# Introduction

The bachelor’s Thesis is realised in collaboration with Nordic Semiconductor and NTNU at Trondheim. Each collaborator society has its own goal, explained below. The main idea of this project is to use the operating system Zephyr RTOS with nRF5x series SoC from Nordic Semiconductor.

## What is Zephyr and Why to use it

Zephyr RTOS is a recent open source RTOS under the Apache 2.0 license designed for IoT technology and it implements all the protocols to use the technology Bluetooth Low Energy (BLE).

At first, this RTOS is particularly interesting for Nordic Semiconductor because BLE is the main feature of the Nordic produce.

In the other hand, the SoCs of Nordic Semiconductor have now the memory requirement to use a RTOS as Zephyr.

## Goal for Nordic Semiconductor

The goal for Nordic semiconductor is to test the behaviour of Nordic’s nRF5x series SoC using Zephyr RTOS. More specifically, it is important for Nordic Semiconductor that the requirements to use the BLE with high traffic are respected and provide an advantage compared to a Bare Metal system.

## Goal for NTNU

The goal for NTNU is to simplify the data transfer from a sensor, developed at the University, to a PC. An embedded solution is fully adapted to this purpose and the BLE allow all the requirements for a perfect data transfer and to create a network with several sensors.

A template developed on nRF5x, which implements Zephyr, and provides a real-life test to measure the performance of this RTOS.

# Specifications

## Behaviour of Zephyr RTOS

The behaviour of a Nordic’s nRF5x series SoC with Zephyr RTOS is tested under different conditions and the following performances are measured:

* **Interrupt latency and RTOS-induced latency**
* **Power consumption**

Those performances are measured when running the BLE controller with high traffic. To determine if using Zephyr is an advantage, the performances are measured on a Bare Metal system that executes the same tasks.

To create test conditions, a system (server or peripheral in BLE) acquires data from different devices:

* **Sensor developed by NTNU**
* **A/D converter**
* **Accelerometer**
* **Interrupt generator**

The different devices allow to test the processor in real circumstances and to generate interruptions to stress the system. Then a PC (client or central in BLE) are notified of the data acquired via BLE.

