Hardware II Seminar

Sensors and Data Analysis

FAB LAB BCN

Iaac

Óscar González & Daniil Koshelyuk

Getting to know each other

Óscar

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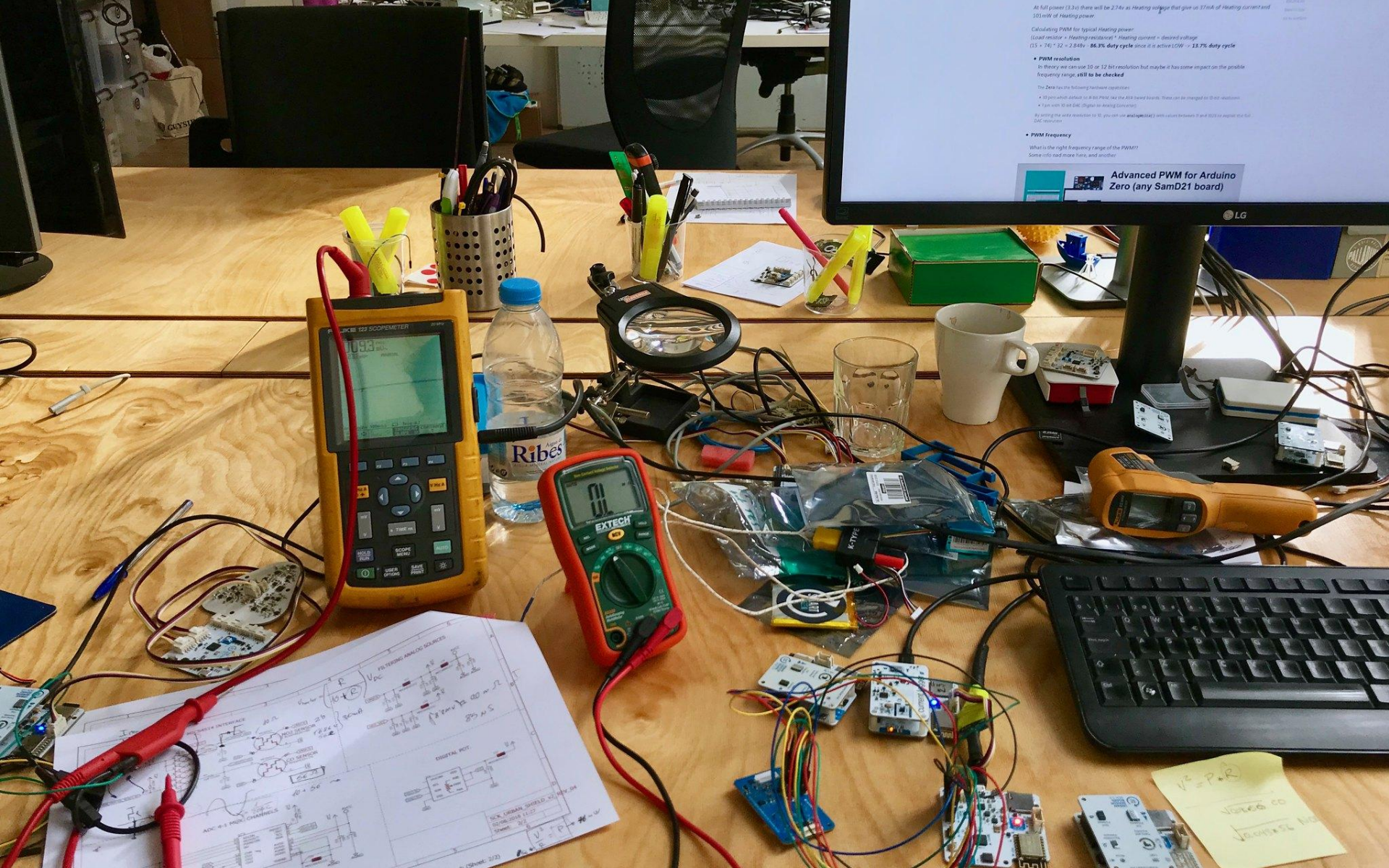
AVL
Schenck
CE 2016
3.21


vigilància
RNW


Advanced PWM for Arduino Zero (any SamD21 board)
Ribes
EXTECH

Getting to know each other

Daniil

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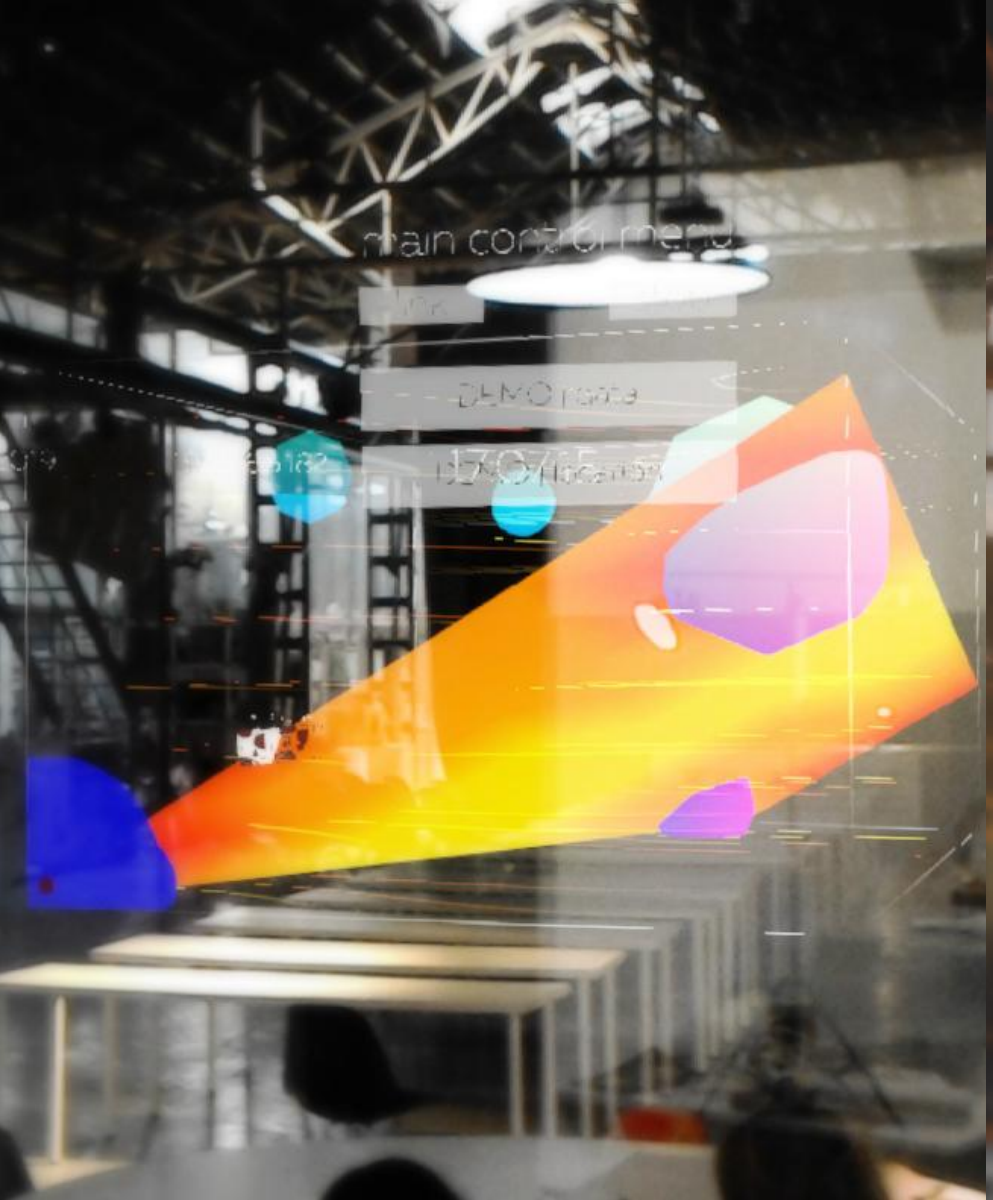
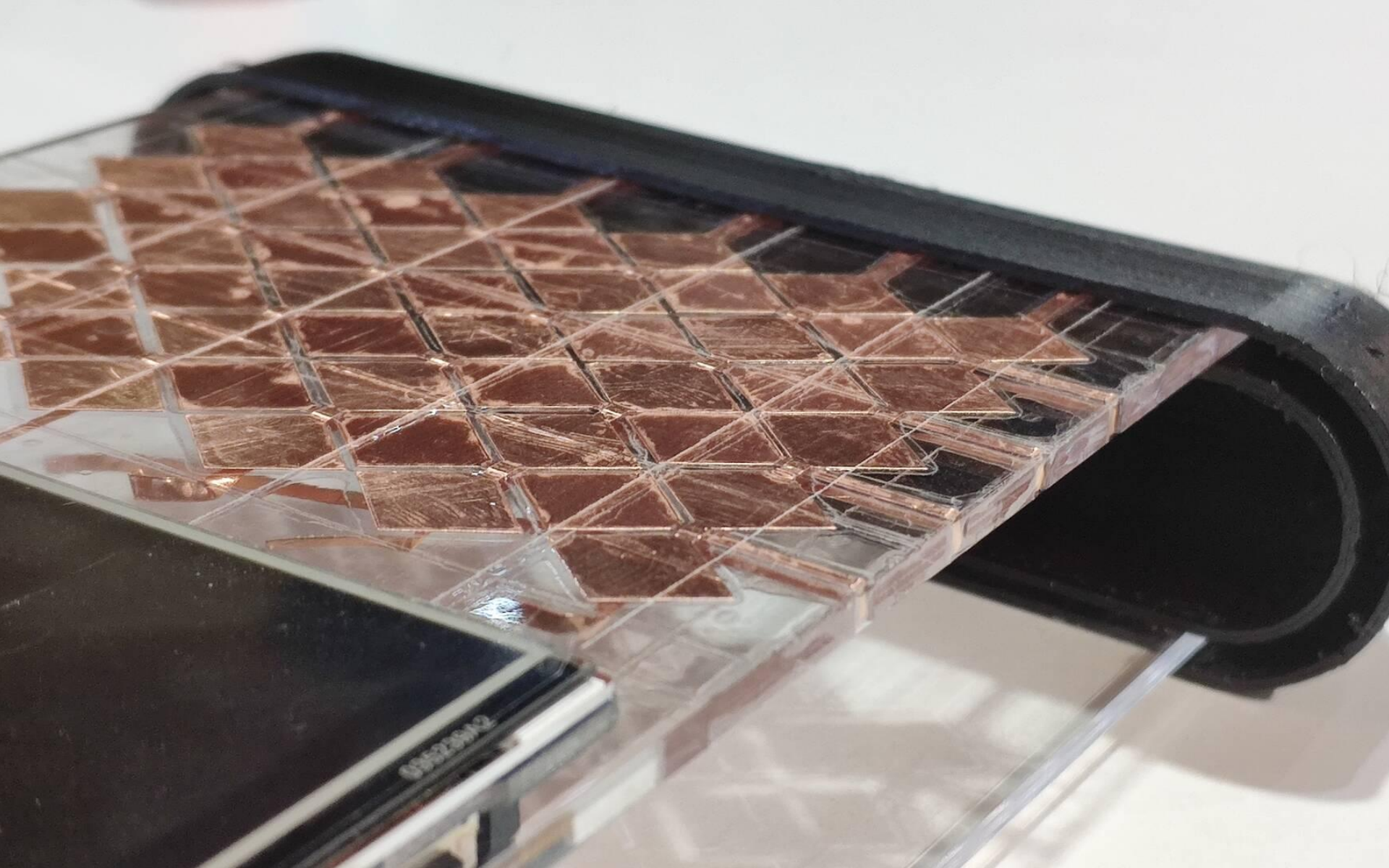

main control menu


main control menu



move
zoom
rotate


HYPERLOOP
POD COMPETITION
ANGELS

Getting to know each other

You!

