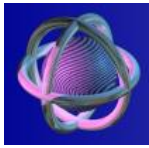
AImage Lab
University of Modena and Reggio Emilia



Biometric System Laboratory
DISI - University of Bologna

Programming with Arduino

DOTT. GUIDO BORGHI

A.A. 2020/21

INNOVATION DESIGN

A project with Arduino

In order to create a project with Arduino there are two part to consider:

1. Hardware part

- The «real» **components** of the project:
  - Circuit
  - Sensors
  - Actuators
  - …

2. Software part

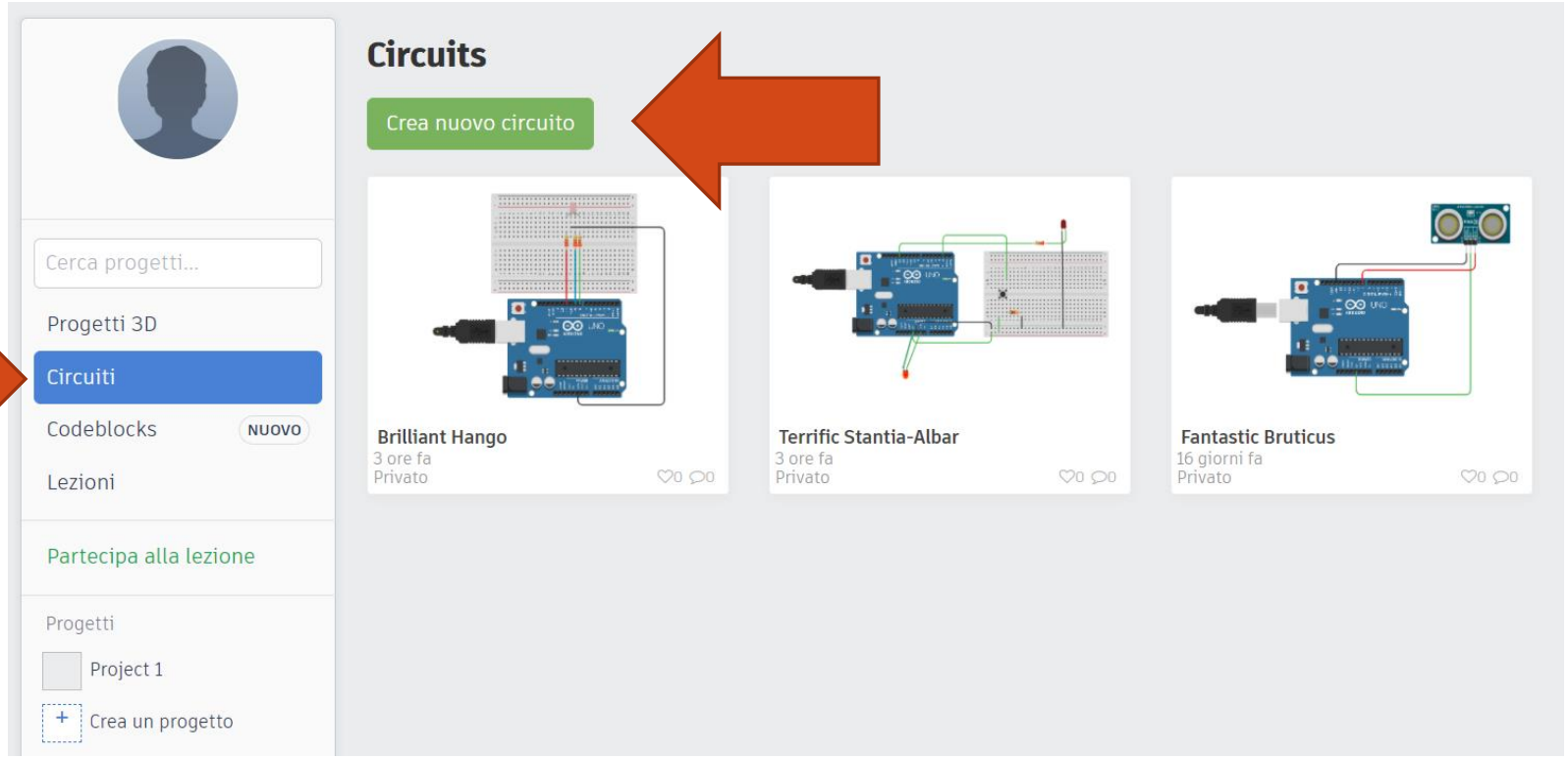
- The **logic** of the project:
  - Setup function
  - Loop function

Arduino simulator

We use a **simulator** of the Arduino embedded board:

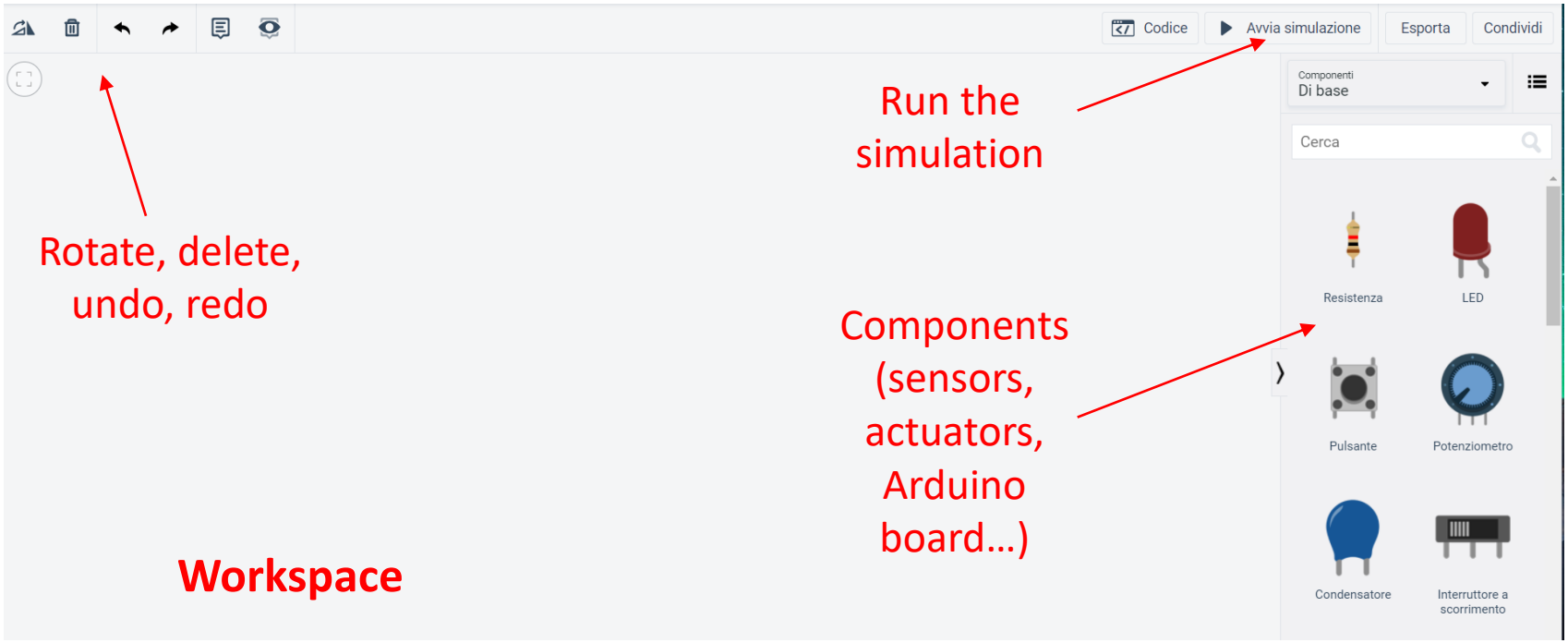
https://www.tinkercad.com/

Tinkercad


Circuits
Crea nuovo circuito
Cerca progetti...
Progetti 3D
Circuiti
Codeblocks
NUOVO
Lezioni
Partecipa alla lezione
Progetti
Project 1
Crea un progetto
Brilliant Hango
3 ore fa
Privato
Terrific Stantia-Albar
3 ore fa
Privato
Fantastic Bruticus
16 giorni fa
Privato