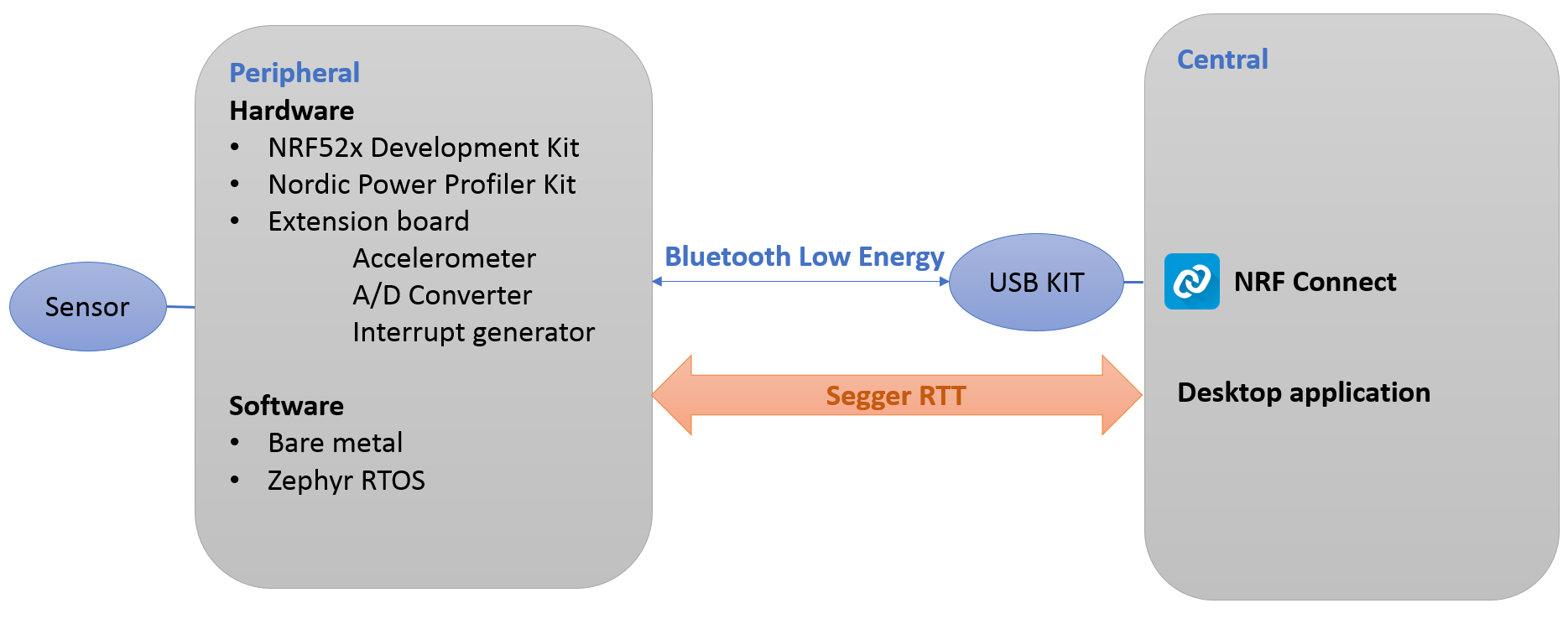


Figure 1: Systems representation

## Template for sensor data acquirement

The template is created for two purposes:

* Make easier **to interface sensor/PC**
* Make easier **to create a star network** with several sensors

The interface with a sensor and a PC is made with BLE and Zephyr RTOS implemented on Nordic’s Chip.

The kind of sensor is the same than the sensor used to test the behaviours of Zephyr RTOS. Therefore, the main part of the implementation will be already done.

