFC in Nordic Thingy:91 operates as a passive tag (e.g. it does not feature a reader function). Nordic Thingy:91 may use this tag function for the Out of Band pairing feature as described in the Bluetooth Core Specification.

A rechargeable Li-Po battery is also part of this prototyping platform giving a smooth transition into prototype field-testing, 1400 mAh for Nordic Thingy:91 v1.0.0, and 1350 mAh for Nordic Thingy:91 v1.4.0.

Key features of Nordic Thingy:91

- 700-960 MHz + 1710-2200 MHz LTE band support[2]. The following bands, based on geographic regions, are used:
  - USA – 2, 4, 12, and 13
  - EU – 3, 8, 20, and 28
- Certifications: CE, FCC

[1] The nRF9160 *SiP* is certified for USA bands 2, 4, 5, 12, 13, 14, 17, 25, 26, and 66. However, Nordic Thingy:91 operates and is only certified for USA bands 2, 4, 12, and 13. The Nordic Thingy:91 firmware is written and documented to only use this subset of USA bands.

[2] The application currently enables the following frequency bands: 2, 3, 4, 8, 12, 13, 20, and 28.

- LTE-M/NB-IoT/*GPS*, Bluetooth LE and *NFC* passive tag antennas
- Nano/4FF *Subscriber Identity Module (SIM)* card slot
- MFF2 M2M Form Factor eUICC (Nordic Thingy:91 v1.4.0 only)
- User-programmable button and RGB LEDs
- Environmental sensor for temperature, humidity, air quality, and air pressure
- Color and light sensor
- Low-power and high-G accelerometer
- Buzzer
- 4 x N-MOS transistor for external DC motors or LEDs
- 16 kbit I2C serial EEPROM (Nordic Thingy:91 v1.4.0 only)
- Rechargeable Li-Po battery with:
  - 1400 mAh capacity for Nordic Thingy:91 v1.0.0
  - 1350 mAh capacity for Nordic Thingy:91 v1.4.0
- Charging through *Universal Serial Bus (USB)*
- PC connection through *USB*
- Normal operating temperature range: $5^{o}C$ ~ $35^{o}C$

nRF9160

- Multimode LTE-M/NB-IoT modem
  - GCF certified for global operation
  - 23 dBm output power
  - *GPS*
  - Power saving features: DRX, eDRX, PSM
  - Coverage enhancement modes
  - Single pin 50 Ω antenna interface
  - *Universal Integrated Circuit Card (UICC)* interface
- Application processor
  - 64 MHz Arm® Cortex®-M33 CPU
  - Arm TrustZone® for trusted execution
  - Arm CryptoCell 310 for application layer security
  - 1 MB flash and 256 kB RAM
  - 4 x SPI/UART/TWI, PDM, I2S, PWM, ADC

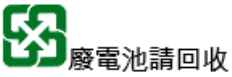
nRF52840 WLCSP

- Bluetooth LE and *NFC* passive tag support
- 64 MHz Arm Cortex-M4F CPU
- 1 MB flash and 256 kB RAM
- *USB*

Environmental Protection

Waste electrical products should not be disposed of with household waste.

Please recycle where facilities exist. Check with your local authority or retailer for recycling advice.



The battery in this product cannot be easily replaced by users themselves. Batteries should be removed only by qualified professionals due to safety concerns.

2 Related documentation

In addition to the information in this document, you may need to consult other Nordic documents.

- nRF9160 Product Specification
- nRF52840 Product Specification
- nRF9160 DK Hardware
- nRF52840 DK
- nRF9160 Errata
- nRF52840 Errata
- nRF Connect SDK documentation
- nRF Connect for Cloud (nrfcloud.com)
- nRF Connect LTE Link Monitor
- nRF Connect Programmer
- nRF91 AT Commands Reference Guide

3 Kit content

The Nordic Thingy:91 kit consists of hardware and access to software components, hardware design files, applications, and documentation.

Figure 1: Nordic Thingy:91 hardware content

The Nordic Thingy:91 kit contains the following:

- Nordic Thingy:91 device with a rubber enclosure serving as a protective cover
- An eSIM (SIM card) from iBASIS supported by the nano/4FF SIM card slot of Nordic Thingy:91
- An information leaflet

WARNING - Power adapter is not included in the kit.[3]

3.1 Downloadable content

The Nordic Thingy:91 prototyping platform includes firmware source code, documentation, hardware schematics, and layout files.

Firmware

- Application firmware for Nordic Thingy:91

[3] Power supply adapter is not included in the safety certification test report, see separate test report according to IEC 62368. The power supply adapter you will use shall meet PS1 requirements.

  - Precompiled HEX files
  - nRF52840 *USB* to UART bridge
- nRF9160 modem firmware
- nRF Connect SDK

PC tools

- nRF Connect LTE Link Monitor
- Segger Embedded Studio
- nRF Connect Programmer

Web applications

- nRF Connect for Cloud (nrfcloud.com)

Hardware files

The hardware files can be downloaded from the Nordic Thingy:91 product page.

The zip file and its subdirectories contain the hardware design files for the Nordic Thingy:91. The hardware files for the circuit board are available in the following folder in the hardware files zip package:

```
\Thingy91 - Hardware files x_x_x\PCA20035-Thingy91 Board x_x_x
```

In this folder, you can find the following hardware design files:

- Altium Designer files
- Schematics and PCB layout files in PDF format
- Bill of materials
- Production files:
  - Drill files
  - Assembly drawings
  - Gerber files
  - Pick-and-place files

4 Getting started

Setting up Nordic Thingy:91 requires completing the following steps.

Before you start:

- Unpack Nordic Thingy:91.
- Make sure to update the Nordic Thingy:91 firmware as explained in Programming Nordic Thingy:91.
- Make sure you have an nRF Connect for Cloud account and sign in to nRF Connect for Cloud (nrfcloud.com). See Creating an nRF Connect for Cloud account for more information.

Once you are signed in, perform the following steps.

1. Add new LTE device.

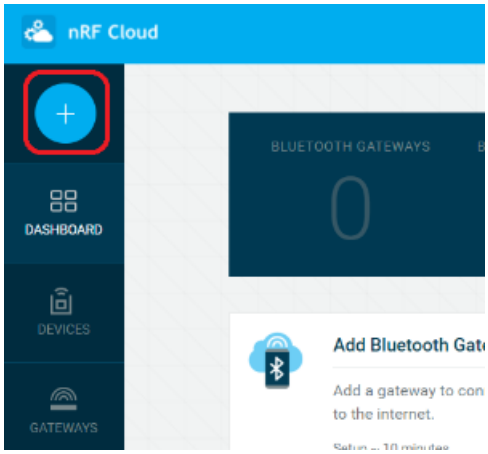


Figure 2: Adding new LTE device in nRF Connect for Cloud

2. Verify and activate the *SIM* card.

   Input *SIM* ICCID and *Personal Unblocking Key (PUK)* from the *SIM* card, and add personal information.

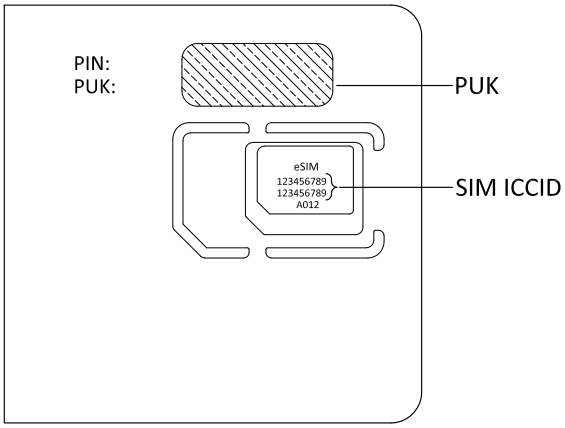


Figure 3: Placement of PUK and SIM ICCID on the SIM card

3. Gently remove the rubber overlay to reveal the power switch and the top of Nordic Thingy:91. Insert the *SIM* card.

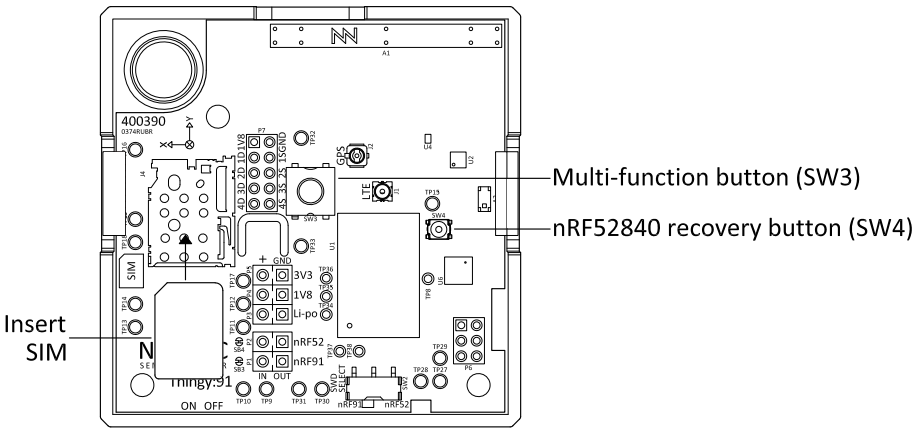


Figure 4: Inserting the SIM card

4. Once the *SIM* card is inserted, power on Nordic Thingy:91. You will find the power switch next to the micro-*USB* port.

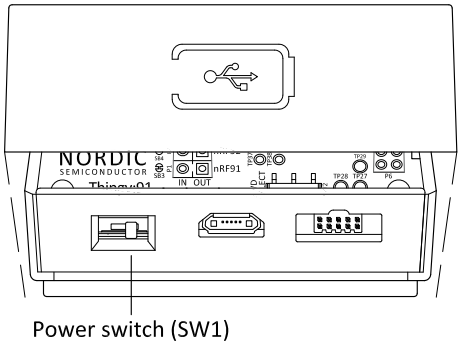


Figure 5: Nordic Thingy:91 Power switch

Wait for yellow breathing in the indicator LED. If the LED does not turn yellow, check Operating states of Nordic Thingy:91 to determine the present state of Nordic Thingy:91.

5. Associate the Nordic Thingy:91 to your user account.

   Enter the *International Mobile (Station) Equipment Identity (IMEI)* and *Personal Identification Number (PIN)* information that is found on the sticker on the Nordic Thingy:91 PCB. Wait for blue breathing which means that your Nordic Thingy:91 is associated and connected.

Figure 6: Associating Nordic Thingy:91 to nRF Connect for Cloud

6. For optional activation of *GPS*, go outdoors and press the **SW3** button for a minimum of 10 seconds until the indicator LED begins breathing purple.

   - Purple breathing: *GPS* is active and searching
   - Green breathing: *GPS* has fix

   Wait for green breathing in the indicator LED which indicates that your Nordic Thingy:91 has *GPS* fix.

   Check that the position data and the environment sensor data are sent to nRF Connect for Cloud.

4.1 Connecting LTE Link Monitor

To get debug output and to send AT commands directly to the modem, you can connect to the Nordic Thingy:91 using nRF Connect LTE Link Monitor.

Before you begin, install and open nRF Connect for Desktop. To download the latest version, go to nRF Connect for Desktop. For instructions, see nRF Connect LTE Link Monitor.

To connect to the Nordic Thingy:91 using LTE Link Monitor, perform the following steps.

1. Install and launch LTE Link Monitor.
2. Connect your Nordic Thingy:91 to your computer with a *USB* cable.
3. Make sure that Nordic Thingy:91 is powered on.
4. Click **Select device** and select the device entry from the drop-down list in the LTE Link Monitor.
5. Verify the connection to the Nordic Thingy:91 modem by sending the command `AT` to the modem from the LTE Link Monitor terminal and observing that the modem responds with `OK`.

All asset tracker debug output shows up in the terminal view, and you can send AT commands to the modem to try out different settings. For further details on available AT commands, see nRF91 AT Commands Reference Guide.

5 Firmware

The firmware of Nordic Thingy:91 has been developed using the nRF Connect *SDK*. It is open source, and can be modified according to specific needs.

The asset tracker application firmware, which is pre-loaded in the Nordic Thingy:91, enables the device to use the environment sensors as described in Environment sensors on page 32, and provides an option of tracking the device using *GPS*. The data, along with information about the device, is transmitted to Nordic Semiconductor's cloud solution, nRF Connect for Cloud, where it can be visualized. For more information on the asset tracker application, see nRF9160: Asset Tracker.

