Hardware II Seminar

Sensors and Data Analysis

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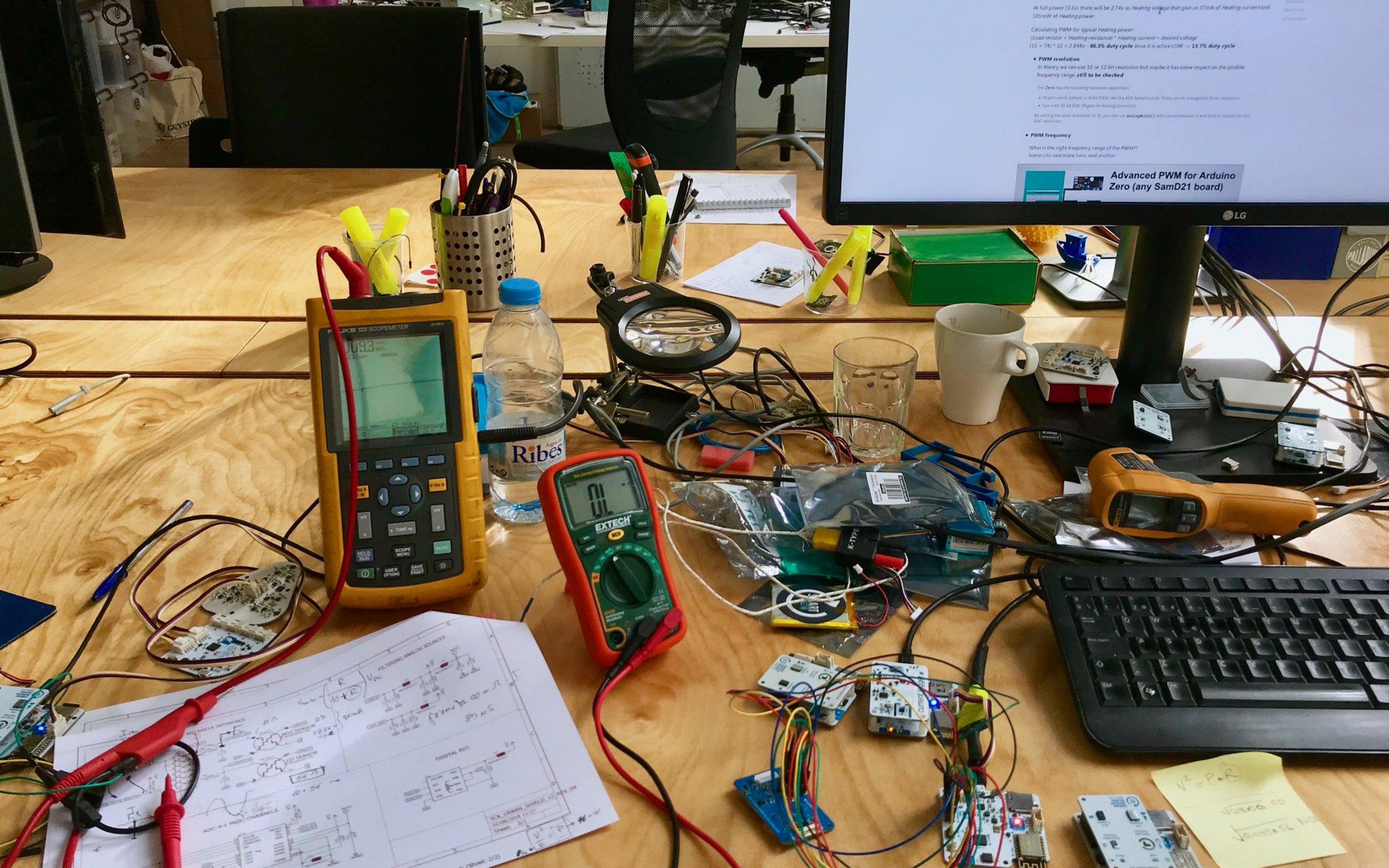
Óscar González & Antoine Jaunard

Getting to know each other

Óscar


CE 2016
3.21
AVL

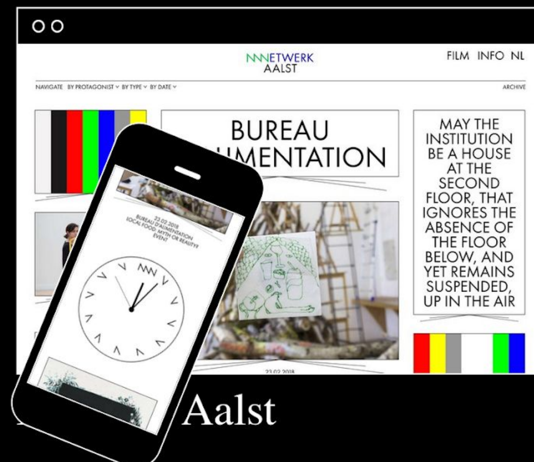

PWM resolution
still to be checked
PWM Frequency
Advanced PWM for Arduino
Zero (any SamD21 board)
LG
123 SCOPEMETER
Ribes
EXTECH
K-TYPE
FILTERING ANALOG SOURCES
DIGITAL POT

Getting to know each other

Antoine

Variable est un studio de design et développement web spécialisé dans la création de sites et d'outils. Parcourez nos derniers projets et contactez-nous pour en savoir plus.

Éva Le Roi



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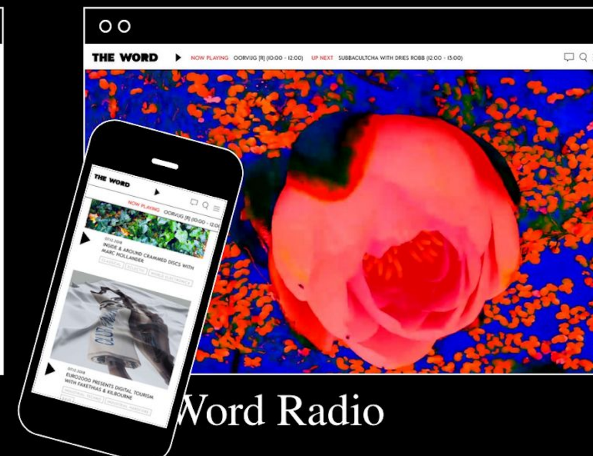
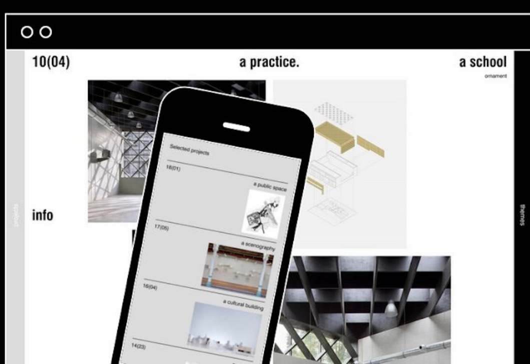
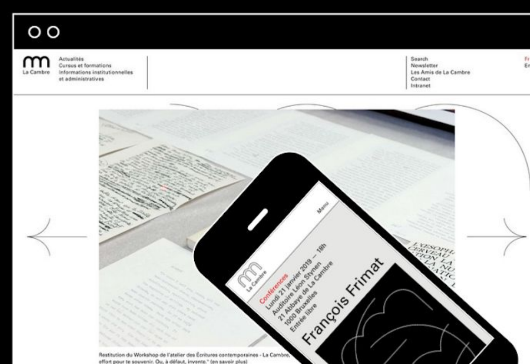
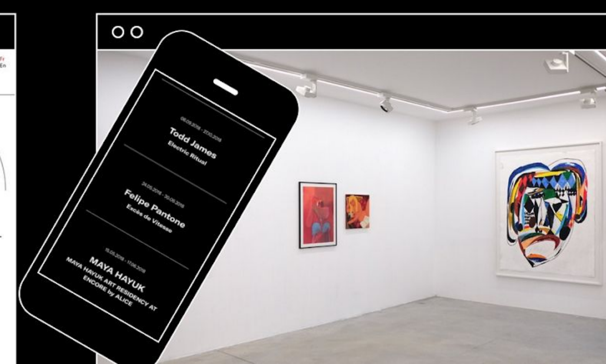
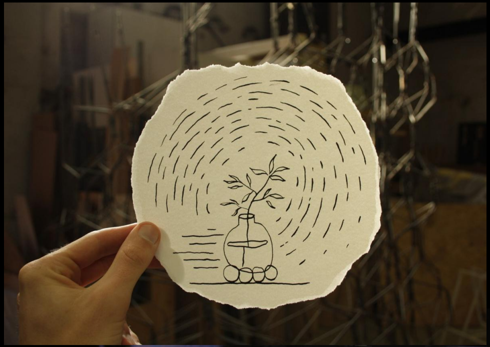