Tinkercad

Open the code section



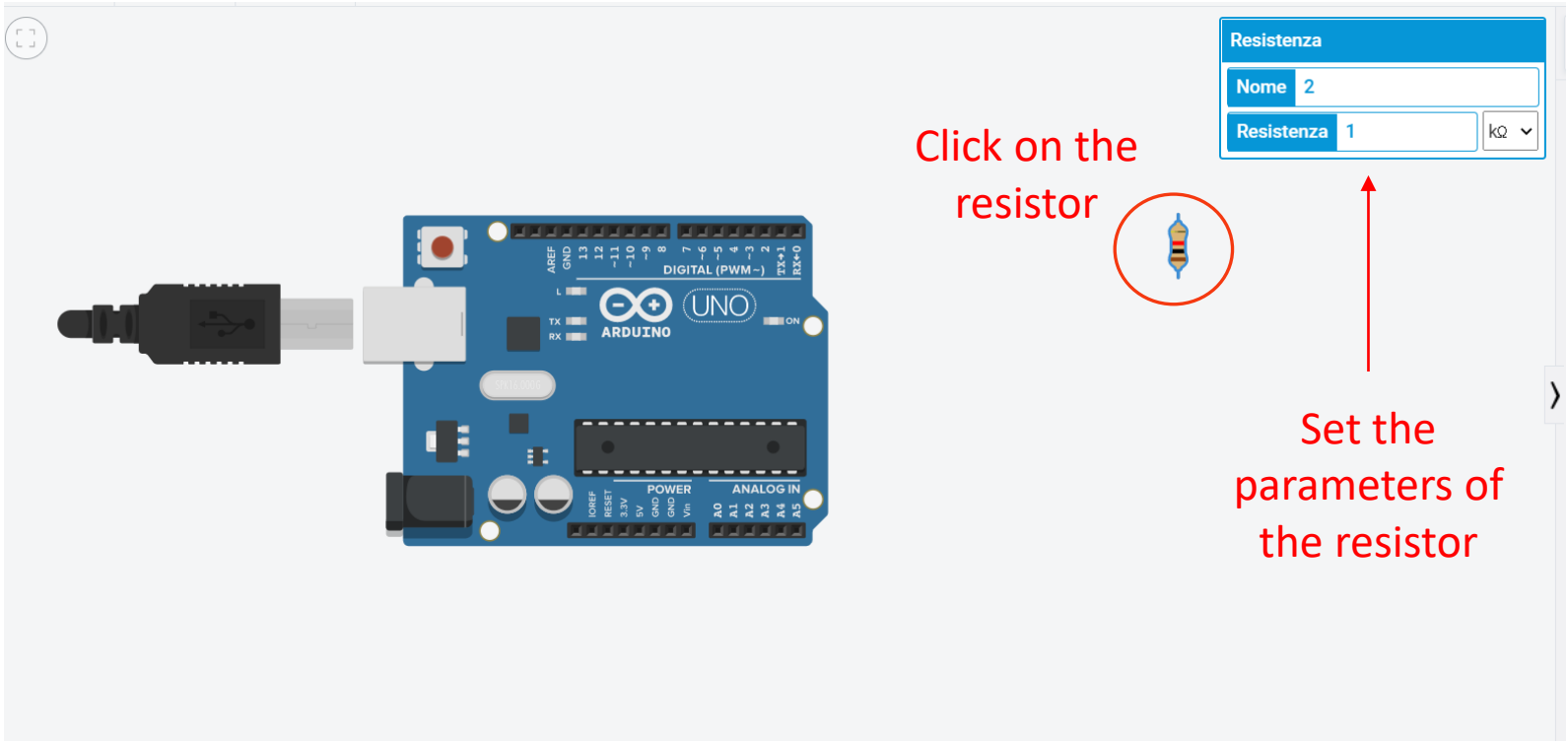
Run the simulation

Rotate, delete, undo, redo

Components (sensors, actuators, Arduino board…)

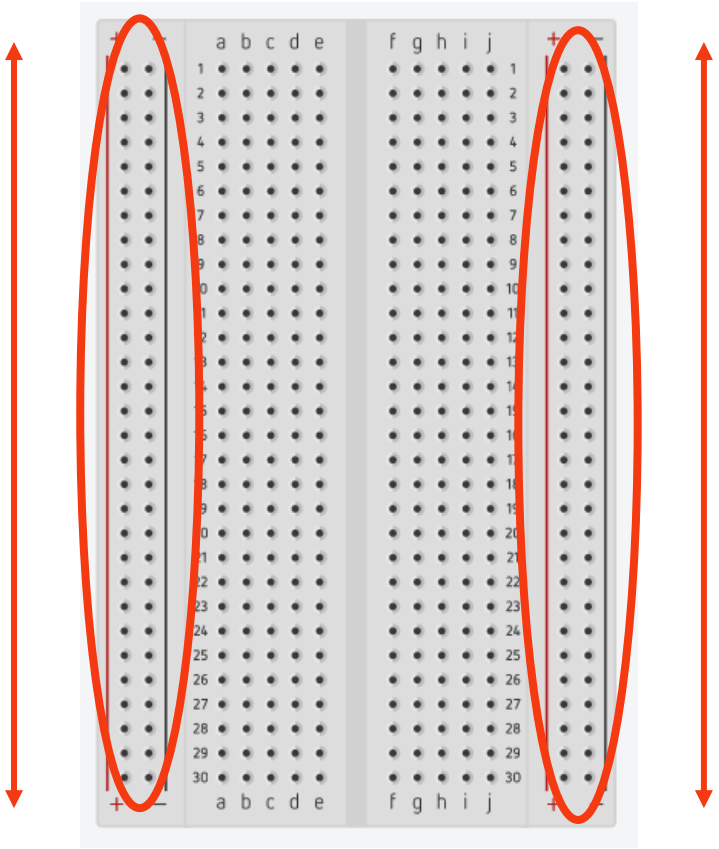
Workspace

Tinkercad


Resistenza
Nome 2
Resistenza 1
kΩ
Click on the resistor
Set the parameters of the resistor
DIGITAL (PWM~)
UNO
ARDUINO
POWER
ANALOG IN