What we are going to do

Seminar Info

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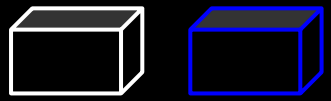
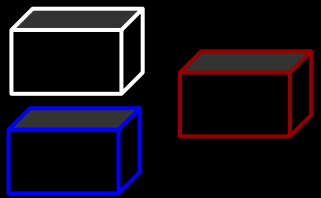
What we are going to do - Course objectives

- *Understanding different types of sensors and measurement principles*
- *Learn how to extract meaningful insights from different sensors using data analysis techniques*
- *Understand data logging processes in real time and with buffers*
- *Understand the trade-off between cost and complexity in the sensor selection*
- *More expensive is not always better*

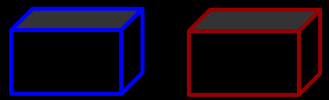
What we are going to do - Course overview



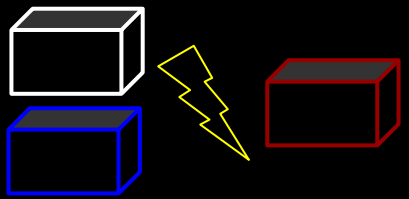
Day 1: Sensors and cameras



Day 2: Sensors, cameras and computers



Day 3: Basics of image processing



Day 4: Data Analysis

What we are going to do - Exercise

- *Groups of 2 to 4 people each. You decide.*
- *The exercise consists in creating a hardware setup and data acquisition system using at least one sensor type of the sensors we'll see during this week and doing data analysis and postprocessing*
- *See examples here:*

https://www.iaacblog.com/programs/wearable-assistive-robotics-with-emg-sensor/

https://www.iaacblog.com/programs/drawing-bot-hardware-ii-seminar/

https: //www.iaacblog.com/programs/hallucinating-culture/

https://www.iaacblog.com/programs/automated-assistance-h-2/

https://www.iaacblog.com/programs/projection-mapping-h-2/

https://www.iaacblog.com/programs/automated-echo-crack-detection/

https://www.iaacblog.com/programs/record-collect-project-h-2/

What we are going to do - Exercise: hardware

21/01 - Project idea presentation - potential conceptualization, plan and BOM:

- **Focus on hardware**
- Presentation (readme or slides - **5min max**.) - Put it in a folder in Github repository called `hardware`
  - Concept idea
  - State of the art review
  - Development plan
- BOM (spreadsheet): list of materials, including source and cost
- Answer to these questions:
  - Type of setup: stationary, moving (with what, how, for how long)
  - Data storage (local, remote) or capture method
  - Deployment type: punctual, stationary, etc.
- **Showcase - First *minimum viable product* prototype**
  - Prototype, wired and working at least on a breadboard setup
  - Firmware
  - Functional diagram and hardware schematic

What we are going to do - Exercise: data

11/02 - Data Analysis Plan

- **Focus on data**
- Presentation (readme or slides - **5min max.**) - Put it in a folder in Github repository called `data`
  - Data analysis plan
  - What are your final metrics or proxies?
  - Type of data storage, where does the data come from and where does it go?
  - Where is it analysed and how?
  - How is it transported?

What we are going to do - Exercise

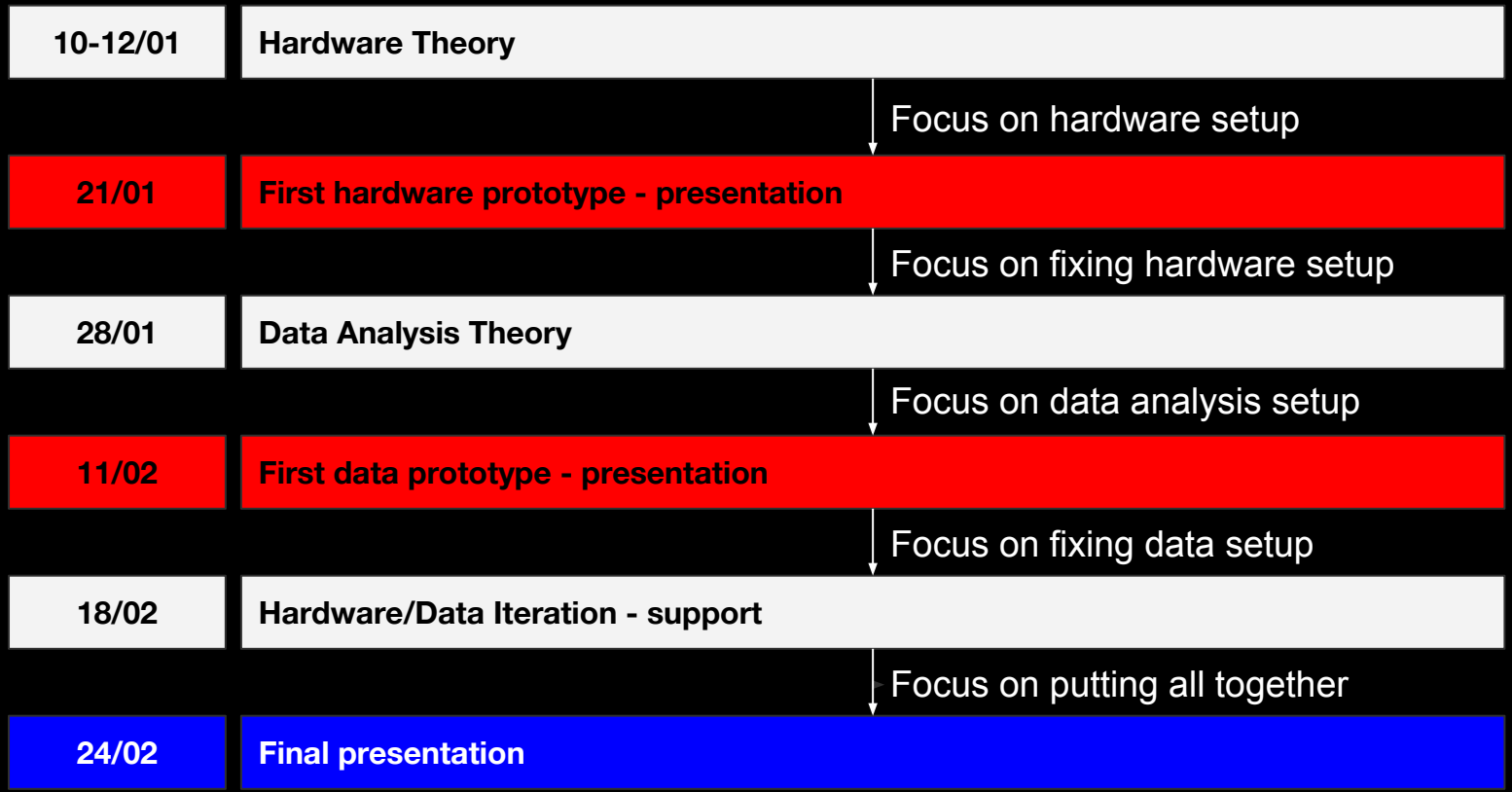
Requirements: All deliverables will be submitted to a git repository except for the IAAC Blog Post. The git repository should have:

```
REPOSITORY-NAME
├── hardware
├──── README.md
├──── BOM.csv
├──── embedded
├─────── arduino_files
├──── ...
├── data
├──── scripts.py
├──── README.md
├──── ...
├── instructions
├──── README.md
├──── ...
├── presentation
├──── README.md
├──── ...
README.md
```

This will be the only requirement for the repository's quality:

Anyone, including yourself in 5 years from now, should be able to build, use and reproduce the complete hardware and software setup with the materials and instructions provided.