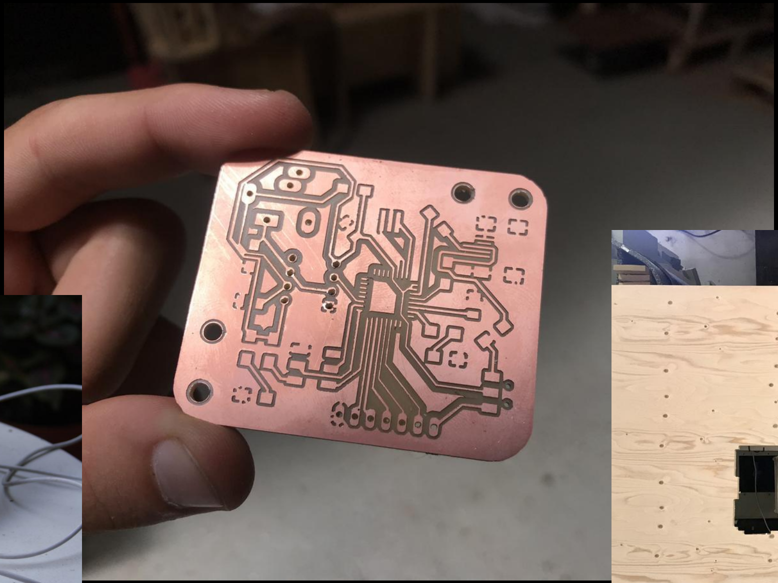
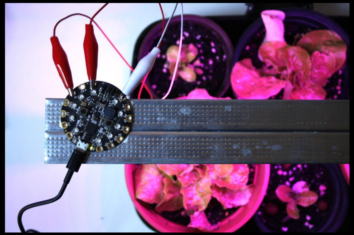
Word Radio

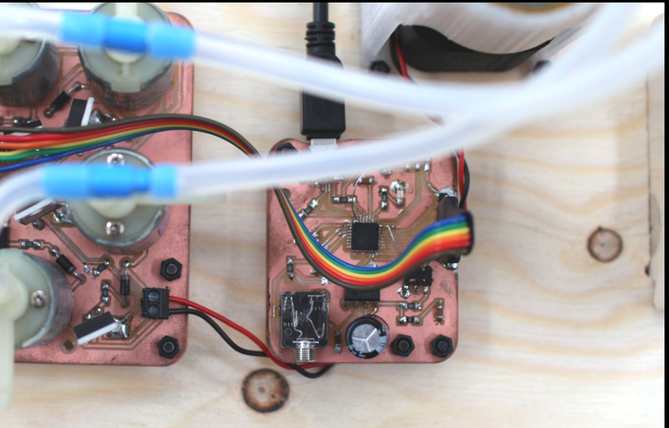











https://antoine.studio

Getting to know each other

You!

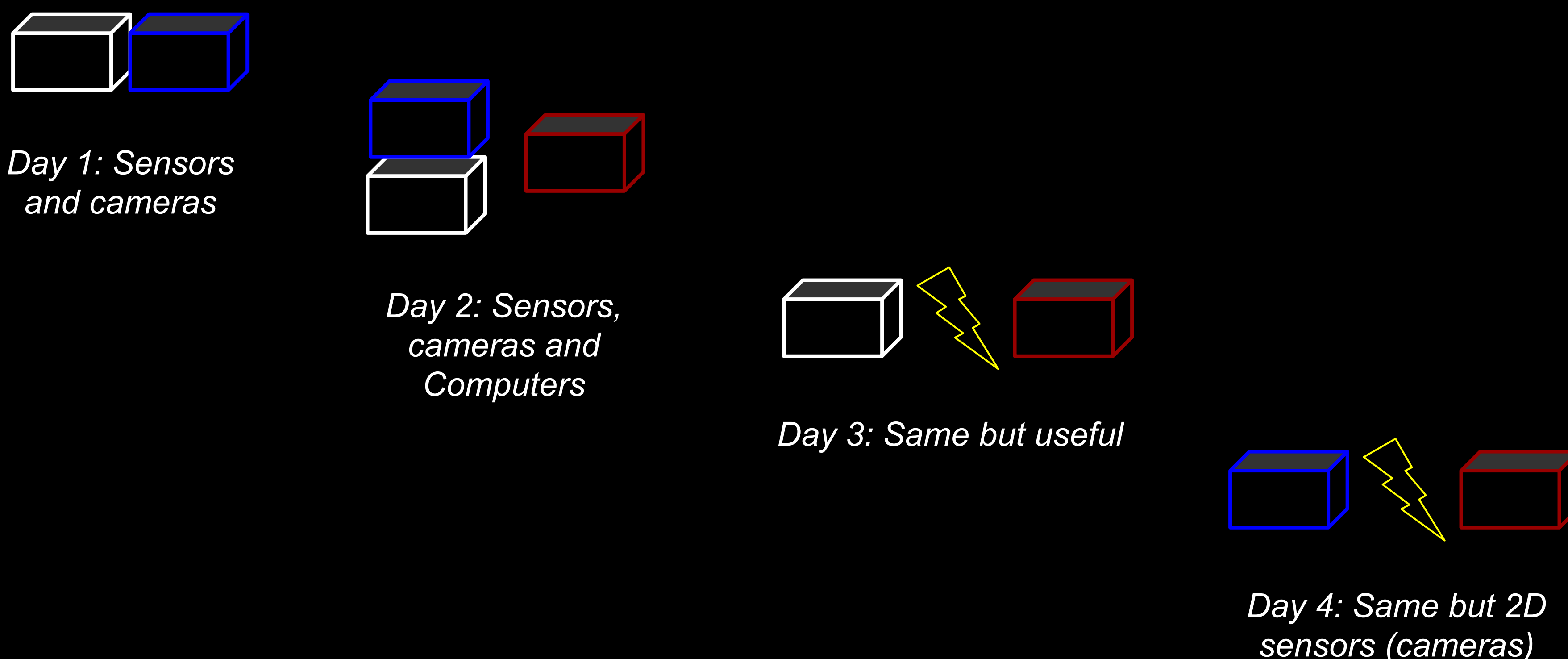
What we are going to do

Seminar Info

What we are going to do - Course overview

- *Day 1: Introduction*
  - *Getting to know each other*
  - *Seminar info:*
    - *Overview and objectives*
    - *Exercise explanation*
  - *Inspiration*
  - *Sensor basics*
    - *Digitalising information*
    - *Sensor types*
    - *Sensor deployment scenarios*
- *Day 2: Making your own data-logger*
  - *Making an actual sensor setup*
    - *Use case 1: Arduino with sensor*
    - *Use case 2: RPI with digital sensor*
    - *Use case 3: Camera with various options*
    - *Use case 4: Multiple sensors network*
- *Day 3: Introduction to Data Analysis*
  - *1D DSP*
  - *2D DSP*
- *Day 4 Computer vision (Ángel Muñoz)*

What we are going to do - Course overview



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 - Exercise

- *Groups of 2 to 3 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*

22/01	**Project idea presentation - potential conceptualization, plan and BOM**
29/01	**First *minimum viable product* prototype**
12/02	**Second iteration**
19/02	**Mid-term review**
26/02	**Third iteration**
12/03	**Final presentation - Back to life**

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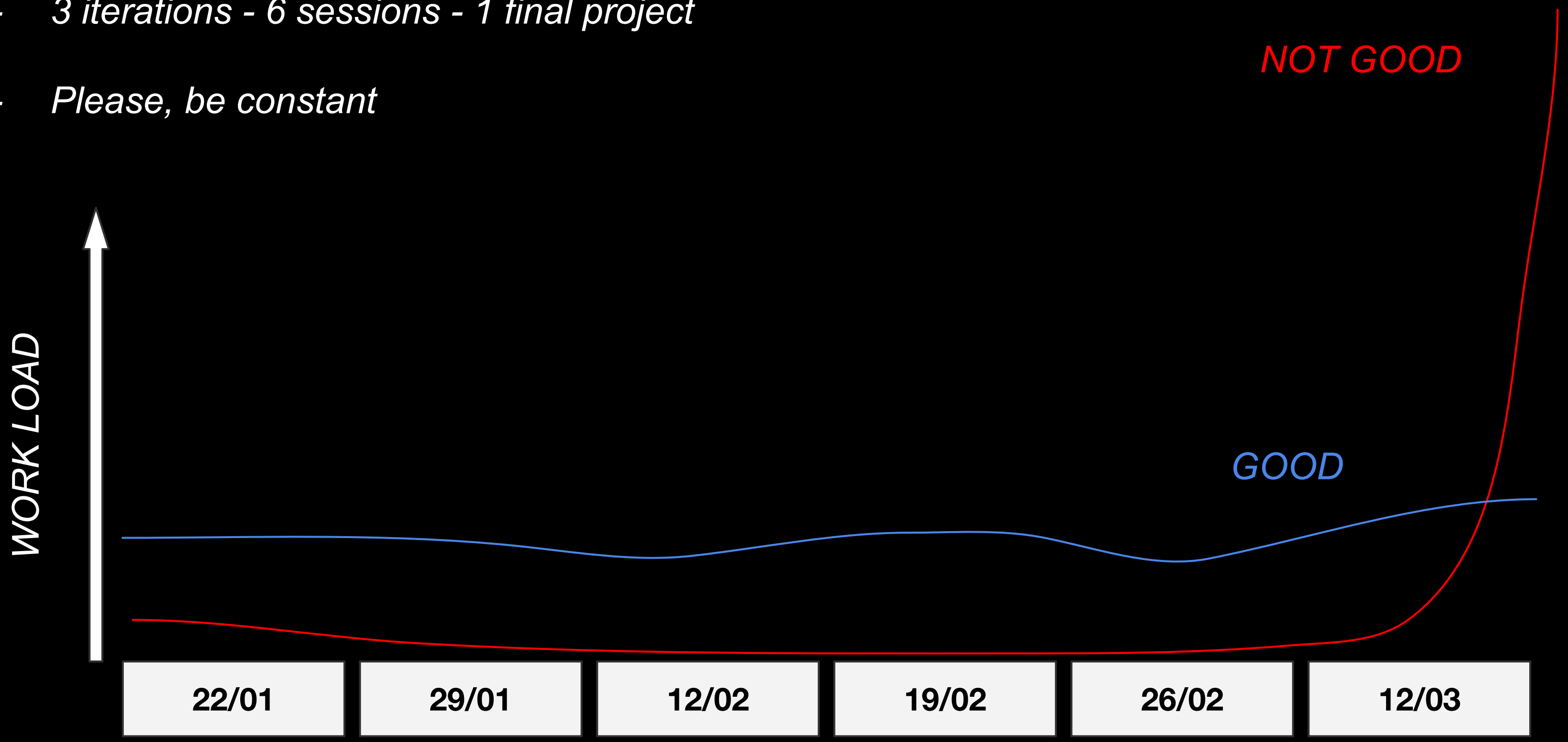
What we are going to do - How to go for it