You can find more information on the firmware and the associated features in the Working with Thingy:91 nRF Connect *SDK* documentation.

5.1 Programming Nordic Thingy:91

You can program the modem and applications on a Nordic Thingy:91 using multiple methods. Applications can be programmed either on the nRF9160 *SiP* or on the nRF52840 *SoC*.

The different ways to program the modem and the applications on a Nordic Thingy:91 are listed below.

- Using USB (MCUboot)
- Using an external debug probe

If you are programming applications using USB, you can choose the component to be programmed by pushing the **SW3** or **SW4** button of a Nordic Thingy:91 while powering on. This puts the device in serial recovery mode. The **SW3** button is used to program the nRF9160 *SiP*, and the **SW4** button is used to program the nRF52840 *SoC*.

If you are programming applications using an external debug probe, you can use an nRF9160 *DK* or any J-Link device supporting Arm Cortex-M33 as the external debug probe. The component to be programmed is determined by the setting of the **SWD** selection switch **(SW2)** of Nordic Thingy:91 to **`nRF91`** or **`nRF52`**.

See the following documentation for the detailed procedures to program applications and to program the modem on a Nordic Thingy:91.

- Programming applications on Nordic Thingy:91
- Programming the Nordic Thingy:91 modem

6 Updating the nRF Connect for Cloud certificate

The nRF9160: Asset Tracker application transmits data to *nRF Connect for Cloud* for visualization. Therefore, it requires a valid up-to-date security certificate.

After you have established a connection with *nRF Connect for Cloud*, if the security certificate is overwritten at some point of time, you might need to update the security certificate that is stored in Nordic Thingy:91.

> **Note:** Nordic Thingy:91 comes pre-provisioned with a valid *nRF Connect for Cloud* certificate, and the following steps are required only if you need to update the certificate on Nordic Thingy:91.

6.1 Downloading the nRF Connect for Cloud certificate

You can download the *nRF Connect for Cloud* certificate for your Nordic Thingy:91 from *nRF Connect for Cloud*.

Complete the following steps to download the certificate:

1. Go to nRF Connect for Cloud (nrfcloud.com) and sign in.
2. Click the menu icon in the top-right corner and select **Account**.
3. In the **Device Certificates** section, enter your device ID and ownership code.

   Device ID
   The device ID is composed of `nrf-` and the 15-digit *IMEI* number that is printed on the label of your Nordic Thingy:91. For example: `nrf-123456789012345`

   Ownership code
   The ownership code is the *PIN* or the hardware ID of your Nordic Thingy:91. You can find it on the label of your Nordic Thingy:91. If the label contains a *PIN* in addition to the *IMEI* number, enter this *PIN*.

   You need to enter this information several times while setting up your Nordic Thingy:91. Therefore, it can be helpful to note it down somewhere on your computer.

   > **Note:** The ownership code serves as a password and proves that you own the specific Nordic Thingy:91. Therefore, you should not share it with anyone.

4. Click **Download Certificate** and save the `*.cert.json` file to a folder of your choice.

   > **Note:** The certificate contains all information that is needed to connect your Nordic Thingy:91 to *nRF Connect for Cloud*. Therefore, you should not share the certificate with anyone.

6.2 Provisioning the nRF Connect for Cloud certificate

After retrieving the certificate from *nRF Connect for Cloud*, you must provision it to your Nordic Thingy:91.

Note: The application firmware on the Nordic Thingy:91 must support long AT commands up to 3 kB to provision the certificate. If you updated the application firmware as described, this requirement is fulfilled.

Complete the following steps to provision the certificate:

1. Open nRF Connect for Desktop and launch nRF Connect LTE Link Monitor.
2. In the **Settings** pane on the right, deselect the check box for **Automatic requests**.
3. If you have already inserted the *SIM* card into your Nordic Thingy:91, remove it before you continue.
4. Connect Nordic Thingy:91 to the computer with a micro-USB cable, and turn it on.
   In the navigation bar, **No devices available** changes to **Select device**.
5. Click **Terminal** in the navigation bar to switch to the terminal view.
6. Enter `AT+CFUN=4` in the AT command text field and click **Send**.
   This AT command puts the modem to offline state.
7. Enter `AT+CFUN?` in the AT command text field and click **Send**.

   This AT command returns the state of the modem.

   The command should return `+CFUN: 4`, which indicates that the modem is in offline state. If it returns a different value, repeat the previous step.
8. Click **Certificate manager** in the navigation bar to switch to the certificate manager view.
9. Click **Load from JSON** and select the `*.cert.json` file that you downloaded from *nRF Connect for Cloud*.

   You can also drag and drop the file onto the GUI.
10. Ensure that the **Security tag** is set to `16842753`, which is the security tag for *nRF Connect for Cloud* credentials.
11. Click **Update certificates**.
    The log message "Certificate update completed" indicates that the certificate was provisioned successfully.

    If you encounter any errors, switch to the terminal view and check the output of the AT commands that were sent to the Nordic Thingy:91 modem.

Note: If you had connected your Nordic Thingy:91 to *nRF Connect for Cloud* before, you must delete the device there after provisioning the certificate. To do so, open the entry for your device from the **Devices** view, click **Configure**, and select **Delete Device**. Then, add the Nordic Thingy:91 again as described in Getting started on page 11.

7 Hardware description

This chapter focuses on the hardware components of Nordic Thingy:91 with detailed descriptions of the various hardware blocks that are present on the device.

The sensors available in Nordic Thingy:91 are not calibrated in production. Nordic Semiconductor does not specify the accuracy of measurements. Users who want to reuse parts of this design to create measurement devices should conform to documentation of the specific sensors.

7.1 Block diagram

The block diagram represents interactions between hardware components on Nordic Thingy:91.

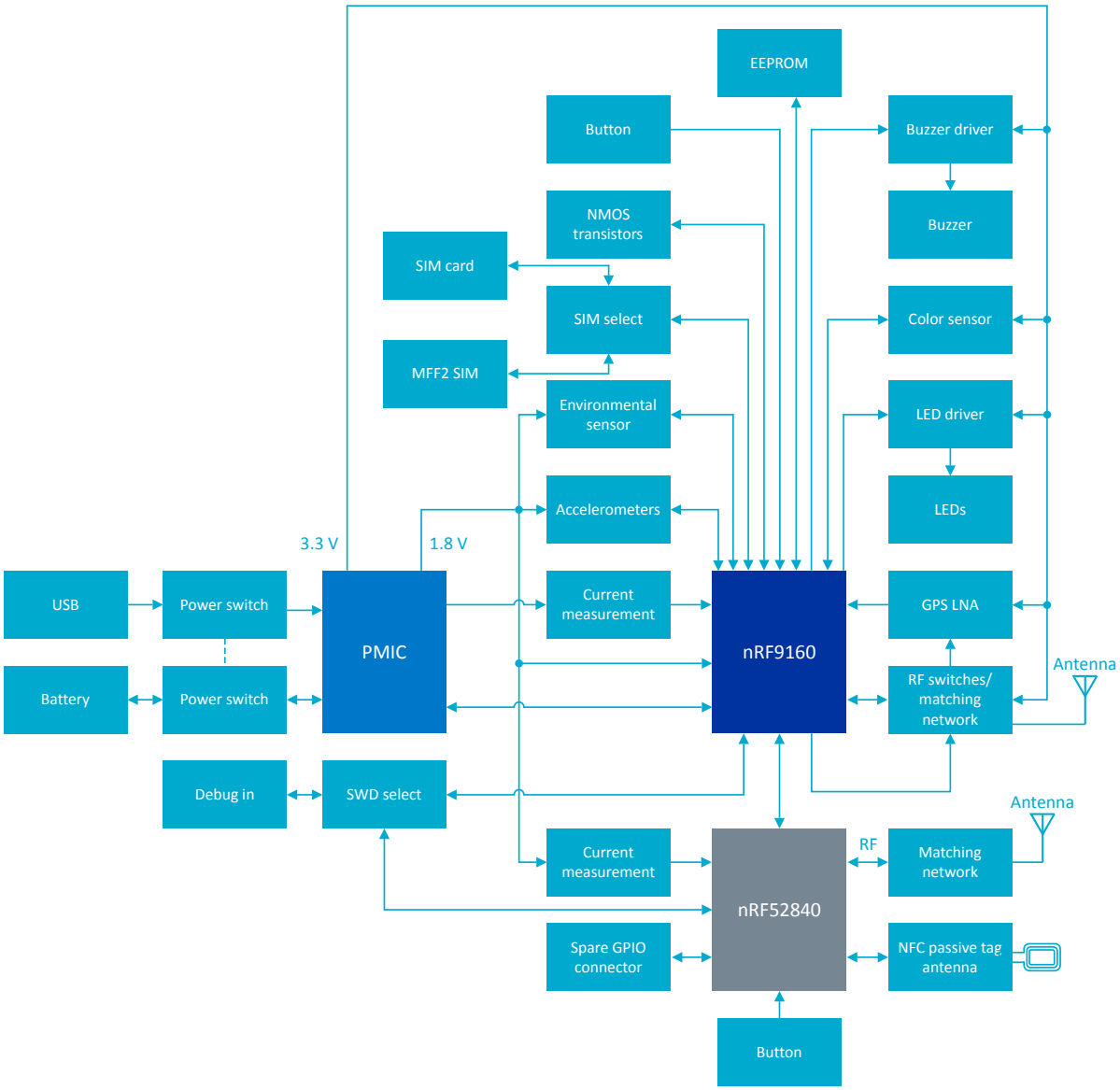


Figure 7: Nordic Thingy:91 hardware block diagram

7.2 Hardware figures

The hardware figures show elements on both sides of the Nordic Thingy:91 PCB.

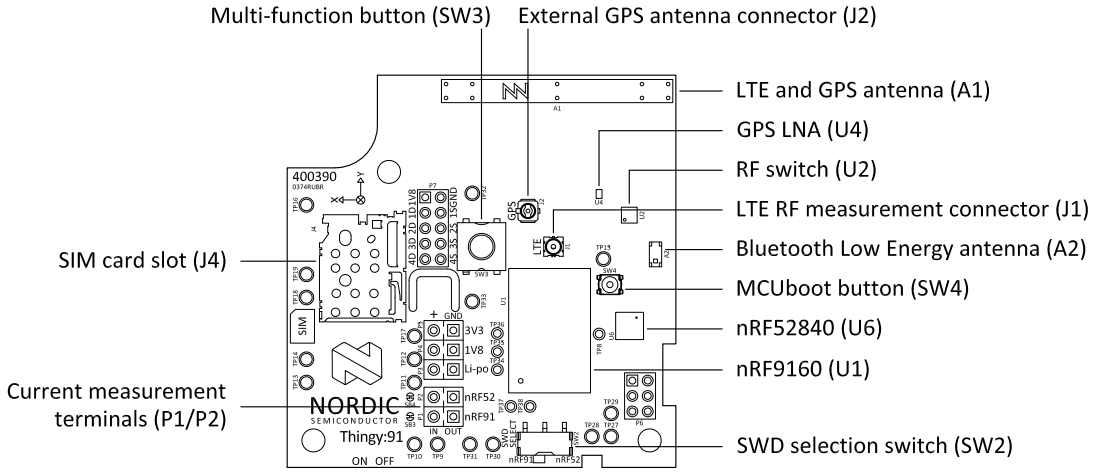


Figure 8: Nordic Thingy:91 PCB, top

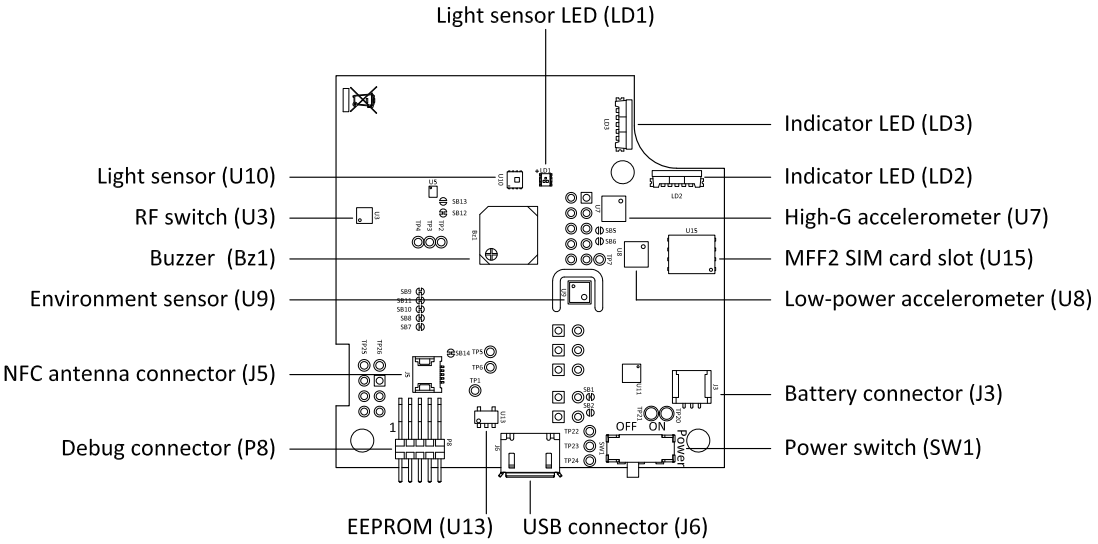


Figure 9: Nordic Thingy:91 PCB, bottom

7.3 nRF9160

The nRF9160 is the main device of Nordic Thingy:91. It is a compact, highly integrated *SiP* that makes use of the latest low-power LTE technology. It has advanced processing capabilities and security features. It also has the accessibility and flexibility to be used with a wide range of single-device low-power cellular IoT applications.