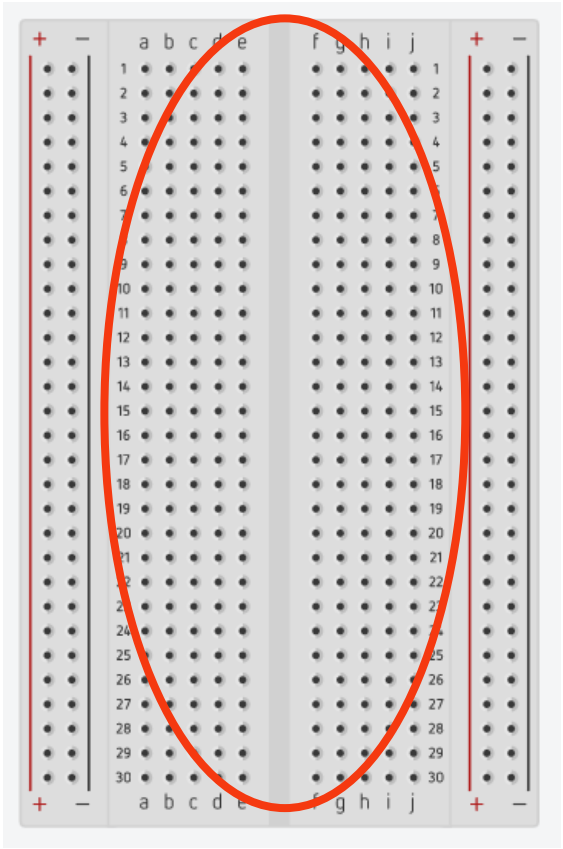
Breadboard

Scheme of the connections on both sides

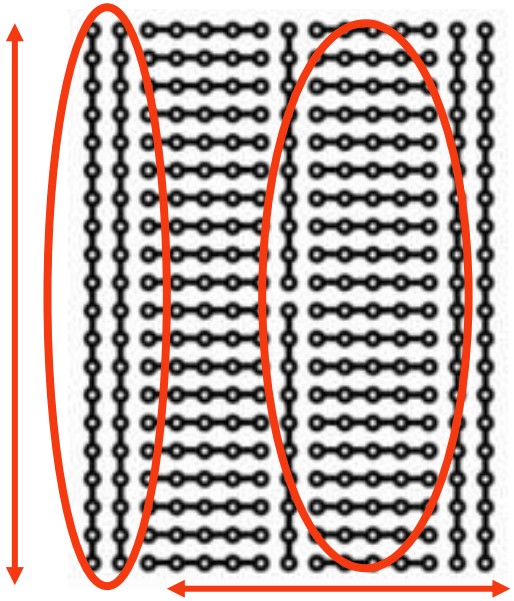


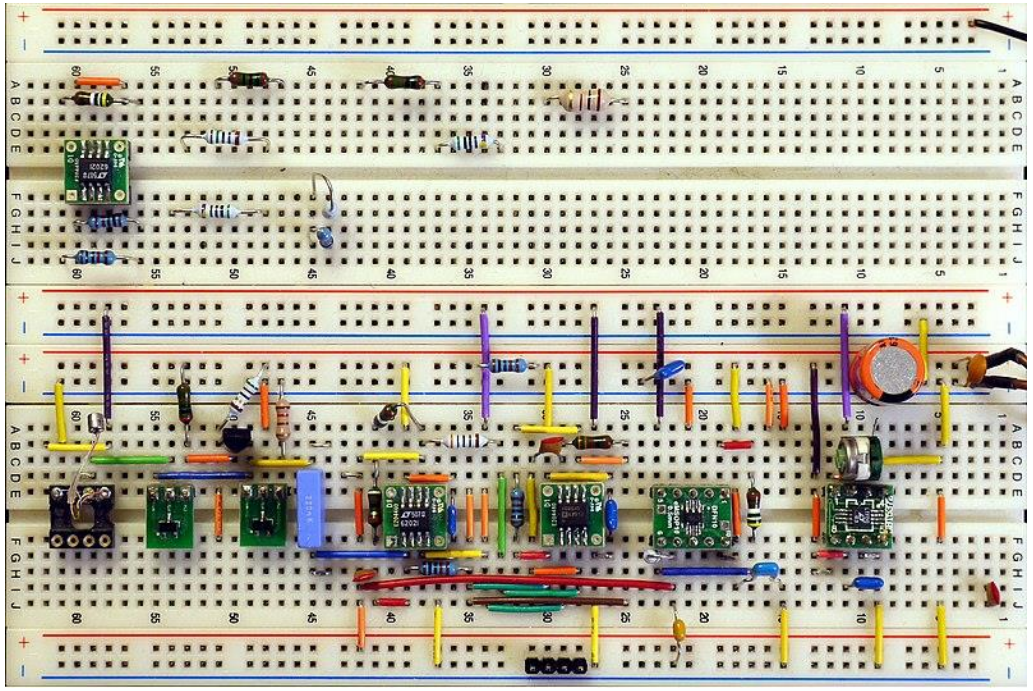
Breadboard

Scheme of the connections in the central part

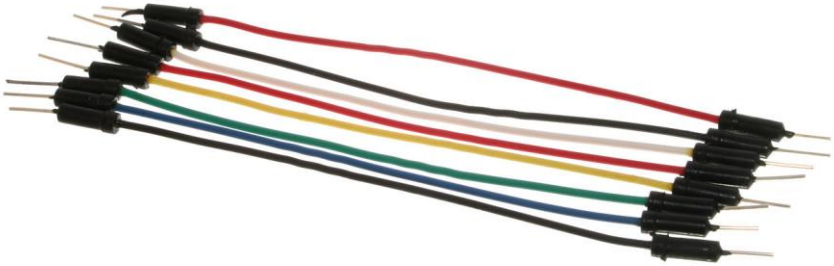


