nRFready Smart Remote 3 for nRF51

User Guide

v1.2

Contents

Revision history

Date	Version	Description
July 2017	1.2	Updated: • Chapter Hardware description: Smart Remote 3 DK add-on on page 27
December 2016	1.1	Created PDF
December 2015	1.0	First release

Chapter 1
Introduction

The nRFready Smart Remote 3 reference design for the nRF51 Series (nRF6934) is a low-cost development platform providing a quick and easy starting point for TV remote control applications for Internet-enabled TVs, set-top boxes, and media players. Providing a single-chip solution that is easily implemented, this kit comes complete with source code and documentation for *Bluetooth*® low energy applications.

This reference design contains two remote controls, one for development and another for demo purposes.

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.

1.1 Smart Remote 3 DK add-on

The Smart Remote 3 DK add-on (nRF6932) is a board that allows you to connect to the nRF51 Development Kit (nRF51 DK, not included in this kit). Plugging the DK add-on onto the nRF51 DK gives you access to the radio components for developing your remote control design.

Based on the nRF51822 multiprotocol System on Chip (SoC), it is optimized for low-power and low-cost applications and leverages both *Bluetooth*® low energy and 2.4 GHz proprietary protocols.

> **Important:** The Smart Remote 3 DK add-on (nRF6932) v1.2 and later is compatible with both nRF51 and nRF52 development kits.

Features:

- Standard remote control keypad
- Motion wakeup detection using low-power accelerometer
- 3D motion tracking using gyroscope and InvenSense® motion library
- Multi-touch trackpad (supports up to five points of contact)
- Voice input using an analog electrostatic microphone (only nRF51)
- Voice input using two digital PDM microphones (only nRF52)
- Infrared LED for legacy support (only nRF52)
- Arduino standard interface for connection to the nRF5x Development Kit
- Optimized power management for low power consumption

1.2 Smart Remote 3 nRF51 product example

The Smart Remote 3 nRF51 product example (nRF6933) is a fully-designed remote control featuring an analog microphone input, a gyroscope, and a typical remote control keypad. It features a subset of the functionality of the Smart Remote 3 DK add-on, allowing the board to fit nicely into a remote control plastic housing.

Features:

- Standard remote control keypad

- Motion wakeup detection using low-power accelerometer
- 3D motion tracking using gyroscope and InvenSense® motion library
- Voice input using an analog electrostatic microphone
- Optimized power management for low power consumption
- Powered by two AA batteries
- SWD interface connector for programming and debugging

Chapter 2
Kit content

The nRFready Smart Remote 3 reference design consists of hardware and access to software components, reference design files, and documentation.

2.1 Hardware content

nRFready Smart Remote 3 reference design hardware consists of the DK add-on, product example, batteries and a *Bluetooth*® dongle.

Figure 1: nRFready Smart Remote 3 for nRF51 Series hardware content

2.2 Downloadable content

The nRFready Smart Remote 3 for nRF51 Series reference design includes firmware source code, documentation, hardware schematics, and layout files.

To access these files, go to the Smart Remote 3 for nRF51 web page and follow the instructions given there.

Firmware package

- Firmware for nRFready Smart Remote 3
  - Precompiled HEX files
  - Source code
- nRF51 SDK 9.0.0 (with Keil 5 Packs, and MDK packages for Keil 4 and IAR)
- Project files for Keil, ARM®, IAR and ARM GCC
- S110 SoftDevice
- Nordic Voice System (NVS) package version 4.4 (requires Ubuntu 14.04 LTS)
- Firmware documentation (will be available in a folder on your computer after you have run the installer file)

Hardware files

The zip file and its subdirectories contain the hardware design files for the nRFready Smart Remote 3 for nRF51 Series reference design.

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

Other relevant nRF51822 documentation

- nRF51 Series Reference Manual
- nRF51822 Product Specification
- S110 SoftDevice Specification
- nRF51822 PAN
- nRF51 SDK v9.0.0

Chapter 3
Quick start

Setting up the nRFready Smart Remote 3 reference design requires only a few steps. Example applications help you start programming your device.

Hardware requirements

Additional hardware needed to use the Smart Remote 3 DK add-on:

- nRF51 Development Kit (sold separately)

Operating system requirements

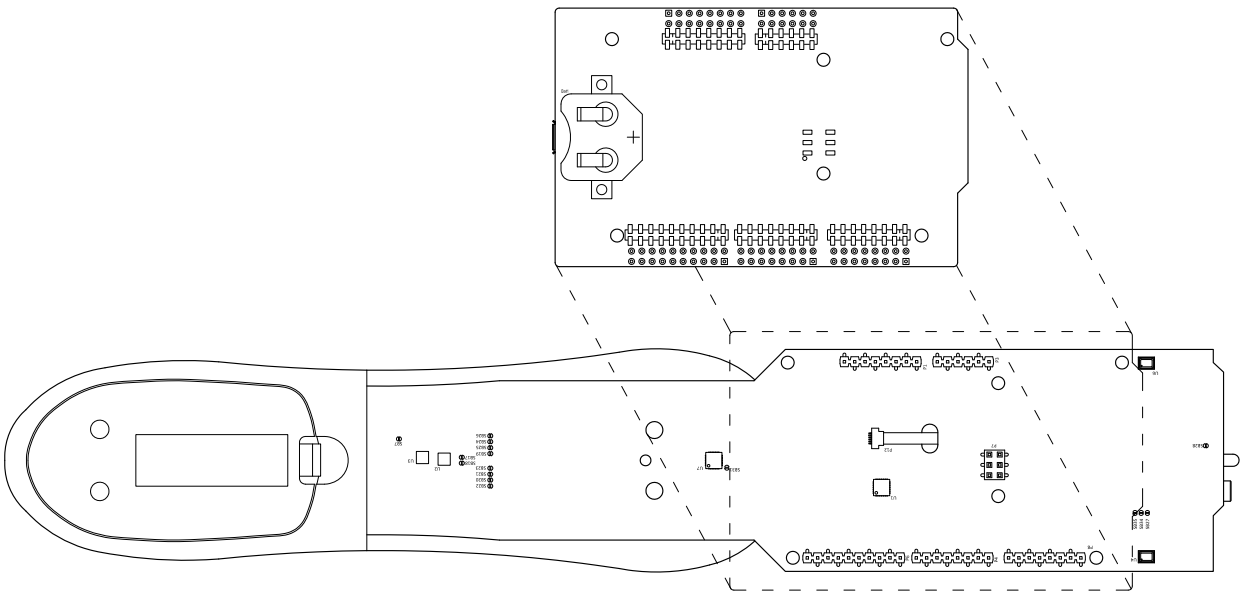
The nRFready Smart Remote 3 complies with the HID-over-GATT profile. The following is needed to set up a computer as the *Bluetooth*® low energy host.

- Basic use:
  - Windows 8, Windows RT, or Windows 10 for HID-over-GATT standard functions
  - Linux with *Bluetooth*® 4.0 support (for example BlueZ 5.0 or later)
- Use with audio:
  - Ubuntu 14.04 LTS with Nordic Voice System (NVS) package. See Ubuntu setup on page 12

3.1 Assemble the Smart Remote 3 hardware

Unpack the kit and connect the DK add-on to the nRF51 Development Kit.

1. Unpack your nRFready Smart Remote 3 for nRF51 Series reference design.
2. Plug the nRF51 Development Kit (sold separately) carefully in on the backside of the Smart Remote 3 DK add-on as shown in the figure.

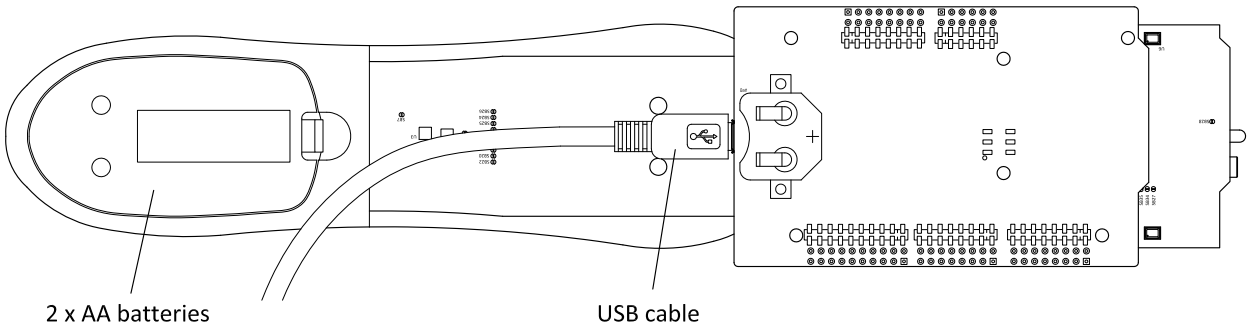


3.2 Power up

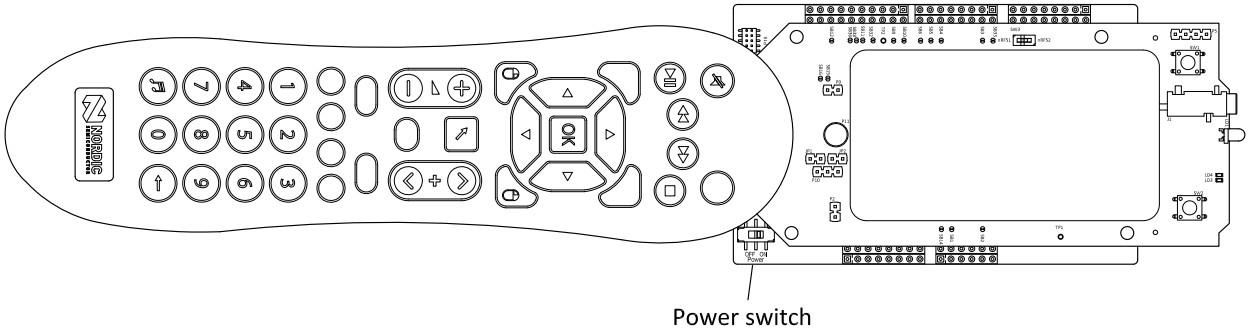
The Smart Remote 3 for nRF51 product example will be on as soon as the batteries are inserted. The DK add-on can be powered either by the USB or the batteries.

Powering up the add-on requires the following steps:

1. Plug in the USB cable or insert batteries into the battery compartment.



2. If powered by the USB, turn on the power with the power switch. If powered by the batteries it will be on as soon as the batteries are inserted.



3.3 Program your DK with the Smart Remote 3 firmware

To use the DK add-on, the nRF51 Development Kit must first be programmed with the firmware. The product example is preprogrammed, and does not need any programming to get started.

1. Connect the nRF51 DK with DK add-on attached to a computer with a USB cable.

   Important: When programming the DK for the first time, it is recommended not to connect the DK add-on hardware, as the DK I/Os are in an unknown state, which may result in overcurrent consumption.

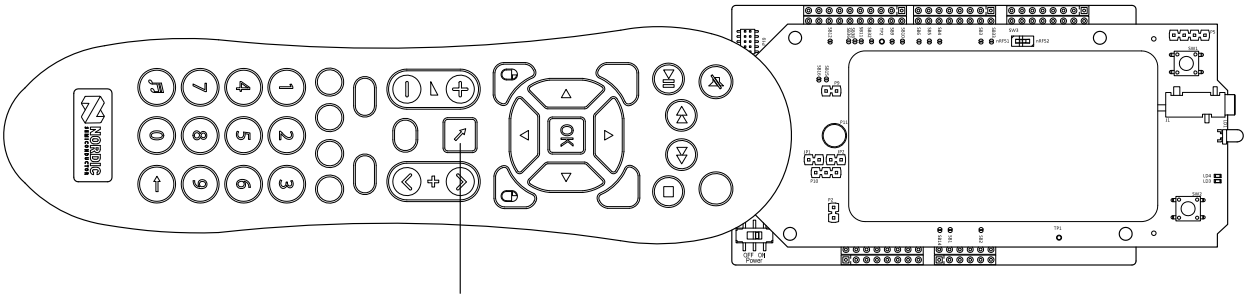
2. See Firmware update of Smart Remote 3 on page 54 for details on firmware update.

3.4 Turn on and pair with Windows

The Smart Remote 3 for nRF51 can be connected with *Bluetooth*® to a host system using Windows.

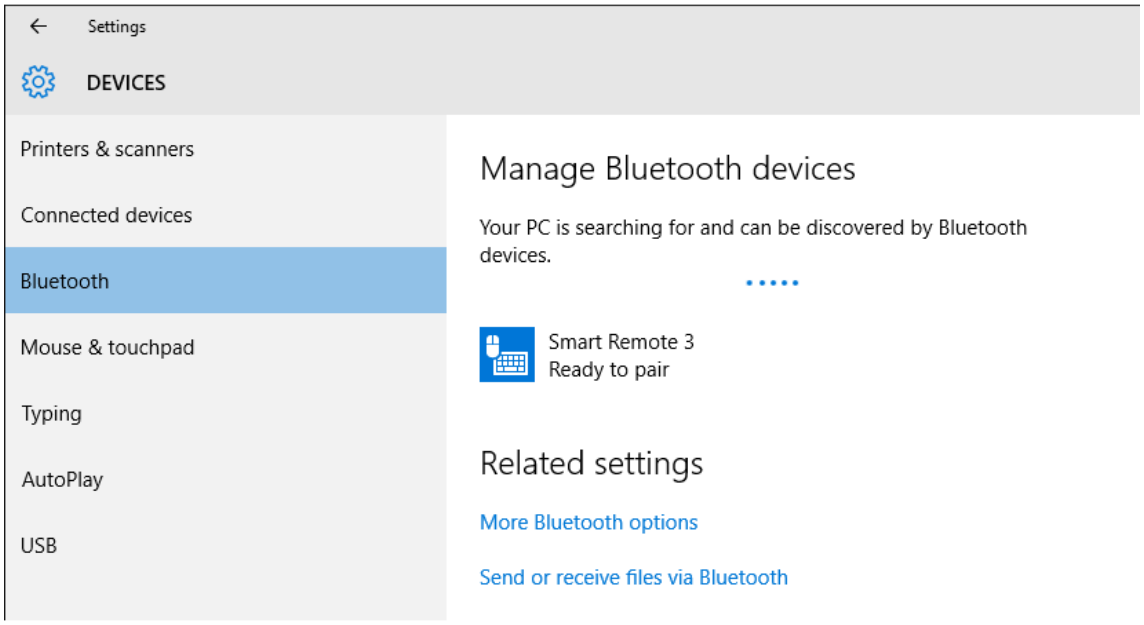
nRFready Smart Remote will only pair and work with *Bluetooth*® 4.0 or later, and HID-over-GATT-compliant host systems. The nRFready Smart Remote 3 functionality will vary depending on the supported features in these platforms.

1. If your computer is not *Bluetooth*® 4.0 enabled, insert the *Bluetooth*® dongle (supplied) into your computer and wait until the dongle is recognized and the drivers installed properly.
2. Power up the board either by inserting batteries into the battery compartment or by sliding the **power switch** on the DK to **ON** position (DK add-on only).
3. Pairing mode is automatically selected if Smart Remote 3 was not bound to a previous host. To delete existing bonds and to enter into pairing mode, power up Smart Remote 3 while pressing the orange button between the **Channel +** and **Volume +** buttons.

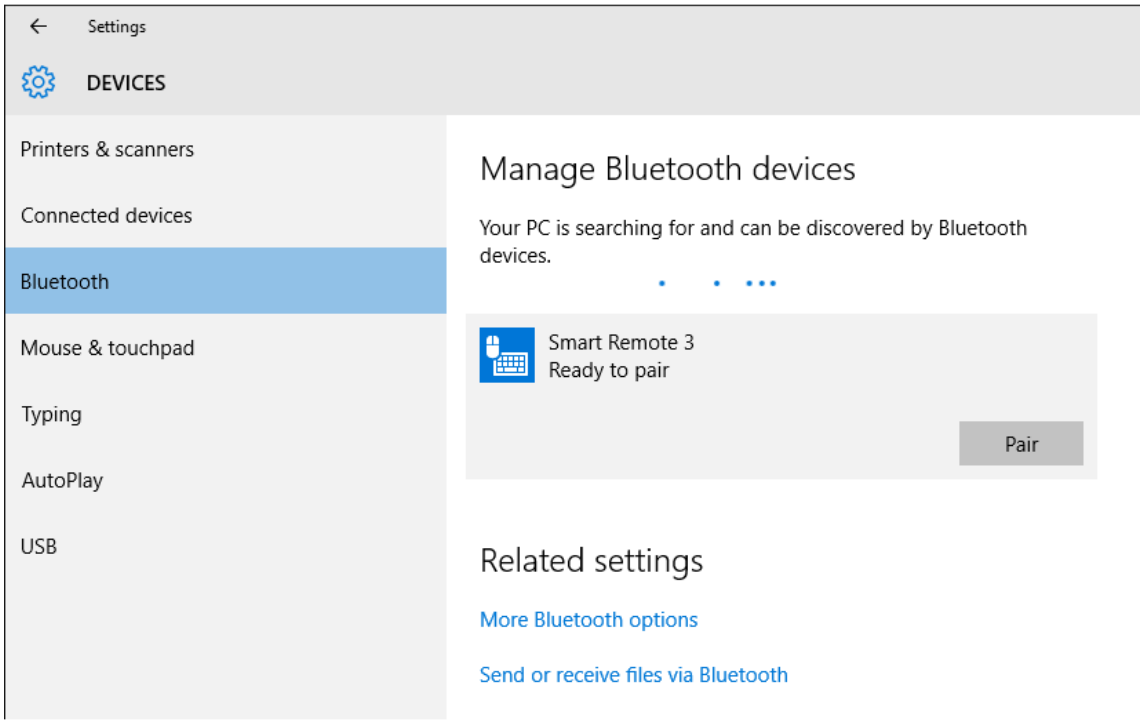


To delete existing bonds and enter pairing mode, hold button while powering up

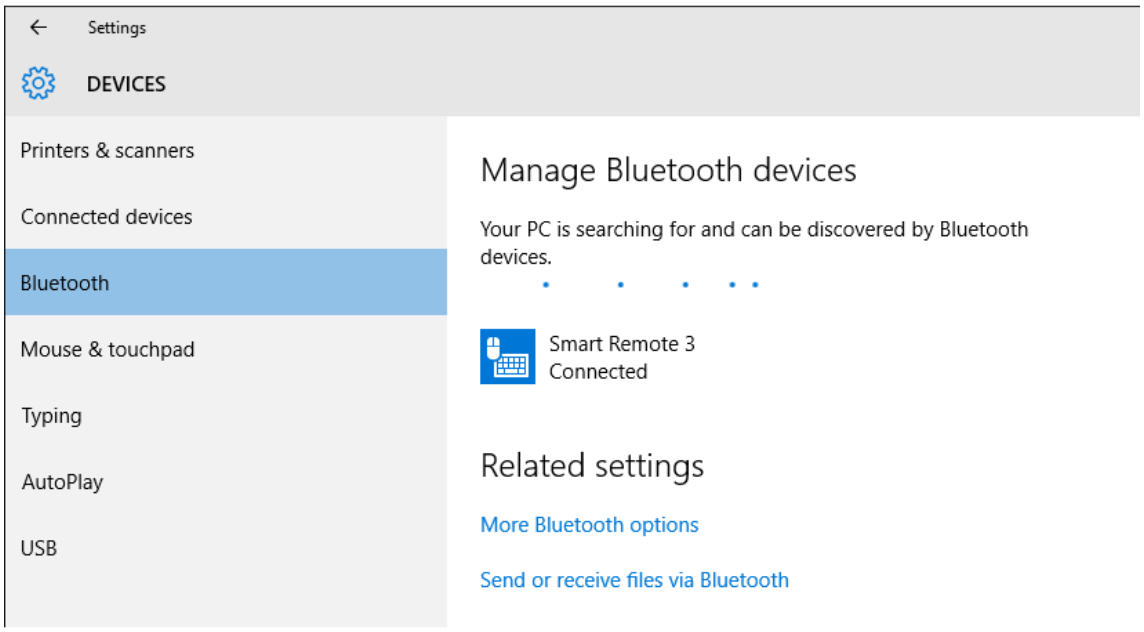
4. On your computer, navigate to the **Bluetooth** menu (press the **Windows** key or open the **Start** menu and type `Bluetooth`).



