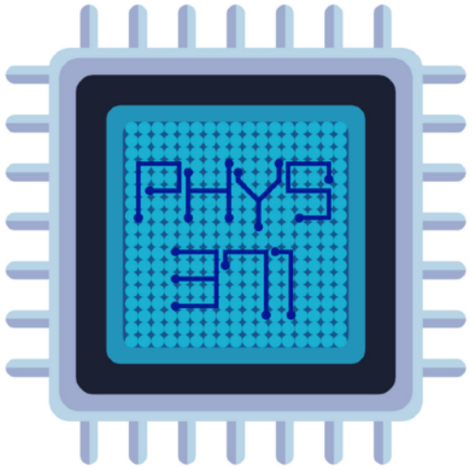


BRIEF INTRO TO DATA ACQUISITION

Dr. Riccardo Longo

02/03/2023

Week 3

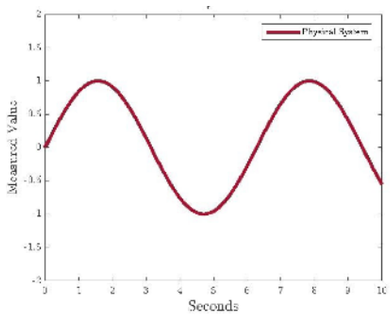
What's DAQ

DAQ is the abbreviation for **D**ata **A**cquisition **S**ystem

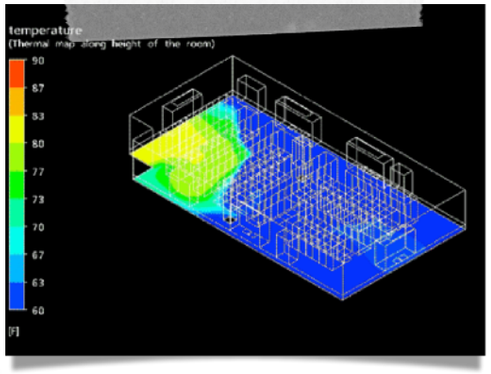
Data acquisition is the process of digitizing data from the world around us so it can be displayed, analyzed, and stored in a computer. It is comprised of different steps

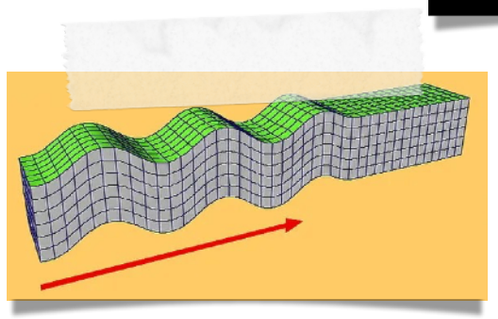
All starts with a measurement to be done!

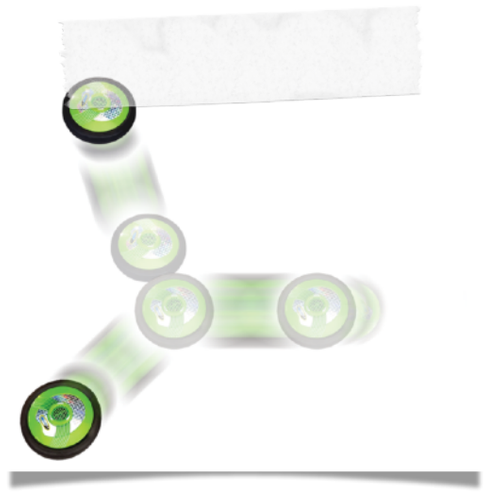
Physical signal (raw input) → Sensor (or transducer) → Signal conditioning → A to D conversion → Computer



Physical Signal





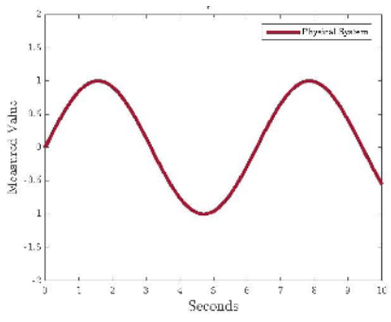


Measurement

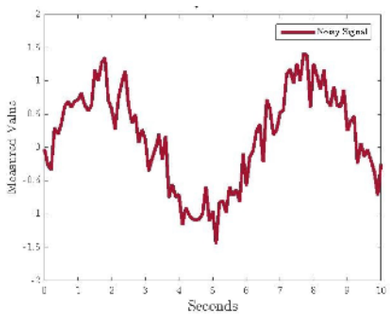
Step 1: use sensors to carry out the measurement