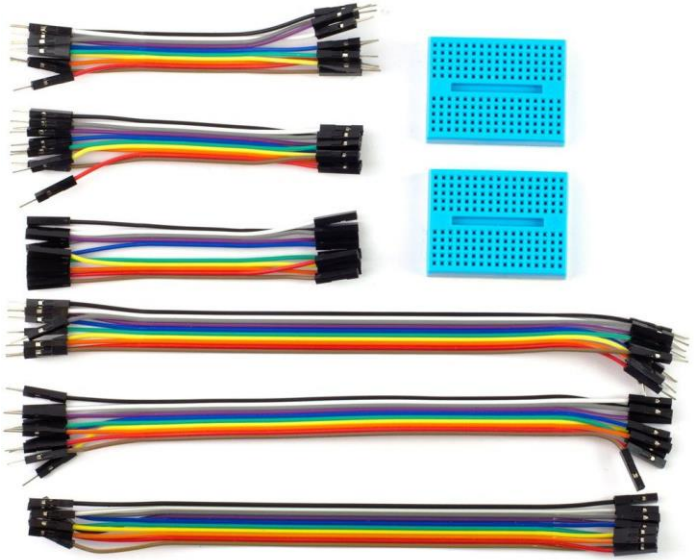
Breadboard



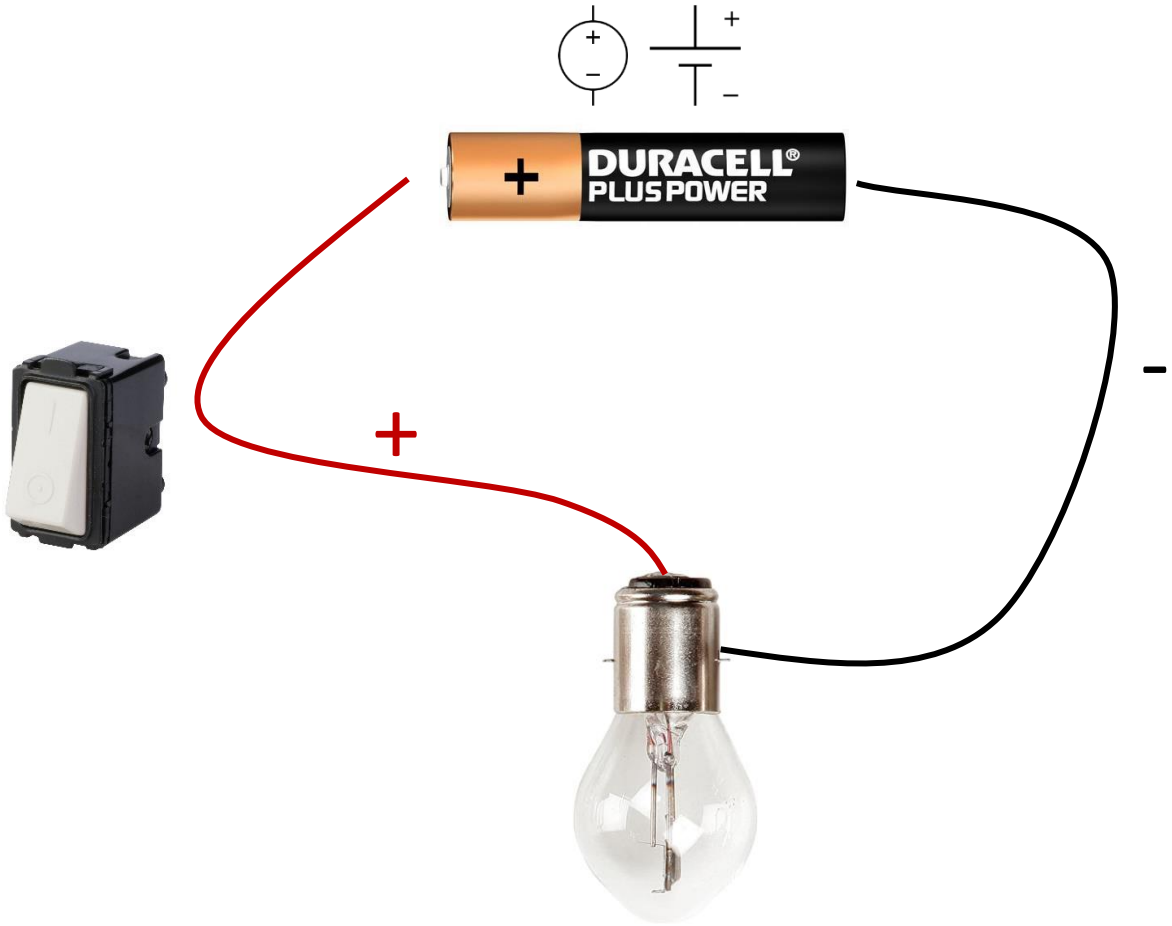


Breadboard wires



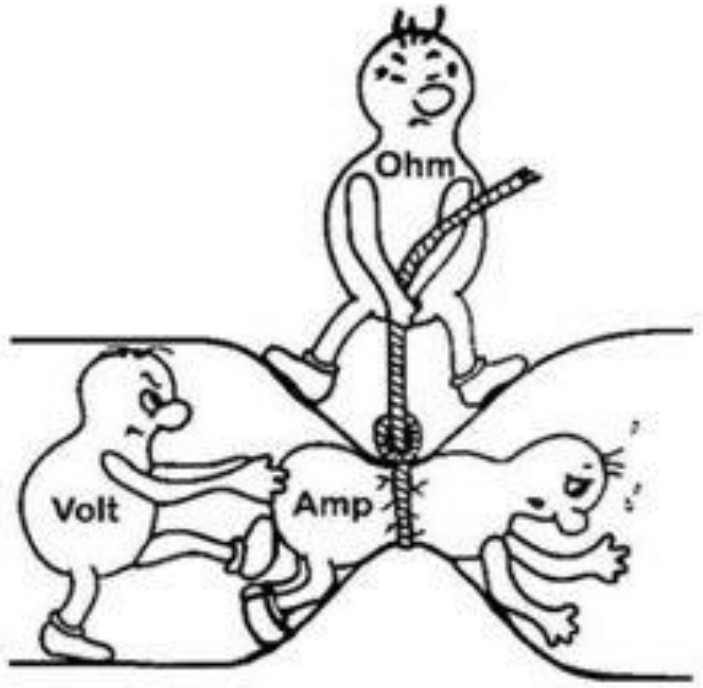


Circuit

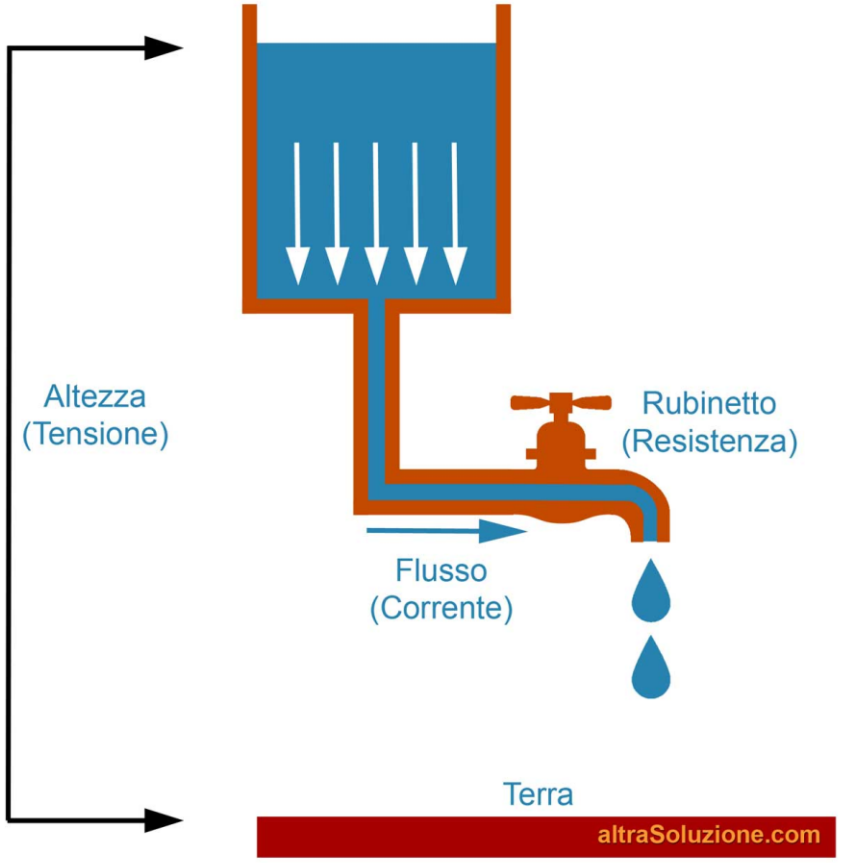


Ampere, Volt and Ohm

Voltage (Volt, V)
Current (Ampere, A)
Electrical resistance (Ohm, Ω)