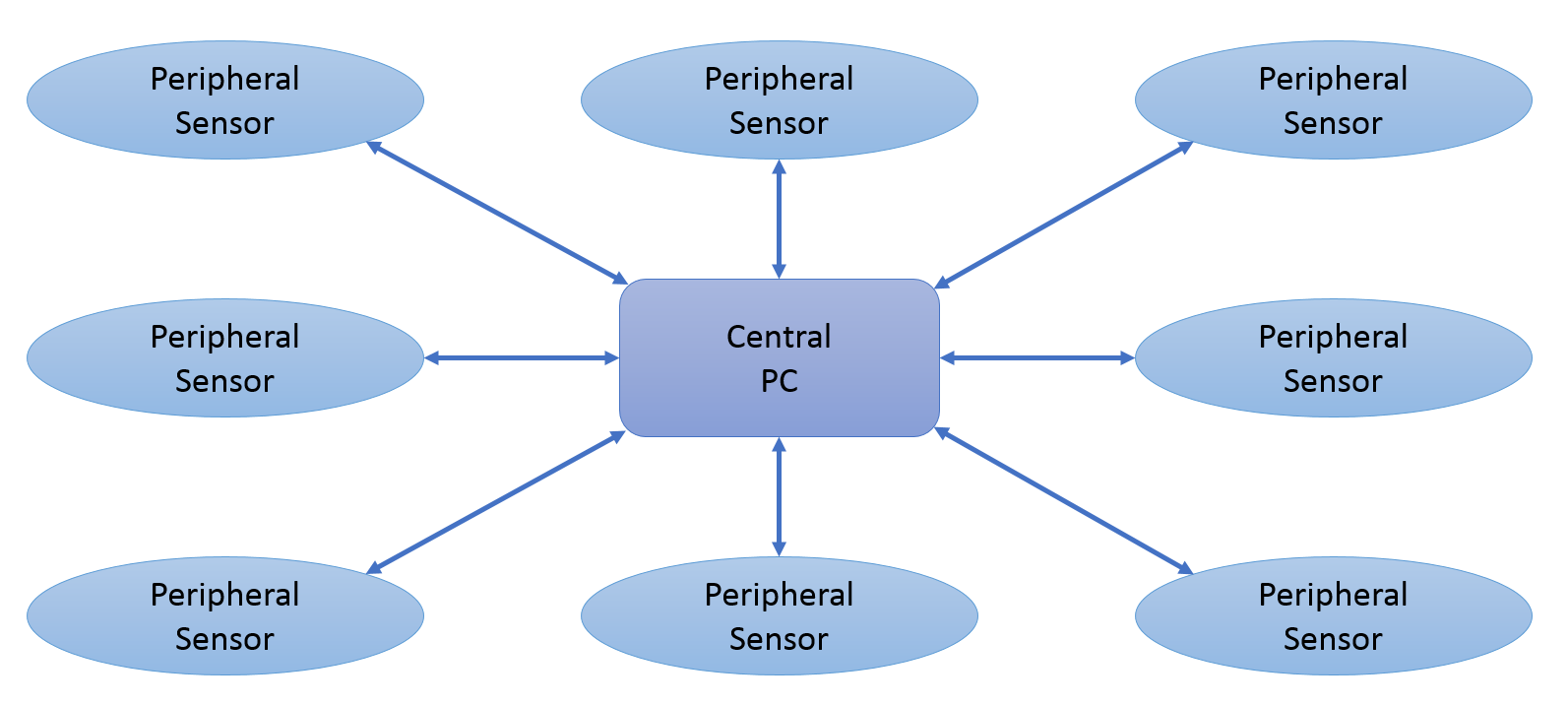


Figure 2: Start network

## Provided materials

To realise the Bachelor’s Thesis, some materials are provided:

* **Nordic nRF52840 Development Kit** to implement the BLE peripheral
* **Nordic Power Profiler Kit** to measure the power consumption
* **Sensor developed by NTNU** to provide real data

# Hardware

The Hardware is separate in six parts:

* **nRF52840 SoC**
* **Micro USB-B** to communicate with a PC and programme the chip
* **Power supply** provided by the Micro USB-B
* **Nordic Power Profiler** **Kit (PPK)** to measure the power consumption of the chip only
* **Connector interface** to connect the extension board, Power Profiler Kit and nRF52840 DK
* **Extension Board** to provide data to the chip

The extension board is the only part that is developed for this project. The Power supply 3V, the Micro USB-B and the nRF52840 SoC are on the nRF52840 Development Kit.

