FYS3240/4240

Lab3: **Arduino and IDE basics, sensors & serial communication**

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Introduction

In this lab you will

- read data from the IMU and magnetometer on the Nano 33 board,
- find the direction of the sensitive axis of the sensors and define a common body frame.
- send sensor data to a LabVIEW program on a PC and
- measure angles by processing rate gyroscope data in LabVIEW.

Install Arduino IDE

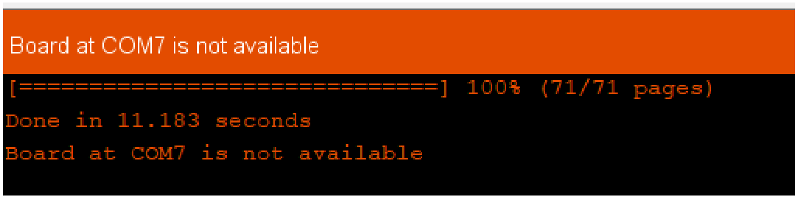
Follow https://www.arduino.cc/en/Guide/NANO33BLESense

Exercise 1 – Run your first Arduino programs

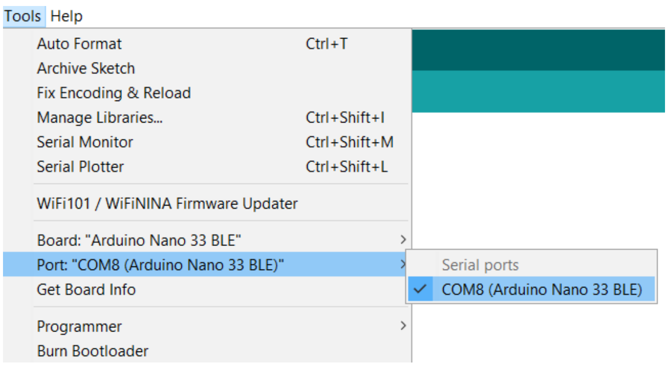
Read the "Getting started with the Arduino NANO 33 BLE Sense" from https://www.arduino.cc/en/Guide/NANO33BLESense. See also the lecture "Arduino and Arduino Nano 33 BLE sense". See also chapter 6.1 in the Arduino Cookbook. Chapter 6.15 and 6.17 in the Arduino Cookbook give examples of the use of accelerometer and gyroscope, but using a different IMU and IMU library.

Note:

- Normal error message due to switch between two COM-ports on the Nano 33 board:



- **Solution: After upload of the code to the Nano 33, select the correct COM-port before you open serial Monitor/Plotter.**



Run the accelerometer example in IDE:

1. Open sketch: **File – Example – SimpleAccelerometer**
2. **Verify** and **upload** code to the board.
3. Open the **serial plotter (**Tools-menu).
4. Observe how the signals change when you turn the board.
5. Verify the positive directions of the sensitive axis (ax, ay, az) of the accelerometer, see Figure 1, by measuring the Earth gravity vector and/or creating a linear acceleration. Hint: see the lectures!
6. Similarly, upload the sketch **SimpleGyroscope**, and verify that the positive rotation directions are as expected based on point 5 and Figure 3.
7. Upload the sketch **SimpleMagnetometre.** Determine the positive directions of the sensitive axis (Bx, By, Bz) of the magnetometer by measuring the Earth magnetic field vector. Make a drawing of the magnetometer axis on Figure 2.
   Hint: The Earth's magnetic field points down, and a sensor axis pointing up then gives out a negative value.
8. Are all sensitive (sensor) axis as expected when you compare with the datasheet (Figure 3), for the LSM9DS1? Yes, but I use BMM150 and BMI270
9. We can convert the accelerometer measurements from accelerometer sensor frame S to a defined body frame B (see lectures), to get a right-handed coordinate system:

$$R^{BS} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

   What is the transformation matrix R^{BM} that we need to apply to convert the magnetometer measurements from the magnetometer frame M to the same body frame B?