Sensor: interact with the subject of the measurement (directly or indirectly), and produce an output of electrical signals directly related to the observed phenomenon. The type and characteristics of the sensor depends on the nature of the measurement

Physical signal (raw input) → Sensor (or transducer) → Signal conditioning → A to D conversion → Computer



Physical Signal

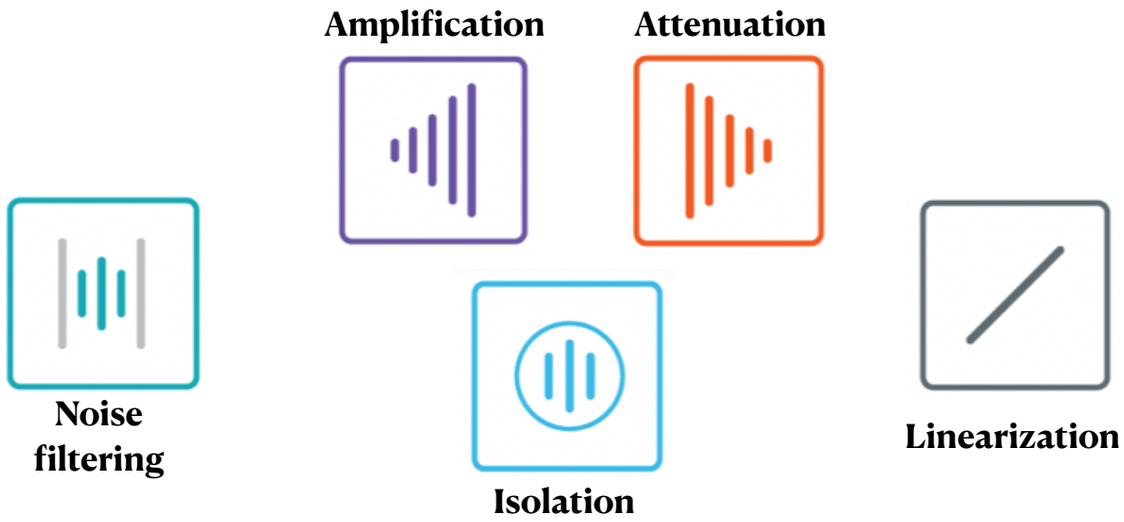


Noisy Electrical Signal

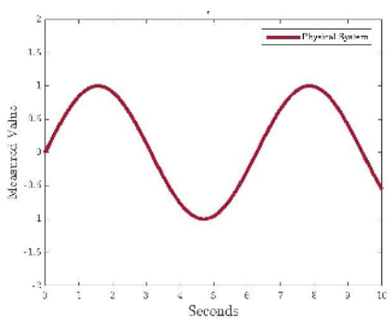
Signal conditioning

Step 3: signal conditioning

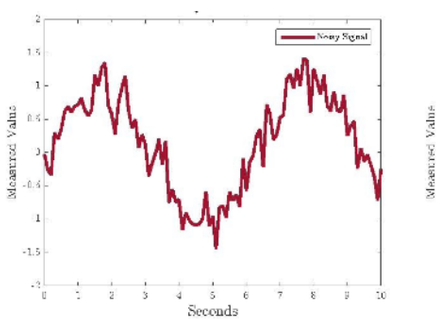
Signal conditioning: manipulation of an analog signal in such a way that it meets the requirements of the next stage for further processing



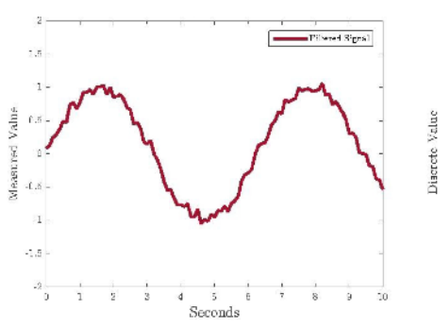
Physical signal (raw input) → Sensor (or transducer) → **Signal conditioning** → A to D conversion → Computer