What we are going to do - Course overview



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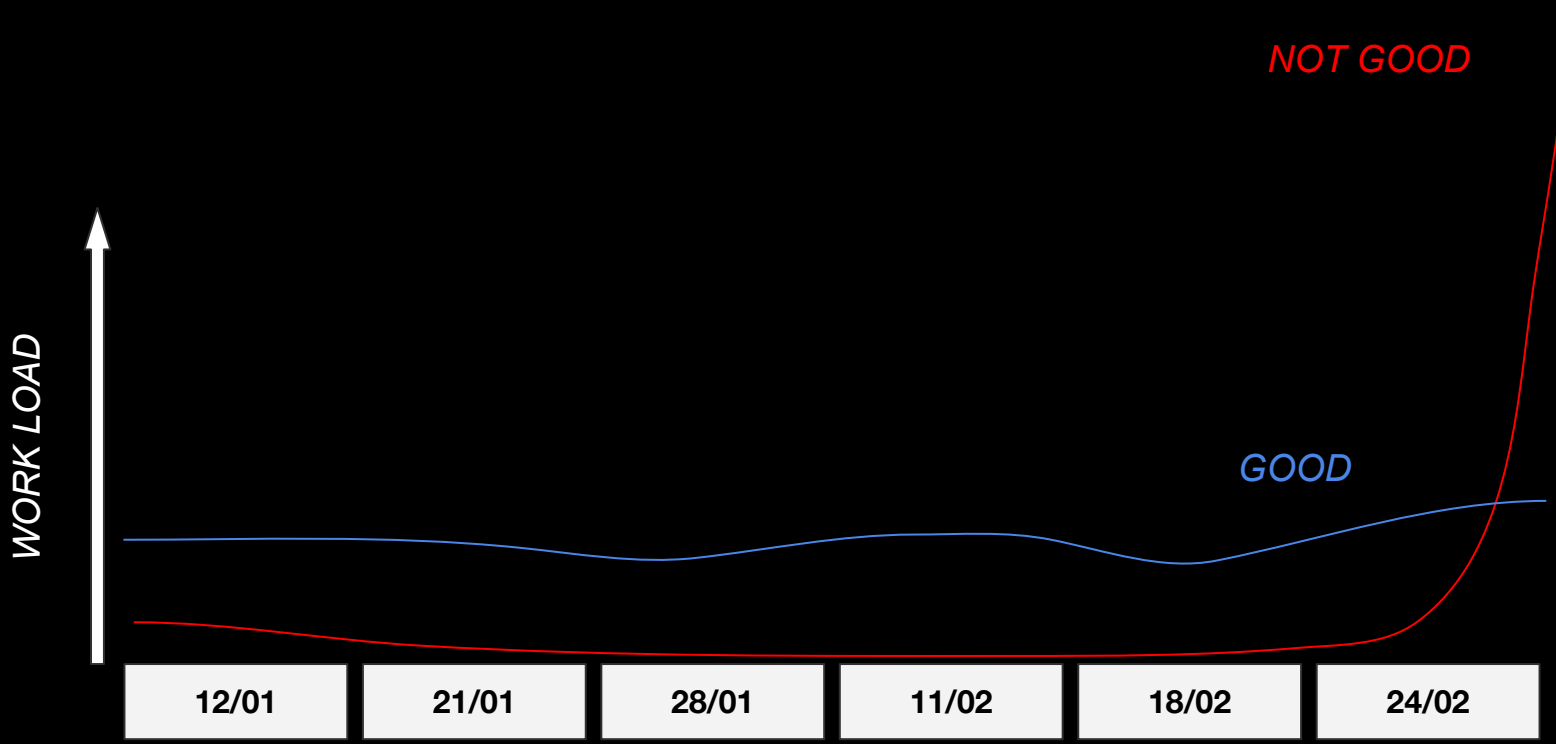
What we are going to do - How to go for it



Before we get started

Important resources

Before we get started - Important information

- ***Code repository:*** *https://github.com/oscgonfer/sensors_dsp_lectures*

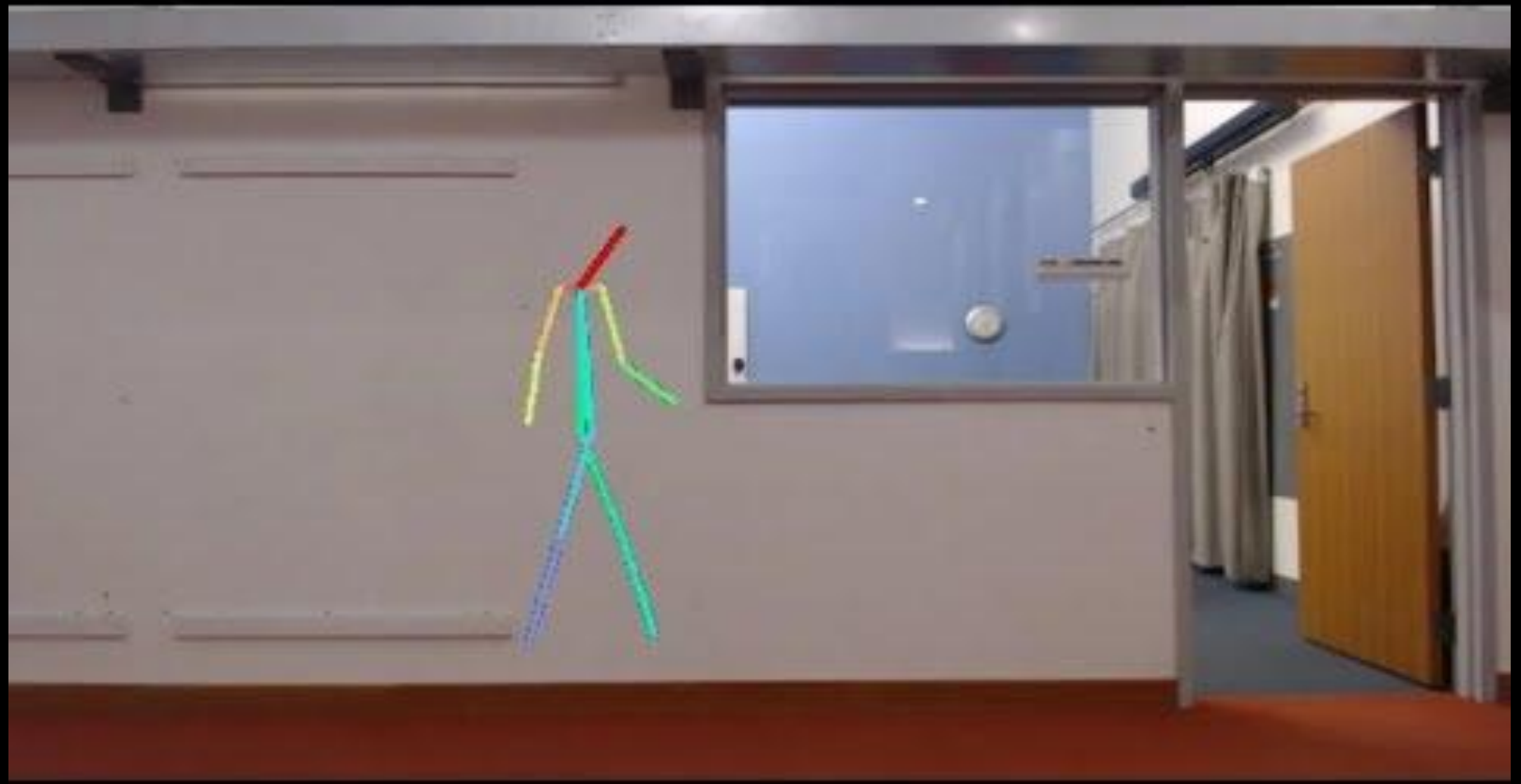
```
cd /path/to/nice/mrac/documents/folder

git clone https://github.com/oscgonfer/sensors_dsp_lectures.git
```

- ***MRAC Group on Github:*** *https://github.com/MRAC-IAAC/*

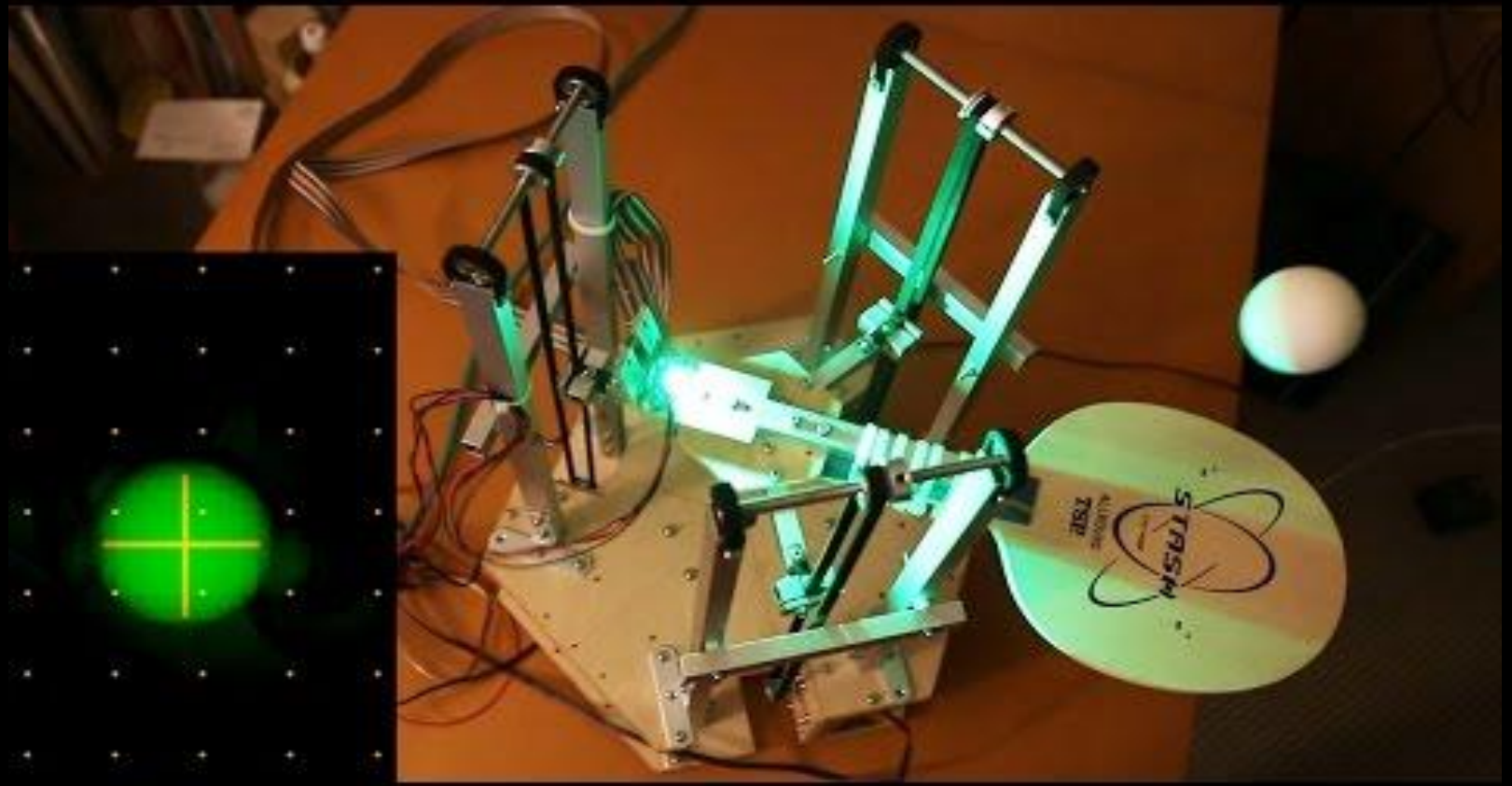
Some inspiration


Faucet Running
(LAPTOP FOR ILLUSTRATION)

Touché: Enhancing Touch Interaction on Humans, Screens, Liquids, and Everyday Objects



AI Senses people through walls



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OpenCV and raspberryPi Ping Pong

Want more?

Check the repo

Why do we need sensors?

