



# Open source hardware

## Fostering creativity

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24/11/2015

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1. Passive students or creative students?
2. What is open source hardware?
3. Types of open source hardware
4. Arduino: from a blinking LED to a project with LDR (analog input) controlling RGB-LED (analog output)
5. Creating open source hardware (Arduino type)
6. Fostering creativity: Empowering Arduino with Processing libraries (computer vision, augmented reality, text to speech, voice recognition, etc)





# Coding to prepare students for the future

“We are currently preparing students for jobs that don’t yet exist, using technologies that haven’t been invented, in order to solve problems we don’t even know are problems yet.”

Karl Fisch



**Internet  
Zettabyte**

**Find  
problems**

**Different  
solutions**

**Skills and competences**

**Teachers**

**Students**

**Politicians**



## Mathematical description

$$\text{Wind } \rho \dot{\mathbf{v}} = -\nabla p + \rho \mathbf{g} - 2\Omega \times (\rho \mathbf{v}) + \mathbf{F}$$

$$\text{Pressure } \dot{p} = -(c_{pd}/c_{vd}) p \nabla \cdot \mathbf{v} + (c_{pd}/c_{vd} - 1) Q_h$$

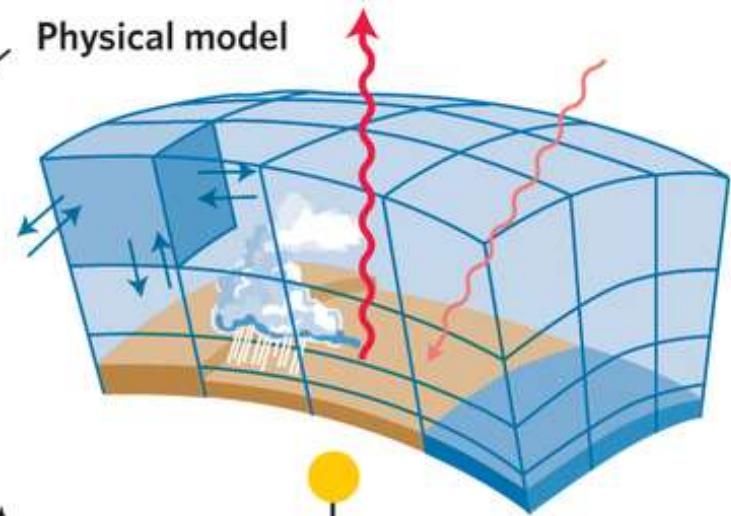
$$\text{Temperature } \rho c_{pd} \dot{T} = \dot{p} + Q_h$$

$$\text{Water } \rho \dot{q}^v = -\nabla \cdot \mathbf{F}^v - (I^l + I^f)$$

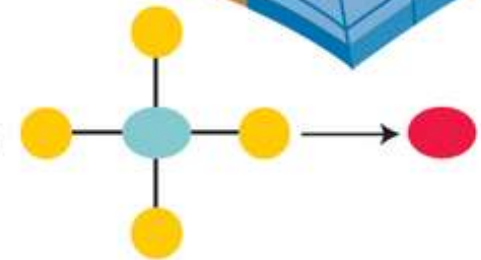
$$\rho \dot{q}^{lf} = \nabla \cdot (\mathbf{P}^{lf} + \mathbf{F}^{lf}) + I^{lf}$$

$$\text{Density } \rho = p [R_d (1 + (R_v/R_d - 1) q^v - q^l - q^f) T]^{-1}$$

## Physical model



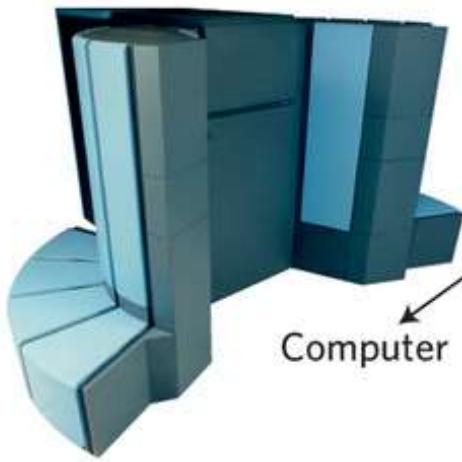
## Algorithmic description



## Imperative code

```
lap(i, j, k) = -4.0 * data(i, j, k) +  
data(i+1, j, k) + data(i-1, j, k) +  
data(i, j+1, k) + data(i, j-1, k);
```

## Computer engineering

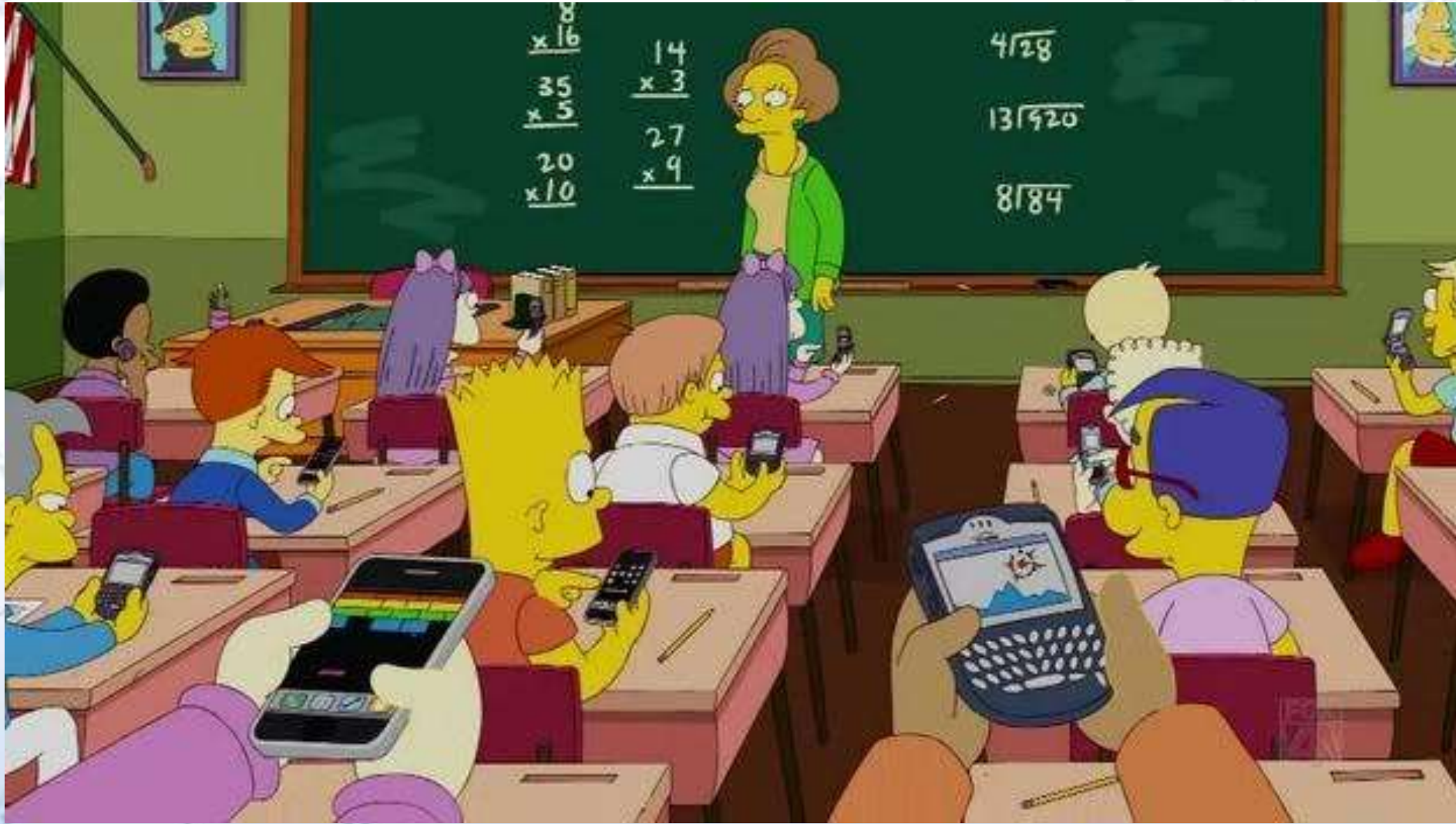


Compilation

Computer

Nature Physics 11, 369–373 (2015)





## PASSIVE TECHNOLOGY USERS

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**Creating**  
**Evaluating**  
**Analyzing**  
**Applying**  
**Understanding**  
**Remembering**

*Bloom's Taxonomy*



## CREATIVE STUDENTS

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## USING OLD HARDWARE TO PROGRAM NEW OPEN HARDWARE DEVICES

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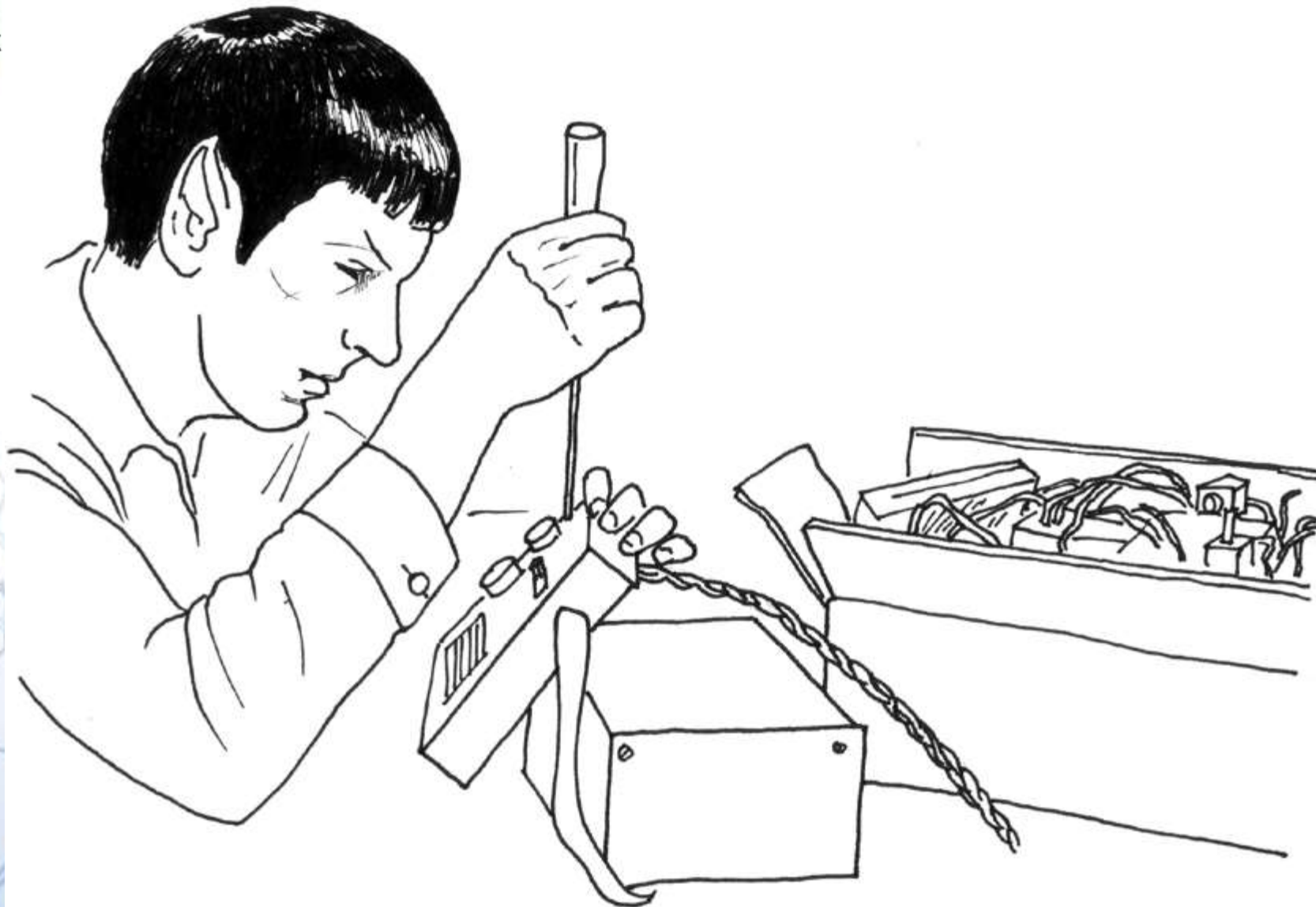


# Prototyping

Actually there is not a manual on how to do things but a reference collection of samples that people can modify and combine with other examples to learn about the logic of the programme and the board. It's a "hands on" way of working in which even junk becomes a source for learning and building prototypes. The reuse of material from other fields is an other big knowledge and material source. Learning how to do things by looking how other things work and can be hacked.

Circuit bending and patching are two key words in this learning school.





# What is open source hardware?



# open source hardware



# What is open source hardware?

**Open source** is a development model promoting universal access via a free license to a product's design or blueprint, and universal redistribution of that design or blueprint, including subsequent improvements to it by anyone.