5. When discovered, you will see Smart Remote 3 in the list over Bluetooth devices. Select it and click **Pair** to begin pairing.



6. After successfully pairing, the device will show up as connected in the list of Bluetooth devices.



3.5 Ubuntu setup

Ubuntu LTS has no native support for HID-over-GATT, and therefore you have to first install the Nordic Voice System (NVS) package to support the HID-over-GATT profile.

1. Download the NVS package `nvs-4.4.tgz` from the Smart Remote 3 for nRF51 start page.
2. Open a terminal (**CTRL + ALT + T**).

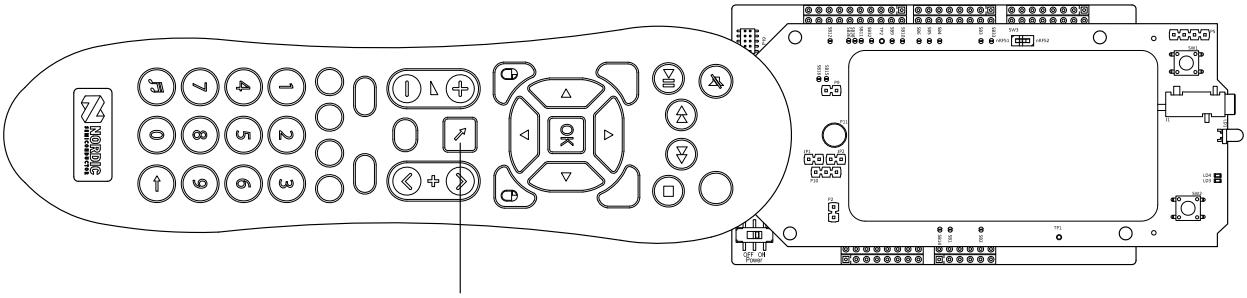
3. Navigate to the folder where `nvs-4.4.tgz` is located.
4. Unpack the `nvs-4.4.tgz` file by typing `tar -xf nvs-4.4.tgz`.
5. Open the file `nvs-4.4/binaries/HOWTO-install.txt` and follow the steps there to complete the installation.

3.6 Turn on and pair with Ubuntu

The Smart Remote 3 for nRF51 can be connected with *Bluetooth*® to a host system using Ubuntu.

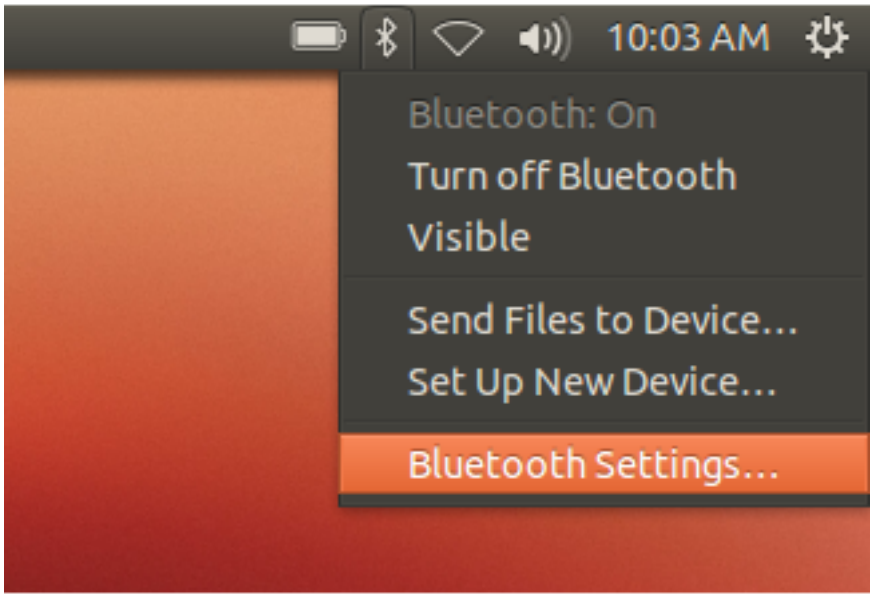
Make sure that you have set up Ubuntu as described in Ubuntu setup on page 12 before you start.

1. If your computer is not *Bluetooth*® 4.0 enabled, insert the *Bluetooth*® dongle (supplied) into your computer and wait until the dongle is recognized and the drivers installed properly.
2. Power up the board, either by inserting batteries into the battery compartment, or by sliding the **power switch** on the DK to ON position (DK add-on only).
3. Pairing mode is automatically selected if the Smart Remote 3 was not bound to a previous host. To delete existing bonds and enter pairing mode, power up the Smart Remote 3 while pressing the orange button between between the **Channel +** and **Volume +** buttons.

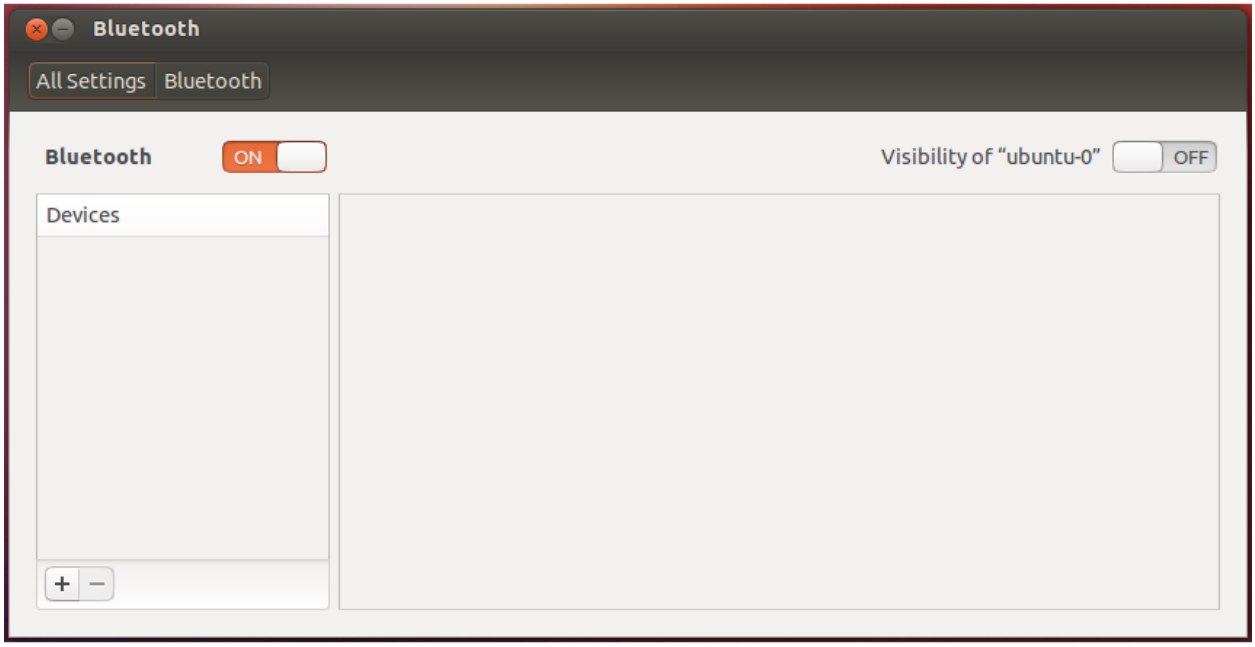


To delete existing bonds and enter pairing mode, hold button while powering up

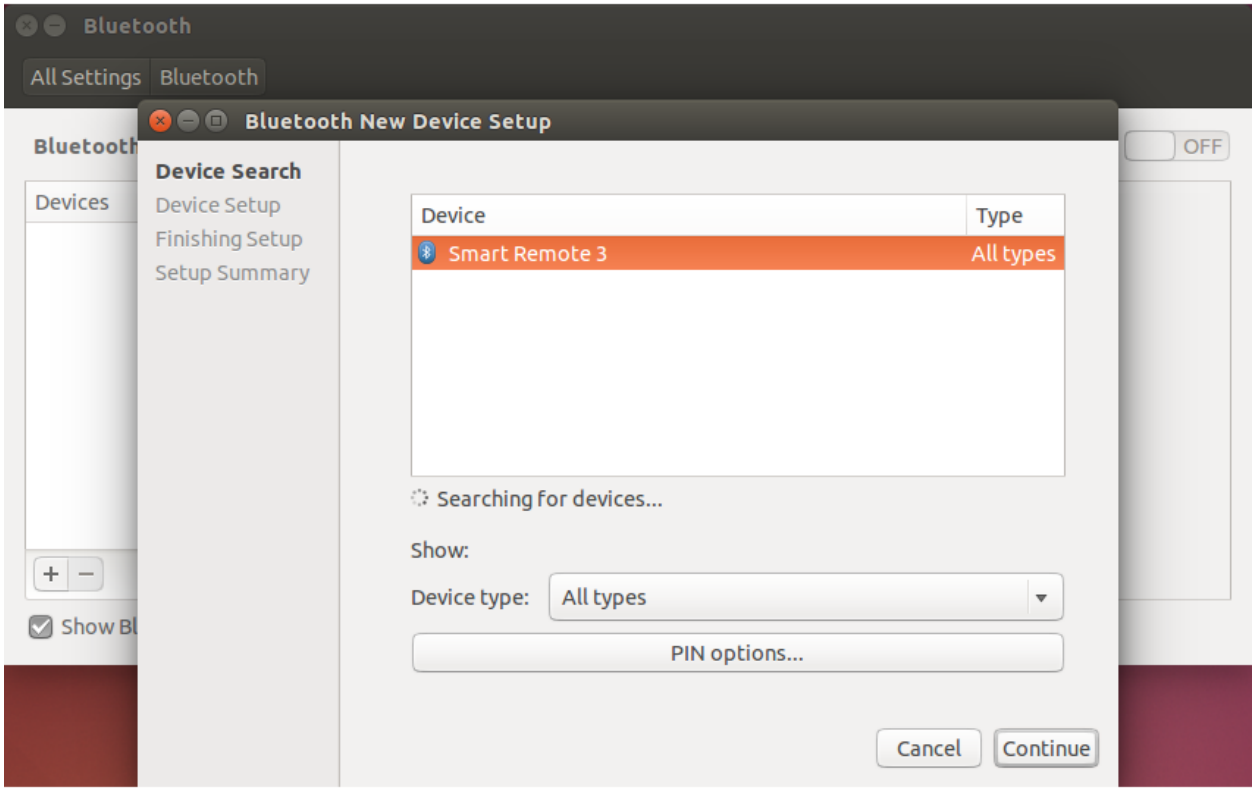
4. On your computer, navigate to the **Bluetooth** icon and select **Bluetooth Settings**.



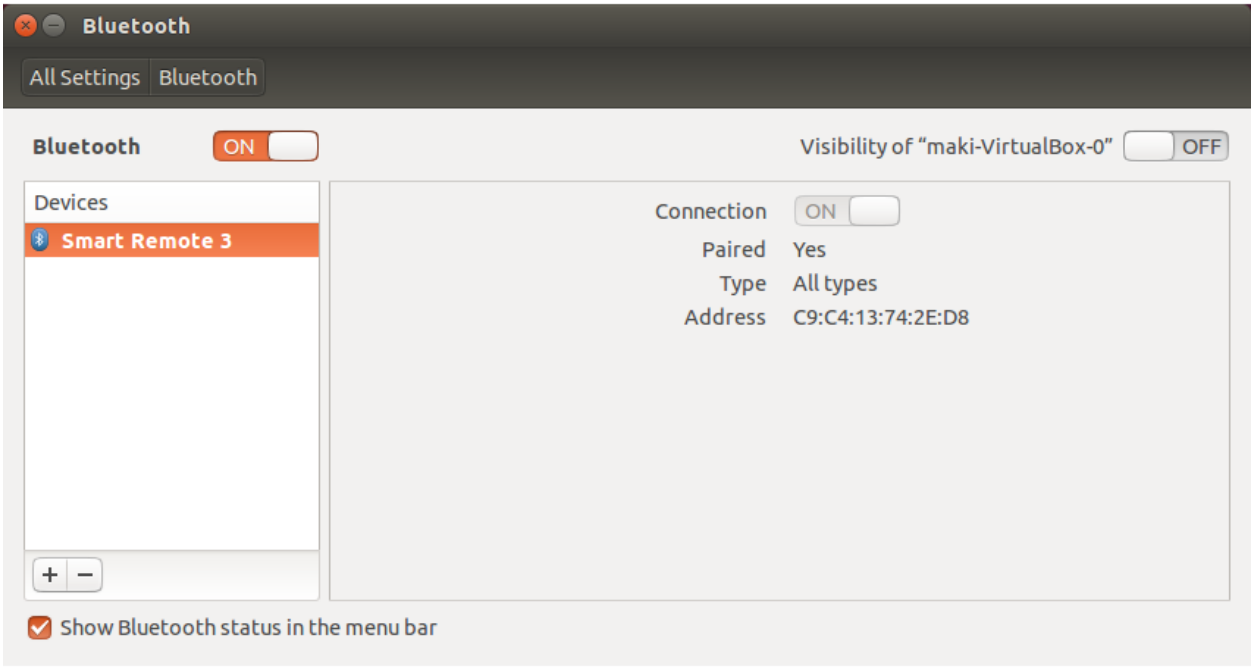
5. To search for a new device, click the **+** button in the **Bluetooth** window.



6. When discovered, you will see Smart Remote 3 in the **Device** list. Select it and click **Continue** to begin pairing.



7. After successfully pairing, the device will show up connected in the **Devices** list.

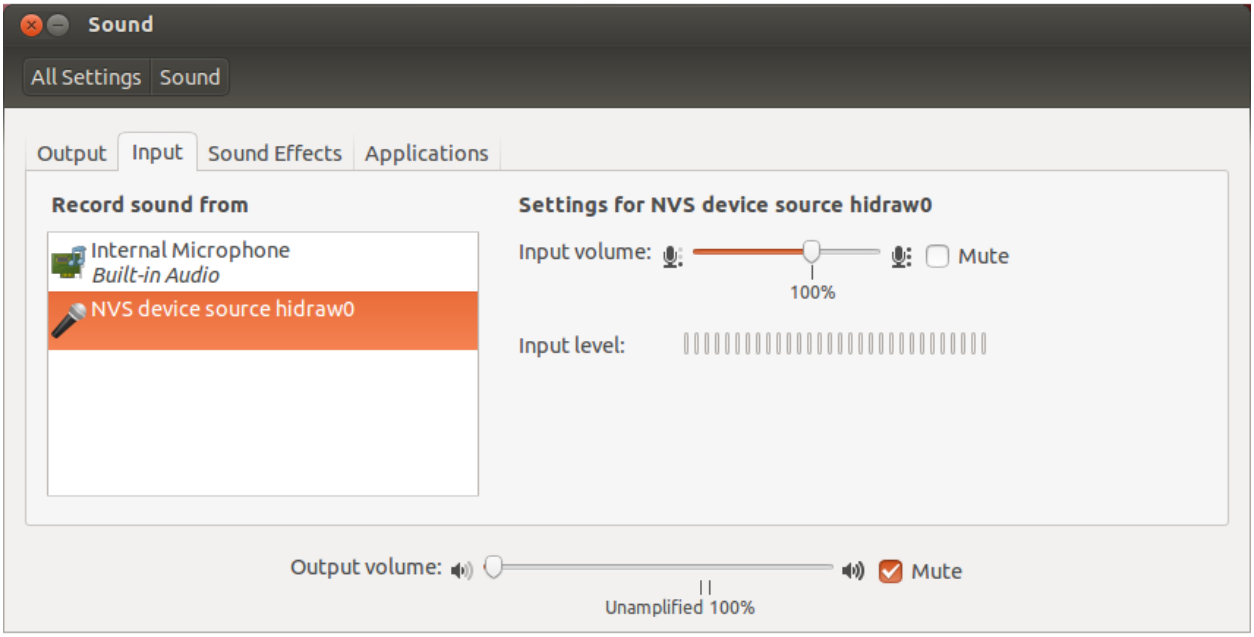


3.7 Configure audio input

The Ubuntu audio settings need to be configured before voice recognition will work.

Before you start, make sure that you have set up Ubuntu as described in Ubuntu setup on page 12.

1. Under **All Settings**, select **Sound** and then select the **Input** tab.
2. Select the **NVS device** from the list of input sources.
   Input level should now indicate that it is receiving input.

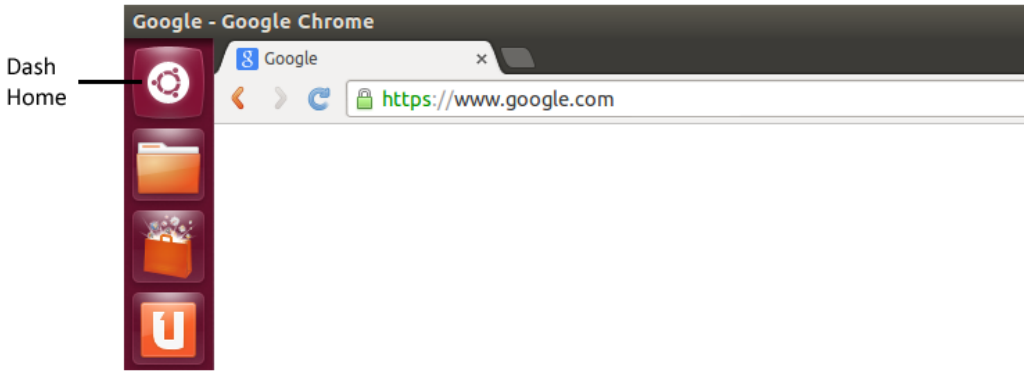


3. To stop streaming, select **All Settings** or close the window.

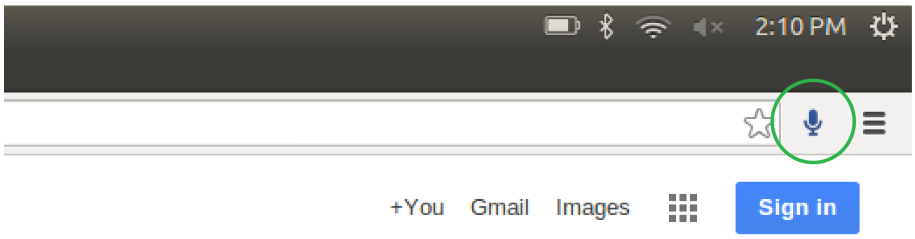
3.7.1 Test voice recognition

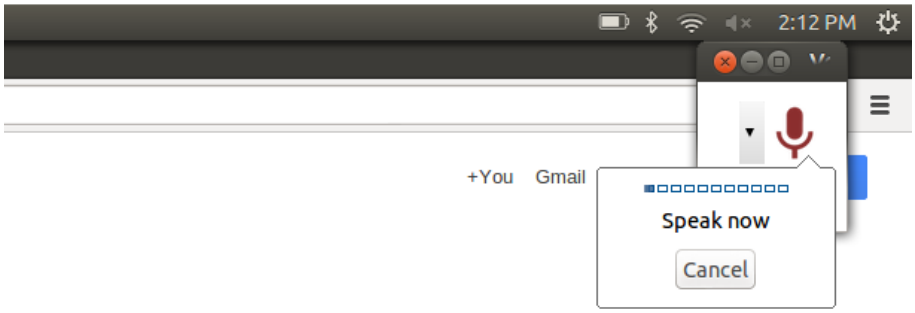
To test the voice recognition feature, download and install Google Chrome.

1. Open up Chrome. Select **Dash Home** and type `Google Chrome`. Click the **Google Chrome** icon that is displayed.



2. Go to google.com. If you are redirected to a local Google version, click **Google.com** in the lower-right corner of the webpage.
3. Click the **microphone** icon. Chrome will stop recording automatically when you stop talking. If you do not see the microphone icon, the GVoice application might not be installed. Go to the Google Chrome Web Store to download and install GVoice.





3.7.2 Listening to audio quality

Audio quality can be verified by looping the sound directly from the Ubuntu input source (Voice Input Module) to the output (speakers).