Understanding the basics

An overview of sensing techniques

Sensors

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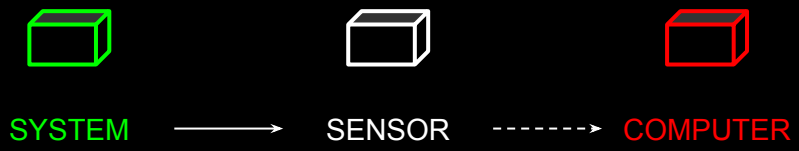
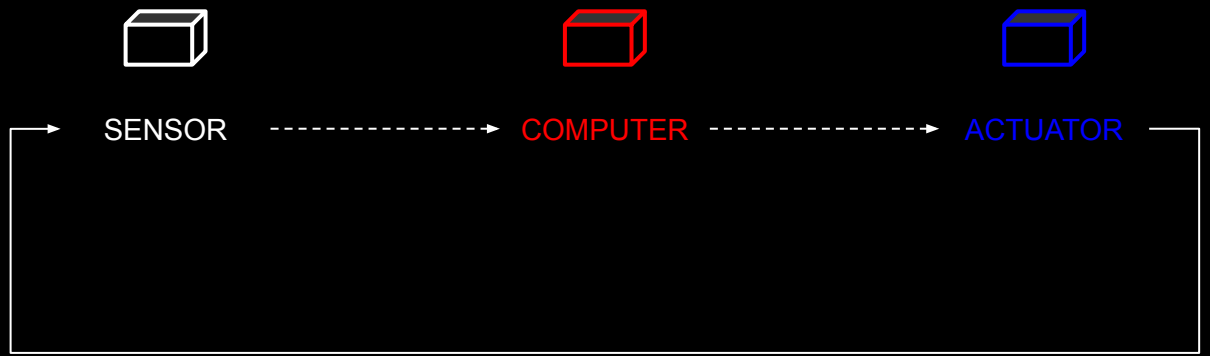
Understanding the basics - why do we need sensors?

Monitoring something

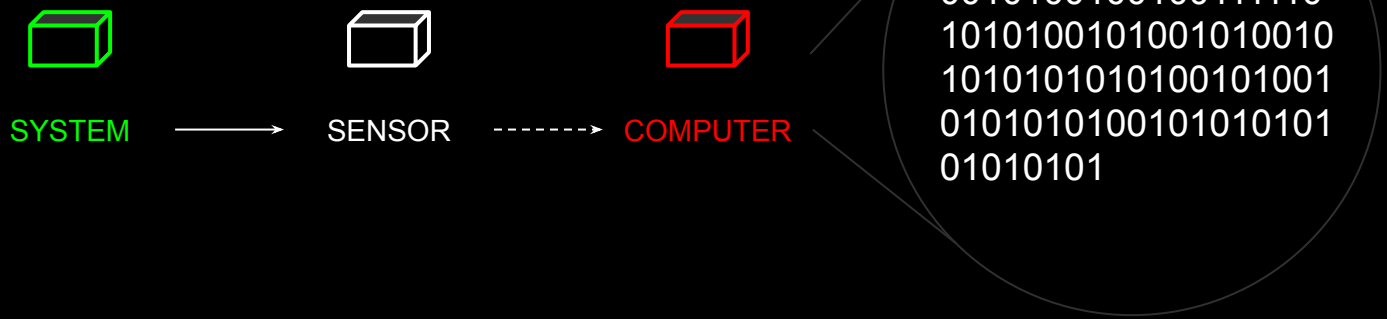


Understanding the basics - why do we need sensors?

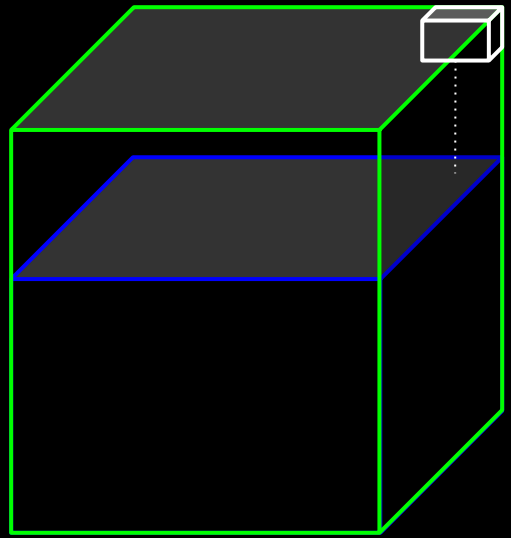
Controlling something (closed loop)



Understanding the basics - digitalising physical phenomena



Understanding the basics - inference

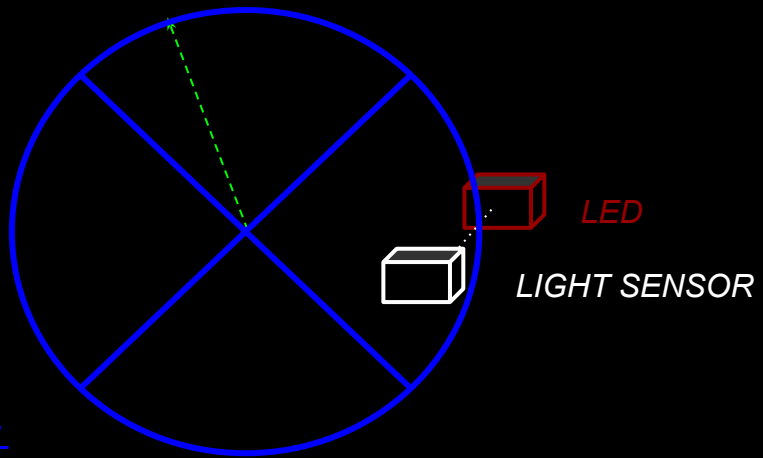


DISTANCE SENSOR

WATER (OBVIOUSLY)

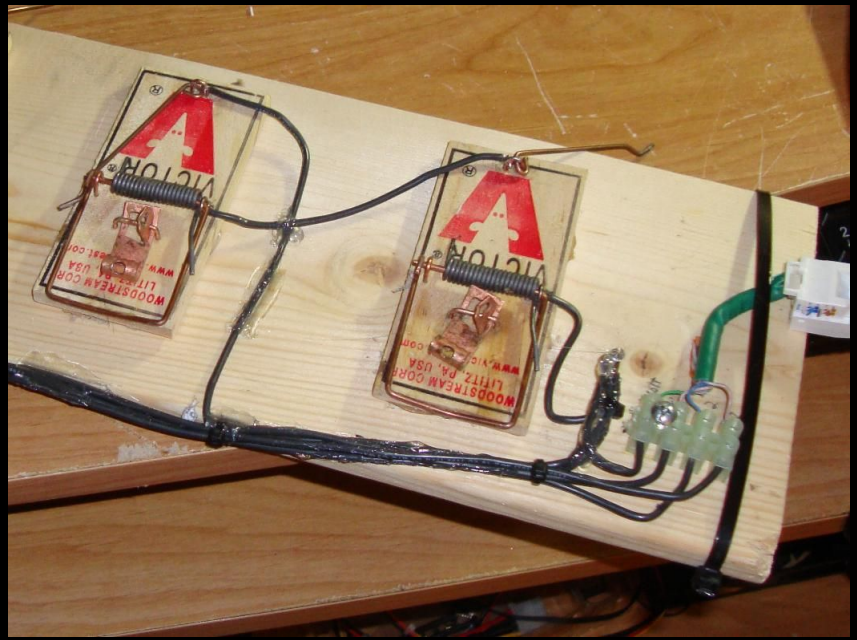
WATER LEVEL** = **TANK HEIGHT** - **SENSOR READING

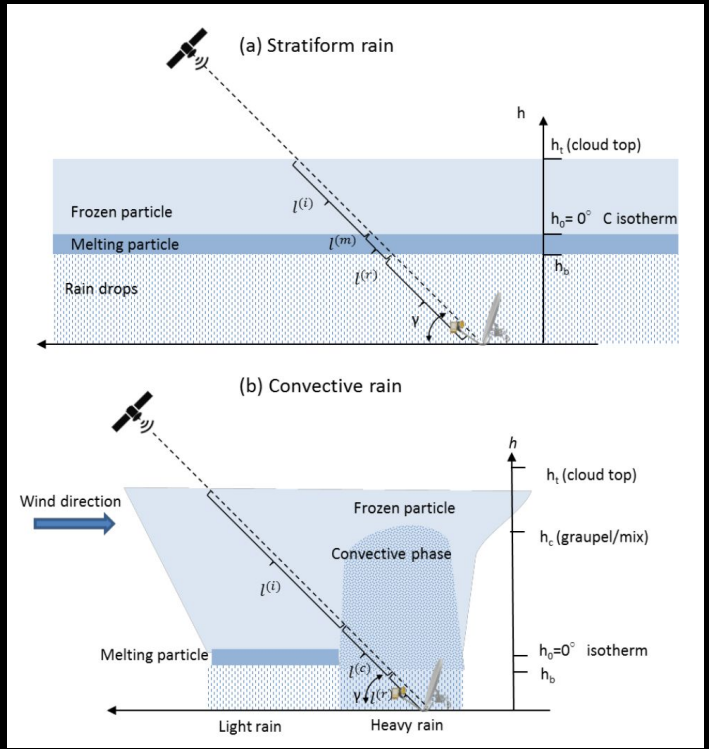
Understanding the basics - inference



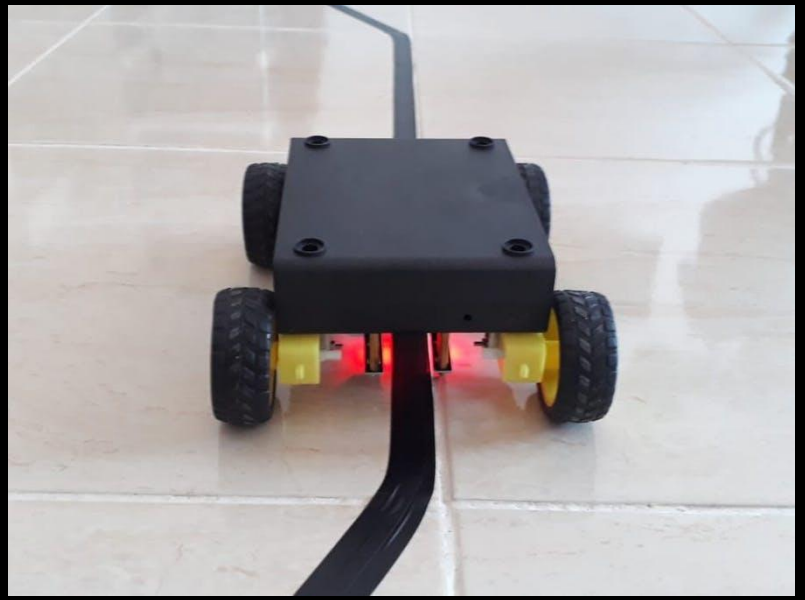
HORIZONTAL SPEED **= *(PULSES/min)/4 * WHEEL_RADIUS***

