

FABRICADEMY 2022-23

TUTORIALS

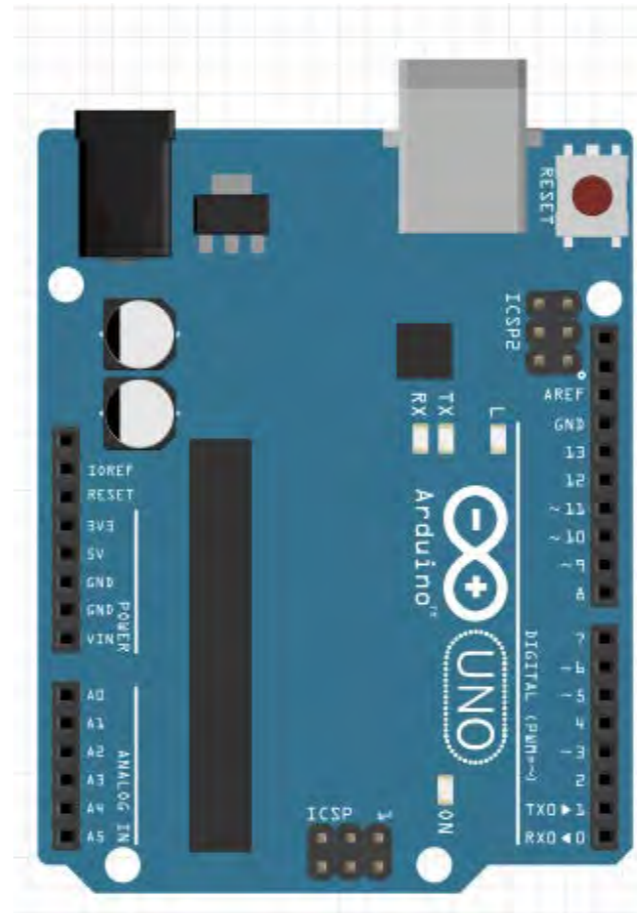


ARDUINO and SENSORS TUTORIAL

EMMA PARESCHI

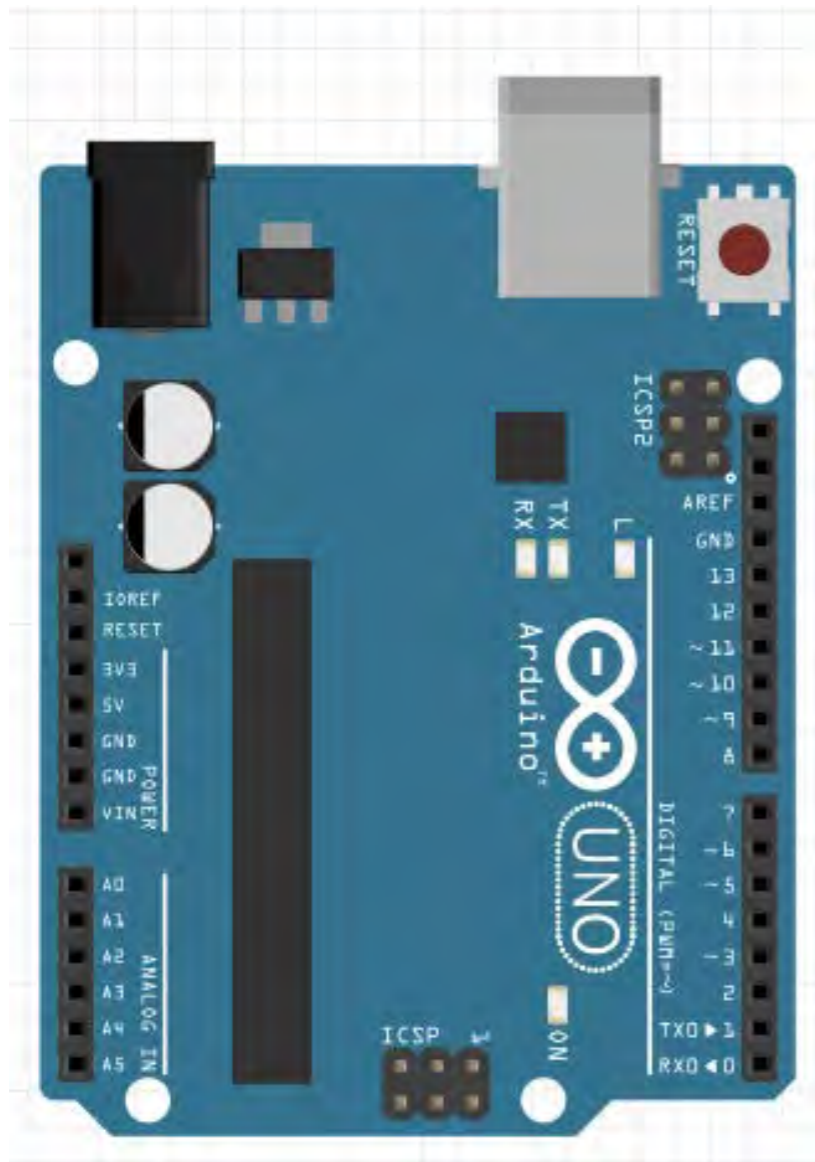
Arduino

Sensor
(input device)



Led
(output device)

Arduino today



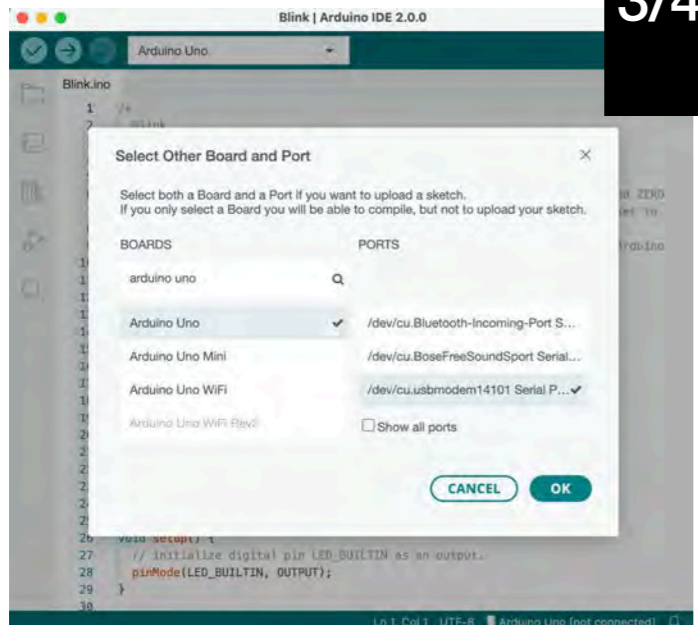
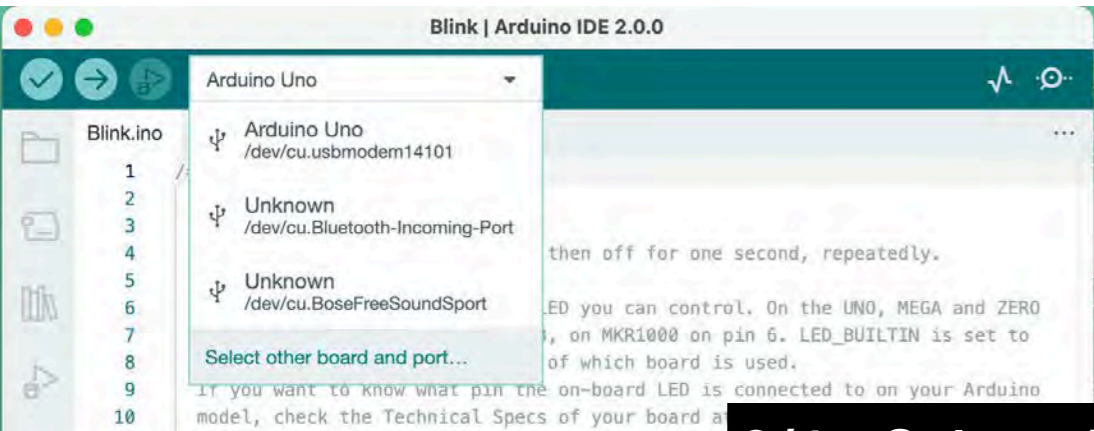
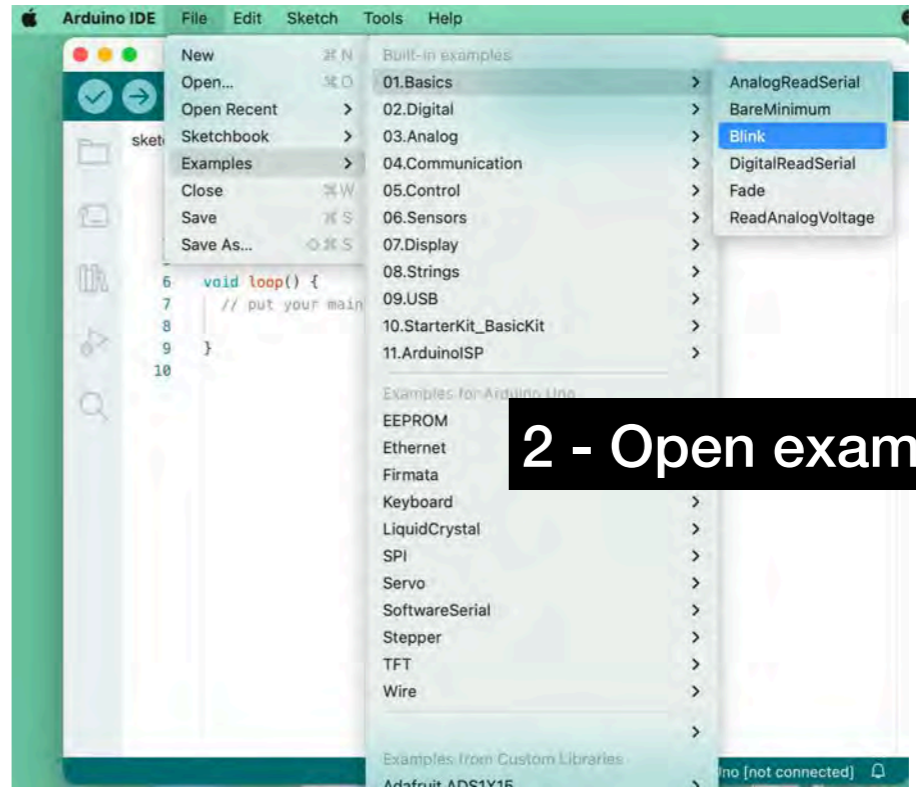
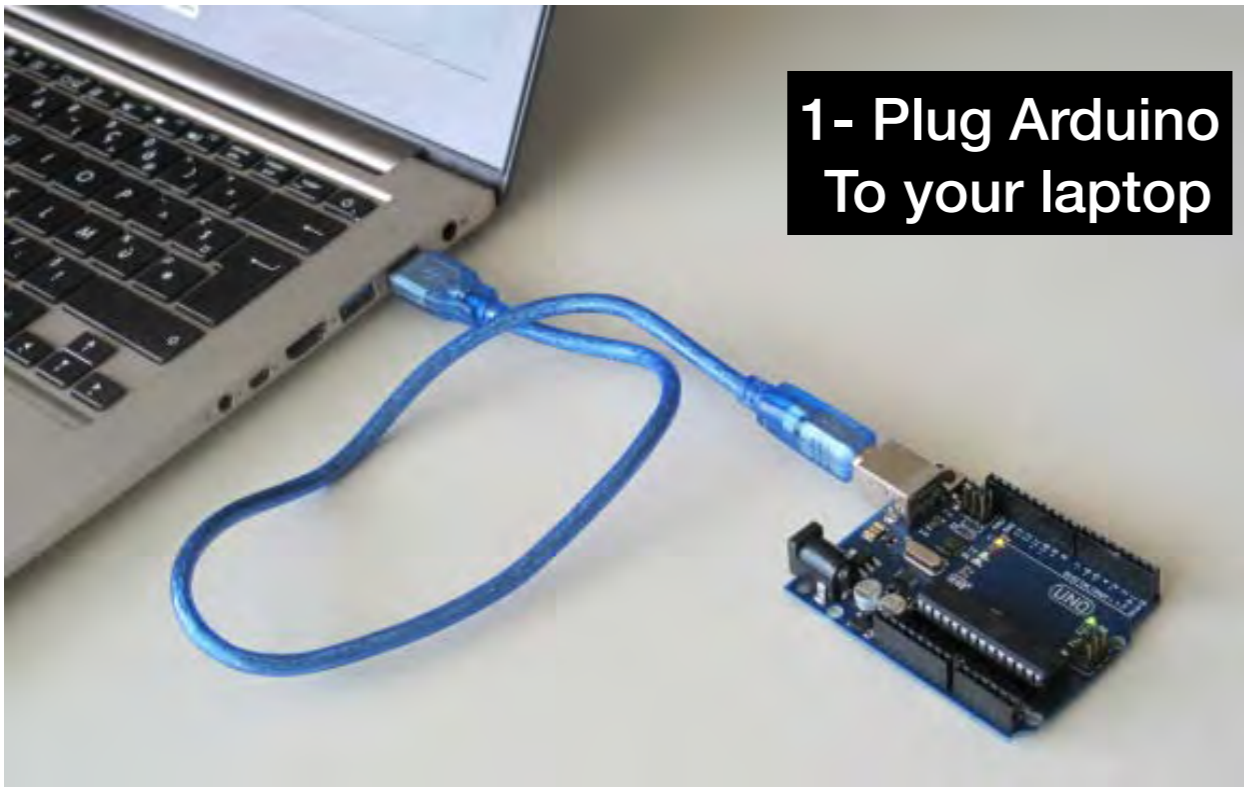
How we will use Arduino

- control a Led
- read a sensor
- to control a Led based on the interaction with the sensor

What do we need:

- make a circuit (with Arduino)
- 'write' (use the right) the code for the circuit

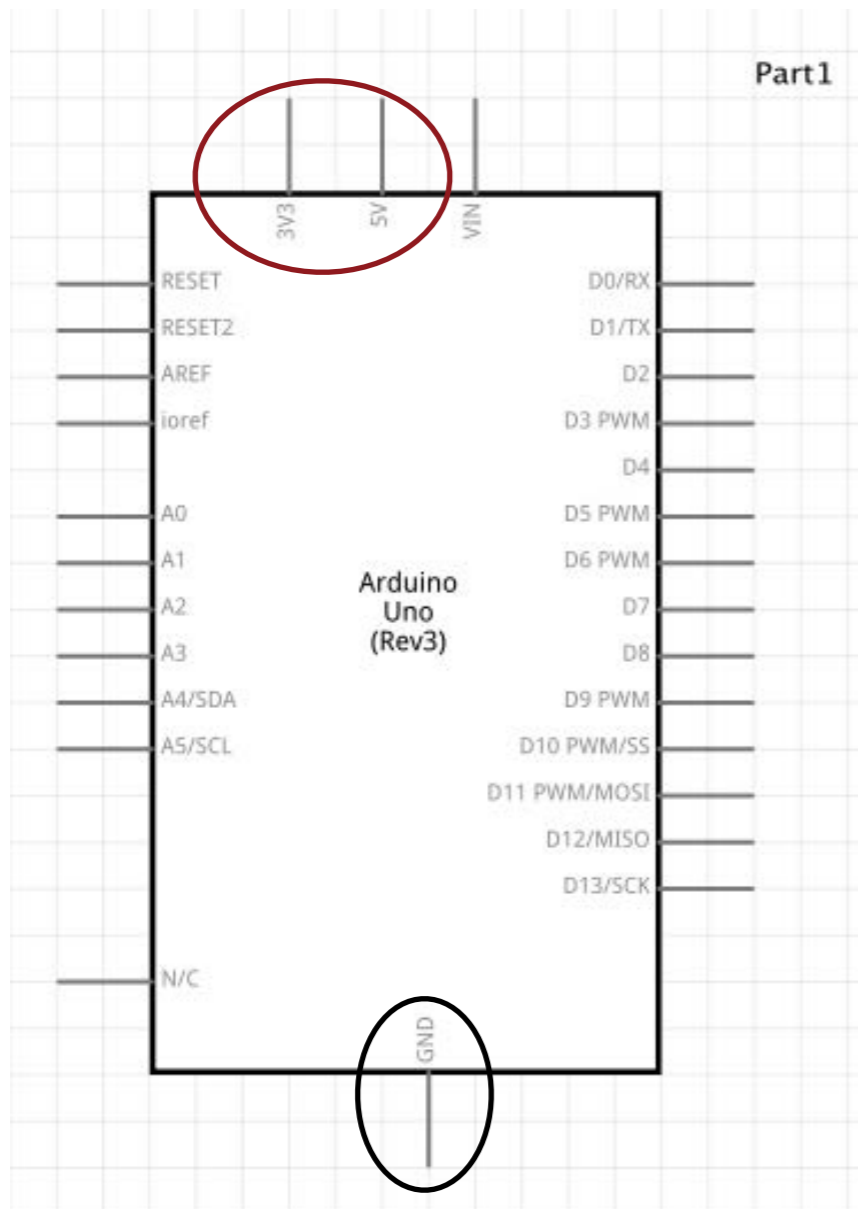
...check if the environment works



If it works, the led embedded on the board blinks

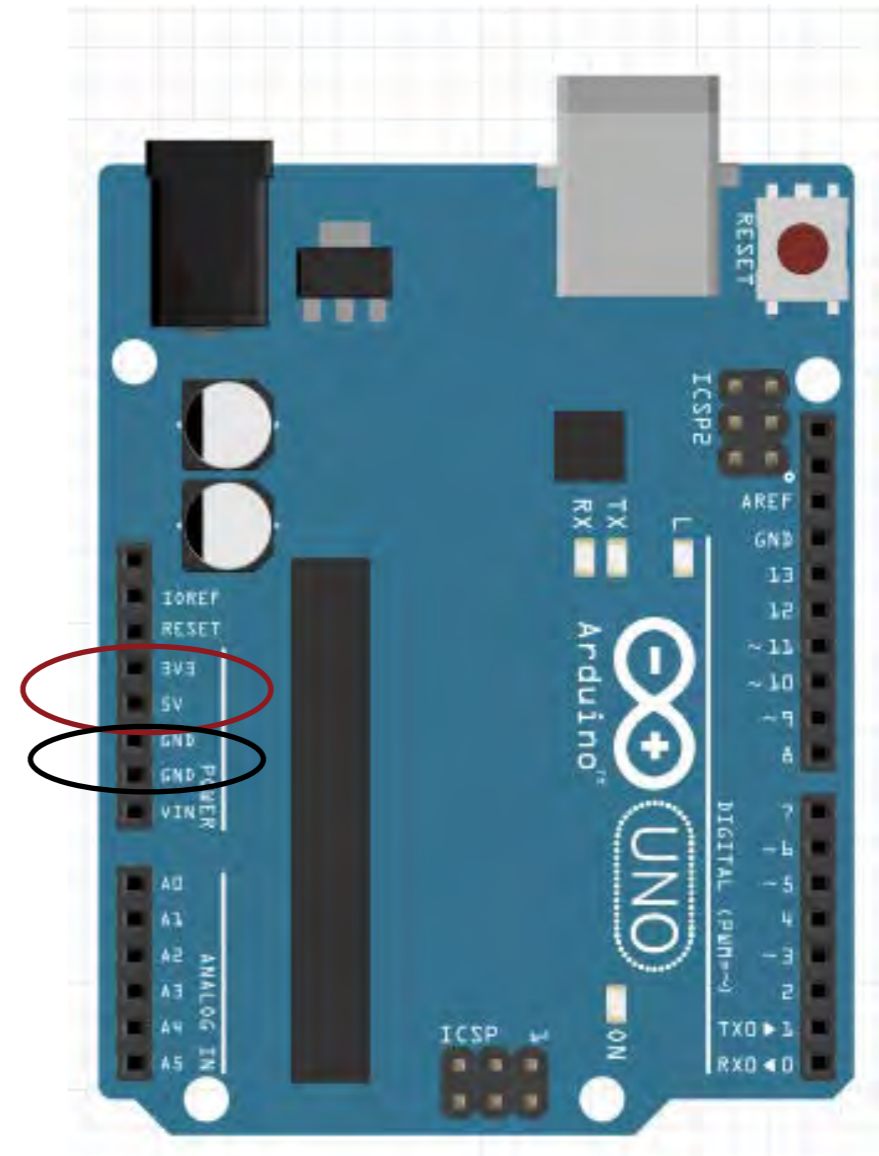
Arduino - Power Pins

Power Pins

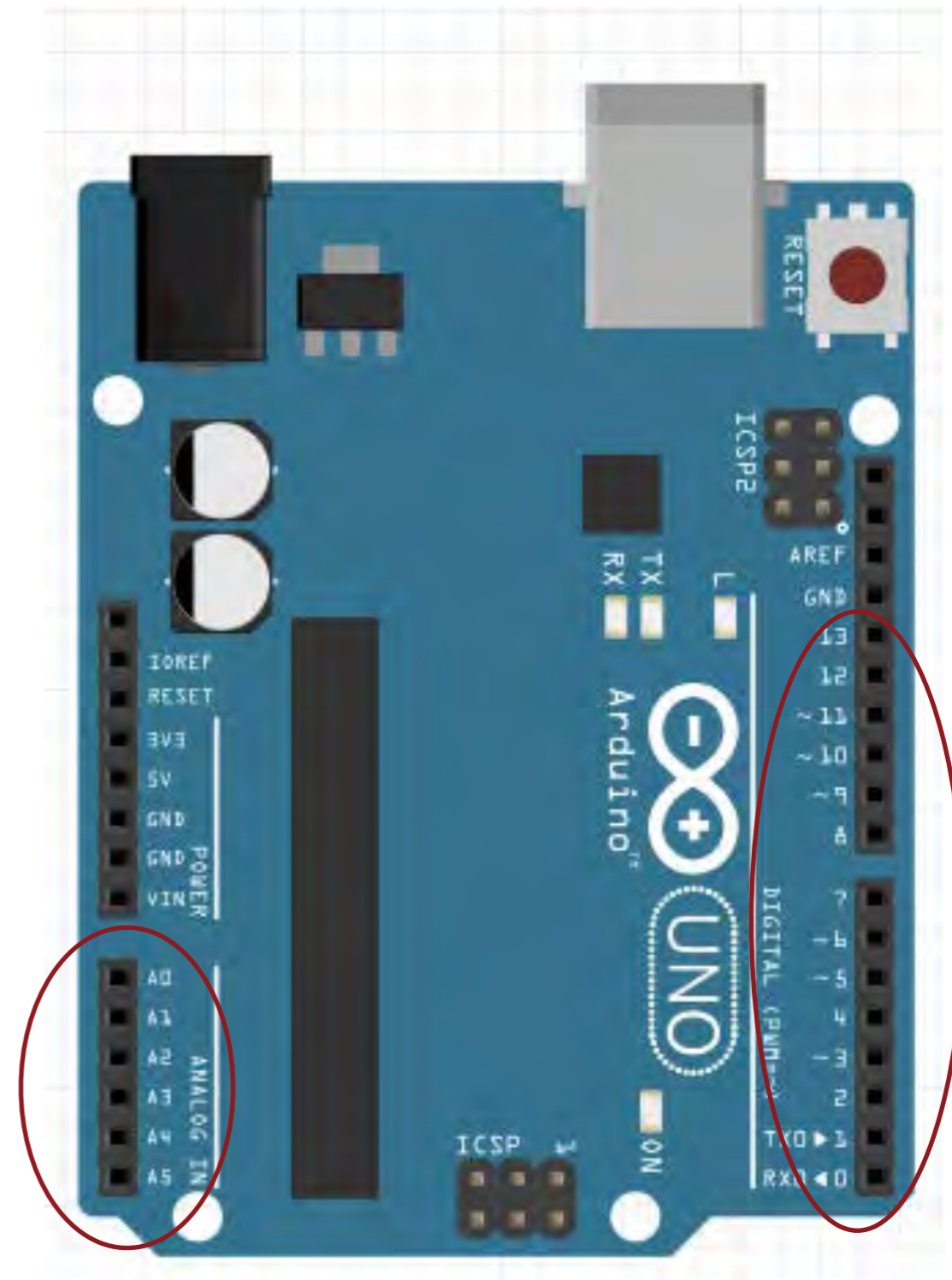
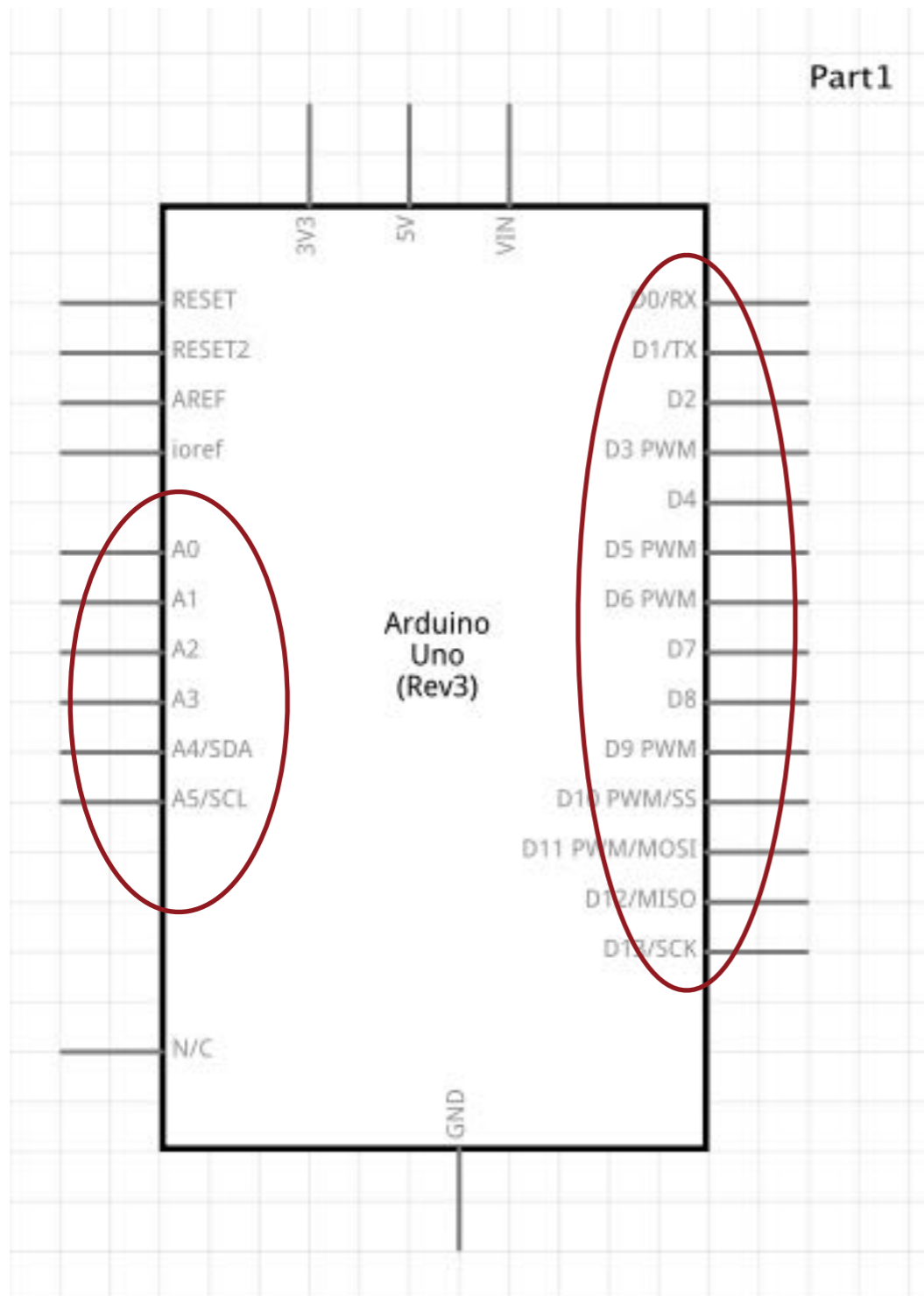


