



DEEC

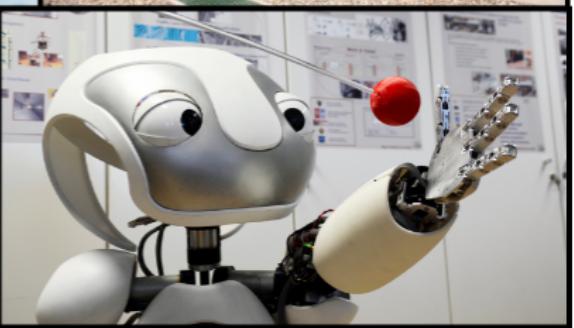
DEPARTAMENTO DE ENGENHARIA
ELETROTÉCNICA E DE COMPUTADORES
TÉCNICO LISBOA

Arduino 101

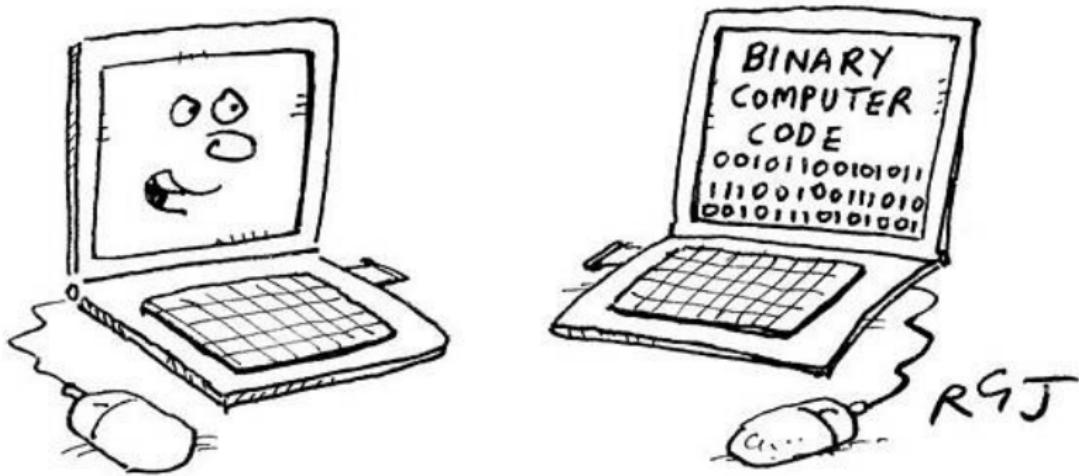
A sprint presentation on MCUs and I/O devices

DEEC-IST | HackerSchool | NEEC | IEEE-SB

Why are we where?



How do computers communicate?



"Now you're TALKING MY LANGUAGE"

How do computers communicate?

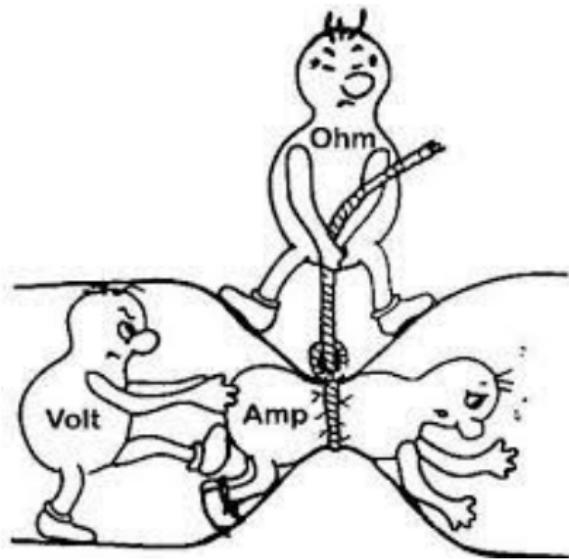
- ❖ **bit:** The most basic unit of computing information
 - ❖ Either 0
 - ❖ Or 1
- ❖ **byte:** Normally the smallest addressable unit of memory in most computing systems
 - ❖ It consists of **8 bits**