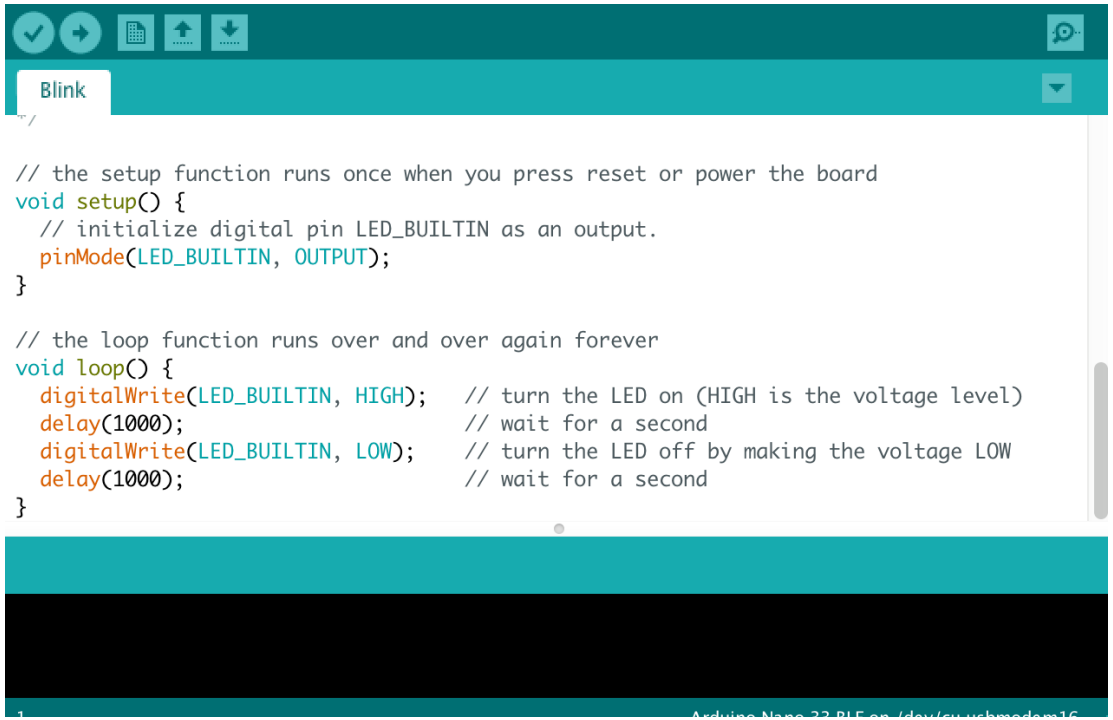
Comparison


Altezza
(Tensione)
Rubinetto
(Resistenza)
Flusso
(Corrente)
Terra
altraSoluzione.com

Software

Arduino has its *Integrated Development Environment* (IDE)

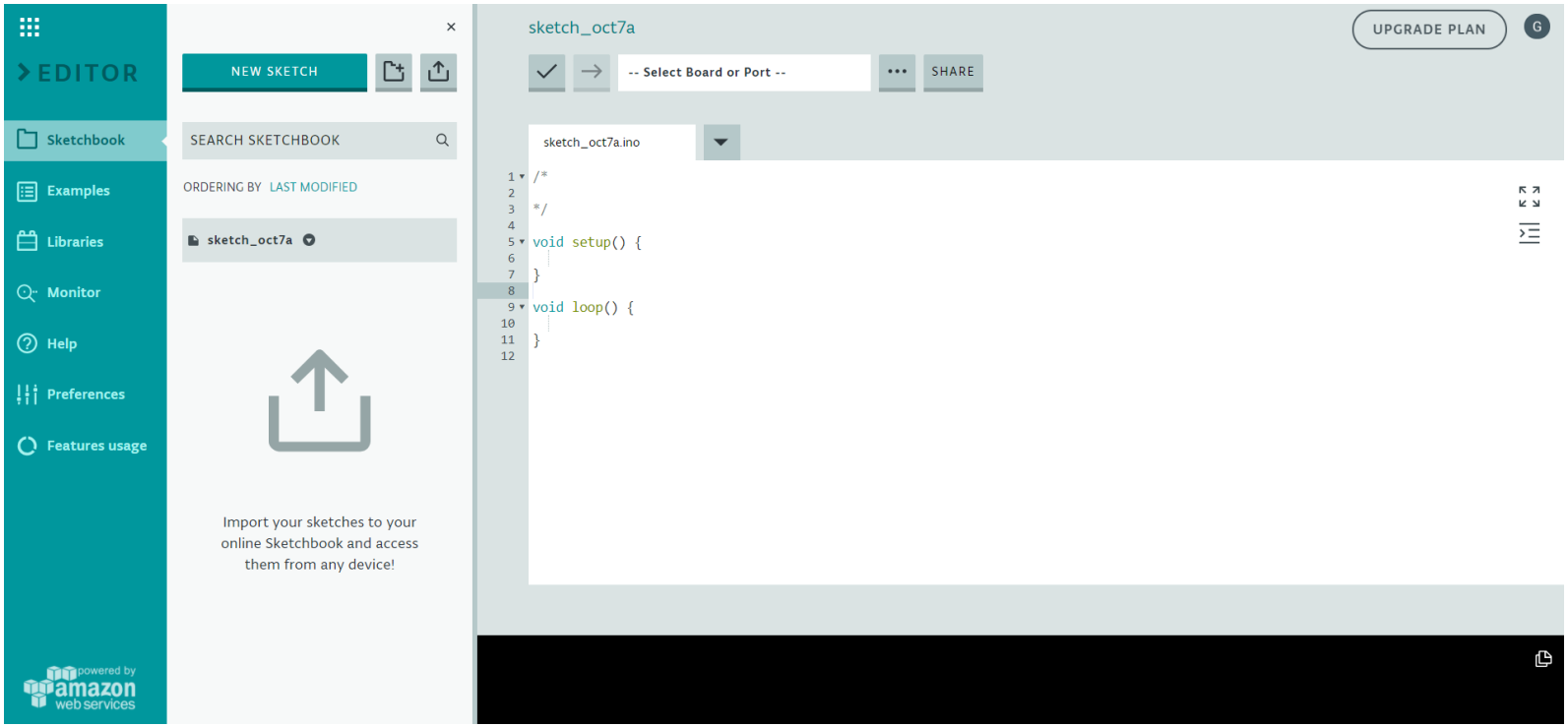
- https://www.arduino.cc/en/main/software