For more information, see nRF9160 Product Specification.

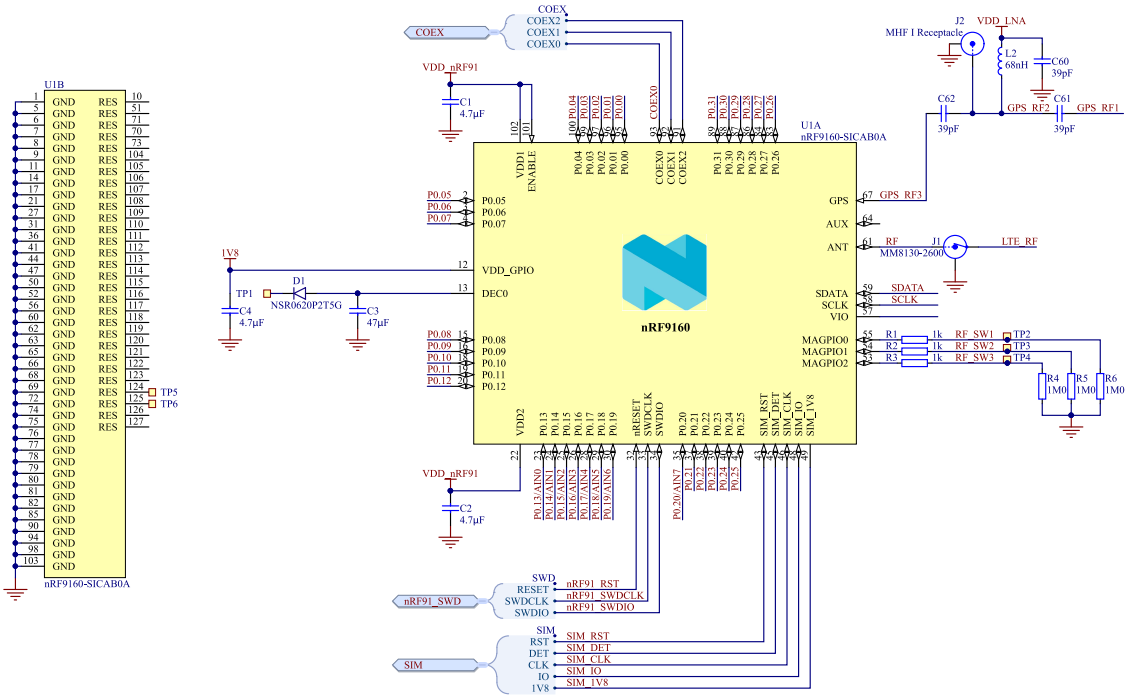


Figure 10: nRF9160 schematic

7.3.1 Antenna tuning

To improve antenna efficiency, Nordic Thingy:91 has dynamic antenna tuning.

Different tuning components are used for different frequencies. This is achieved by using tuning components between two SP8T RF switches. The switches are automatically controlled by the nRF9160 LTE modem and set to the correct state based on the frequency of operation. Six paths are used for LTE frequency, and one path is used for *GPS* frequency.

RF_SW3	RF_SW2	RF_SW1	State	Band	Frequency
0	0	0	RF2 - RFC	Not used	Not used
0	0	1	RF7 - RFC	13U/D, 28D	746 MHz - 803 MHz
0	1	0	RF5 - RFC	12U/D, 17U/D, 28U 1U/D, 2U/D, 3U/D, 4U/D, 25U/D	698 MHz - 748 MHz 1710 MHz - 2200 MHz
0	1	1	RF3 - RFC	5D, 20U, 26D	824 MHz - 894 MHz
1	0	0	RF1 - RFC	8U/D	880 MHz - 960 MHz
1	0	1	RF8 - RFC	5U, 20D, 26U	791 MHz - 849 MHz
1	1	0	RF6 - RFC	Not used	Not used
1	1	1	RF4 - RFC	GPS	1574 MHz - 1577 MHz

Table 1: Antenna tuning bands

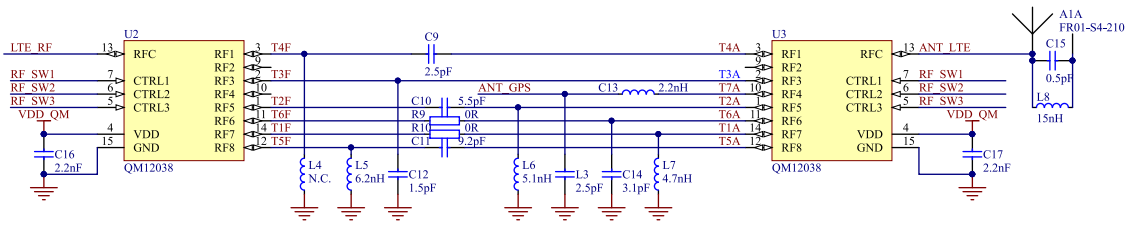


Figure 11: Antenna tuning circuitry schematic

7.3.2 Antenna performance

Performance of the Nordic Thingy:91 antenna has been measured in an environment as close to an actual use case as possible, where Nordic Thingy:91 typically is standalone and battery operated.

The table below shows basic average performance data of the antenna.

Technical features	698–748 MHz	746–803 MHz	791–849 MHz	824–894 MHz	880–960 MHz	1575 MHz	1710–2220 MHz
Average efficiency	9.2%	12.6%	15.8%	18.5%	11.1%	39.8%	47.4%
VSWR (voltage standing wave ratio)	< 3:1						

Table 2: Technical overview of the antenna

The figure below shows the antenna efficiency curves for each individual tuning path for LTE frequencies.

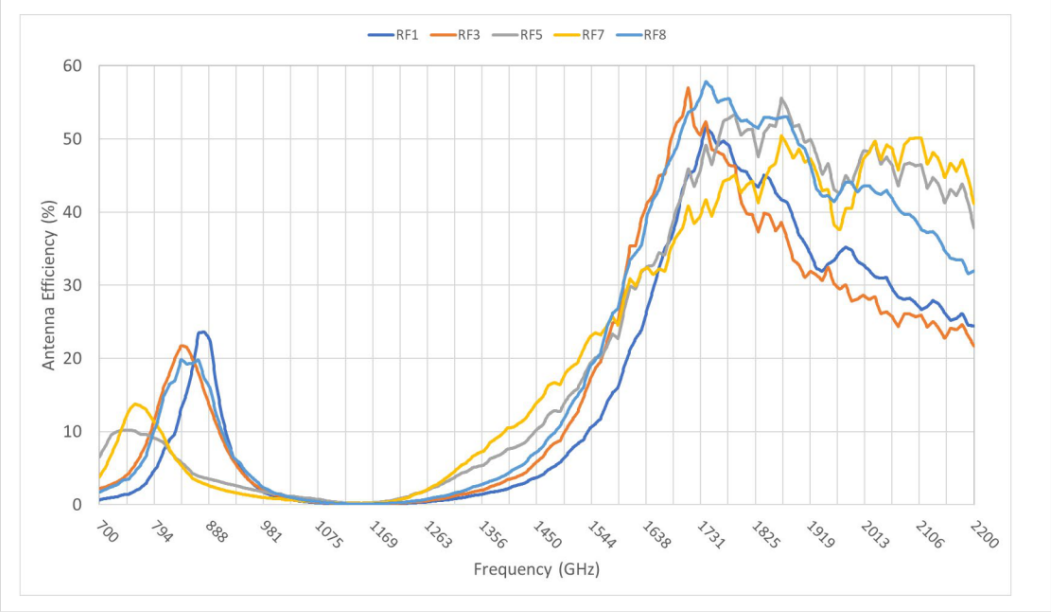


Figure 12: Individual antenna efficiency plot for LTE bands

The different tuning paths used for the LTE frequencies give best antenna efficiency in one part of the frequency band. By defining the frequency switching in a way that ensures the next range taking over once the performance of the current range starts declining, the overall antenna efficiency can be improved.

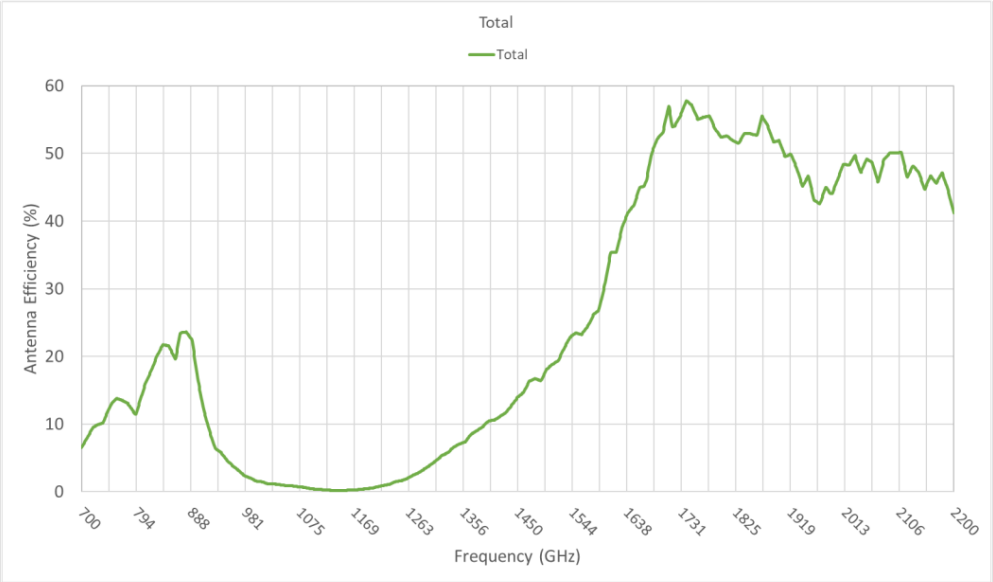


Figure 13: Overall antenna efficiency plot for LTE bands

Figure below shows the antenna efficiency for the *GPS* band and the neighboring frequencies.