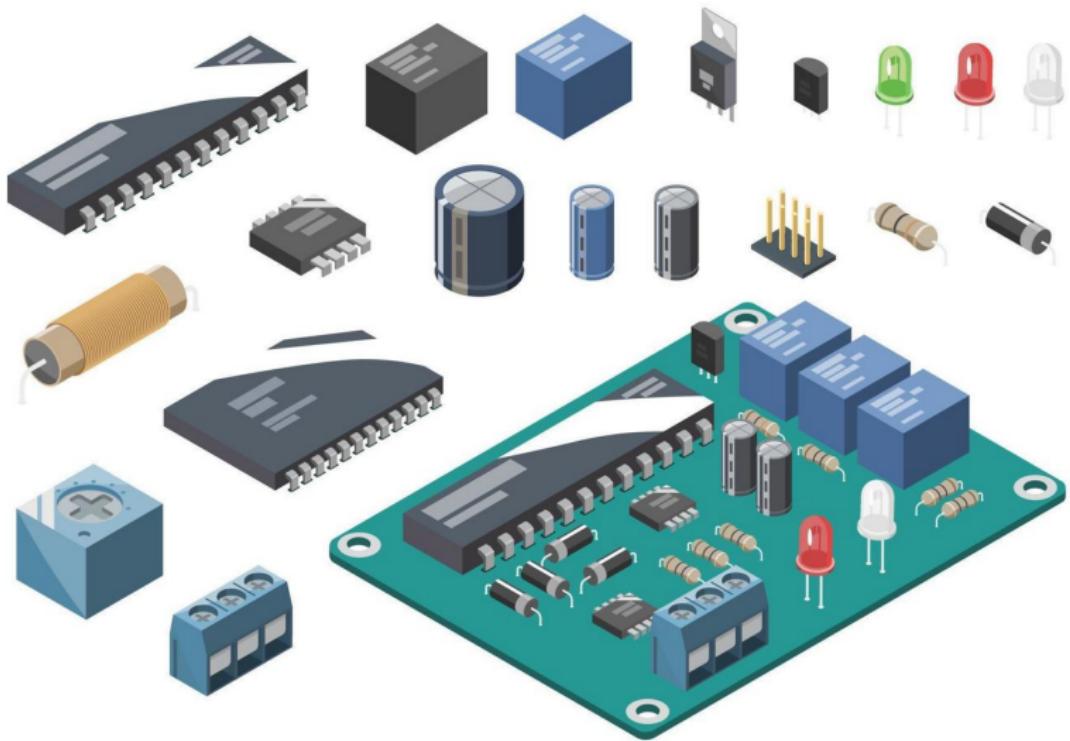
"Oh, what the hell, I'll add another zero."

Ohm's Law

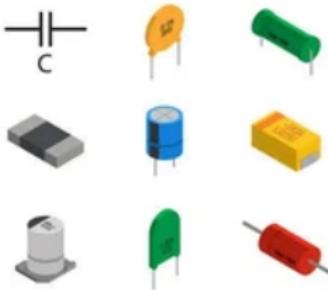
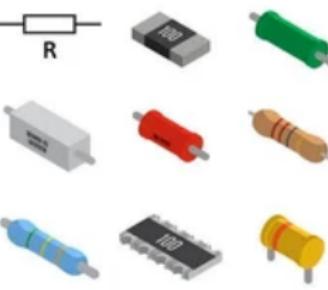
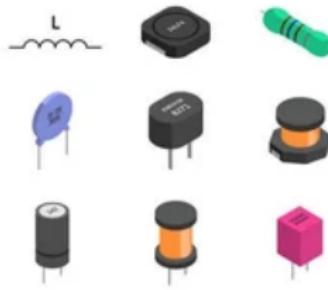
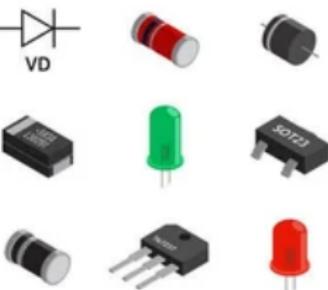
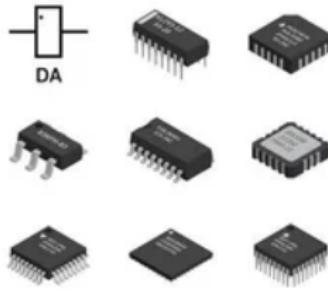
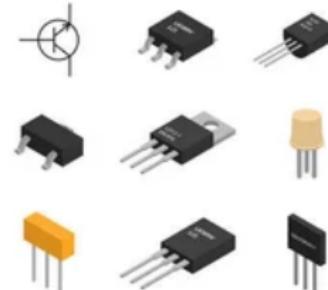
We are Electrical and Computer Engineers, not Computer Scientists! We have to understand the underlying hardware too, lets start with the basics!



Simple electronic components



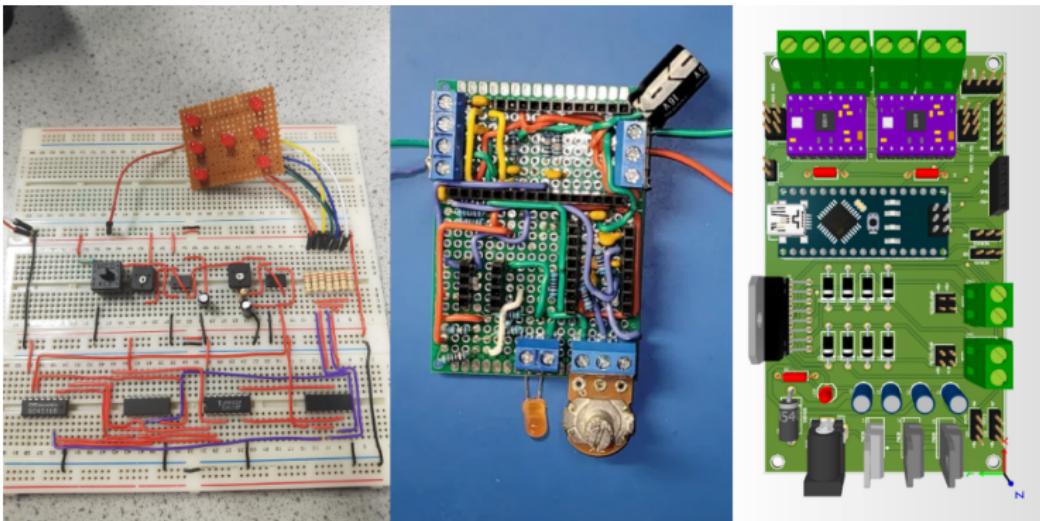
Simple electronic components

Capasitors 	Resistors 	Inductors 
Diodes 	Microchips 	Transistors 

But how can I make the connections?