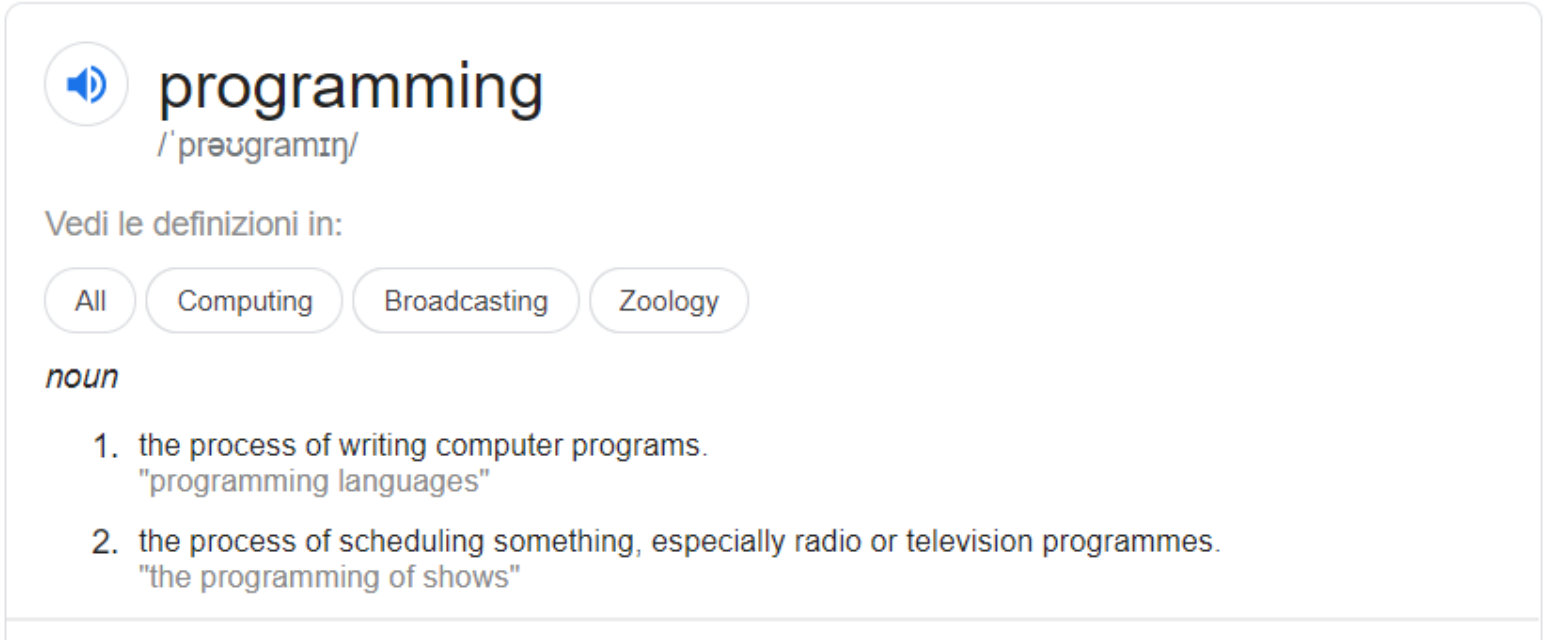
Software


HARDWARE
SOFTWARE
DOCUMENTATION
COMMUNITY
BLOG
ABOUT
Download the Arduino IDE
ARDUINO 1.8.13
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 Processi
source software.
This software can be used with any
Refer to the Getting Started page for Installation instructions.
Windows Installer, for Windows 7 and up
Windows ZIP file for non admin install
Windows app Requires Win 8.1 or 10
Get
Mac OS X 10.10 or newer
Linux 32 bits
Linux 64 bits
Linux ARM 32 bits
Linux ARM 64 bits
Release Notes
Source Code
Checksums (sha512)

IDE web editor



The meaning of programming



programming

/ˈprəʊgramɪŋ/

Vedi le definizioni in:

All | Computing | Broadcasting | Zoology

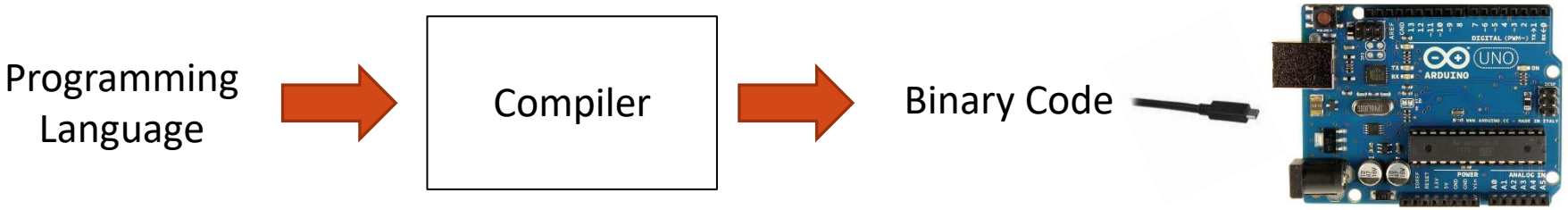
noun

1. the process of writing computer programs.
   "programming languages"
2. the process of scheduling something, especially radio or television programmes.
   "the programming of shows"

The meaning of programming

A programmer:

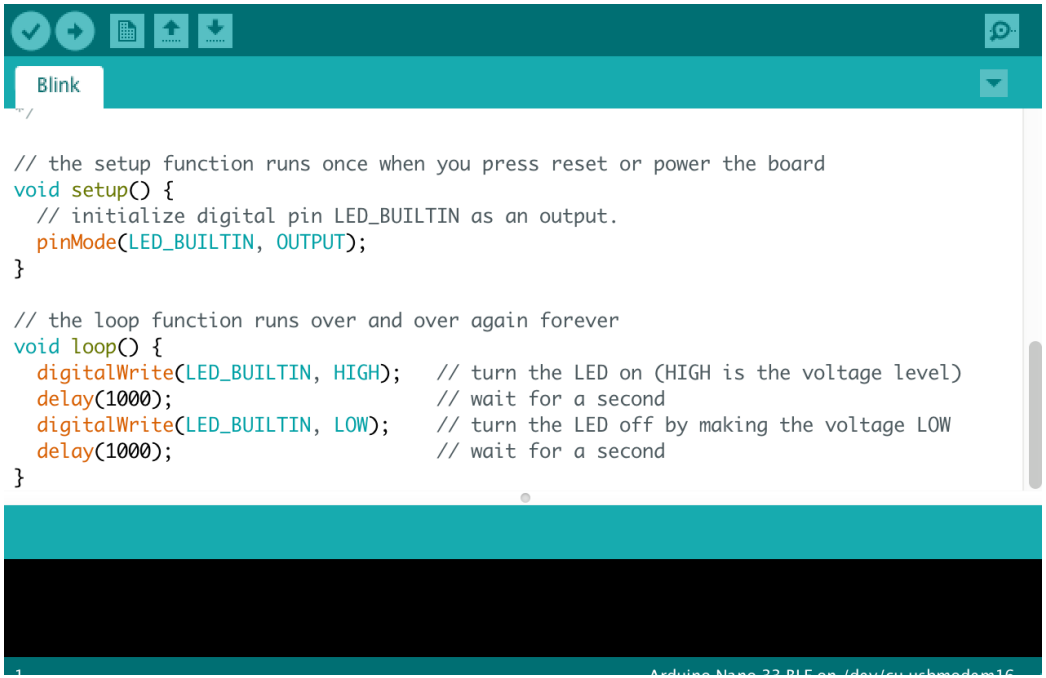
- Writes **a sequence of instructions** for the processor
- Uses a programming language «*understandable*» for humans
  - C/C++ for Arduino
- A compiler «transforms» this language in the binary representation



Programming with Arduino

There are two main **functions**:

- Function **setup**
  - executed *only once*
- Function **loop**
  - *continuously* executed



Common functions

- `pinMode(<number_of_pin>, INPUT or OUTPUT);`
  Set the pin in the input or output modality
- `val = digitalRead(<number_of_pin>);`
  Reads the value from the specified digital pin and puts the value in val.
- `val = analogRead(<number_of_pin>);`
  Reads the value from the specified analog pin and puts the value in val.
- `digitalWrite(<number_of_pin>, LOW/HIGH);`
  Write a HIGH or a LOW value to a digital pin.