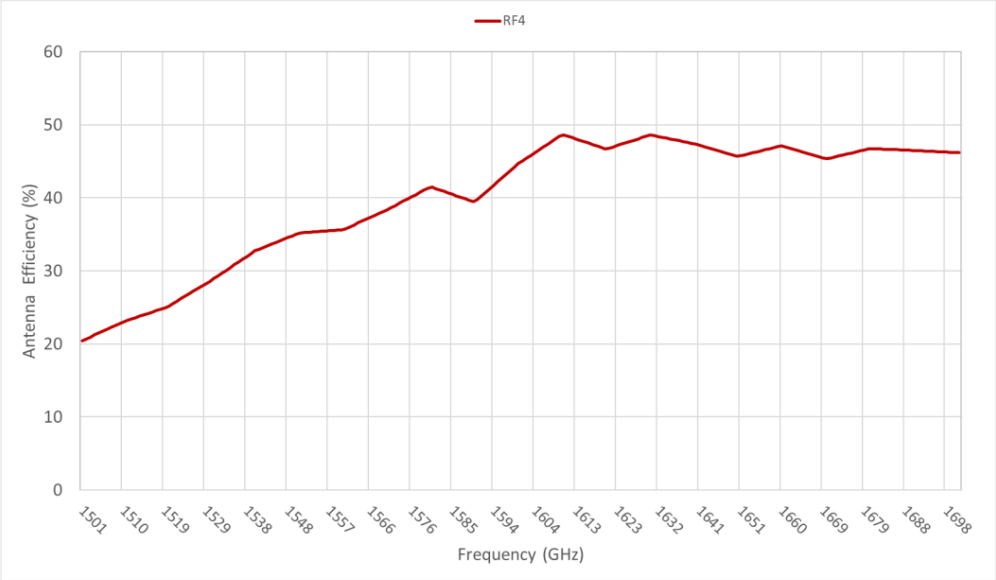


Figure 14: Antenna efficiency plot for GPS band

7.3.3 RF measurements

The LTE signals are propagated through a coaxial connector. This makes it possible to perform conducted measurements or attach external antennas.

By default, when no cable is attached, the RF signal is routed to the onboard antenna. When connecting the adapter, the internal switch in the SWF connector will disconnect the onboard antenna and connect the RF signal from the nRF9160 to the adapter.

The connector is of SWF type (Murata part no. MM8130-2600) with an internal switch. An adapter is available (Murata part no. MXHS83QE3000) with a standard SMA connection on the other end for connecting instruments. The adapter is not included in the kit. The insertion loss in the adapter cable is approximately 0.5–1 dB.

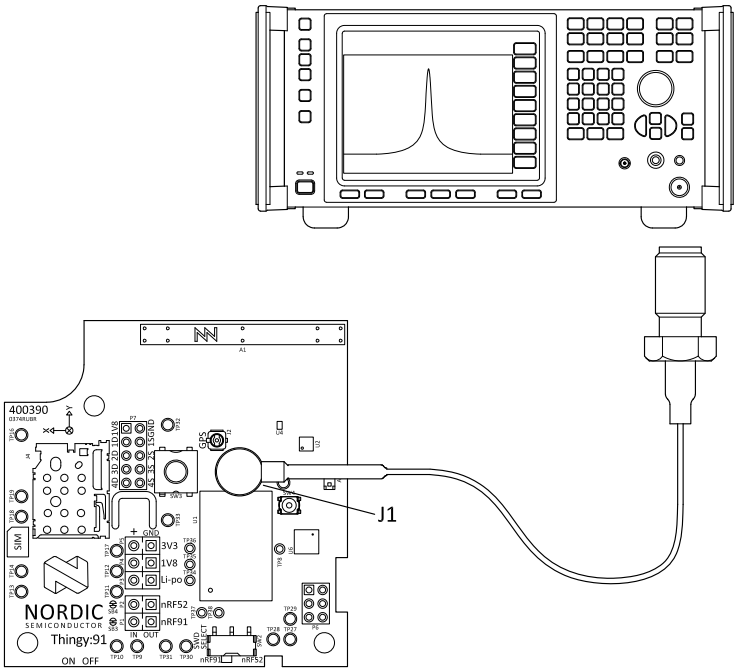


Figure 15: Connecting a spectrum analyzer

7.3.4 GPS

The nRF9160 *SiP* has a dedicated *GPS* port to support global navigation, and the same antenna is used for both LTE and *GPS*. The *GPS* signal is RX only, and there is a low-noise amplifier (*Low-Noise Amplifier (LNA)*) that amplifies the signal before it is fed to the *GPS* RF port on the nRF9160.

Note: *GPS* signals do not usually penetrate ceilings or other structures. For best *GPS* performance, Nordic Thingy:91 should be used outside in an open space, far from sources of interference and other structures that may block the signals.

7.3.4.1 GPS in Nordic Thingy:91 v1.0.0

For Nordic Thingy:91 v1.0.0, the *GPS* signals are propagated through a coaxial connector located between the antenna and the *LNA*.

The coaxial connector makes it possible to attach external antennas. The connector is of SWF type (Murata part no. MM8130-2600) with an internal switch. An adapter is available (Murata part no. MXHS83QE3000) with a standard SMA connection on the other end for connecting instruments. The adapter is not included in the kit. The insertion loss in the adapter cable is approximately 0.5–1 dB.

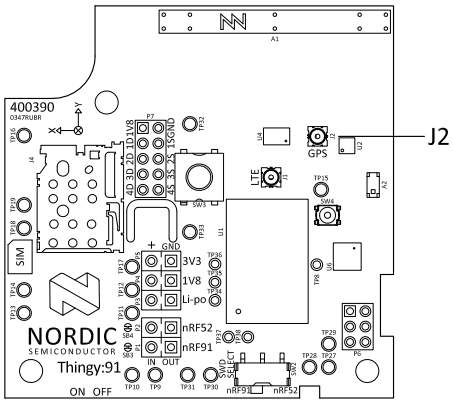


*Figure 16: External **GPS** antenna connector on Nordic Thingy:91 v1.0.0*

The *LNA* enable signal is controlled by the logic circuitry. It is enabled only when the antenna tuning circuitry is set to operate at the *GPS* frequency band. The *LNA* makes the *GPS* receiver more sensitive to *GPS* signals and less sensitive to interference from other sources nearby.

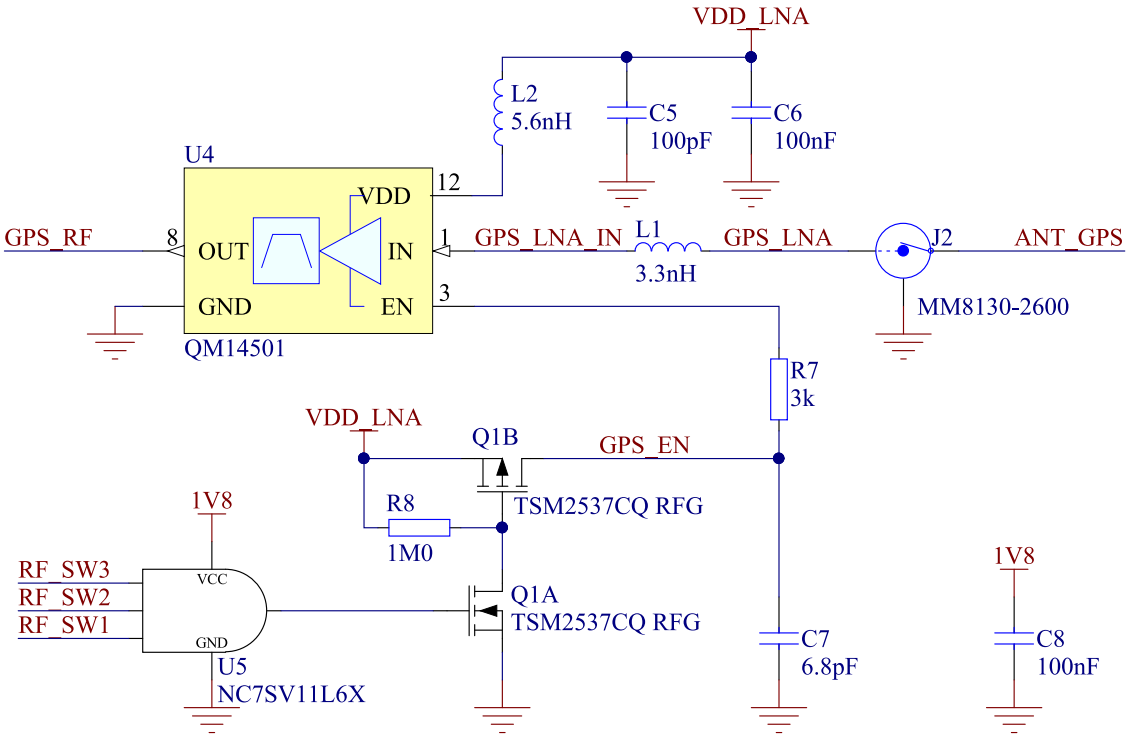


*Figure 17: **GPS** circuit schematic for Nordic Thingy:91 v1.0.0*

7.3.4.2 GPS in Nordic Thingy:91 v1.4.0

With Nordic Thingy:91 v1.4.0, the connector type changed to a Hirose U.FL compatible connector (I-PEX MHF).

An external active *GPS* antenna can be connected to connector **J2**.

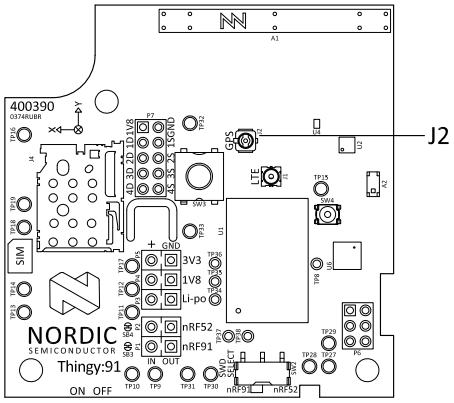


Figure 18: External GPS antenna connector on Nordic Thingy:91 v1.4.0

When an external antenna is used, the on-board *LNA* should be disabled. The *LNA* enable signal is controlled by the **COEX0** pin of the nRF9160, and its function is set by the AT%XCOEX0 AT command. The *LNA* makes the *GPS* receiver more sensitive to *GPS* signals and less sensitive to interference from other sources nearby.

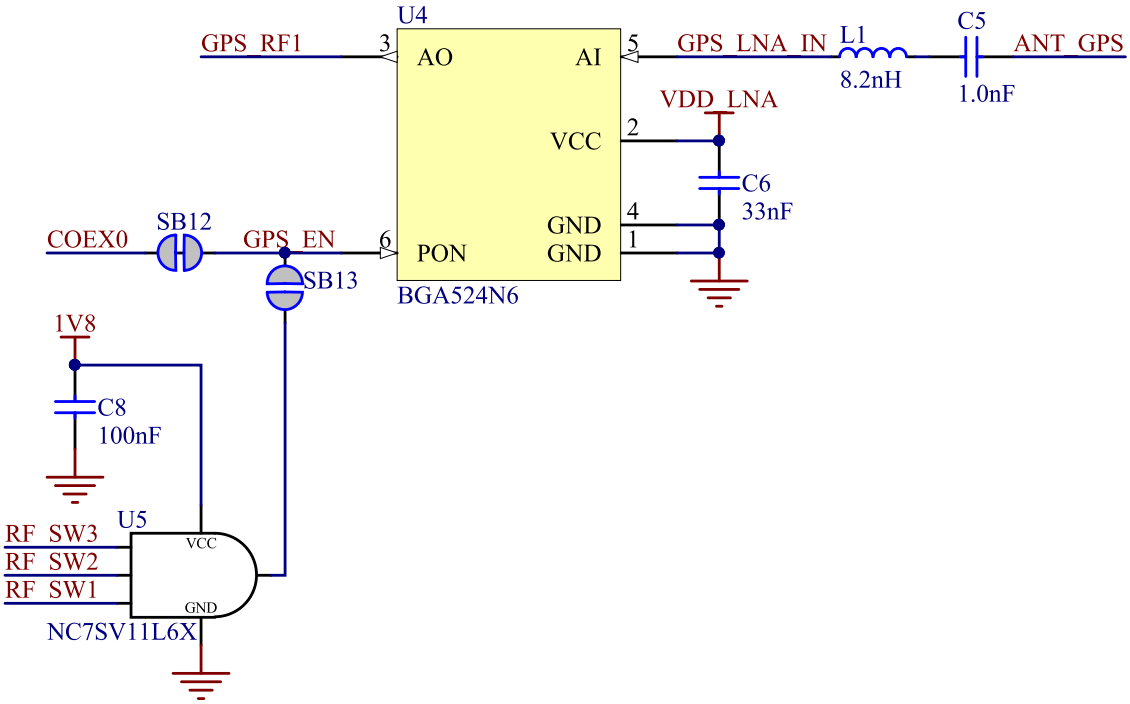


Figure 19: GPS circuit schematic for Nordic Thingy:91 v1.4.0

To disable the on-board *LNA*, the following needs to be done in the firmware:

1. In the file `nrf/boards/arm/thingy91_nrf9160/board_nonsecure.c`, change the line `#define AT_CMD_COEX0 "AT%XCOEX0=1,1,1570,1580"` to `#define AT_CMD_COEX0 "AT%XCOEX0"`.
2. Save the file, and rebuild the firmware as described in Working with Thingy:91 nRF Connect *SDK* documentation.