**Open-source hardware (OSH)** consists of physical artifacts of technology designed and offered by the open design movement. FOSH (free and open source hardware) can be use with free and **open-source software (FOSS)** in education



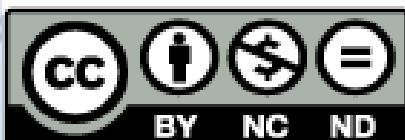
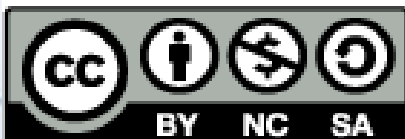
# What is open source hardware?



open source  
initiative



# LICENSES



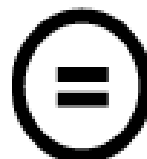
# TERMS



BY

## Attribution

Others can copy, distribute, display, perform and remix your work if they credit your name as requested by you



ND

## No Derivative Works

Others can only copy, distribute, display or perform verbatim copies of your work



SA

## Share Alike

Others can distribute your work only under a license identical to the one you have chosen for your work



NC

## Non-Commercial

Others can copy, distribute, display, perform or remix your work but for non-commercial purposes only.

# Open source hardware in the classroom

## The Hacker Attitude for our students

Five things taken from Eric S. Raymond's How To Become a Hacker:

1. The world is full of fascinating problems waiting to be solved.
2. No problem should ever have to be solved twice.
3. Boredom and drudgery are evil.
4. Freedom is good.
5. Attitude is no substitute for competence.





# Open source hardware in the classroom

“Computer science is no more about computers than astronomy is about telescopes”. Edsger Dijkstra

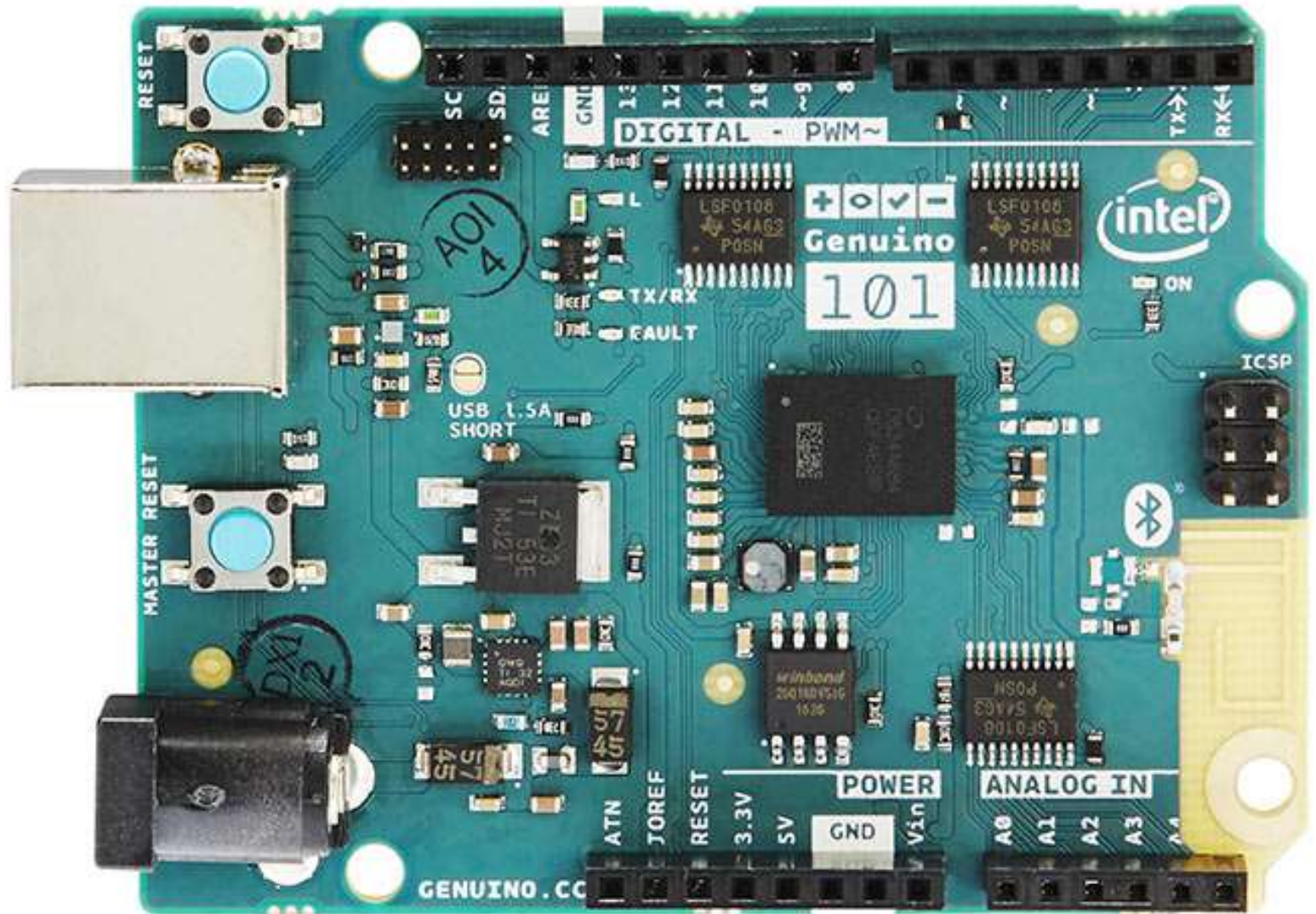
“The computer revolution hasn’t happened yet”. Allan Kay

“Debugging is the essence of intellectual activity”.  
Seymour Pappert



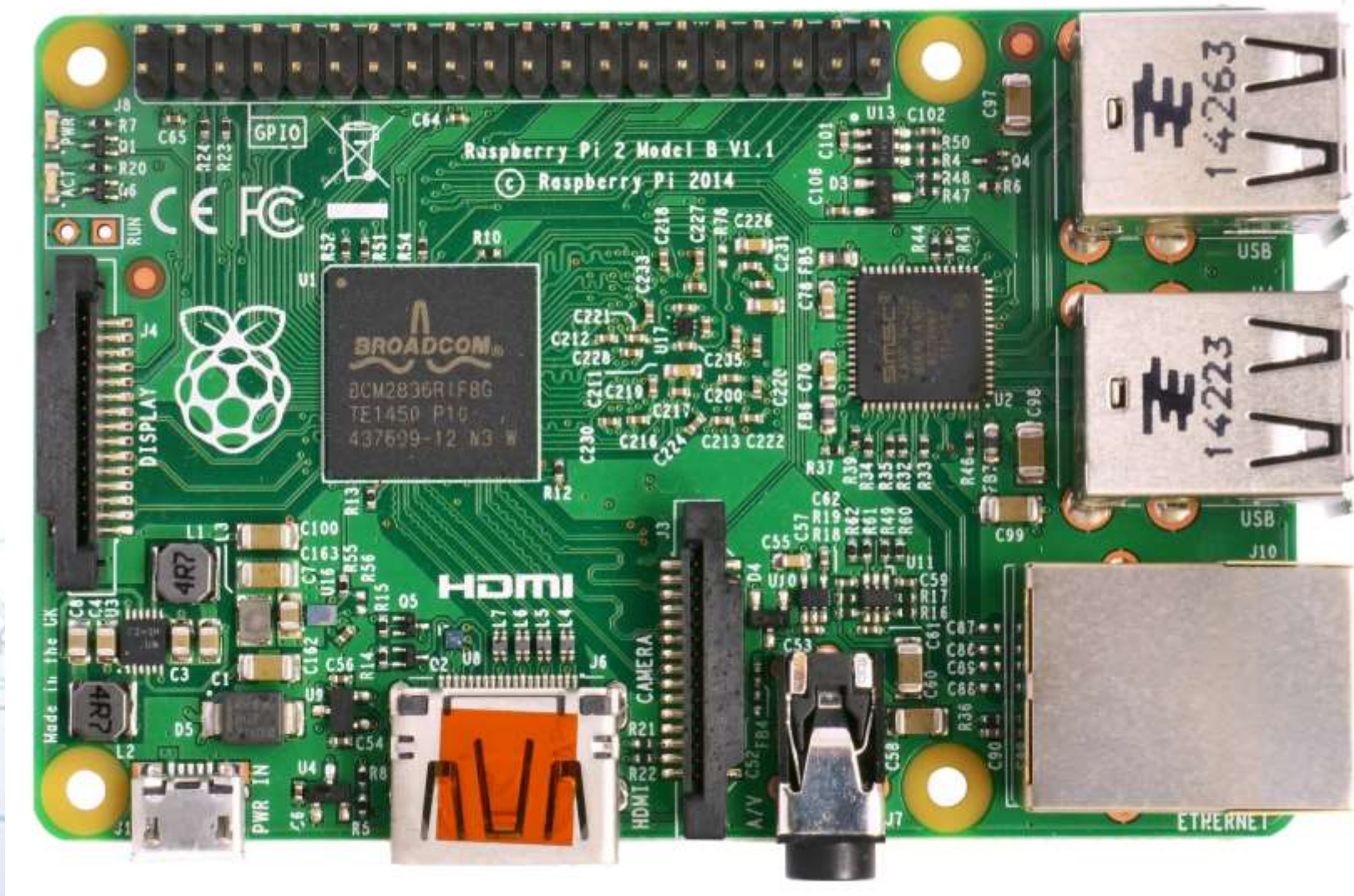
# How? Some examples of available open source hardware for the classroom





## Genuino 101 (available in 2016)

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## Raspberry Pi 2





	Arduino Uno	Genuino 101	Raspberry Pi 2	Intel Edison + Arduino
Chip	8 bits 16 MHz 0.02 Mb	32 bits 32 MHz 0.20 Mb	32 bits 700 MHz 1 Gb	32 bits, intel, 500 MHz 500 Mb
GPIO Inputs and outputs	14 6 analog inputs 6 PWM outputs	14	40	40
Extras	No (available shields)	Accelerometer Bluetooth	Ethernet HDMI, SD	Wi-fi, bluetooth
Programming languages	Arduino Processing C	Arduino Processing	Python IDLE Scratch Processing 3.0.1+ (Nov. 2015)	Arduino Intel XDK
Price	20 €	Aprox. 30€ (2016)	49 €	90 €

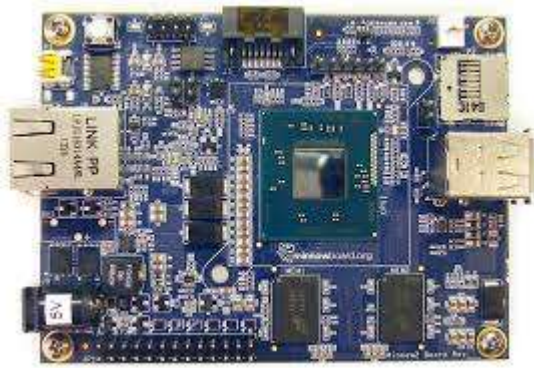




**BEAGLEBONE BLACK**



**SHARKS COVE (MICROSOFT)**



**MINNOWBOARD MAX (MICROSOFT)**

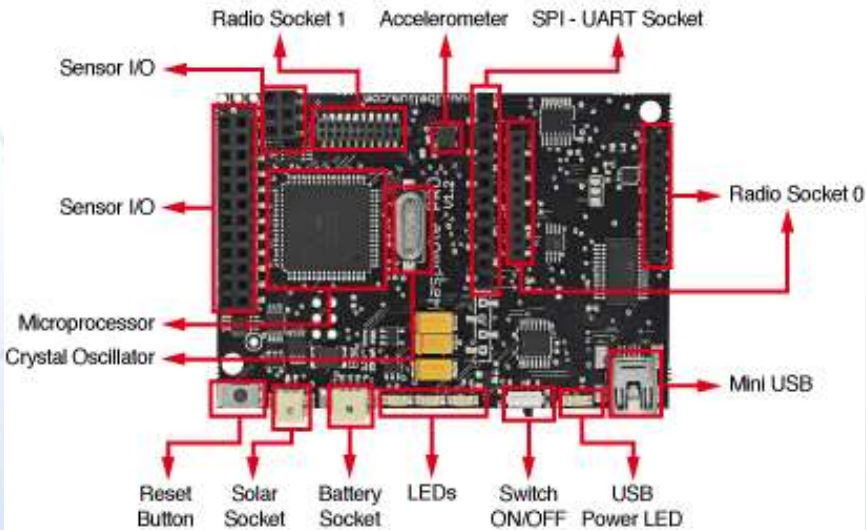
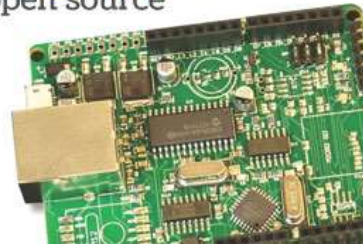


**GROVE PI + SENSORS**



# OTHER HARDWARE ALTERNATIVES

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## One million computers to be given away

The BBC is to give away one million miniature *Micro:Bit* computers to British schoolchildren in an effort to teach them how computers work

### PROGRAMMING SIDE

**Reset button:** Upload code to Micro:Bit and press "reset" to run it

**Micro USB:** Links to computer for coding\*

**Bluetooth antenna**

**Processor:** ARM Cortex M-0

**Compass**

**Accelerometer:** Senses motion

### "KID'S" SIDE

**Face button:** Two buttons can be programmed to perform different tasks

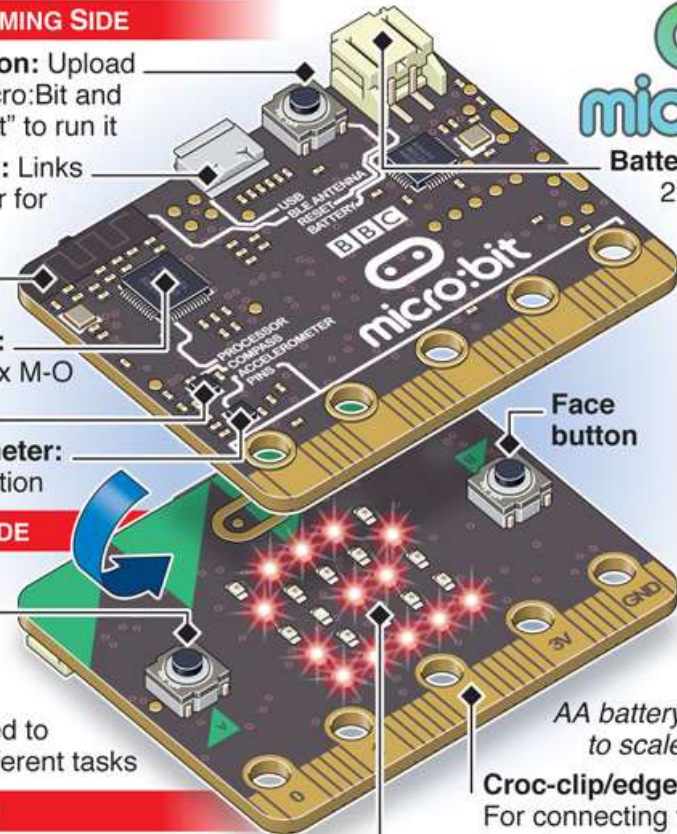
### FUNCTION

*Aimed at 11-year-old children, Micro:Bit is intended as introduction to computer programming and springboard to more advanced devices*

\*Web-based programming tool compatible with PC/Mac, and iOS/Android tablets and smartphones  
Sources: BBC, Technology Will Save Us, Wired



**Battery connector:** 2 x AA batteries power device



AA battery to scale

**Croc-clip/edge connector:** For connecting to similar boards such as **Arduino** and **Raspberry Pi**

**5 x 5 LED grid:** Can display characters and scrolling animations



# OTHER HARDWARE ALTERNATIVES



# ARDUINO UNO

Open Source Hardware, you can make your own board, or buy one.