See the manual for available functions:

https://www.arduino.cc/reference/en/

Arduino functions

Digital operations

Analogic operations

Mathematical operations

FUNCTIONS

For controlling the Arduino board and performing computations.

Digital I/O
digitalRead()
digitalWrite()
pinMode()

Analog I/O
analogRead()
analogReference()
analogWrite()

Zero, Due & MKR Family
analogReadResolution()
analogWriteResolution()

Advanced I/O
noTone()
pulseIn()
pulseInLong()

Math
abs()
constrain()
map()
max()
min()
pow()
sq()
sqrt()

Trigonometry
cos()
sin()
tan()

Characters
isAlpha()
isAlphaNumeric()
isAscii()

Random Numbers
random()
randomSeed()

Bits and Bytes
bit()
bitClear()
bitRead()
bitSet()
bitWrite()
highByte()
lowByte()

External Interrupts
attachInterrupt()
detachInterrupt()

Interrupts

Arduino variables

In addition to functions, we can declare variables.

<type> <variable_name> = <value>

For example:

```
int buttonPin = 3;

int valueFromSensor;

valueFromSensor = digitalRead(buttonPin);
```

Remember to add a `;` at the end of each instruction and variable definition.

Arduino data types

int

Integers are your primary data-type for number storage.

On the Arduino Uno an int stores a 16 bit value. This yields a range of -32,768 to 32,767 (minimum value of -2^{15} and a maximum value of $2^{15}- 1$).

Int's store **negative numbers** with the **2's complement technique**.

The Arduino takes care of dealing with negative numbers for you, so that arithmetic operations work transparently in the expected manner.

Arduino data types

char

A data type used to store a **character value**.
Character literals are written in single quotes, like this: 'A' (for multiple characters - strings - use double quotes: "ABC").

Characters are stores as numbers however through the **ASCII chart**.

The size of the char datatype is at least 8 bits.

Arduino data types

array

An array is a collection of variables that are eccessed with an index number.

All of the methods below are valid ways to create (declare) an array.

- `int myInts[6];`
- `int myPins[] = {2, 4, 8, 3, 6};`
- `int mySensVals[6] = {2, 4, -8, 3, 2};`
- `char message[6] = "hello";`

Arduino data types

Arrays are zero indexed, that is, referring to the array initialization above, the first element of the array is at index 0, hence

```
mySensVals[0] == 2, mySensVals[1] == 4
```

It also means that in an array with ten elements, index nine is the last element. Hence:

```
int myArray[10]={9, 3, 2, 4, 3, 2, 7, 8, 9, 11};

// myArray[9]    contains 11

// myArray[10]   is invalid and contains random
information (other memory address)
```

Arduino variables

VARIABLES

Arduino data types and constants.

Constants

HIGH | LOW
INPUT | OUTPUT | INPUT_PULLUP
LED_BUILTIN
true | false
Floating Point Constants
Integer Constants

Conversion

(unsigned int)
(unsigned long)
byte()
char()
float()
int()
long()
word()

Data Types

array
bool
boolean
byte
char
double
float
int
long
short
size_t
string
String()
unsigned char
unsigned int
unsigned long
void