- *3 iterations - 6 sessions - 1 final project*
- *Please, be constant*



Before we get started

Important resources

Before we get started - Important information

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

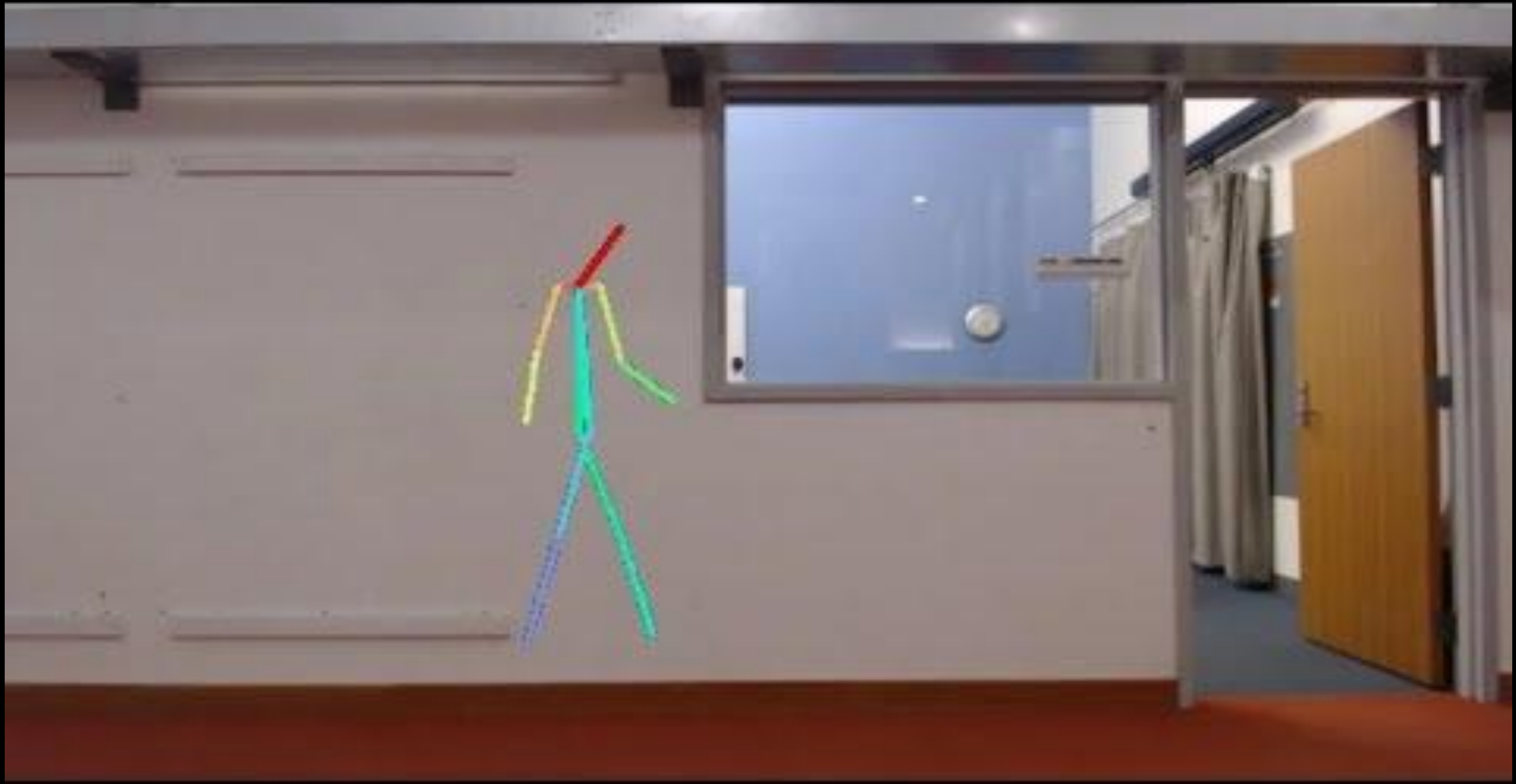
```
cd /path/to/nice/mrac/documents/folder

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

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

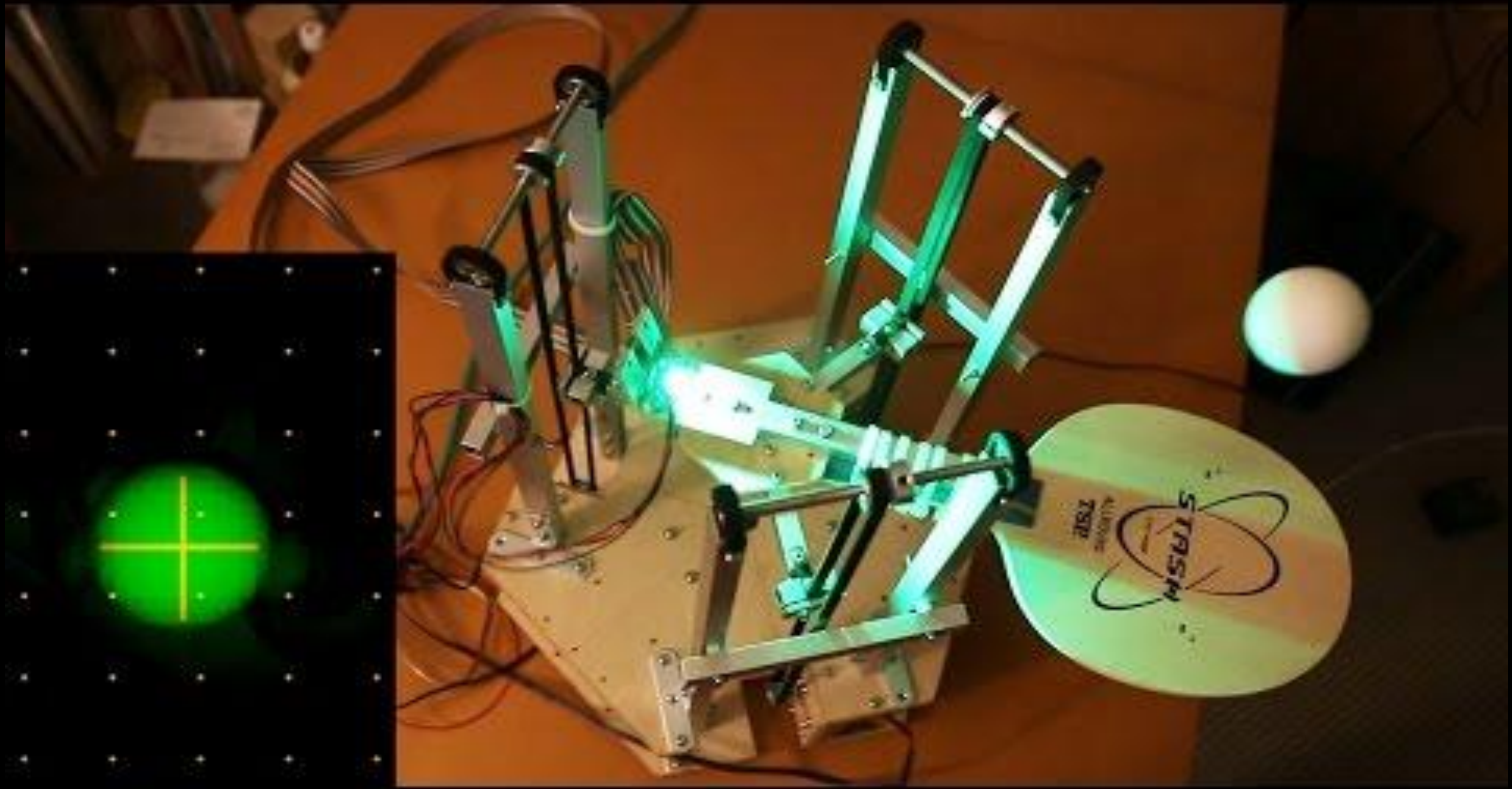
Some inspiration

[Synthetic Sensors: Towards General-Purpose Sensing]

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



[AI Senses people through walls]



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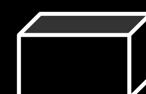
[OpenCV and raspberryPi Ping Pong]

Want more?

Check the repo