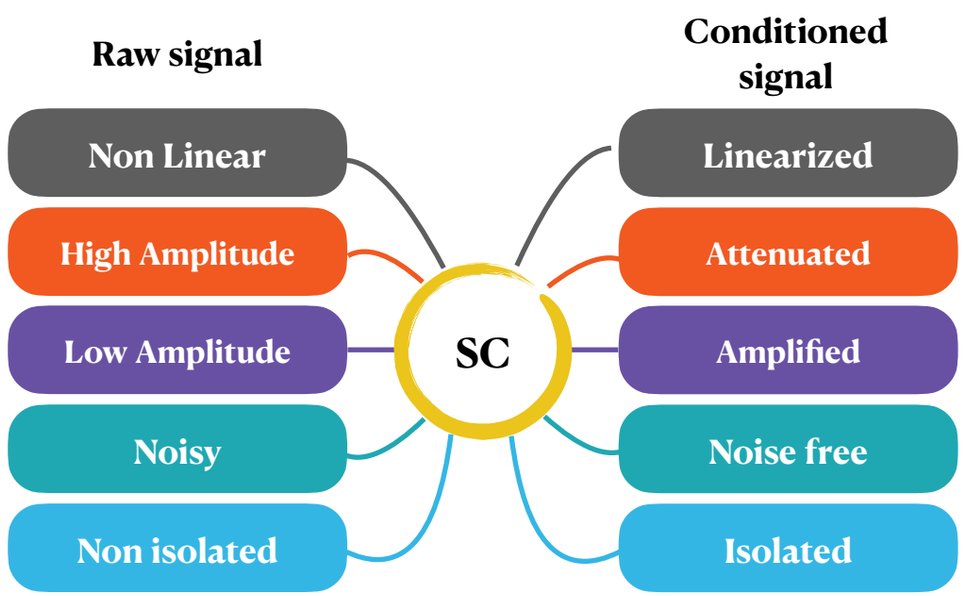
Physical Signal



Noisy Electrical Signal



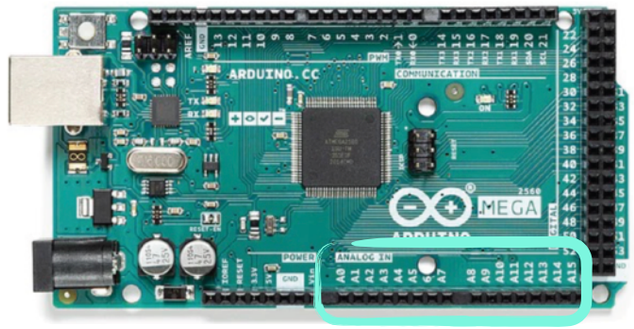
Conditioned Signal



Analog to Digital conversion

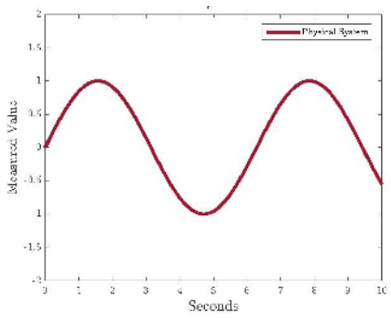
Step 4: Analog to Digital Conversion

Conversion of analog signals to a digital number. Can happen either on the sensor or on the board, before data are fed to the microcontroller.

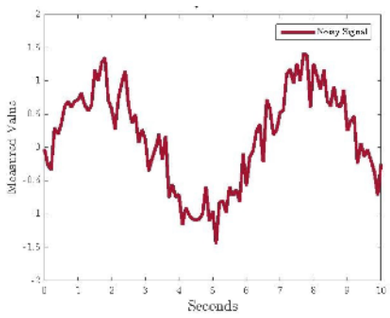


These pins can read analog signals in input

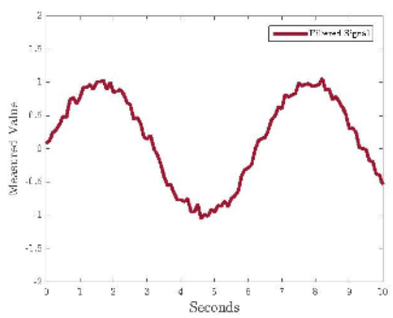
Physical signal (raw input) → Sensor (or transducer) → Signal conditioning → A to D conversion → Computer