Understanding the basics - simple vs. complex





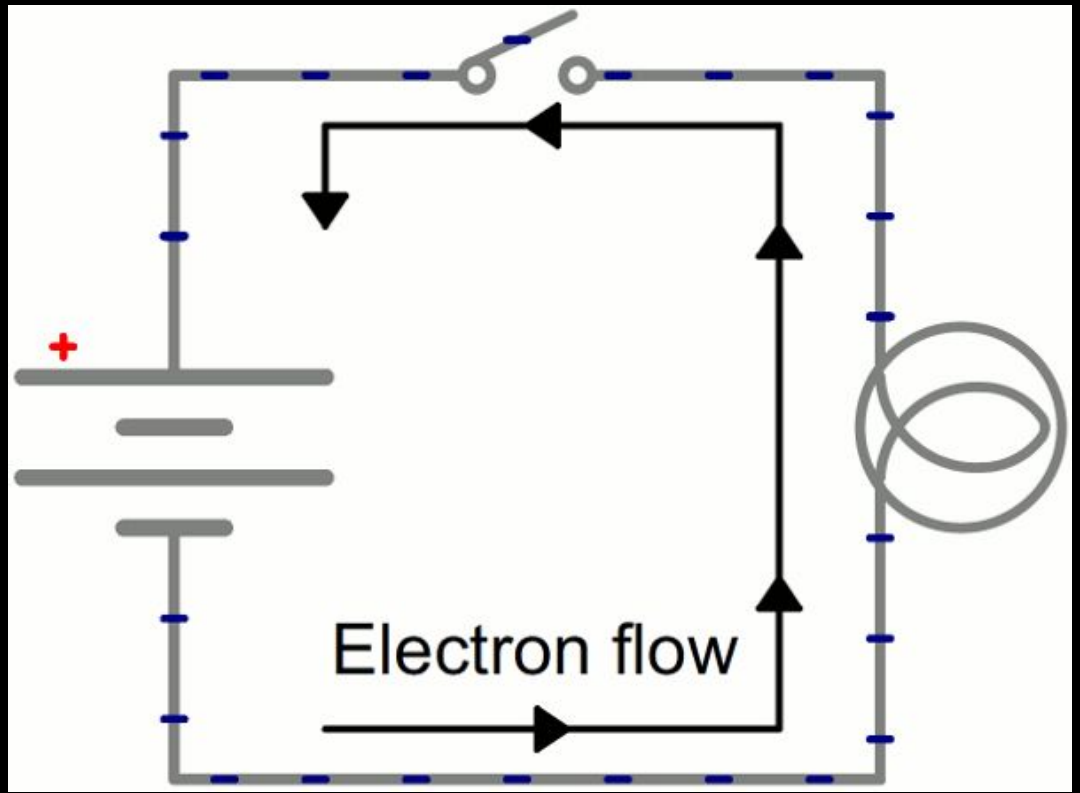
Understanding the basics - static vs. dynamic



Digging deeper

From signals to information

Digging deeper - The simplest sensor



HIGH

or

LOW

1

or

0

TRUE

or

FALSE

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YES

or

NO

FAB LAB BCN

Iaac

PERSON

or

NOT PERSON

FAB LAB BCN

Iaac

CAT

or

DOG

5V

or

GROUND

Digging deeper - The simplest sensor (or maybe not-so-simple)

- *To read a digital input (HIGH, or LOW) we will use Arduino* `digitalRead` function (reference https://www.arduino.cc/reference/en/language/functions/digital-io/digitalread/) connecting the switch to a pin in our microcontroller
- *Depending on the type (and age) of the electronics we use the HIGH value corresponds to different voltages, for example: 5V, 3.3V, 1.8V...*
- *You might need to use* `pull-up resistors` *to avoid floating states*
- *You might need to* `debounce` *the signal*

Digging deeper - The simplest sensor (or maybe not-so-simple)

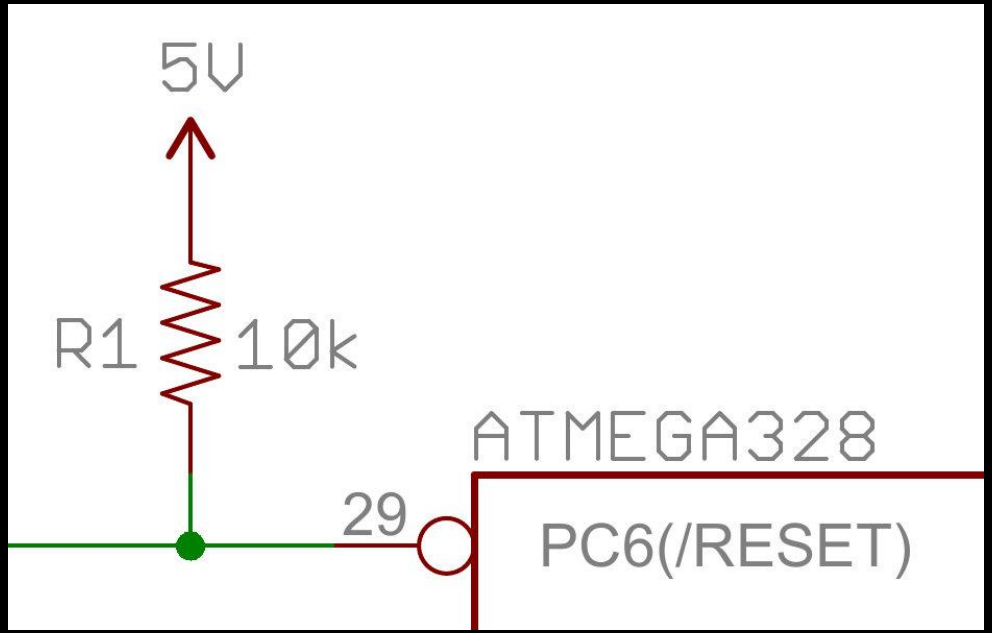
Pull-up resistors

*[...] pins configured as pinMode(pin, INPUT) with **nothing connected to them**, or with wires connected to them that are not connected to other circuits, will report seemingly **random changes in pin state**, picking up electrical noise from the environment, or capacitively coupling the state of a nearby pin.*

https://www.arduino.cc/en/Tutorial/DigitalPins

Digging deeper - The simplest sensor (or maybe not-so-simple)

Pull-up resistors



https://www.arduino.cc/en/Tutorial/DigitalPins

Digging deeper - The simplest sensor (or maybe not-so-simple)

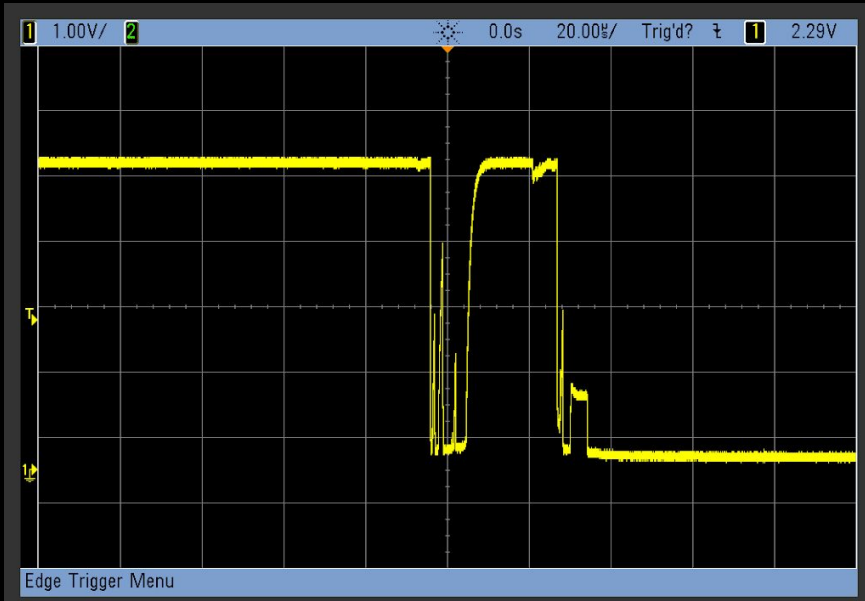
Debouncing

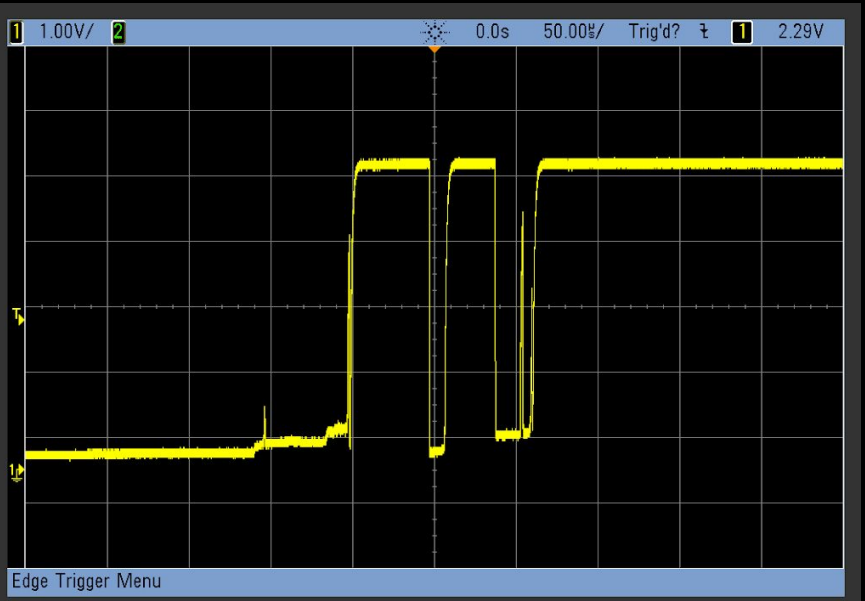
Pushbuttons often generate spurious open/close transitions when pressed, due to mechanical and physical issues: these transitions may be read as multiple presses in a very short time fooling the program.

https://www.arduino.cc/en/Tutorial/BuiltInExamples/Debounce/

Digging deeper - The simplest sensor (or maybe not-so-simple)