1. To enable loopback, open a terminal (**CTRL + ALT + T**).
2. In the terminal window, type the following command:

   ```
   pactl load-module module-loopback latency_msec=20
   ```

   The command `latency_msec=20` is optional. It helps to minimize the acoustic feedback. Some machines do not accept the command and may return error codes. In that case, just invoke module-loopback without specifying latency.
3. If successful, this command returns a handle number. Invoking this command multiple times generates multiple loopback instances with independent handles.
4. To disable the loopback, type the following command in the terminal window:

   ```
   pactl unload-module x
   ```

   where x is the handle module number returned when enabling the loopback.

   If Smart Remote 3 is not connected and selected as the audio input source, sound will be streamed from the computer microphone to the computer speakers causing acoustic feedback.

Chapter 4
System overview

This chapter describes the functionality of the remote control including how it can be used for development purposes.

There are two main hardware components in the reference design:

- nRFready Smart Remote 3 DK add-on (nRF6932)
- nRFready Smart Remote 3 nRF51 product example (nRF6933)

When the Smart Remote 3 DK add-on (nRF6932) is inserted into a nRF51 DK, you have a functioning remote control (see Assemble the Smart Remote 3 hardware on page 9 for instructions). The term remote control refers to the Smart Remote 3 product example (nRF6933) or Smart Remote 3 DK add-on (nRF6932) after it is inserted into the nRF51 DK.

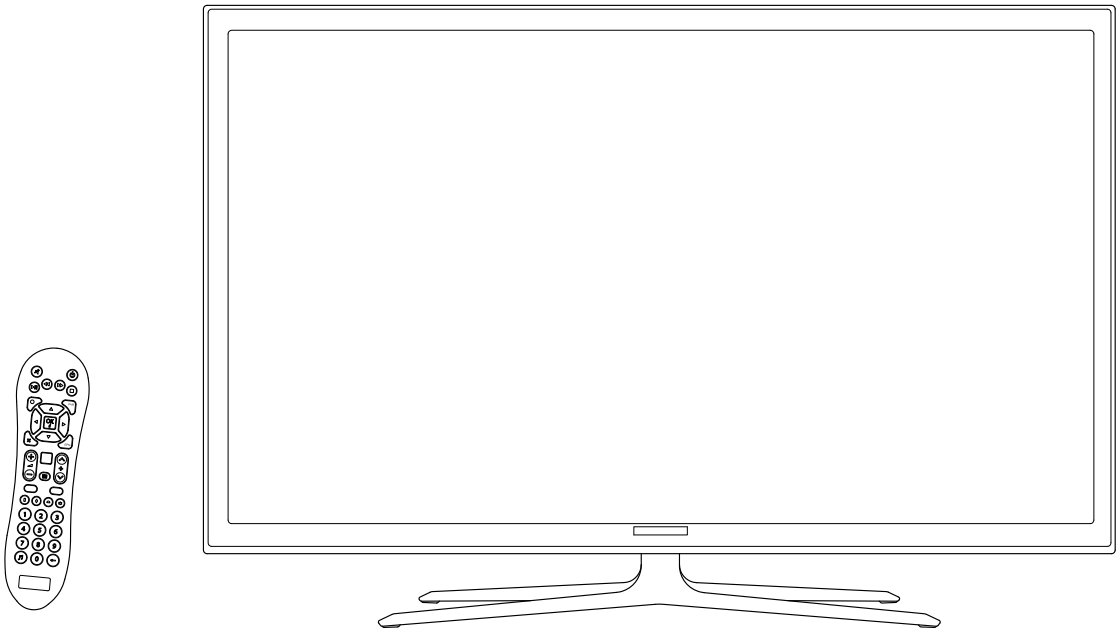


Figure 2: The remote control with a connected TV

Communication in the system is digital and packet-based, which means that data between the remote control and the host is exchanged as discrete packets of information. The nRF device checks the status of the trackpad and the keypad matrix before sending this information to the host. The driver on the computer decodes the packages allowing you to use the remote control as both a pointing device and keypad.

> **Important:** The term host refers to a *Bluetooth*® low energy compliant device which supports the HID-over-GATT profile. Windows 10, for instance, natively supports the HID-over-GATT profile provided there is *Bluetooth*® low energy hardware connected to the system. A computer with Ubuntu 14.04 LTS, Nordic Voice System (NVS) package and *Bluetooth*® 4.0 dual-mode (low energy) hardware can also be a host.

For further details on the software and firmware included, please consult the firmware documentation, code API, or the code itself.

4.1 Remote control

The flexibility of the remote control allows you to experiment with your own firmware and functionality. After pairing, the trackpad, accelerometer, and free-space navigation can be enabled and calibrated.

> **Important:** Gyroscope calibration is performed automatically the first time the firmware is run on the hardware.

4.1.1 Pairing

When the remote control is turned on, it will attempt to connect to a bonded *Bluetooth*® low energy compatible master if bonds are available. Otherwise it will be in pairing mode and will wait for connection from host.

The Smart Remote 3 features the HID-over-GATT profile and can connect to any *Bluetooth*® low energy host system supporting this profile. The HID-over-GATT profile is a direct mapping from the USB HID standard. In addition to controlling how the HID data is transferred through the wireless link, the profile requires the use of *Bluetooth*® device security. Security and data encryption are handled by the *Bluetooth*® Security Manager, which is a *Bluetooth*® protocol layer handled by nRF51822. On the master side of the *Bluetooth*® link, the Security Manager is handled in the *Bluetooth*® driver stack.

If no bonds are stored in flash, the remote control will start to advertise to Smart Ready devices for pairing when it is turned on. When Smart Remote 3 is in this advertising state, the *Bluetooth*® host platform should be instructed to start scanning for and then to connect to it. During this initial connection an encrypted link is configured by nRF51822 and the host transmits HID commands to the Smart Remote 3 according to the HID-over-GATT profile.

The remote control will stay in bond mode for 180 seconds waiting for a *Bluetooth*® connection. If no connection is established, the remote control will enter deep sleep. Bonding mode will be resumed upon user activity.

Although the specifics of the pairing process may differ between platforms, the main steps remain the same.

1. Scan for Smart Remote 3.
2. Connect to Smart Remote 3.
3. Bond/pair with Smart Remote 3.

Read more about *Bluetooth*® low energy and HID- over-GATT at developer.bluetooth.org.

4.1.2 Trackpad

The trackpad has five-point multi-touch functionality and advanced gesture recognition, making it a versatile interface device for the remote control.

The trackpad is a Synaptics® ClickPad. It is identified as a standard mouse by your computer and does not require any special software application to work.

Basic use

To use the trackpad, place one of your fingers on the surface of the pad as shown in Figure 3: One-finger movement on page 20. As you move your finger along the trackpad surface, you should see the mouse cursor on your computer screen moving according to the movement of your finger.

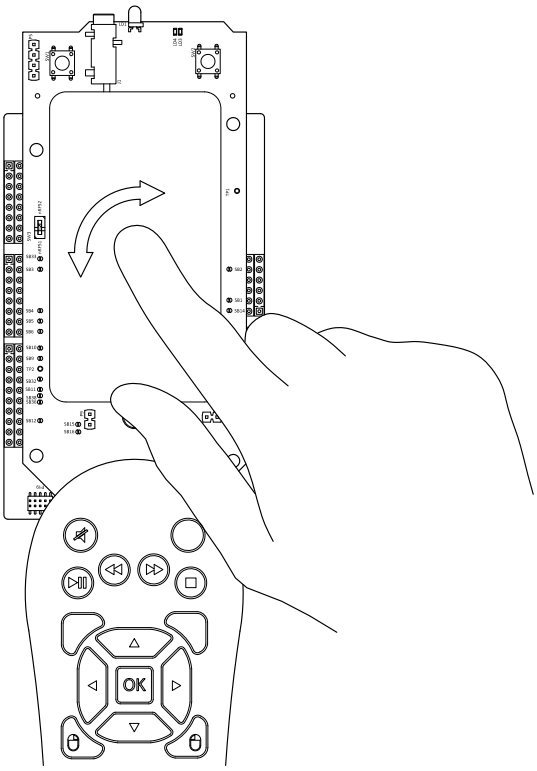


Figure 3: One-finger movement

To perform the equivalent to a left-click on your mouse, you can either press down the left side of the trackpad until you feel a button-like click, or tap the surface of the trackpad anywhere with your finger.

Common gestures

Figure 4: Two-finger horizontal scroll on page 21 and Figure 5: Two-finger vertical scroll on page 21 depict trackpad gestures that can be performed.

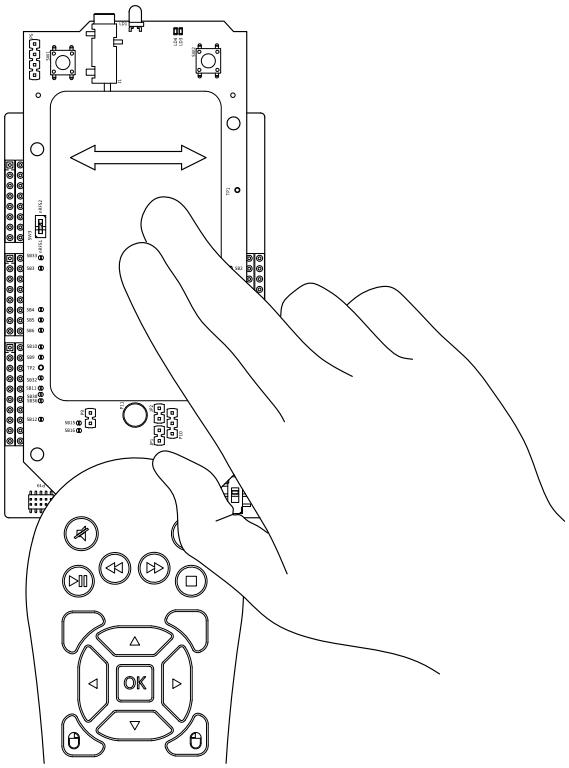


Figure 4: Two-finger horizontal scroll

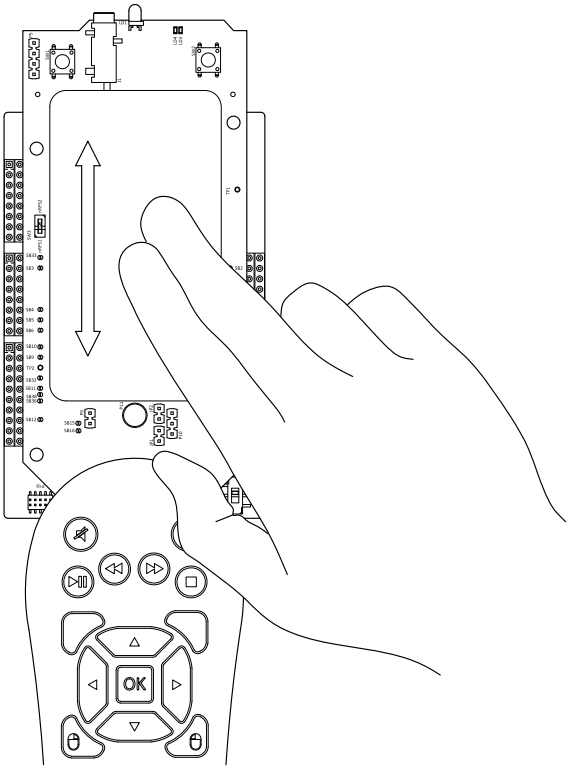


Figure 5: Two-finger vertical scroll

4.1.3 Accelerometer

When the remote control is in low-power sleep mode, any user interaction will be detected by the accelerometer, which will then wake up the remote control.

The LIS3DH three-axis ultra-low-power accelerometer from ST Microelectronics is used to detect user interaction and wake up the MCU, which in turn wakes up the rest of the system. This provides intelligent power-saving (see Intelligent power saving on page 24).

4.1.4 Free-space navigation

The remote control includes a powerful three-axis gyroscope and three-axis accelerometer combo circuit that can be used as a free-space navigation sensor, enabling the user to move a mouse cursor through gesturing with the remote control.

The gyroscope and accelerometer combo circuit is the ICM-20608 from InvenSense®. The gyro and accelerometer circuit is used as an input device for a SmartMotion® firmware library from InvenSense that is integrated into the Smart Remote 3 firmware. Output data from the InvenSense library is fitted into a HID mouse report and sent to the host.

> **Important:** The in-air pointing functionality is only provided as precompiled HEX files. To use the SmartMotion library in your design, please contact InvenSense® or visit the InvenSense® Developers Corner (sign up required).

Basic use

To enable the free-space navigation mode, press the orange button between the **Channel +** and **Volume +** buttons shown in Figure 6: Enabling free-space navigation mode on page 22. The remote control will then switch from trackpad to free-space navigation mode. In this mode, acceleration and rotational data from the gyro is processed by the SmartMotion firmware library.

When operating in the free-space navigation mode, use the **Left mouse** button and **Right mouse** button for point-and-click functionality.

To deactivate the free-space mode and go back to the trackpad mode, press the orange button again. The free-space navigation mode will also be deactivated if the remote control has not moved in seven seconds.

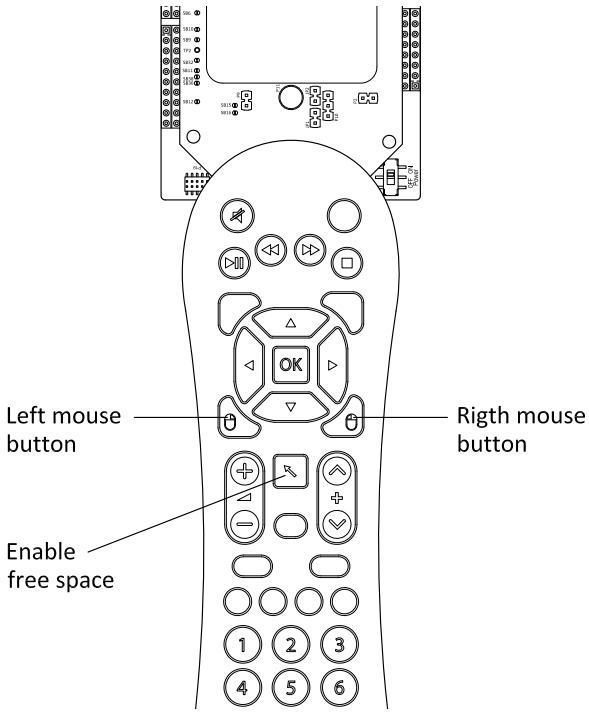


Figure 6: Enabling free-space navigation mode

Movement of the remote control is translated into two-dimensional mouse cursor movement. Rotation around the x-axis (upward and downward movements) of the remote control will lead to vertical mouse

cursor movement and rotation around the z-axis (side to side movements) will lead to horizontal mouse cursor movement. See Figure 7: Coordinate system for free-space movement on page 23 as reference.

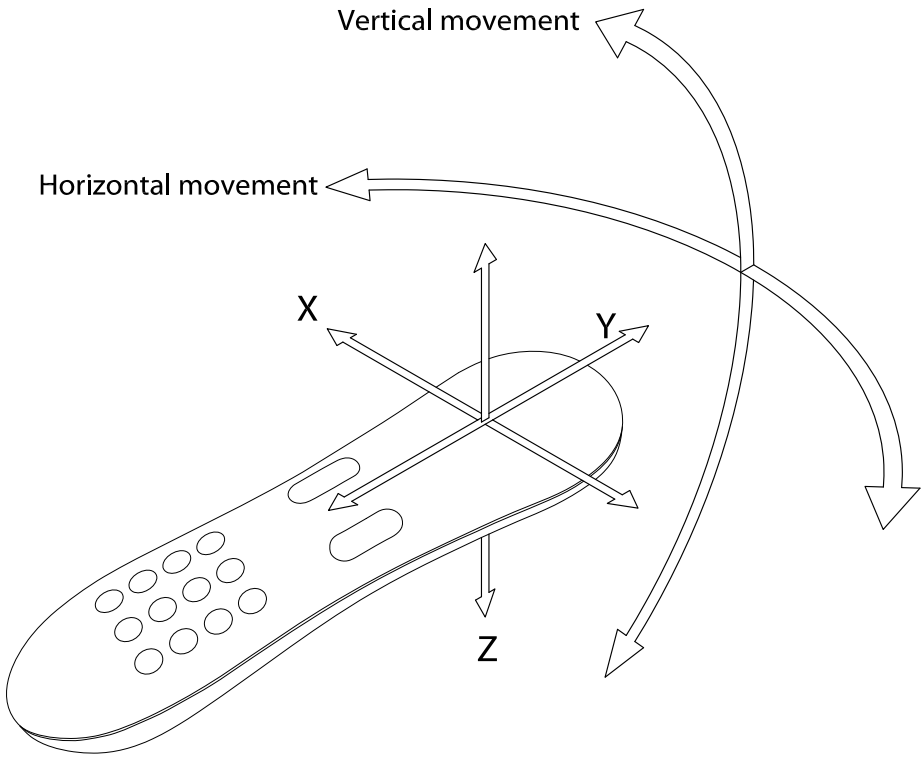


Figure 7: Coordinate system for free-space movement

Trackpad functionality in free-space mode

Once free-space navigation mode is enabled, the trackpad functionality changes. Moving a finger on the trackpad does not cause the cursor to move, but results in a “scroll” motion (similar to the scroll wheel on a mouse). Vertical movement on the trackpad causes vertical scroll while horizontal movement results in horizontal scroll motion. This is illustrated in Figure 8: Trackpad functionality in free-space mode on page 24.

Tapping or clicking the trackpad results in left-click gestures, which is not any different from the regular trackpad use.

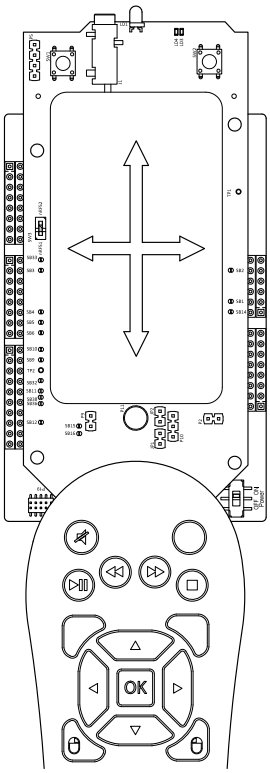


Figure 8: Trackpad functionality in free-space mode

Gyro calibration

Smart Remote 3 firmware performs initial calibration on first firmware run, but if you experience that the cursor is moving involuntarily when you start using the free-space navigation, this is due to gyro wandering, a trait inherent to this kind of motion sensor. The SmartMotion firmware library will automatically compensate for this movement. Simply leave the Smart Remote on a flat surface with free-space navigation enabled. After a few seconds the cursor will stop moving and you can pick up the Smart Remote and start using the free-space navigation feature.

4.1.5 Intelligent power saving

To save power, most the functions of the remote control, including the trackpad, are powered down when the remote control has not been used for a few seconds. This means then it will not react to user input.

In this powered-down state, the remote control relies on the low-power accelerometer for notification of user activity. When the remote control is picked up or nudged lightly it will resume normal operation.

4.1.6 Keypad

The remote control includes a common remote control keypad that is used in TVs and set-top boxes.

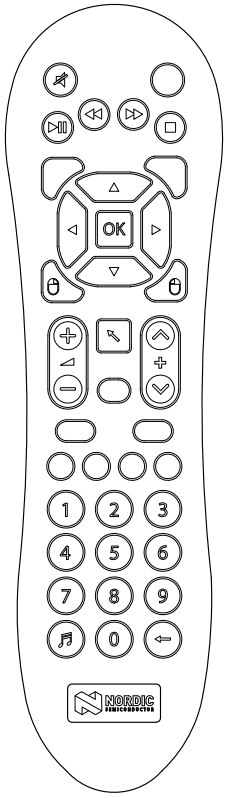


Figure 9: Remote control keypad

4.1.7 Infrared LED

To support the control of legacy electronic devices that are only fitted with infrared (IR) remote control receivers, the DK add-on is fitted with an IR LED.

The IR LED and IR protocols are handled by the MCU.

Important: There is no IR LED functionality application implemented in the Smart Remote 3 firmware.