5V / 3.3V:
Power

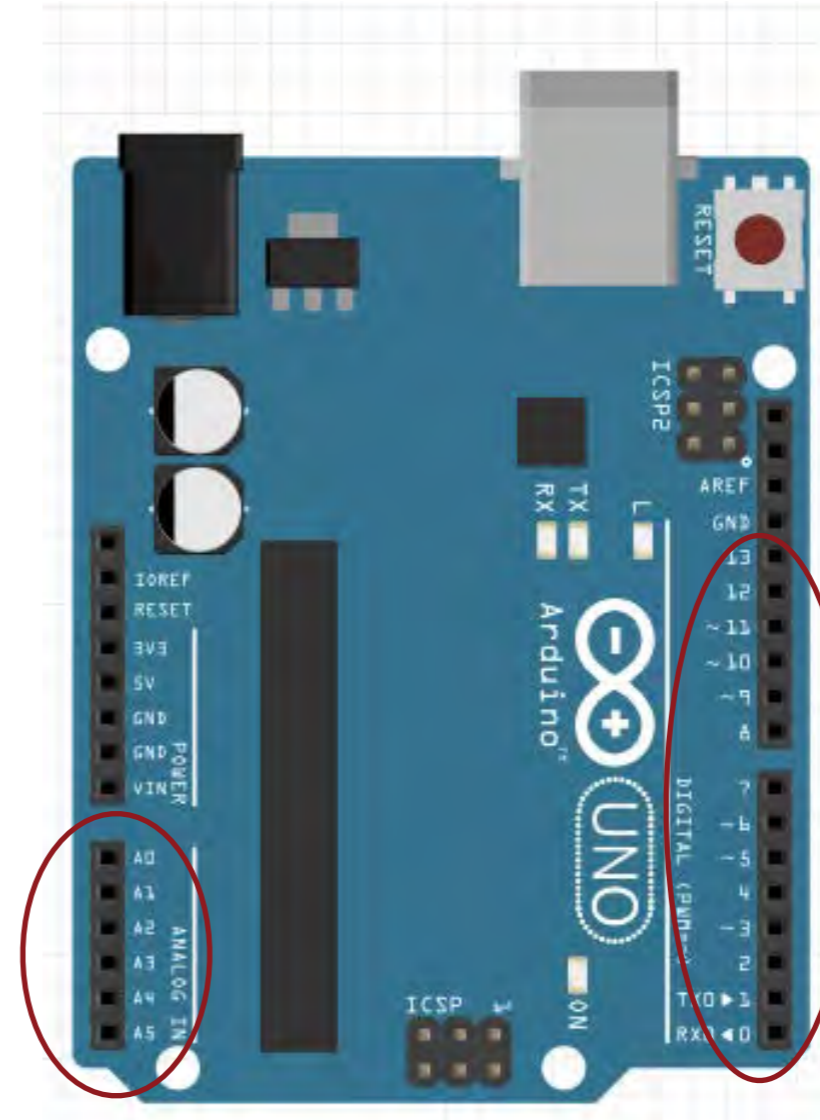
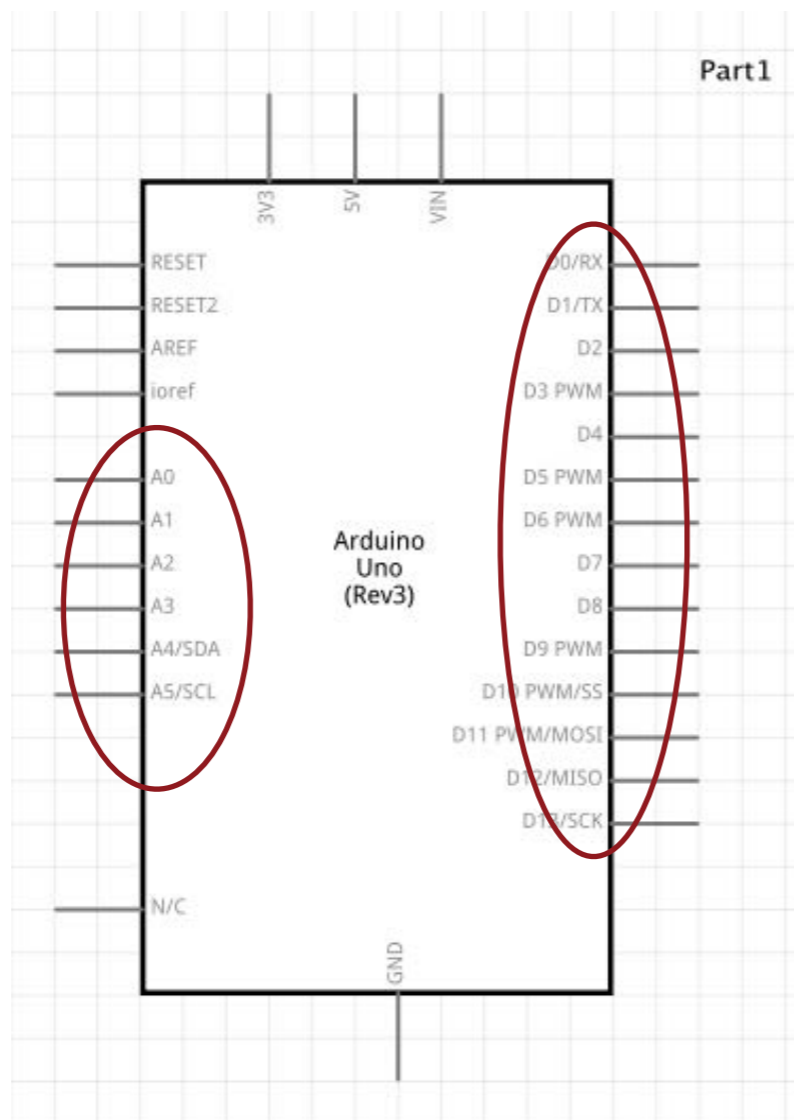
GND:
Ground Pin



Arduino - Input/Output pins



Arduino - Input/Output pins

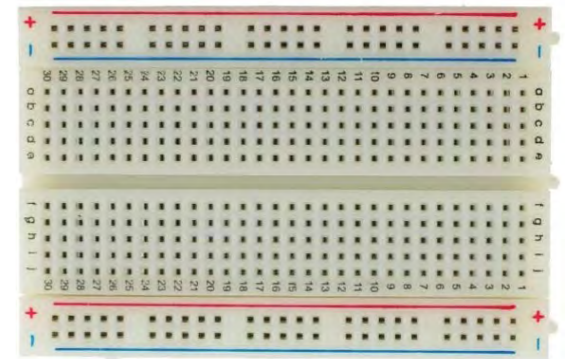
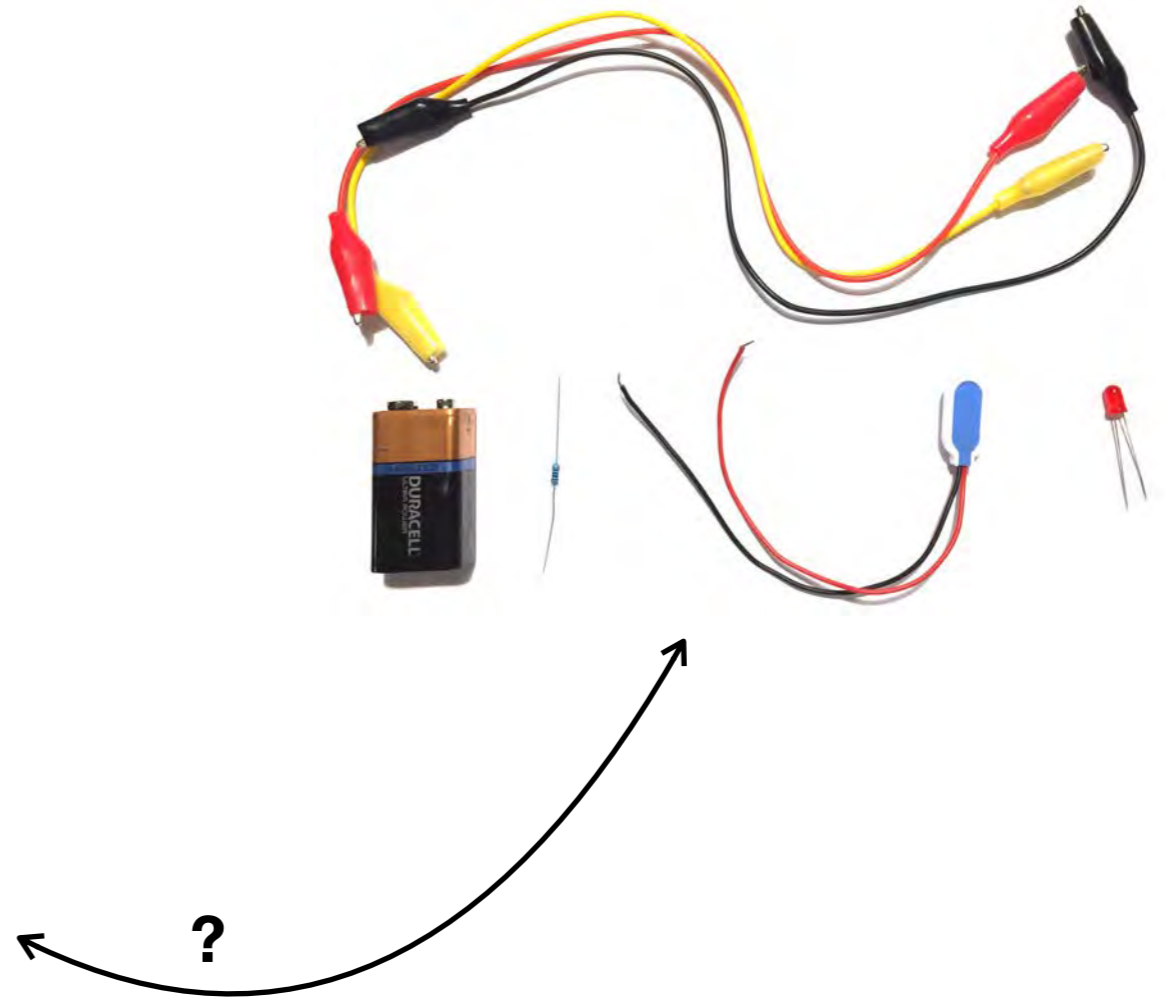
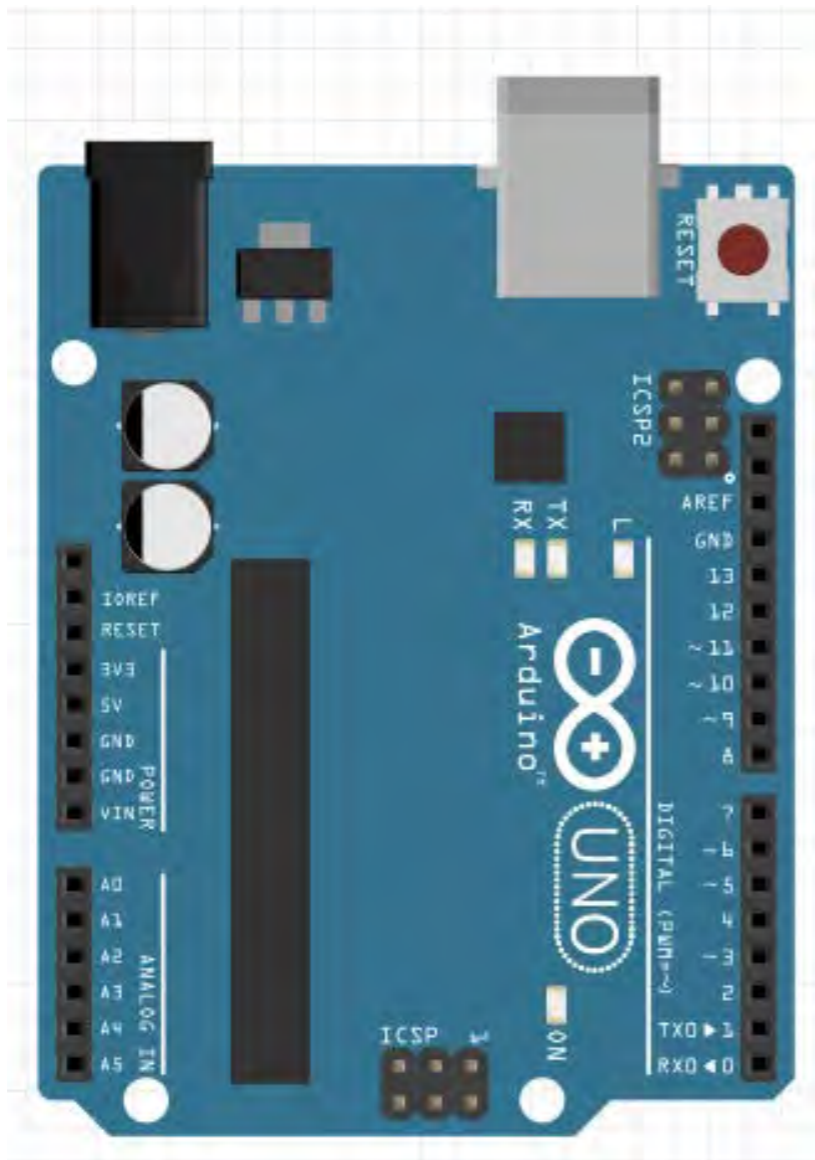


With the INPUT - OUTPUT pins you can:

- **Read Voltage**
- **Control Voltage**

Like we did yesterday with the MULTIMETER!!!!

To make the circuit: tools



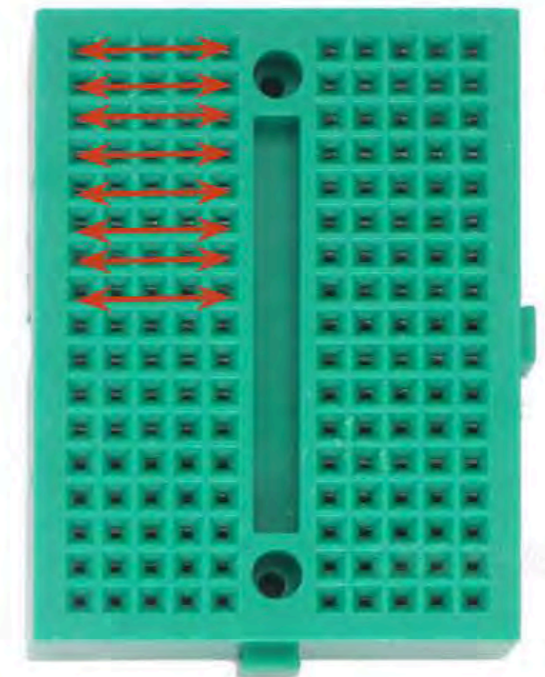
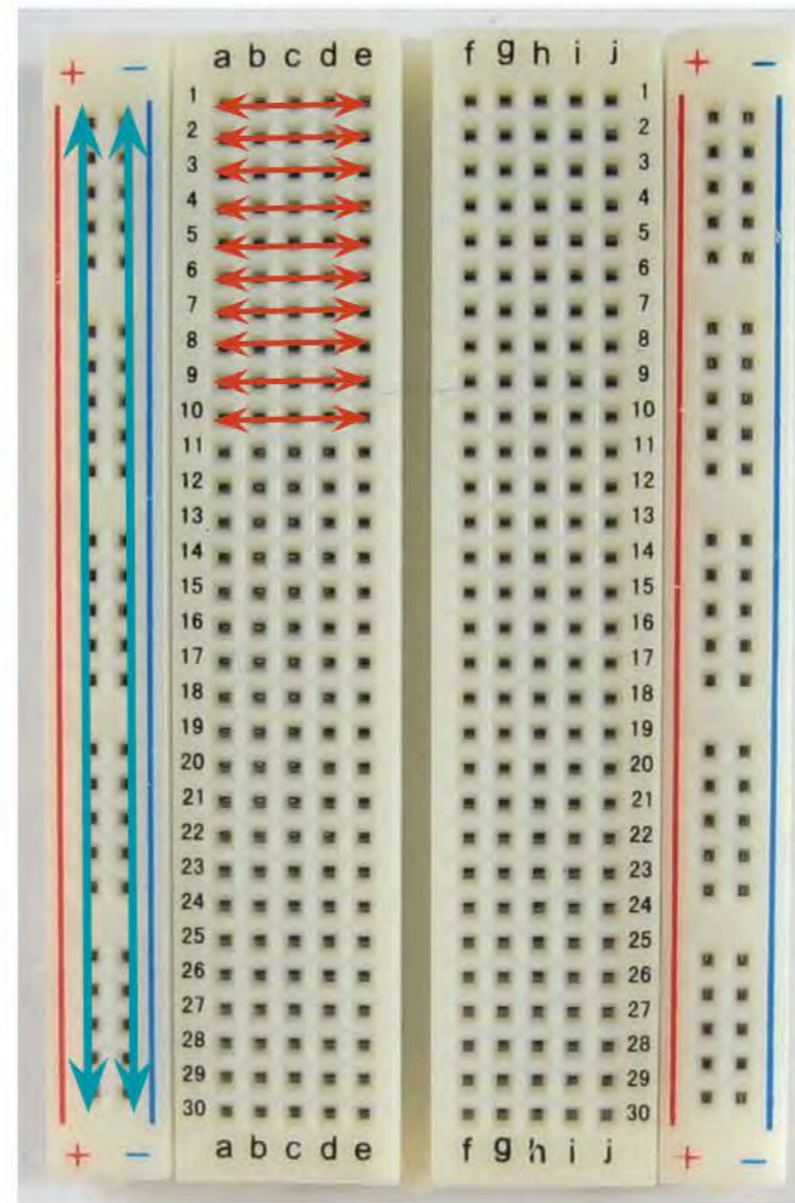
Use to prototype your circuit first.

Vertical lines are connected

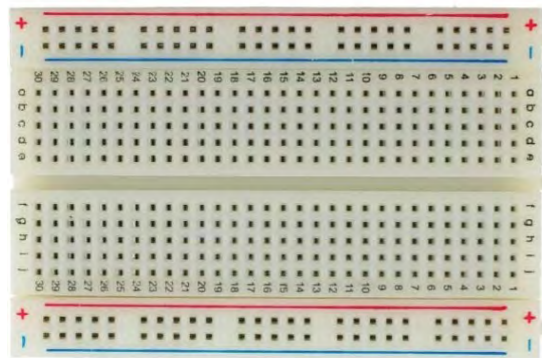
Horizontal lines are connected

BREADBOARDS

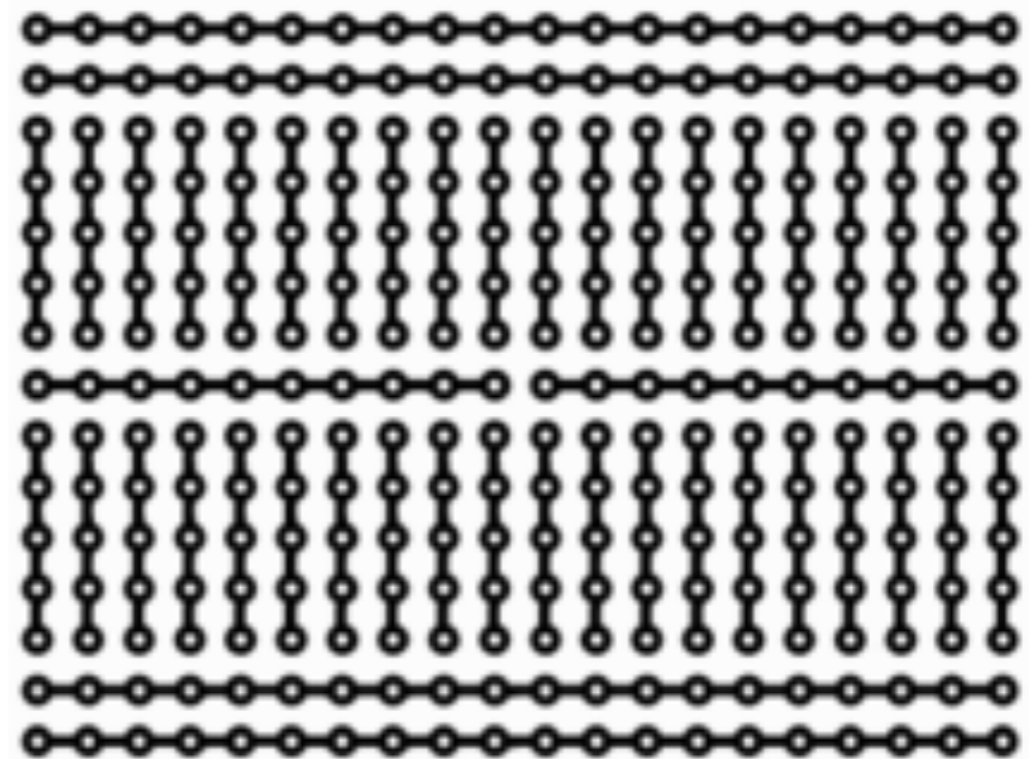
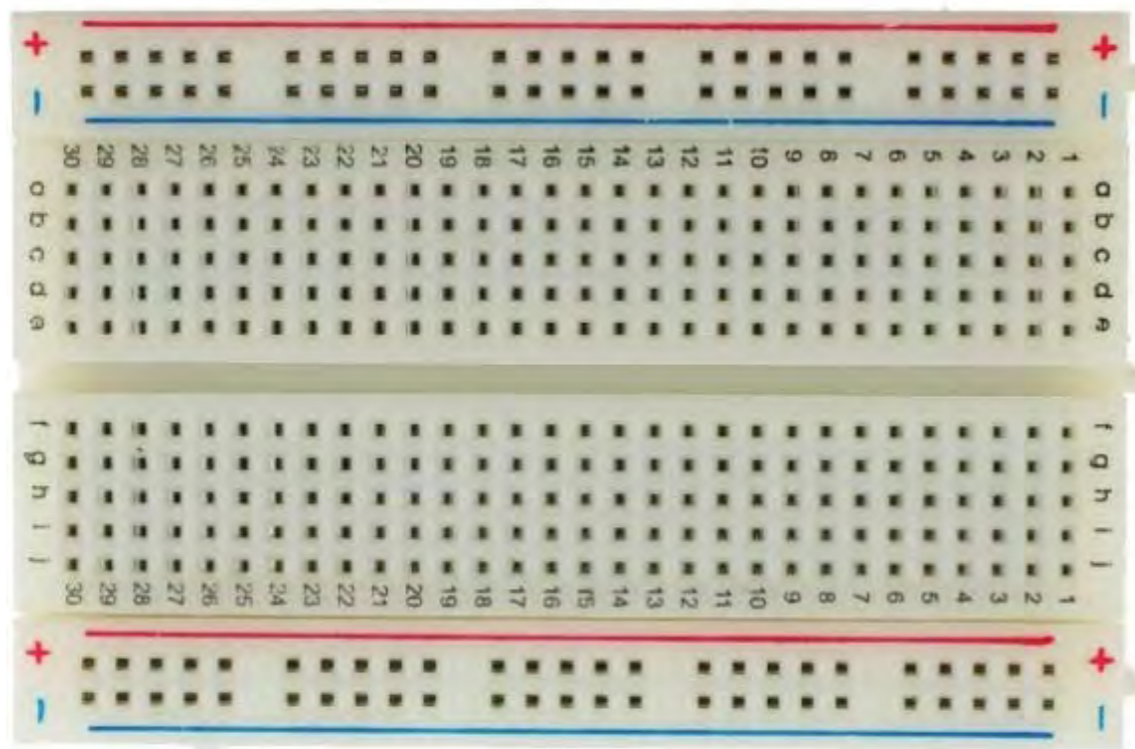
COMPONENTS+TOOLS