Debouncing





https://www.arduino.cc/en/Tutorial/BuiltInExamples/Debounce/

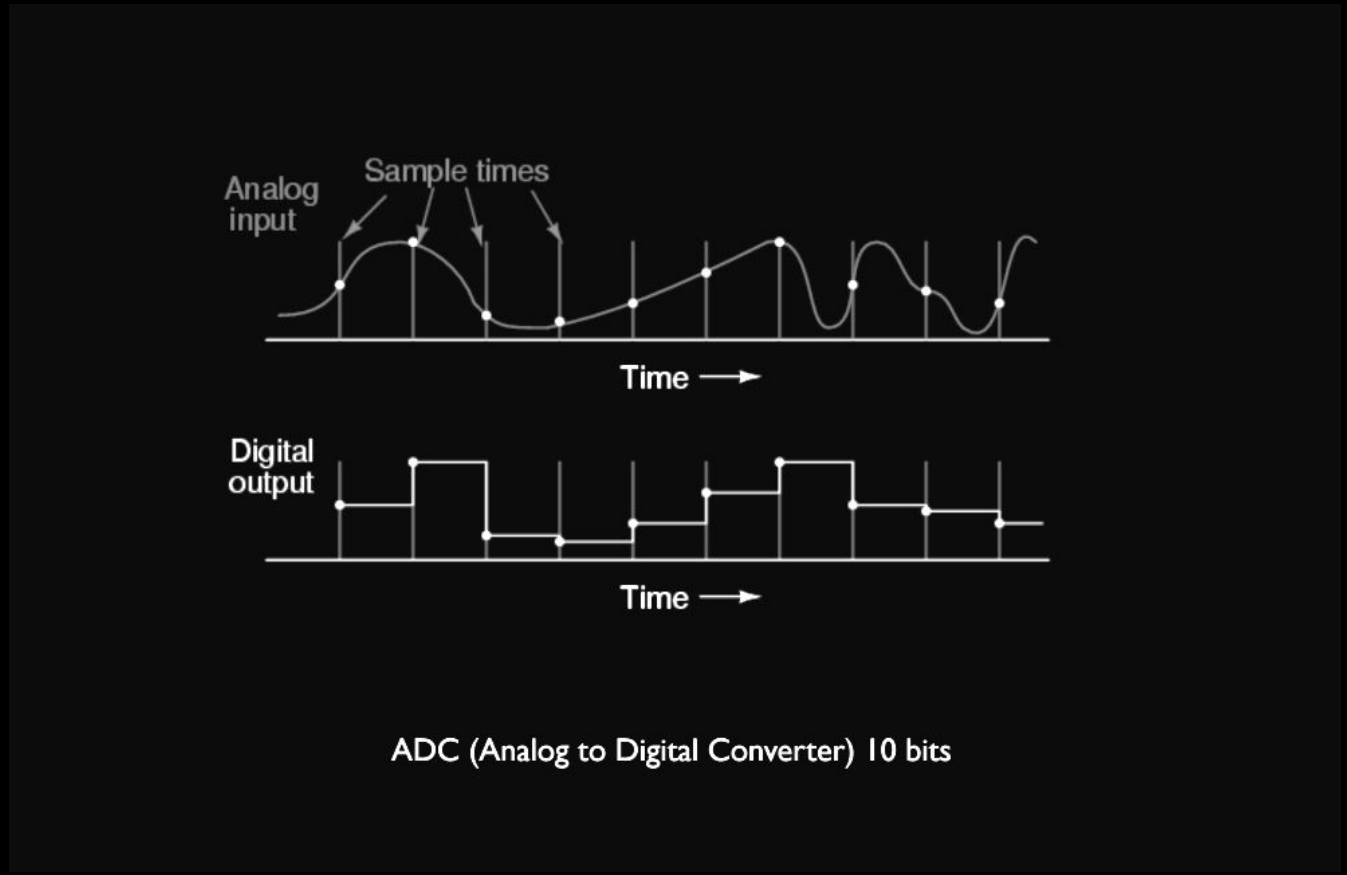
Digging deeper - The simplest sensor (or maybe not-so-simple)

Reading Pulses

Reads a pulse (either `HIGH` *or* `LOW`*) on a pin. For example, if value is* `HIGH`*,* `pulseIn()` *waits for the pin to go from* `LOW` *to* `HIGH`*, starts timing, then waits for the pin to go* `LOW` *and stops timing. Returns the length of the pulse in microseconds or gives up and returns* `0` *if no complete pulse was received within the timeout.*

https://www.arduino.cc/reference/en/language/functions/advanced-io/pulsein/

Digging deeper - Going Analog



ADC (Analog to Digital Converter) 10 bits

Digging deeper - Going Analog

*In an **ADC** circuit there are several steps to go from an **analog signal to a digital value**. The first stage is called **Sampling and Holding**:*

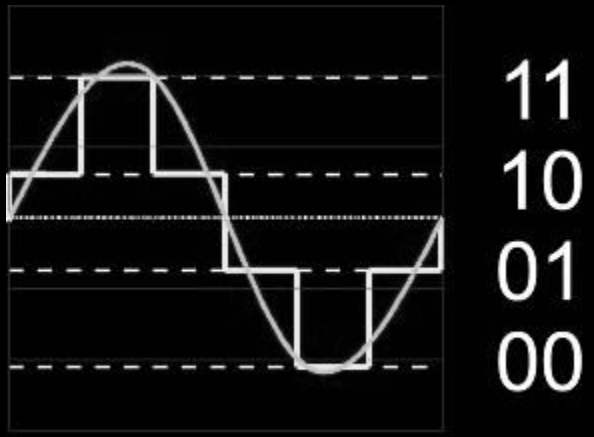
An analog signal continuously changes with time, in order to measure the signal we have to keep it steady for a short duration so that it can be sampled.

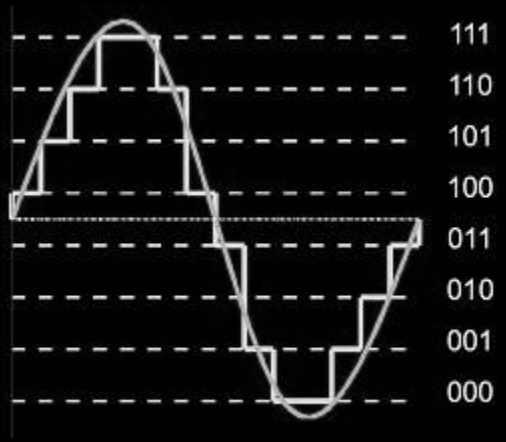
*The next stage is **Quantizing and Encoding:***

On the output of (S/H), a certain voltage level is present. We assign a numerical value to it. The nearest value, in correspondence with the amplitude of sampling and holding signal, is searched.

Digging deeper - Going Analog

The **resolution** of an ADC is measured in bits, a one bit resolution ADC is capable of delivering 2^1 different values (0 and 1). The Arduino UNO has a **10 bit** integrated ADC that means it can deliver 2^{10} values **from 0 to 1023**.





Digging deeper - Going Analog

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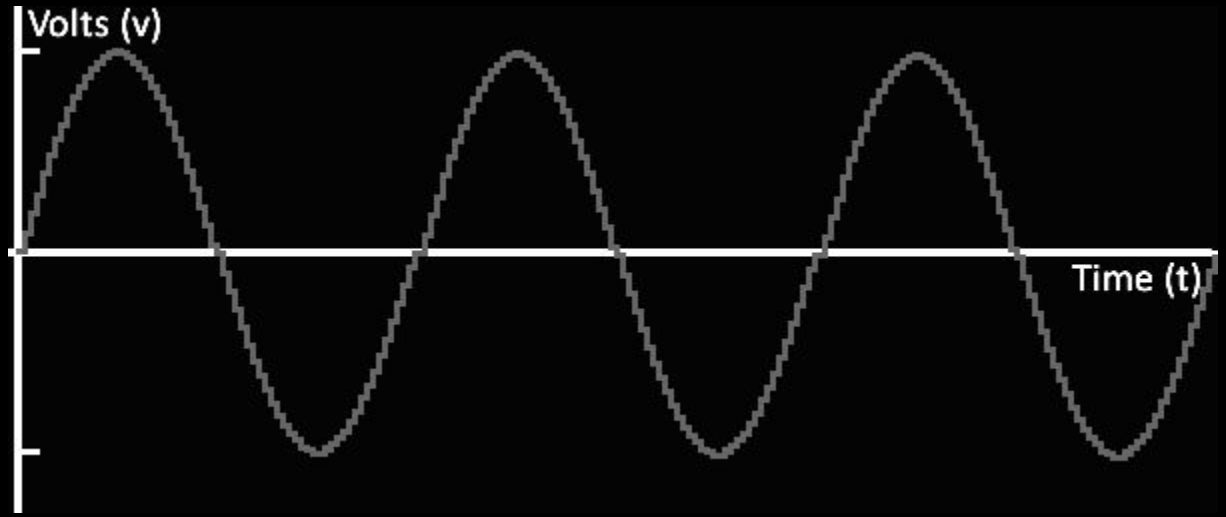
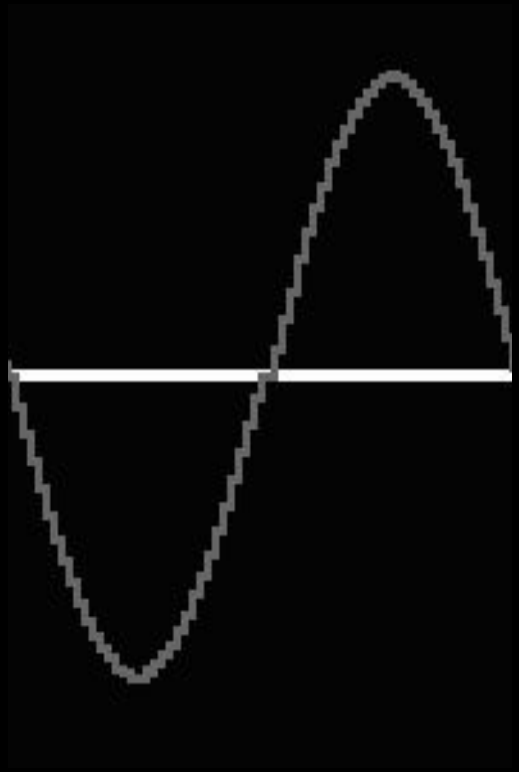
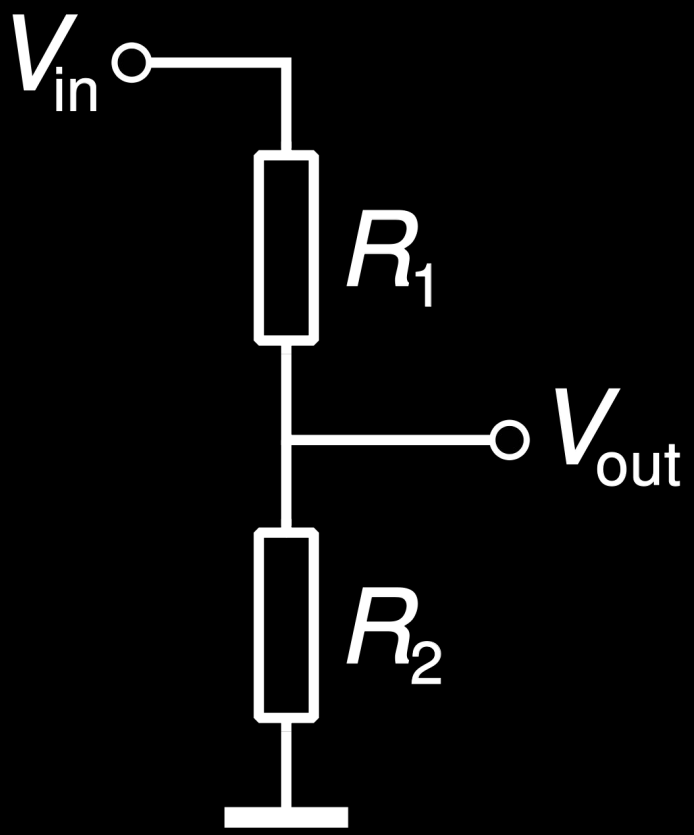