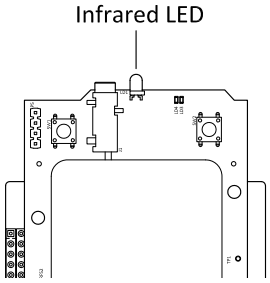


Figure 10: Location of the infrared LED on SR3 add-on

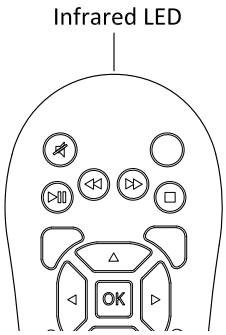


Figure 11: Location of the infrared LED on SR 3 product example

4.2 Firmware upgrading

The Smart Remote 3 firmware can be freely modified and upgraded.

See Firmware update of Smart Remote 3 on page 54 for how to upgrade the firmware for the Smart Remote 3.

Chapter 5
Hardware description: Smart Remote 3 DK add-on

The DK add-on contains all the hardware necessary for user interaction, including batteries.

> **Important:** The Smart Remote 3 DK add-on rev 1.2 and beyond is compatible with both nRF51 and nRF52 DKs. For using this add-on with nRF51 DK, switch **SW3** must be set in the position **nRF51**.

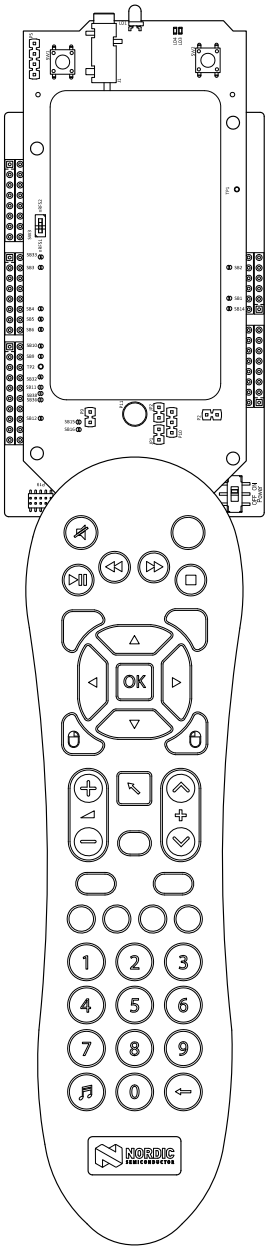


Figure 12: Smart Remote 3 DK add-on

5.1 Hardware figures: Smart Remote 3 DK add-on

The hardware drawings show both sides of the DK add-on board (PCA63519).

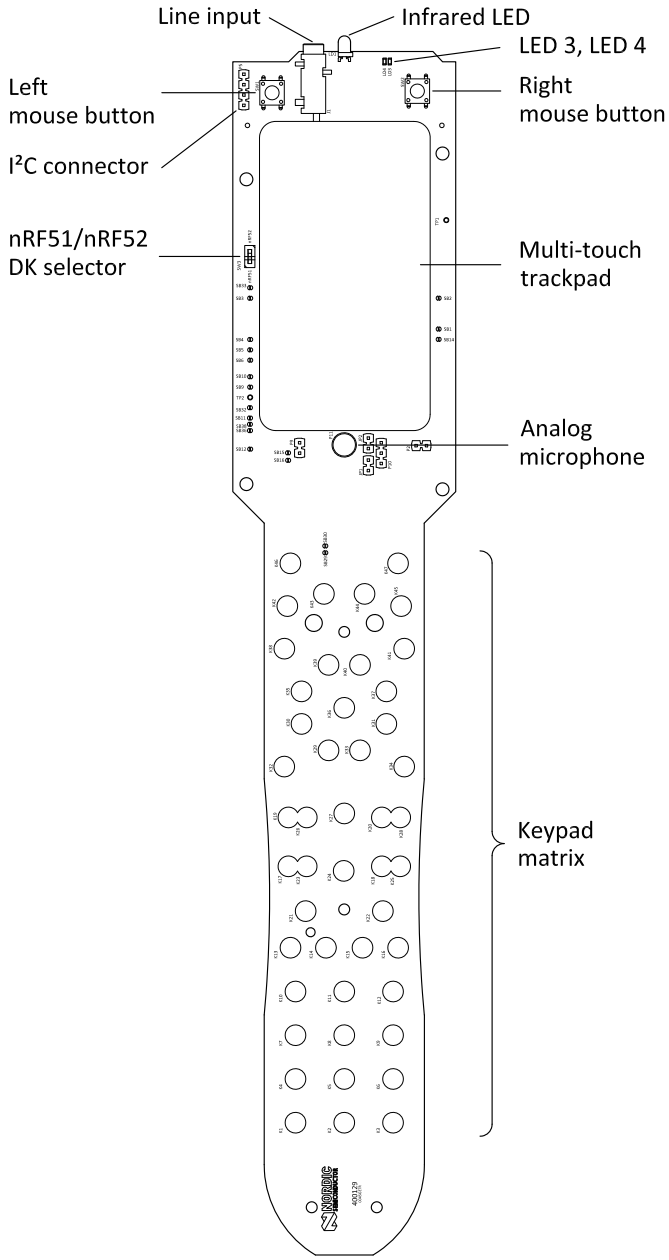


Figure 13: DK add-on board (PCA63519), front side

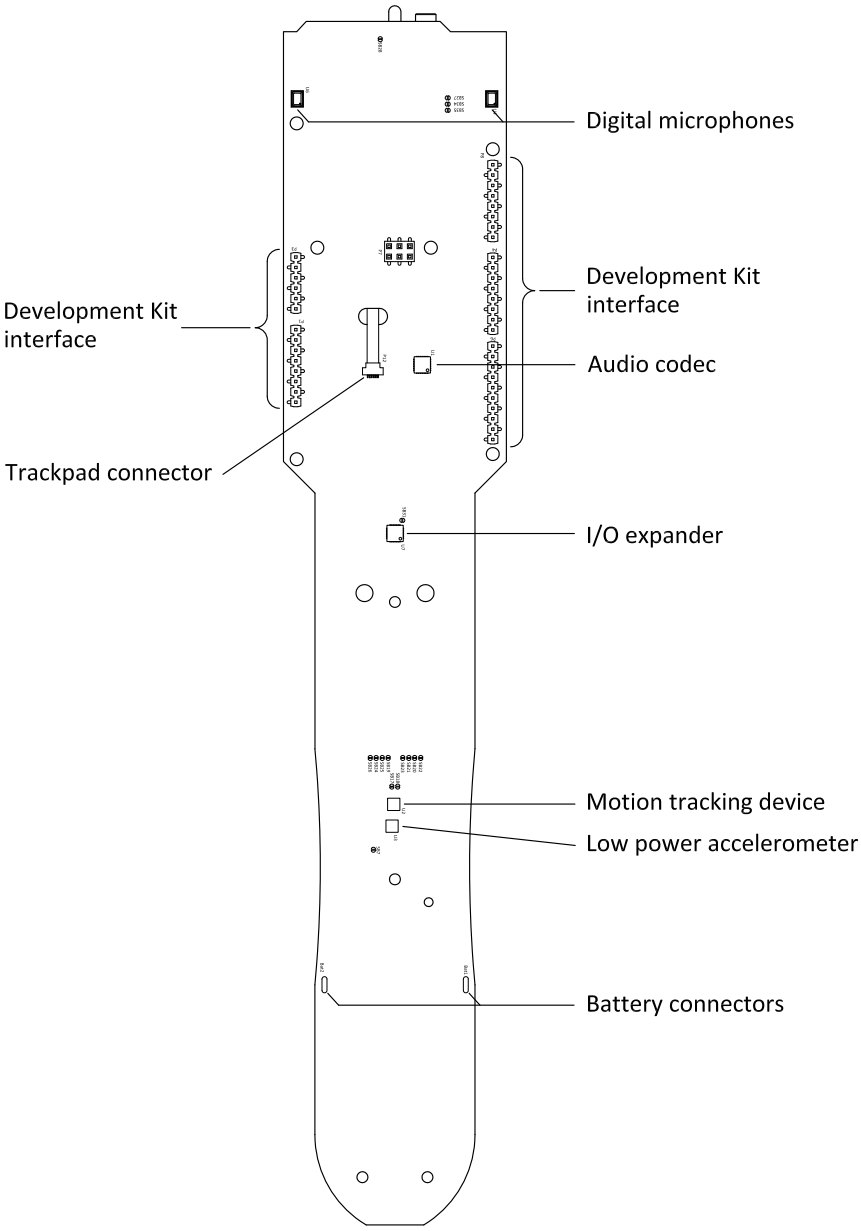


Figure 14: DK add-on board (PCA63519), back side

5.2 Block diagram

The block diagram illustrates Smart Remote 3 DK add-on functional architecture.

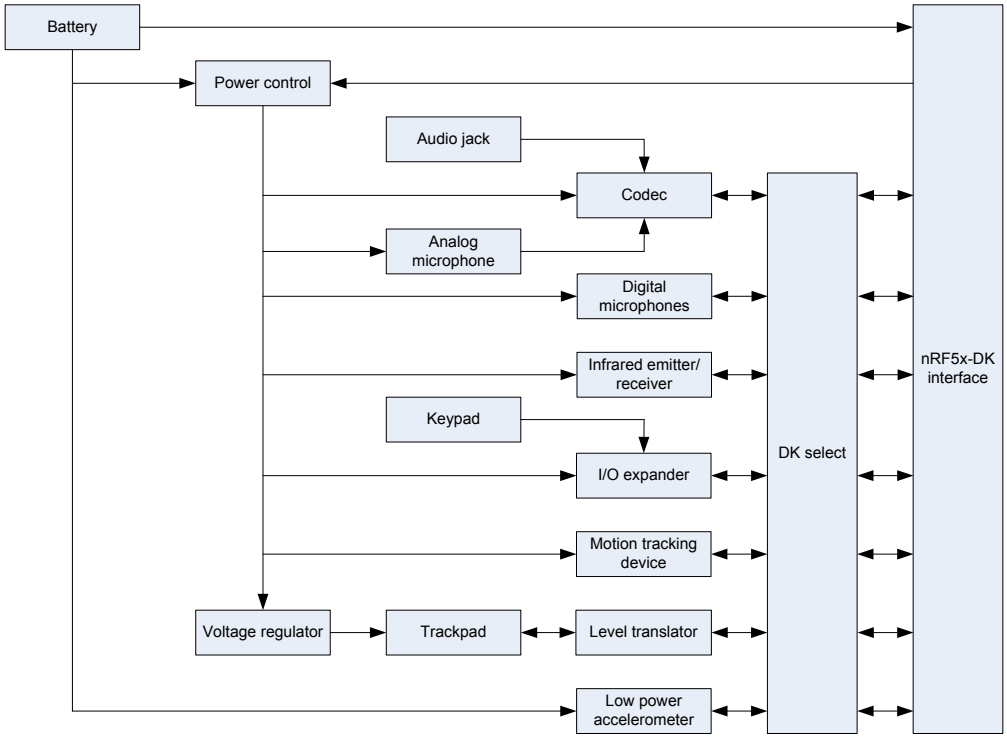


Figure 15: Block diagram

5.3 Design description

The design description provides detailed descriptions of Smart Remote 3 DK add-on hardware blocks.

5.3.1 Trackpad

The trackpad is mounted onto the PCA63519 board and connected to the **P12** connector.

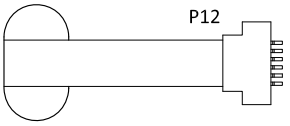


Figure 16: Trackpad interface connector

The trackpad is interfaced through the two-wire bus interface. See the table below for the trackpad pin description:

Table 1: Trackpad pin description

Pin	Label	Description
1	NC	Not connected
2	WU_IRQ_TP	Interrupt from trackpad
3	GND	Ground
4	I2C_CLK_TP	Two-wire serial clock

Pin	Label	Description
5	I2C_DATA_TP	Two-wire serial data
6	3V3	Power supply for trackpad

The trackpad requires a stable 3.3 V supply (see Figure 24: Voltage regulator for the trackpad on page 36 for details). Because of this the signals going from the nRF device to the trackpad needs to be level shifted. See the figure below:

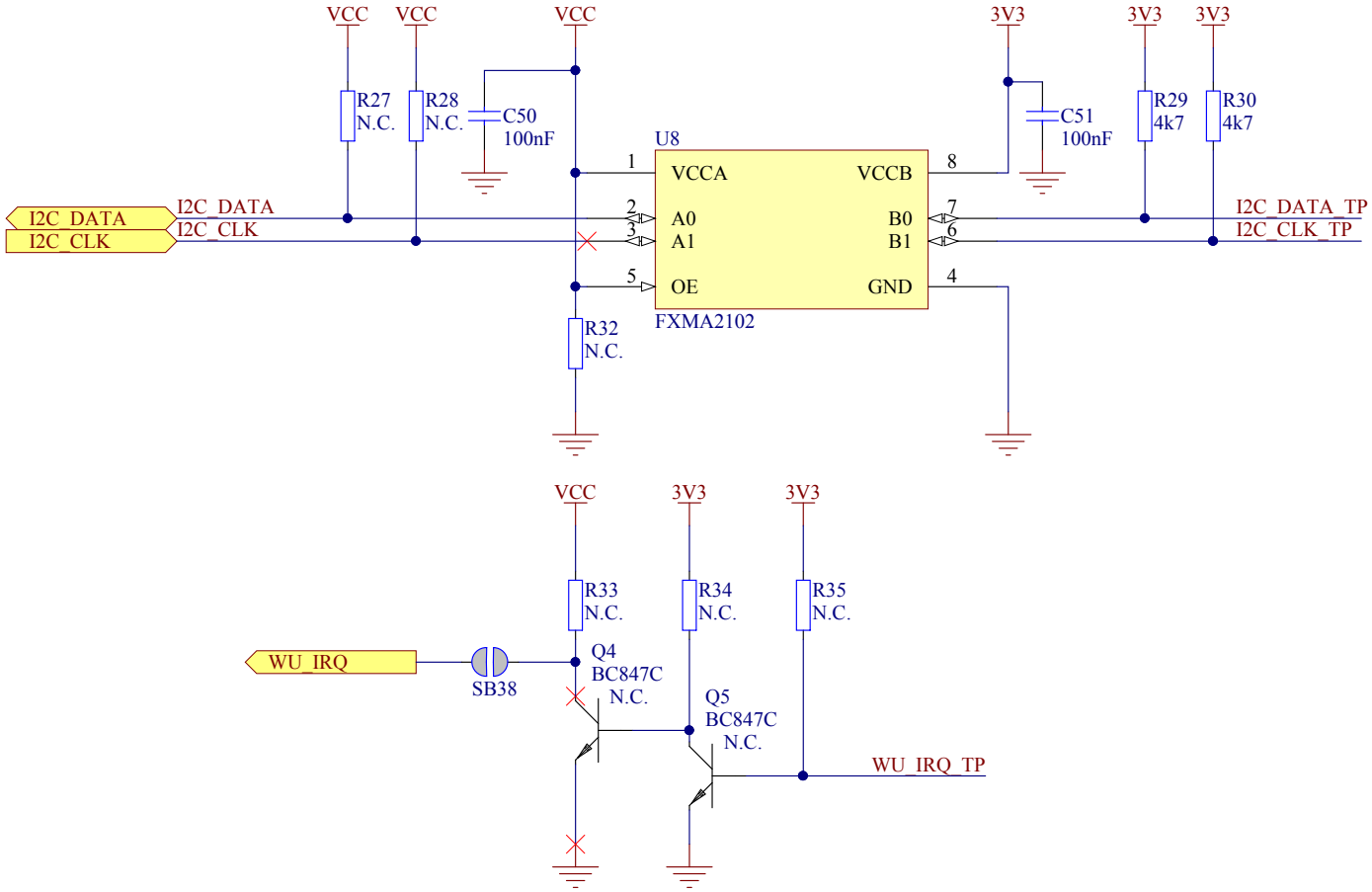


Figure 17: Level translation circuit for the trackpad

5.3.2 Keypad matrix

The keypad on the Smart Remote 3 DK add-on board (PCA63519) board has 39 buttons.

The matrix has six rows and eight columns that gives room for 48 buttons in firmware, of which 39 are used by the keypad, and one row is used for two push buttons that function as left and right mouse buttons. A total of 41 of 48 locations are in use. See Figure 18: Keypad matrix on page 32.

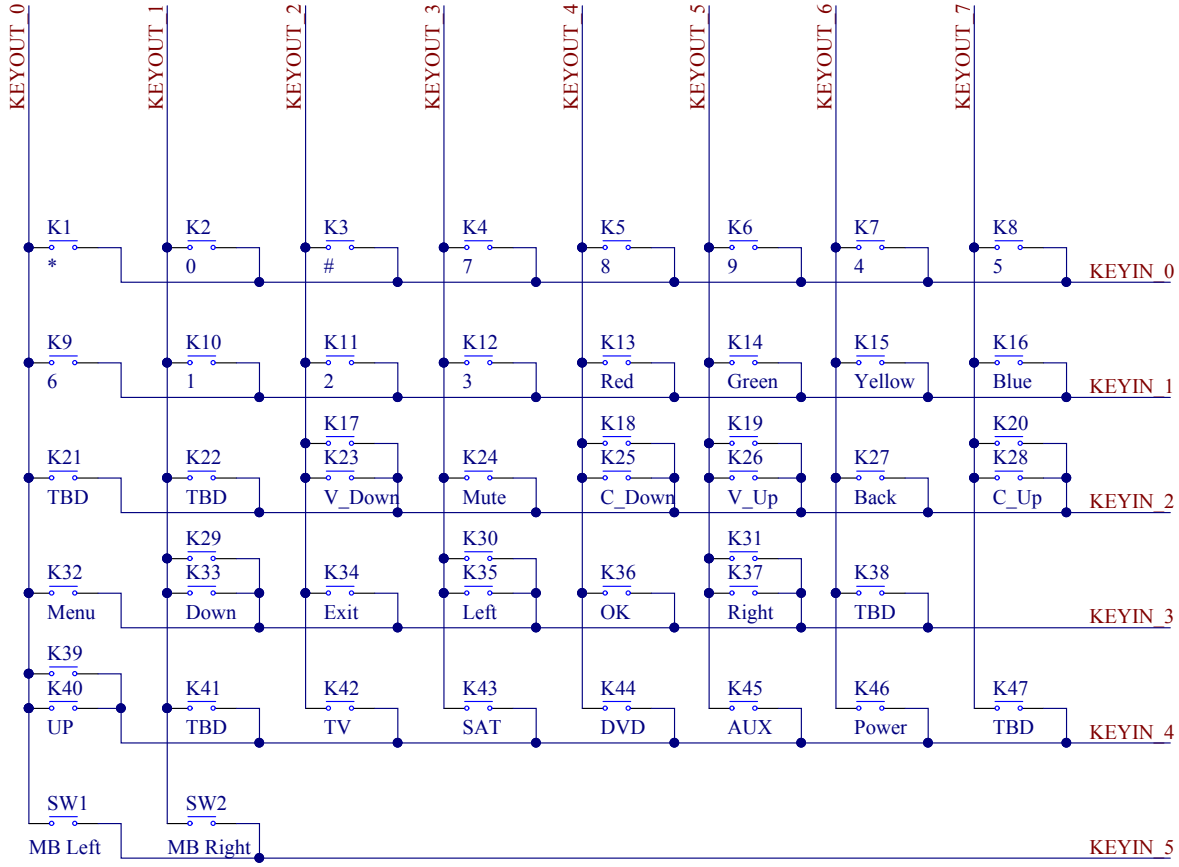


Figure 18: Keypad matrix

The matrix is connected to an I/O expander that is controlled by the nRF device using I^2C. See Figure 19: Keypad matrix I/O expander on page 33.

The I/O expander circuit is added on the DK add-on so that it strictly uses the I/O set available in the Arduino interface system. On the Product example - where no Arduino interface is used - the I/O expander circuit is not needed.