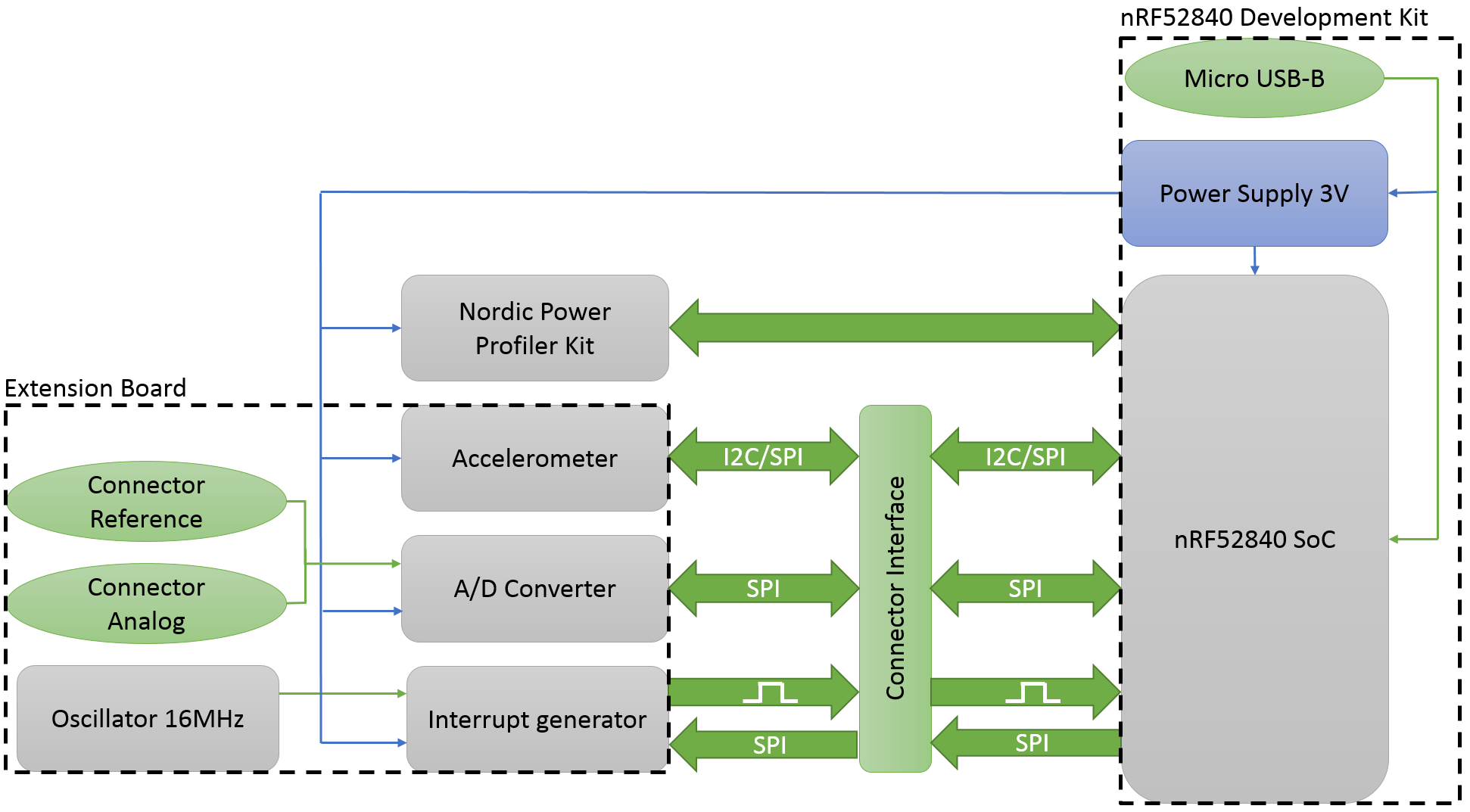


Figure 3: Hardware schema block

## nRF52840 SoC

… Why this chip

Describe some features

## Micro USB-B

The connector Micro USB-B is used for different purposes:

* **To programme** the nRF52840 Chip
* **To provide 5V power supply** to the system
* **To Debug** the nRF52840 Chip
* **To transfer the data measured** with SEGGER Real Time Transfer

The connection SEGGER Real Time Transfer (RTT) is used by the Nordic Power Profiler Kit to transfer the data to a PC. This connection can be used to transfer other data from nRF52840 chip as results of performance measured.

## Power Supply

The power supply transforms the power supply of 5V, provided by the Micro USB-B, to 3V to supply all the system. To transforms the power supply, there is a fixed 3V buck regulator and one voltage follower regulator on the nRF52840 DK.

Due to the low consumption of the system, **estimation**, the power supply of the nRF52840 DK is far enough to provide power to all the system.

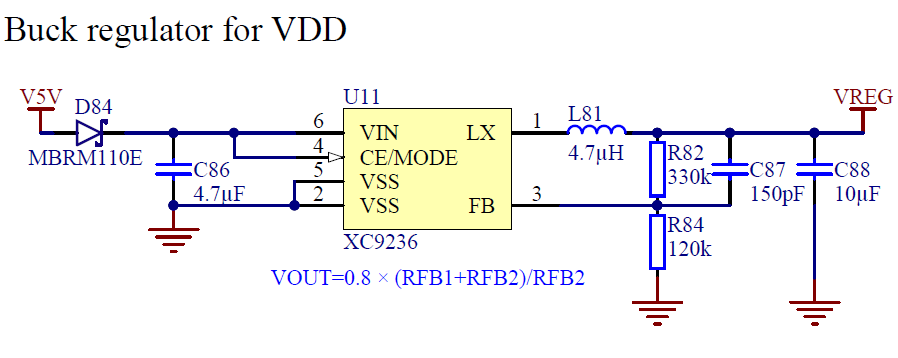


Figure 4: Regulator buck 3V schematic

## Connector Interface

The connector interface is defined by the nRF52840 development kit and is almost the same for all the Nordic’s DK.