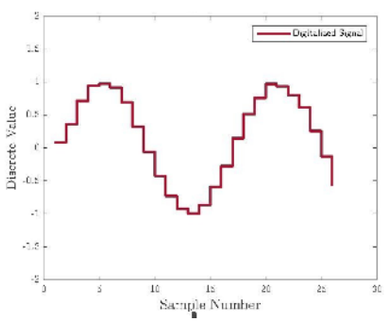
Physical Signal

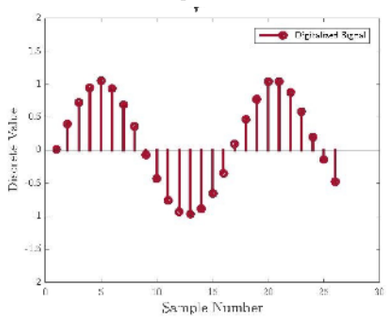


Noisy Electrical Signal



Conditioned Signal





Digitalized Signal

Analog to Digital conversion [2]

Resolution of the ADC

Smallest incremental voltage that can be recognized and thus causes a change in the digital output. Usually expressed in terms of Least Significant Bit (LSB)

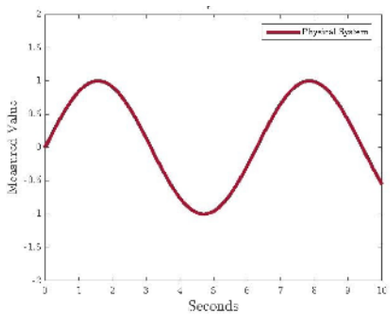
$$1\ \text{LSB} = \frac{\Delta V_{input}}{2^n}$$

n = Number of digital bits output by the ADC

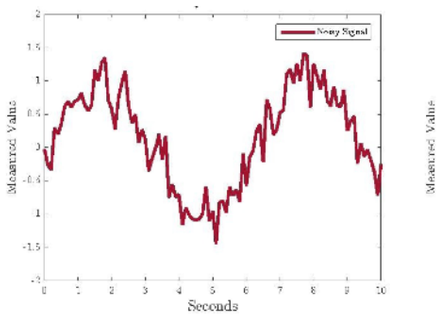
ΔV_{input} = V input range

Example: $\Delta V_{input} = 1$ V, $n = 10$, 1 LSB = 0.98 mV

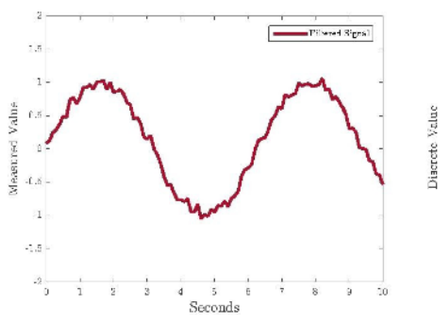
Physical signal (raw input) → Sensor (or transducer) → Signal conditioning → **A to D conversion** → Computer



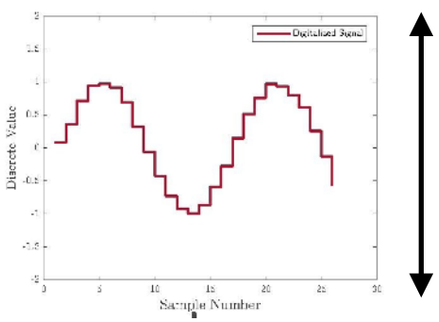
Physical Signal

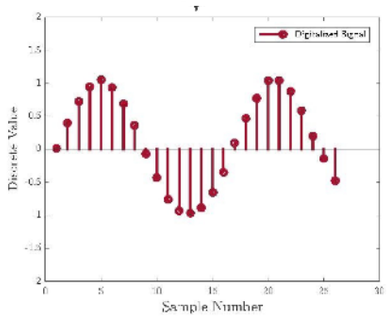


Noisy Electrical Signal



Conditioned Signal





Digitalized Signal

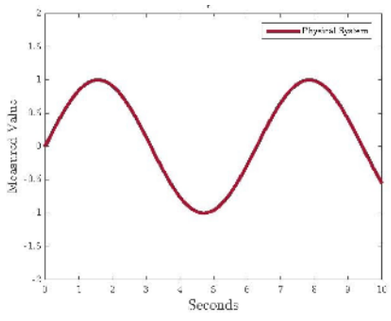
X-axis granularity driven by the 'sampling rate' of the ADC

Data recording

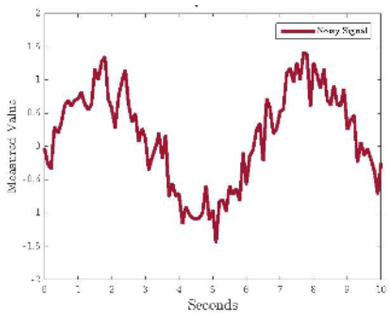
Final step: data recording on a computer!