Why do we need sensors?

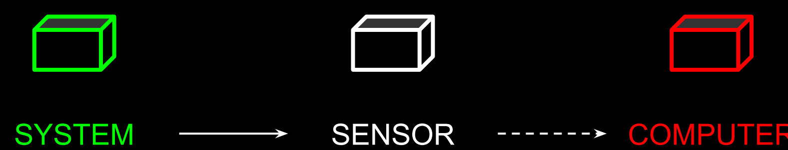
Understanding the basics
An overview of sensing techniques



Sensors

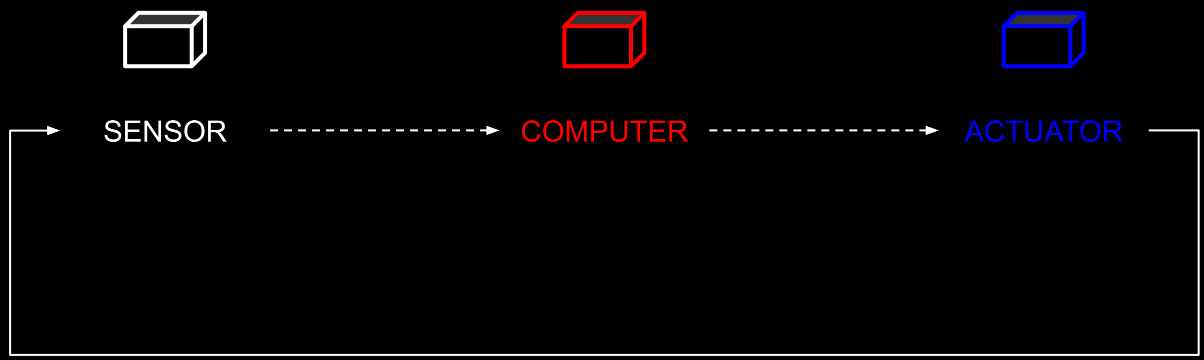
Understanding the basics - why do we need sensors?

Monitoring something

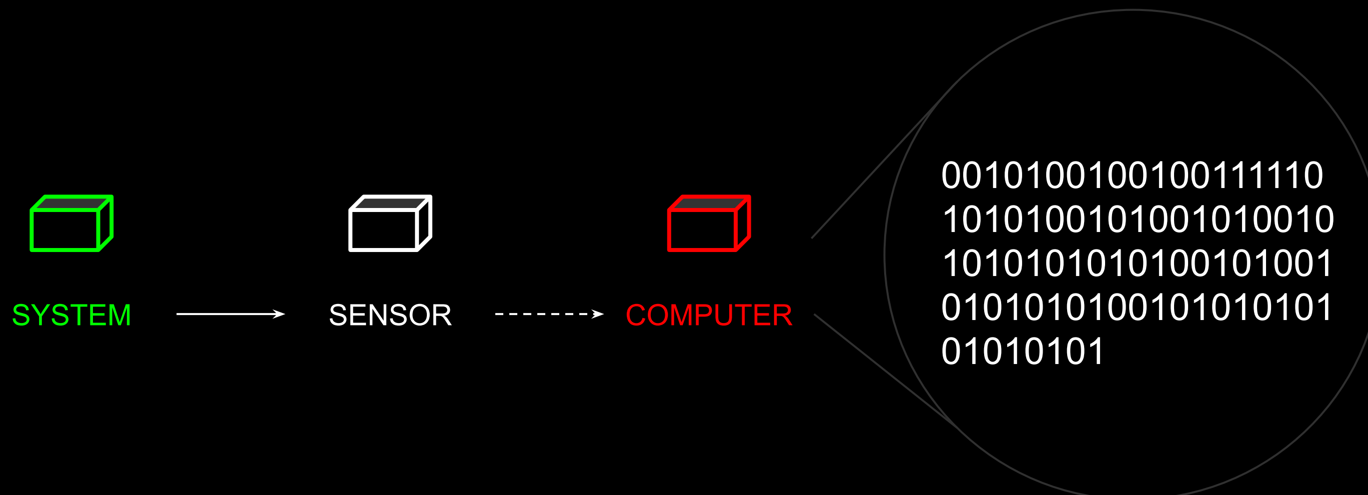


Understanding the basics - why do we need sensors?

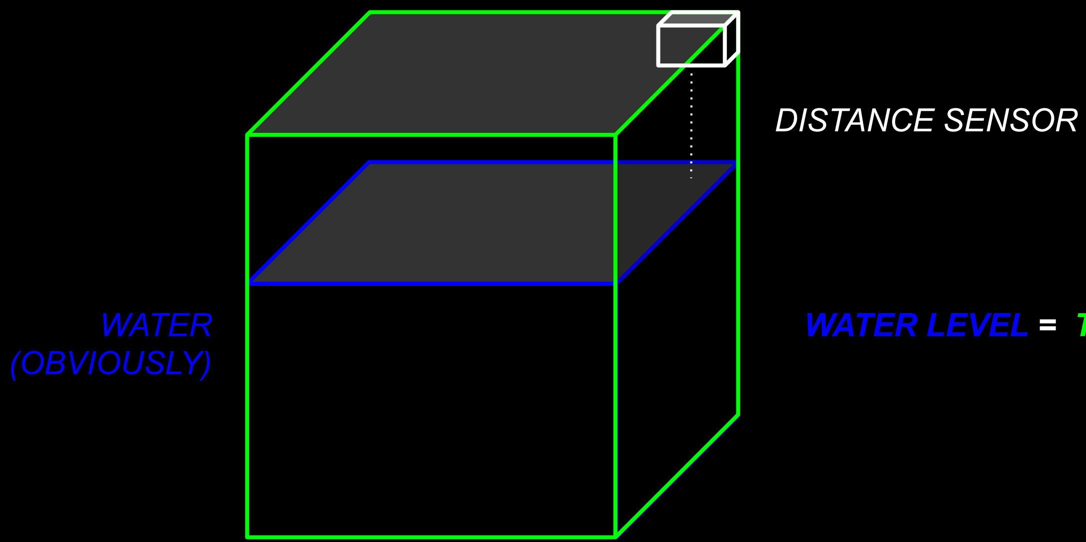
Controlling something
(closed loop)



Understanding the basics - digitalising physical phenomena

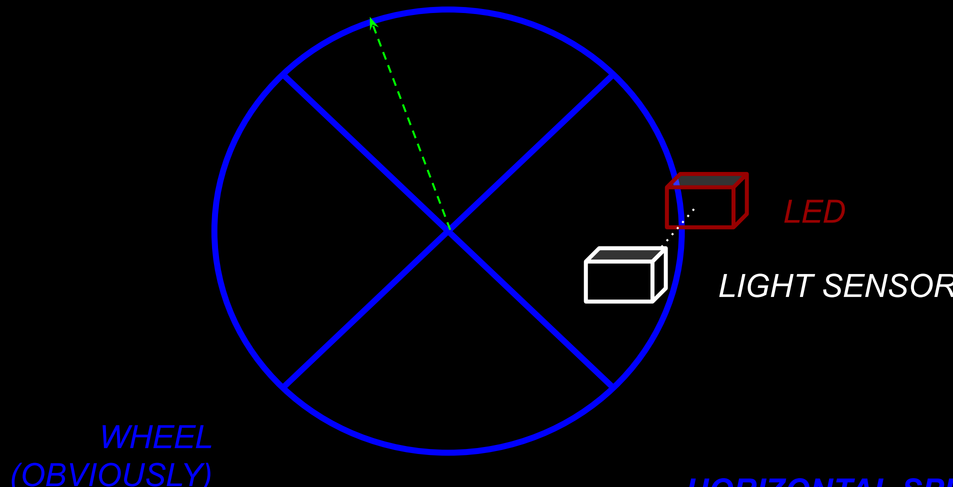


Understanding the basics - inference



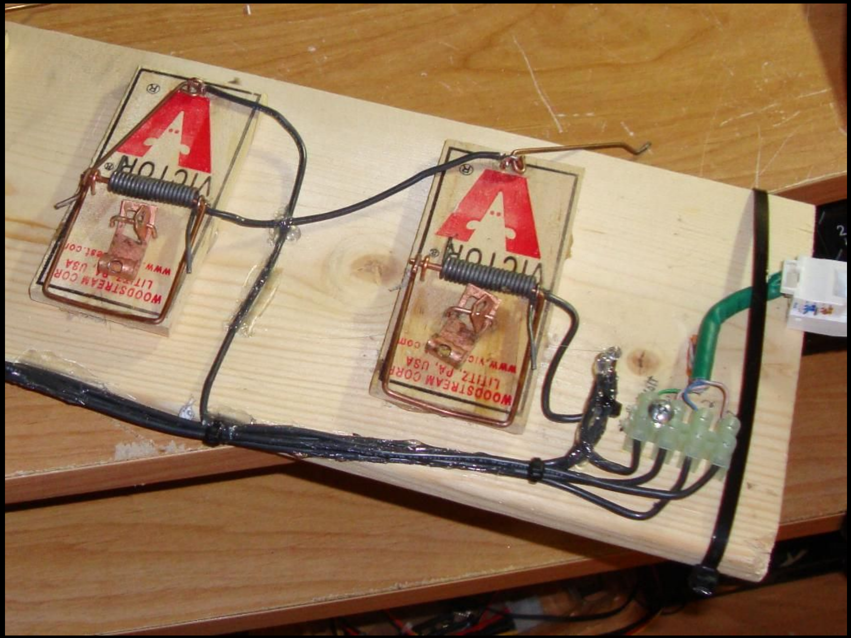
WATER LEVEL = TANK HEIGHT - SENSOR READING

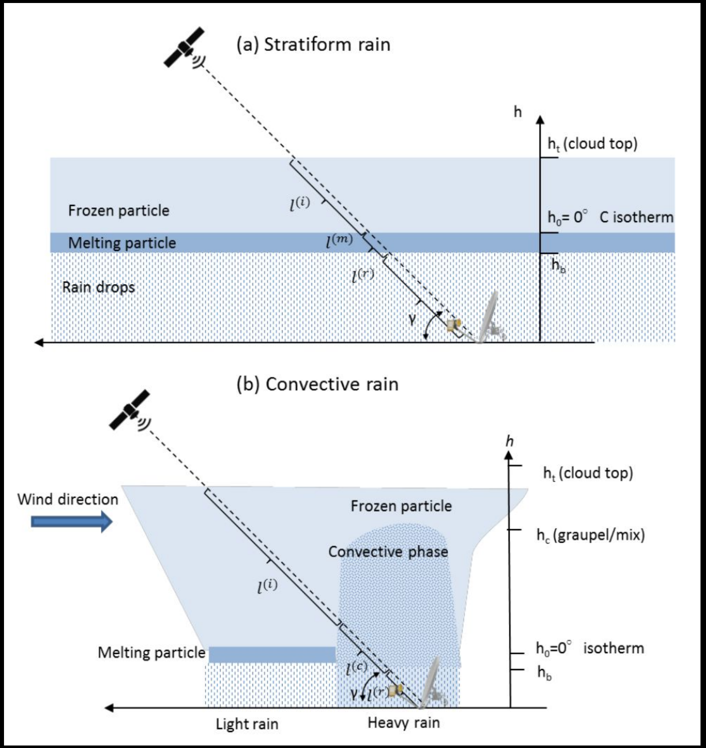
Understanding the basics - inference



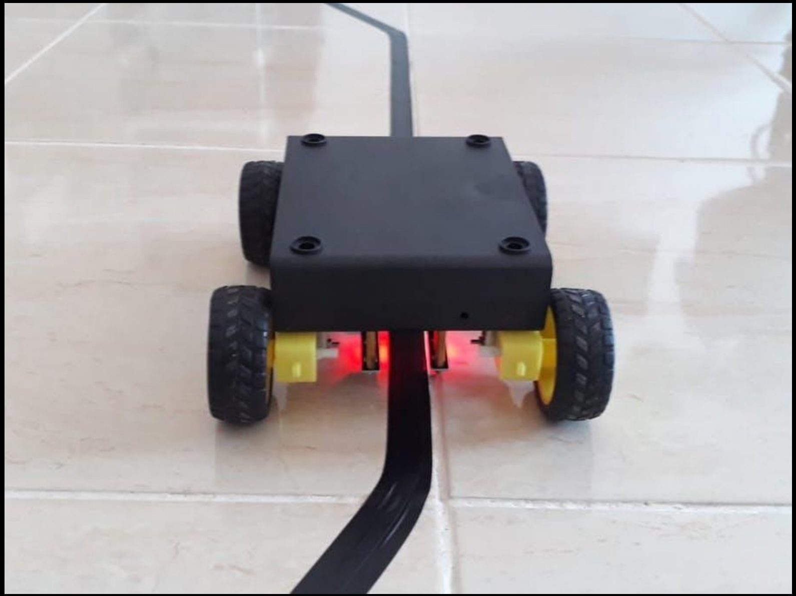