Cheap, easily available.

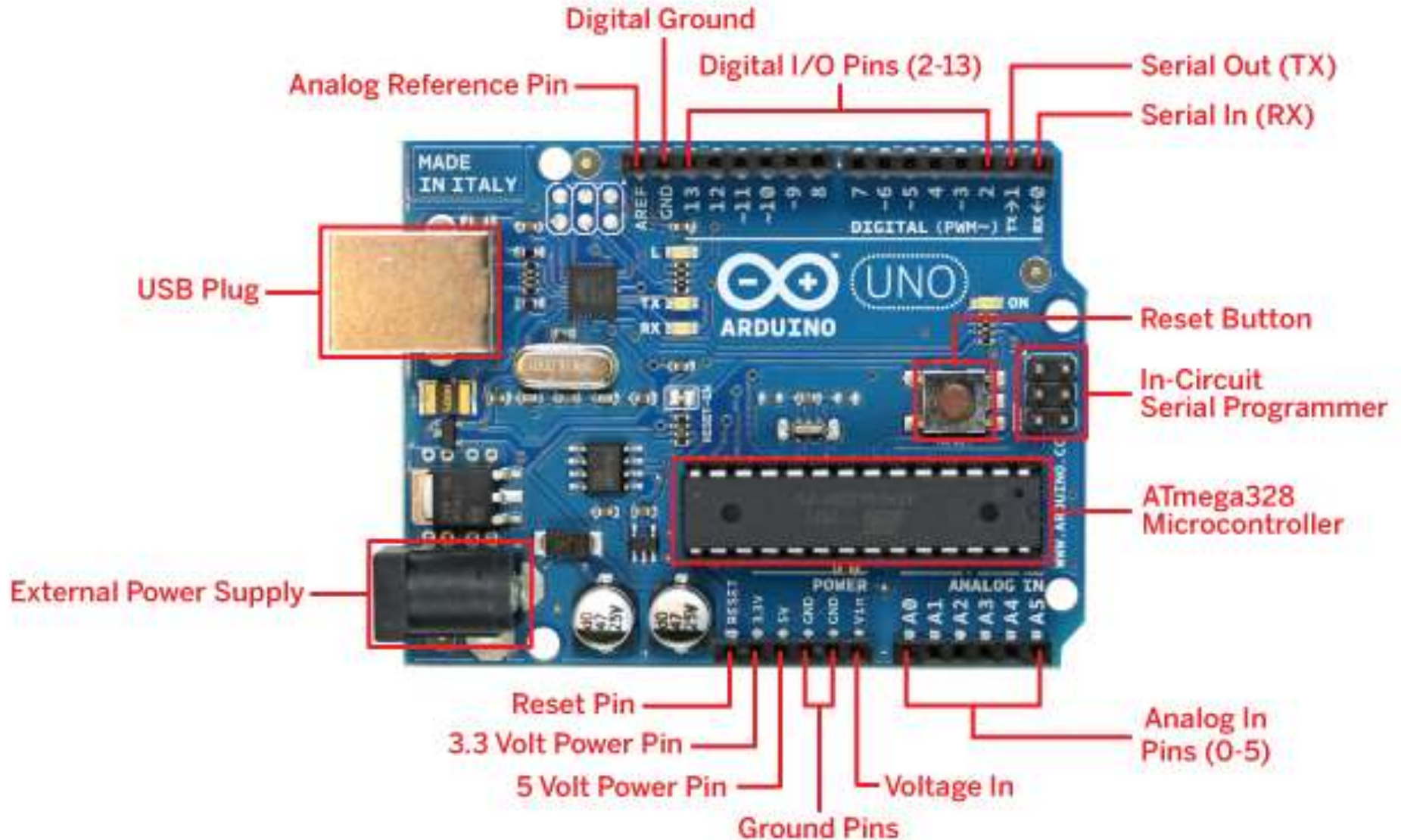
Open Source Software.

Very widespread, many projects openly available.

Extra HW (shields) available.



# Arduino Uno



ESPLORA



MEGA



UNO

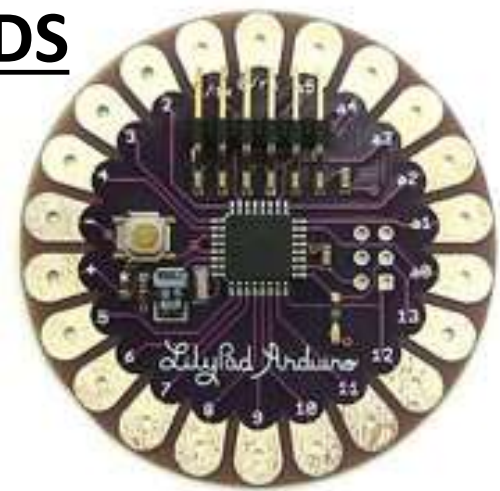
SOME ARDUINO BOARDS



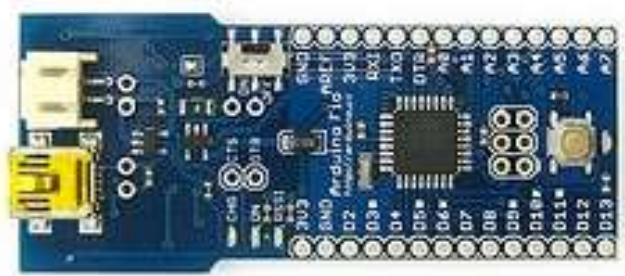
ETHERNET



NANO



LilyPad



FIO



MINI

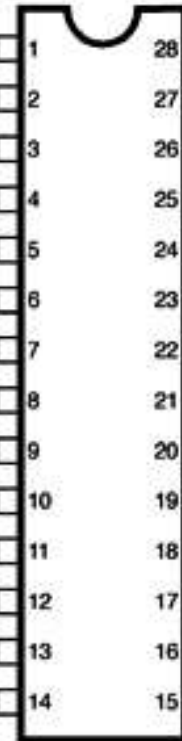
# Build your Arduino board

## Atmega168 Pin Mapping

### Arduino function

- reset
- digital pin 0 (RX)
- digital pin 1 (TX)
- digital pin 2
- digital pin 3 (PWM)
- digital pin 4
- VCC
- GND
- crystal
- crystal
- digital pin 5 (PWM)
- digital pin 6 (PWM)
- digital pin 7
- digital pin 8

- (PCINT14/RESET) PC6
- (PCINT16/RXD) PD0
- (PCINT17/TXD) PD1
- (PCINT18/INT0) PD2
- (PCINT19/OC2B/INT1) PD3
- (PCINT20/XCK/T0) PD4
- VCC
- GND
- (PCINT6/XTAL1/TOSC1) PB6
- (PCINT7/XTAL2/TOSC2) PB7
- (PCINT21/OC0B/T1) PD5
- (PCINT22/OC0A/AIN0) PD6
- (PCINT23/AIN1) PD7
- (PCINT0/CLKO/ICP1) PB0



- PC5 (ADC5/SCL/PCINT13)
- PC4 (ADC4/SDA/PCINT12)
- PC3 (ADC3/PCINT11)
- PC2 (ADC2/PCINT10)
- PC1 (ADC1/PCINT9)
- PC0 (ADC0/PCINT8)
- GND
- AREF
- AVCC
- PB5 (SCK/PCINT5)
- PB4 (MISO/PCINT4)
- PB3 (MOSI/OC2A/PCINT3)
- PB2 (SS/OC1B/PCINT2)
- PB1 (OC1A/PCINT1)

### Arduino function

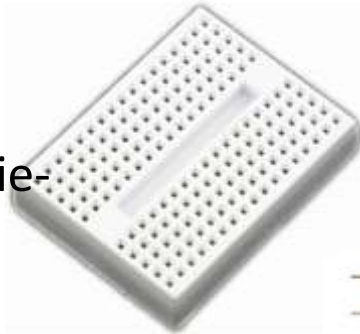
- analog input 5
- analog input 4
- analog input 3
- analog input 2
- analog input 1
- analog input 0
- GND
- analog reference
- VCC
- digital pin 13
- digital pin 12
- digital pin 11 (PWM)
- digital pin 10 (PWM)
- digital pin 9 (PWM)

Digital Pins 11, 12 & 13 are used by the ICSP header for MOSI, MISO, SCK connections (Atmega168 pins 17, 18 & 19). Avoid low-impedance loads on these pins when using the ICSP header.

# ATMEGA328P-PU Microcontroller With ARDUINO UNO R3 Bootloade



Solderless  
Prototype  
Breadboard 170 Tie-  
points Arduino  
Shield



Resistors and capacitors

16MHz 16.000MHz, HZ HC-49S Inline Feet  
Passive Crystal Oscillator



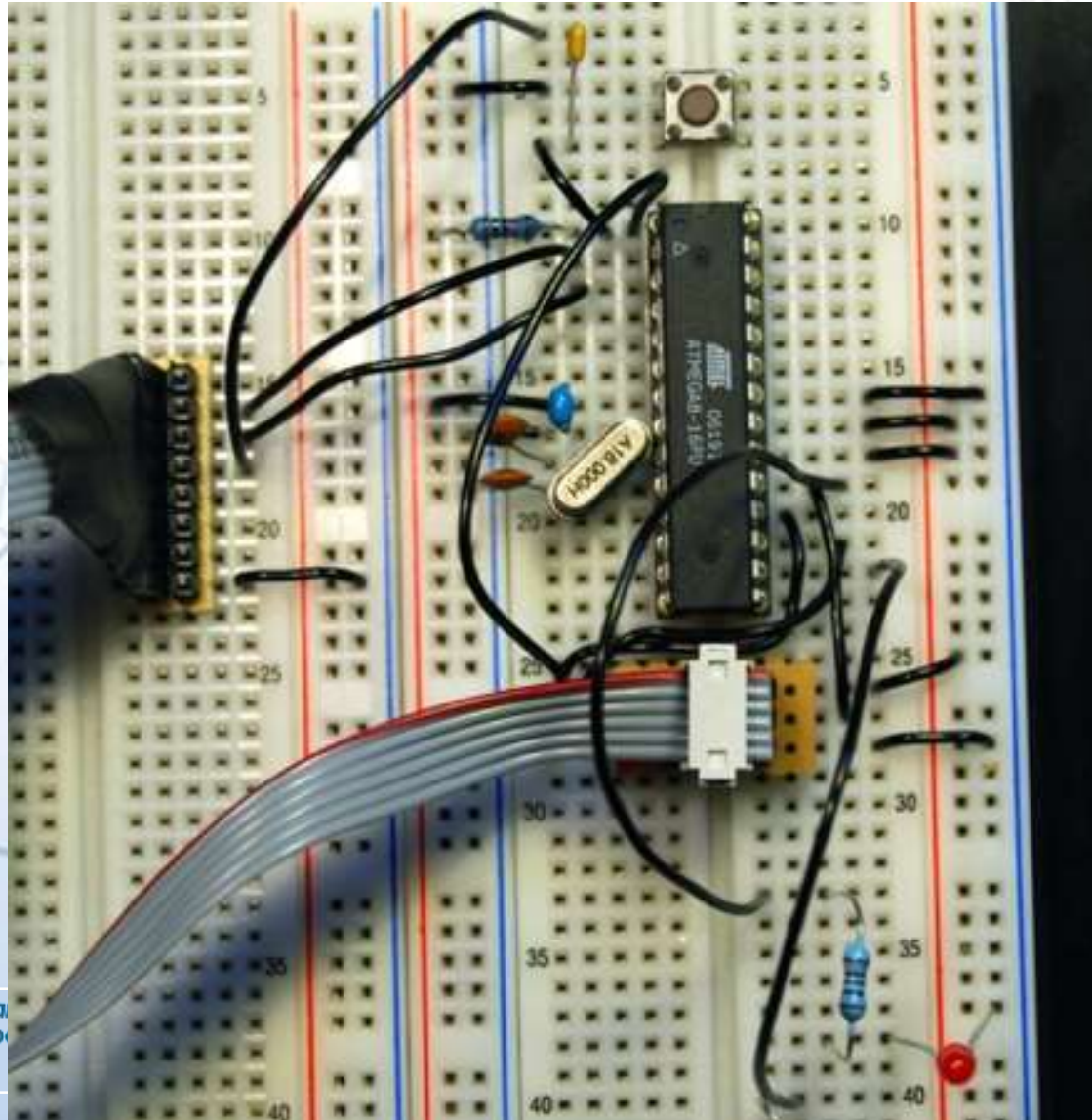
USB2.0 6Pin CH340G  
Converter for STC Arduino  
Or **CP2102 PL2303** To TTL



**VIDEO BUILD YOUR ARDUINO: <https://www.youtube.com/watch?v=sNIMCdVOHOM>**



# Arduino on breadboard





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DOWNLOAD

ENGLISH

# Download the Arduino Software



## ARDUINO 1.6.6

The open-source Arduino Software (IDE) makes it easy to write code and upload it to the board. It runs on Windows, Mac OS X, and Linux. The environment is written in Java and based on Processing and other open-source software.