The end piece of a DAQ chain is a computer that gathers all the data coming through the DAQ hardware and stores them for further analysis.

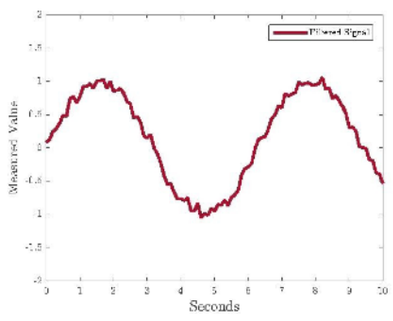
Physical signal (raw input) → Sensor (or transducer) → Signal conditioning → A to D conversion → Computer



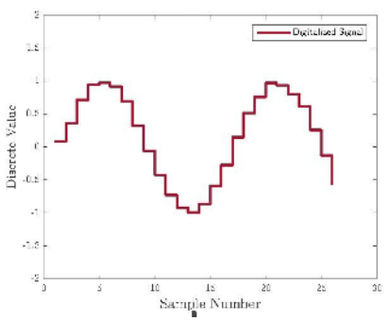
Physical Signal

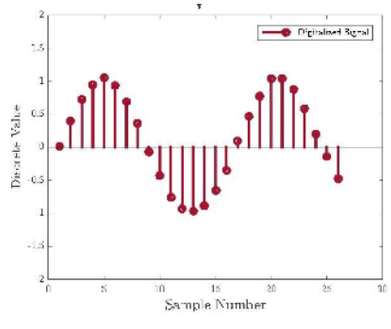


Noisy Electrical Signal



Conditioned Signal





Digitalized Signal

0	1	1	1
0	0	0	1
0	1	1	1
1	0	1	1
1	1	0	0
1	1	1	1
0	1	1	0
1	0	1	0
1	1	1	0
1	1	1	1
0	1	1	1
1	1	1	0
1	1	1	1
0	0	1	1
1	1	0	0
0	1	1	1
0	1	1	1
0	1	1	0
0	1	1	0
1	0	1	1
1	1	1	0
0	0	0	1
1	1	1	1
1	0	1	1
0	0	1	0
0	0	1	1

Data recording [2]

A few questions to be addressed:

What data need to be stored?

Do I need to store all what the sensor measures?

What is the best way to pack the data?

How much buffer memory do I need?

Do I envision problems with streaming data from multiple sensors?

How can I make sure data from different sensors are in-time?

How can I make sure I understand the data afterwards?

How can I make sure that the data I am taking are good?

Data recording [3] - hints

A few questions to be addressed:

What data need to be stored?

Do I need to store all what the sensor measures?

Do I need a trigger?

What is the best way to pack the data?

Do I need compression?

How much buffer memory do I need?

When do I plan to download the data from the SD to the PC?

Do I envision problems with streaming data from multiple sensors?

What is the best communication protocol to be used?

How can I make sure data from different sensors are in-time?

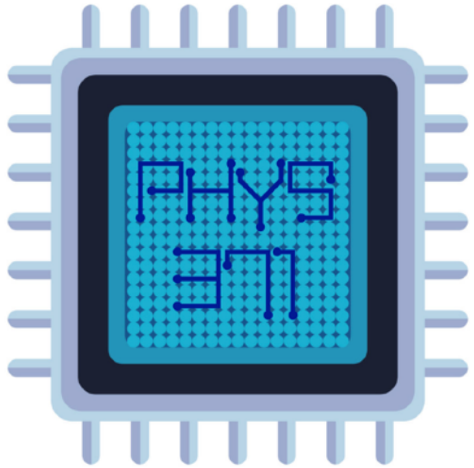
How can I assign a common time-stamp to my data?

How can I make sure I understand the data afterwards?

How can I make sure that the data I am taking are good?

Do I need to write a monitoring software?

Learning how you addressed these questions (if relevant for your application) in your project presentation on Week 5 would surely be a +...