HORIZONTAL SPEED* = (PULSES/min)/4 * *WHEEL_RADIUS

Understanding the basics - simple vs. complex





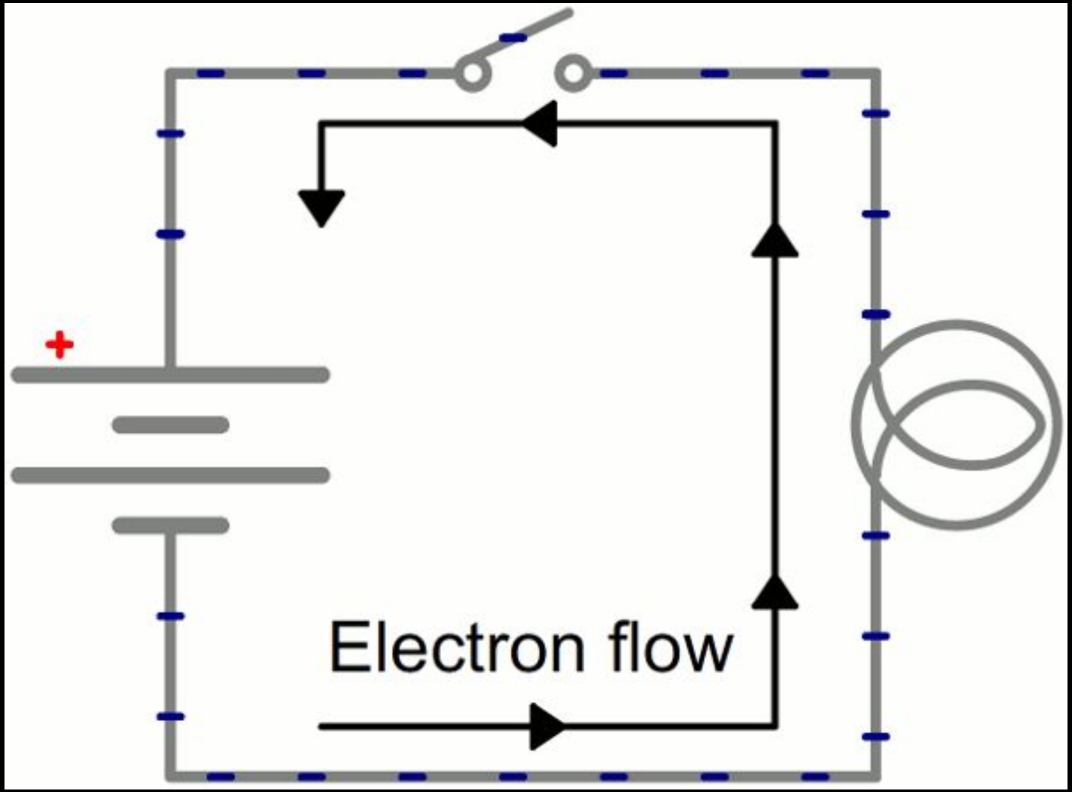
Understanding the basics - static vs. dynamic



Digging deeper

From signals to information

Digging deeper - The simplest sensor



HIGH

or

LOW

1

or

0

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TRUE

or

FALSE

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YES

or

NO

PERSON

or

NOT PERSON

CAT

or

DOG

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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)

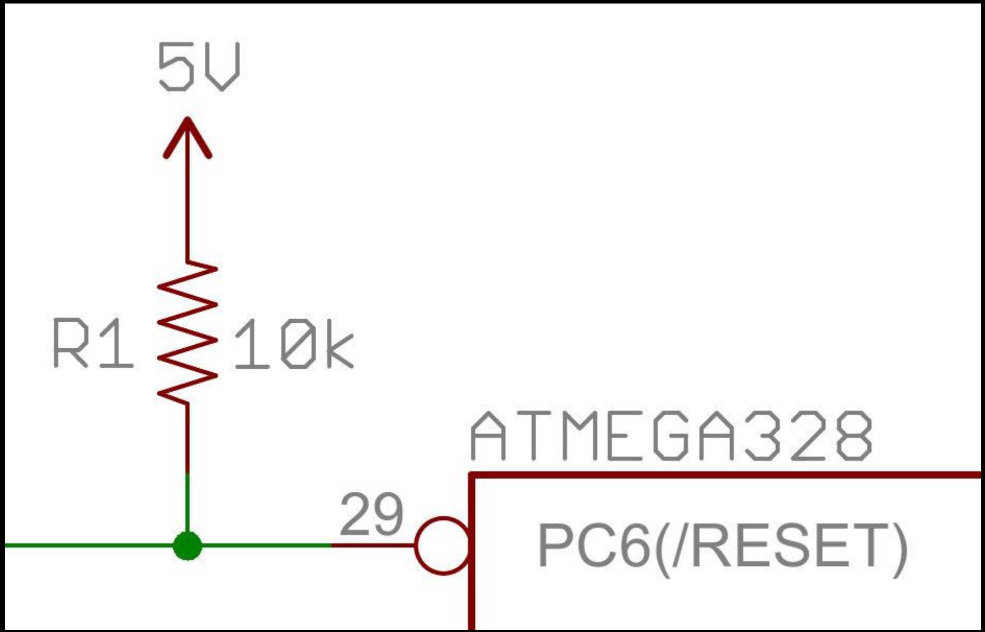
Pull-up resistors

*[...] 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)

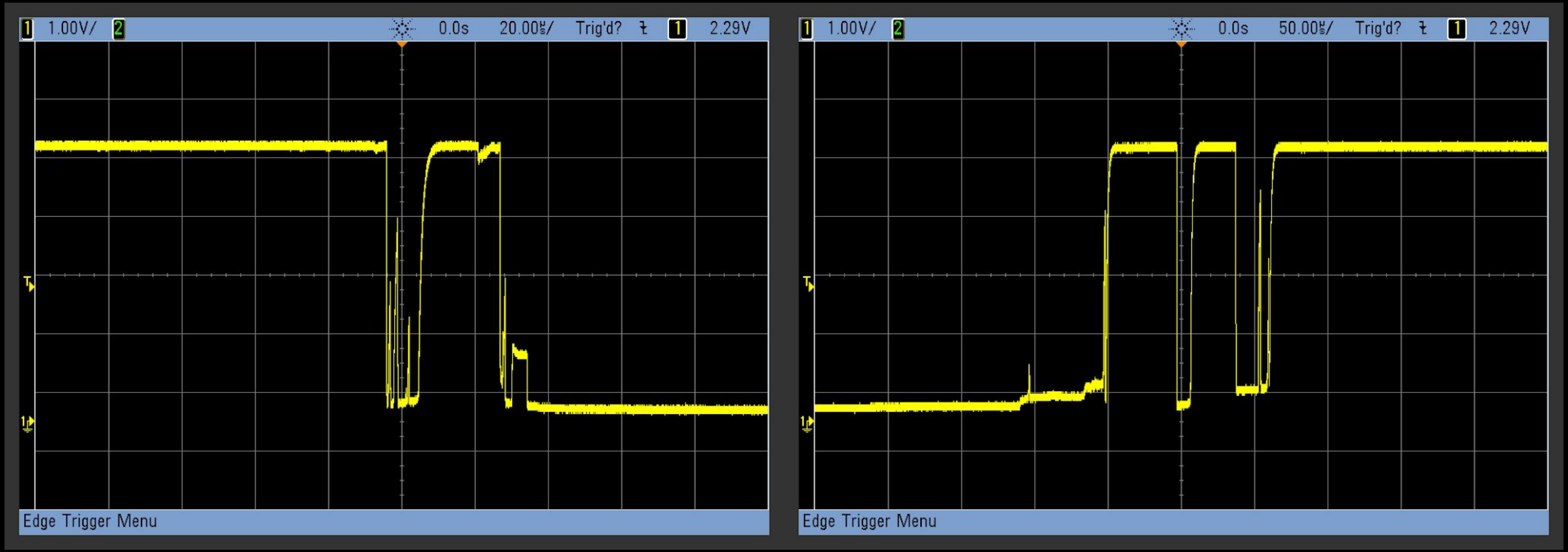
Debouncing