This software can be used with any Arduino board. Refer to the [Getting Started](#) page for Installation instructions.

**Windows** Installer

**Windows** ZIP file for non admin install

**Mac OS X** 10.7 Lion or newer

**Linux** 32 bits

**Linux** 64 bits

[Release Notes](#)

[Source Code](#)

[Checksums](#)



<http://www.arduino.cc>

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# Arduino Language

C like syntax, but simplified

Abstracts the pin naming to numbers

Trades efficiency for ease of use

Easy to learn, yet powerful

Lots of example code

Easy to reuse C-code from other projects

Libraries can be written in C++

Lots of libraries available





```
/*
```

```
Blink
```

Turns on an LED on for one second,  
then off for one second, repeatedly.

This example code is based on example  
code

that is in the public domain.

```
*/
```

```
void setup() {
```

```
// initialize the digital pin as an output.
```

```
// Pin 13 has an LED connected on most  
Arduino boards:
```

```
pinMode(13, OUTPUT);
```

```
}
```

```
void loop() {
```

```
digitalWrite(13, HIGH); // set the LED on
```

```
delay(1000); // wait for a second
```

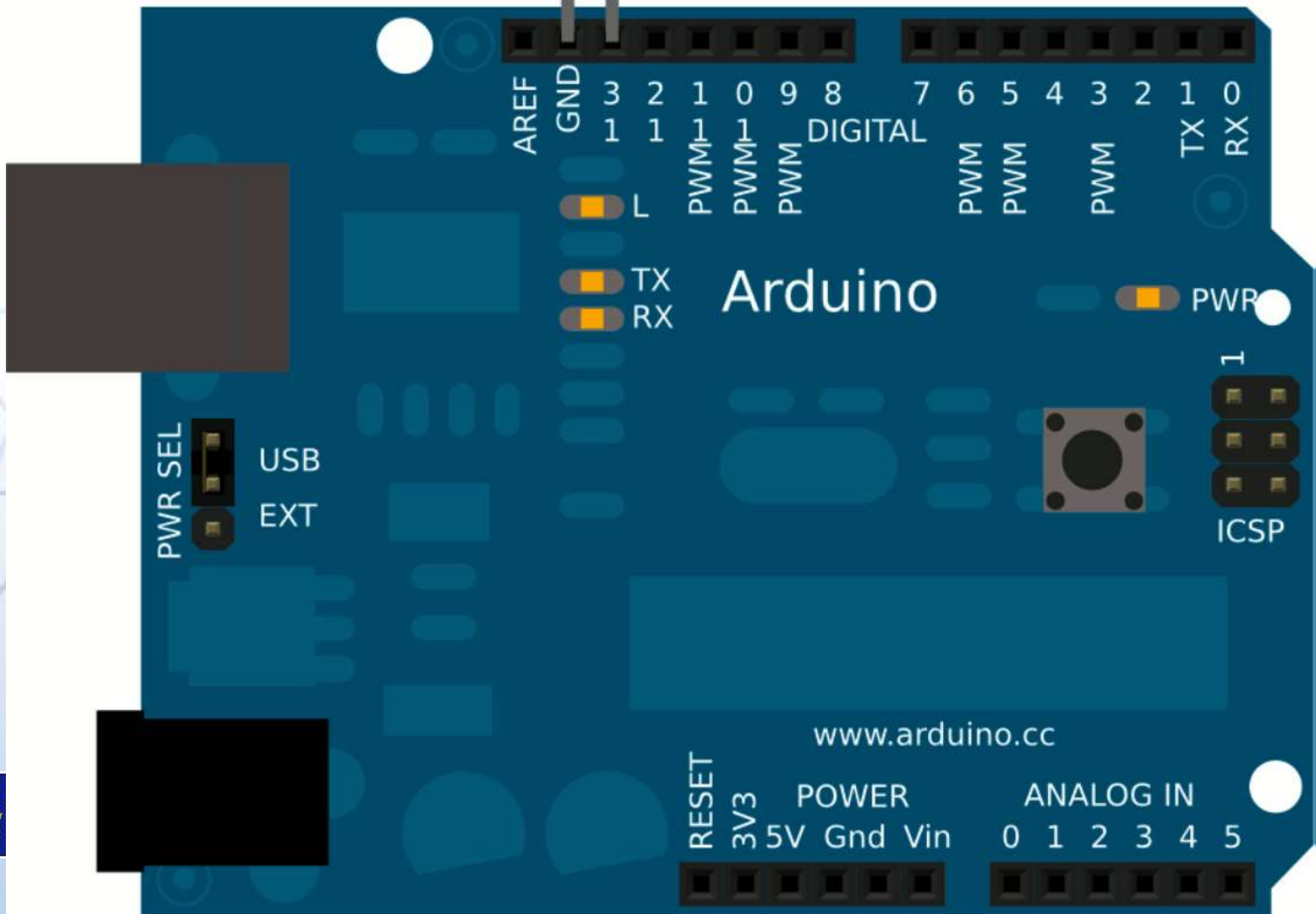
```
digitalWrite(13, LOW); // set the LED
```

```
offdelay(1000); // wait for a second
```

```
}
```



Handwritten notes and diagrams in the top right corner, including mathematical formulas and circuit symbols.



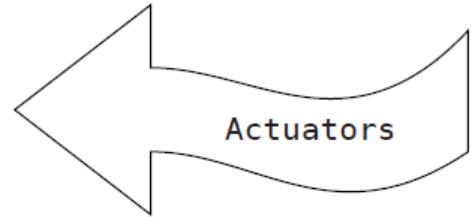
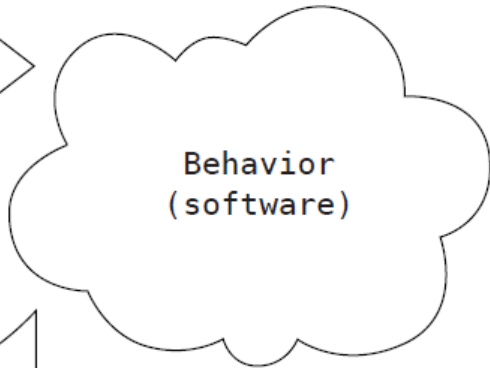
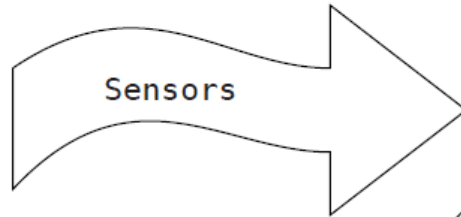
# Materials for LDR and RGB-LED using Arduino

- 4 resistor 220  $\Omega$
- 1 LDR sensor
- 1 RGB LED
- 1 potentiometer
- 1 Arduino Uno
- Wires, USB wire and breadboard

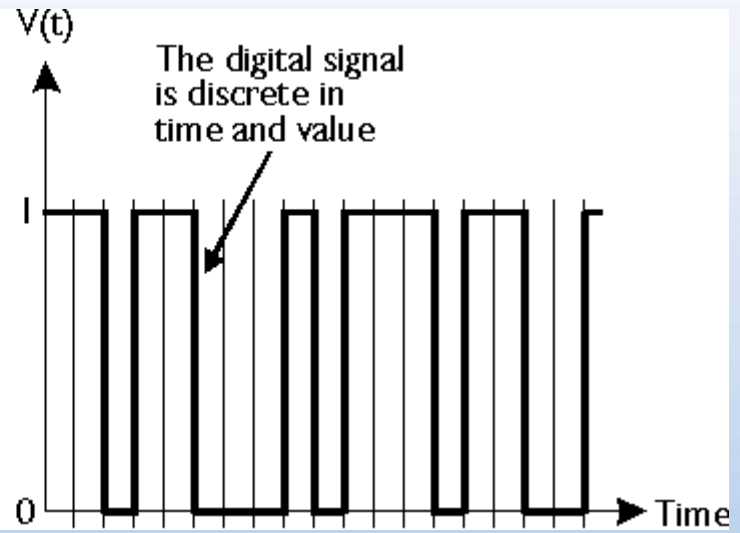
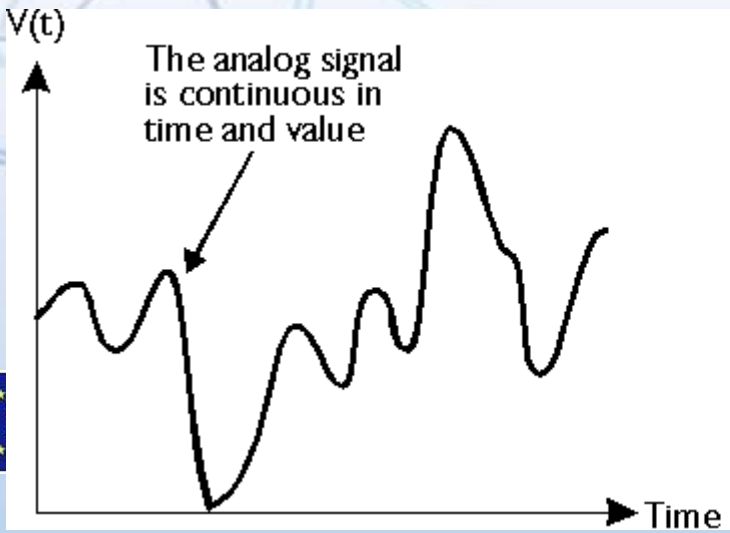




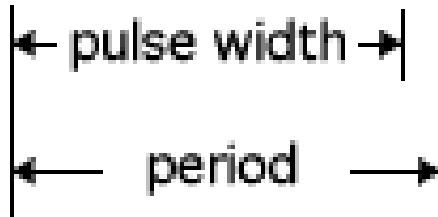
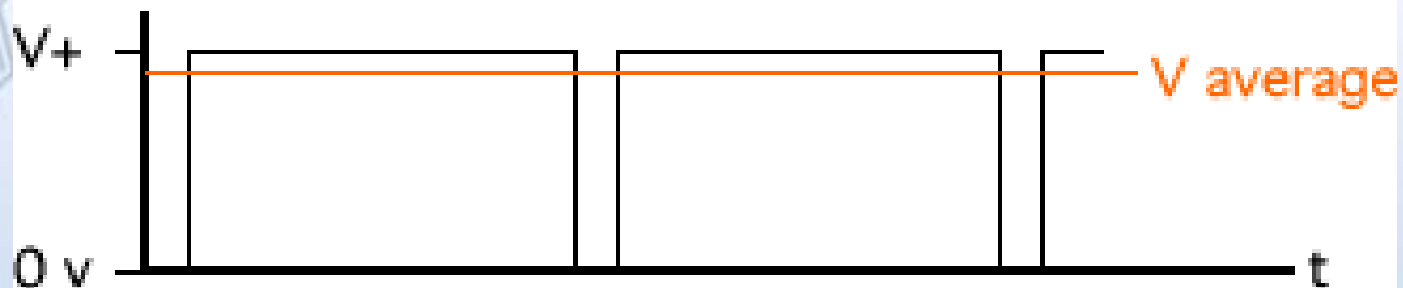
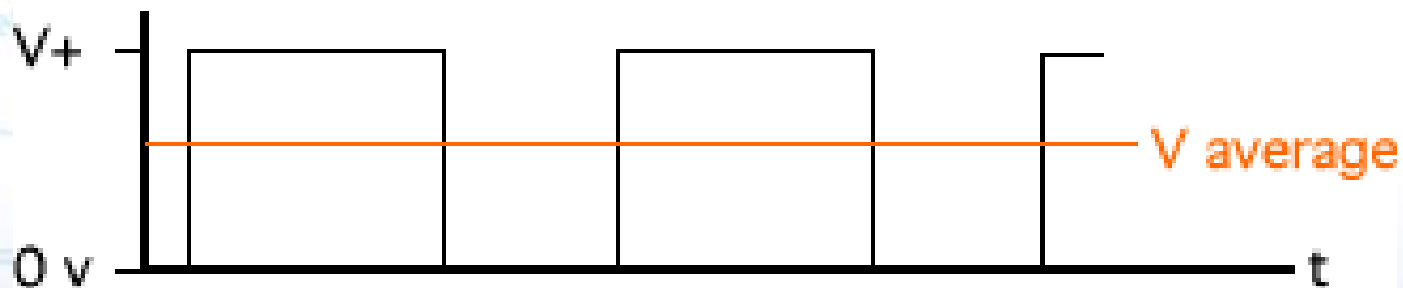
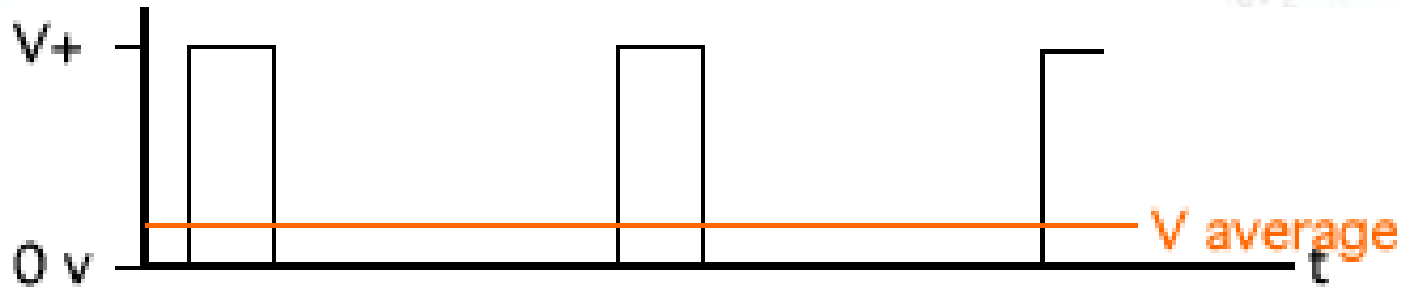
Sense/Perceive