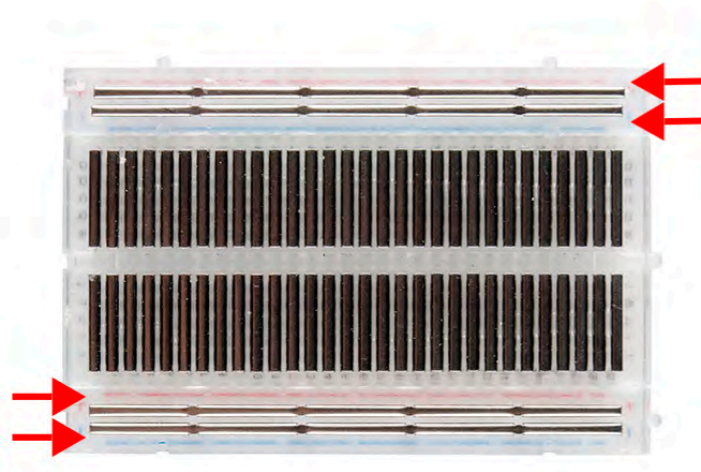
BreadBoard



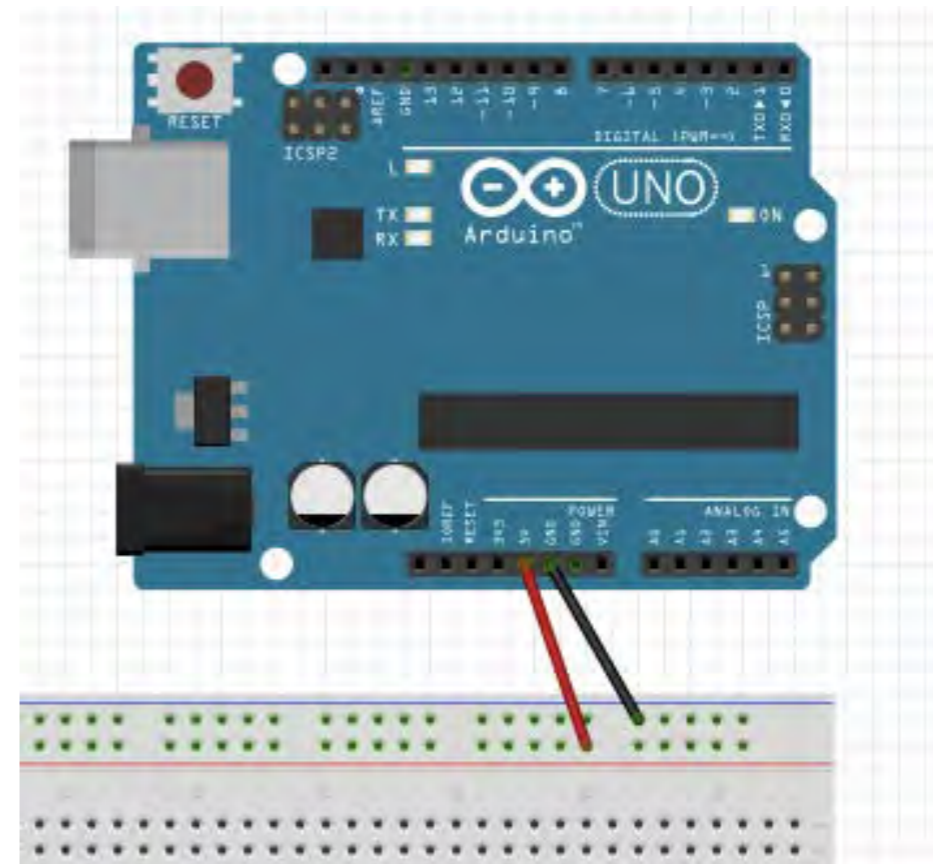
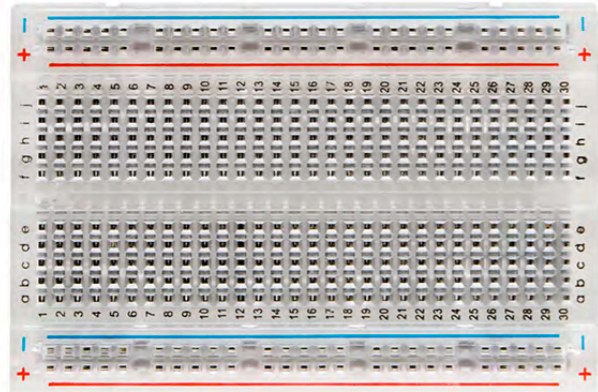
It is a physical support for making temporary circuits and prototyping, and they require absolutely no soldering.



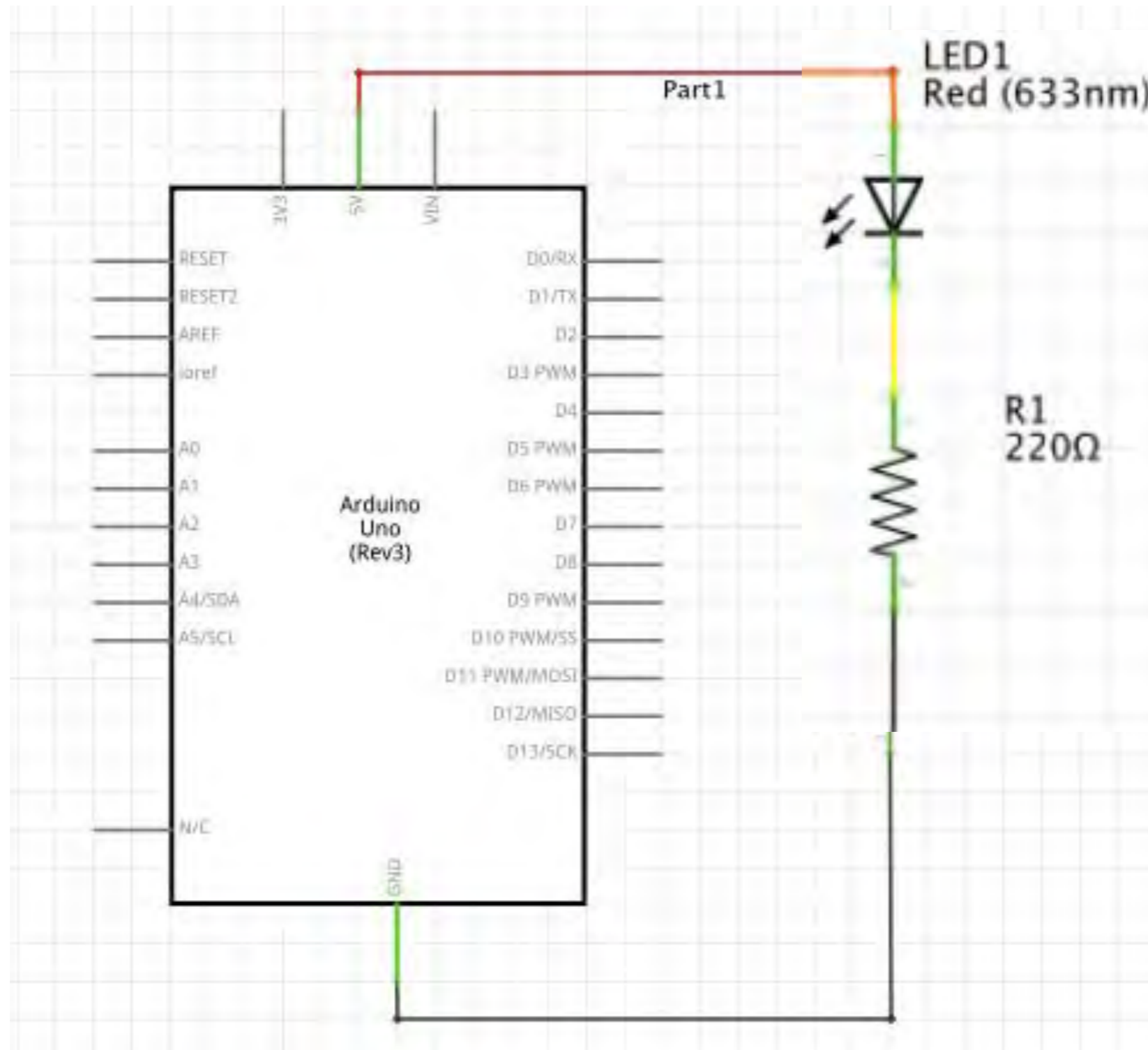
BreadBoard - best practice



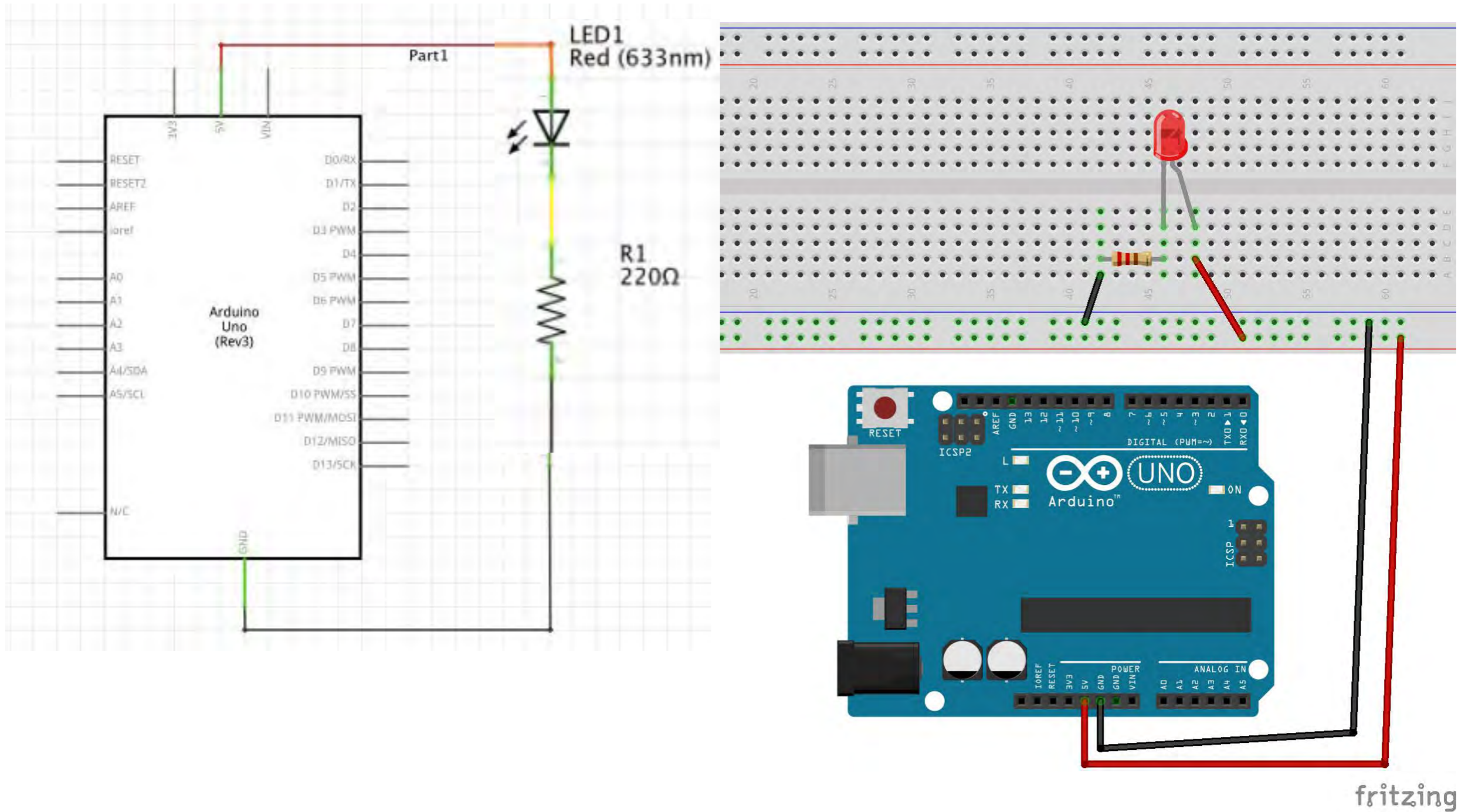
Power Rails



Exercise: Led ON



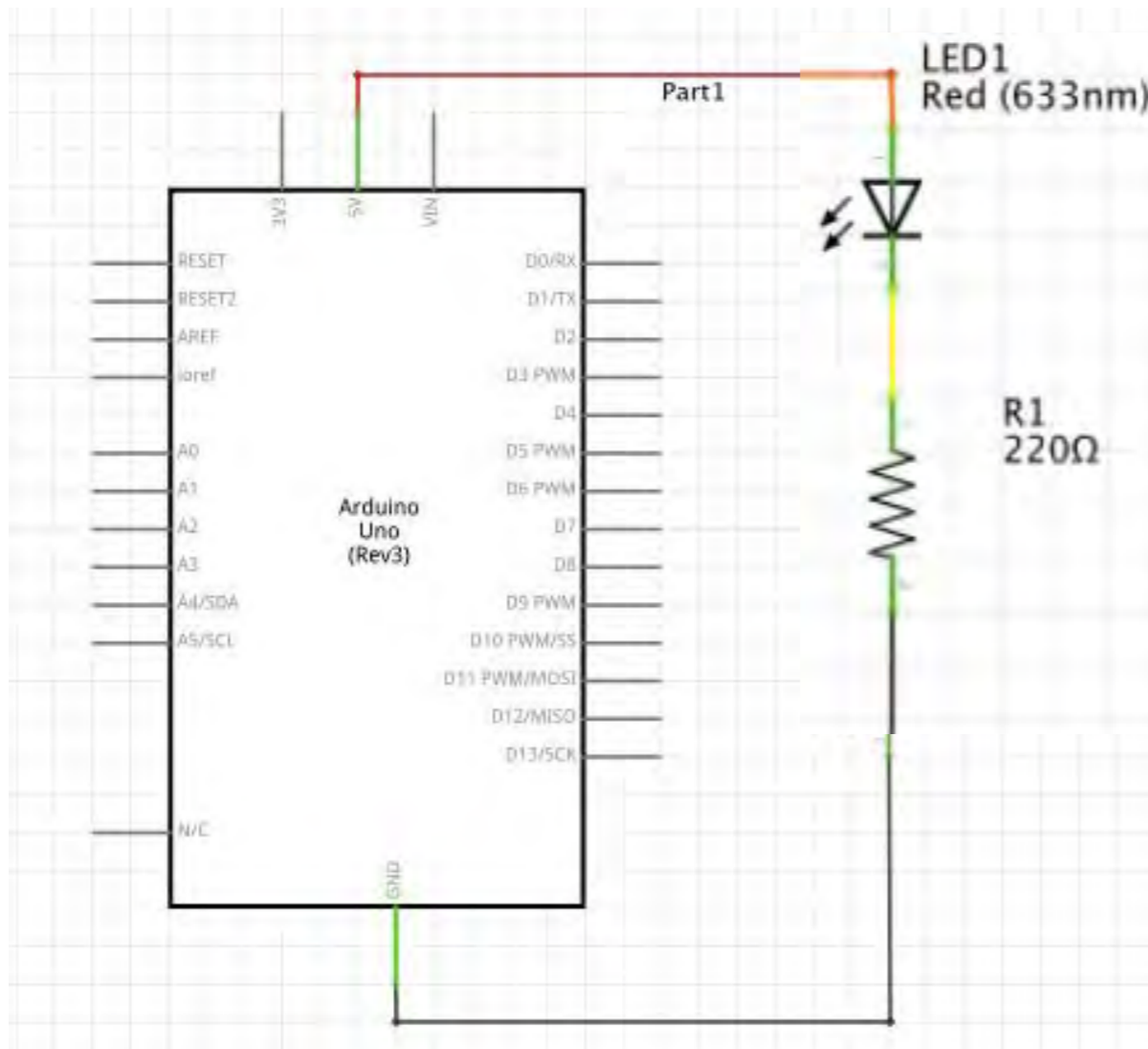
Exercise: Led ON



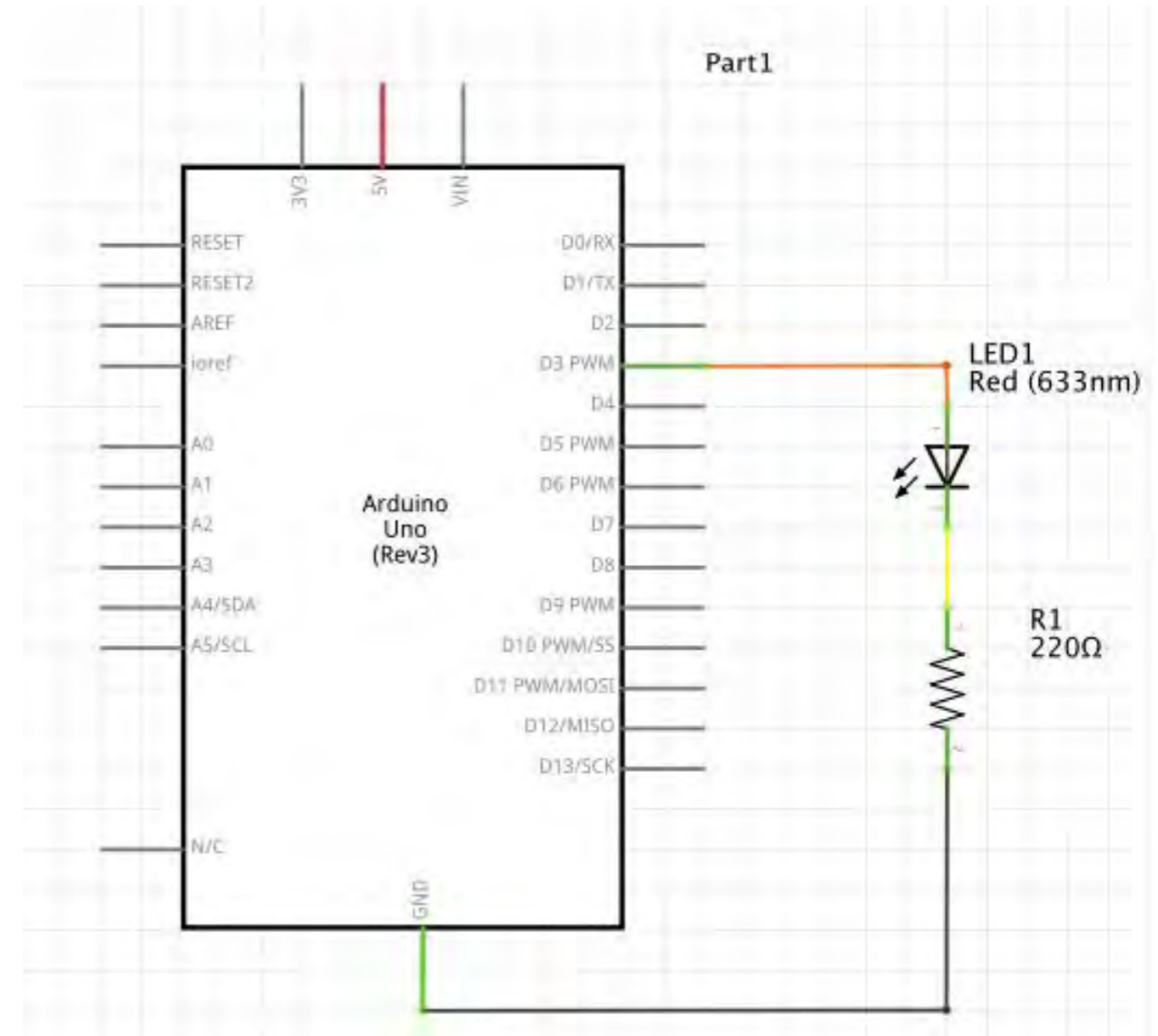
Arduino: Led

Make a Led blinks

Arduino and a Led

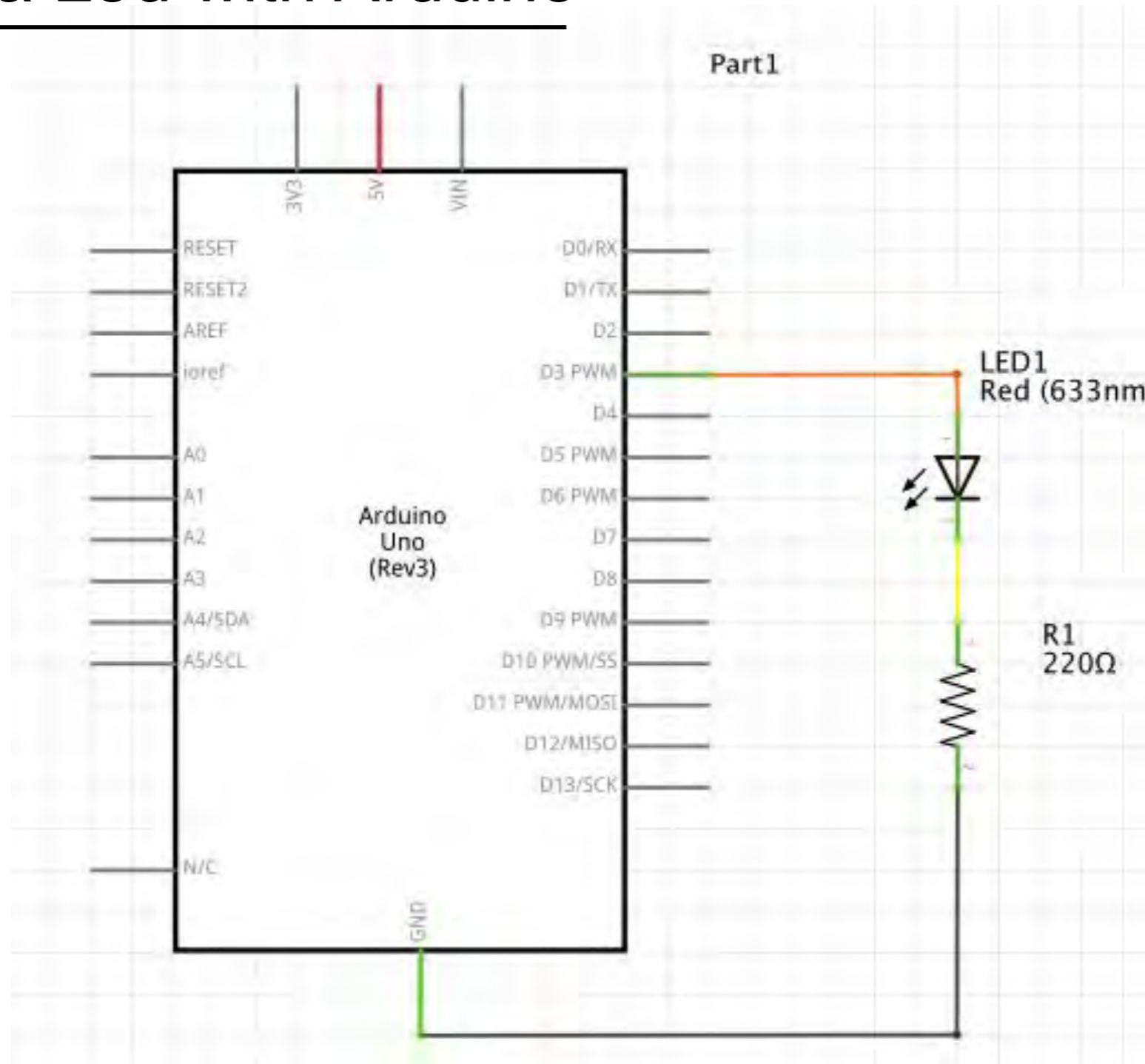


We can't control the power pins.