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/

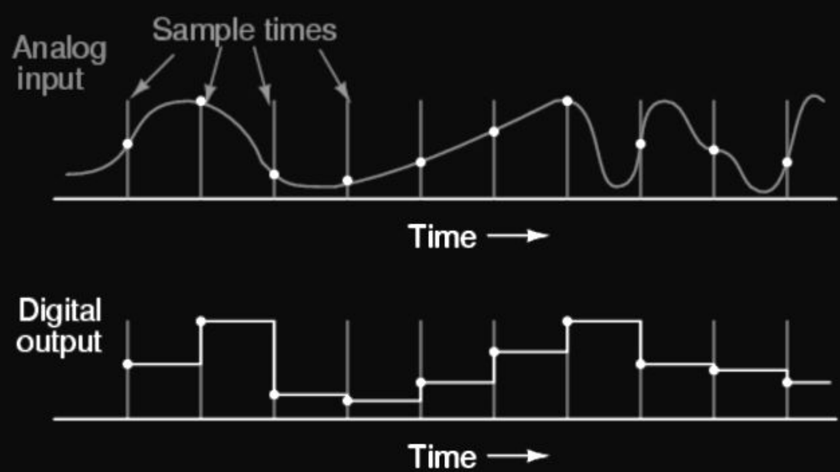
Digging deeper - The simplest sensor (or maybe not-so-simple)

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**:*

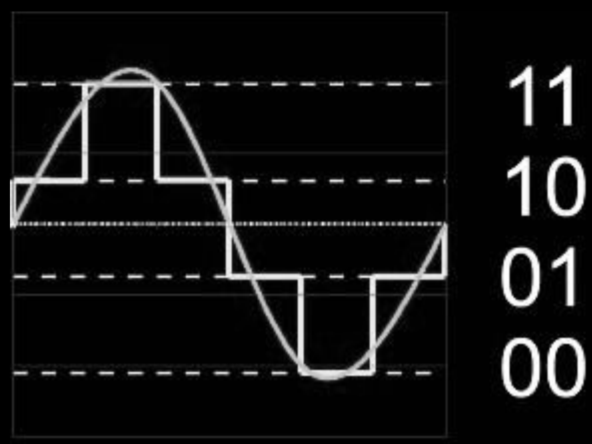
> An analog signal continuously changes with time, in order to measure the signal we have to keep it steady for a short duration so that it can be sampled.

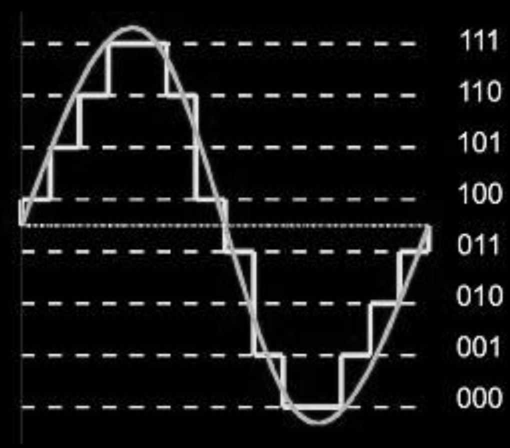
*The next stage is **Quantizing and Encoding:***

> 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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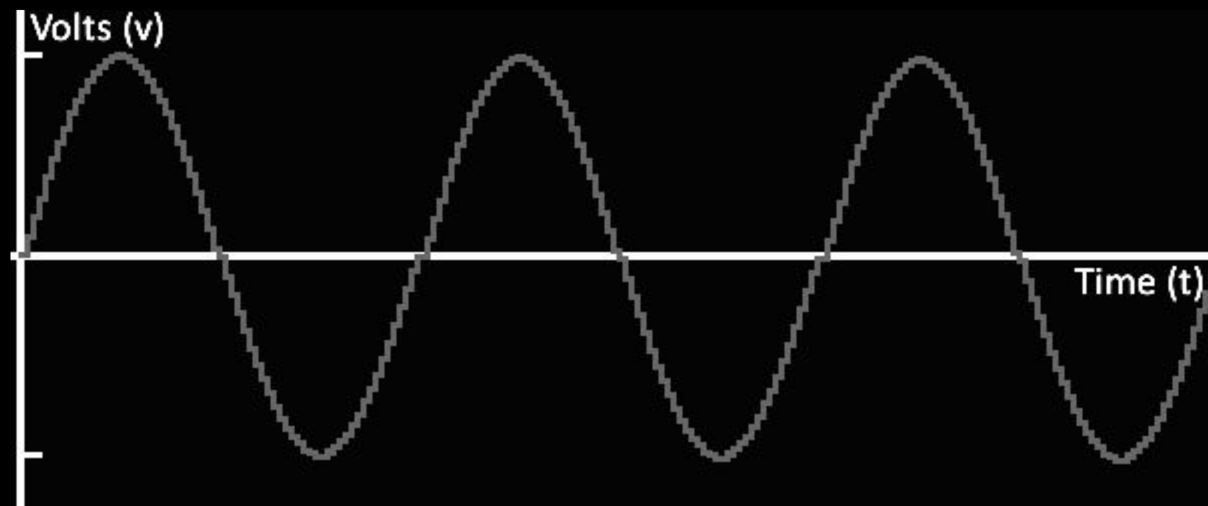
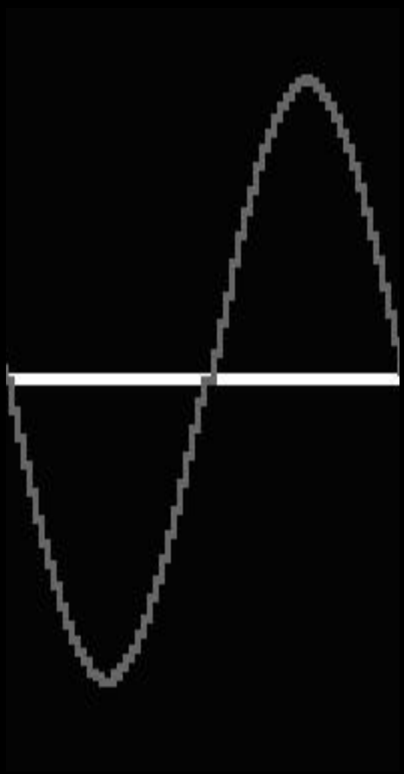
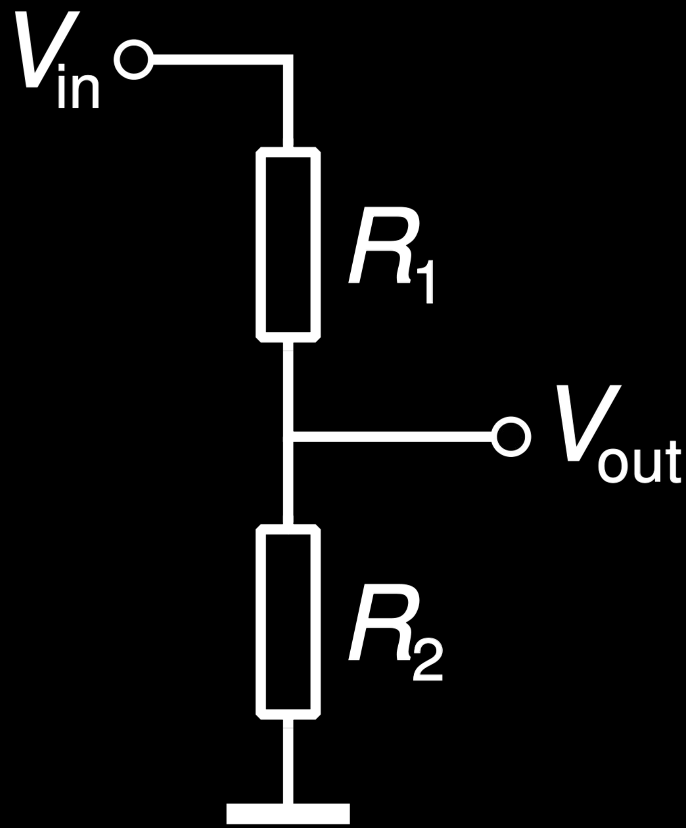


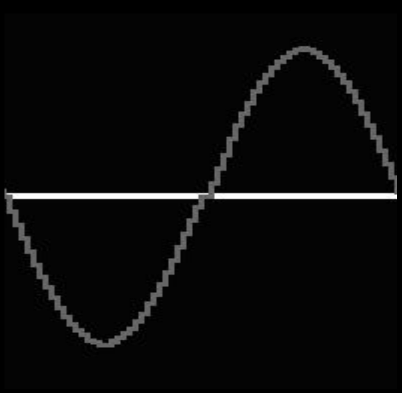