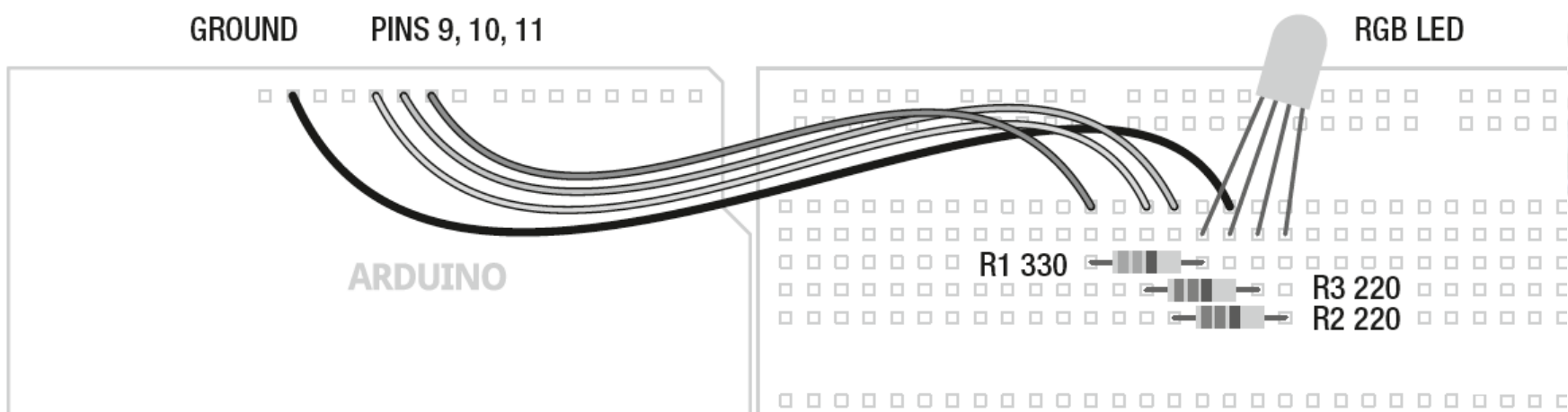


Act/React



# Pulse width modulation

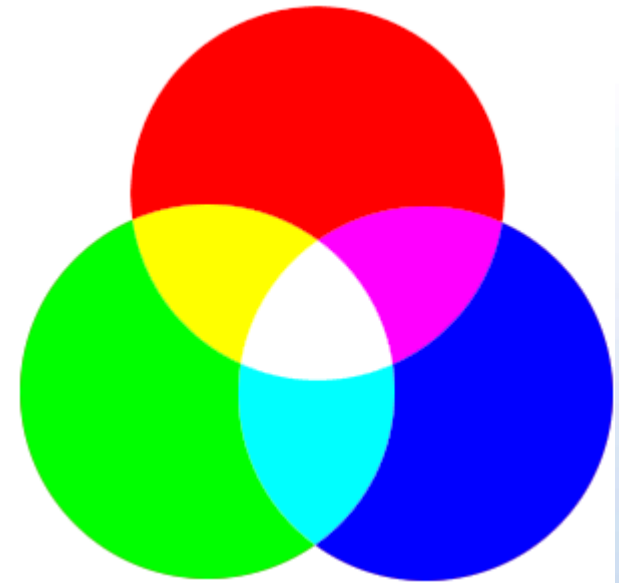


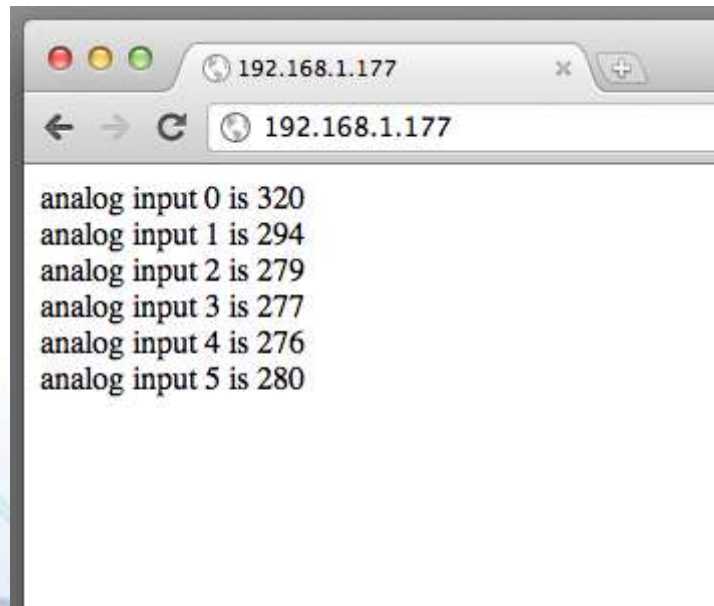


```
*/
  RGB LED BLINKING
```

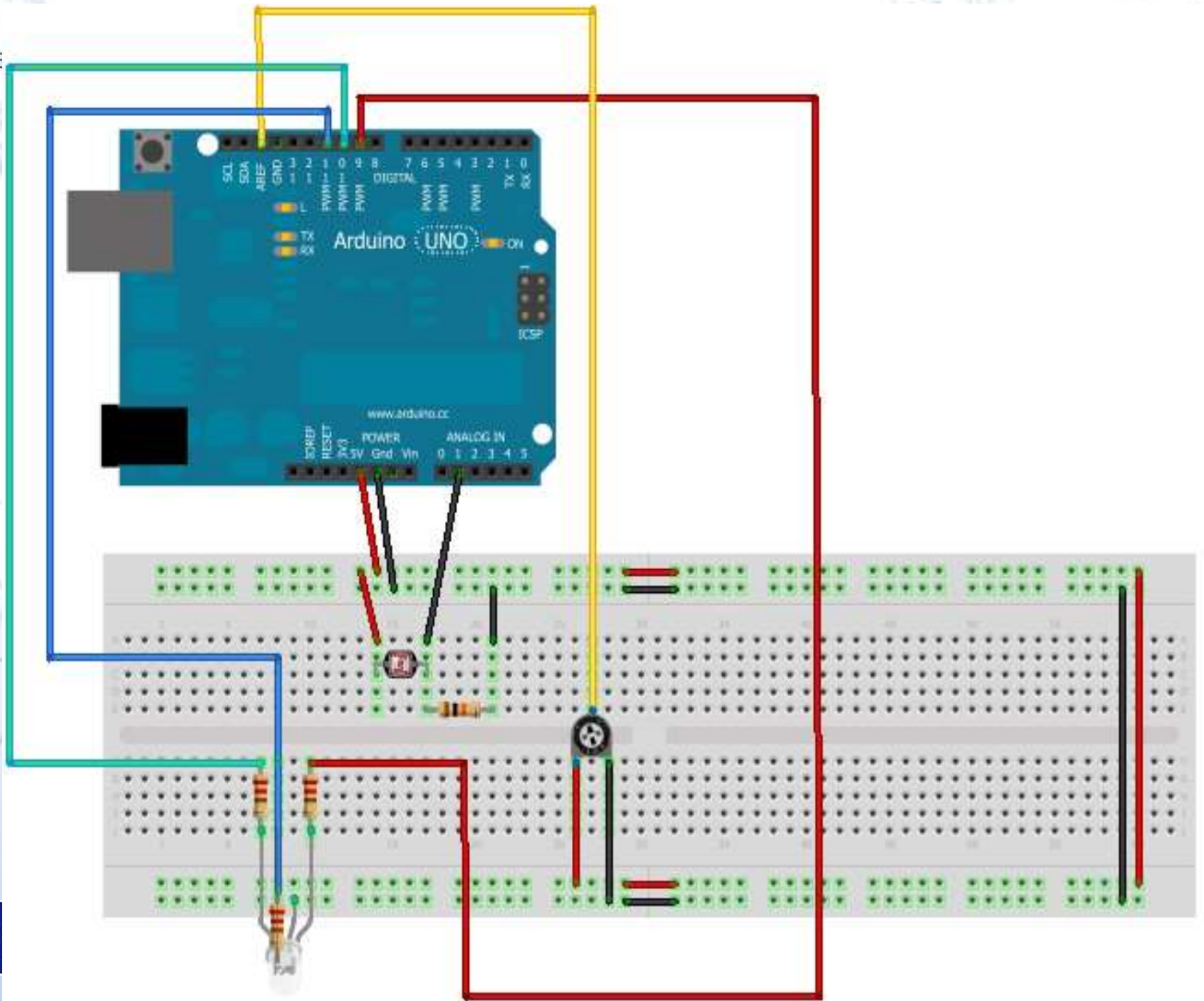
```
void setup() {
  pinMode(9, OUTPUT);      // sets digital pins as outputs
  pinMode(10, OUTPUT);
  pinMode(11, OUTPUT);
}

void loop() {
  digitalWrite(9, HIGH);   // turns on red
  digitalWrite(11, LOW);  // turns off blue
  delay(1000);            // waits for 1 second
  digitalWrite(10, HIGH); // turns on green
  digitalWrite(9, LOW);   // turns off red
  delay(1000);            // waits for 1 second
  digitalWrite(11, HIGH); // turns on blue
  digitalWrite(10, LOW);  // turns off green
  delay(1000);            // waits for 1 second
}
```

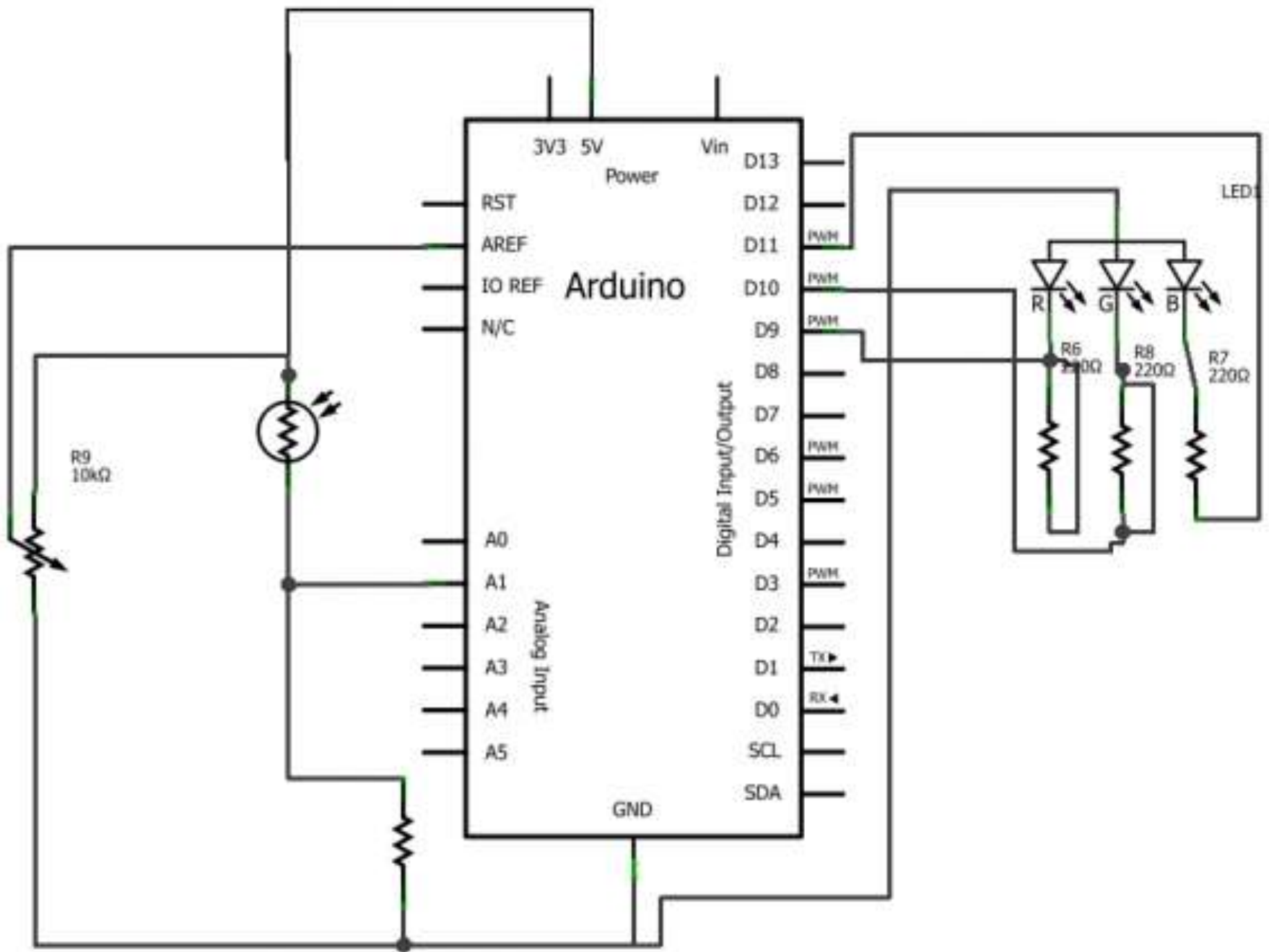




```
192.168.1.177
analog input 0 is 320
analog input 1 is 294
analog input 2 is 279
analog input 3 is 277
analog input 4 is 276
analog input 5 is 280
```