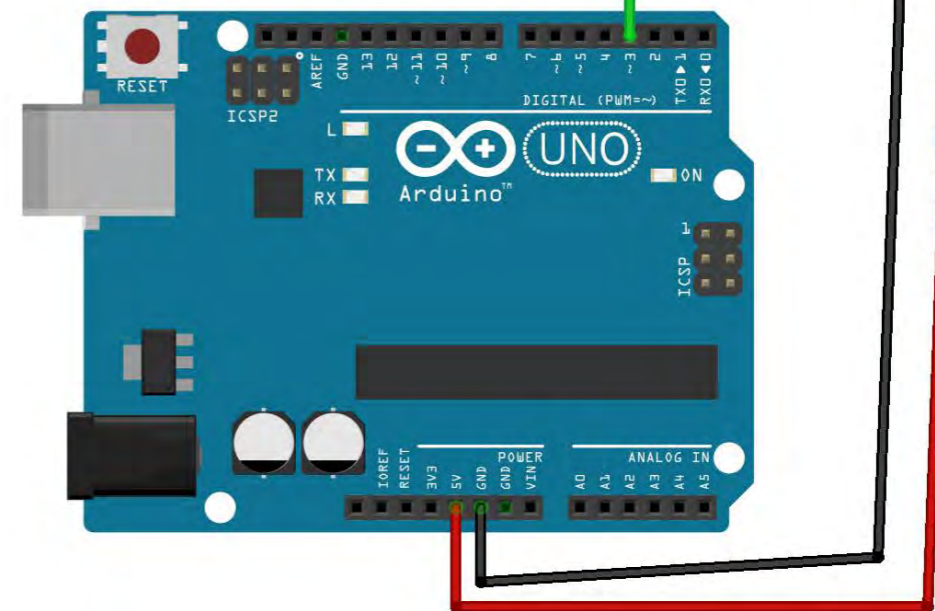
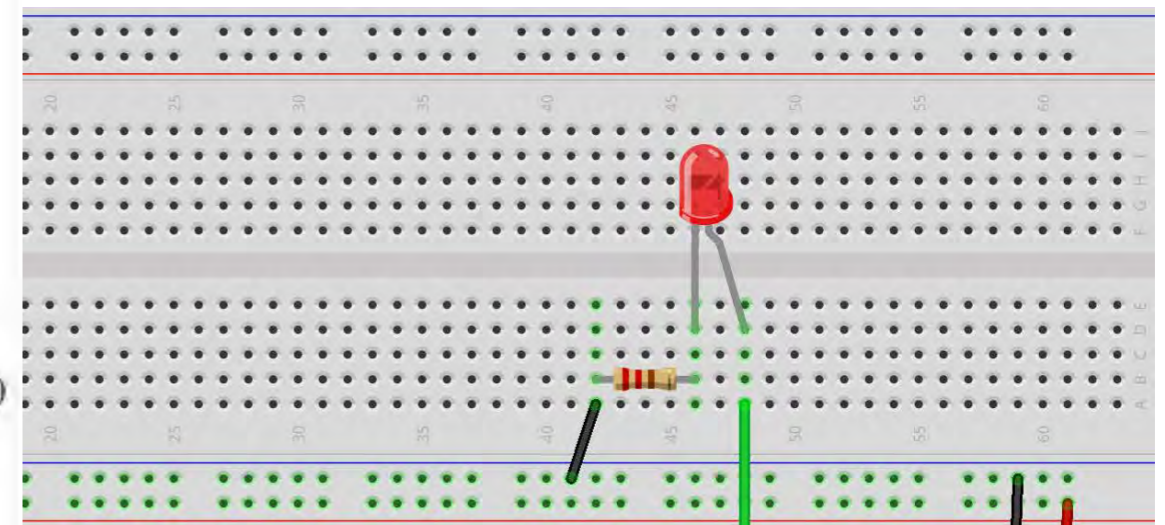
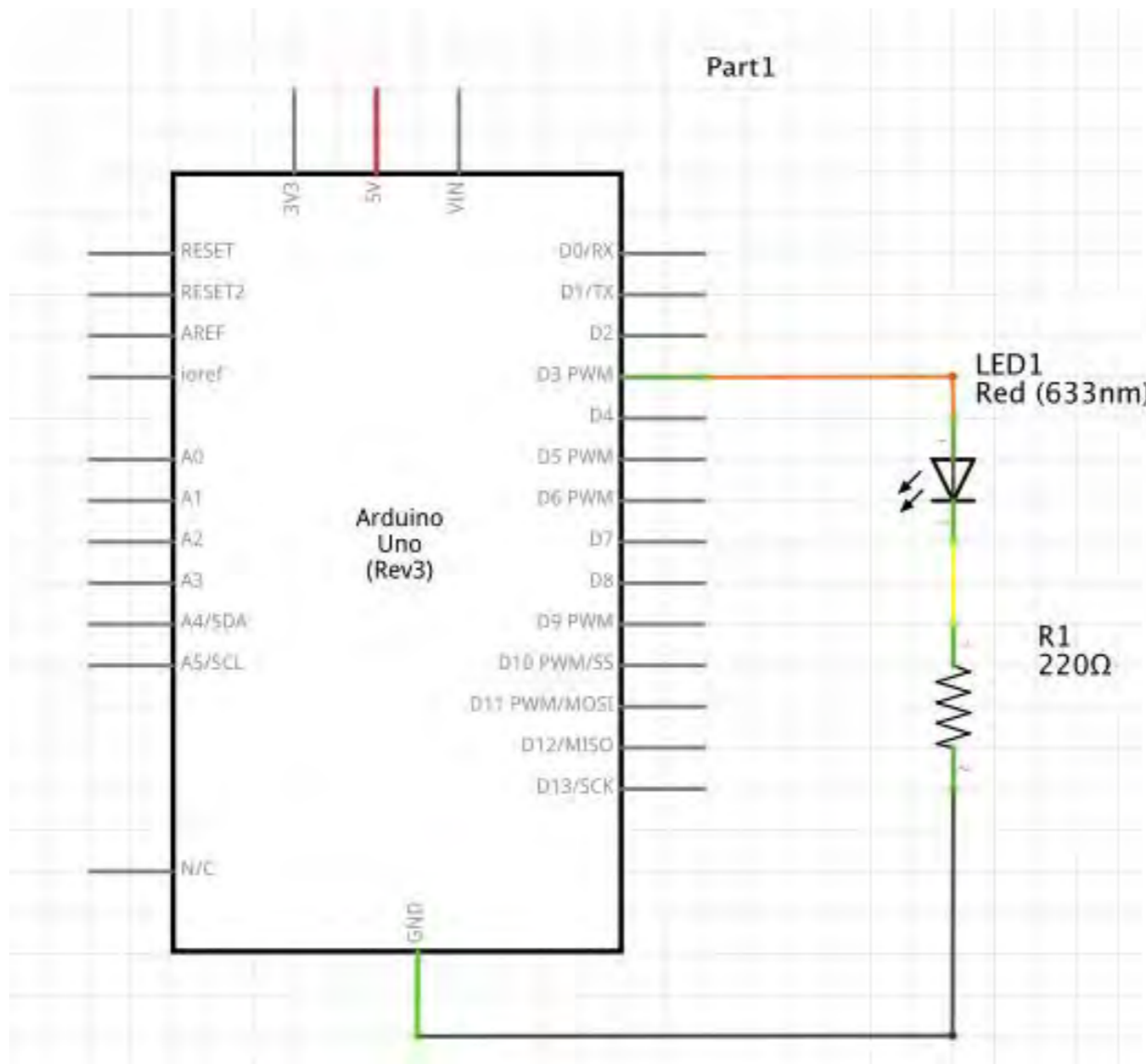
Connect the LED to pin D3

Control a Led with Arduino



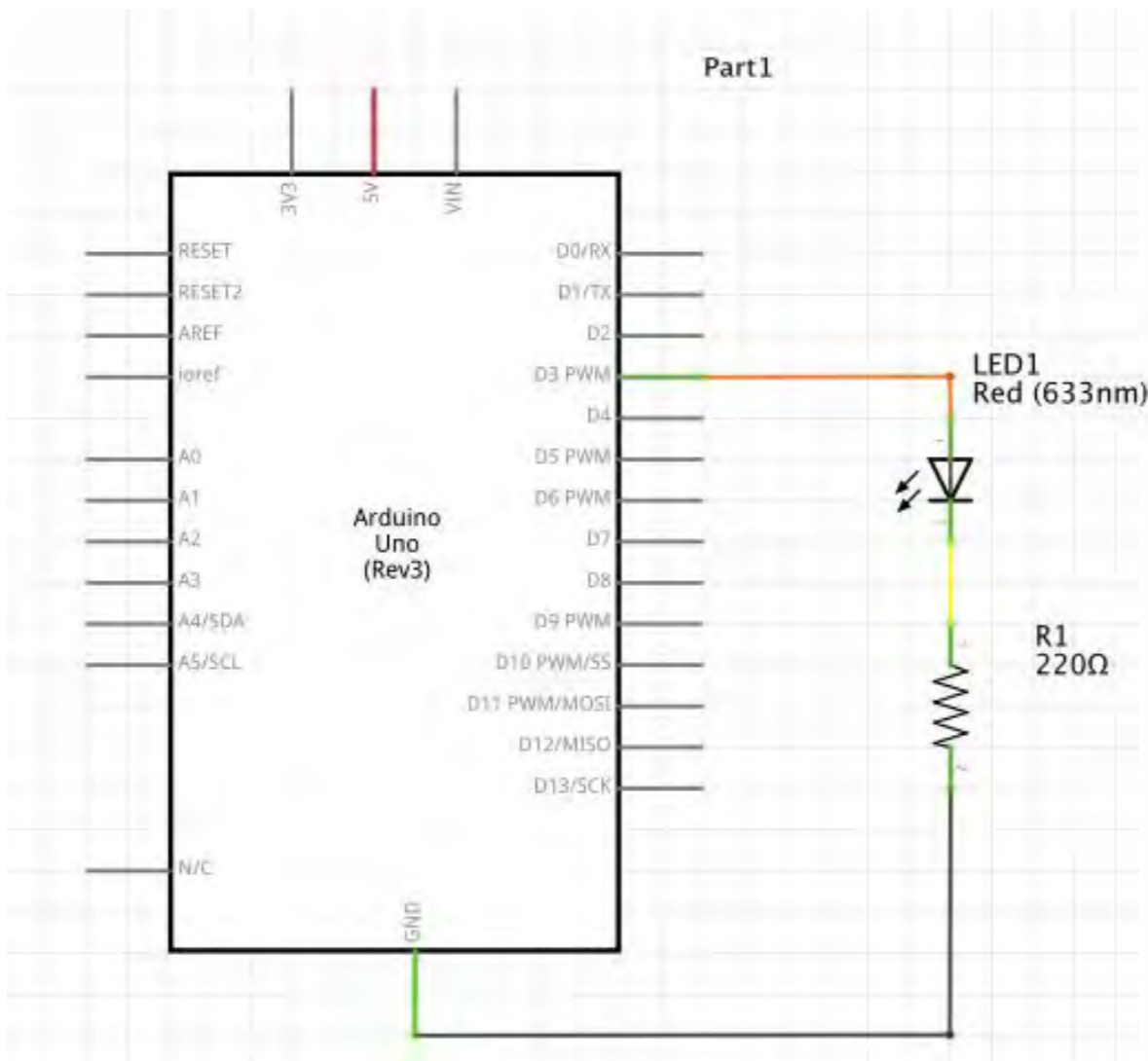
Connect the LED to pin D3

Control a Led with Arduino



fritzing

Control a Led with Arduino



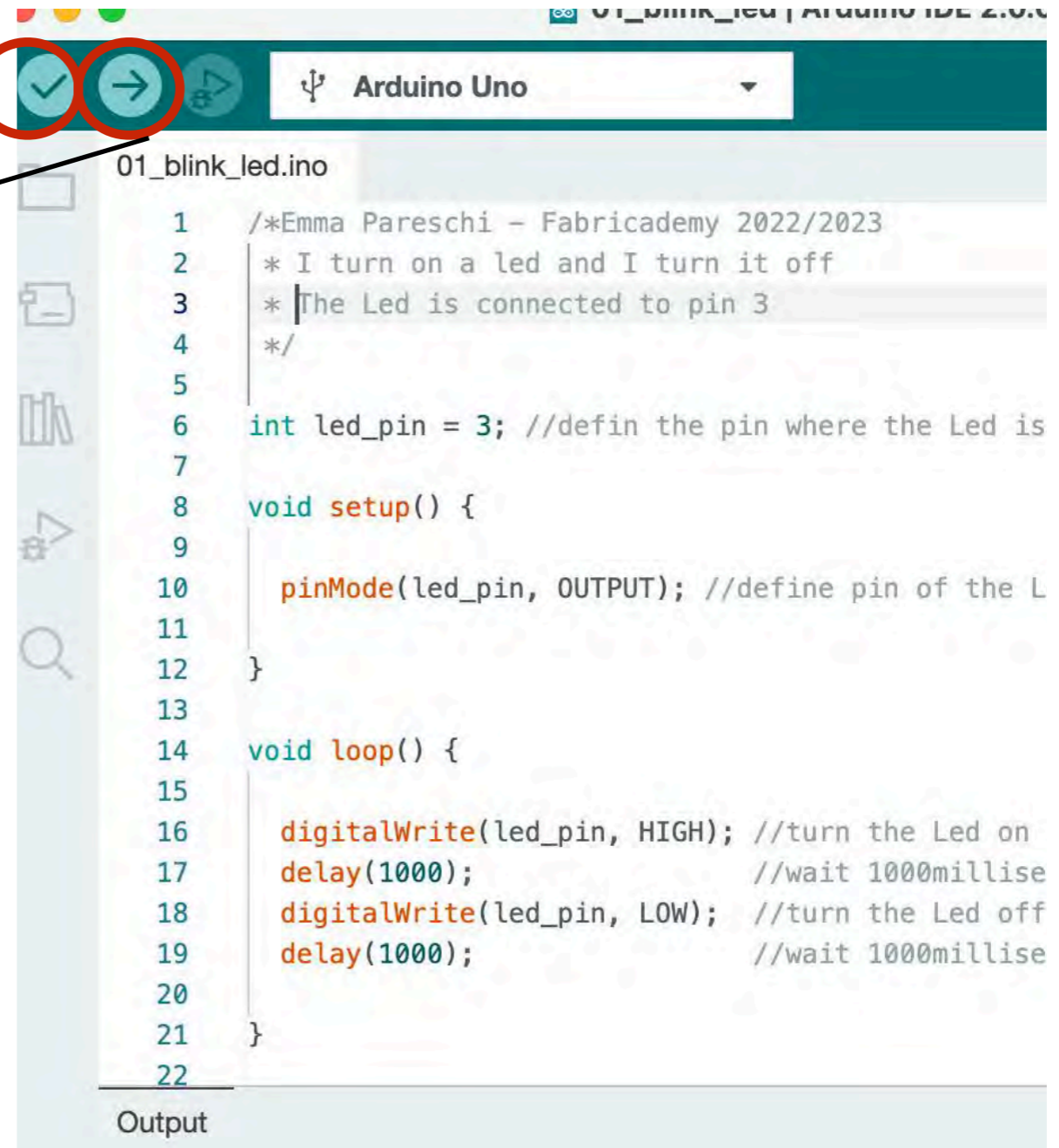
```
01_blink_led | Arduino IDE 2.0.0
Arduino Uno
01_blink_led.ino
1  /*Emma Pareschi - Fabricademy 2022/2023
2  * I turn on a led and I turn it off
3  * |The Led is connected to pin 3
4  */
5
6  int led_pin = 3; //defin the pin where the Led is connected
7
8  void setup() {
9
10     pinMode(led_pin, OUTPUT); //define pin of the Led as an output
11 }
12
13
14 void loop() {
15
16     digitalWrite(led_pin, HIGH); //turn the Led on
17     delay(1000); //wait 1000millisecond
18     digitalWrite(led_pin, LOW); //turn the Led off
19     delay(1000); //wait 1000millisecond
20 }
21 }
22
Output
```

01_blink_led

Connect, Compile and Upload

1. Compile

2. Upload



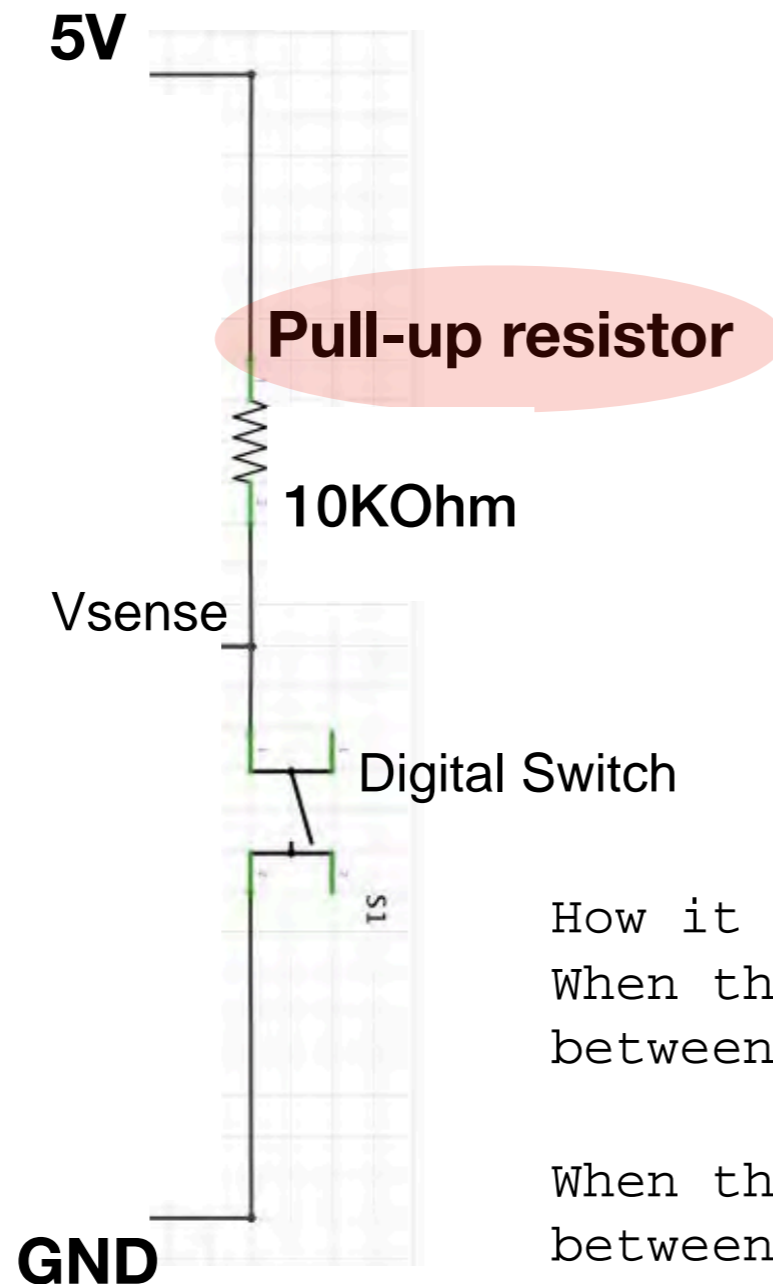
```
01_blink_led.ino
1  /*Emma Pareschi - Fabricademy 2022/2023
2  * I turn on a led and I turn it off
3  * The Led is connected to pin 3
4  */
5
6  int led_pin = 3; //defin the pin where the Led is
7
8  void setup() {
9
10     pinMode(led_pin, OUTPUT); //define pin of the L
11
12 }
13
14 void loop() {
15
16     digitalWrite(led_pin, HIGH); //turn the Led on
17     delay(1000); //wait 1000millise
18     digitalWrite(led_pin, LOW); //turn the Led off
19     delay(1000); //wait 1000millise
20
21 }
22
```

Output

Arduino: Digital Sensors

Read a Digital Sensor and print the value on the Serial Monitor

How the digital sensor changes the Voltage

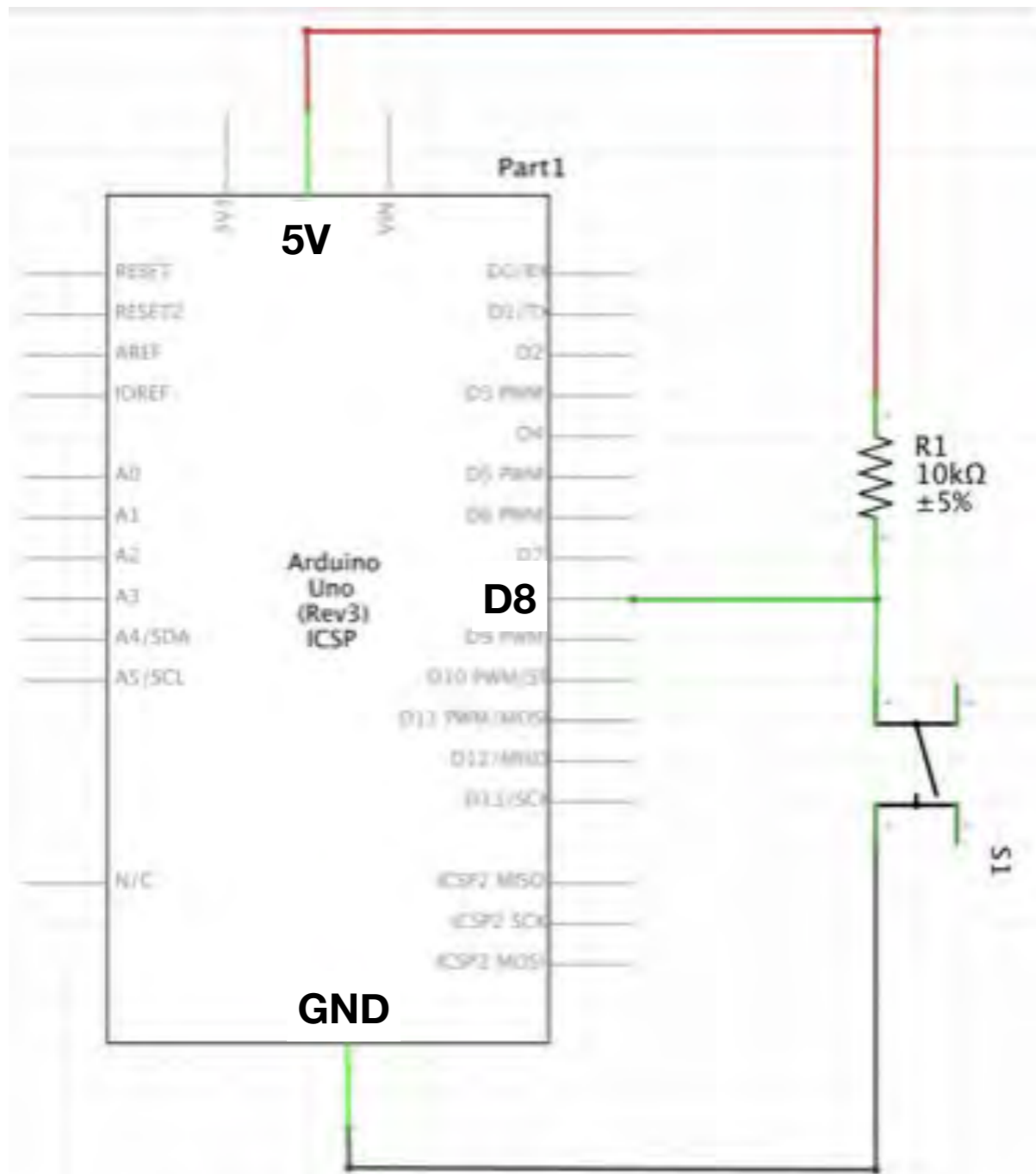


How it works:

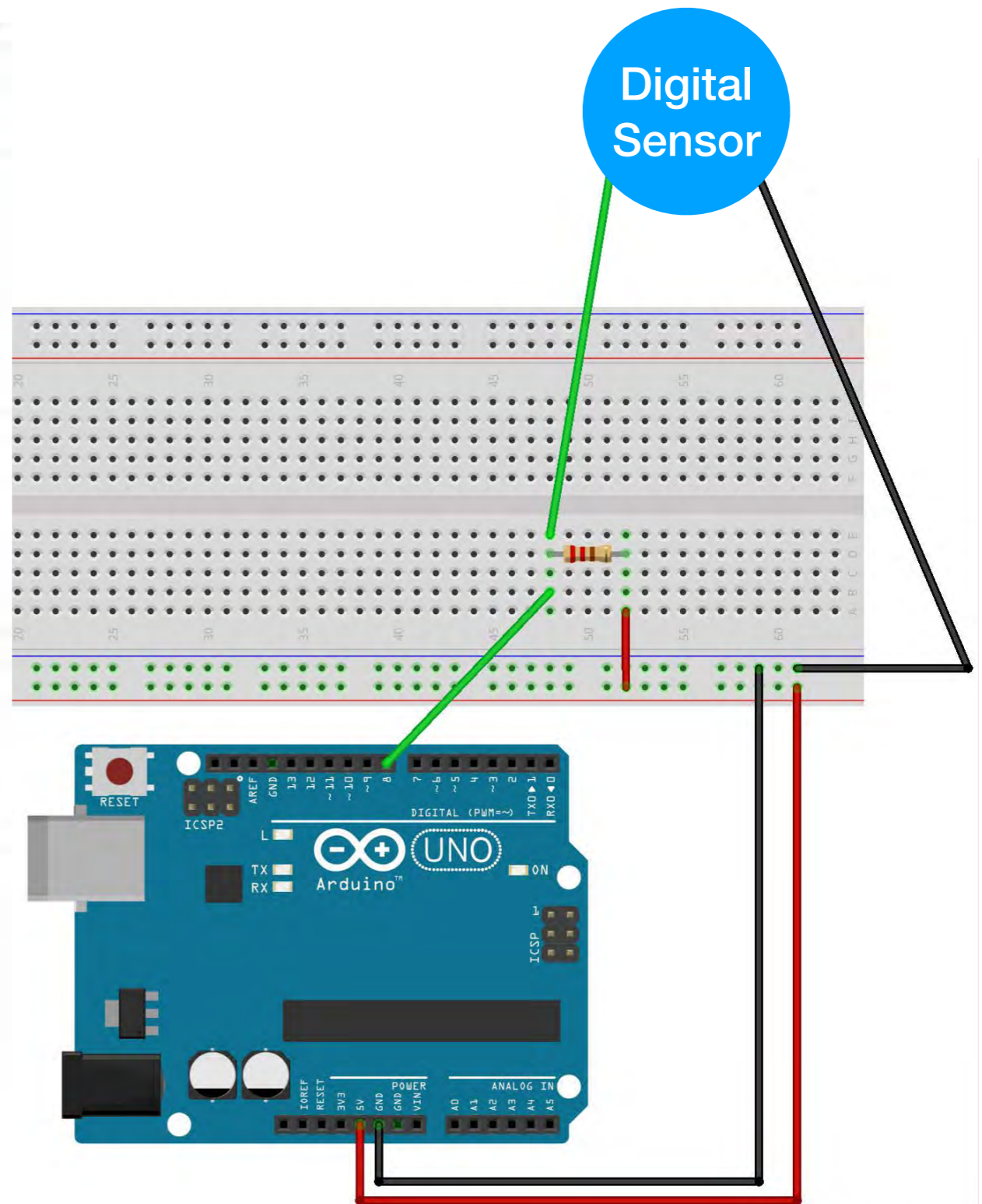
When the switch is NOT pushed the voltage between Vsense and GND is 5 Volt