7.3.5 SIM card

Nordic Thingy:91 is equipped with a nano-*SIM* (4FF) card slot. As of Nordic Thingy:91 v1.4.0 it is also equipped with a footprint for an MFF2 *SIM* card.

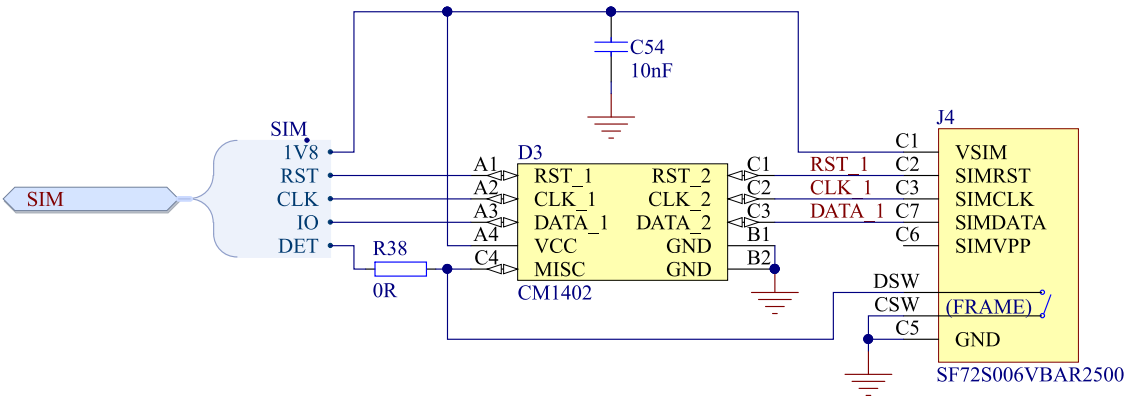


Figure 20: SIM card schematic for Nordic Thingy:91 v1.0.0

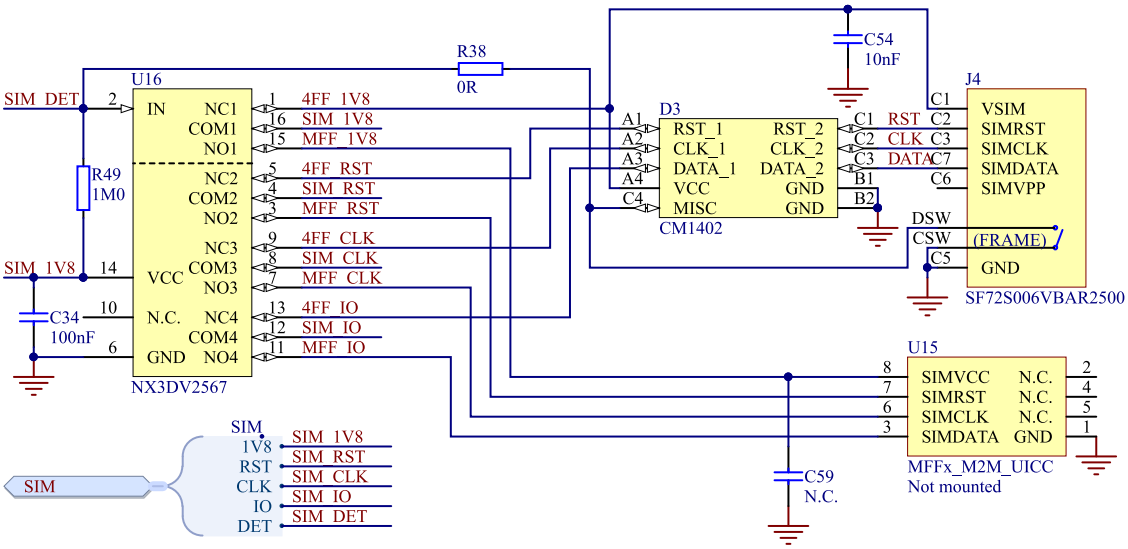


Figure 21: SIM card schematic for Nordic Thingy:91 v1.4.0

Switching between the two types is controlled by the presence of a 4FF *SIM* card.

7.4 nRF52840

For *USB*, Bluetooth, and *NFC* passive tag connectivity, Nordic Thingy:91 uses a nRF52840 *SoC*. It is a powerful, highly flexible, ultra-low power *SoC* that incorporates a Bluetooth Low Energy radio and a 32-bit Arm Cortex-M4F CPU.

For more information on the *SoC*, see nRF52840 Product Specification.

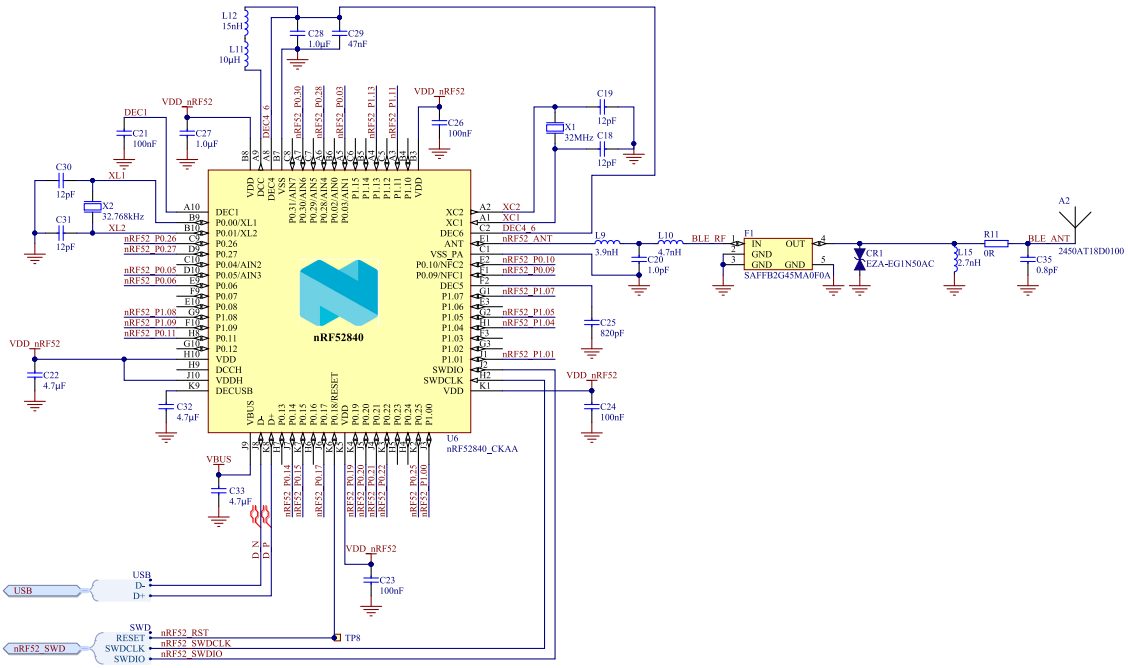


Figure 22: nRF52840 schematic

7.4.1 NFC passive tag

Nordic Thingy:91 supports an *NFC* passive tag. NFC-A listen mode operation is supported on the nRF52840.

The *NFC* passive tag antenna input is available on connector **J5**.

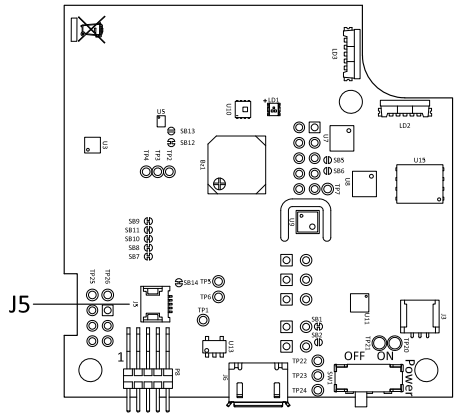


Figure 23: NFC passive tag antenna connector

The *NFC* passive tag uses two pins, **`F1`** (NFC1) and **`E2`** (NFC2), to connect the antenna. These pins are shared with *GPIO*s (**`P0.09`** and **`P0.10`**), and the PROTECT field in the NFCPINS register in UICR defines the usage of these pins and their protection level against abnormal voltages. The content of the NFCPINS register is reloaded at every reset.

> **Note:** The *NFC* passive tag pins are enabled by default.

The *NFC* passive tag can be disabled and the *GPIO*s enabled by defining the *CONFIG_NFCT_PINS_AS_GPIOS* variable in the project settings. The way of doing this depends on the *Integrated Development Environment (IDE)* or toolchain in use.

- When using SEGGER Embedded Studio, go to **Project** > **Edit Options** > **Code** > **Preprocessor** > **Preprocessor Definitions** and add the *CONFIG_NFCT_PINS_AS_GPIOS* variable.

- When using Keil, go to **Project** > **Options for Target** > **C/C++** > **Preprocessor Symbols** > **Define** and add the *CONFIG_NFCT_PINS_AS_GPIOS* variable.

7.4.2 USB

The Nordic Thingy:91 *USB* connector is connected to the *USB* interface of the nRF52840 *SoC*. This enables PC communication and battery charging.

7.5 Pin maps

The pin assignments for the nRF9160 *SiP* and nRF52840 *SoC* are listed in the pin map tables.

I/O	Label	Description
P0.00	SENSE_LED_RED	Red color of the color sensor support LED
P0.01	SENSE_LED_GREEN	Green color of the color sensor support LED
P0.02	SENSE_LED_BLUE	Blue color of the color sensor support LED
P0.03	SCK	SPI clock line
P0.04	MOSI	SPI master output, slave input data line
P0.05	MISO	SPI master input, slave output data line
P0.06	ADXL372_INT1	High-G accelerometer interrupt line
P0.07	ADXL372_CS	High-G accelerometer chip select line
P0.08	ADXL362_CS	Low-power accelerometer chip select line
P0.09	ADXL362_INT1	Low-power accelerometer interrupt line
P0.10	nRF52_RESET (Default Nordic Thingy:91 v1.4.0) ADXL362_INT2 (Optional) ADXL372_INT2 (Optional)	On Nordic Thingy:91 v1.4.0, P0.10 is connected to the reset line of the nRF52840 device by default. Optionally, P0.10 can be connected to the interrupt line 2 of the accelerometers, selectable by solder bridge. On Nordic Thingy:91 v1.0.0, P0.10 is not connected by default. Optionally, P0.10 can be connected to the interrupt line 2 of the accelerometers, selectable by solder bridge.
P0.11	SDA	I^2C data line
P0.12	SCL	I^2C clock line
P0.13	N-MOS_1	Gate of N-MOS transistor externally available
P0.14	N-MOS_2	Gate of N-MOS transistor externally available
P0.15	N-MOS_3	Gate of N-MOS transistor externally available
P0.16	N-MOS_4	Gate of N-MOS transistor externally available
P0.17	ADP_INT	PMIC interrupt line
P0.18	MCU_IF0	nRF52840 interface
P0.19	MCU_IF1	nRF52840 interface

I/O	Label	Description
P0.20	MCU_IF2	nRF52840 interface
P0.21	MCU_IF3	nRF52840 interface
P0.22	MCU_IF4	nRF52840 interface
P0.23	MCU_IF5	nRF52840 interface
P0.24	MCU_IF6	nRF52840 interface
P0.25	MCU_IF7	nRF52840 interface
P0.26	BUTTON	Button input
P0.27	BH_INT	Color sensor interrupt line
P0.28	BUZZER	Buzzer PWM signal
P0.29	LIGHTWELL_RED	Red color of the lightwell LEDs
P0.30	LIGHTWELL_GREEN	Green color of the lightwell LEDs
P0.31	LIGHTWELL_BLUE	Blue color of the lightwell LEDs