The connector allows:

* **To supply the extension board and the Power Profiler Kit**
* **To measure the power consumption** of a nRF5x SoC
* **To access to the GPIOs** of a nRF5x SoC

The extension board and the Power Profiler Kit are plugged on the nRF52840 DK with the connector interface that allow an easy connection of the different part of the system.

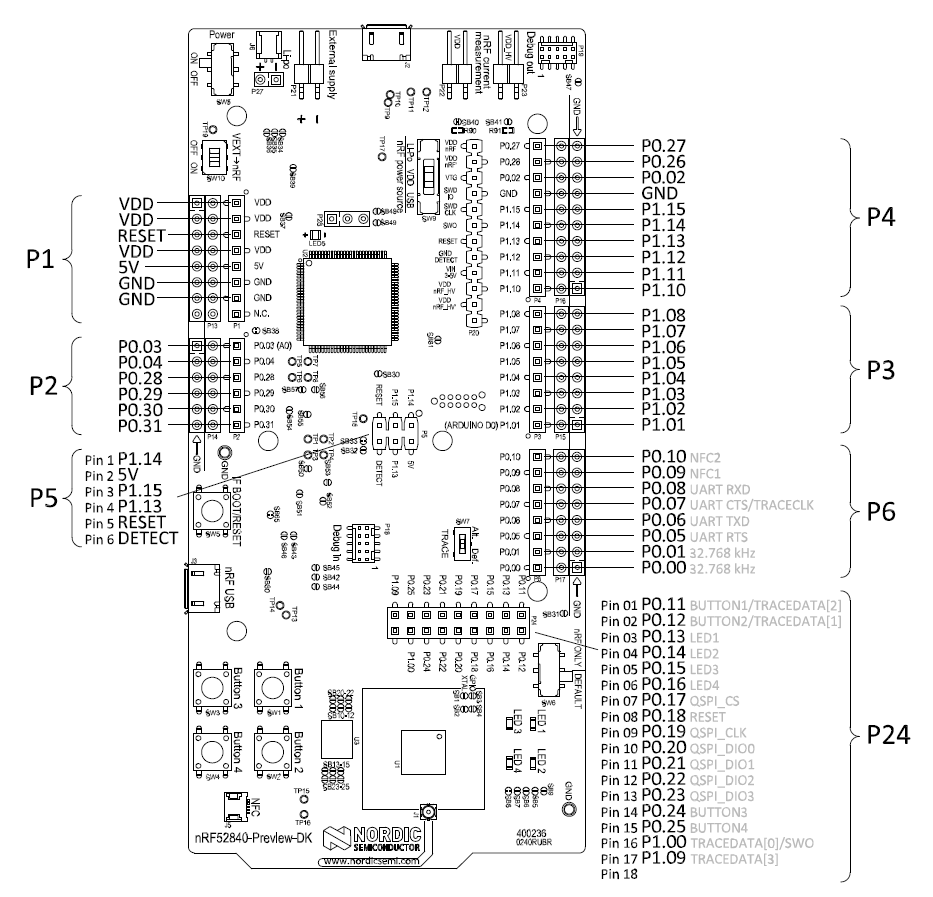


Figure 5: nRF52840 Preview DK board connectors

## Nordic Power Profiler Kit

The Nordic Power Profiler Kit is an easy use tool for the measurement and power consumption optimization of embedded solutions. It provides the following features:

* **1µA-70mA current measurement range**
* **0.2µA measurement resolution**
* **77kHz sampling rate**
* **Desktop application** in python allowing customization

The Nordic Power Profiler Kit is the best solution because it allows to measure only the power consumption of the nRF5x chip.