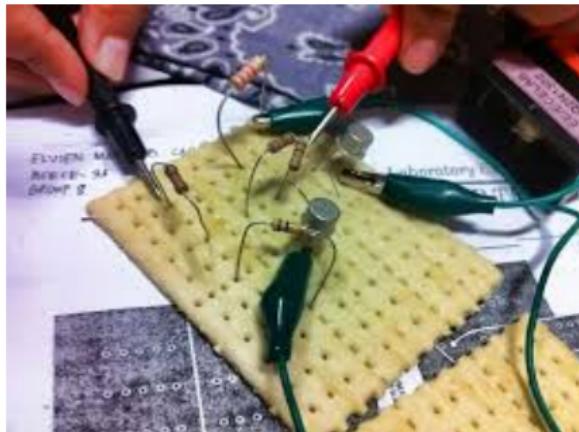
I need to have a conductive material between my components so they are electrically connected... But how?

Short Answer: **ECAD and Soldering**, in many shapes and forms.



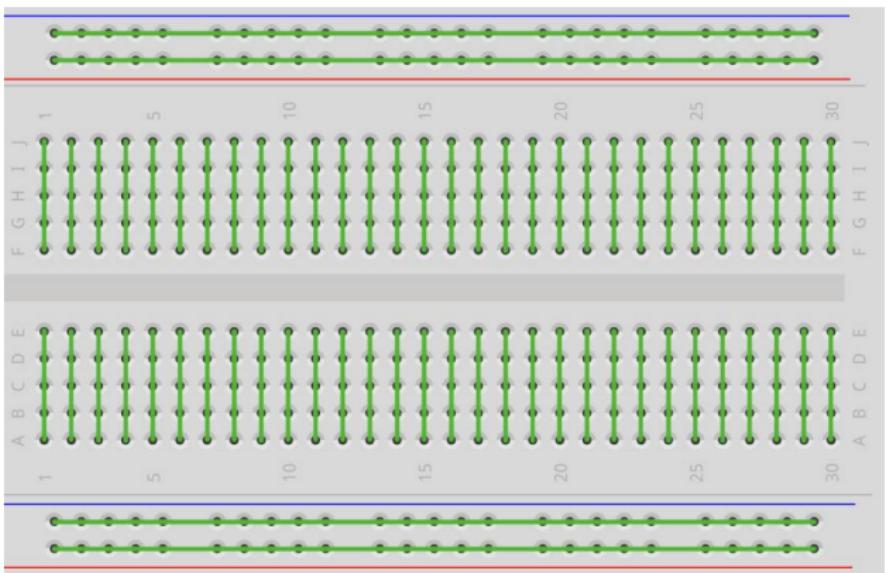
But is soldering viable for **prototyping**?

Breadboard?



Use a breadboard they say....

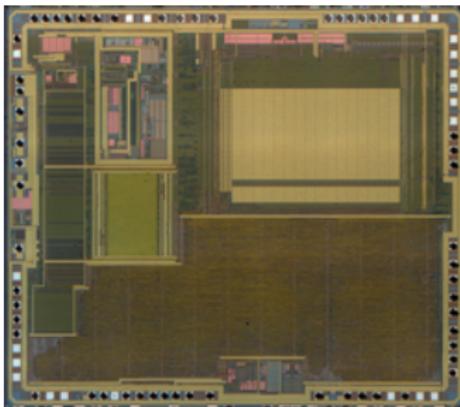
Breadboard.



He now have a conductive array where we can connect cables to prototype our circuit!

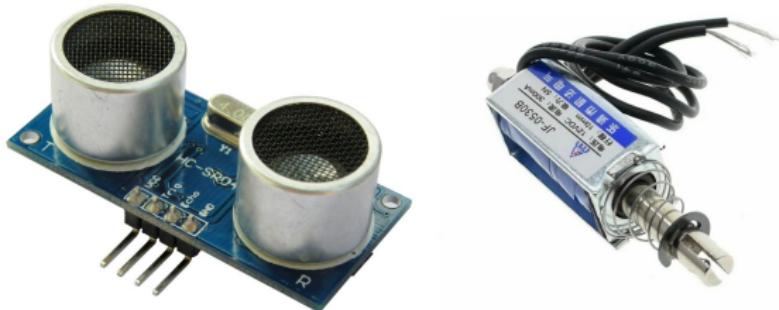
What is a Microcontroller?