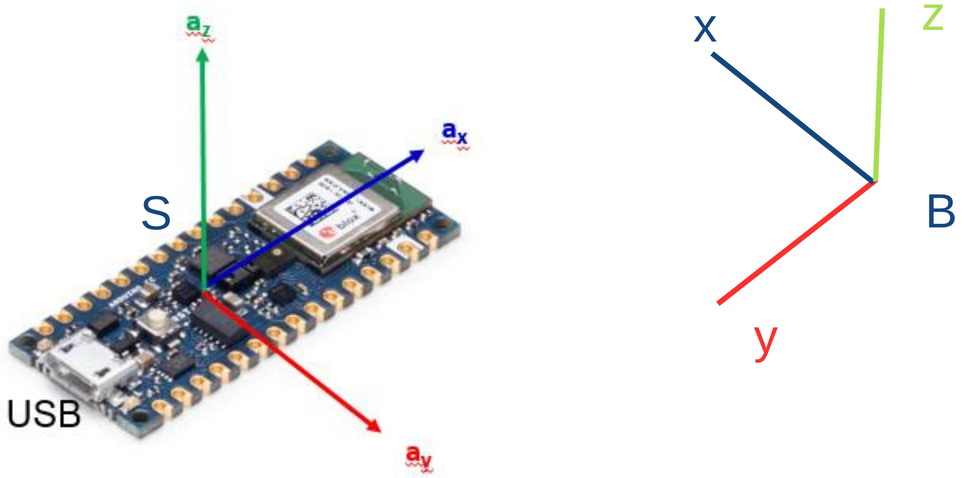
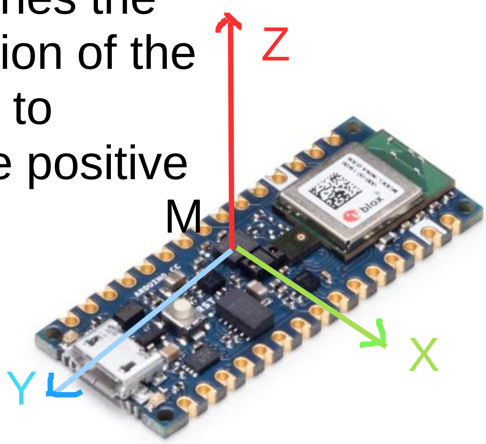


Figure 1 Positive directions of the accelerometer sensor axis in xyz (with accelerometer output +1g, meaning axis opposite with the Earth's downward gravitational field) defines the sensor frame S.

The axes determines the orientation of the arduino to produce positive values



$$ {}^{BM}R = \boxed{\begin{matrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{matrix}} $$

Figure 2 Draw magnetometer sensitive axis, defining the magnetometer frame M.

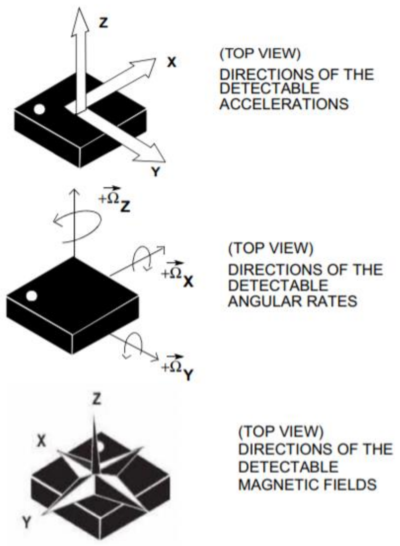
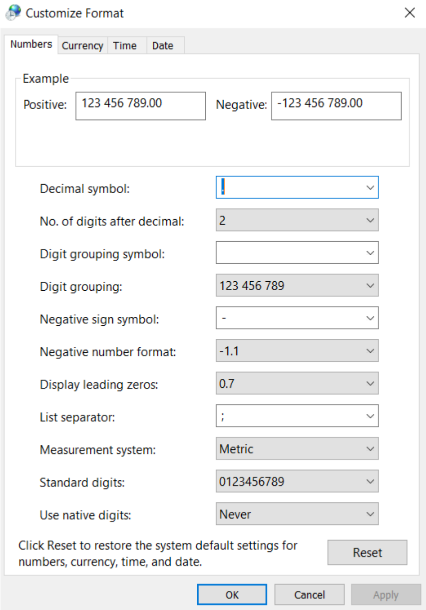