When the switch is pushed the voltage between Vsense and GND is 0

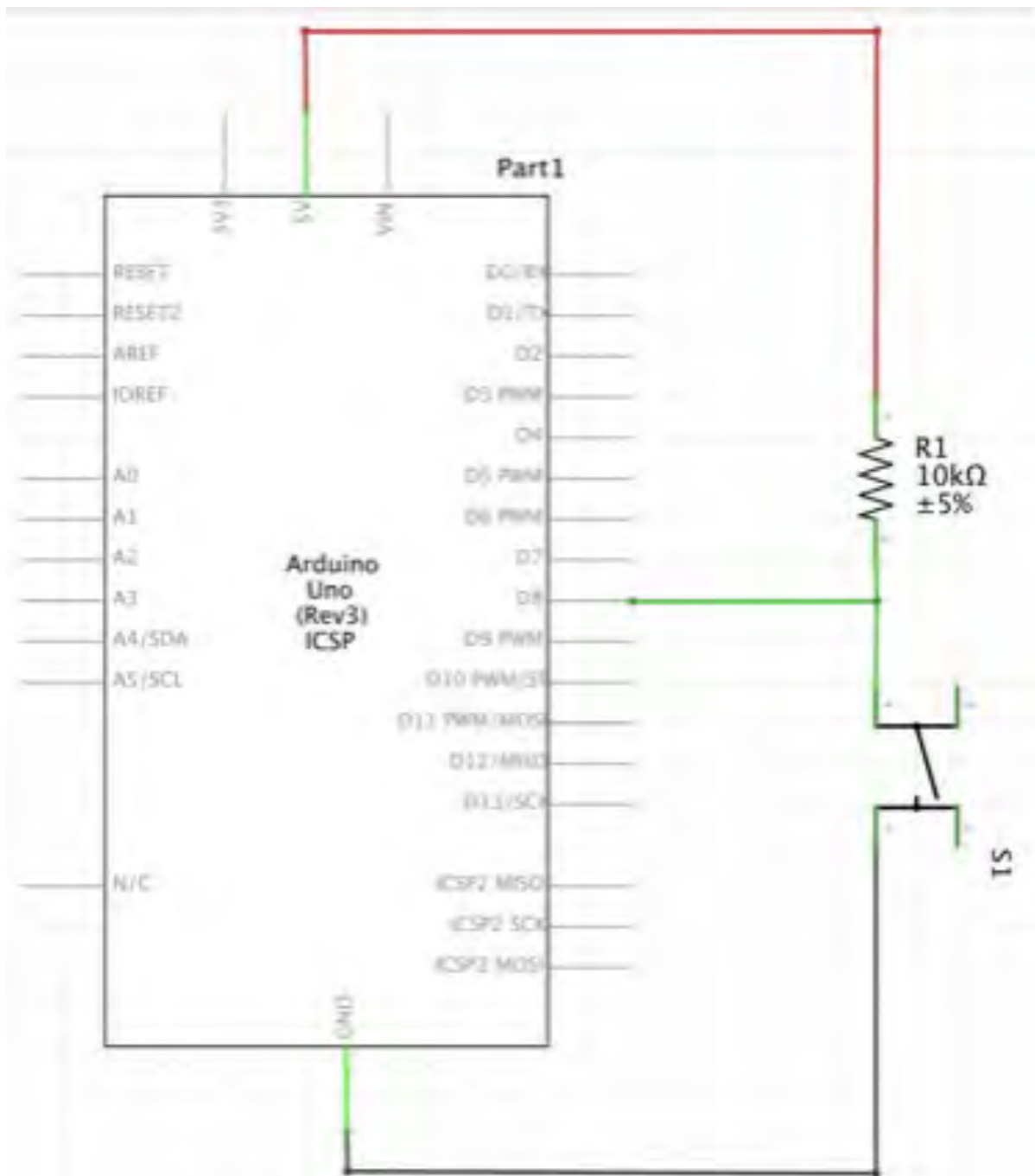
Digital switch and Arduino



```
pinMode(8, INPUT);
```



Digital switch and Arduino



```
pinMode(8, INPUT);
```

03_read_DigitalSensor

```
/*Emma Pareschi
 * we read the value of a digital sensor connected to pin digital_sensor_pin and
 * we print it on the Serial Monitor
 */

int digital_sensor_pin = 8; //change the pin, where the sensor is connected?
int digital_sensor_value = 0;

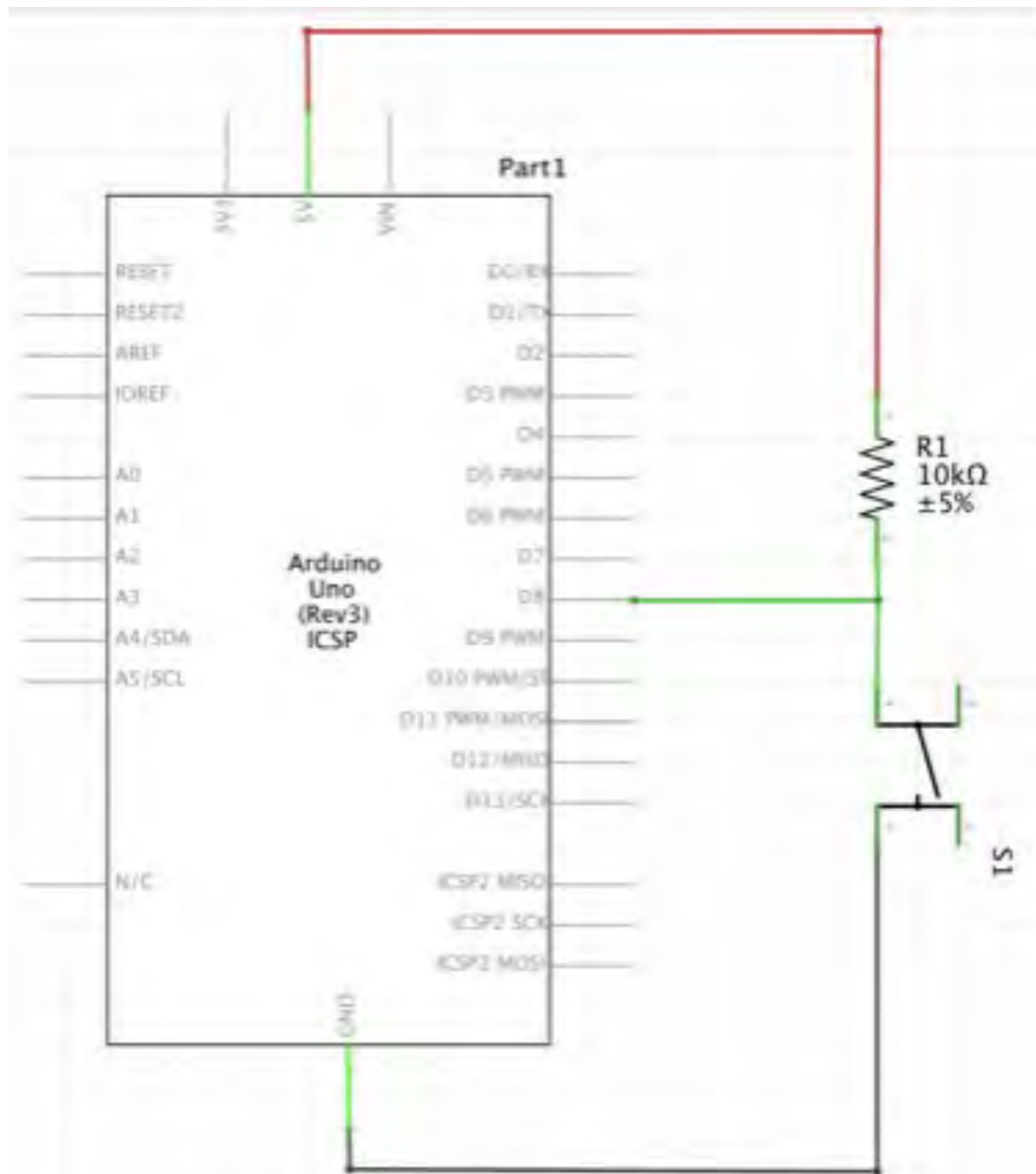
void setup() {
  // put your setup code here, to run once:
  pinMode(digital_sensor_pin, INPUT); //define the pin as INPUT
  Serial.begin(9600);
}

void loop() {
  // put your main code here, to run repeatedly:
  digital_sensor_value = digitalRead(digital_sensor_pin); // read the sensor

  Serial.println(digital_sensor_value); //print the value
  delay(100);
}
```

03_read_DigitalSensor

Digital switch and Arduino - Serial Monitor



`pinMode(8, INPUT);`

The screenshot shows the Arduino IDE 2.0.0 interface. The code in the main editor is as follows:

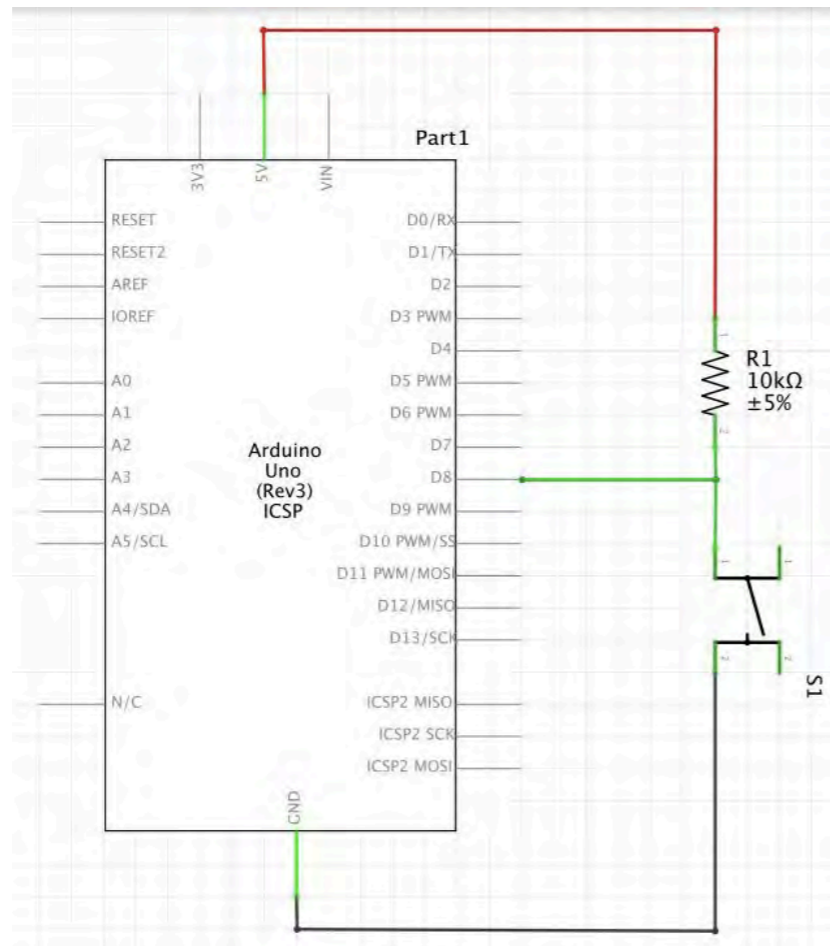
```
03_read_DigitalSensor | Arduino IDE 2.0.0
Arduino Uno
03_read_DigitalSensor.ino
5
6 int digital_sensor_pin = 8; //change the pin, where the sensor is connected
7 int digital_sensor_value = 0; //variable in which we save the sensor voltage
8
9 void setup() {
10 // put your setup code here, to run once:
11
12 //pinMode(digital_sensor_pin, INPUT);
13 pinMode(digital_sensor_pin, INPUT); //define the pin as INPUT PULLUP
14 Serial.begin(9600); //open communication
15
16 }
17
18 void loop() {
19 // put your main code here, to run repeatedly:
20 // digitalWrite(pin);
21 digital_sensor_value = digitalRead(digital_sensor_pin); // read the sensor
22
23 Serial.print("the status of the sensor is: ");
24 Serial.println(digital_sensor_value); //print the value
25 delay(100);
}

Output Serial Monitor x
Message (% + Enter to send message to 'Arduino Uno' on '/dev/cu.usbmodem14101' New Line 9600 baud

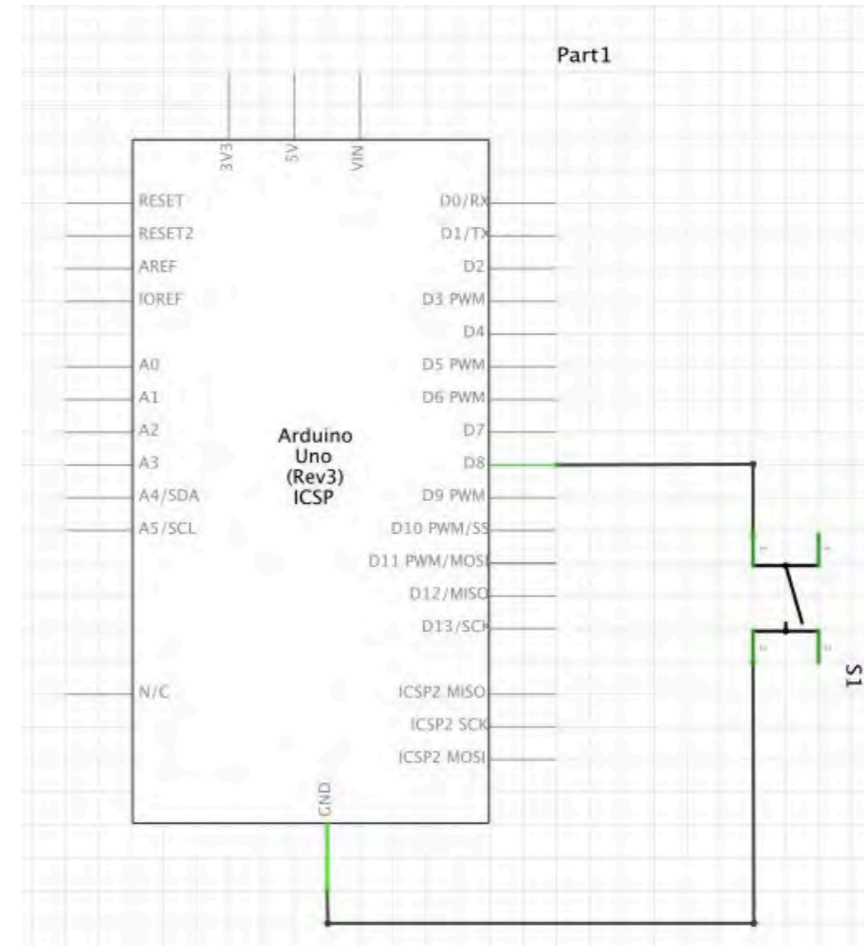
the status of the sensor is: 0
the status of the sensor is: 0
the status of the sensor is: 0
the status of the sensor is: 0
the status of the sensor is: 0
the status of the sensor is: 1
the status of the sensor is: 1
the status of the sensor is: 1
the status of the sensor is: 1
the status of the sensor is: 1
```

`03_read_DigitalSensor`

Digital switch and Arduino



```
pinMode(8, INPUT);
```

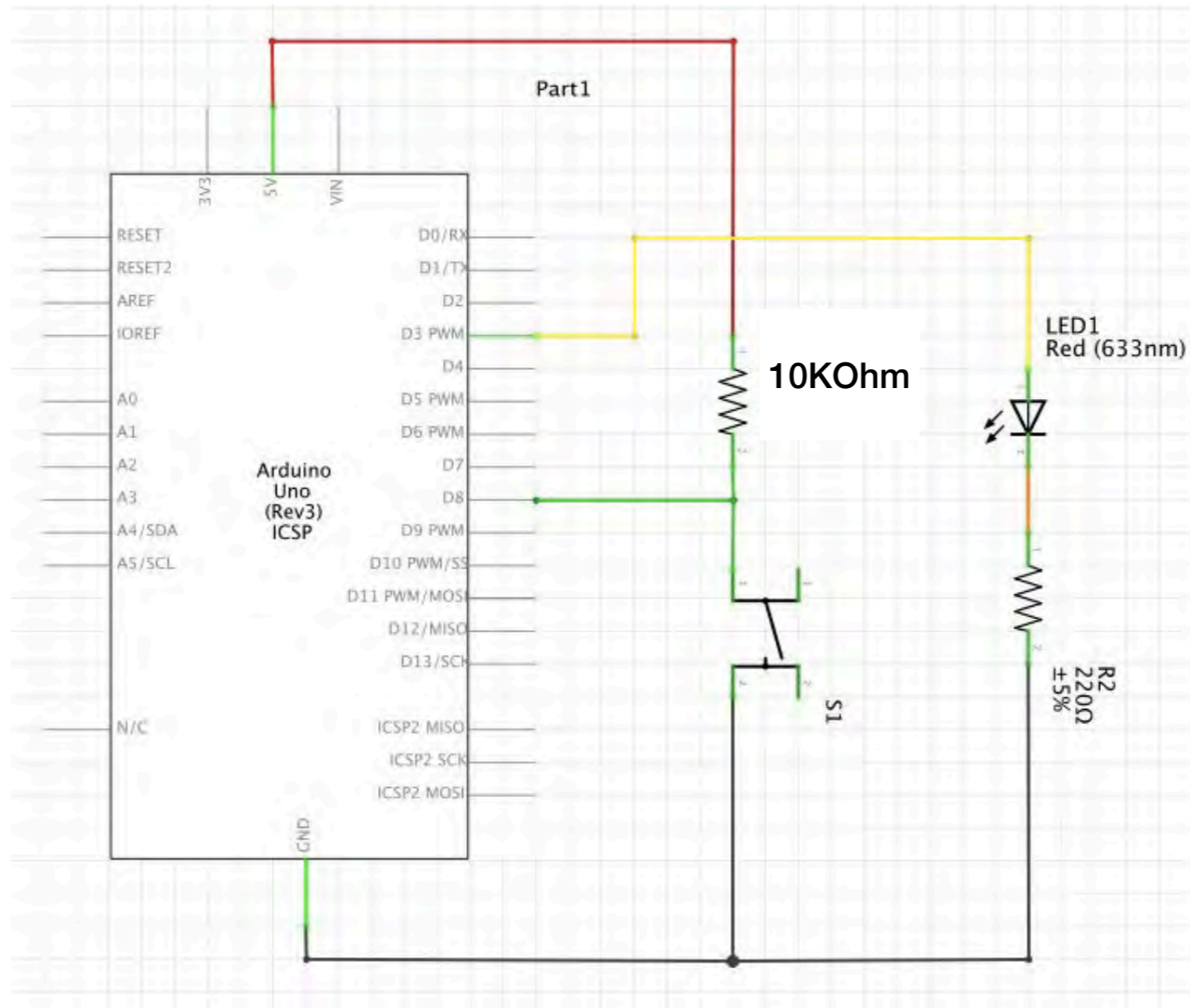


```
pinMode(8, INPUT_PULLUP);
```

Arduino: Digital Sensors - Led

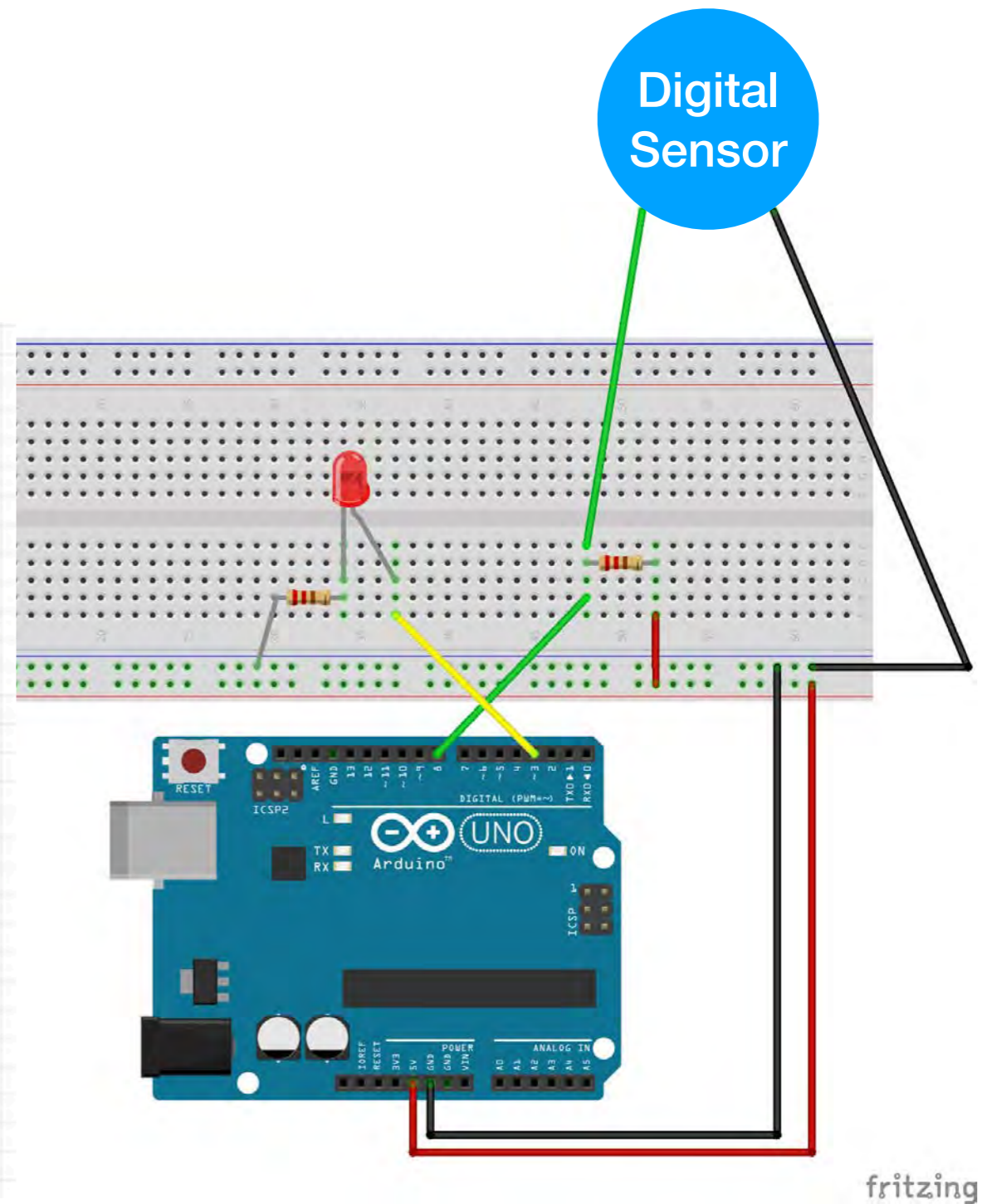
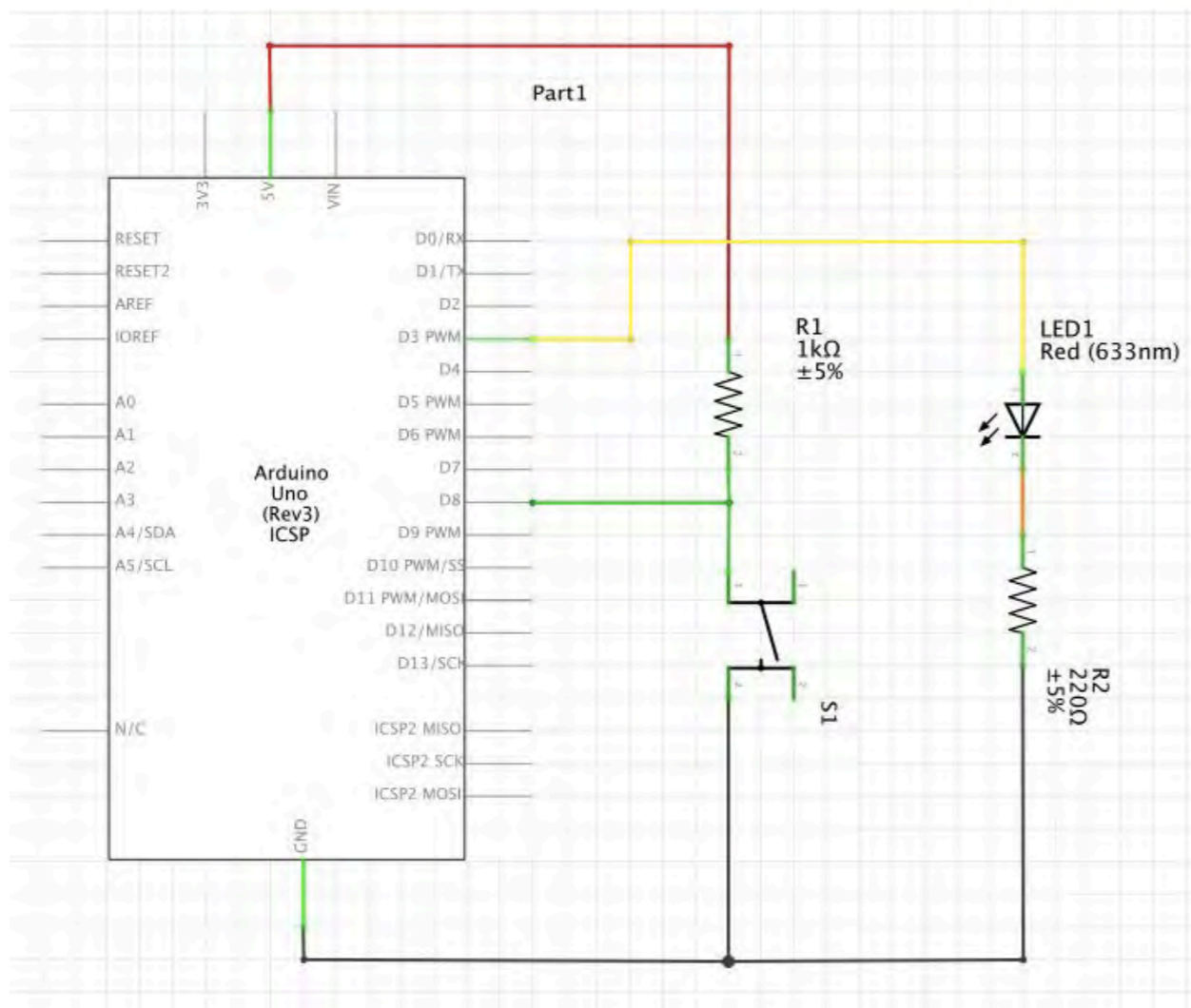
Control a Led with a Digital Sensor