- ❖ Small embedded computer
- ❖ Generically includes:
 - ❖ processor (CPU)
 - ❖ memory (RAM/Flash)
 - ❖ and I/O pins
- ❖ Normally the code runs on the baremetal
- ❖ Alternatively it can run a simple, deterministic OS
 - ❖ **FreeRTOS**



What are Sensors and Actuators?

- ❖ **Sensors:** collect data from the environment
- ❖ **Actuators:** perform actions over the environment



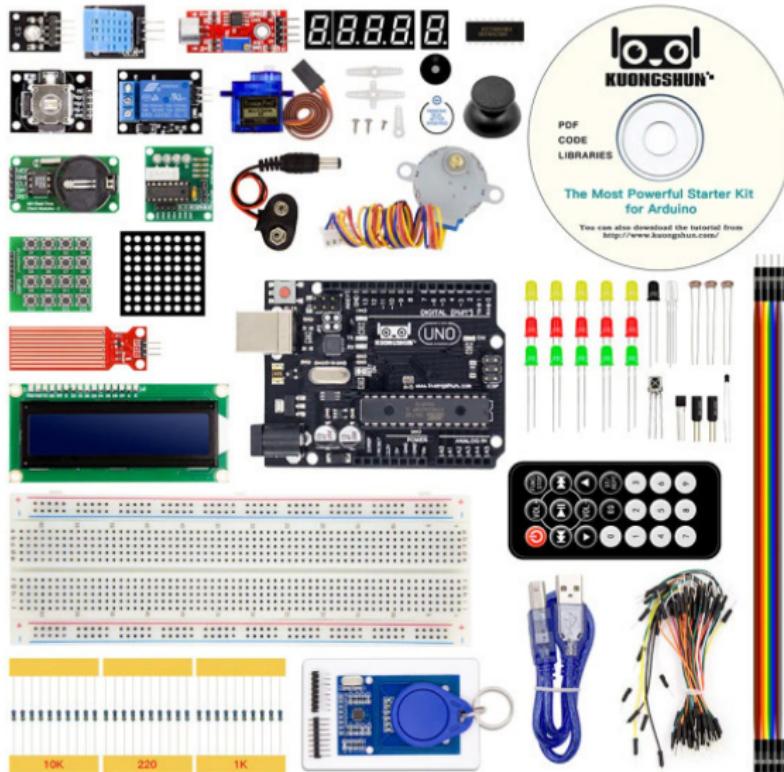
What are Sensors and Actuators?

These devices can communicate with the MCU through various protocols:

- General Purpose I/O (GPIO) and ADC I/O
- Inter-Integrated Circuit (I²C)
- Serial Peripheral Interface (SPI)
- Universal Asynchronous Receiver-Transmitter (UART)
- etc...



Some of the sensors you have....



Arduino UNO

ATmega328P

- Single-core 8-bit AVR microprocessor
- 20 MHz max frequency
- 2 kB of on-chip SRAM for data and instructions
- 23 GPIO pins
- 6 channel 10-bit Analog-to-Digital converter

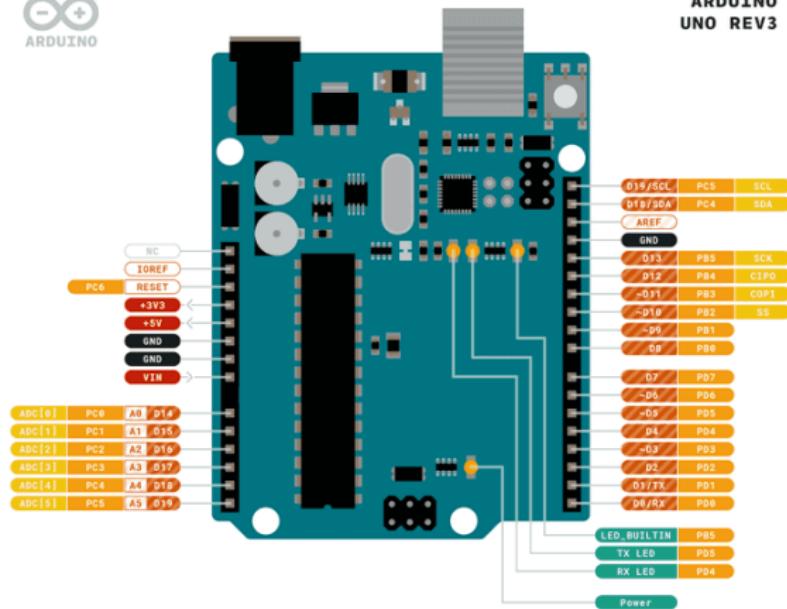
Arduino UNO

- Board that integrates a ATmega328P chip
- Adds peripherals such as
 - Quartz Oscillator for clock signal
 - USB Controller
 - Interfaces for Power signals

Arduino UNO Pinout

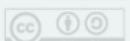


ARDUINO
UNO REV3



■ Ground ■ Internal Pin ■ Digital Pin ■ Microcontroller's Port
■ Power ■ SWD Pin ■ Analog Pin ■ Other Pin
■ LED ■ Other Pin ■ Default

ARDUINO.CC



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444 Castro Street, Suite 900, Mountain View, CA 94031, USA.