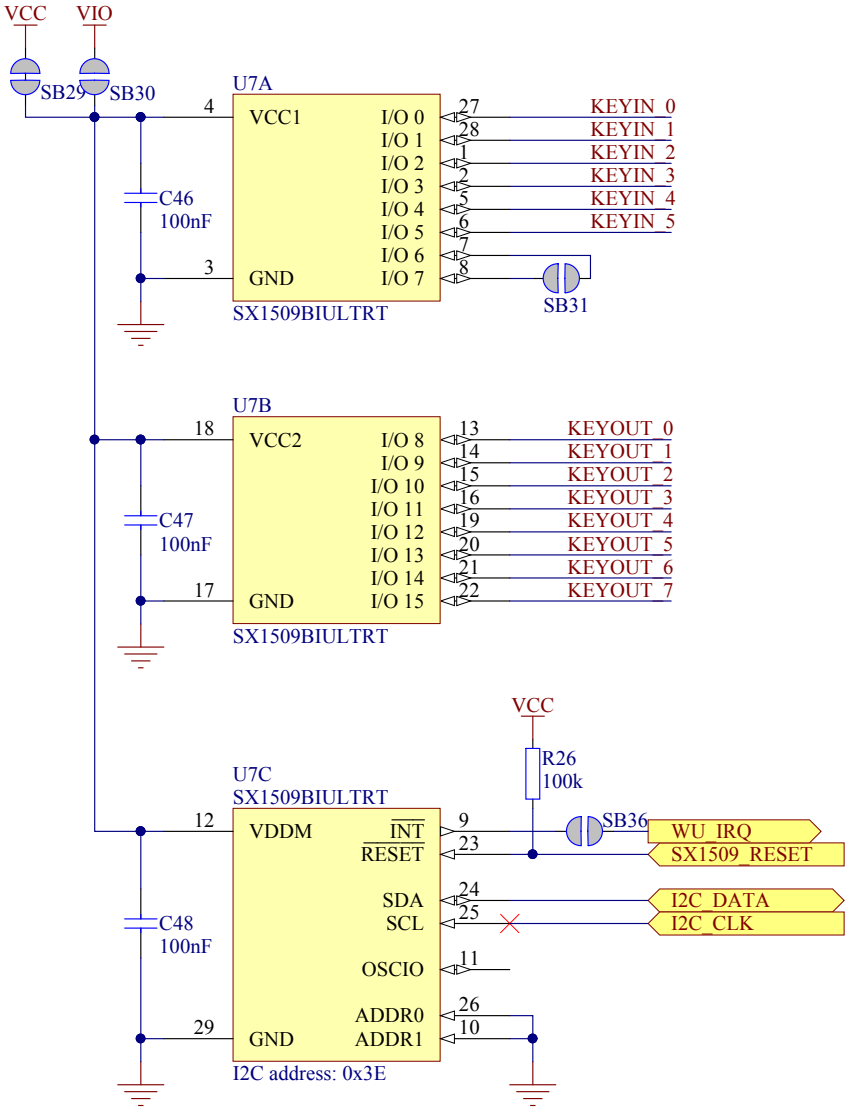


Figure 19: Keypad matrix I/O expander

5.3.3 Low-power accelerometer circuit

To obtain low power consumption and long battery lifetime, a low-power three-axis accelerometer (**U3**) has been added to the remote control.

See below for the schematic. See also Intelligent power saving on page 24.

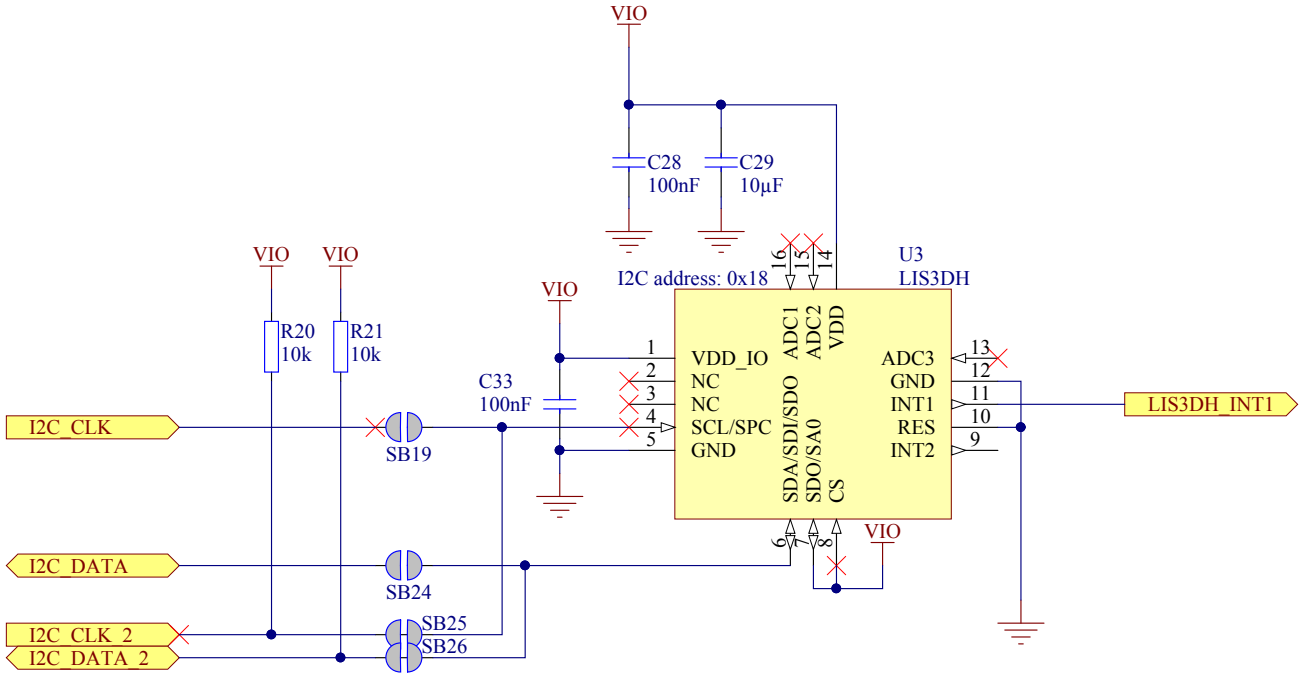


Figure 20: Accelerometer circuit

The accelerometer has I^{2}C outputs and can detect motion on three axes. The sensitivity is configurable to ±2 g/±4 g/±8 g/±16 g.

5.3.4 Motion tracking device

For advanced features, the remote control has a three-axis gyro integrated with a three-axis accelerometer (**U2**).

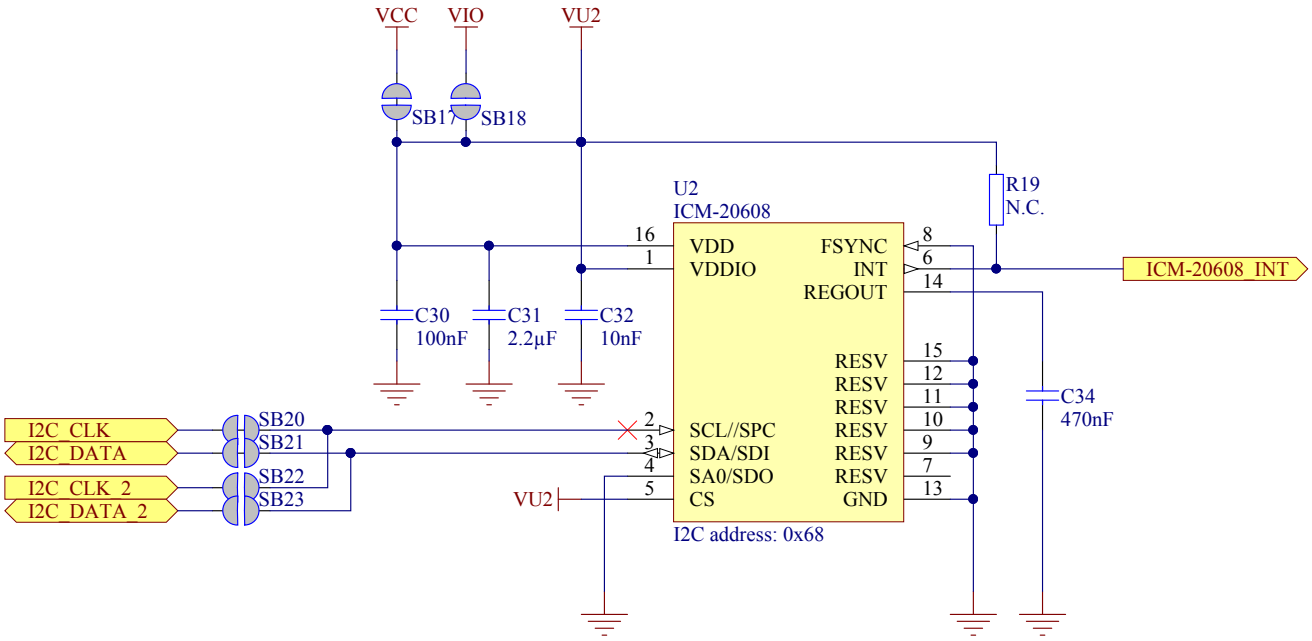


Figure 21: Gyro/accelerometer circuit

The circuit is connected to the MCU by the first I^{2}C. If you want to use the second I^{2}C there are four solder bridges that you need to change:

- Solder **SB22** and **SB23**

- Cut **SB20** and **SB21**

This circuit is a ±250° per sec/±500° per sec/±1000° per sec/±2000° per sec selectable three-axis gyro and a ±2 g/±4 g/±8 g/±16 g selectable three-axis accelerometer.

5.3.5 Power supply

The Smart Remote 3 DK add-on gets its power from two AA batteries or from the nRF5x Development Kit (DK).

The batteries can be alkaline (2 × 1.5 V) or rechargeable NiMH (2 × 1.2 V) batteries. The battery circuit has a protection diode to avoid reverse current if the USB is connected to the nRF5x DK while batteries are inserted.

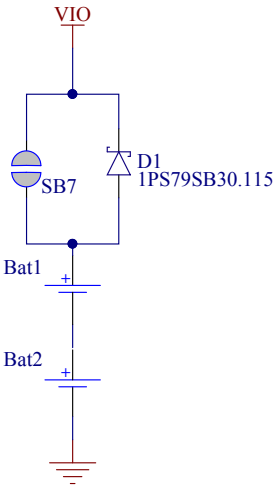


Figure 22: Battery schematic

Smart Remote 3 has a switch for turning the power on or off for most of the circuits. One transistor is used for this, which is controlled by the nRF chip on the nRF5x DK. See Figure 23: Power on/off switch on page 35. The low-power accelerometer is always powered.

Figure 23: Power on/off switch

The voltage from the batteries or nRF5x DK is used unregulated for most part of the design. However, the trackpad requires a stable voltage of 3.3 V. To achieve this, the trackpad gets the power from a fixed step-up/step-down charge pump generator that outputs 3.3 V. See Figure 24: Voltage regulator for the trackpad on page 36.

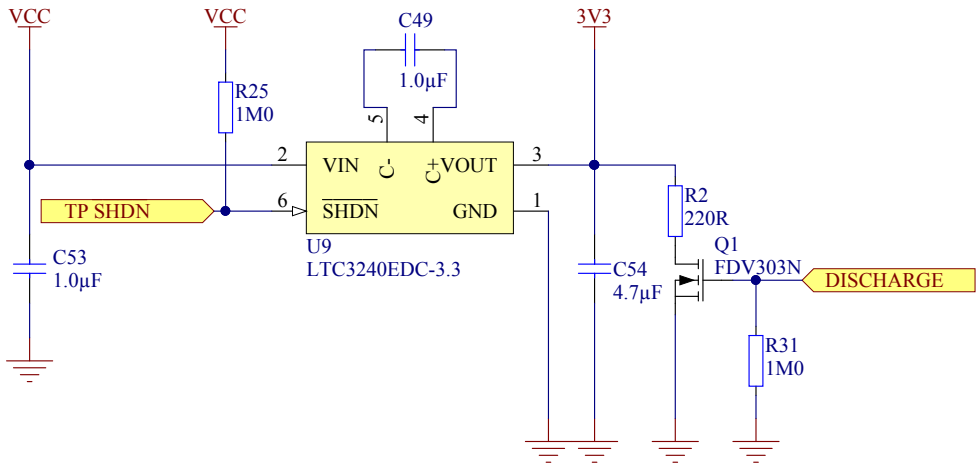


Figure 24: Voltage regulator for the trackpad

Important: The input voltage for this regulator is 1.8 V–5.5 V.

5.3.6 Infrared LED and driver

To support legacy products, the remote control has an infrared LED with a driver circuit.

The infrared LED is driven by a transistor (**Q3**) to offer higher current than the MCU I/O can offer.

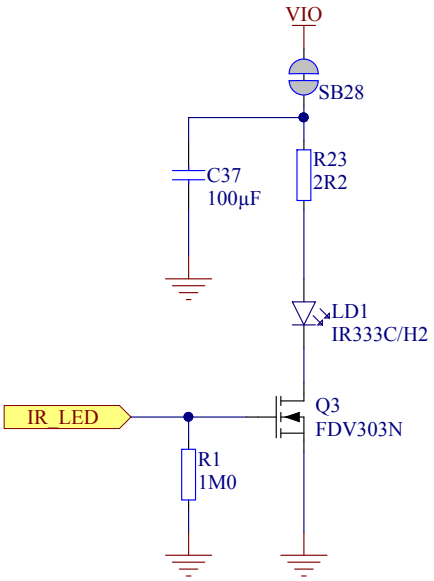


Figure 25: Infrared LED and driver circuit

The control signal is active high meaning that when the IR_LED signal has logic high level, the LED emits infrared light.

5.3.7 Codec

A codec is used in conjunction with the nRF51 DK to get the analog signal from the microphone to digital signals.

For codec, the ES8218 from Everest Semiconductor is chosen. ES8218 is set up with the use of two-wire interface. The microphone signal is transferred to the nRF51 DK via I^2S interface.

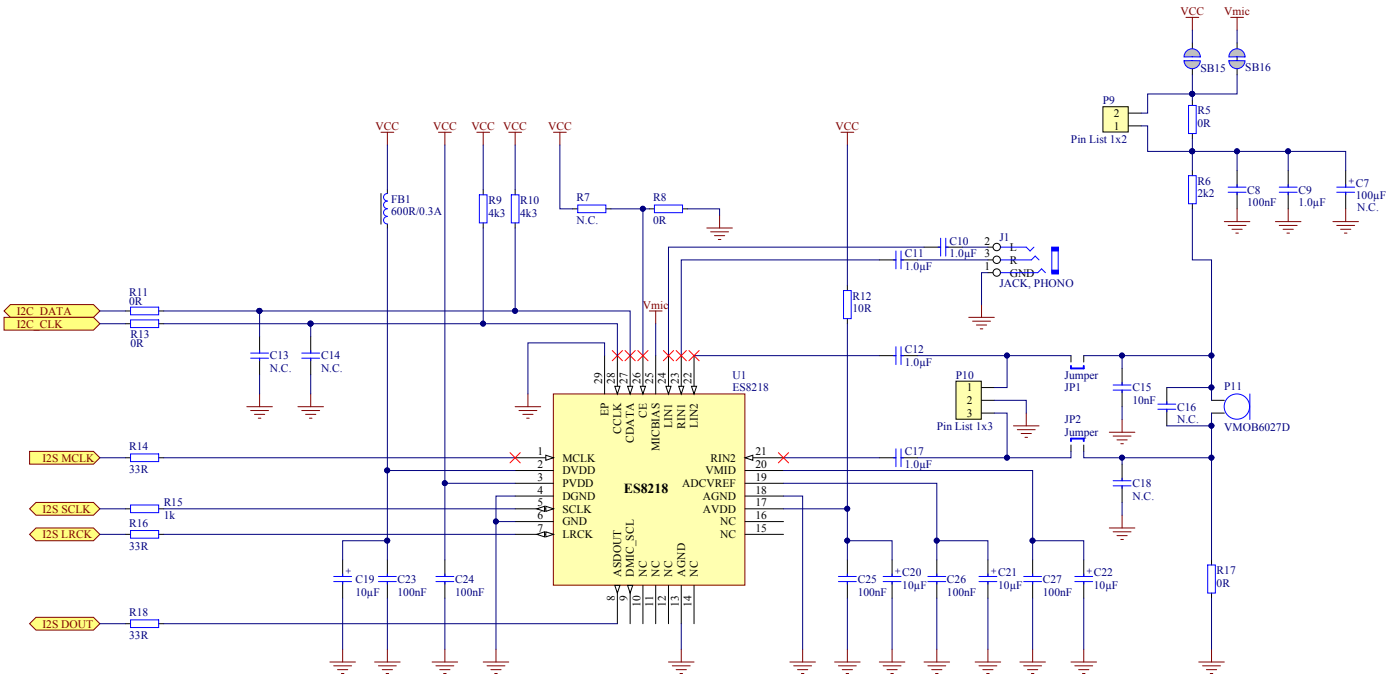


Figure 26: Codec and appurtenant components

5.3.8 Digital microphones (only for use with nRF52 DK)

The Smart Remote 3 DK add-on is equipped with two digital output PDM microphones.

The microphones are configured so that they can be used to sample stereo audio, but are by default set to mono audio. The microphones are by default disconnected from the power supply and the interface connectors. To connect to the development kit and enable power, solder bridges **SB34**, **SB35**, and **SB27** must be shorted, see the schematic below:

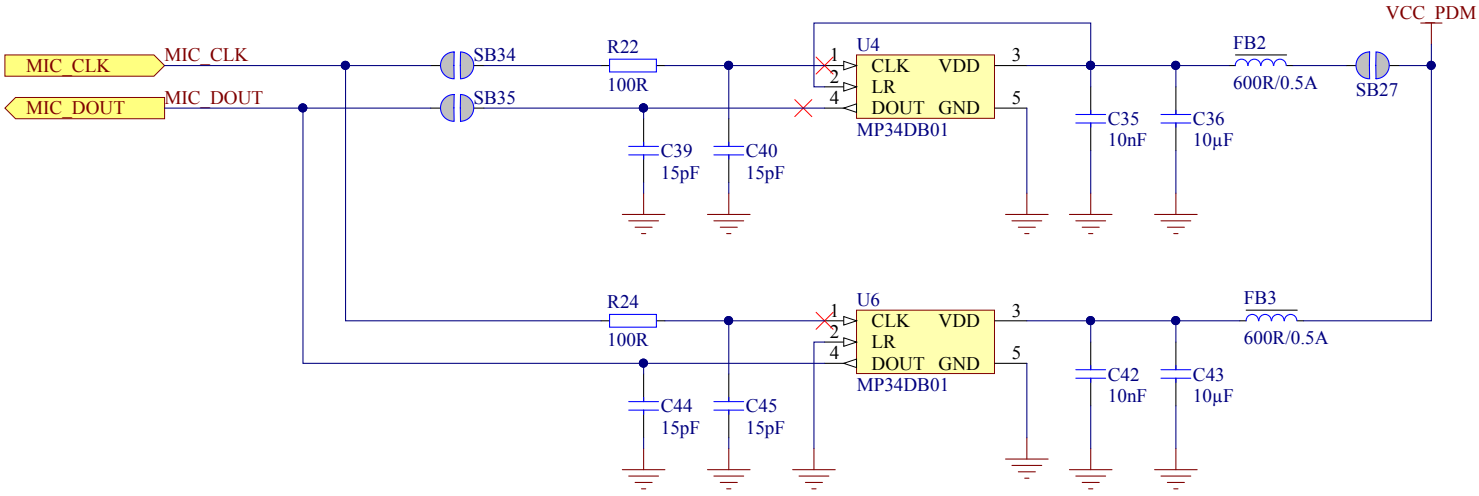


Figure 27: Digital microphones

5.3.9 nRF51 DK interface

Connectors **P1**, **P3**, **P4**, **P6**, **P7**, and **P8** are used to connect the DK add-on to the nRF51 DK.

Through these connectors, all the functionality of the DK add-on can be accessed by the nRF51 DK. See Table 2: nRF51 DK interface connections on page 38 for pin information.