Table 3: nRF9160 pin map

I/O	Label	Description
P0.00	XL1	Low frequency crystal
P0.01	XL2	Low frequency crystal
P0.02	N.A.	Not used
P0.03	SPARE7	Analog/digital *GPIO* externally available
P0.04	N.A.	Not used
P0.05	SPARE2	Analog/digital *GPIO* externally available
P0.06	SPARE1	Digital *GPIO* externally available
P0.07	N.A.	Not used
P0.08	N.A.	Not used
P0.09	NFC1	*NFC* passive tag antenna
P0.10	NFC2	*NFC* passive tag antenna
P0.11	MCU_IF0	nRF9160 interface
P0.12	N.A.	Not used
P0.13	N.A.	Not used
P0.14	IF_SWD_IO	nRF9160 SWD interface data line
P0.15	MCU_IF1	nRF9160 interface
P0.16	N.A.	Not used
P0.17	IF_SWD_CTRL	nRF9160 SWD interface control
P0.18	RESET	nRF52840 reset line
P0.19	MCU_IF6	nRF9160 interface
P0.20	MCU_IF2	nRF9160 interface
P0.21	MCU_IF3	nRF9160 interface
P0.22	MCU_IF7	nRF9160 interface
P0.23	N.A.	Not used
P0.24	N.A.	Not used
P0.25	MCU_IF5	nRF9160 interface
P0.26	SPARE3	Digital *GPIO* externally available
P0.27	SPARE4	Digital *GPIO* externally available
P0.28	SPARE5	Digital *GPIO* externally available
P0.29	N.A.	Not used
P0.30	SPARE6	Analog/digital *GPIO* externally available
P0.31	N.A.	Not used
P1.00	MCU_IF4	nRF9160 interface
P1.01	COEX2	nRF9160 COEX interface

I/O	Label	Description
P1.02	N.A.	Not used
P1.03	N.A.	Not used
P1.04	COEX1	nRF9160 COEX interface
P1.05	IF_SWK_CLK	nRF9160 SWD interface clock line
P1.06	N.A.	Not used
P1.07	COEX0	nRF9160 COEX interface
P1.08	SDA	I^2C data line
P1.09	SCL	I^2C clock line
P1.10	N.A.	Not used
P1.11	SPARE8	Digital *GPIO* externally available
P1.12	N.A.	Not used
P1.13	BOOT	Boot button
P1.14	N.A.	Not used
P1.15	N.A.	Not used

Table 4: nRF52840 pin map

7.6 Motion sensors

Nordic Thingy:91 includes a low-power accelerometer and a high-G accelerometer.

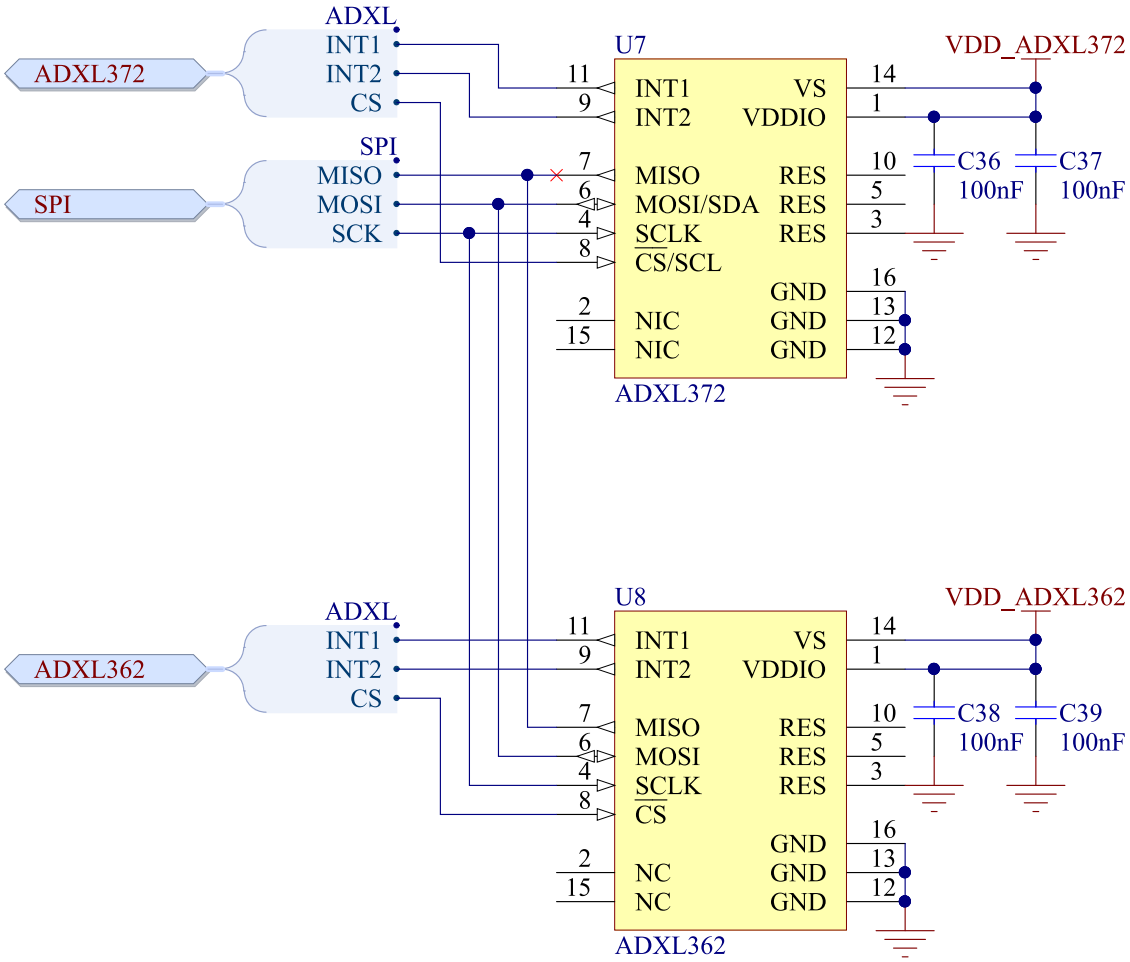


Figure 24: Low-power and high-G accelerometers schematic

When Nordic Thingy:91 is in low-power sleep mode, any user interaction will be detected by the low-power accelerometer. The accelerometer has an SPI interface and it can detect motion on three axes. By default, the INT2 line of the accelerometer is not connected to nRF9160. If you want to use the INT2 line, solder **SB6**.

For detecting shocks, Nordic Thingy:91 uses a high-G accelerometer. The accelerometer has an SPI interface, and it can detect motion on three axes. By default, the INT2 line of the accelerometer is not connected to nRF9160. If you want to use the INT2 line, solder **SB5**.

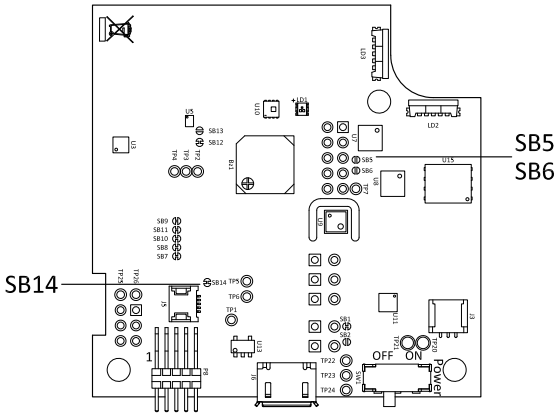


Figure 25: Low-power accelerometer and high-G accelerometer interrupt line 2 selection

Note: On Nordic Thingy:91 v1.4.0, by default, **P0.10** is connected to the nRF52_RESET line through **SB14**. The nRF52840 **P0.18** can be configured as a regular *GPIO* instead of RESET or **SB14** should be cut to avoid having the accelerometer reset nRF52840.

7.7 Environment sensors

To monitor its surroundings, Nordic Thingy:91 has a multi-sensor chip that contains several sensors for detecting different environmental properties and a separate color and light sensor.

The multi-sensor chip contains sensors for temperature, humidity, air quality, and air pressure.

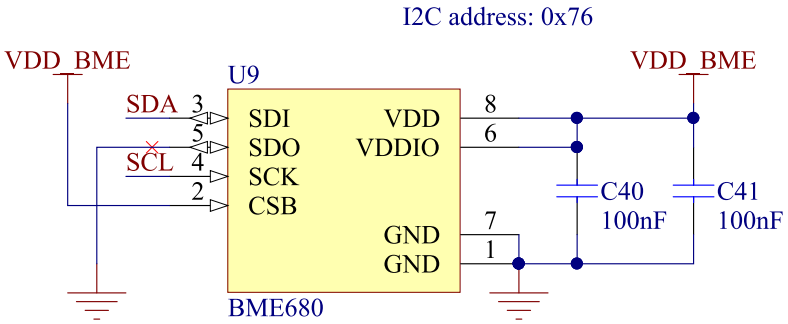


Figure 26: Environment sensor schematic

The color sensor onboard Nordic Thingy:91 senses red, green, blue, and infrared light. The sensor faces towards the blue transparent bottom case with light pipes guiding the light towards the sensor. To measure the color on a surface, the color sensor is accompanied with an RGB LED that can illuminate the surface enabling the color sensor to read the color of the reflected light. The color sensor is accessed through I^2C (slave address 0x38).

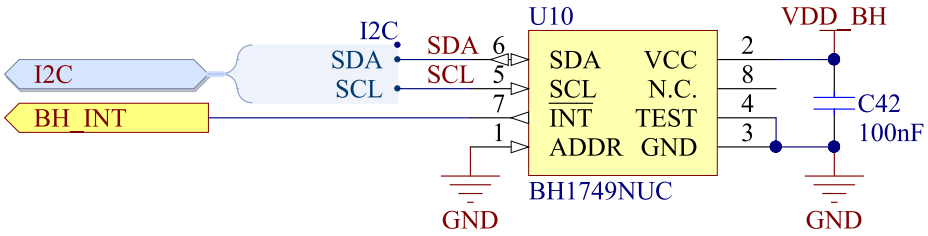


Figure 27: Color sensor schematic

7.8 EEPROM

To store important information off-chip, Nordic Thingy:91 is equipped with a 16-Kbit I^2C serial EEPROM (electrically erasable programmable read-only memory) as of version 1.4.0. The I^2C address is 0x50.

Information stored in region 0x0600 - 0x07FF is written during the production of Nordic Thingy:91. This is critical for the correct operation and should not be changed.

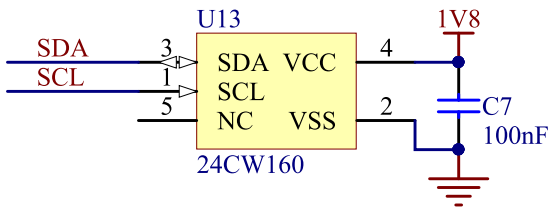


Figure 28: EEPROM schematic

7.9 Buzzer

For audio output, Nordic Thingy:91 has a magnetic buzzer. The buzzer is driven by a transistor using a PWM input.

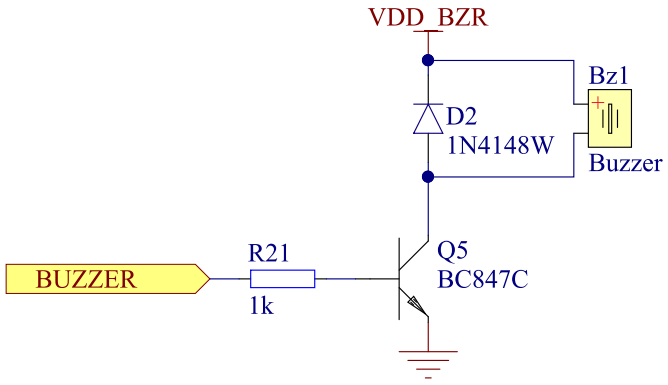


Figure 29: Buzzer schematic

7.10 LEDs and buttons

Nordic Thingy:91 user interface consists of RGB LEDs and two buttons.

7.10.1 RGB LED

Nordic Thingy:91 is equipped with three RGB LEDs.

Two of the LEDs are used to light up the light well and are controlled by the same signals using transistors as switches. The third LED is located near the color sensor and is used as auxiliary light for color measurements.