The Desktop application communicate with the PPK using the SEGGER Real Time Transfer of the nRF5x Chip. This connection can be used to transmit other measurements via RTT. The Desktop application can be modified to display those measurements.

## Extension Board

The extension board is the single part that the hardware is developed. It is connected to the nRF52840 DK using the interface connector.

The purpose of the extension board is to use the nRF52840 Chip under real conditions of use. To do that, the extension board provide the different elements.

* **A/D converter** that can be connected to a generator function or an external sensor.
* **Accelerometer**
* **Interrupt generator**

All components as some general criterion to ease the order:

* **Not too expensive (max 5CHF/43NOK)**
* **Package easy to solder**
* **Same provider**

### A/D Converter

The A/D Converter provides a large quantity of data that the chip must be able to deal with no loss. As the large quantity of data to stress the chip, the way to get the data must stressful as well.

The component used is the Delta-Sigma ADC **MAX11200** that provides the following features:

* **24 bits Resolution**
* **2.7 to 3.6V power supply**
* **Reference Voltage**
* **SPI (SCL max 5MHz)** to calibrate and get the data
* **Ultra-low-power** with power-down mode
* **Data range bandwidth**

An ADC communicating with SPI is chosen due to the requirement to communicate fast.

The Analog input can be provided by a function generator (Connector BNC 50Ω) or by an external analogue sensor (Pin 2x1). Two resistances can be soldered to use the ADC in current loop system.

The Reference voltage can be the power supply voltage or an external reference if the external sensor has specific requirement.

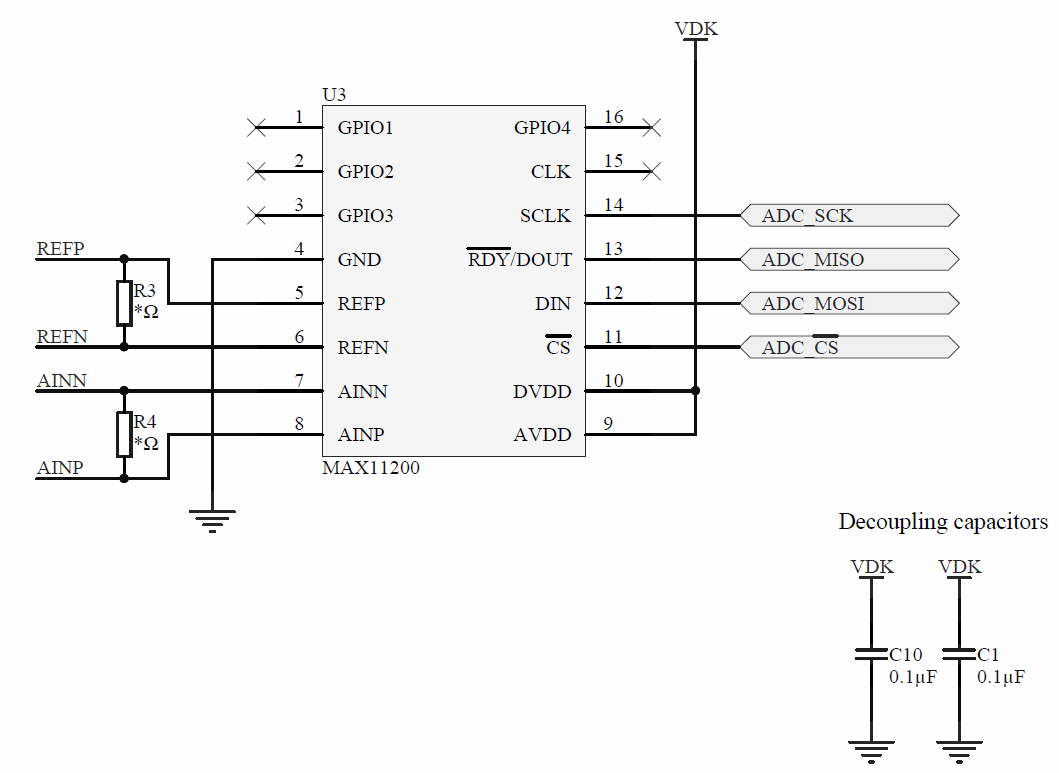


Figure 6:MAX11200 schematic

### Accelerometer

As the A/D Converter, the accelerometer provides a large quantity of data that the chip must be able to deal with no loss.