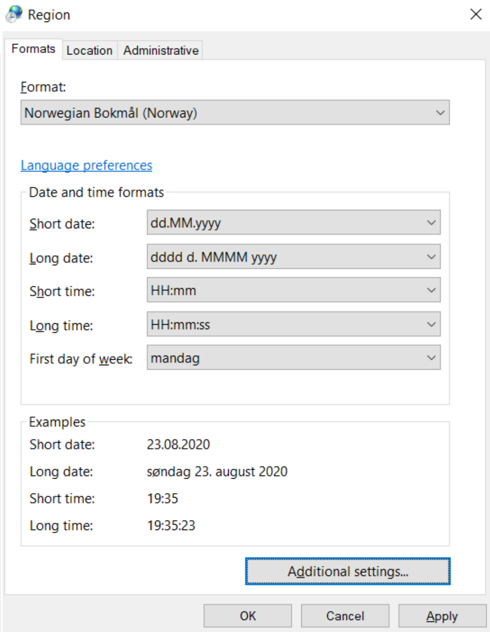
Figure 3 LSM9DS1 (IMU and TAM) sensor axis.

Exercise 3 - Send sensor data to LabVIEW using serial communication

Note: Change decimal symbol to "." under computer **regional settings - *Additional settings***!

- Change <u>decimal symbol</u> to "." (from "," which is standard in Norwegian) - see ARDUINO LECTURE.
- *This is required by the Spreadsheet string to Array* function in LabVIEW!





1. Read chapter 4, page 113 to 149, in the Arduino Cookbook.
2. Upload the sketch **SimpleGyroscope** to the Arduino board.
3. Study the Arduino program, and make sure that you understand the code!
4. Open the LabVIEW-program **SerialDataRead_3CH.vi**
5. Study the LabVIEWprogram, and make sure that you understand the code! Remember to look at the sub-vi Timer.vi.
6. Run the program **SerialDataRead_3CH.vi** on the computer to receive serialized gyroscope data from the Arduino board. Observe the measured loop frequency. Is the loop frequency as expected according to the default setting of the LSM9DS1 library? See Figure 4.
7. Open the LabVIEW-program **SerialDataReadWrite_3CH.vi**. Explain what happens to the loop frequency and why this happens.
8. Change the program SerialDataReadWrite_3CH.vi such that the write to spreadsheet function is in a separate while loop and the data transfer between loops is by a queue. With other words, use a producer-consumer structure. Save the new files as **SerialDataReadWrite_3CH_parallel.vi**
9. **Run** your new program **SerialDataReadWrite_3CH_parallel.vi** and observe the loop frequency, is it as expected? Explain.

The ArduinoLSM9DS1 library allows you to use the inertial measurement unit (IMU) available on the Arduino® Nano 33 BLE board. The IMU is a LSM9DS1, it is a 3-axis accelerometer, 3-axis gyroscope, and 3-axis magnetometer. The IMU is connected to the Nano 33 BLE board's microcontroller through I2C. The values returned are signed floats.

To use this library:

```
#include <Arduino_LSM9DS1.h>
```

The ArduinoLSM9DS1 library takes care of the sensor initialization and sets its values as follows:

- Accelerometer range is set at ±4 g with a resolution of 0.122 mg.
- Gyroscope range is set at ±2000 dps with a resolution of 70 mdps.
- Magnetometer range is set at ±400 uT with a resolution of 0.014 uT.
- Accelerometer and gyrospcope output data rate is fixed at 119 Hz.
- Magnetometer output data rate is fixed at 20 Hz.

Figure 4 LSM9DS3 sensor configuration.

Exercise 3 – use the gyroscopes to measure angles

The rate gyroscopes measures angular rate and need to be integrated to give an angle.

1. Have the sketch **SimpleGyroscope** running on the Nano33 BLE sense board.
2. Open the LabVIEW-program **IntegrateGyroscopeData.vi** and look at the code for the consumer. Look at sub-Vis the **RemoveMean.vi** and **Intgrator_v2.vi**. The median is used to calculate the mean without being affected by outliers.
3. **Run** the LabVIEW-program with the **remove initial offset** not selected (no "tick" in the box), and observe how fast the angle is increasing even when the board is static on the table.
4. **Run** the LabVIEW-program again but now with the **remove initial offset** selected (a "tick" in the box). Observe the angle measurements. Why do we still get this drift in measured angle?

What to hand in

- Answers to 1.7, 1.8, 1.9, 2.6, 2.7, 2.9 and 3.4.
- The LabVIEW code **SerialDataReadWrite_3CH_parallel.vi** you made for exercise 2.8