# SOURCE CODE: RGB-LED colour change depending on light level

SCIENTIX

```
int valueLDR = 1; /*First we define the variable name as integer and it is assigned a value*/
```

```
int ledRed = 9;
```

```
int ledGreen=10; // or /*Comment*/ can be anywhere, do not affect code, help others
```

```
int ledBlue=11;
```

```
int pinLDR = 1;
```

```
/*3 outputs for each RGB colour: red, green and blue
```

```
void setup(){ /*The setup function comes before the loop function, and everything happens inside the curly brackets*/
```

```
pinMode(ledRed, OUTPUT);
```

```
pinMode(ledGreen, OUTPUT);
```

```
pinMode(ledBlue, OUTPUT);
```

/\*Outputs are declared in setup, this is done by using the pinMode function, in this particular example we declare numbers 9, 10 and 11 as OUTPUT (in capital letters)\*/

```
analogReference(EXTERNAL);
```



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```
void loop() {
```

SCIENTIX

```
valueLDR = analogRead(pinLDR);
```

```
if(valueLDR >= 1023){
```

```
digitalWrite(ledRed, 128);
```

```
digitalWrite(ledGreen, 0);
```

```
digitalWrite(ledBlue, 0);
```

```
// digitalWrite to obtain different colours
```

```
}
```

```
else if((valueLDR >= 959) & (valueLDR < 1023)){
```

```
digitalWrite(ledRed, 255);
```

```
digitalWrite(ledGreen, 0);
```

```
digitalWrite(ledBlue, 0);
```

```
}
```

The “void” in the header is what the function will return (or spit out) when it happens, in this case it returns nothing so it is void



```
else if((valueLDR >= 895) & (valueLDR < 959)){
```

```
digitalWrite(ledRed, 255);
```

```
digitalWrite(ledGreen, 128);
```

```
digitalWrite(ledBlue, 0);}
```

```
else if((valueLDR >= 831) & (valueLDR < 895)){
```

```
digitalWrite(ledRed, 255);
```

```
digitalWrite(ledGreen, 255);
```

```
digitalWrite(ledBlue, 0);}
```

```
else if((valueLDR >= 767) & (valueLDR < 831)){
```

```
digitalWrite(ledRed, 255);
```

```
digitalWrite(ledGreen, 255);
```

```
digitalWrite(ledBlue, 128);}
```

```
else if((valueLDR >= 703) & (valueLDR < 767)){
```

```
digitalWrite(ledRed, 128);
```

```
digitalWrite(ledGreen, 255);
```

```
digitalWrite(ledBlue, 255);
```

```
}
```

```
else if((valueLDR >= 639) & (valueLDR < 703)){
```

```
digitalWrite(ledRed, 128);
```

```
digitalWrite(ledGreen, 128);
```

```
digitalWrite(ledBlue, 255);}
```

```
else if((valueLDR >= 575) & (valueLDR < 639)){
```

```
digitalWrite(ledRed, 0);
```

```
digitalWrite(ledGreen, 128);
```

```
digitalWrite(ledBlue, 255);}
```

```
else if((valueLDR >= 511) & (valueLDR < 575)){
```

```
digitalWrite(ledRed, 0);
```

```
digitalWrite(ledGreen, 0);
```

```
digitalWrite(ledBlue, 255);}
```

```
else if((valueLDR >= 447) & (valueLDR < 511)){
```

```
digitalWrite(ledRed, 0);
```

```
digitalWrite(ledGreen, 0);
```

```
digitalWrite(ledBlue, 128);
```

```
}
```

```
else if((valueLDR >= 383) & (valueLDR < 447)){
```

```
digitalWrite(ledRed, 0);
```

```
digitalWrite(ledGreen, 128);
```

```
digitalWrite(ledBlue, 0);}
```

```
else if((valueLDR >= 319) & (valueLDR < 383)){
```

```
digitalWrite(ledRed, 0);
```

```
digitalWrite(ledGreen, 255);
```

```
digitalWrite(ledBlue, 0);}
```

```
else if((valueLDR >= 255) & (valueLDR < 319)){
```

```
digitalWrite(ledRed, 128);
```

```
digitalWrite(ledGreen, 255);
```

```
digitalWrite(ledBlue, 0);}
```

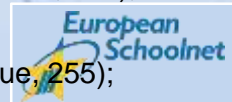
```
else if((valueLDR >= 191) & (valueLDR < 255)){
```

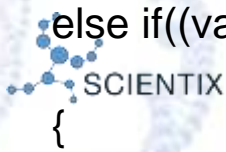
```
digitalWrite(ledRed, 0);
```

```
digitalWrite(ledGreen, 255);
```

```
digitalWrite(ledBlue, 128);
```

```
}
```



 else if((valueLDR >= 127) & (valueLDR < 191)) else  
{

```
digitalWrite(ledRed, 128);  
digitalWrite(ledGreen, 255);  
digitalWrite(ledBlue, 128);}
```

```
else if((valueLDR >= 63) & (valueLDR < 127))  
{
```

```
digitalWrite(ledRed, 128);  
digitalWrite(ledGreen, 128);  
digitalWrite(ledBlue, 128);}
```

```
else if((valueLDR >=0) & (valueLDR < 63)){  
digitalWrite(ledRed, 55);
```

```
digitalWrite(ledGreen, 55);  
digitalWrite(ledBlue, 55); }
```

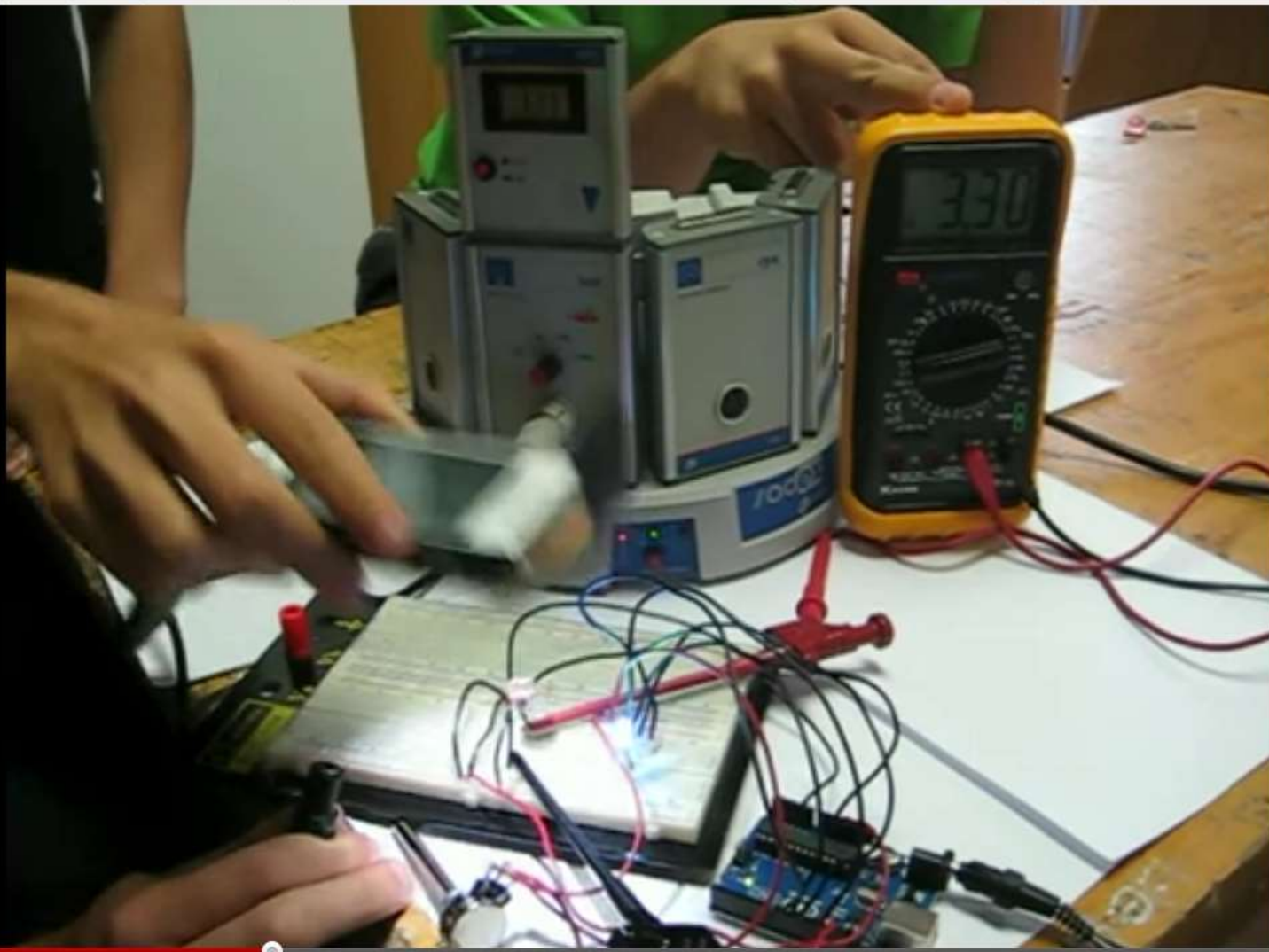
```
{  
digitalWrite(ledRed, 0);  
digitalWrite(ledGreen, 0);  
digitalWrite(ledBlue, 0);  
}
```

```
void color(int red, int green, int blue)  
{
```

```
analogWrite(ledRed, 255-red);  
analogWrite(ledGreen, 255-green);  
analogWrite(ledBlue, 255-blue);
```