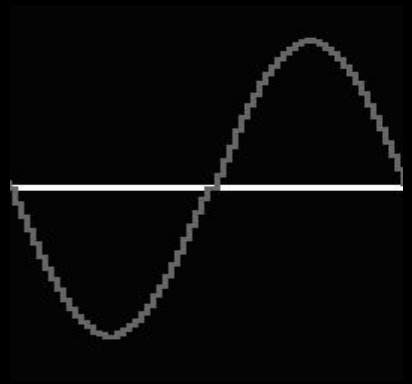
Digging deeper - Going Analog

- *To read an analog input (continuous values) we will use Arduino* `analogRead` *function (reference https://www.arduino.cc/reference/en/language/functions/analog-io/analogread/) connecting the sensor to a pin in our microcontroller (which needs to have an ADC)*
- *Depending on the sensor type, we might need more or less* ***resolution***
- *You might need to use a* `voltage divider` *if the sensor range is too large with respect to that of the ADC*

Digging deeper - Going Analog / Voltage dividers

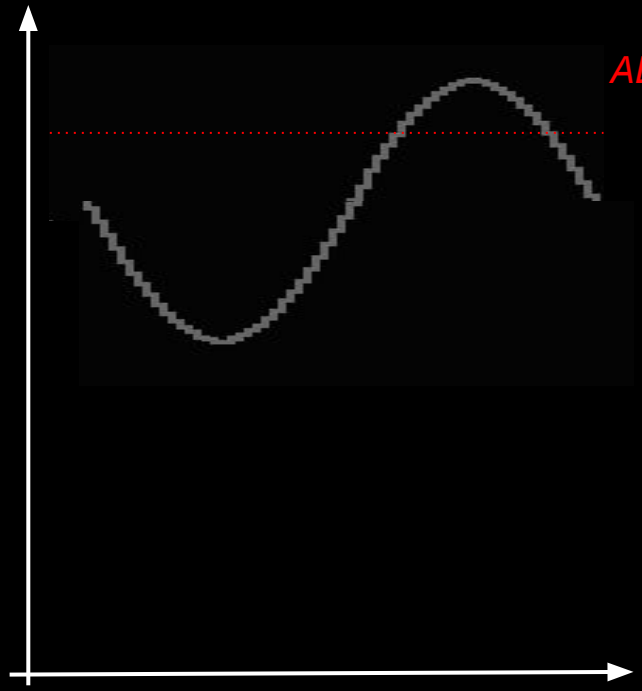


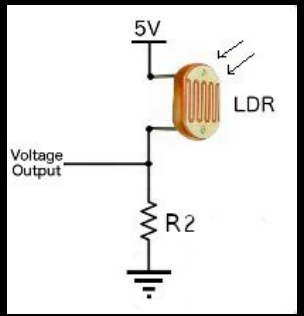




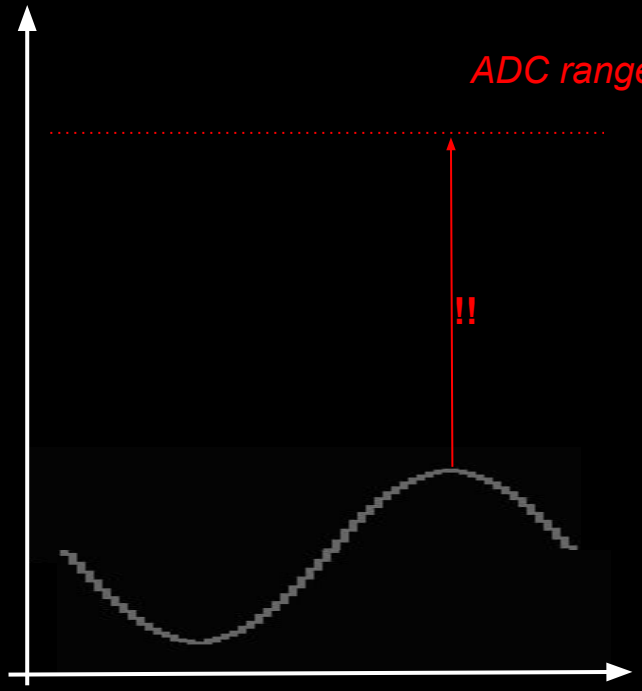
Digging deeper - Going Analog / Voltage dividers

WITHOUT Voltage Divider





WITH Voltage Divider



Digging deeper - Analog and digital / Understanding voltage levels

- *Sometimes the sensors we use have a different voltage **range** and for that reason we use a voltage divider to adapt the signal to the range of our microcontroller*
- *We can also use a voltage divider to measure a sensor that is not **centered** with our ADC range*

Example time!

Before we continue...

I’m sorry

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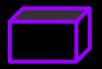
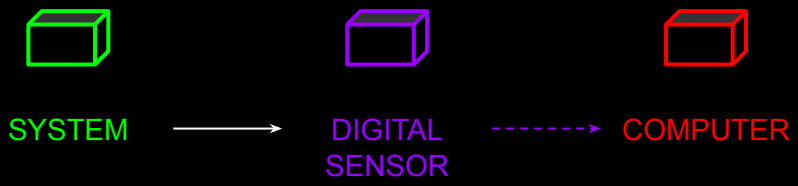
Digital sensors

Digital Sensors



- *Some sensors have more complex technical specifications and might even have a tiny microcontroller*
- *We can make our microcontroller (Arduino, Raspberry Pi, …) talk with those sensors by using digital communication protocols such as* `I2C`, `SPI`, ...

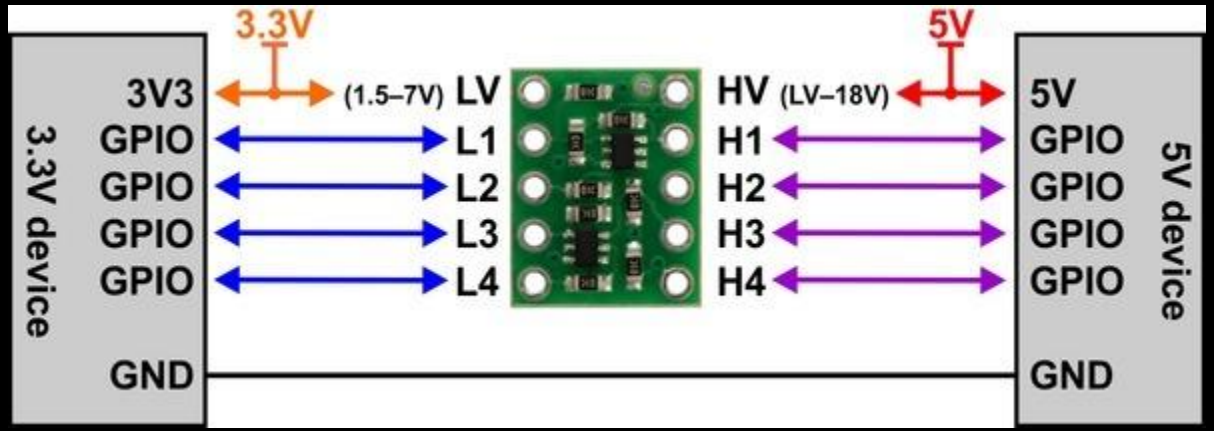


Digital Sensors

- *To talk with a digital sensor we will mostly use Arduino* `Wire` *(reference https://www.arduino.cc/en/Reference/Wire) or* `SPI` (https://www.arduino.cc/en/Reference/SPI)
- *If using a raspberry pi, you will need to enable* `I2C` *interface in* `raspi-config`
- *Part of the processing (heavy lifting) is done by the sensor itself*
- *You might need to use a level shifter to adapt voltage levels*

Digital Sensors / Level Shifter

As digital devices get smaller and faster, once ubiquitous 5 V logic has given way to ever lower-voltage standards like 3.3 V, 2.5 V, and even 1.8 V, leading to an ecosystem of components that need a little help talking to each other. For example, a 5 V part might fail to read a 3.3 V signal as high, and a 3.3 V part might be damaged by a 5 V signal.



https://www.pololu.com/product/2595

Example time!