Digital switch and a Led



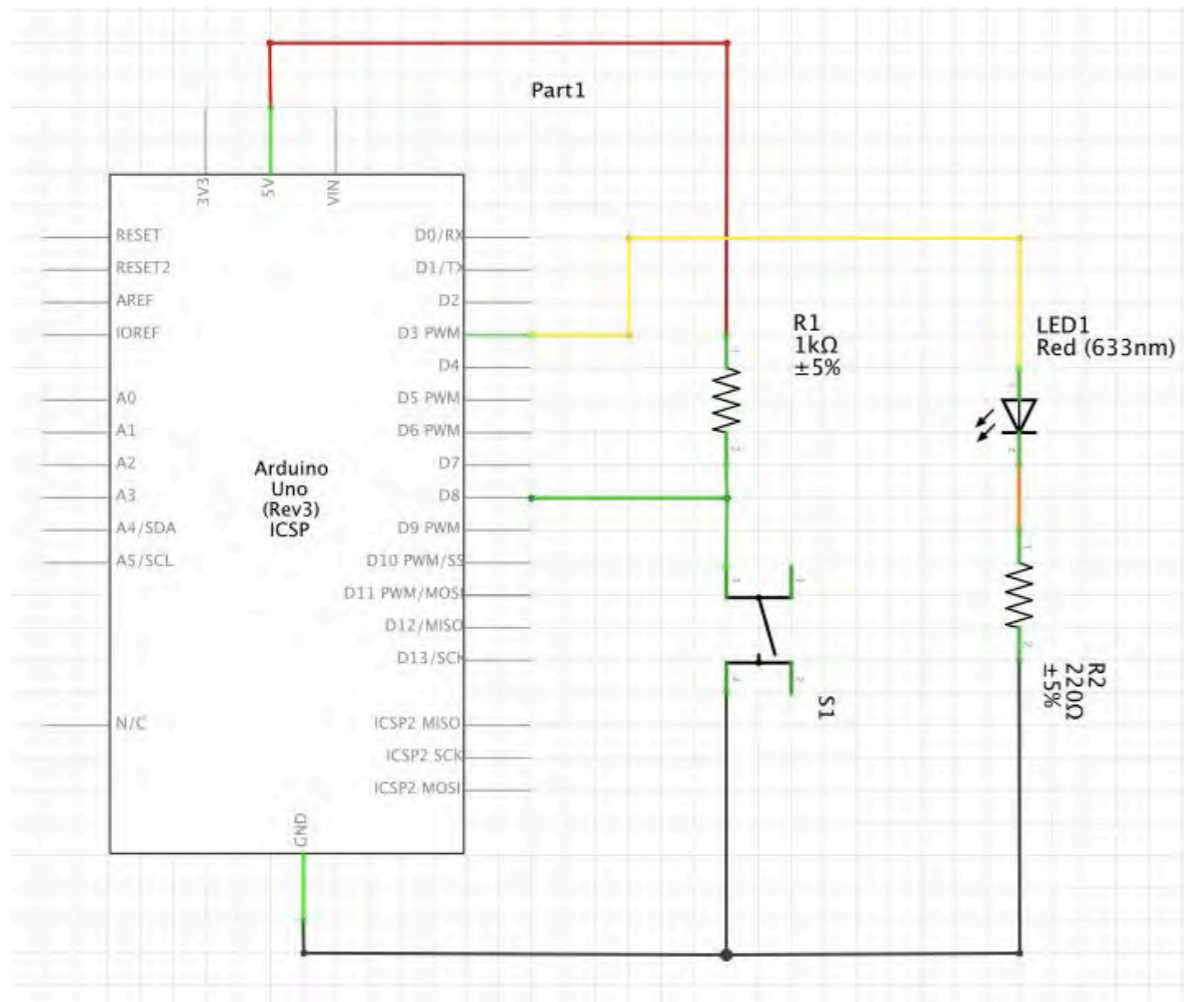
You already have the circuit of the sensor, you have to add the Led!

Digital switch and a Led



You already have the circuit of the sensor, you have to add the Led!

Digital switch and a Led



03_button_led

```
/*Emma Pareschi,
 * this sketch is a modification of the example button!!
 */

int digital_sensor_pin = 7; //change the pin, where the sensor is connected?
int digital_sensor_value = 0;
int led_pin = 3; //change the pin of the Led

void setup() {
  // put your setup code here, to run once:
  pinMode(digital_sensor_pin, INPUT);
  Serial.begin(9600);
  // initialize digital pin LED_BUILTIN as an output.
  pinMode(led_pin, OUTPUT);
}

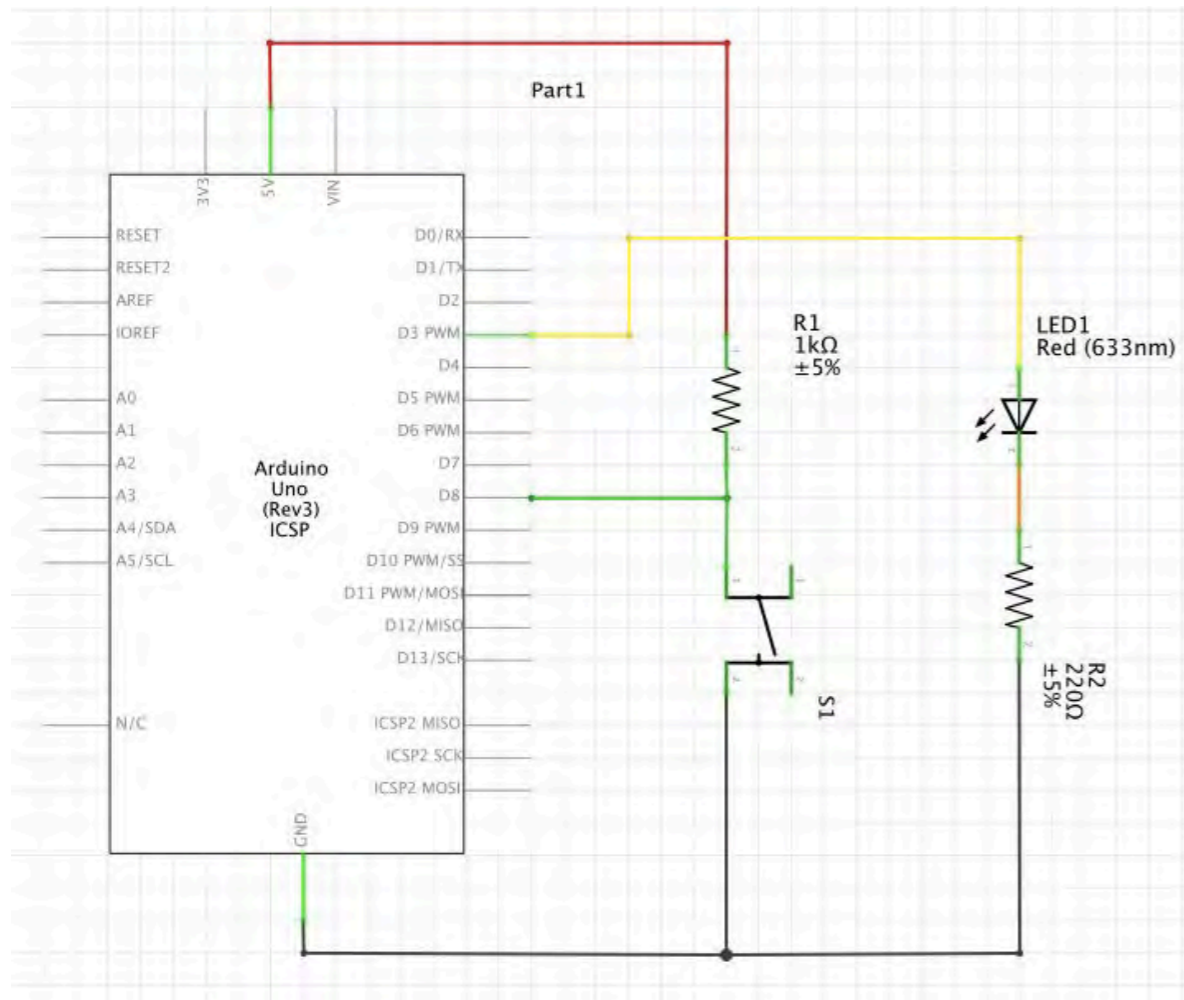
void loop() {
  // put your main code here, to run repeatedly:
  digital_sensor_value = digitalRead(digital_sensor_pin);

  // check if the pushbutton is pressed. If it is, the buttonState is HIGH:
  if(digital_sensor_value == HIGH){
    // turn LED on:
    digitalWrite(led_pin, HIGH);
  } else {
    // turn LED off:
    digitalWrite(led_pin, LOW); // turn the LED off by making the voltage LOW
  }
}
```

04_button_led_on_off

From Example -> Digital -> Button

Digital switch and a Led



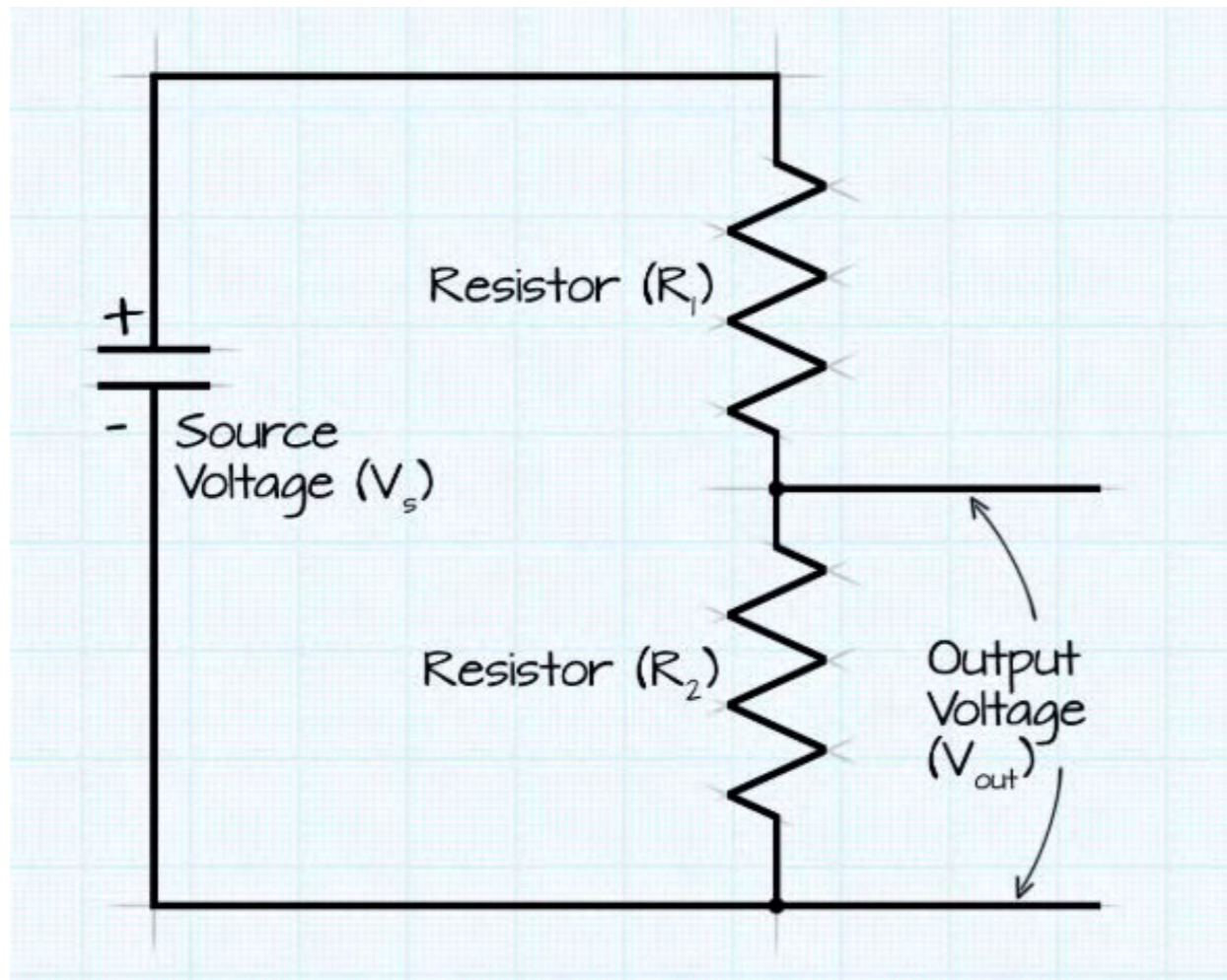
```
04_button_led_on_blink | Arduino IDE 2.0.0
Arduino Uno
04_button_led_on_blink.ino
1  /* Emma Pareschi - Fabricademy 2022/2023
2  * while the digital sensor is pressed, the Led blinks
3  */
4
5  int digital_sensor_pin = 8;    //change the pin, where the sensor is connected?
6  int digital_sensor_value = 0; //variable in which we save the sensor voltage
7  int led_pin = 3; //change the pin of the Led
8
9  void setup() {
10     // put your setup code here, to run once:
11     pinMode(digital_sensor_pin, INPUT_PULLUP); //initialize the sensor pin
12     pinMode(led_pin, OUTPUT); //initialize led pin
13     Serial.begin(9600);
14 }
15
16
17 void loop() {
18     //digital_sensor_value = digitalRead(digital_sensor_pin); //read the Voltage at p
19
20     // check if the pushbutton is pressed.
21     while(digitalRead(digital_sensor_pin) == LOW){ //If it is pressed
22
23         digitalWrite(led_pin, HIGH); // turn the LED on
24         delay(100);
25         digitalWrite(led_pin, LOW);
26         delay(100);
27     }
28 }
29
Output
```

04_button_led_blink

Arduino: Analog Sensor

Read and print the value of an Analog Sensor connected to Arduino

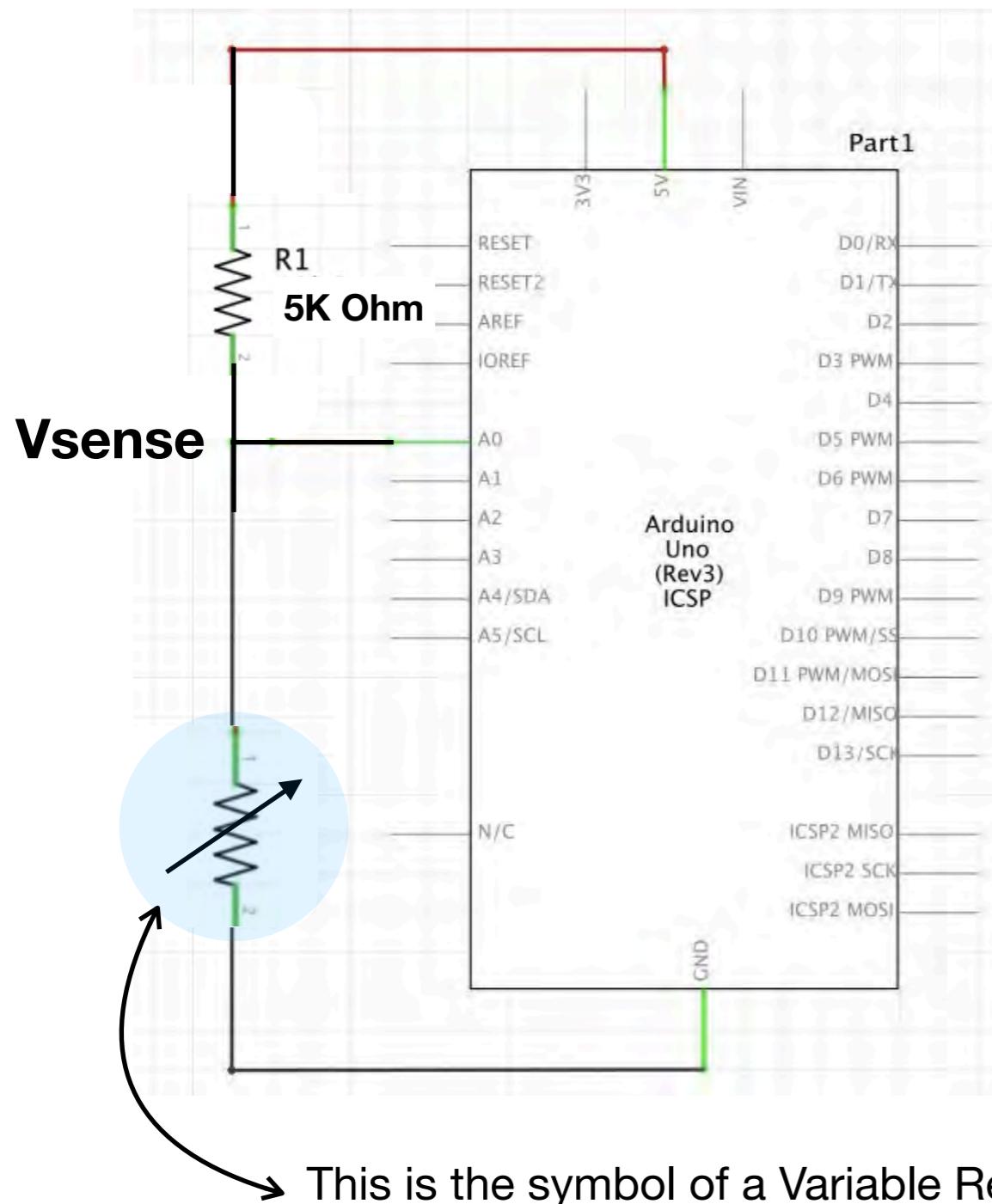
Voltage divider (analog sensor)



$$V_{\text{out}} = \frac{V_s \times R_2}{(R_1 + R_2)}$$

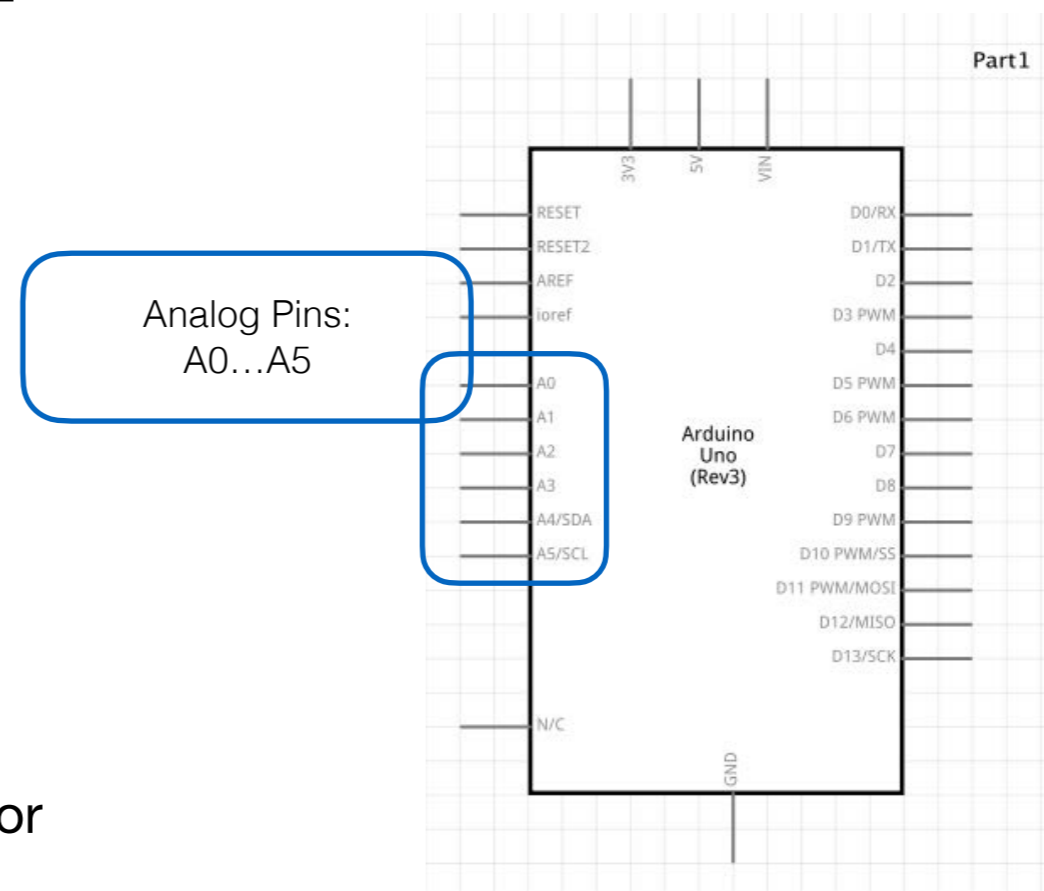
<http://www.ohmslawcalculator.com/voltage-divider-calculator>

Analog sensor - schematic

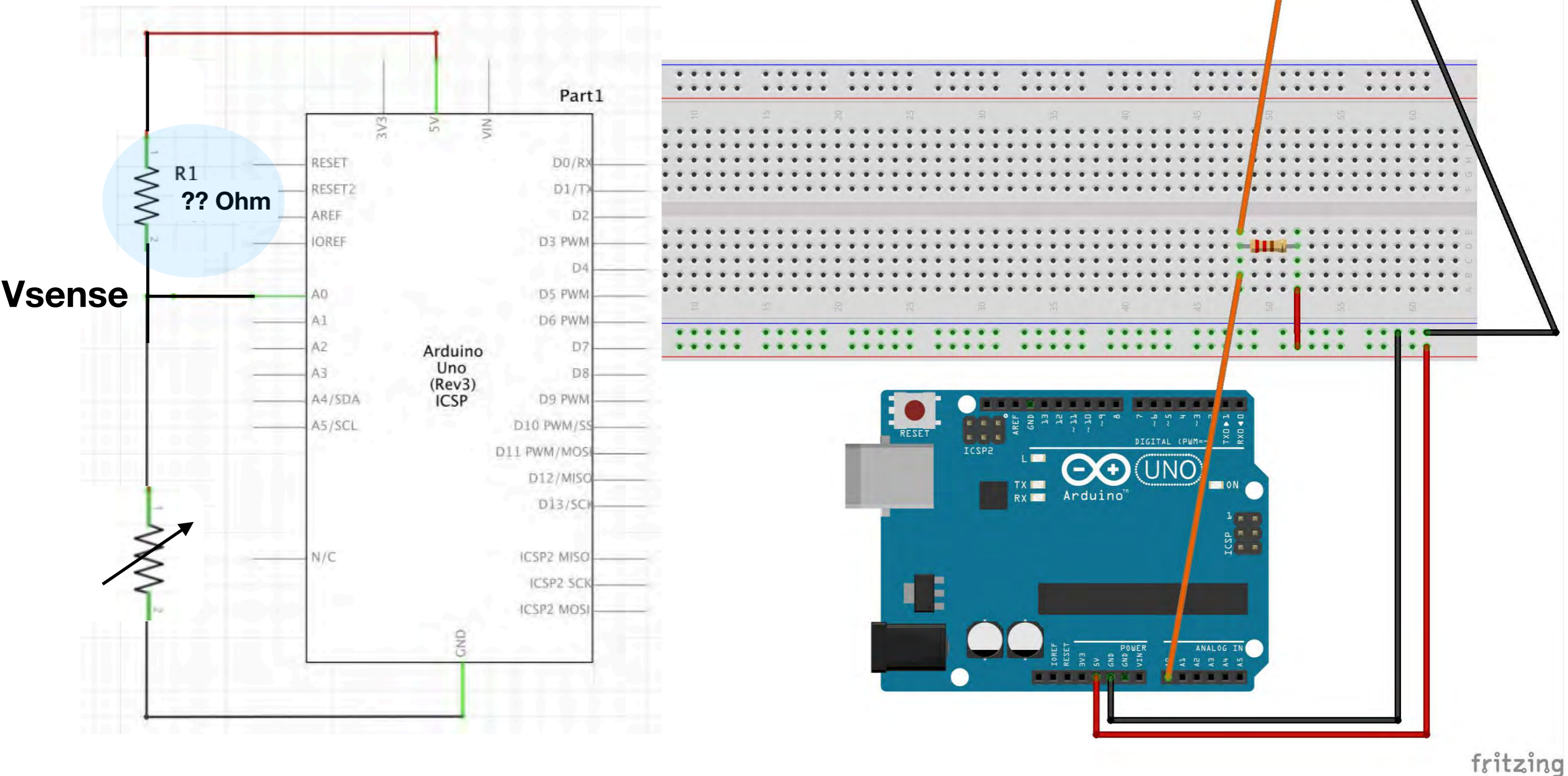


An Analog sensor is a variable resistor!! Change the resistance and you change the Voltage Vsense....the Arduino will read this Voltage.

To read an Analog sensor that generates an analog voltage => you need to use the ANALOG PINS.