The component used is the accelerometer **LIS3DH** that provides the following features:

* **16 bits Resolution**
* **3-axis**
* **±2g/±4g/±8g/±16g**
* **1.7 to 3.6V power supply**
* **FIFO 32-level 6 bytes**
* **I2C (SCL max 400kHz)/SPI (SCL max 10MHz)** to get the data
* **2 Interrupt pins** to notify when new data are available
* **Ultra-low-power** with automatic power-down mode
* **Data range bandwidth**

An accelerometer communicating with I2C is chosen to use different features of the chip. However, the SPI can be used as well.

The LIS3DH provide a FIFO to store data. This FIFO can be read at one time with a frame of 192 bytes, 2 bytes per axis. This frame provides a good test to stress the chip.

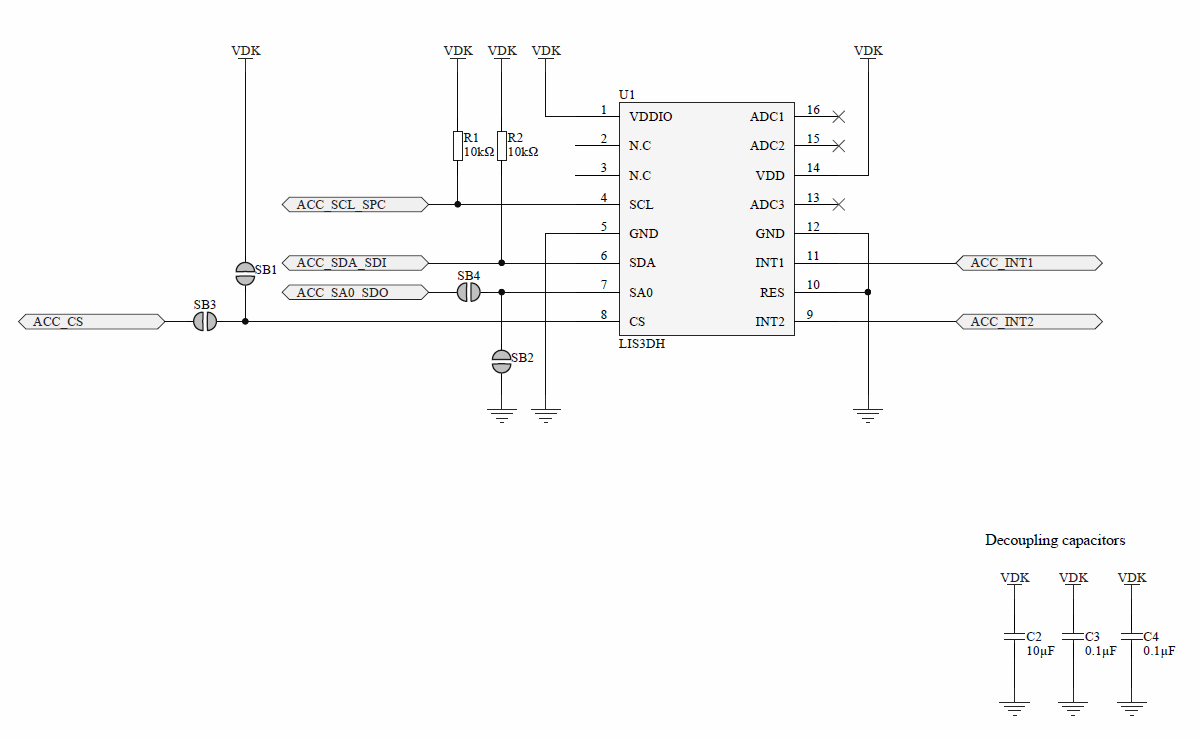


Figure 7:LIS3DH Schematic

### Interrupt generator

The interrupt generator generates pulse that create interruptions in the programme. The period of interruptions can be easily changed to modify the test conditions.