Table 2: nRF51 DK interface connections

Pin	Label	Description	Short
P1_1	VIO	Voltage domain VIO	
P1_2	VIO	Voltage domain VIO	
P1_3	NC	Not connected	
P1_4	VIO	Voltage domain VIO	
P1_5	V5V	Voltage domain V5V	
P1_6	GND	Ground	
P1_7	GND	Ground	
P1_8	VIN	Voltage domain VIN	
P3_1	TP SHDN	TP voltage regulator on/off	
P3_2	A1	LD3 control	SB1
P3_3	I2S LRCK	ADC audio data left and right	
P3_4	I2S MCLK	Master clock	
P3_5	NC	Not connected	
P3_6	I2S DOUT	ADC audio data	
P4_1	I2S SCLK	Audio data bit clock	SB33
P4_2	I2S SCLK	Audio data bit clock	SB3
P4_3	D2	Connected to D3	
P4_4	D3	Connected to D2	
P4_5	POWER ON/OFF	Control signal power switch	
P4_6	D5	LD4 control	SB4
P4_7	I2S CLK2	I^2C 2 clock	SB5
P4_8	ICM-20608 INT	Motion tracking device interrupt	SB6
P6_1	DISCHARGE	Discharges the TP voltage regulator	SB10
P6_2	NC	Not connected	SB9
P6_3	NC	Not connected	
P6_4	IR LED	Infrared LED control signal input	
P6_5	WU IRQ	TP interrupt or I/O expander interrupt	SB11
P6_6	LIS3DH INT1	Low-power accelerometer interrupt 1	
P6_7	GND	Ground	
P6_8	I2C_DATA2	I^2C 2 data	SB12
P6_9	I2C_DATA	I^2C 1 data	
P6_10	I2C_CLK	I^2C 1 clock	

Pin	Label	Description	Short
P7_1	NC	Not connected	
P7_2	NC	Not connected	
P7_3	NC	Not connected	
P7_4	NC	Not connected	
P7_5	NC	Not connected	
P7_6	GND	Ground	
P8_1	NC	Not connected	
P8_2	NC	Not connected	
P8_3	NC	Not connected	
P8_4	NC	Not connected	
P8_5	NC	Not connected	
P8_6	NC	Not connected	
P8_7	NC	Not connected	
P8_8	NC	Not connected	

5.3.10 nRF52 DK interface

Connectors **P1**, **P3**, **P4**, **P6**, **P7**, and **P8** are used to connect the DK add-on to the nRF52 DK.

Through these connectors, all the functionality of the DK add-on can be accessed by the nRF52 DK. See Table 3: nRF52 DK interface connections on page 39 for pin information.

Table 3: nRF52 DK interface connections

Pin	Label	Description	Short
P1_1	VIO	Voltage domain VIO	
P1_2	VIO	Voltage domain VIO	
P1_3	NC	Not connected	
P1_4	VIO	Voltage domain VIO	
P1_5	V5V	Voltage domain V5V	
P1_6	GND	Ground	
P1_7	GND	Ground	
P1_8	VIN	Voltage domain VIN	
P3_1	TP SHDN	TP voltage regulator on/off	
P3_2	A1	LD3 control	SB1
P3_3	NC	Not connected	
P3_4	NC	Not connected	
P3_5	I2C CLK	I^2C clock	SB2

Pin	Label	Description	Short
P3_6	NC	Not connected	
P4_1	NC	Not connected	SB33
P4_2	I2C CLK2	I^2C 2 clock	SB3
P4_3	MIC CLK	Digital microphone clock	
P4_4	MIC DOUT	Digital microphone data output	
P4_5	POWER ON/OFF	Control signal power switch	
P4_6	D5	LD4 control	SB4
P4_7	NC	Not connected	SB5
P4_8	NC	Not connected	SB6
P6_1	DISCHARGE	Discharges the TP voltage regulator	SB10
P6_2	ICM-20608 INT	Motion tracking device interrupt	SB9
P6_3	NC	Connected to test point 2	
P6_4	IR LED	Infrared LED control signal input	
P6_5	WU IRQ	TP interrupt or I/O expander interrupt	SB11
P6_6	LIS3DH INT1	Low-power accelerometer interrupt 1	
P6_7	GND	Ground	
P6_8	I2C_DATA2	I^2C 2 data	SB12
P6_9	I2C_DATA	I^2C 1 data	
P6_10	I2C_CLK	I^2C 1 clock	
P7_1	NC	Not connected	
P7_2	NC	Not connected	
P7_3	NC	Not connected	
P7_4	NC	Not connected	
P7_5	NC	Not connected	
P7_6	GND	Ground	
P8_1	NC	Not connected	
P8_2	NC	Not connected	
P8_3	NC	Not connected	
P8_4	NC	Not connected	
P8_5	NC	Not connected	
P8_6	NC	Not connected	
P8_7	NC	Not connected	
P8_8	NC	Not connected	

5.3.11 Current measurement

The Smart Remote 3 DK add-on has two pin headers available for current measurement. These pin headers make it possible to measure current for the DK add-on and for the microphone.

By default, a 10 Ω resistor (**R3**) is parallel to **P2** and a 0 Ω resistor (**R5**) is parallel to **P9**. When performing current measurement, the resistor has to be removed.

There are two ways of measuring the current consumption: using an ampere-meter or an oscilloscope.

With ampere-meter:

- Remove **R3** and/or **R5**
- Connect an ampere-meter between the pins of connector **P2** and/or **P9**. This will monitor the current directly.

With oscilloscope:

- On **R3**, use the default mounted 10 Ω resistor. On **R5**, replace the 0 Ω resistor with a resistor not larger than 10 Ω.
- Connect an oscilloscope in differential mode or similar with two probes on the pins of the **P2** and/or **P9** connectors.
- Measure the voltage drop. The voltage drop will be proportional to the current consumption. For example, if a 10 Ω resistor is chosen, 10 mV equals 1 mA.

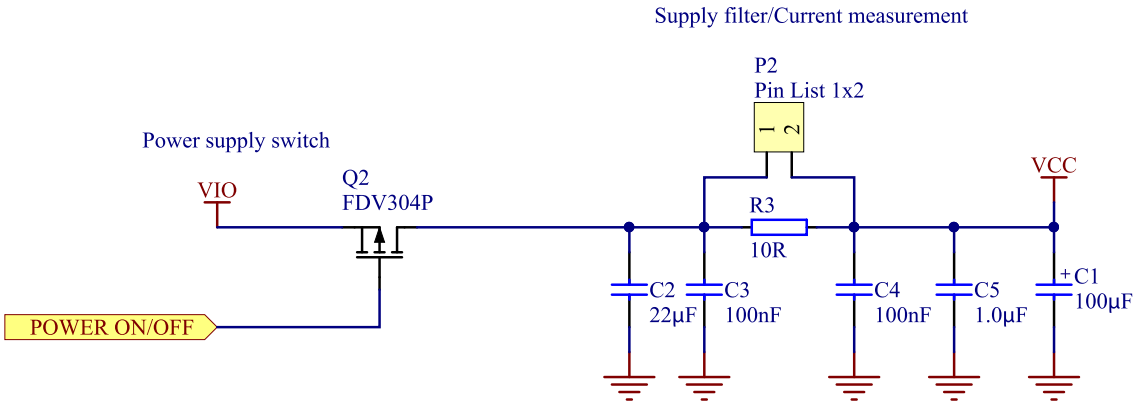


Figure 28: DK add-on current measurement

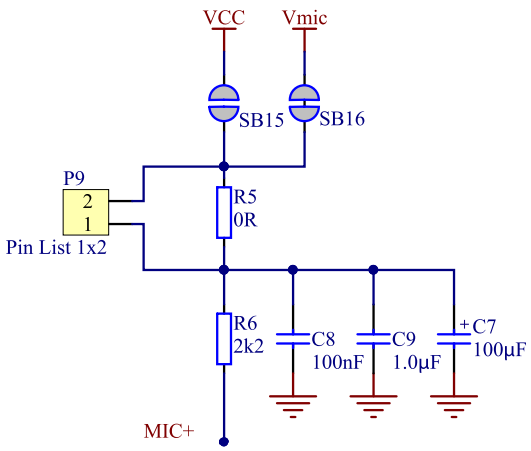


Figure 29: Microphone current measurement

In the figure above, MIC+ refers to the positive side of the microphone.

5.3.12 I²C bus connector

A connector for the I²C bus is available on the **P5** header. This can be used for debugging or connecting to external sensors.

Table 4: I²C bus connector pin configuration

Pin	Label	Description
P5_1	VCC	Power supply
P5_2	GND	Ground
P5_3	I2C_CLK	I²C 1 clock
P5_4	I2C_DATA	I²C 1 data

5.3.13 Schematics, bill of materials, PCB layout files, production files

All hardware files for the Smart Remote 3 DK add-on are available in a zip package.

The hardware files for the Smart Remote 3 DK add-on are located in the following folder in the hardware files zip package:

```
\nRFready Smart Remote 3 for nRF51 series x_x_x\nRF6932 - DK Add-on x_x_x
```

In this folder you can find the bill of materials, schematics and PCB layout files in PDF format, Altium Designer files, and production files (assembly drawings, gerber files, drill files, pick-and-place files).

Chapter 6
Hardware description: Smart Remote 3 nRF51 product example

The product example contains all the hardware necessary for user interaction, including batteries.

It has a regular remote control keypad matrix as the main input device. It features a low-power accelerometer and a motion tracking device for implementing customized features.

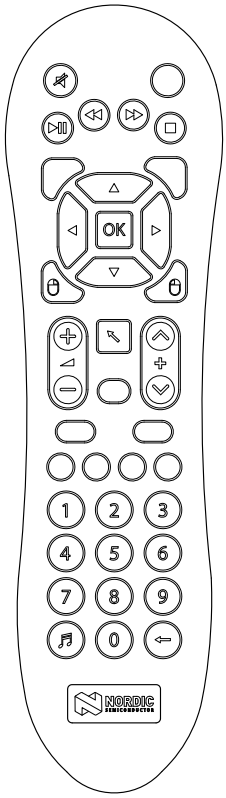


Figure 30: Smart Remote 3 nRF51 product example

6.1 Hardware figures: SR 3 product example

The hardware drawings show both sides of the SR 3 product example board (PCA20018).

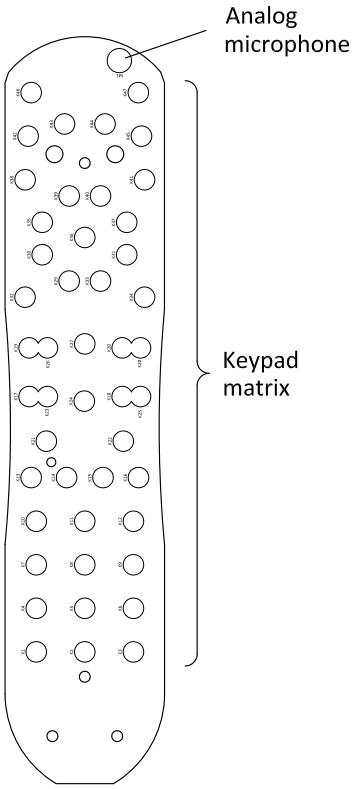


Figure 31: SR 3 product example board (PCA20018), front side

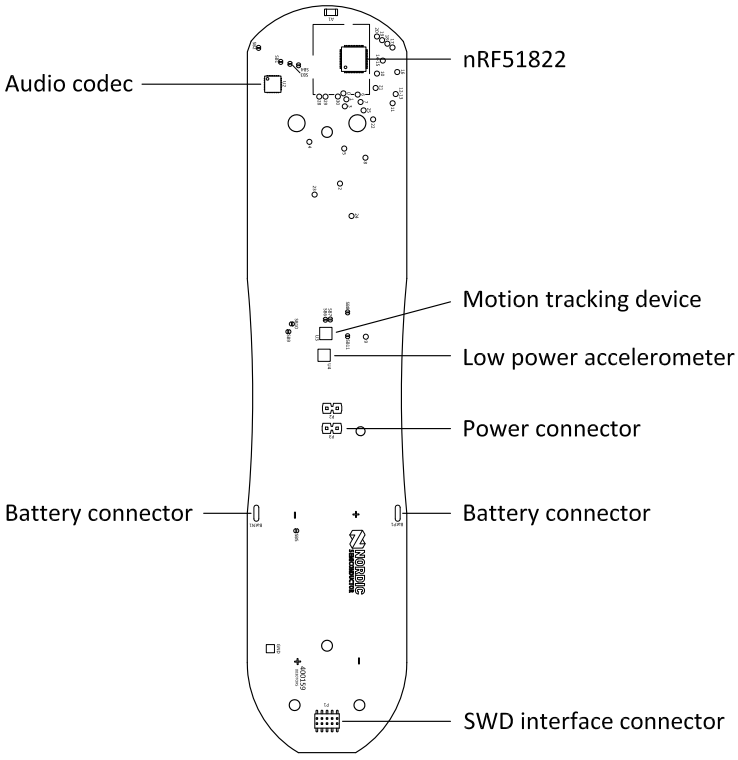


Figure 32: SR 3 product example board (PCA20018), back side

6.2 Block diagram

The block diagram illustrates Smart Remote 3 DK product example functional architecture.

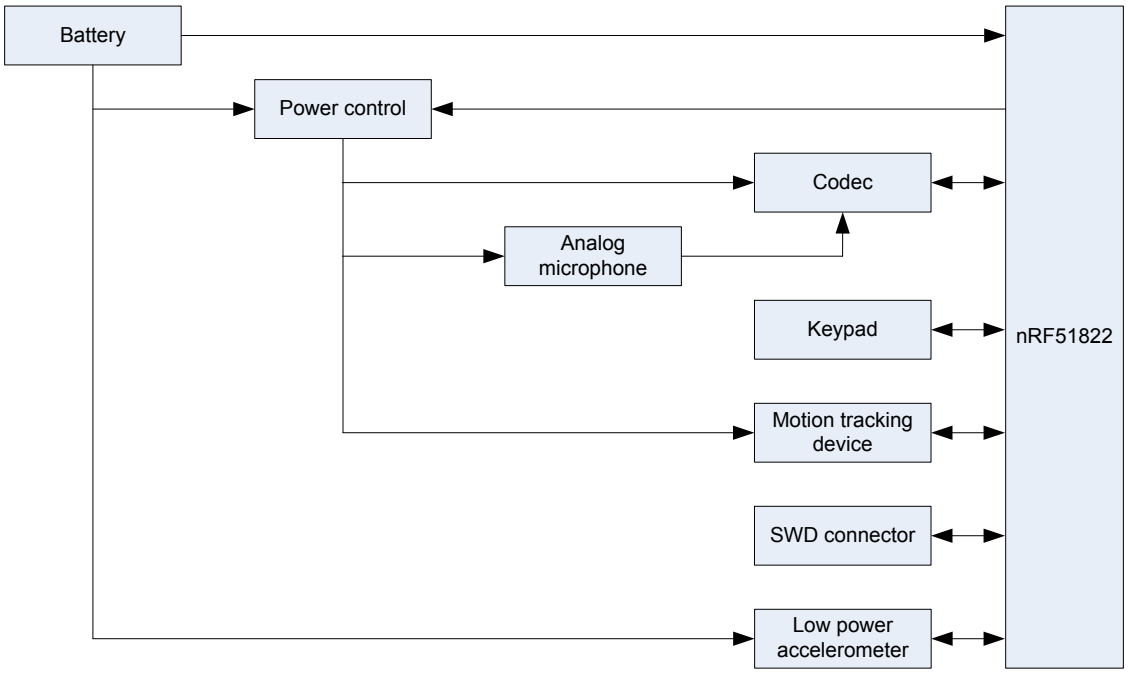


Figure 33: Block diagram

6.3 Design description

The design description contains details about the hardware blocks on the Smart Remote 3 for nRF51 product example.

6.3.1 I/O usage

The nRF51822-QFAA has 31 generic I/Os available. All I/Os are used in this design and are organized as shown in table below.

Table 5: I/O usage

I/O	Label	Description
P0.00	DEBUG HALF	
P0.01	DEBUG FULL	
P0.02	I2C_DATA_2	Two-wire 2 master data
P0.03	I2S LRCLK	ADC audio data left and right
P0.04	I2S MCLK	Master clock
P0.05	I2C_CLK_2	Two-wire 2 master clock
P0.06	I2S DOUT	ADC audio data
P0.07	I2C_CLK	Two-wire 1 master clock
P0.08	KEYIN_0	Input from keypad row 0
P0.09	KEYIN_1	Input from keypad row 1

I/O	Label	Description
P0.10	KEYIN_2	Input from keypad row 2
P0.11	KEYIN_3	Input from keypad row 3
P0.12	I2S SCLK	Audio data bit clock
P0.13	I2S SCLK	Audio data bit clock
P0.14	P0.14	Connected to P0.15
P0.15	P0.15	Connected to P0.14
P0.16	Power switch	Control signal power switch
P0.17	KEYIN_4	Input from keypad row 4
P0.18	ICM-20608_INT	Motion tracking device interrupt
P0.19	KEYOUT_0	Output to keypad column 0
P0.20	KEYOUT_1	Output to keypad column 1
P0.21	KEYOUT_2	Output to keypad column 2
P0.22	KEYOUT_3	Output to keypad column 3
P0.23	KEYOUT_4	Output to keypad column 4
P0.24	KEYOUT_5	Output to keypad column 5
P0.25	KEYOUT_6	Output to keypad column 6
P0.26	XL1	32.768 kHz crystal
P0.27	XL2	32.768 kHz crystal
P0.28	KEYOUT_7	Output to keypad column 7
P0.29	LIS3DH_INT1	Low-power accelerometer interrupt 1
P0.30	I2C_DATA	Two-wire 1 master data

6.3.2 Keypad matrix

The keypad on the PCA20018 board has 39 buttons.

The keyboard matrix is five rows by eight columns, providing 40 available buttons for firmware. Thirty-nine are used by the keypad with one unused. The matrix is connected directly to the nRF51 device on the board. See Figure 34: Keypad matrix on page 47.

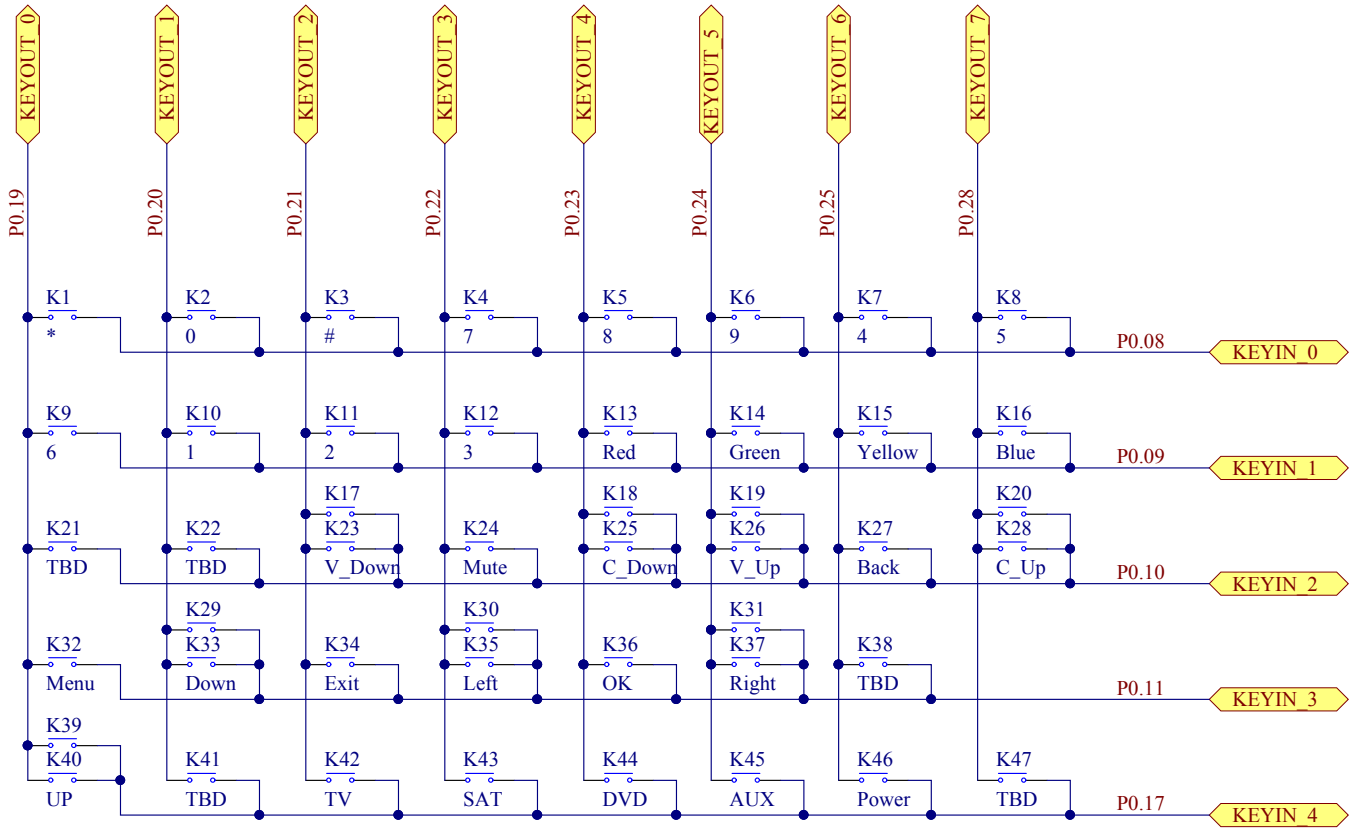


Figure 34: Keypad matrix

6.3.3 Low-power accelerometer circuit

To obtain low-power consumption and long battery lifetime, a low-power three-axis accelerometer (**U4**) has been added to the remote control.