Micropython

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Setup

1. *Get MicroPython flushed on PiPico (from here)*
2. *Restart and find COM port*
3. *Ready!*

Test 1. Send python commands over Serial (for example, with PuTTY)

https://www.pololu.com/product/2595

Extend

Test 2. For more complex things use Python IDE with a Serial connection to send and receive feedback (for example, with Thonny)

- *Set the COM port (Options > Tools > Interpreter)*
- *Explore!*

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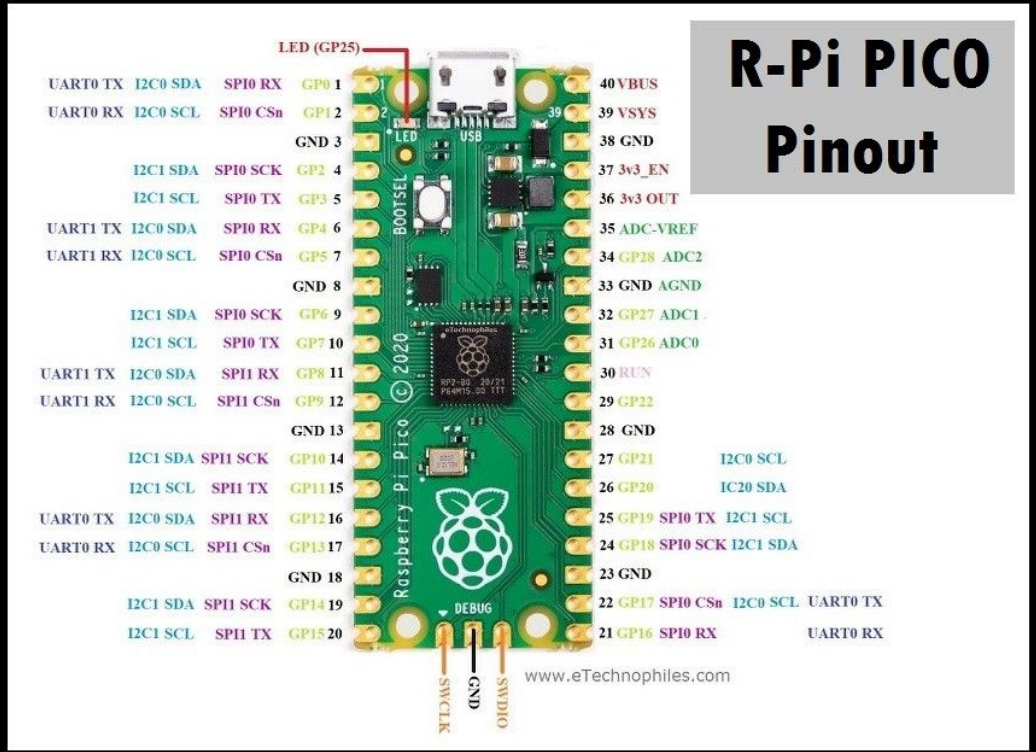
PiPico Pinout



https://www.pololu.com/product/2595

Where to go next?

documentation

https://www.pololu.com/product/2595

How to choose a sensor

Main aspects to consider

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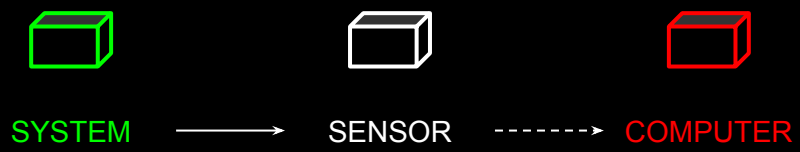
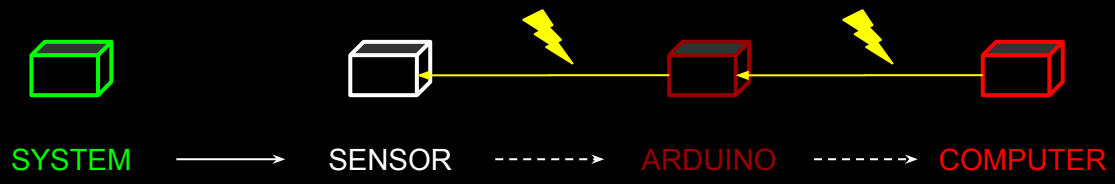
How to choose a sensor - Who does the heavy lifting?

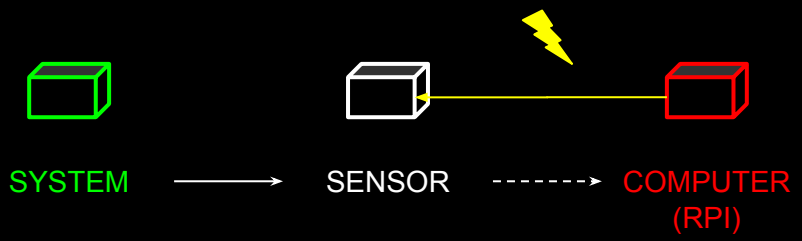
First - What is heavy lifting?

1. *Energy consumption - who provides it?*
2. *Computing power*
3. *Computing power (post) and because of that, data storage*

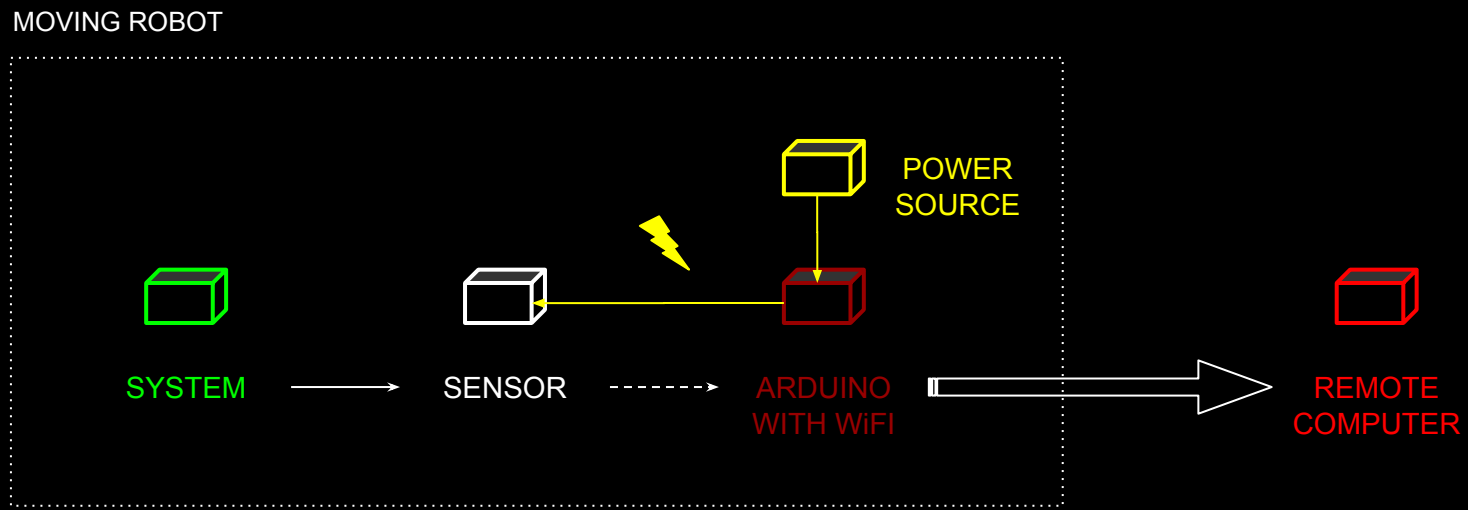


How to choose a sensor - Who does the heavy lifting?





How to choose a sensor - Who does the heavy lifting?



How to choose a sensor - What are the voltage levels?

Remember, this can kill your sensor

1. *Are both the same? Good!*
2. *Are they different? Can it be solved with a* ***voltage divider (analog or digital input)*** *or a* ***level shifter (digital sensor)****?*

The three rules of every project

1. ***Do not overkill - the simpler, the better***
2. ***Always look for existing solutions first***
    - *look for well documented sensors learn.sparkfun.com, learn.adafruit.com, github.com...*
3. ***Do not forget about software - use libraries, specially for digital sensors***

Cameras

Some basics

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Cameras - Some basics

We have three types of cameras

1. *RGB cameras - Mobius action camera*
2. *Depth cameras (normally with RBG, so RGBD) - Kinect v1 and INTEL REALSENSE*
3. *Thermal cameras - Flir one*

Things to consider:

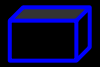
1. *RGBD or RGB cameras for positioning are both valid, one putting more emphasis on the post-processing stage with more calibration needs*
2. *Make sure you have enough processing power for image capture and/or storage*

Cameras - Some basics

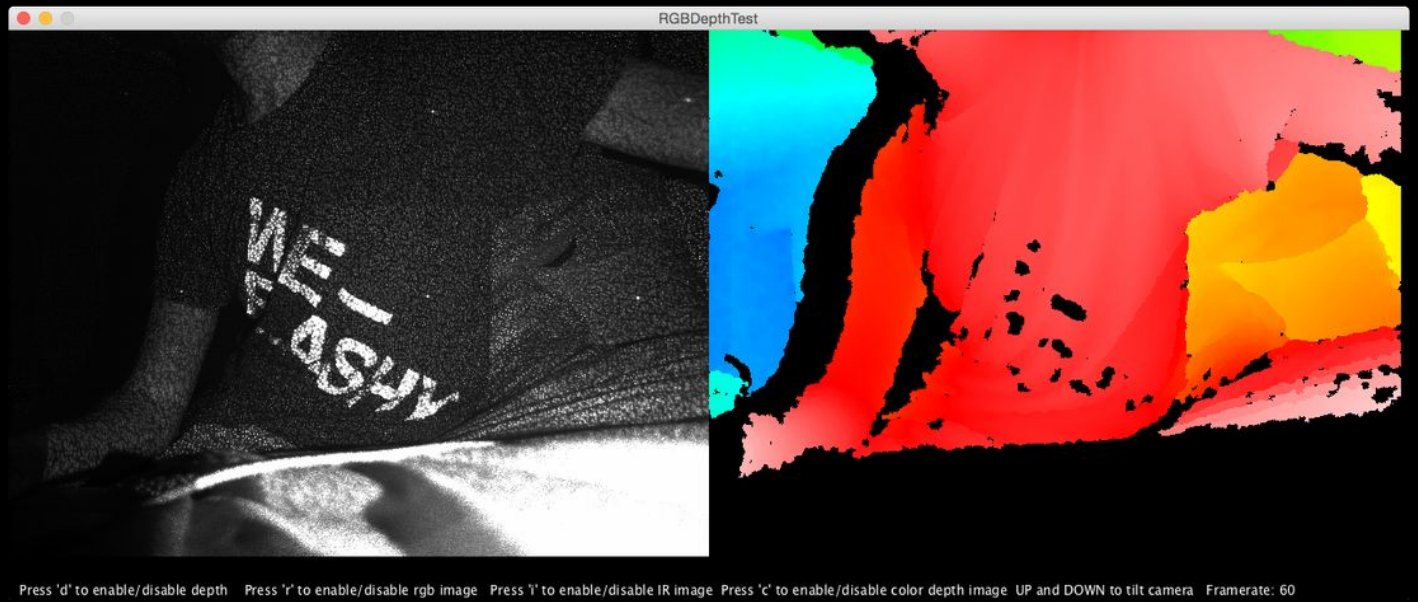
RGBD cameras

Image found found at: https://wiki.ros.org/kinect_calibration/technical originally from http://www.ifixit.com/Teardown/Microsoft-Kinect-Teardown/4066/1

Cameras - Some basics



RGBD cameras



From https://github.com/shiffman/OpenKinect-for-Processing

Cameras - Some basics

Thermal imaging cameras

Located far from the visible light spectrum thermal imaging doesn't require a light source at all. Instead, thermal imaging works by collecting the infrared radiation emitted by all objects with a temperature above absolute zero. Differences in radiation between objects make up the image which is then shown on screen.

From https://thermalbase.com/thermal-camera-basics

Thanks!

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