The component used is the Programmable Waveform Generator **AD9837** that provides the following features:

* **16MHz Clock**
* **28 bits (0.06Hz)** **Resolutions**
* **2.3V to 5.5V power supply**
* **3 Wires SPI** to programme the waveform type and frequency
* **Low power** with power-down option

A 28Bits Register is used and programmable via SPI to calculate the frequency. The formula below defines the frequency:

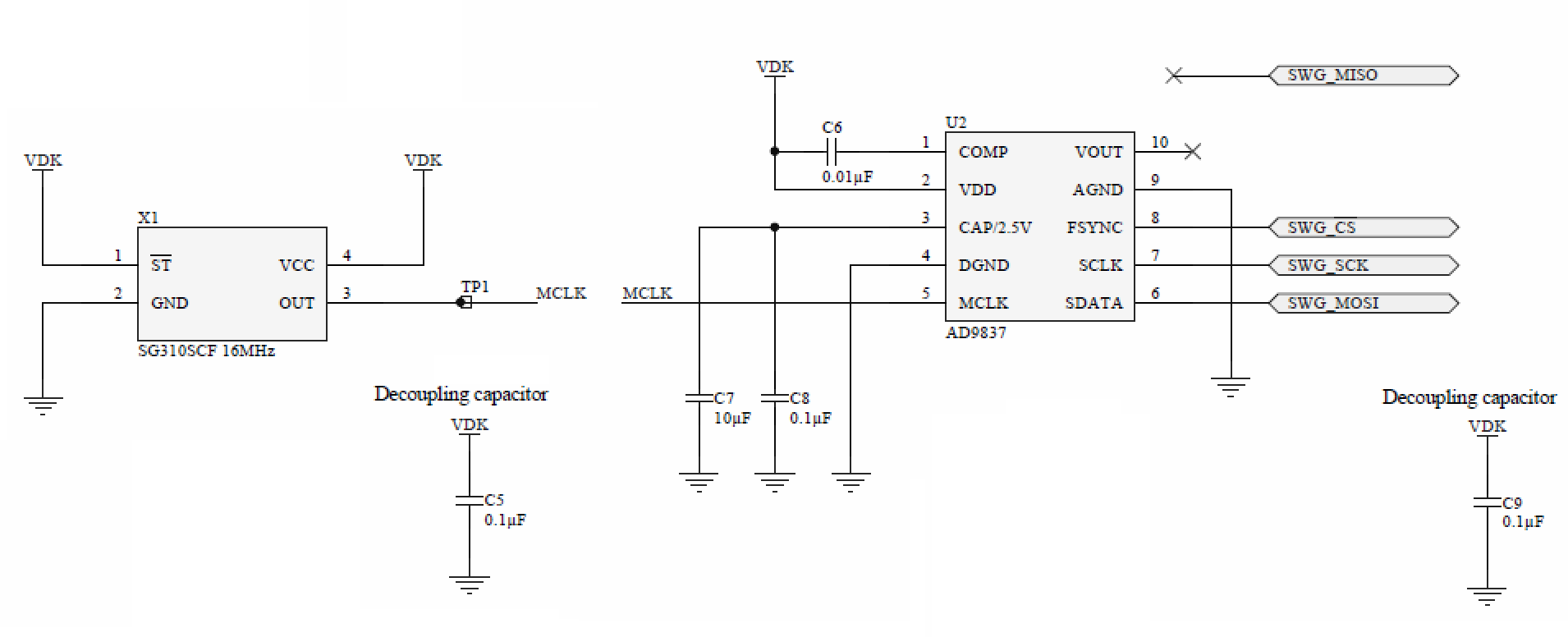


Figure 8: AD9837 schematics