See the schematic below. See also Intelligent power saving on page 24.

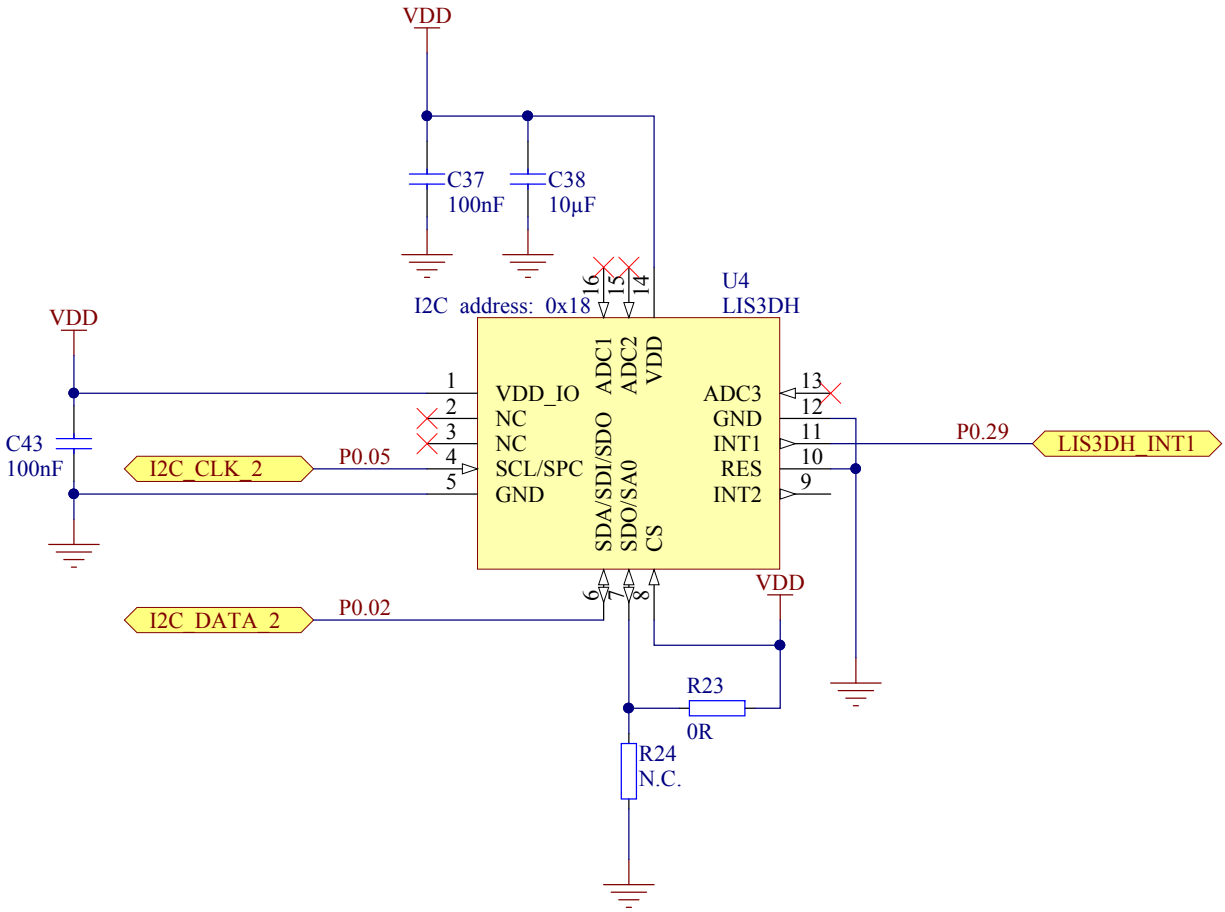


Figure 35: Accelerometer circuit

The accelerometer has I^{2}C outputs and can detect motion on three axes. The sensitivity is configurable to ±2 g/±4 g/±8 g/±16 g.

6.3.4 Motion tracking device

For advanced features, the remote control has a three-axis gyro integrated with a three-axis accelerometer (**U3**).

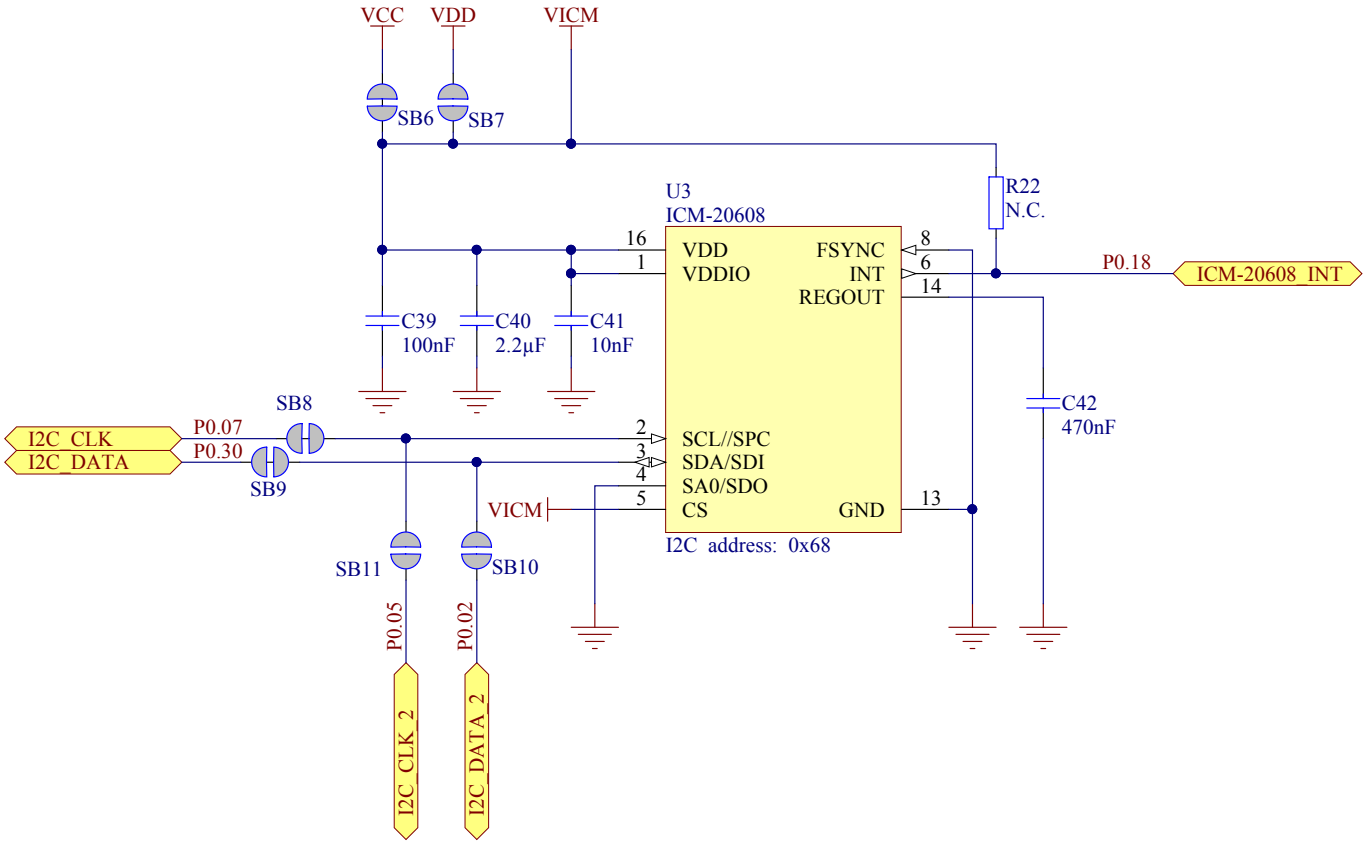


Figure 36: Motion tracking device

The circuit is connected to the MCU by the first I^{2}C. If you want to use the second I^{2}C, there are four solder bridges that you need to change. **SB10** and **SB11** have to be soldered and **SB8** and **SB9** have to be cut. This circuit is a ±250° per sec/±500° per sec/±1000° per sec/±2000° per sec selectable three-axis gyro and a ±2 g/±4 g/±8 g/±16 g selectable three-axis accelerometer.

6.3.5 Power supply

The Smart Remote 3 product example is powered by two AA batteries.

The batteries can be alkaline (2 × 1.5 V) or rechargeable NiMH (2 × 1.2 V) batteries. The battery circuit has a protection diode to avoid reverse current if the board is powered elsewhere. In parallel with the battery there is a connector (**P3**) that can be used for supply during development. See Figure 37: Battery schematic on page 50.

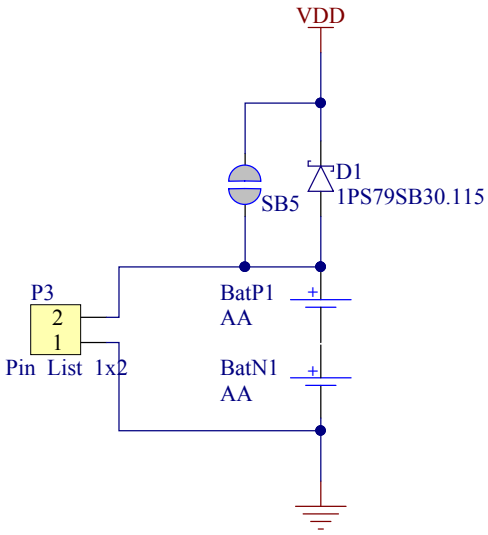


Figure 37: Battery schematic

There is a power switch on the Smart Remote 3 that is connected to most of the circuits. The nRF chip controls the two transistors. See Figure 38: Power on/off switch schematic on page 50. The low-power accelerometer is always powered.

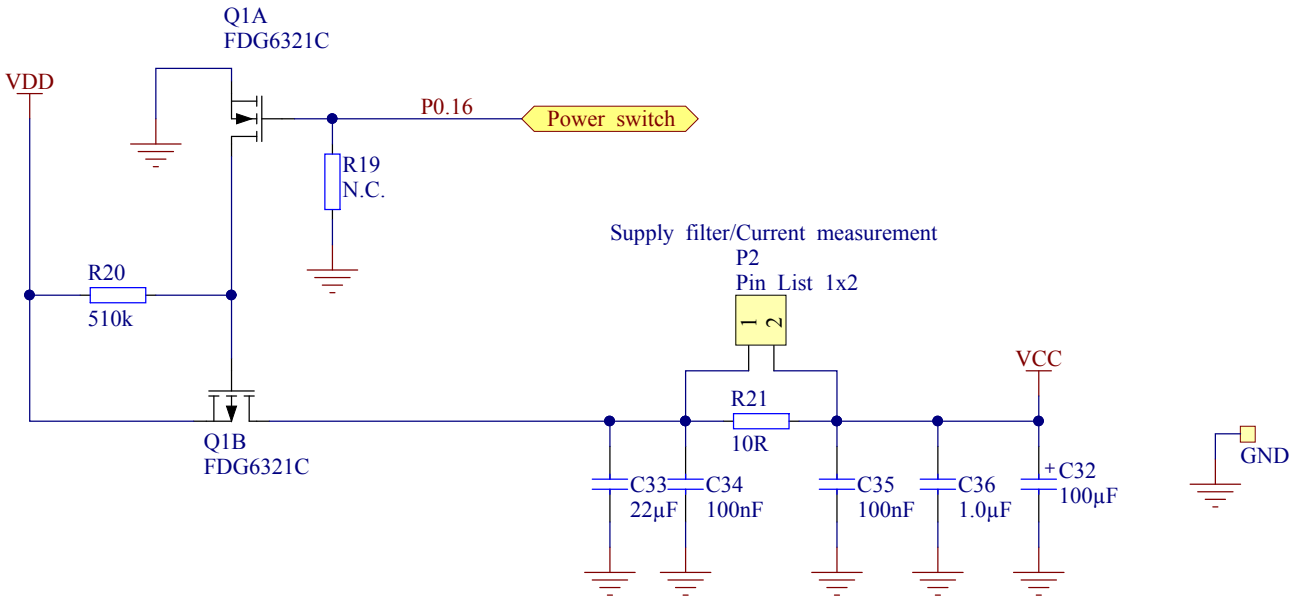


Figure 38: Power on/off switch schematic

6.3.6 Codec

The CODEC is used to digitize and code the signal from the analog microphone.

The Smart Remote 3 uses the ES8218 CODEC from Everest Semiconductor, that utilizes a two-wire interface for setup commands. The microphone signal is transferred to the nRF chip via I^2S interface.

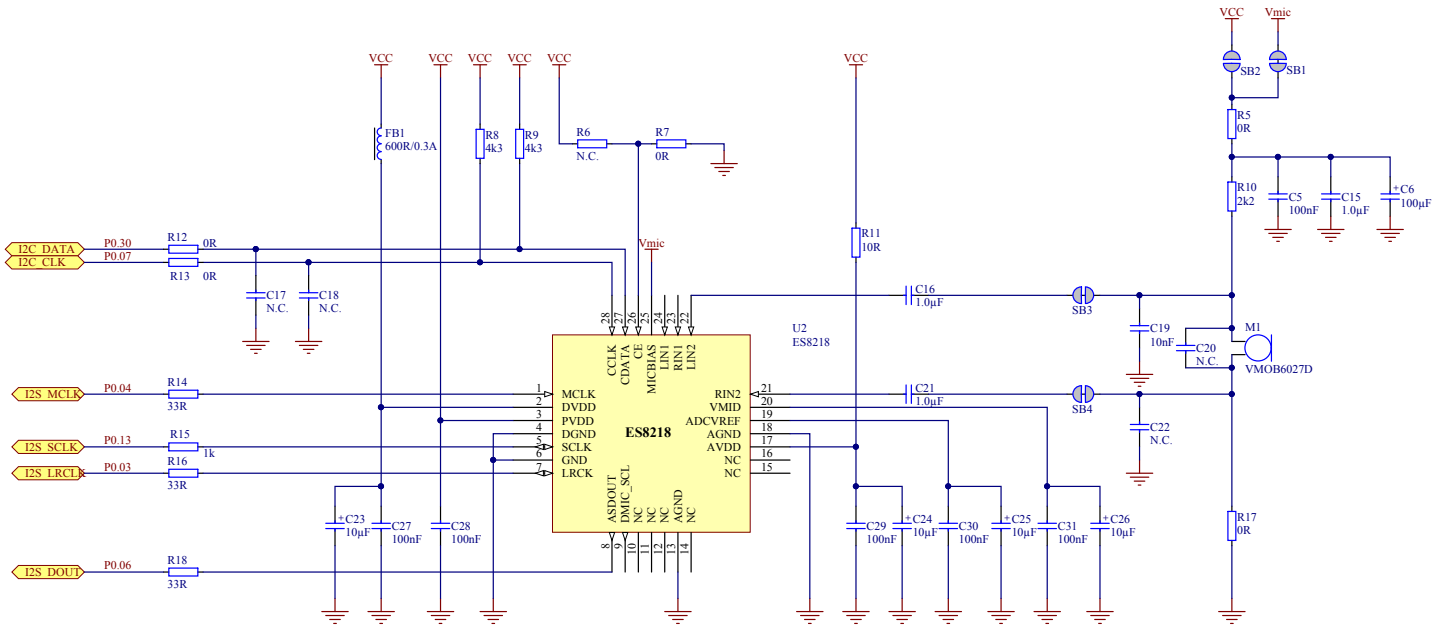


Figure 39: Codec and appurtenant components

6.3.7 Programming interface

A connector for the ARM SWD interface is included on the product example for easy firmware upgrade purposes.

When this interface is connected to a compatible programmer, firmware upgrades can be made directly on the board. The interface is found on the 10 pin connector **P1**, see the figure below.

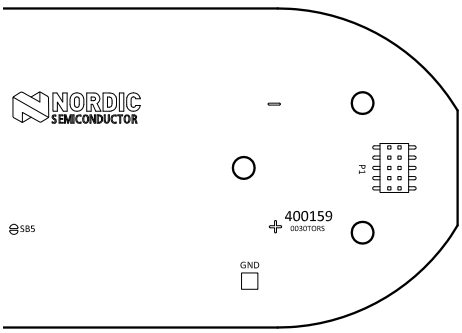


Figure 40: Location of SWD interface connector P1

Firmware update of Smart Remote 3 on page 54 describes how to connect and perform firmware upgrades and debugging of the product example.

> **Important:** Make sure that pin 1 on the **P1** connector on the PCA20018 board is connected to pin 1 of the connector on the programmer unit.

Table 6: SWD interface connector pin configuration

Pin	Label	Description
P1_1	VDD	Reference voltage for programmer
P1_2	SWDIO	Serial wire debug data
P1_3	GND	Ground
P1_4	SWDCLK	Serial wire debug clock

Pin	Label	Description
P1_5	GND	Ground
P1_6	NC	No connection
P1_7	NC	No connection
P1_8	NC	No connection
P1_9	GND	Ground
P1_10	NC	No connection

6.3.8 Matching network

The design is using an integrated balun from Johanson Technology for converting from differential to single-ended signal and transforming the impedance to 50 Ω.

Layout of the matching network, component size, and component values are exactly as given in the application example found on Johanson Technology's website. This reference matching network layout is also available for download from Johanson Technology.

6.3.9 Antenna

The product example has an integrated chip antenna from Johanson Technology.

Go to Johanson Technology for more information on the chip antenna. The antenna is tuned to be resonant at 2.44 GHz, and the impedance is matched to the 50 Ω output of the balun with the use of two series inductors (**L1** = 3.3 nH, **L2** = 1.5 nH) and a shunt capacitor to ground (**C4** = 1.2 pF). The antenna in this design is tuned for this layout only, and with the same plastic casing. If the layout and/or the casing is changed, it is likely the antenna must be retuned. The antenna can be retuned by adjusting the values of **L1**, **L2** and **C4**. The exact values of the components must be determined by measurements with a vector network analyzer.