Setup and Microcontroller programming

For ease of use we will be using **Arduino IDE**

The screenshot shows the Arduino IDE interface with a teal header bar. The menu bar includes File, Edit, Sketch, Tools, and Help. A toolbar with icons for file operations (New, Open, Save, Print, etc.) is visible. The main window has a tab labeled "embedded" and contains C++ code for a water monitoring system. The code includes definitions for NTP server, time offset, and various sensor and control pins. It also initializes Firebase Data objects and defines pin modes for the Arduino pins. The status bar at the bottom shows compilation and upload information.

```
File Edit Sketch Tools Help
File Edit Sketch Tools Help
embedded
DallasTemperature waterTempSensor(twoWire);

const char* ntpServer = "pool.ntp.org";
const long gmtOffset_sec = 0; //Replace with your GMT offset (seconds)

const int daylightOffset_sec = 3600;
//const int daylightOffset_sec = 0;

char verboseWaterTime[512];
String timeRTDB;
time_t waterTime, timeThreshold;
bool manualWater, enAutoWater, enWaterSaving, enWaterSchedule;
float turbiThreshold, humiThreshold, tempThreshold, waterTempThreshold;
// Define the Firebase Data object
FirebaseData fbd;
FirebaseAuth auth;
FirebaseConfig config;

void setup() {
    pinMode(LED, OUTPUT);
    pinMode(pumpWater, OUTPUT);
    //pinMode(pumpRemove, OUTPUT);
    //pinMode(pumpAdd, OUTPUT);
    digitalWrite(pumpWater, INACTIVE);
    pinMode(waterLevel, INPUT);
    //digitalWrite(waterLevel, LOW);
    pinMode(waterTurbidity, INPUT);
    //digitalWrite(waterTurbidity, LOW);
    pinMode(waterTemperature, INPUT);
}

Compiling sketch...

```

```
/home/jbcr/IST/MEng/RNIC/GreenThumb/EmbeddedSystem/embedded/embedded.ino:57:1: warning: 'typedef' was ignored in this declaration
 57 |     typedef enum TankCode (NO_WATER, DIRTY_WATER, HOT_WATER);
      |     ^~~~~~

```

```
sd@niced: ~ pgm_read macros for iRAMPROGMEM, dr (aka nodemcu), 26 MHz, 40MHz, DOUT (compatible), 1MB (FS:84KB OTA~470KB), 2, nodeos-sdk 2.2.1+100 (190703), v2 Lower Memory, Disabled, None, Only Sketch, t15200 on devtinyUSB0
```

Digital I/O - How does it work?

The information can only be in two states:

- **HIGH** (between 5V and 3.0V)
- **LOW** (between 1.5V and 0V)

Our information is a **single binary digit** - a bit!

Analog I/O - How does it work?

Question: If my ADCs have a 10-bit (binary digit) resolution, how many states can I have?

Analog I/O - How does it work?

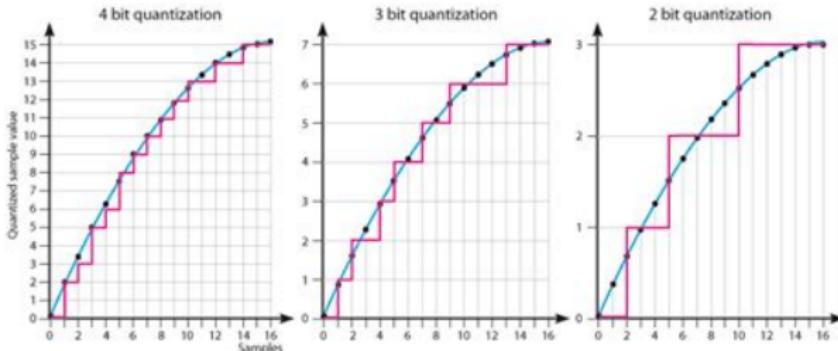
A bit represents one of two possible states

- **HIGH** (0)
- **LOW** (1)

Therefore with 10-bits:

Analog I/O - How does it work?