Digging deeper - Going Analog

- *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

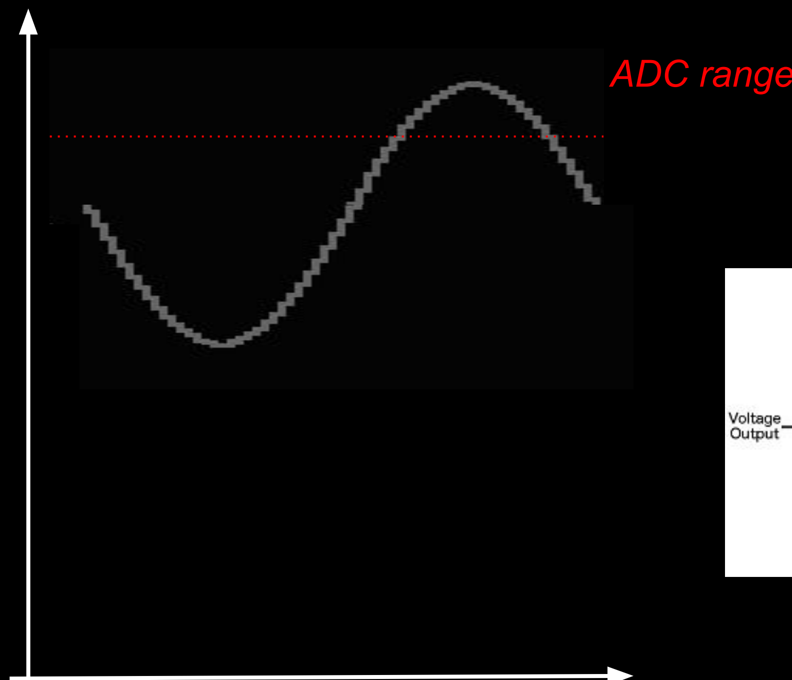


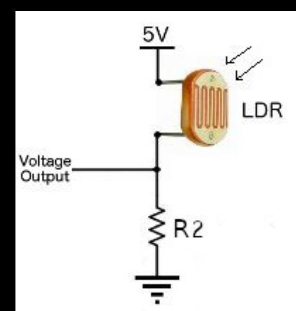




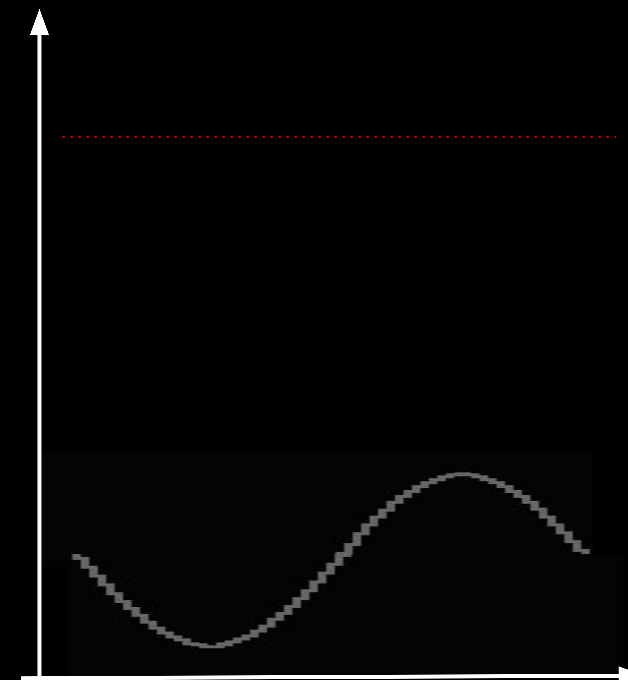
Digging deeper - Going Analog / Voltage dividers

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!

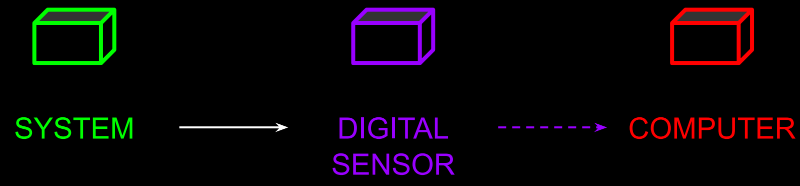
Before we continue...

I'm sorry

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`, *...*

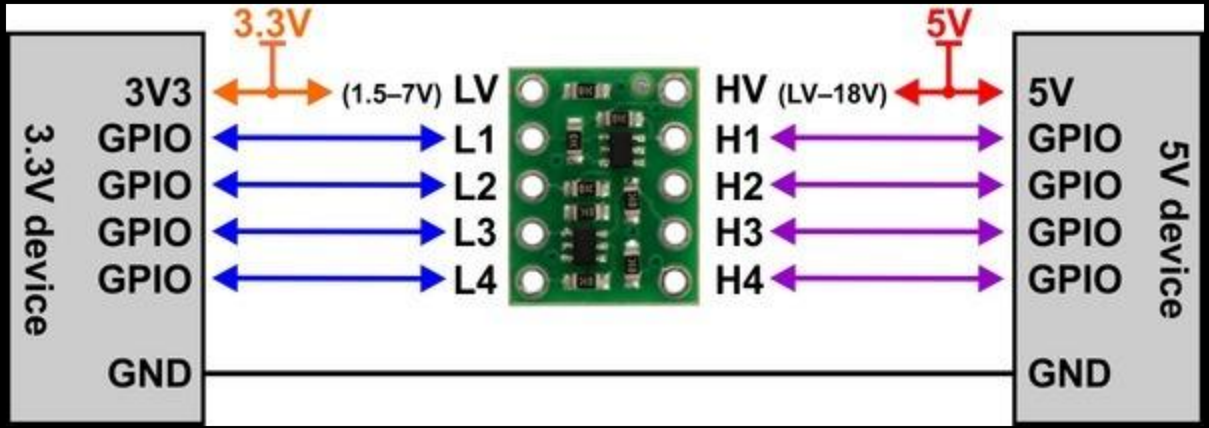


Digital Sensors

- *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!

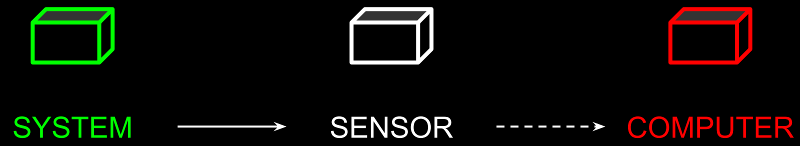
How to choose a sensor

Main aspects to consider

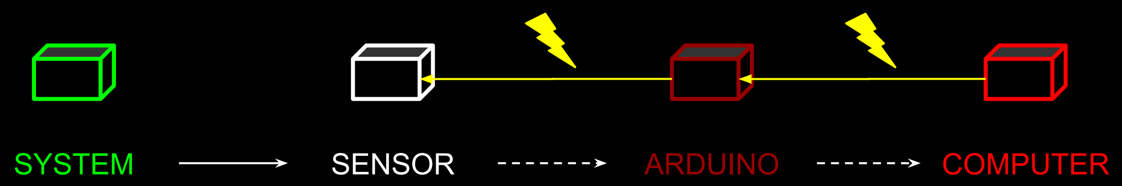
How to choose a sensor - Who does the heavy lifting?