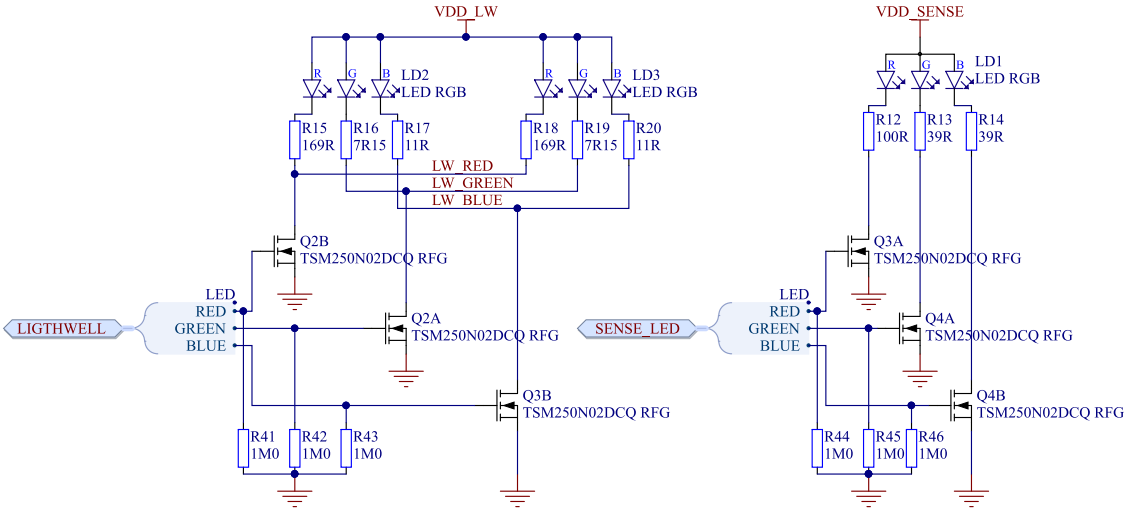


Figure 30: LED schematic

7.10.2 Buttons

Nordic Thingy:91 has two buttons.

The main button, located underneath the Nordic Semiconductor logo, is termed as the **SW3** button and it is used for user input. It is connected to the nRF9160 *SiP*. The second button, termed as **SW4**, is connected

to the nRF52840 *SoC*. It is accessible only when the rubber cover on the device is removed. Refer the image Figure 4: Inserting the SIM card on page 12 to locate the buttons.

Either of the two buttons, **SW3** or **SW4**, can be used to activate the serial recovery mode of Nordic Thingy:91 to update the nRF9160 *SiP* or the nRF52840 *SoC* respectively.

For more information, see Programming applications on Nordic Thingy:91 through USB (MCUboot).

7.11 Power supply

The main power source is a rechargeable lithium polymer (Li-Po) battery. The battery has a nominal capacity of 1400 mAh and can be recharged through *USB*.

Nordic Thingy:91 has a power switch that physically disconnects the battery and the *USB* power from the rest of the circuits. This switch must be on for Nordic Thingy:91 to work and charge the battery. When the power switch is in the OFF position, it activates a circuit that drains the 1.8 V power domain.

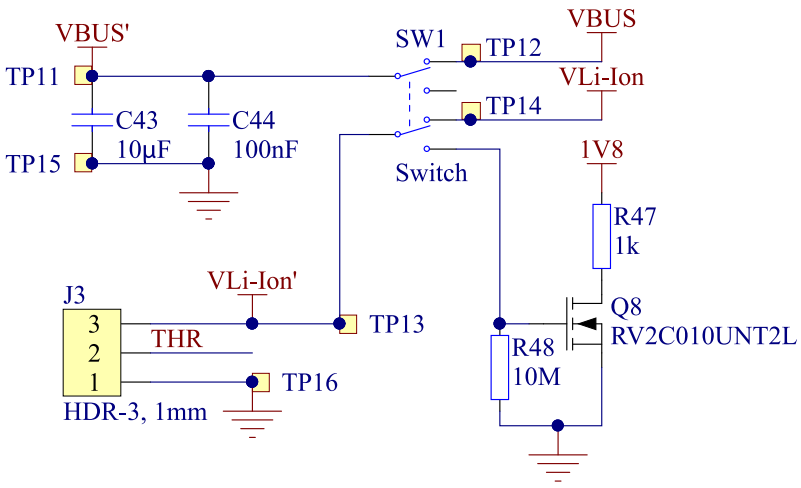


Figure 31: Schematics for battery connector, and the power switch

7.11.1 PMIC

Nordic Thingy:91 uses a power management IC (PMIC) as internal power management. The PMIC includes a battery charger, a fuel gauge and two regulator outputs.

The PMIC has three voltage domain outputs that are used on Nordic Thingy:91:

- VSYS used for the nRF9160 *SiP*
- One 1.8 V output used as *GPIO* voltage
- One 3.3 V output used for analog circuitry

The 1.8 V domain supplies the nRF52840, the accelerometers, the environment sensors, and the *GPIO*s of the nRF9160. This domain must always be on for Nordic Thingy:91 to work.

The 3.3 V domain supplies the LEDs, the color sensor, the buzzer, the RF switches and the *GPS LNA*. This power domain can be powered down to save power when Nordic Thingy:91 is in sleep mode.

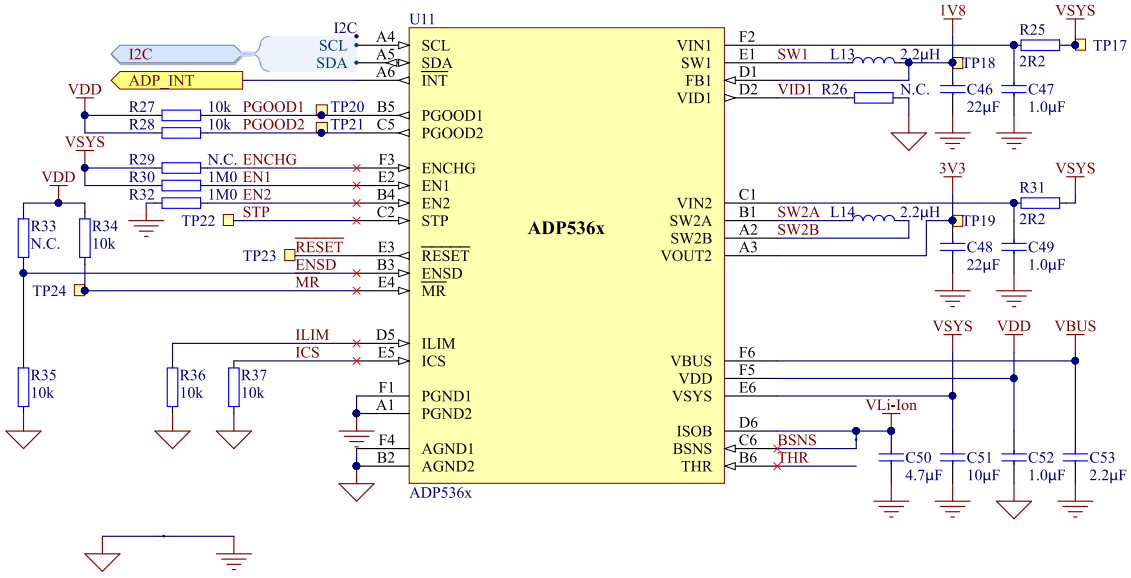


Figure 32: PMIC schematic

7.11.2 Current measurement

It is possible to measure the current flowing to nRF9160 and nRF52840 by cutting the short on SB3 (nRF9160) and/or SB4 (nRF52840) and placing an ampere meter between the terminals of **P1** (nRF9160) and terminals of **P2** (nRF52840).

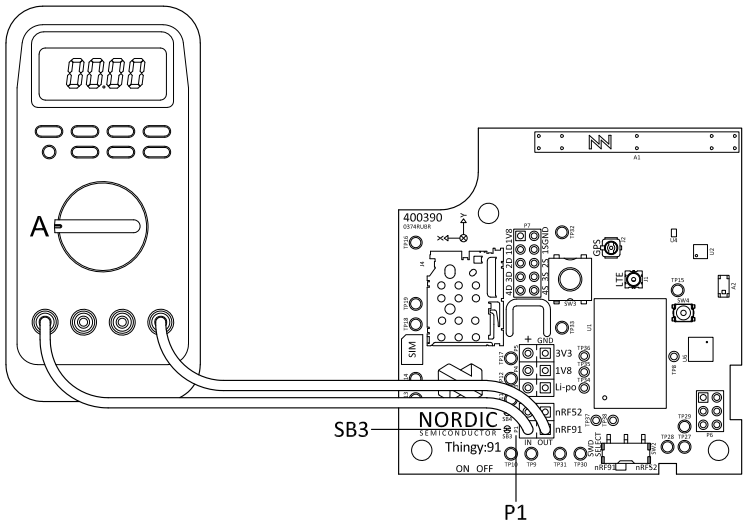


Figure 33: Measuring current to the nRF9160

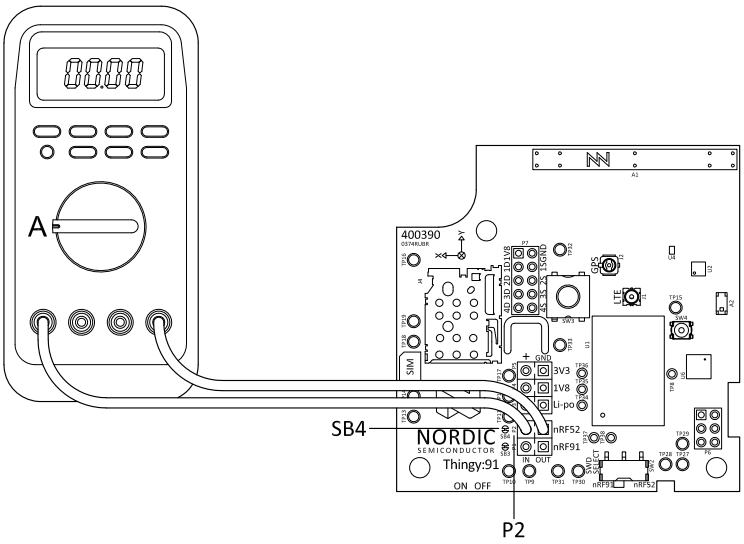


Figure 34: Measuring current to the nRF52840

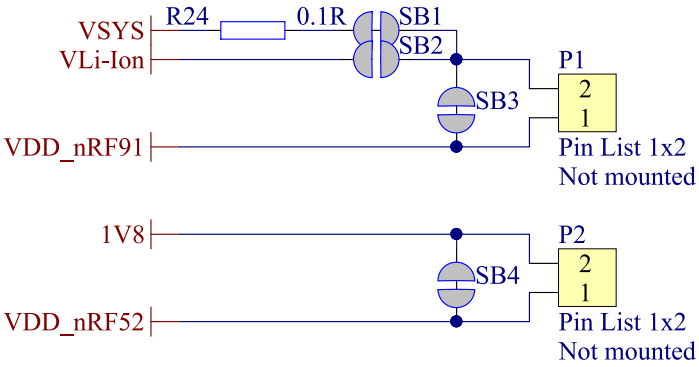


Figure 35: Current measurement schematic

7.12 Programming and debugging interface

Nordic Thingy:91 is equipped with one programming and debugging interface connector (P8) that is shared between the nRF9160 and nRF52840.

The device to be programmed is selected by the SWD SELECT switch (SW2). The selection of device can also be controlled by connecting TP28 to 1.8 V or ground.

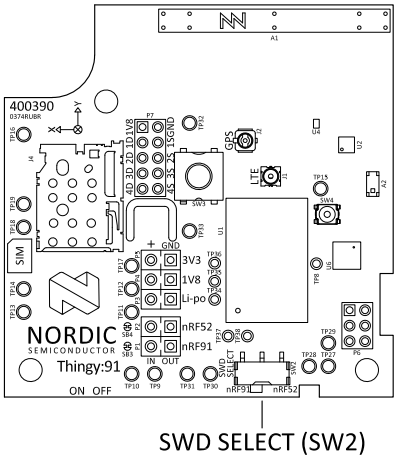


Figure 36: SWD SELECT switch

The SWD interface of the nRF9160 can also be connected to the nRF52840. The enabling of this connection is controlled by the nRF52840.