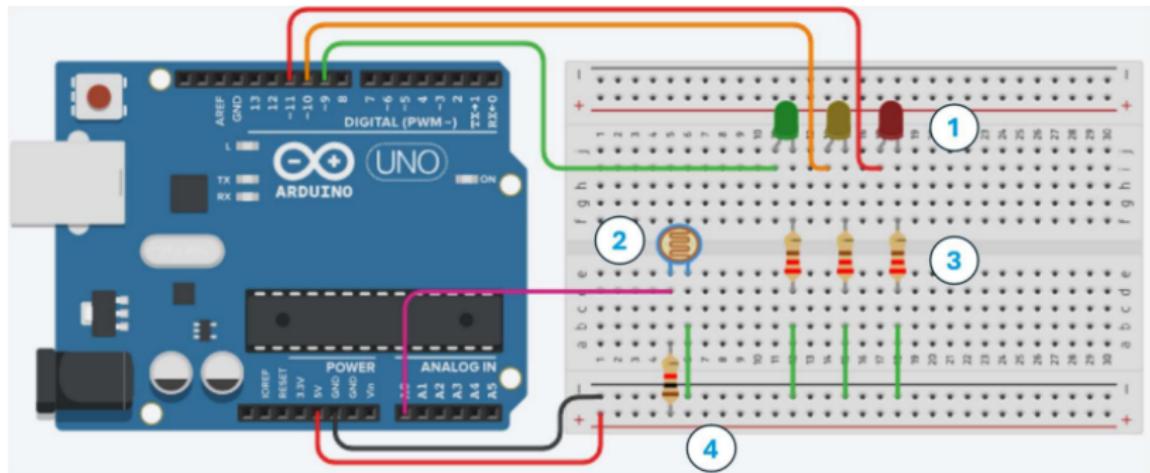
So our ADC acquired a **continuous** signal and converted it into a **discrete** one! This is called **quantization**!