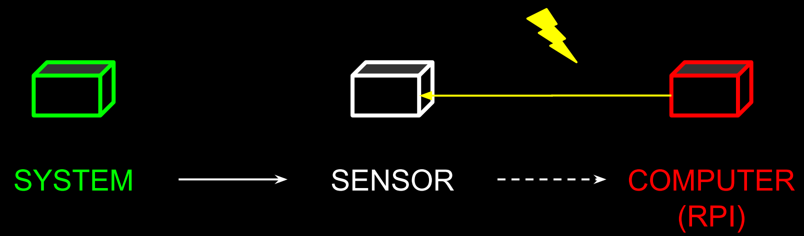
First - What is heavy lifting?

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?





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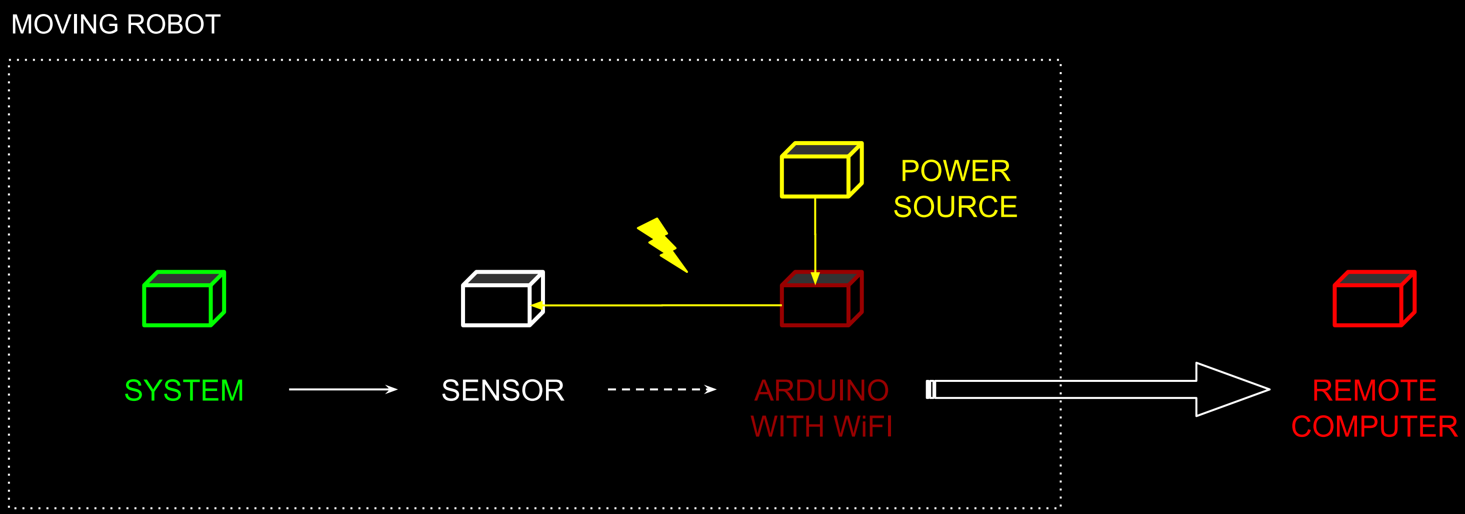
How to choose a sensor - Who does the heavy lifting?



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

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

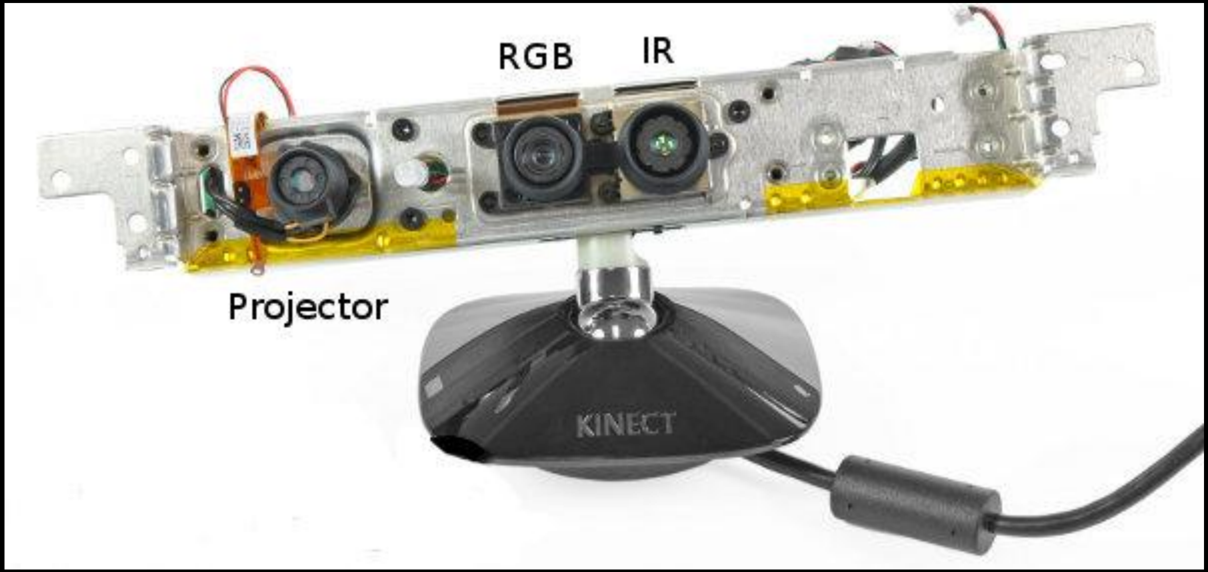
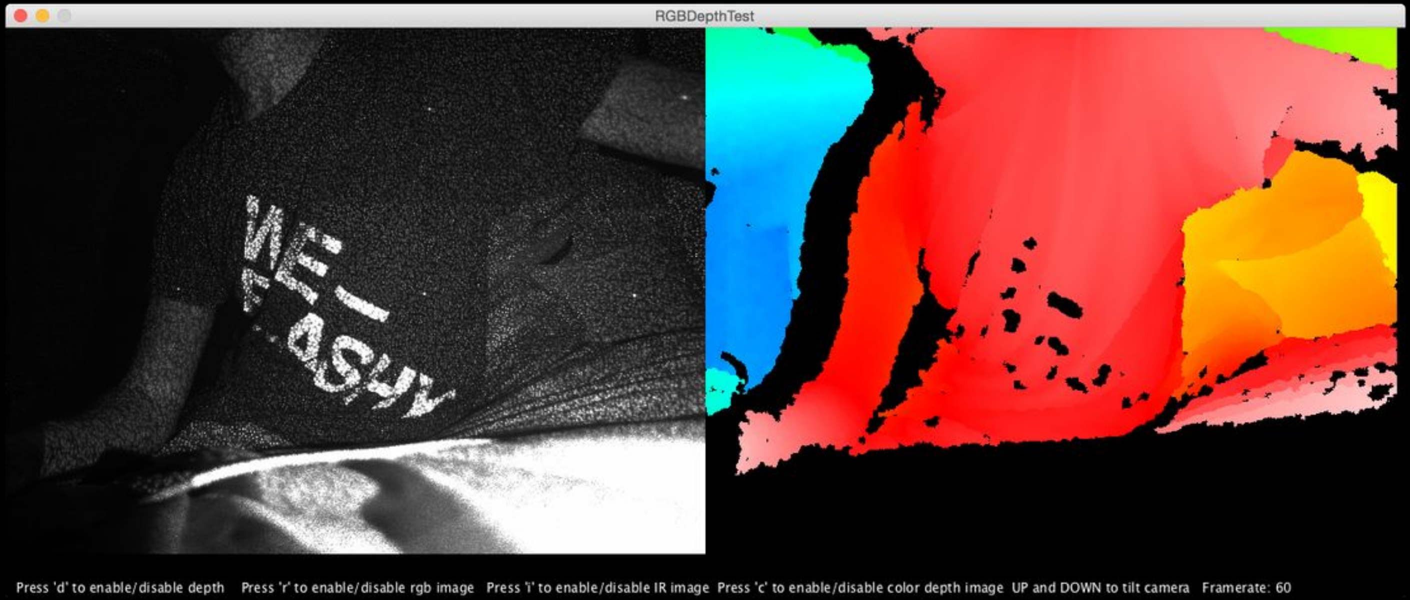


Image found found at: https://wiki.ros.org/kinect_calibration/technical originally from http://www.ifixit.com/Teardown/Microsoft-Kinect-Teardown/4066/1

Cameras - Some basics

RGBD cameras



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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

Well done!