```
// PWM for every colour
```







+

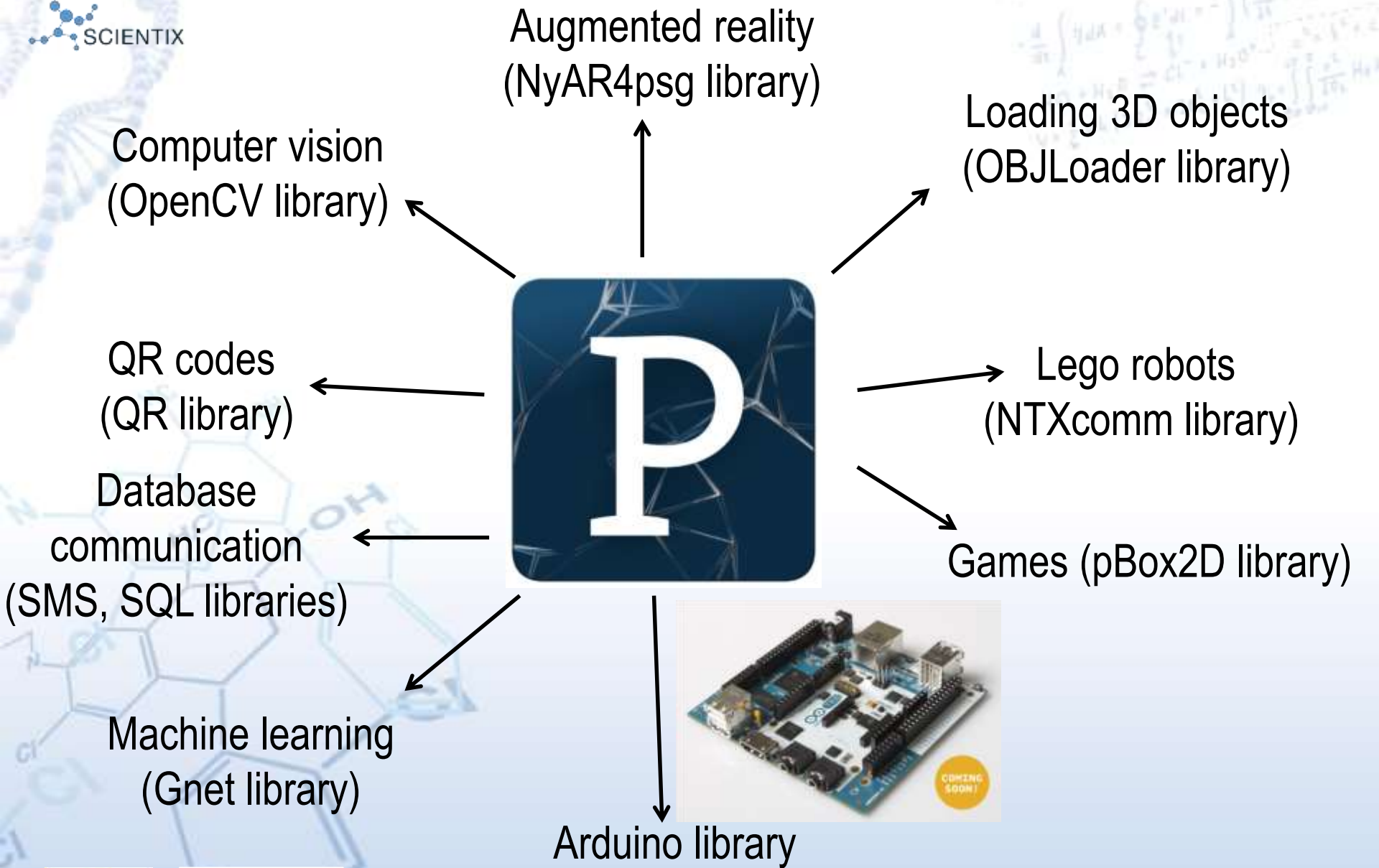


<http://www.processing.org>

<http://www.arduino.cc>

## EMPOWERING ARDUINO WITH PROCESSING LIBRARIES



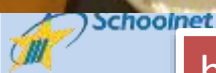
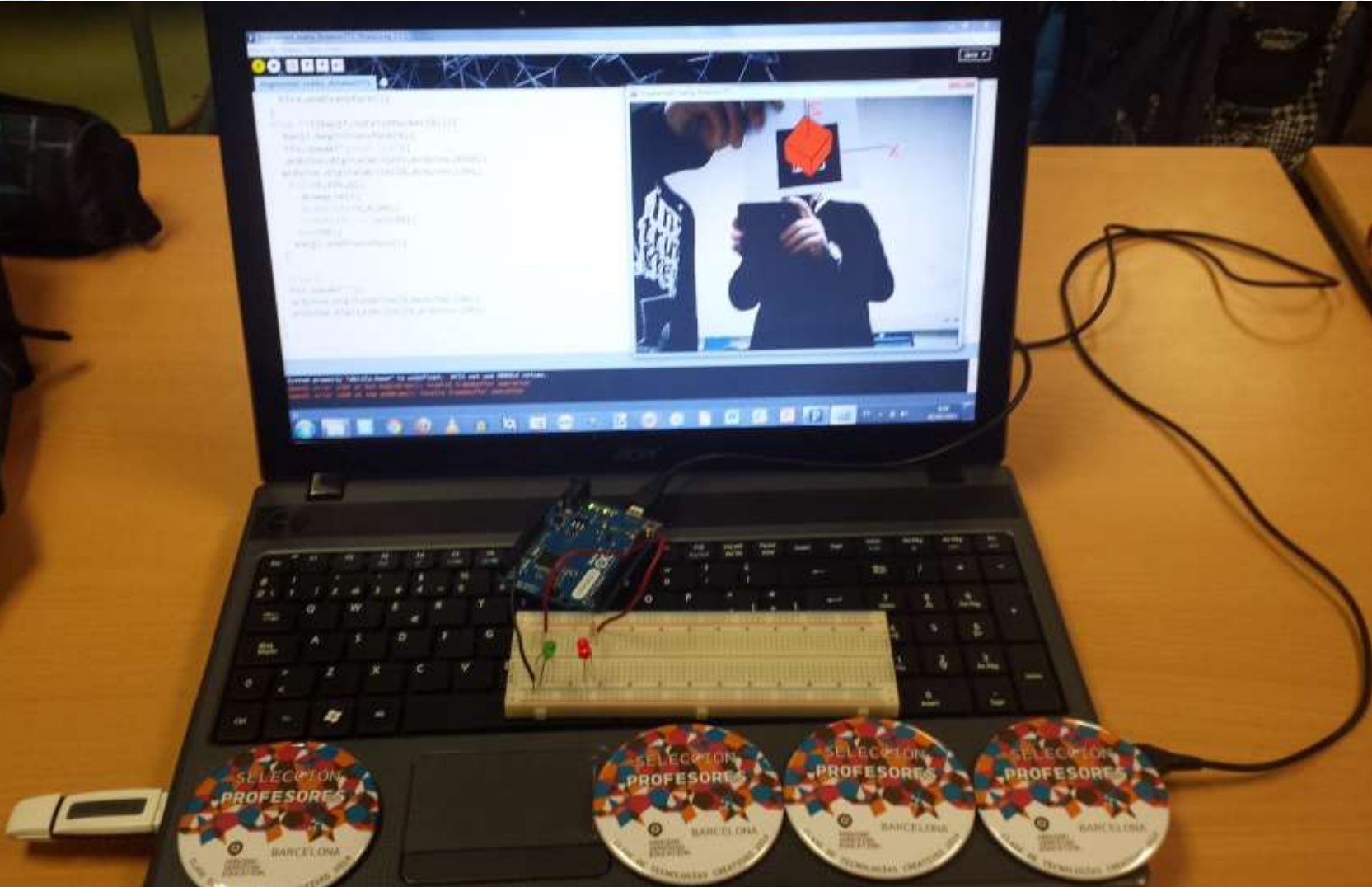




# ARDUINO: FACE RECOGNITION



# ARDUINO: AUGMENTED REALITY



[http://www.tecnologies.net/?page\\_id=641](http://www.tecnologies.net/?page_id=641)

24/11/2015 | Barcelona  
entix webinar: Open source hardware

# ARDUINO: POLLUTANTS



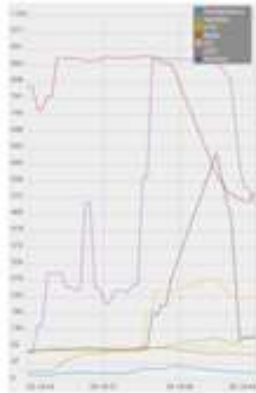


453



50ppm

453



SQL

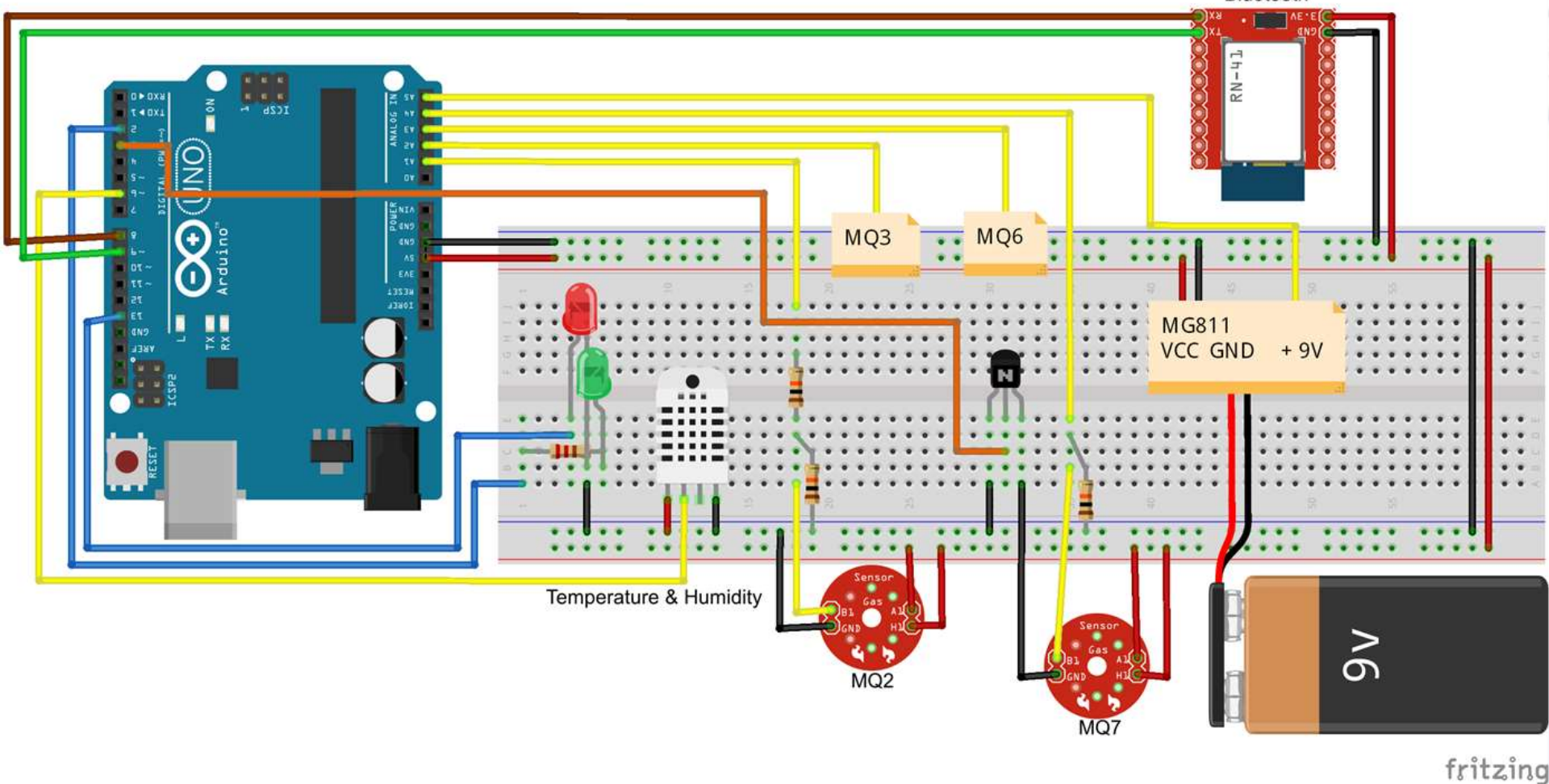


S20;29;50;36;198;924;4E



# ARDUINO & POLLUTANTS

Scientix 2 | Dr. Francisco Pérez García  
24/11/2015 | Barcelona  
Scientix webinar: Open source hardware

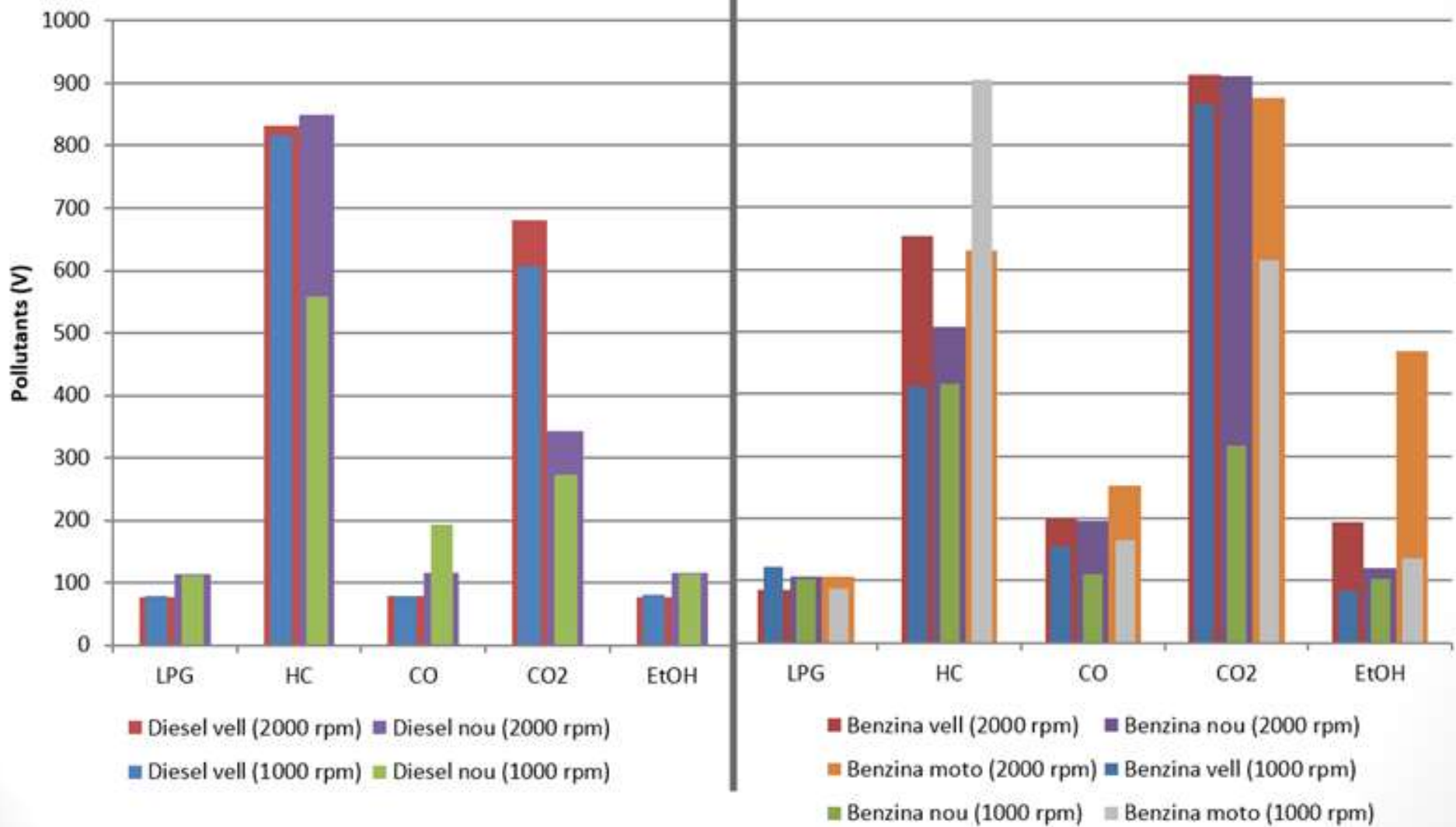


fritzing

[http://www.tecnologies.net/?page\\_id=639](http://www.tecnologies.net/?page_id=639)

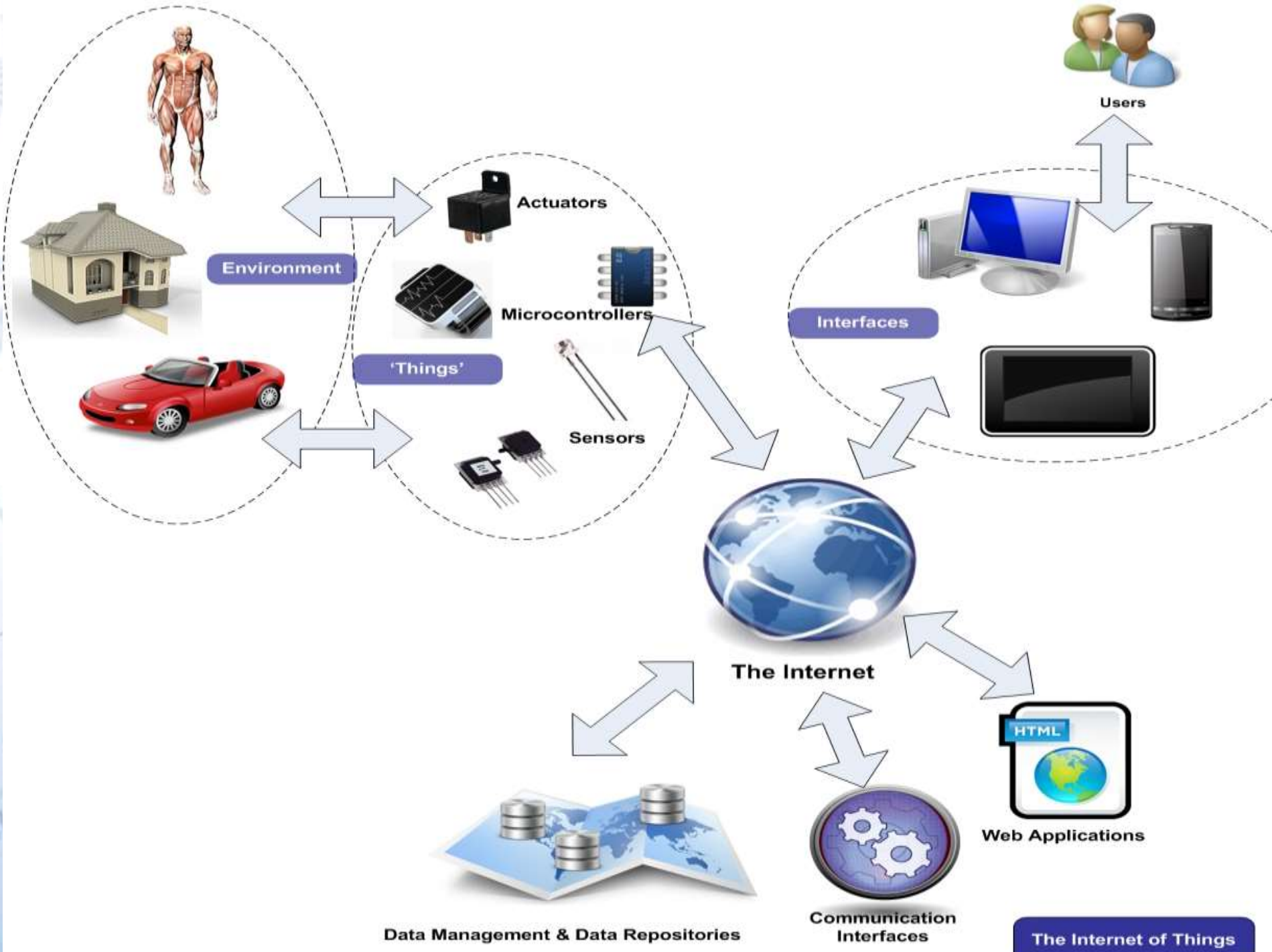


Scientix 2 | Dr. Francisco Pérez García  
24/11/2015 | Barcelona  
Scientix webinar: Open source hardware



## POLLUTANT MEASUREMENT USING ARDUINO (PETROL vs DIESEL, OLD CARS vs NEW CARS and at different rpm)







Window shutter control mechanism



Servo motor



Air Conditioning Unit



Relay Switch



Indoor Light

Microcontroller



Current Sensor



Humidity Sensor



Light Sensor



WiFi Module



The Internet



Web Application

$\int \frac{1}{x} dx = \ln|x| + C$   
 $\frac{d}{dx} \ln|x| = \frac{1}{x}$   
 $\ln \frac{a}{b} = \ln a - \ln b$   
 $\ln a^x = x \ln a$   
 $\ln e^x = x$   
 $\ln 1 = 0$   
 $\ln e = 1$   
 $\ln 0$  is not defined



MicroStrain-SensorCloud: Vi x

https://sensorcloud.microstrain.com/SensorCloud/data/FFFF0015C906B640/

Menu | [Account & Devices Overview](#) | [Data](#) | [Math Engine](#) | [Use JS viewer](#) | [ch.doukas@gmail.com](#) | [Log out](#)