Let's build something! - Concept

Let's build a **very** simple luminosity detection system

Let's build something! - Schematic



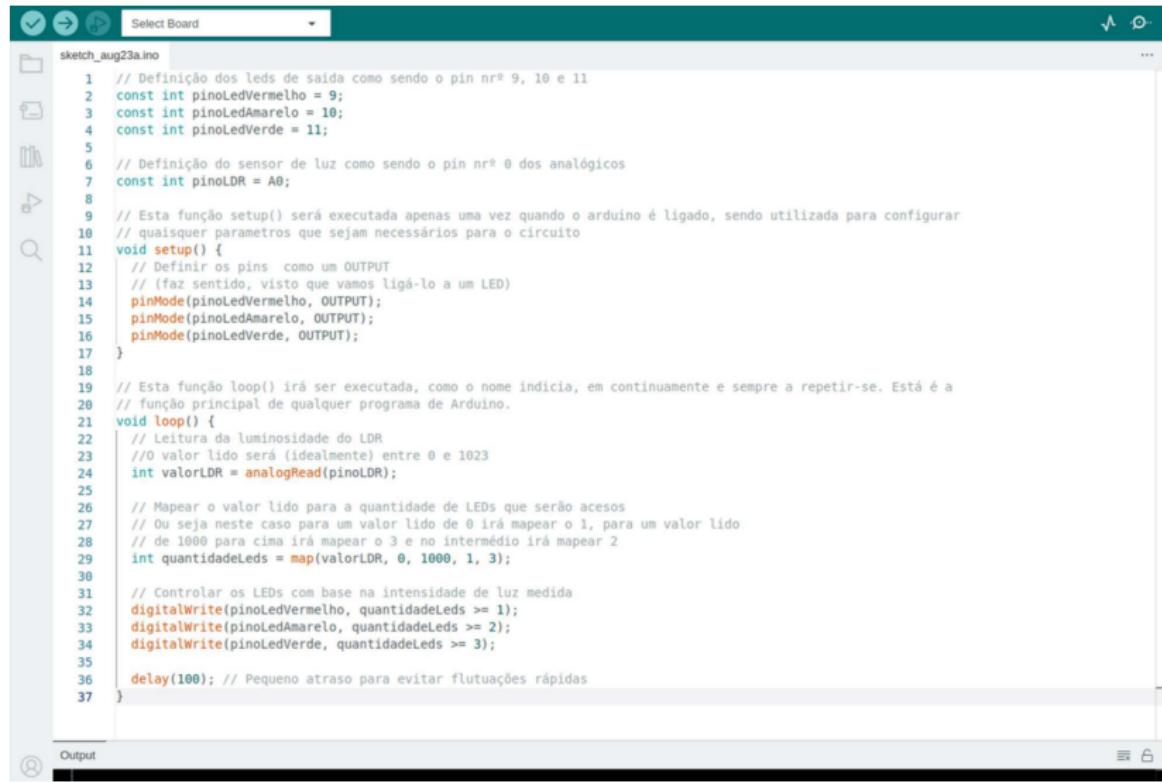
1 3 x LED's

2 1 x LDR

3 3 x Resistência 220 Ω

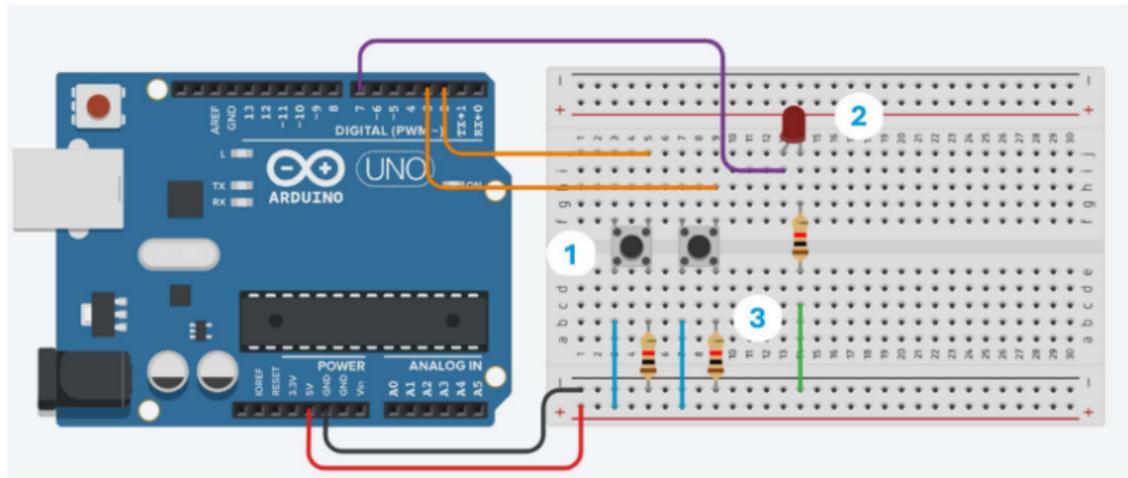
4 1 x Resistência 10kΩ

Let's build something! - Code



```
sketch_aug23a.ino
1 // Definição dos leds de saída como sendo o pin nrº 9, 10 e 11
2 const int pinoLedVermelho = 9;
3 const int pinoLedAmarelo = 10;
4 const int pinoLedVerde = 11;
5
6 // Definição do sensor de luz como sendo o pin nrº 0 dos analógicos
7 const int pinoLDR = A0;
8
9 // Esta função setup() será executada apenas uma vez quando o arduino é ligado, sendo utilizada para configurar
10 // quaisquer parametros que sejam necessários para o circuito
11 void setup() {
12     // Definir os pins como um OUTPUT
13     // (faz sentido, visto que vamos ligá-lo a um LED)
14     pinMode(pinoLedVermelho, OUTPUT);
15     pinMode(pinoLedAmarelo, OUTPUT);
16     pinMode(pinoLedVerde, OUTPUT);
17 }
18
19 // Esta função loop() irá ser executada, como o nome indica, em continuamente e sempre a repetir-se. Está é a
20 // função principal de qualquer programa de Arduino.
21 void loop() {
22     // Leitura da luminosidade do LDR
23     // O valor lido será (idealmente) entre 0 e 1023
24     int valorLDR = analogRead(pinoLDR);
25
26     // Mapear o valor lido para a quantidade de LEDs que serão acesos
27     // Ou seja neste caso para um valor lido de 0 irá mapear o 1, para um valor lido
28     // de 1000 para cima irá mapear o 3 e no intermédio irá mapear 2
29     int quantidadeDeLeds = map(valorLDR, 0, 1000, 1, 3);
30
31     // Controlar os LEDs com base na intensidade de luz medida
32     digitalWrite(pinoledVermelho, quantidadeDeLeds >= 1);
33     digitalWrite(pinoledAmarelo, quantidadeDeLeds >= 2);
34     digitalWrite(pinoledVerde, quantidadeDeLeds >= 3);
35
36     delay(100); // Pequeno atraso para evitar flutuações rápidas
37 }
```