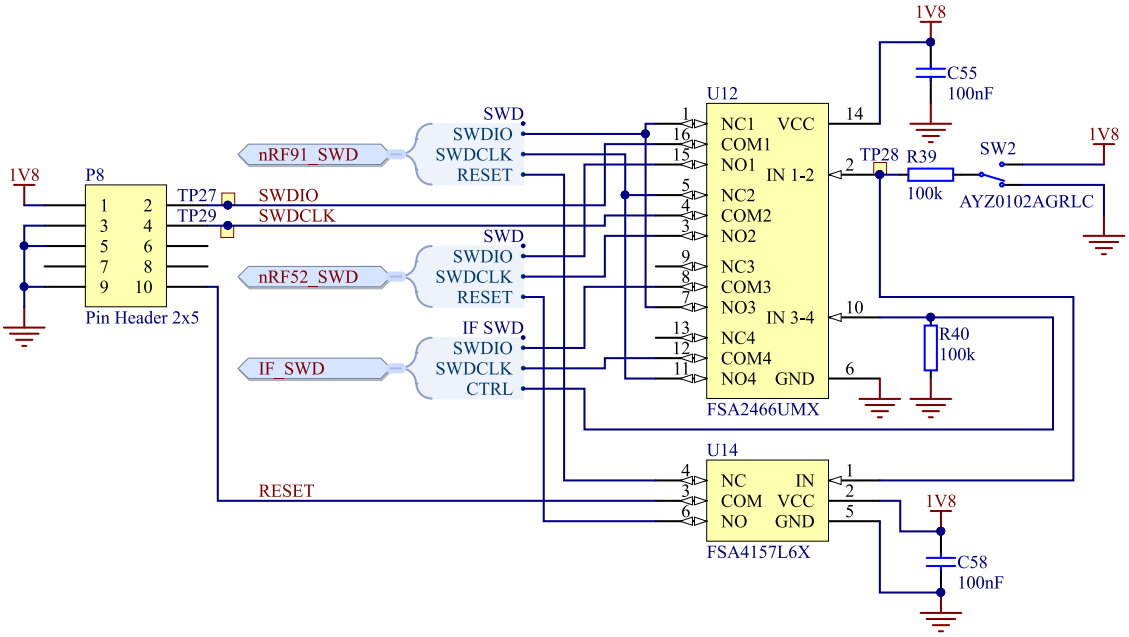


Figure 37: SWD interface and control schematic

7.13 Interface

To enable the user to connect external hardware, Nordic Thingy:91 routes some of the *GPIO*s to connectors or test points and transistors to drive higher currents.

7.13.1 N-MOS transistors

Nordic Thingy:91 is equipped with four N-MOS transistors that can be used to drive small DC motors or LEDs. The drain and source of the transistors are available on external connectors and the gate is connected directly to the nRF9160.

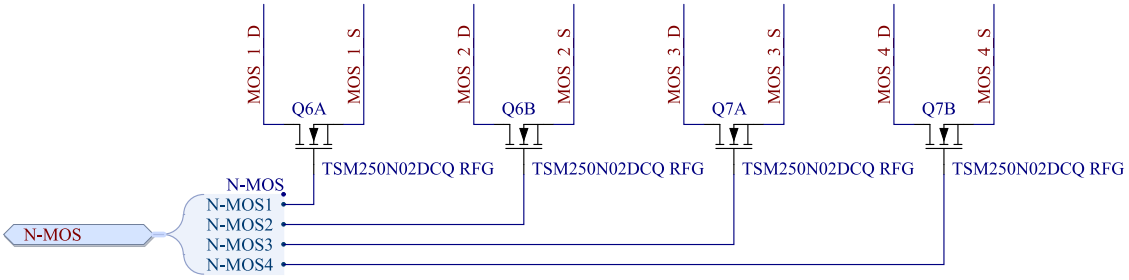


Figure 38: Schematics for the N-MOS transistors

7.13.2 Connectors

In addition to the N-MOS drain and source on **P7**, power domains and extra *GPIO*s can be found on connectors **P3**-**P6**.

For more information, see Connector pinouts on page 38.

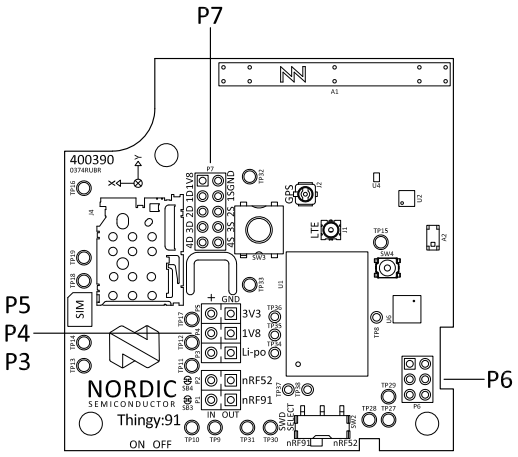


Figure 39: Nordic Thingy:91 external connectors

7.13.2.1 Connector pinouts

Pin	Signal	Description
1	GND	Ground
2	$V_{Li\text{-}Ion}$	Battery voltage

Table 5: Pinout of connector P3

Pin	Signal	Description
1	GND	Ground
2	1V8	Regulated 1.8 V domain

Table 6: Pinout of connector P4

Pin	Signal	Description
1	GND	Ground
2	3V3	Regulated 3.3 V domain

Table 7: Pinout of connector P5

Pin	Signal	Description
1	SPARE1	*GPIO* of the nRF52840
2	SPARE2	*GPIO* of the nRF52840
3	SPARE3	*GPIO* of the nRF52840
4	SPARE4	*GPIO* of the nRF52840
5	SPARE5	*GPIO* of the nRF52840
6	SPARE6	*GPIO* of the nRF52840

Table 8: Pinout of connector P6

Pin	Signal	Description
1	1V8	Regulated 1.8 V domain
2	GND	Ground
3	MOS_1_D	Drain of n-channel MOSFET 1
4	MOS_1_S	Source of n-channel MOSFET 1
5	MOS_2_D	Drain of n-channel MOSFET 2
6	MOS_2_S	Source of n-channel MOSFET 2
7	MOS_3_D	Drain of n-channel MOSFET 3
8	MOS_3_S	Source of n-channel MOSFET 3
9	MOS_4_D	Drain of n-channel MOSFET 4
10	MOS_4_S	Source of n-channel MOSFET 4

Table 9: Pinout of connector P7

7.13.3 Test points

Test point	Location	Signal	Description
TP1	Bottom	N.A.	Reserved
TP2	Bottom	RF_SW1	Bit 0 of RF switch control signals
TP3	Bottom	RF_SW2	Bit 1 of RF switch control signals
TP4	Bottom	RF_SW3	Bit 2 of RF switch control signals
TP5	Bottom	N.A.	Reserved
TP6	Bottom	N.A.	Reserved
TP7	Bottom	nRF91-P0.10	*GPIO* of the nRF9160
TP8	Top	nRF52-P0.18/RESET	*GPIO*/RESET of the nRF52840
TP9	Top	SCL	I^2C clock line
TP10	Top	SDA	I^2C data line
TP11	Top	VBUS'	USB voltage before power switch
TP12	Top	VBUS	USB voltage after power switch
TP13	Top	$V_{Li\text{-}Ion'}$	Battery voltage before power switch
TP14	Top	$V_{Li\text{-}Ion}$	Battery voltage after power switch
TP15	Top	GND	Ground
TP16	Top	GND	Ground
TP17	Top	VSYS	Internal power domain of PMIC and default nRF9160 power supply
TP18	Top	1V8	Regulated 1.8 V domain
TP19	Top	3V3	Regulated 3.3 V domain
TP20	Bottom	ADP_PGOOD1	PMIC output status indication pin 1
TP21	Bottom	ADP_PGOOD2	PMIC output status indication pin 2
TP22	Bottom	ADP_STP	Stop the buck regulator switching of PMIC
TP23	Bottom	ADP_RESET	PMIC reset output
TP24	Bottom	ADP_MR	PMIC manual reset input
TP25	Bottom	SPARE7	*GPIO* of the nRF52840
TP26	Bottom	SPARE8	*GPIO* of the nRF52840
TP27	Top	SWDIO	Programming interface data line
TP28	Top	SWDSEL	Programming interface target select
TP29	Top	SWDCLK	Programming interface clock line
TP30	Top	D-	USB data line
TP31	Top	D+	USB data line
TP32	Top	nRF91-P0.13/AIN0	Analog/digital *GPIO* of the nRF9160, combined with N-MOS1

Test point	Location	Signal	Description
TP33	Top	nRF91-P0.16/AIN3	Analog/digital *GPIO* of the nRF9160, combined with N-MOS4
TP34	Top	SCK	SPI clock line
TP35	Top	MOSI	SPI master output, slave input data line
TP36	Top	MISO	SPI master input, slave output data line
TP37	Top	ADXL372_CS	High-G accelerometer chip select line
TP38	Top	ADXL362_CS	Low-power accelerometer chip select line

Table 10: Pinout of connector P3

8 Regulatory notices

The following regulatory notices apply to Nordic Thingy:91.

8.1 FCC regulatory notices

Modification statement

Nordic Semiconductor ASA has not approved any changes or modifications to this device by the user. Any changes or modifications could void the user's authority to operate the equipment.

Interference statement

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

Wireless notice

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

FCC Class B digital device notice

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

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Glossary

Development Kit (DK)

A development platform used for application development.

International Mobile (Station) Equipment Identity (IMEI)

A unique code consisting of 14 digits and a check digit for identifying 3GPP-based mobile devices.

GPIO

General-Purpose Input/Output

Global Positioning System (GPS)

A satellite-based radio navigation system that provides its users with accurate location and time information over the globe.

Integrated Development Environment (IDE)

A software application that provides facilities for software development.

Low-Noise Amplifier (LNA)

In a radio receiving system, an electronic amplifier that amplifies a very low-power signal without significantly degrading its signal-to-noise ratio.

MCUboot

A secure bootloader for 32-bit microcontroller units, which is independent of hardware and operating system.

Near Field Communication (NFC)

A standards-based short-range wireless connectivity technology that enables two electronic devices to establish communication by bringing them close to each other.

nRF Connect for Cloud

Nordic Semiconductor's platform for connecting IoT devices to the cloud, viewing and analyzing device message data, prototyping ideas that use Nordic Semiconductor chips, and more. It includes a public REST API that can be used for building IoT solutions. See nRF Connect for Cloud (nrfcloud.com).

Personal Identification Number (PIN)

An optional security feature in mobile devices used for identifying a user. PIN is a numeric code which must be entered each time a mobile device is started.

Personal Unblocking Key (PUK)

A digit sequence required in 3GPP mobile phones to unlock a *SIM* that has disabled itself after an in correct personal identification number has been entered multiple times.

Software Development Kit (SDK)

A set of tools used for developing applications for a specific device or operating system.

SEGGER Embedded Studio (SES)

A cross-platform *IDE* for embedded C/C++ programming with support for Nordic Semiconductor devices, produced by SEGGER Microcontroller.

Subscriber Identity Module (SIM)

A card used in *User Equipment (UE)* containing data for subscriber identification.

System in Package (SiP)

A number of integrated circuits, often from different technologies, enclosed in a single module that performs as a system or subsystem.

System on Chip (SoC)

A microchip that integrates all the necessary electronic circuits and components of a computer or other electronic systems on a single integrated circuit.

User Equipment (UE)

Any device used by an end-user to communicate. The UE consists of the Mobile Equipment (ME) and the Universal Integrated Circuit Card (UICC).

Universal Integrated Circuit Card (UICC)

A new generation *SIM* used in *UE* for ensuring the integrity and security of personal data.

Universal Serial Bus (USB)

An industry standard that establishes specifications for cables and connectors and protocols for connection, communication, and power supply between computers, peripheral devices, and other computers.

Acronyms and abbreviations

These acronyms and abbreviations are used in this document.

DK
Development Kit

GPIO
General-Purpose Input/Output

GPS
Global Positioning System

IDE
Integrated Development Environment

IMEI
International Mobile (Station) Equipment Identity

LNA
Low-Noise Amplifier

NFC
Near Field Communication

PIN
Personal Identification Number

PUK
Personal Unblocking Key

SDK
Software Development Kit

SES
SEGGER Embedded Studio

SIM
Subscriber Identity Module

SiP
System in Package

SoC
System on Chip

USB
Universal Serial Bus

UICC
Universal Integrated Circuit Card

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