**Sensors** **Shelburne Vineyard**

Name	Sensor	Channel	Unit	Graph
384	ENV-Link II	Air Temperatun	°F	<input checked="" type="checkbox"/>
384	ENV-Link II	Internal Tempe	°F	<input type="checkbox"/>
384	ENV-Link II	Leaf Wetness	V	<input type="checkbox"/>
384	ENV-Link II	Radio Strength	dBm	<input type="checkbox"/>
384	ENV-Link II	Relative Humid	%RH	<input type="checkbox"/>
384	ENV-Link II	Soil Moisture	mV	<input type="checkbox"/>
384	ENV-Link II	Solar Radiation	W/m <sup>2</sup>	<input type="checkbox"/>

**Views**

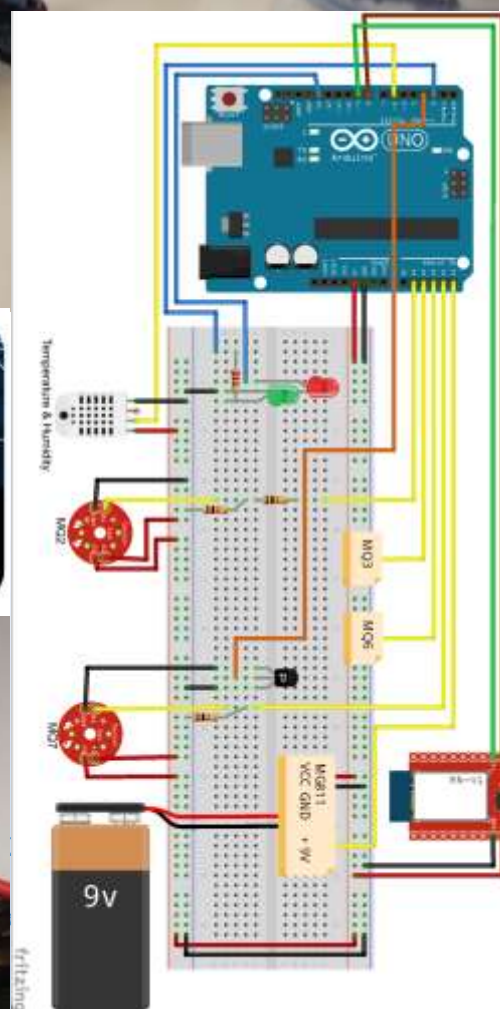
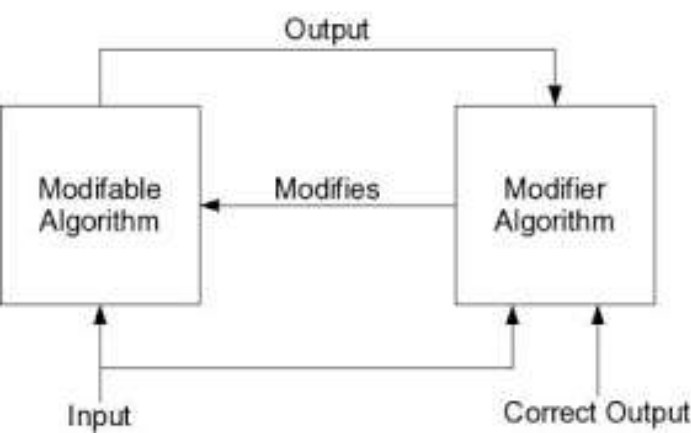
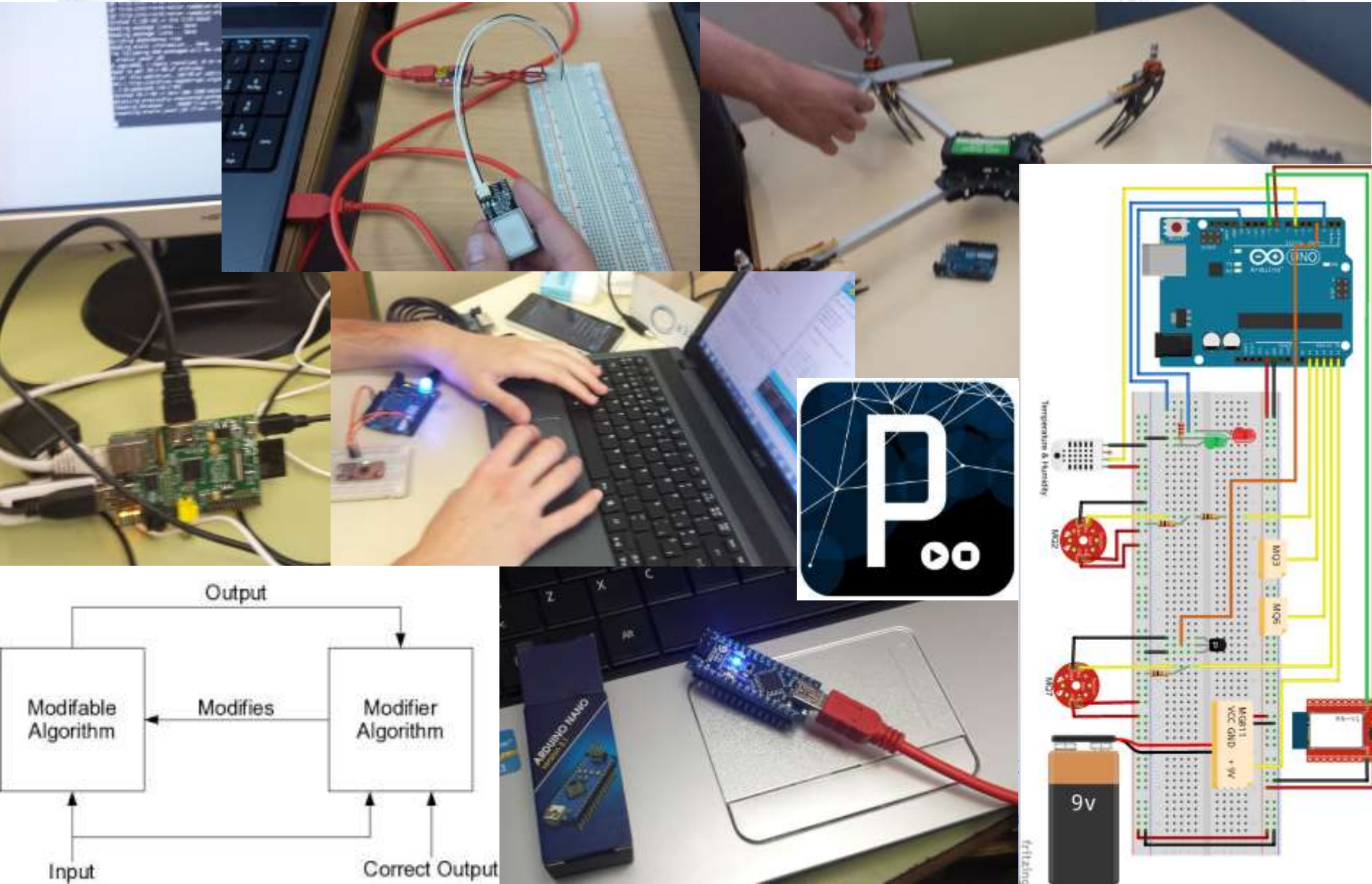
**Download CSV**  1934 pts in 0.18 s **Last Upload:** 1 minute 41 seconds **SensorCloud™**

**Zoom:** [10s](#) [1m](#) [5m](#) [10m](#) [1h](#) [1d](#) [1w](#) [1M](#) [max](#) **Timezone:** [L: Eastern European](#)

4/17/10 0:18   zoom   10/5/11 5:15



# PROGRAMMING SMART DRONES





Erasmus + project: ART (2015-2017): Arduino technology and art  
<http://arteducation.eu>



# Approximate pricing

Arduino Uno.....	25€
Arduino Uno clone (or from components)	5€
Raspberry Pi 2.....	49€
Resistors, LEDs, LDR.....	around 5€
Breadboard.....	10€
MQ sensors (CO, CH4, etc).....	5€ each
MG811 (CO2 sensor).....	50€
Arduino for Android.....	50€
Sometimes very high import taxes from China!	



# Resources

[www.arduino.cc](http://www.arduino.cc)

[www.processing.org](http://www.processing.org)

[www.technologies.net](http://www.technologies.net)



# Thank you very much for your attention Questions?



# More information

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Generalitat de Catalunya  
Departament d'Ensenyament

University Professor // **Universitat de Barcelona**



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Scientix Deputy Ambassador (Spain) // **European Schoolnet**



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