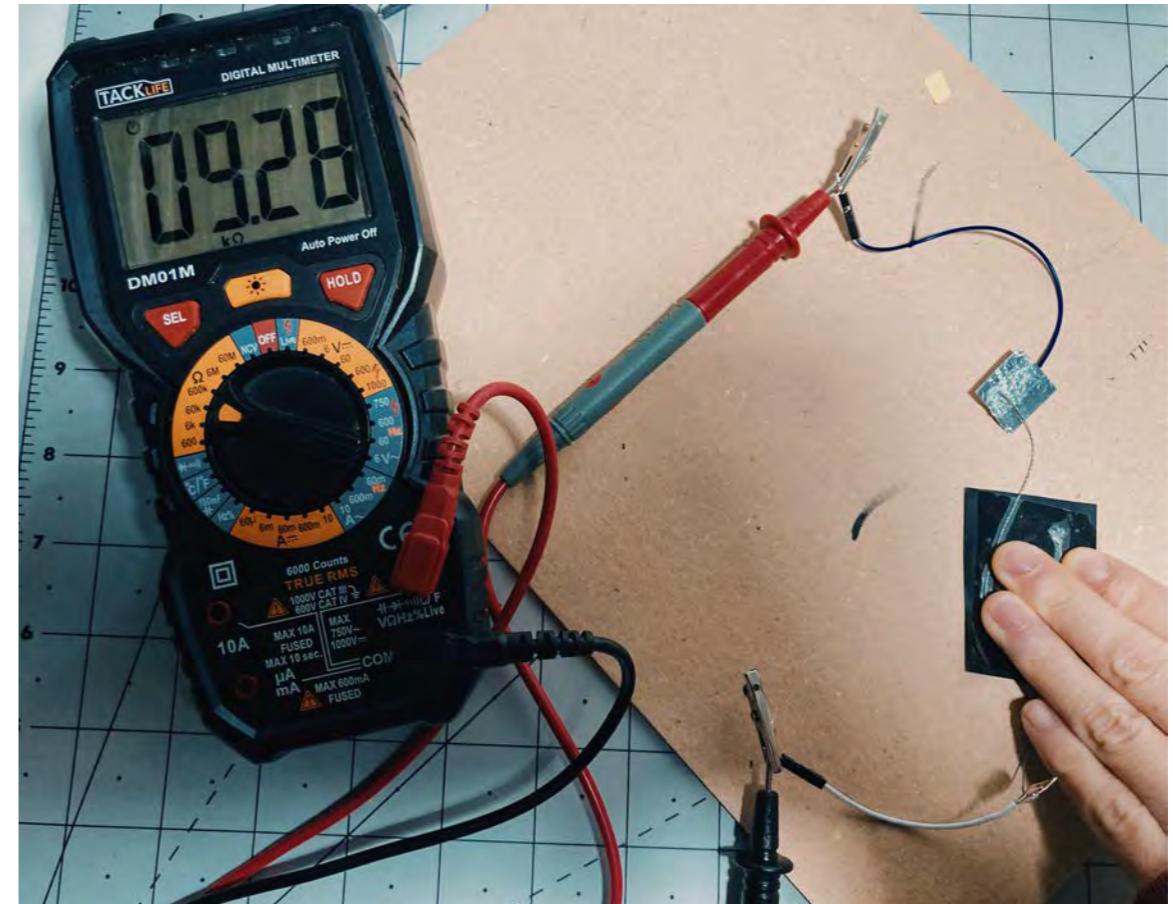
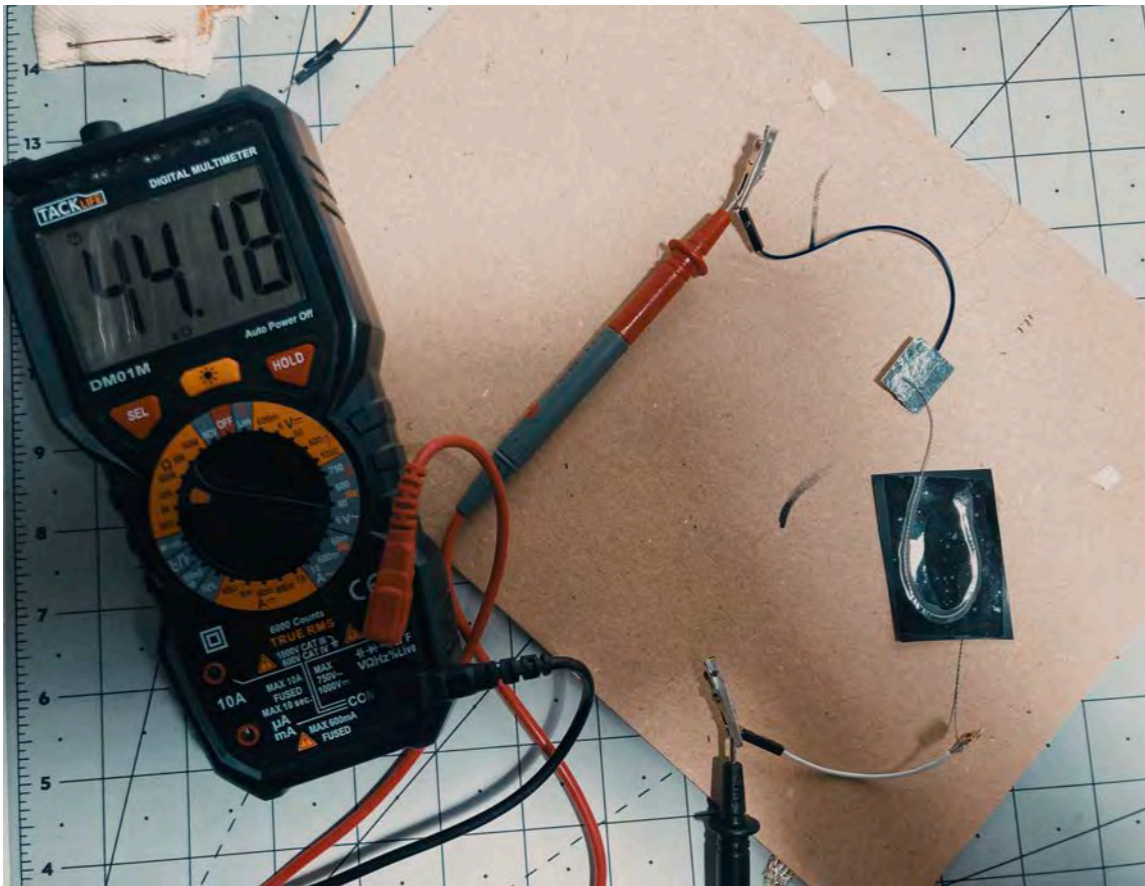


Analog sensor



How to select the right resistor?

Analog sensor - voltage divider

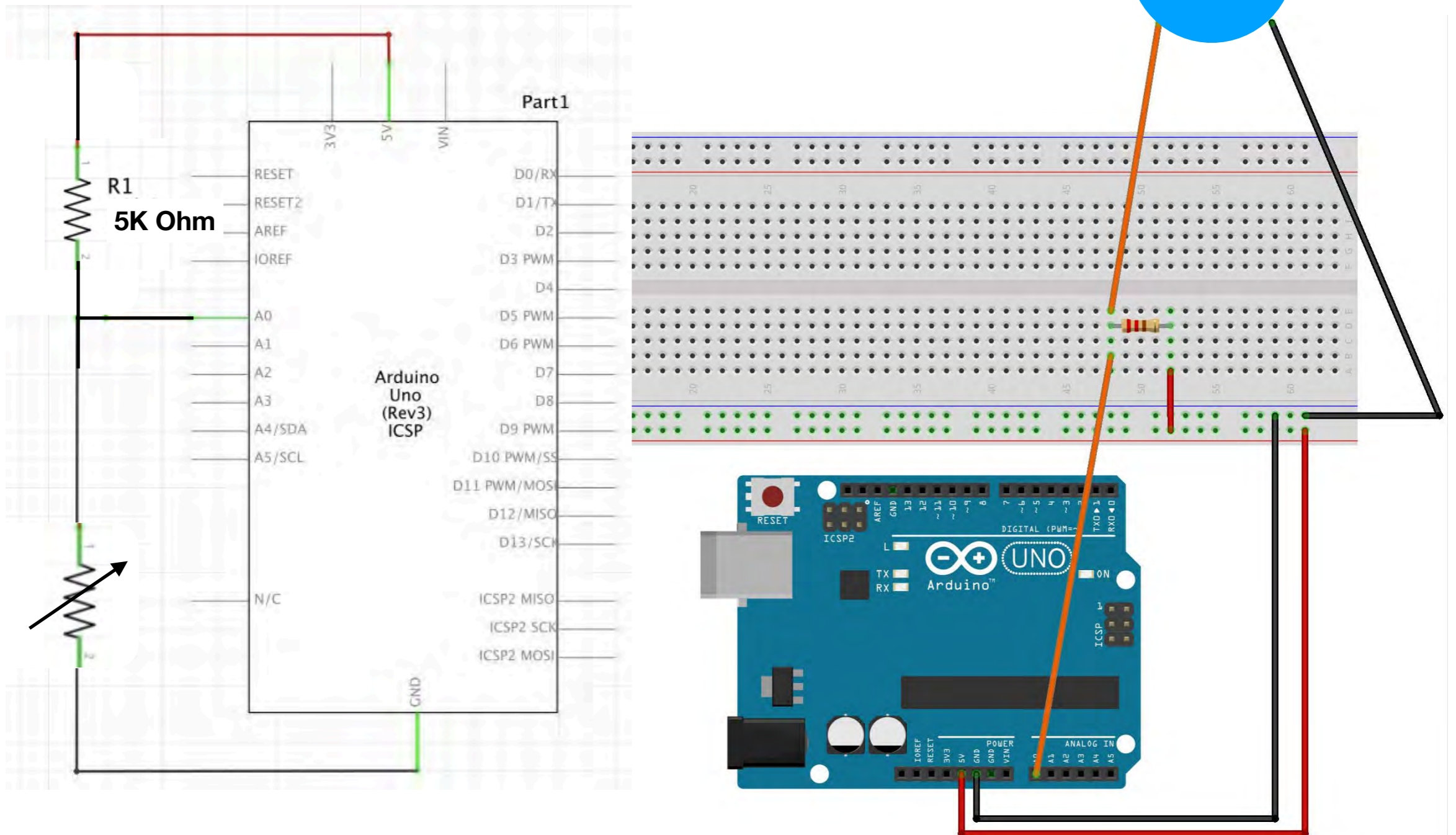


- With the multimeter measure the resistance on the sensor while you interact with it.
- Take note of the min and max resistance values
- Calculate the average of the min and max.
- The average is the optimal value of the extra resistor to use with the analog sensor.

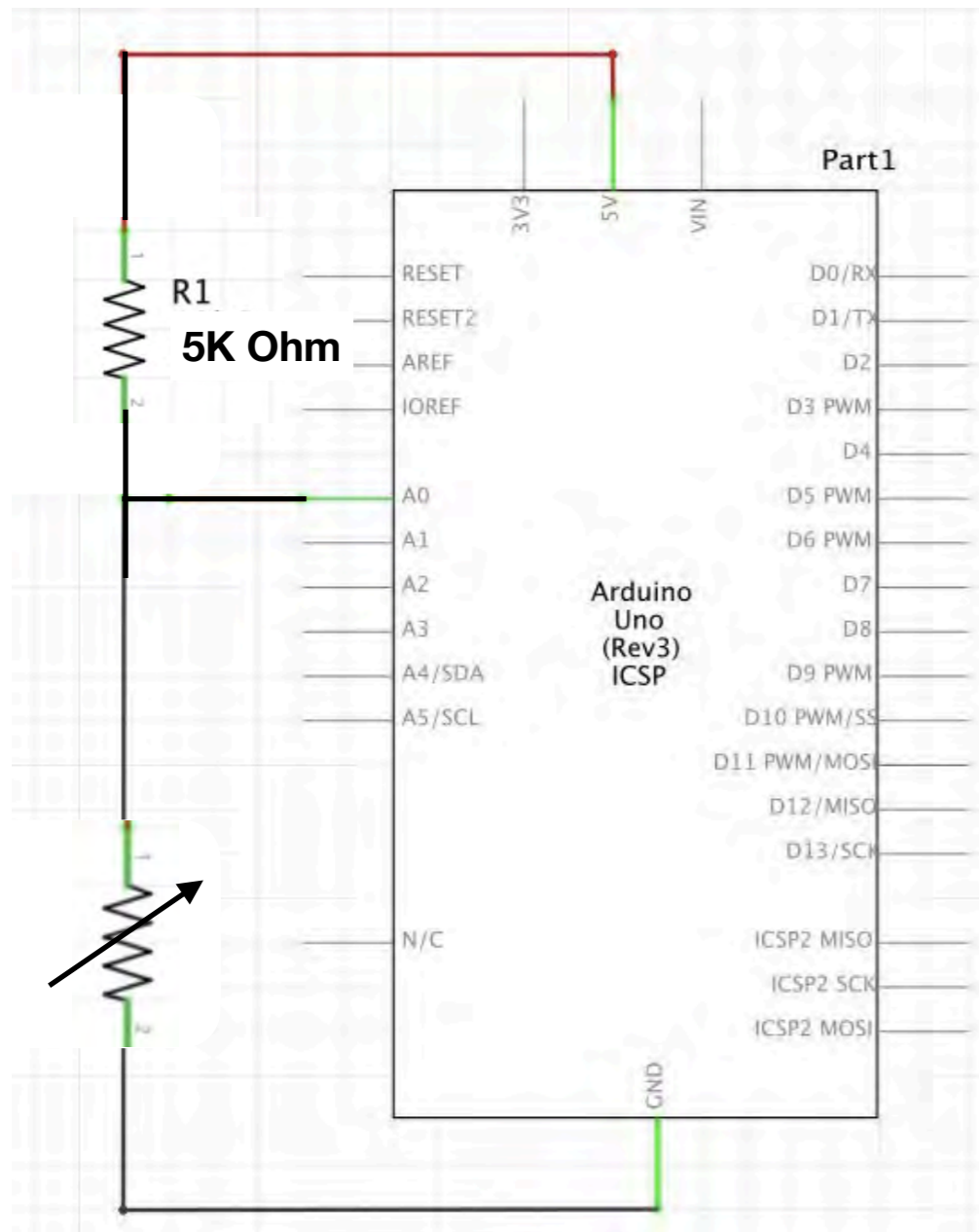
In this case, the resistor should be around 27 kOhm.

You can also just try with a 5k or 10k Ohm.

Analog sensor - schematic



Read an Analog sensor

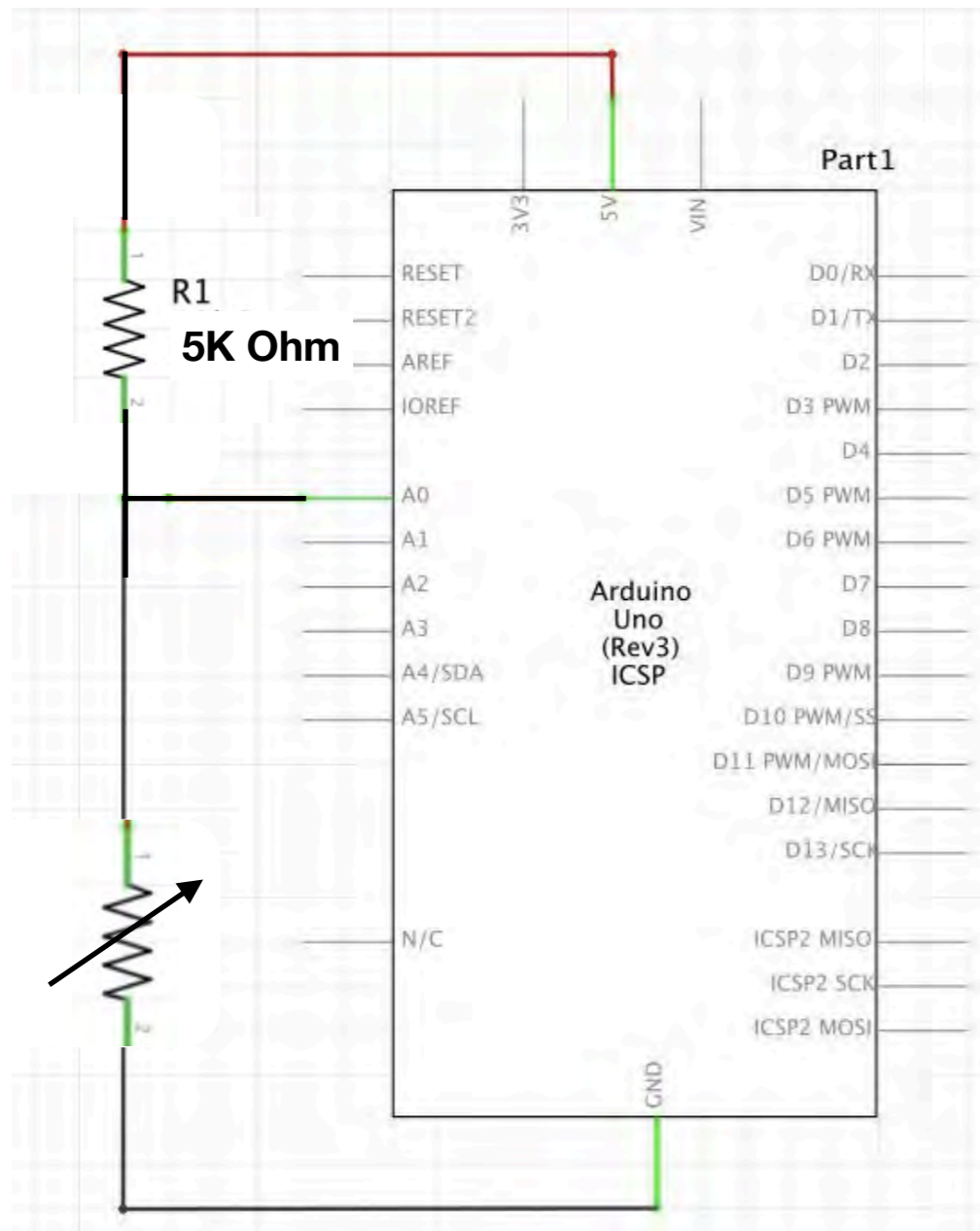


05_read_AnalogSensor.ino

```
1  /* Emma Pareschi - Fabricademy 2022/2023
2  * with this sketch we read the analog sensor connected to pin analog
3  */
4
5  int analog_sensor_pin = A0; //change the pin, where the sensor is c
6  int analog_sensor_value = 0;
7
8  void setup() {
9      // put your setup code here, to run once:
10     pinMode(analog_sensor_pin, INPUT);
11     Serial.begin(9600);
12 }
13
14
15 void loop() {
16     // put your main code here, to run repeatedly:
17     analog_sensor_value = analogRead(analog_sensor_pin); //read the Vol
18
19     Serial.println(analog_sensor_value); // print the value on the Seri
20     delay(100);
21 }
22 }
23
```

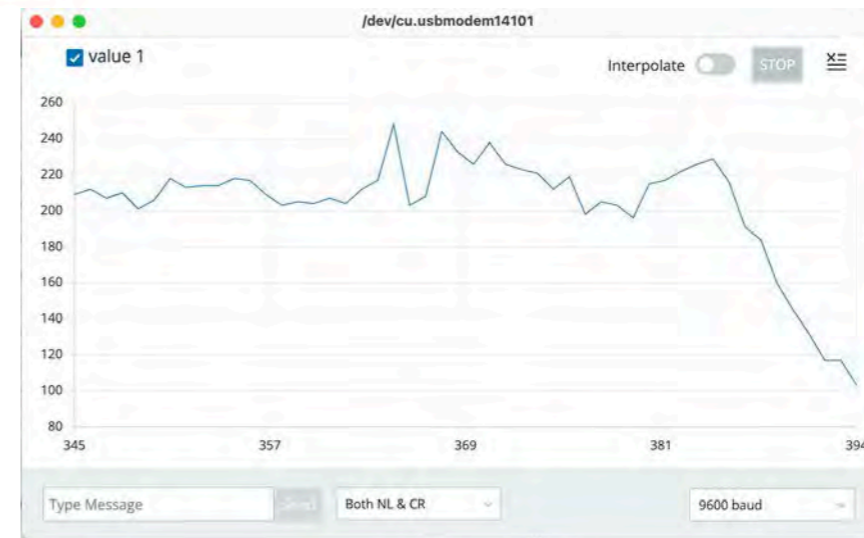
05_read_AnalogSensor

Read an Analog sensor



05_read_AnalogSensor.ino

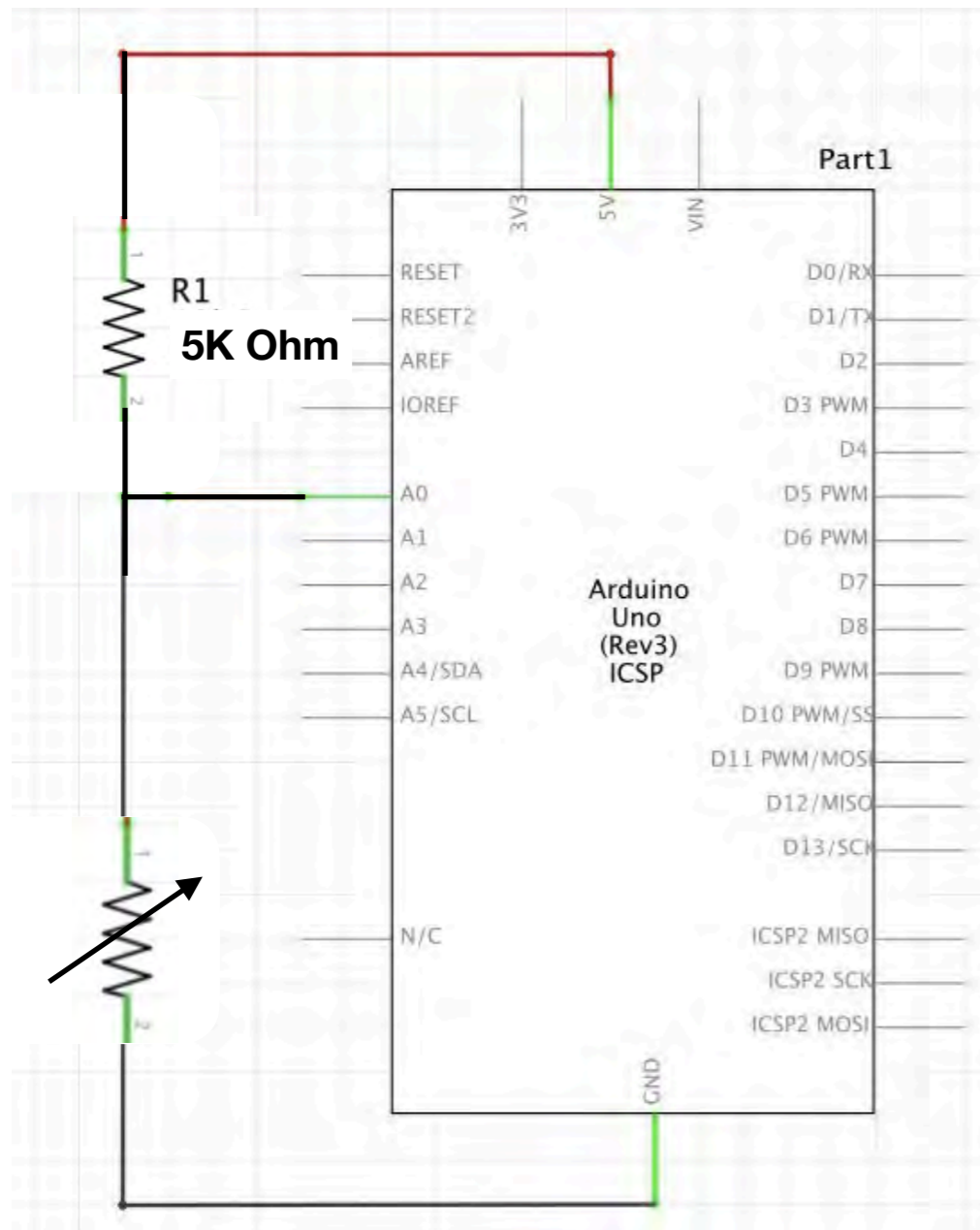
```
1  /* Emma Pareschi - Fabricademy 2022/2023
2  * with this sketch we read the analog sensor connected to pin analog_sensor_pin
3  */
4
5  int analog_sensor_pin = A0; //change the pin, where the sensor is connected?
6  int analog_sensor_value = 0;
7
8  void setup() {
9  // put your setup code here, to run once:
10  pinMode(analog_sensor_pin, INPUT);
11  Serial.begin(9600);
12
13 }
14
15 void loop() {
16 // put your main code here, to run repeatedly:
17 analog_sensor_value = analogRead(analog_sensor_pin); //read the Voltage of the pin sensor
18
19 Serial.println(analog_sensor_value); // print the value on the Serial monitor
20 delay(100);
21
22 }
23
```



05_read_AnalogSensor

Write down the minimum and the maximum.
We will use them in the next demo.