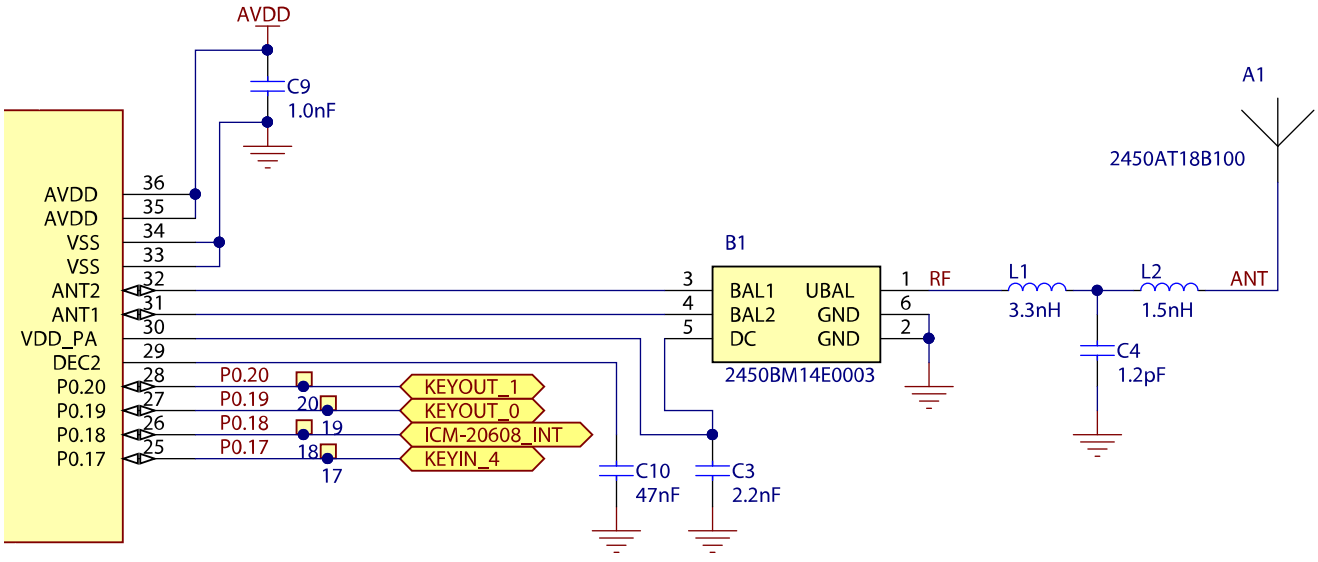


Figure 41: Matching network and antenna circuit

6.3.10 Schematics, bill of materials, PCB layout files, production files

Hardware files for the Smart Remote 3 nRF51 product example are available in a zip package.

The hardware files for the Smart Remote 3 nRF51 product example will be located in the following folder in the hardware files zip package:

`\nRFready Smart Remote 3 for nRF51 series x_x_x\nRF6933 - nRF51 Product Example x_x_x.`

In this folder you can find the bill of materials, schematics and PCB layout files in PDF format, Altium Designer files, and production files (assembly drawings, gerber files, drill files, pick-and-place files).

Chapter 7
Firmware update of Smart Remote 3

A step-by-step guide for connecting your remote control to a debugger for firmware upgrades on the nRF51822 device is included in this section.

If you are programming the DK add-on, the nRF51 DK has the SEGGER J-Link built in, and can be used through the USB cable. If you are programming the product example, the nRF51 DK can be used as the debugger.

7.1 Connect the product example to the nRF51 DK

The programming and debugging interface of the nRF51822 is accessed through a 10-pin connector (**P1**) on the product example.

To be able to program and debug, the product example needs to be connected to a SEGGER J-Link device. In this user guide we will use the nRF51 Development Kit as reference. Make sure that pin 1 on the **Debug Out** connector on the nRF51 DK is connected to pin 1 on the **P1** connector on the PCA20018 board. Figure 42: Pin 1 position on page 54 shows the position of pin 1 on the **Debug out** connector.

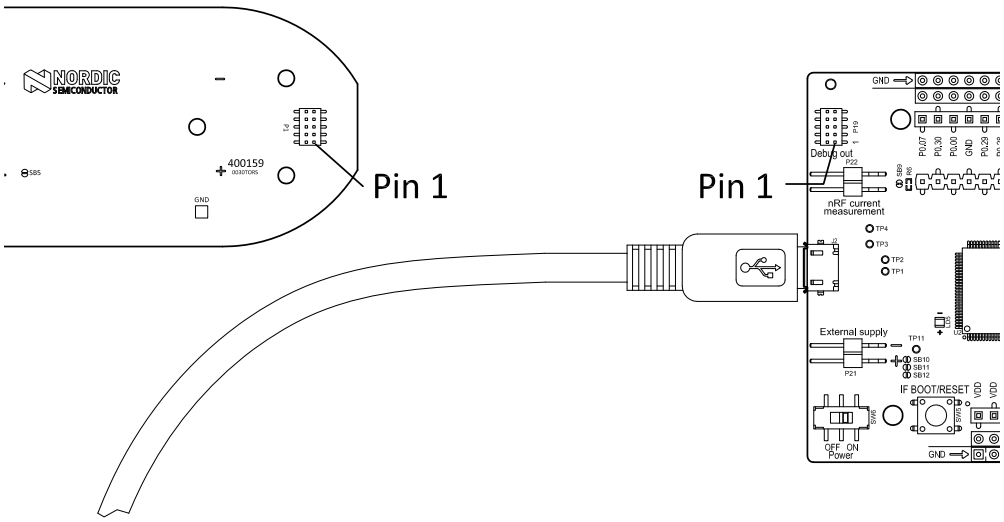


Figure 42: Pin 1 position

To connect the product example to the nRF51 DK, use a 10 pin flat cable. Connect the cable to the product example so there will be a 1-1 mapping of the pins. Figure 43: nRF51 DK connected to the product example on page 55 shows what the connection should look like.

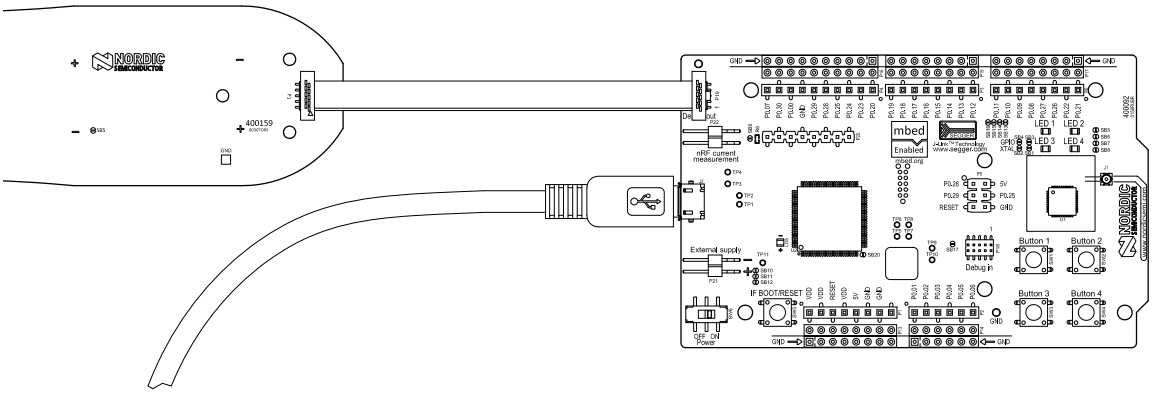


Figure 43: nRF51 DK connected to the product example

7.2 Flash programming

The Smart Remote 3 flash memory can be programmed through the SWD interface.

The application can be used either as a stand-alone application or on top of the S110 SoftDevice (protocol stack). Note that the S110 is not a part of your application, but a completely separate binary. For more information, see the S110 SoftDevice Specification. In this chapter we describe how to program and erase the S110 SoftDevice or another application HEX file on the nRF51822 chip. If you want to start developing on the nRF51822 chip without using the S110 SoftDevice see section Programming application on page 58.

7.3 Programming and erasing flash using nRFgo Studio

Use nRFgo Studio to erase memory content or program SoftDevice and application HEX file onto the nRF51822 chip.

> **Important:** For details on memory organization and protection, see the nRF51 Series Reference Manual.

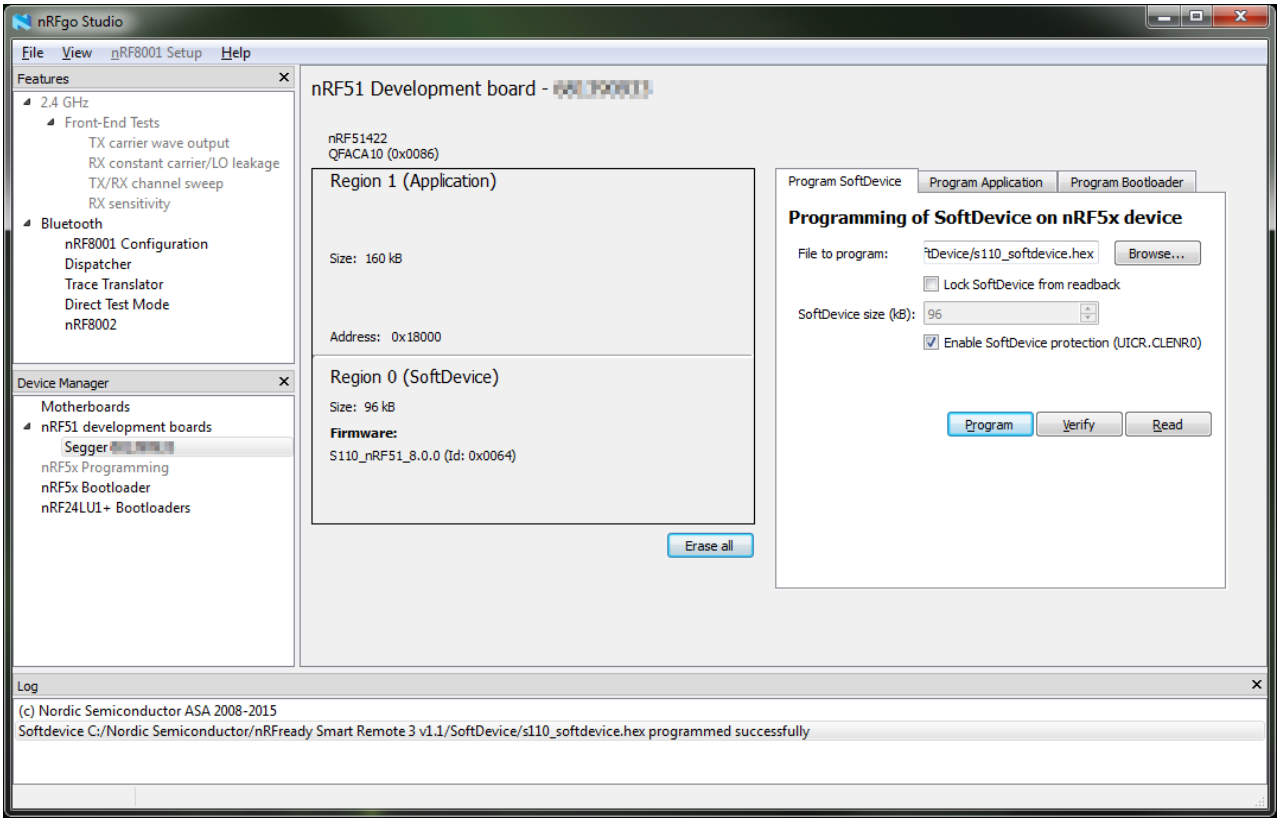


Figure 44: nRFgo Studio dashboard

7.4 Selecting a board to program

This shows the steps you need to do to select the board to program.

1. Open nRFgo Studio.
2. In the **Device Manager** pane, select nRF51 development boards.
3. Select the Segger ID matching the nRF51 DK connected to the product example.

7.5 Chip and memory information

When you select a board, nRFgo Studio identifies the nRF chip and how its memory is organized.

Table 7: Chip and memory information displayed in nRFgo Studio

Chip and memory information	Description
nRF chip identification	Identifies the chip by name and code variant (for example, nRF51822 QFAAA0). If the debugger is not connected to the chip, or the debugger has a problem communicating with the chip, it will show the following message “No device detected. Ensure that you have the SEGGER connected correctly to the board and that the board is powered and configured for debugging.”

Chip and memory information	Description
Code memory	Shows how the code memory is organized in one or two regions (Region 0 and 1) and the size of each region. For devices containing a SoftDevice, the code memory is divided in two regions, with the SoftDevice in Region 0. The tool shows you how much memory is used by the SoftDevice and how much is left for the application.
Memory readback protection	Shows how readback protection is set. The two possible options are readback protection on Region 0 or readback protection of the whole code memory. If there is only one region the option is readback protection on (All) or off.
SoftDevice identification	nRFgo Studio tries to identify the firmware located in the chip at Region 0. For the firmware that it recognizes it displays the ID (in clear text) for the unrecognized firmware it displays the FWID number.

7.6 Erase all

The Erase all function will clear everything in the flash memory.

Use Erase all in the following situations:

- You have a chip that is programmed with a SoftDevice but you want to remove it and have a blank chip.
- You have programmed an application on a clean chip using nRFgo Studio with the option **Lock entire chip from readback**.

To use the Erase all function, follow the steps in section Selecting a board to program on page 56. Then click **Erase all**.

7.7 Programming SoftDevice

This function lets you program the SoftDevice onto the chip.

Before you start, perform the steps in Selecting a board to program on page 56.

Program the SoftDevice onto the chip in the **Program SoftDevice** tab.

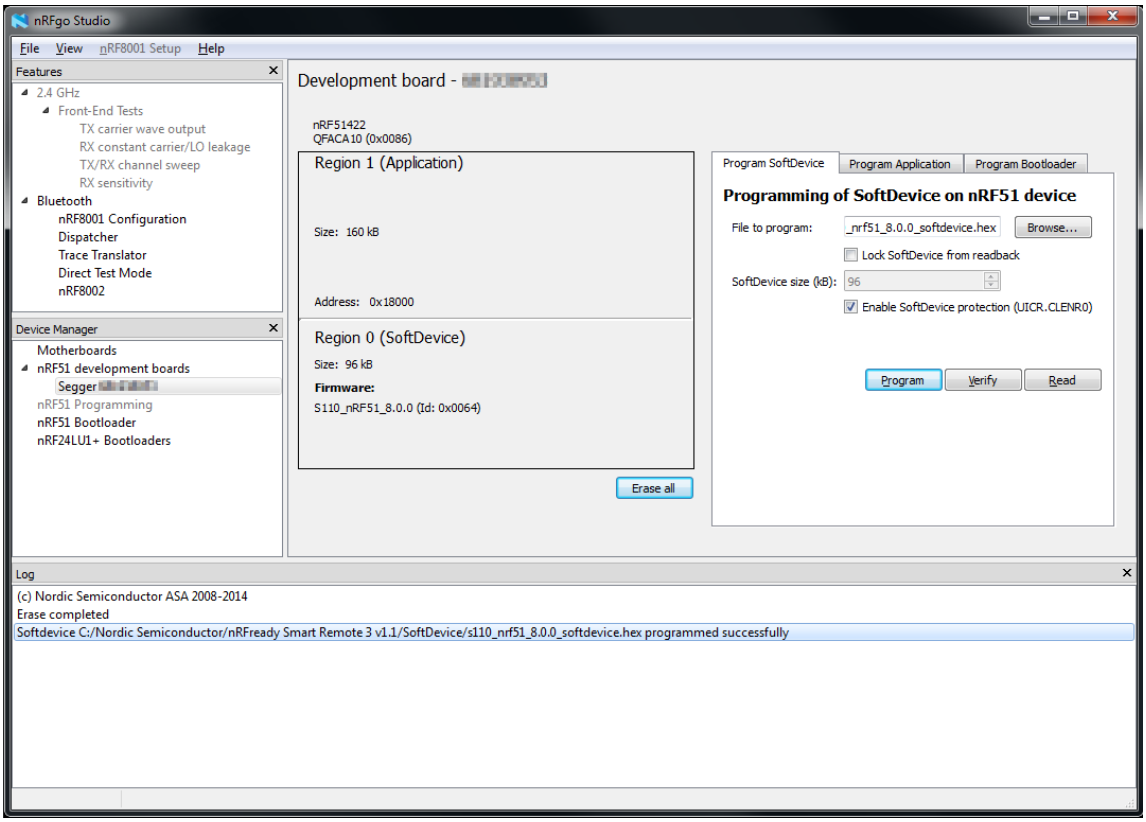


Figure 45: nRFgo Studio Program SoftDevice tab

1. Select the HEX file to program. Click **Browse** to find the file.
2. Select if you want to enable or disable readback protection of Region 0.
3. Set SoftDevice size.
   This sets the size of the code memory region 0 and will not be available if the size is defined by the HEX file.
4. Click **Program**.

   Important:

   The SoftDevice is included in the installer file of the Smart Remote 3 for nRF5x.

7.8 Programming application

This function lets you program an application onto the chip.

Before you start, perform the steps in Selecting a board to program on page 56.

Before nRFgo Studio starts programming, it verifies that the HEX file matches the actual memory configuration. If it matches, nRFgo Studio continues with the programming, if not, it stops the programming and returns an error message. For example, if an application requires the SoftDevice on the chip, it will check the memory configuration for the SoftDevice before programming the chip.

Important: This programming will not set up any memory Regions.

Program an application onto the chip in the **Program Application** tab.

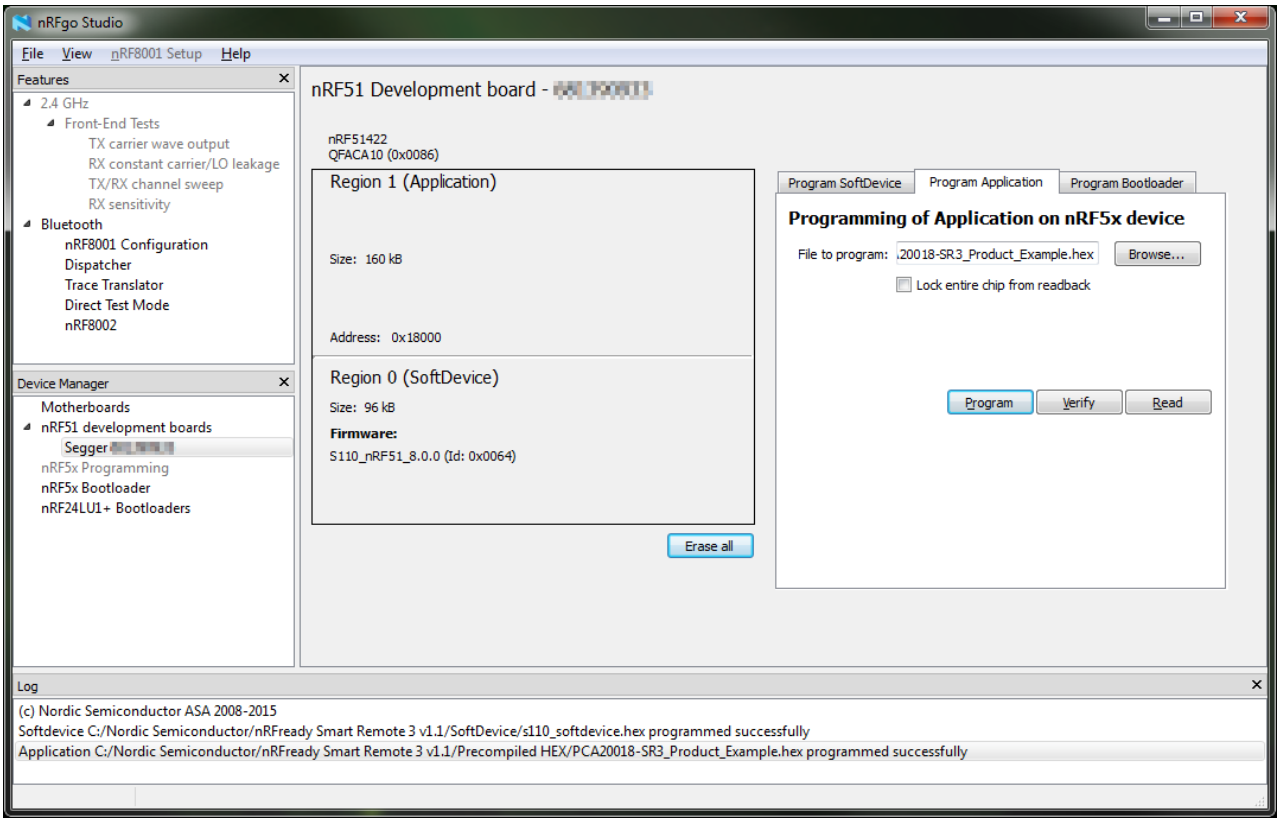


Figure 46: nRFgo Studio Program Application tab

1. Select the HEX file to program. Click **Browse** to find the file.
2. Select if you want enable or disable readback protection of the entire chip.

   If you enable readback protection, you will have to do an Erase all to reprogram the chip again.

   A chip that is programmed with **Lock entire chip from readback** enabled will not work with a development toolchain. To make it work you must perform Erase all. **Lock entire chip from readback** can be used to prevent an accidental overwrite of chip content.
3. Click **Program**.

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