One more challenge

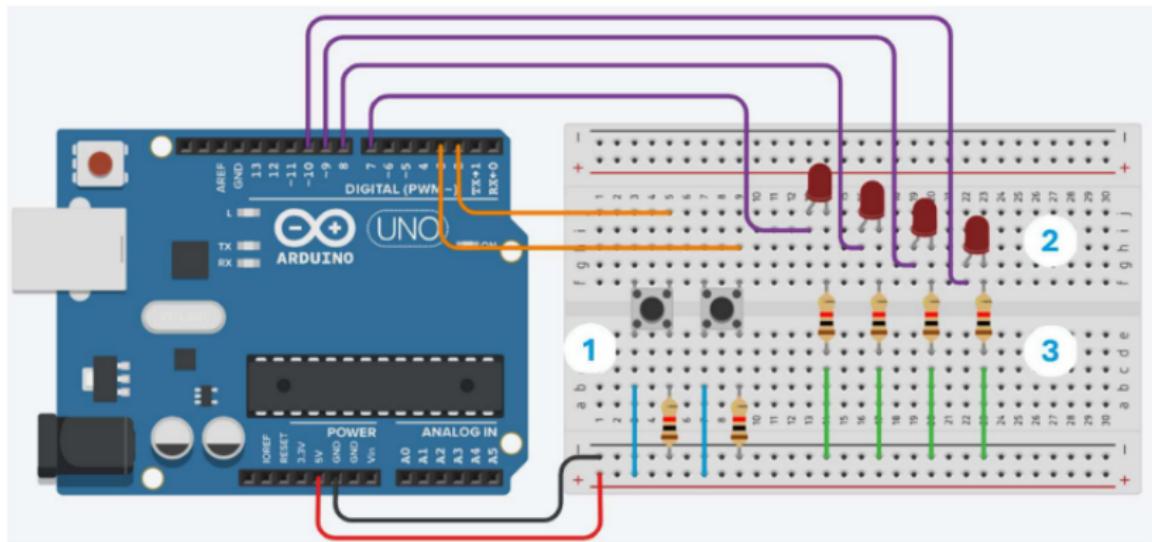


1 2 x Botões

2 1 x LED

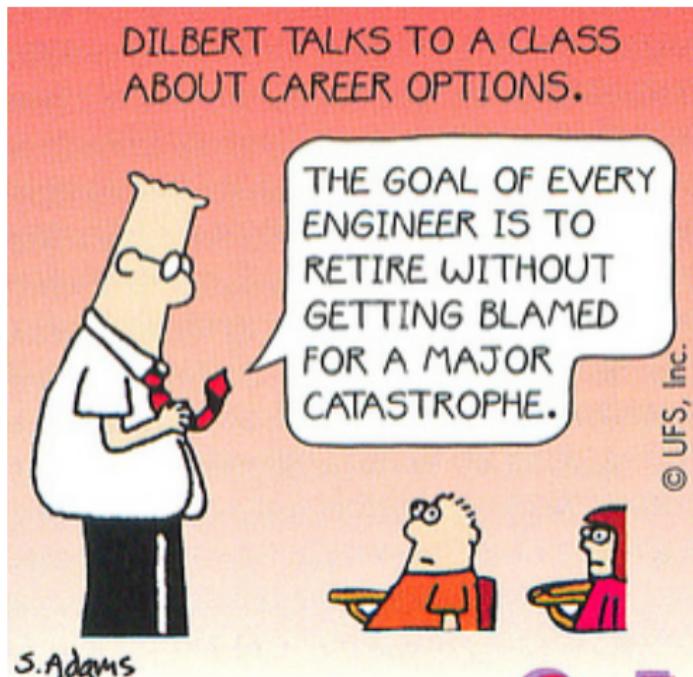
3 3 x Resistência

...And one more for good luck



Thank you for coming

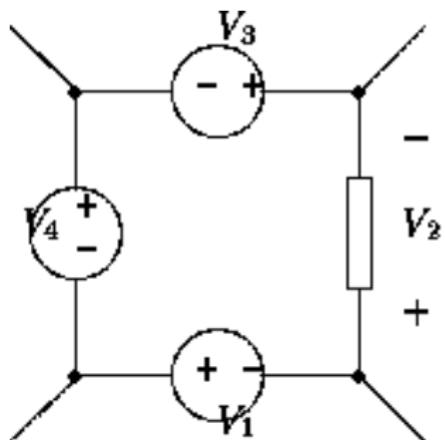
And always remember:



Electronic Fundamentals (Revisions)

- Ohm's Law
- Kirchoff's Voltage Law (KVL)
- Kirchoff's Current Law (KCL)

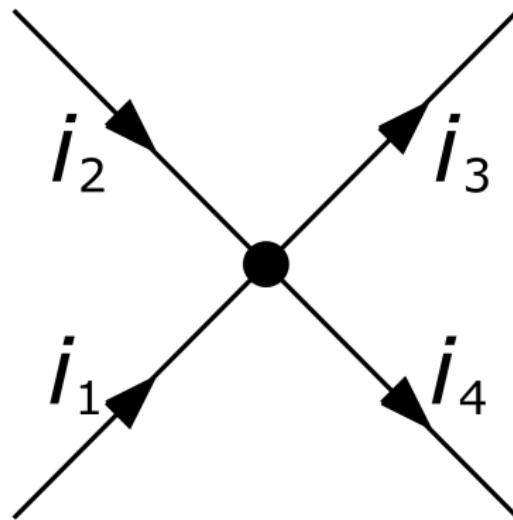
Kirchoff's Current Law



$$V_1 + V_2 + V_3 + V_4 = 0$$

"In loop there can be no residual Voltage"

Kirchoff's Voltage Law



$$i_1 + i_2 = i_3 + i_4$$

"In a node there can be no residual Current"

Common C datatypes

```
bool  
    /* A binary value -> stored in a byte*/  
  
int  
    /* A signed integer value -> stored in 4 bytes*/  
  
unsigned int  
    /* A signed integer value -> stored in 4 bytes*/  
  
long int  
    /*A signed integer value -> stored in 8 bytes*/  
  
float  
    /* A decimal value -> stored in 4 bytes*/  
  
double  
    /*A decimal values -> stored in 8 bytes*/
```

and many, many more....

Functions

```
int add (int arg0, int arg1){  
    int temp = 0;  
    temp = arg0 + arg1;  
    return temp  
}
```

Applying C to arduino

```
void setup(){
    /*code here runs once, at the start of our routine*/
}

void loop(){
    /*code here will run until the board is reset!*/
}
```

Digital I/O - Code example

Digital GPIO

```
digitalRead(PIN);  
digitalWrite(PIN, value);
```

Analog I/O - Code example

Analog GPIO

```
analogRead(PIN);  
analogWrite(PIN, value);
```

More I/O

I²C

```
#include <Wire.h>

Wire.begin(SDA_PIN, SCL_PIN);
Wire.write(data);
```

UART

```
HardwareSerial mySerial(2); // Use UART2
mySerial.begin(BAUD_RATE, SERIAL_8N1, RXD_PIN, TXD_PIN);
```