SHORT TALKS FOR NEXT WEEK

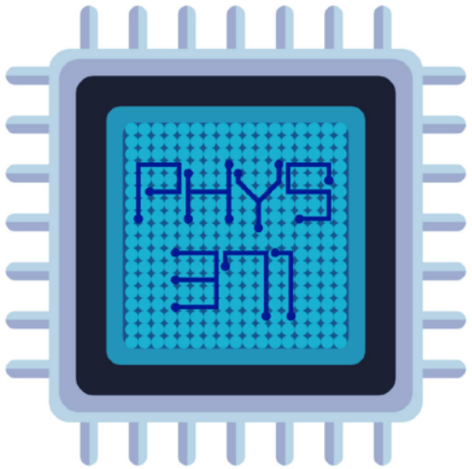
Dr. Riccardo Longo

02/03/2023

Week 3

Short group talks next week

- Atmel 260
- TCA9548A I2C Multiplexer
- W12934-A MicroSD card breakout board
- **LSM90S1 9 DOF** —> up for next week, volunteers?
- Mic Amp MAX 4466
- Plantower PMS5003
- Mini 2-wire Volt Meter
- ~~MCP4725 DAC~~ -> done by group 4 during Week 3
- ~~BME680~~ —> done by group 5 during Week 2
- Mono 2.5W Amp PAM8302A
- ~~Ultimate GPS~~ -> done by group 1 during Week 3
- MLX90614 3V
- ~~DS3231 Precision RTC~~ —> done by group 3 during Week 2
- DPS310 Pressure



TODAY'S HANDS ON SESSION

Dr. Riccardo Longo

02/03/2023

Week 3

First project-driven hands-on session!

- If you have not successfully completed Problem 2 of your homework, this is the time to troubleshoot and try to fix the issues.
- Those who have already turned in the homework should start on working on the project, moving forward according to the task sharing declared last week
  - If not yet done, it's time to start **assembling your project** on the breadboard with all the components you have at hand
    - If you need a particular microcontroller - and you do not have it yet - please start experimenting with your sensors using the Arduino Mega in your kit
  - **Items to tackle today:**
    - Connection (and communication) between your sensors and your microcontroller
    - Calibration of your sensors (do you need it? If yes, it's time to address the item!)
    - DAQ - what data we will be streaming from our data-logger? In what format? How do we monitor their quality?
    - Non-sensitive parts: do we need 3D-printed parts? If yes, it's time to start sketching them using TinkerCad!

Homework assignment

https://courses.physics.illinois.edu/phys371/sp2023/homeworks.asp

Since all the tasks are group related, please try to identify issues or points that need attention before the weekly meeting

Please bring the group Box with you. From now on, absence of the group Box at the weekly meeting will impact your grade.

Questions?

Week 3 homework

Due date reminder

Please email your completed assignment to the course TAs (mch6@illinois.edu and jjc11@illinois.edu cc rlongo@illinois.edu, subject: '[PHYS371]: Week 3 Homework, Your Group Number) by Thursday, 5 pm of week 4 (02/09/2023). Homework that includes only group work should be submitted by one group member, rigorously copying all the other members, the instructor and the TAs.

Each day of delay in turning in the assignment will result in a grade reduction of 10%. We will not grade anything submitted more than one week late. The use of the wildcard should be communicated to the instructor and the TAs before the deadline to turn in the homework, and it does not apply to homework that includes group work only.

When your homework submission includes one or more Arduino code files, please use the template **p398dlp_template.ino** as the starting point for your code. Please fill in ***all*** of the fields shown in the template file. Please use the template also to start your group code and comment on it constantly when you develop new parts. Quote the main authors of different parts of the code too. Keep the code up-to-date on the GitLab repository.

Please compress all the material related to the homework into a .zip or .tar file. If you have questions or points that you need to address, please do not wait for the last day to ask for office hours since it may not be possible to accommodate all the requests on short notice.

Problem 1.

By now, your breadboards probably have nearly all the components you'll need for your project. Please install everything you have on the breadboard and run some test code on each device, for instance, calibrating your sensors or measuring noise levels. Show us screen shots that prove that each component is working in a sensible fashion. Post your code on the GitLab repository before turning in your HW.

Problem 2.

Working with other members of your group, write a single "data acquisition program" (we call this a "DAQ") that reads/controls/… all your hardware, makes some measurements, and writes the measurement data to the SD card. Include screenshots of the system working and provide the files read from your SD card. Analyze data from at least one of the sensor on your board and provide us with some basic analysis output (e.g a histogram of some of the quantities you measured, with associated mean and RMS calculation). Post all the DAQ code to the GitLab repository of your group before turning in your homework (we will also use what is on GitLab to compute the grade).