Variable Scope & Qualifiers

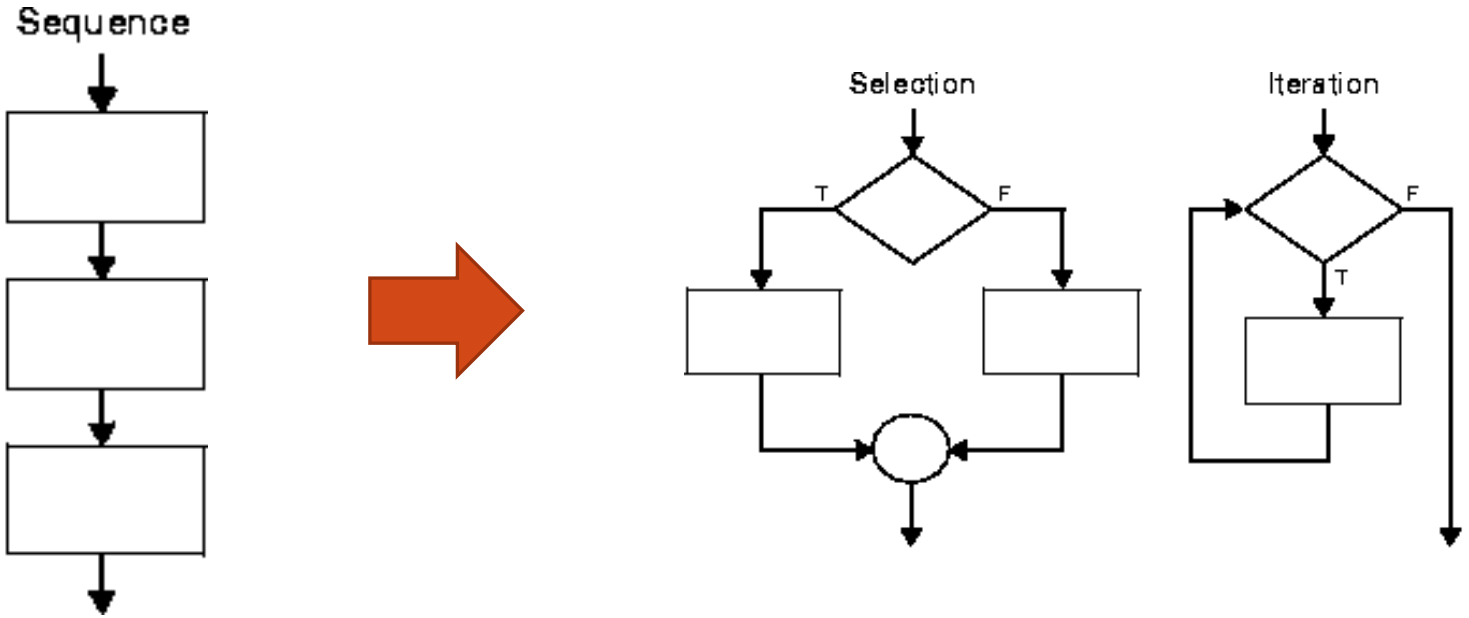
const
scope
static
volatile

Utilities

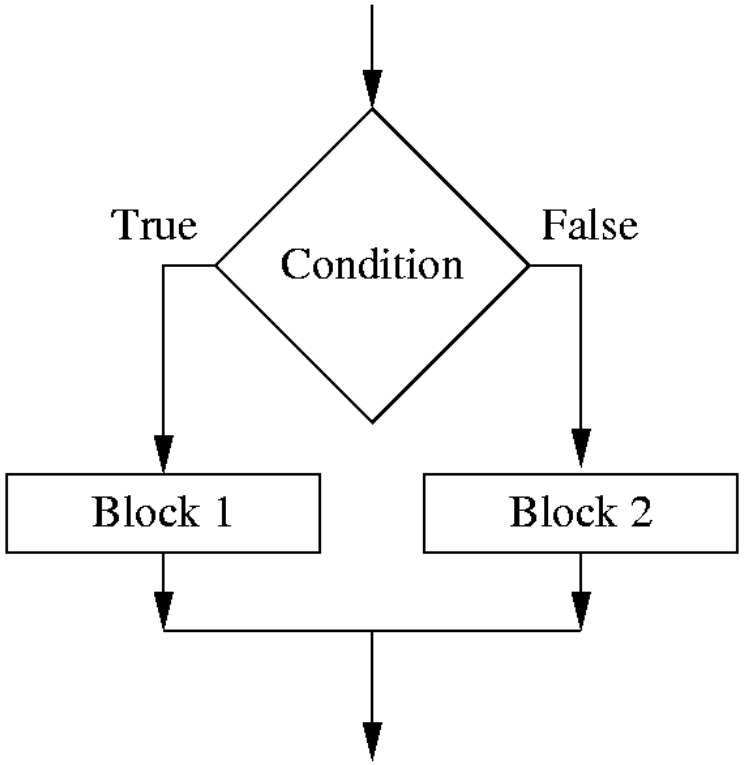
PROGMEM
sizeof()

Arduino structures

We can change the flow of a sequence of instructions with control structures.



IF statement




```
if (condition) {
   //statement(s)
}
else {
}
```

Conditions

Comparison operators:

- `x == y (x is equal to y)`
- `x != y (x is not equal to y)`
- `x <  y (x is less than y)`
- `x >  y (x is greater than y)`
- `x <= y (x is less than or equal to y)`
- `x >= y (x is greater than or equal to y)`

Example

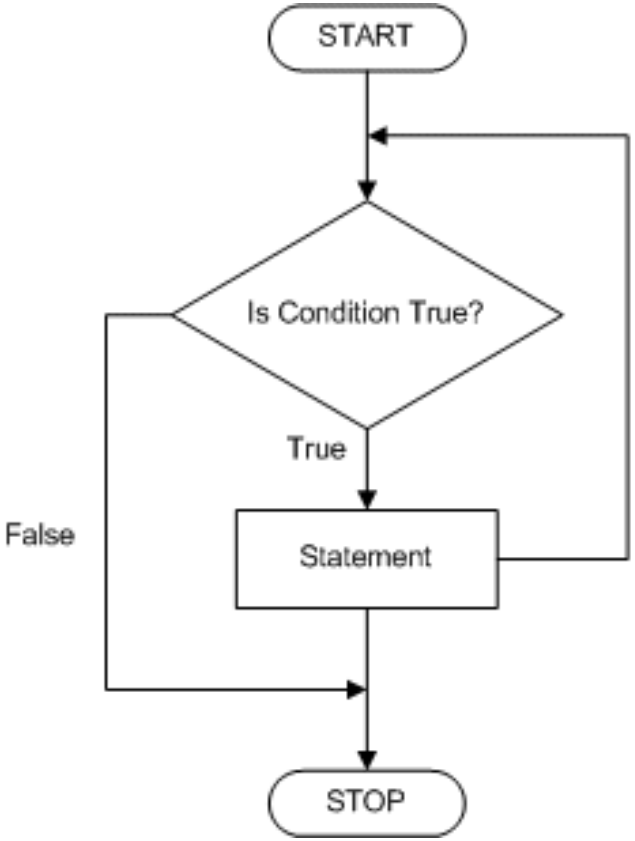
```
if (x > 120)
digitalWrite(LEDpin, HIGH);

if (x > 120)
digitalWrite(LEDpin, HIGH);

if (x > 120)
{digitalWrite(LEDpin, HIGH);}

if (x > 120) {
  digitalWrite(LEDpin1, HIGH);
  digitalWrite(LEDpin2, HIGH);
}
// all are correct
```

For statement




```
for (initialization; condition; increment) {
  // statement(s);
}
```

For statement

```
for (initialization; condition; increment) {
  // statement(s);
}
```

Initialization: happens first and exactly once.

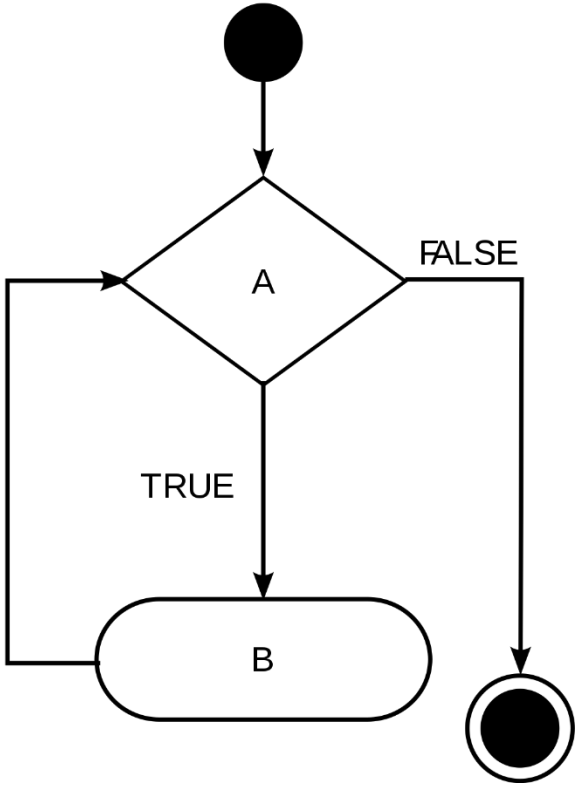
Condition: each time through the loop, condition is tested; if it's true, the statement block, and the increment is executed, then the condition is tested again. When the condition becomes false, the loop ends.

Increment: executed each time through the loop when condition is true.

Example

```
for (int i = 0; i <= 255; i++) {
   analogWrite(PWMpin, i);
   delay(10);
 }
```

While statement




```
while (condition)
{
   // statement(s)
}
```

Example

```
int var = 0;
while (var < 200) {
  // do something repetitive 200 times
  var = var + 1; // same of v++;
}
```

Arduino structures

STRUCTURE

The elements of Arduino (C++) code.

Sketch

loop()
setup()

Control Structure

break
continue
do...while
else
for
goto
if
return
switch...case
while

Further Syntax

Arithmetic Operators

% (remainder)
* (multiplication)
+ (addition)
- (subtraction)
/ (division)
= (assignment operator)

Comparison Operators

!= (not equal to)
< (less than)
<= (less than or equal to)
== (equal to)
> (greater than)
>= (greater than or equal to)

Boolean Operators

Pointer Access Operators

& (reference operator)
* (dereference operator)

Bitwise Operators

& (bitwise and)
<< (bitshift left)
>> (bitshift right)
^ (bitwise xor)
| (bitwise or)
~ (bitwise not)

Compound Operators

%= (compound remainder)
&= (compound bitwise and)
*= (compound multiplication)
++ (increment)

Programming with blocks

In Tinkercad you can program also with logical blocks.

Click on «Code», then choose the version «blocks» (text and blocks + text are also available).