Read and map an Analog sensor



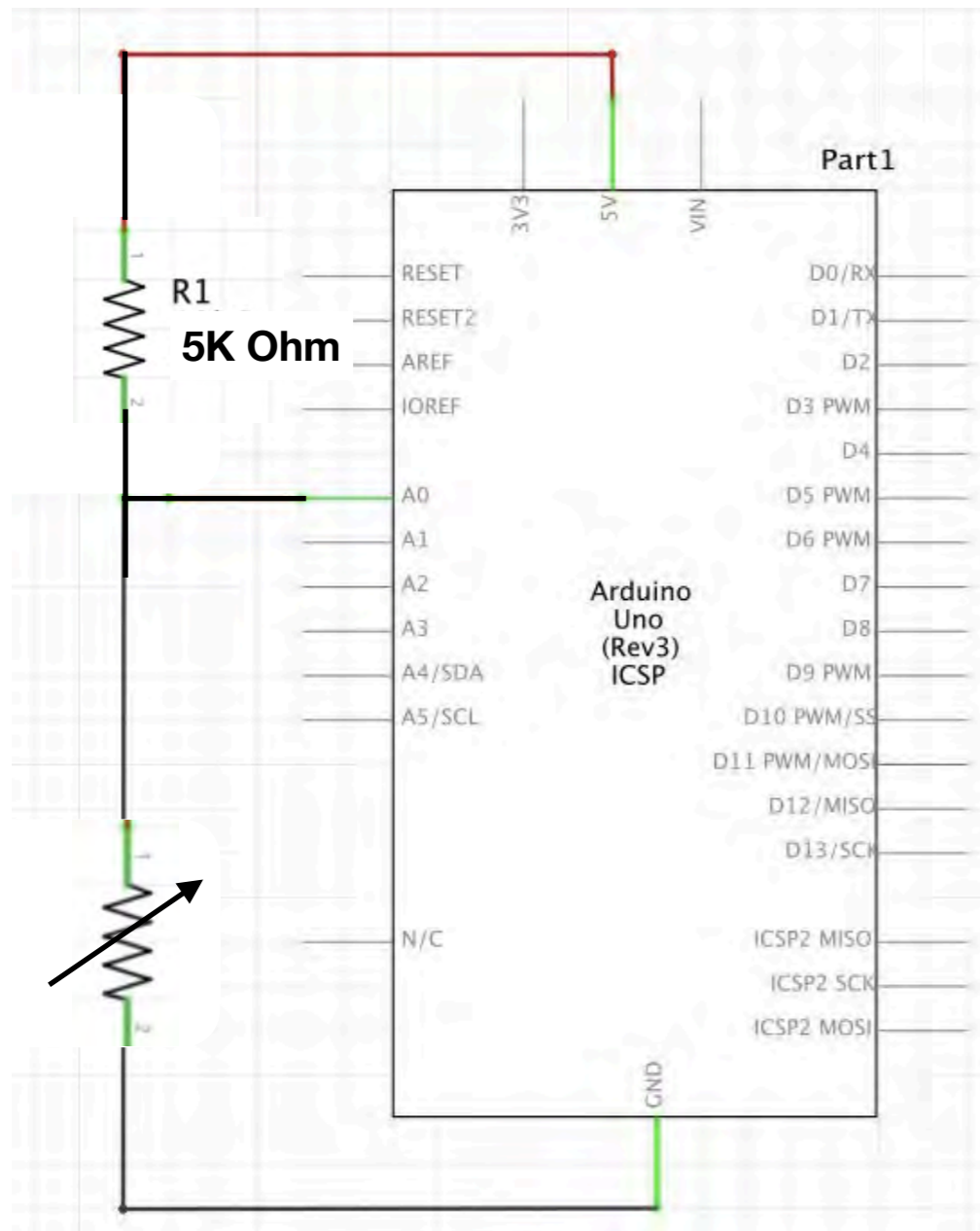
Minimum value: 50
Maximum value: 250

06_read_AnalogSensor_map.ino

```
1  /*Emma Pareschi,
2  * with this sketch we read the analog sensor connected to pin analog_sensor_pin
3  */
4
5  int analog_sensor_pin = A0; //change the pin, where the sensor is connected?
6  int analog_sensor_value = 0;
7
8  void setup() {
9  // put your setup code here, to run once:
10  pinMode(analog_sensor_pin, INPUT);
11  Serial.begin(9600);
12  }
13
14
15  void loop() {
16  // put your main code here, to run repeatedly:
17  analog_sensor_value = analogRead(analog_sensor_pin); //read the Voltage of the pin sensor
18
19  analog_sensor_value = map(analog_sensor_value, 50, 250, 0, 255); //we change the range
20  analog_sensor_value = constrain(analog_sensor_value, 0, 255); //we apply the limits
21
22  Serial.println(analog_sensor_value); // print the value on the Serial monitor
23  delay(100);
24  }
25
26
```

06_read_AnalogSensor_map

Smooth the value of an Analog sensor



Smoothing

```
// Define the number of samples to keep track of. The higher the number, the
// more the readings will be smoothed, but the slower the output will respond to
// the input. Using a constant rather than a normal variable lets us use this
// value to determine the size of the readings array.
const int numReadings = 10;

int readings[numReadings]; // the readings from the analog input
int readIndex = 0; // the index of the current reading
int total = 0; // the running total
int average = 0; // the average

int inputPin = A0;

void setup() {
  // initialize serial communication with computer:
  Serial.begin(9600);
  // initialize all the readings to 0:
  for (int thisReading = 0; thisReading < numReadings; thisReading++) {
    readings[thisReading] = 0;
  }
}

void loop() {
  // subtract the last reading:
  total = total - readings[readIndex];
  // read from the sensor:
  readings[readIndex] = analogRead(inputPin);
  // add the reading to the total:
  total = total + readings[readIndex];
  // advance to the next position in the array:
  readIndex = readIndex + 1;

  // if we're at the end of the array...
  if (readIndex >= numReadings) {
    // ..wrap around to the beginning:
    readIndex = 0;
  }
}
```

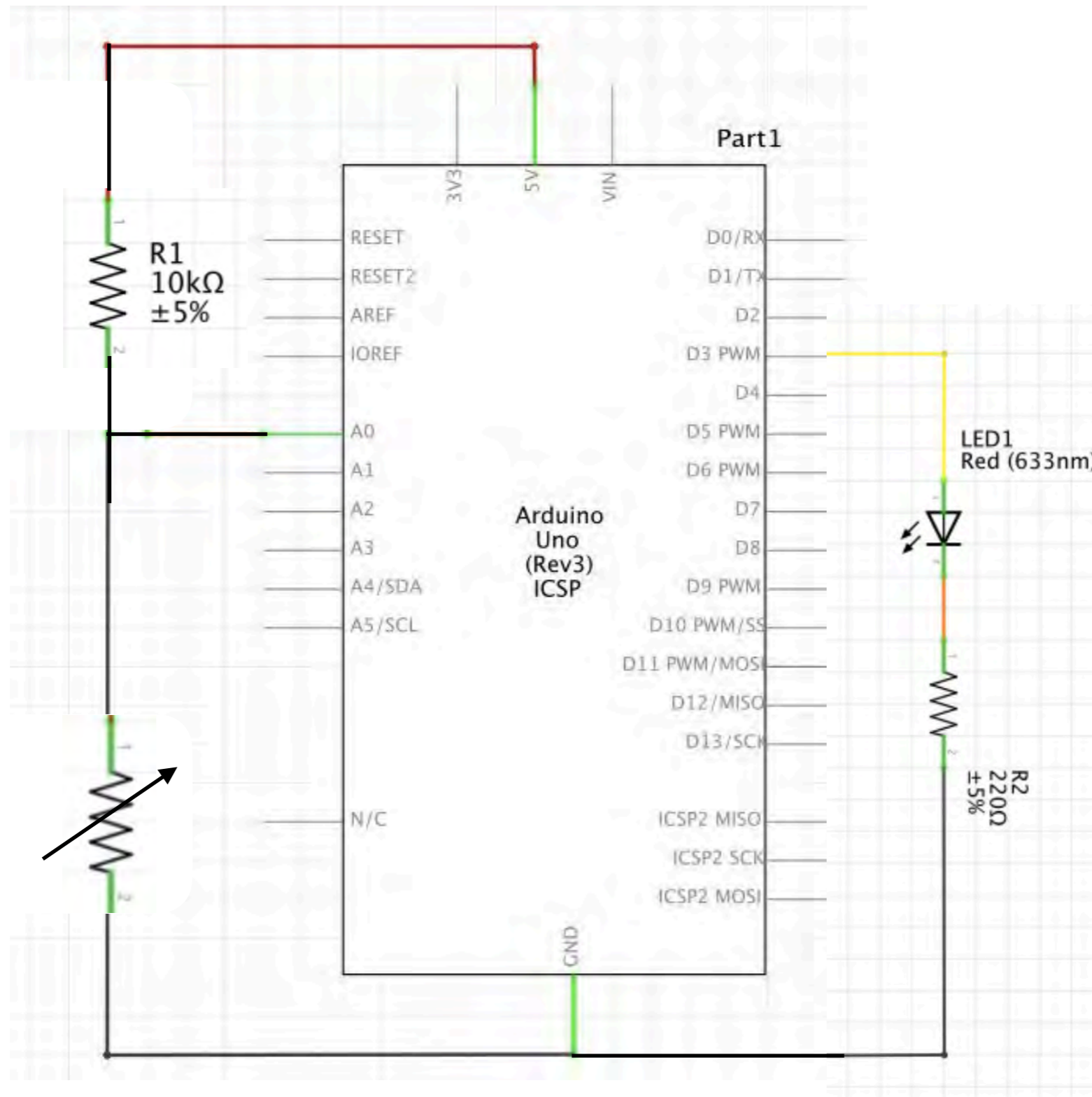
Example -> Analog -> Smoothing

Open Tools -> Serial Plotter and you will see how much smooth is the signal of the sensor... nice :)

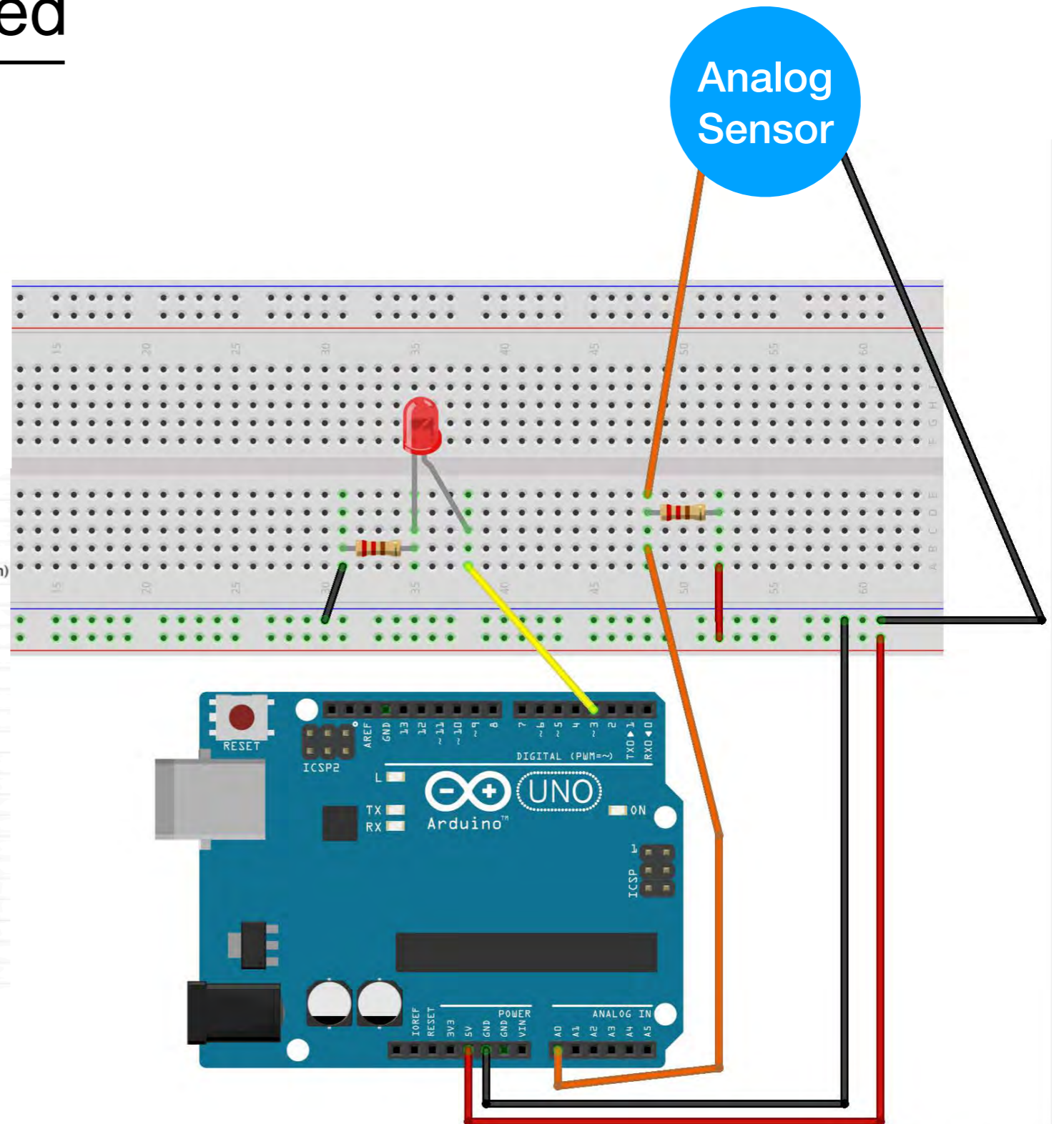
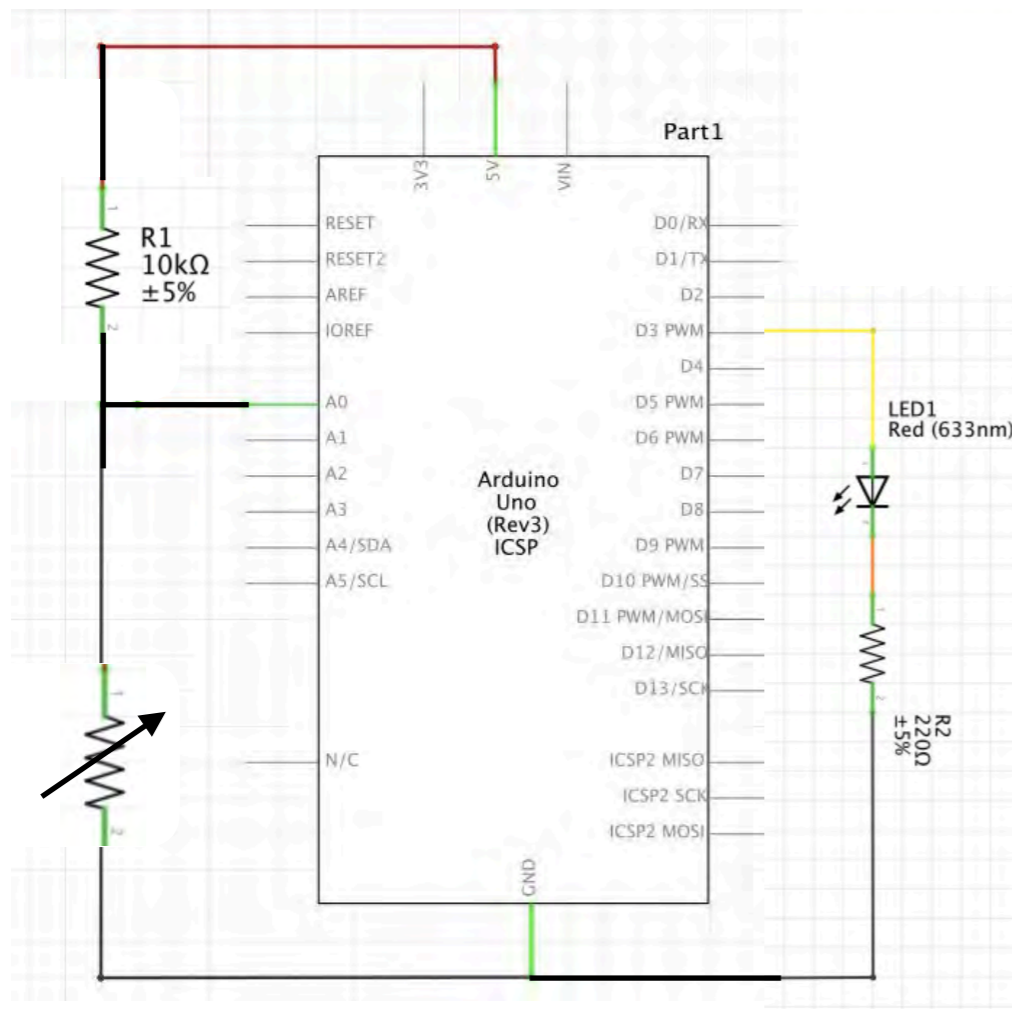
Arduino: Analog Sensor and Led

Use the Analog sensor to control a Led

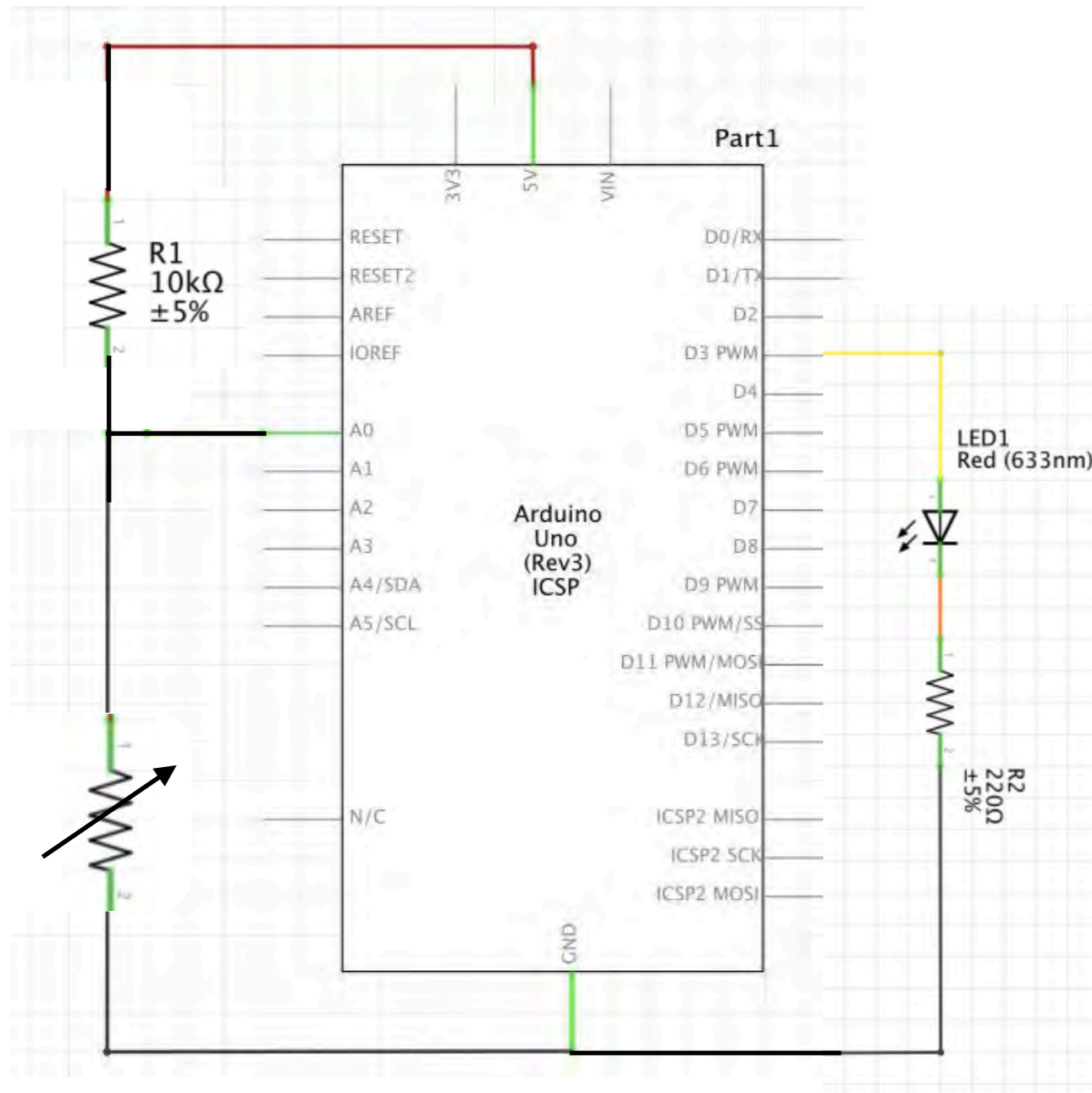
Analog sensor and a Led



Analog sensor and a Led



Analog sensor and a Led

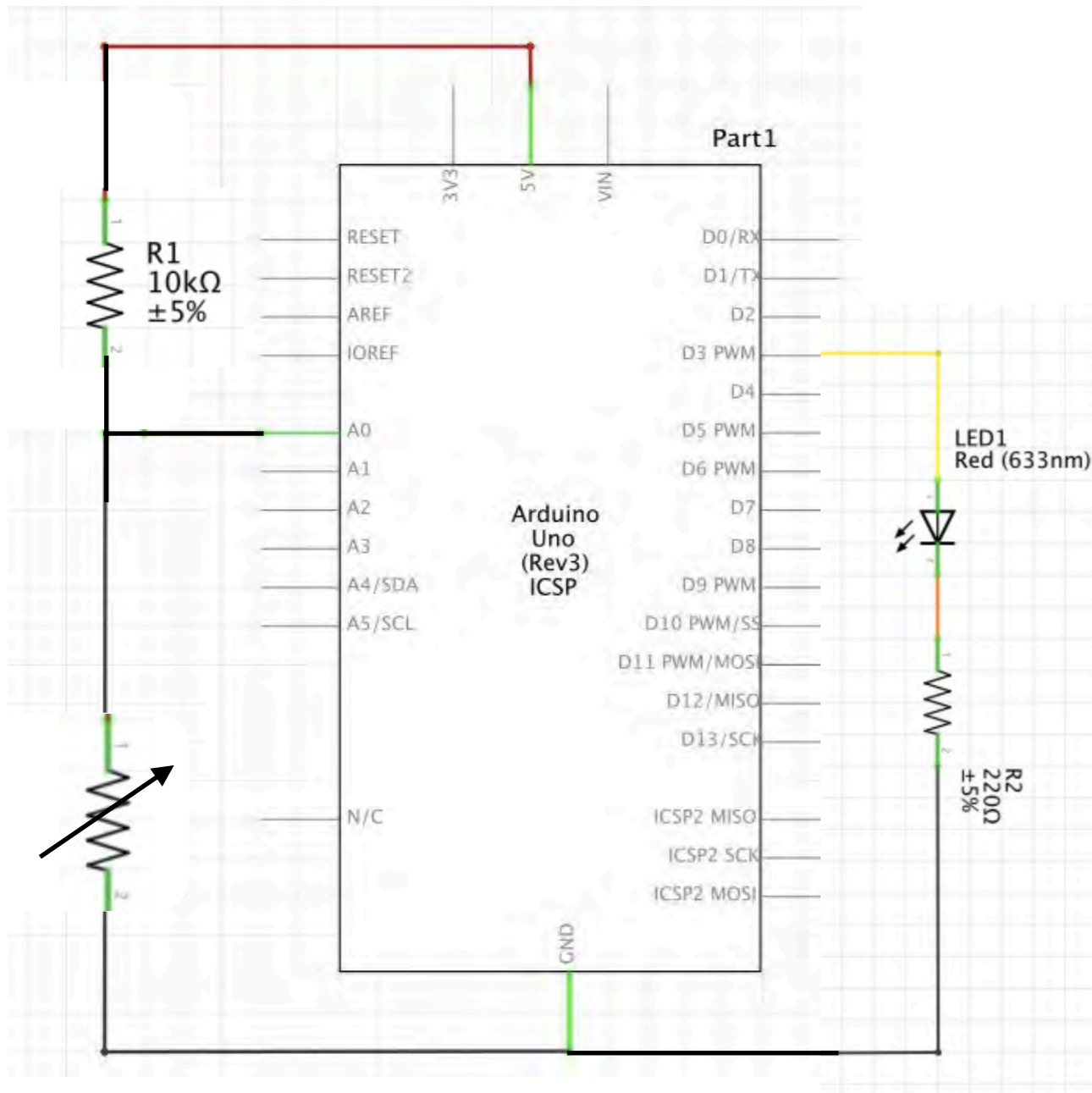


07_AnalogSensor_led_fade.ino

```
37 Serial.begin(9600);
38 // initialize all the readings to 0:
39 for (int thisReading = 0; thisReading < numReadings; thisReading++) {
40   readings[thisReading] = 0;
41 }
42
43 pinMode(led_pin, OUTPUT); //initialize led pin
44 }
45
46 void loop() {
47   // subtract the last reading:
48   total = total - readings[readIndex];
49   // read from the sensor:
50   readings[readIndex] = analogRead(inputPin);
51   // add the reading to the total:
52   total = total + readings[readIndex];
53   // advance to the next position in the array:
54   readIndex = readIndex + 1;
55
56   // if we're at the end of the array...
57   if (readIndex >= numReadings) {
58     // ...wrap around to the beginning:
59     readIndex = 0;
60   }
61
62   // calculate the average:
63   average = total / numReadings;
64
65
66   // send it to the computer as ASCII digits
67   Serial.println(average);
68   average = map(average, 60, 230, 0, 255); //we change the range
69   average = constrain(average, 0, 255); //we apply the limits
70
71   delay(50); // delay in between reads for stability
72   analogWrite(led_pin, average);
73 }
74
```

07_AnalogSensor_led_fade

Analog sensor and a Led



07_AnalogSensor_led_fade.ino

```
37 Serial.begin(9600);
38 // initialize all the readings to 0:
39 for (int thisReading = 0; thisReading < numReadings; thisReading++) {
40   readings[thisReading] = 0;
41 }
42
43 pinMode(led_pin, OUTPUT); //initialize led pin
44 }
45
46 void loop() {
47   // subtract the last reading:
48   total = total - readings[readIndex];
49   // read from the sensor:
50   readings[readIndex] = analogRead(inputPin);
51   // add the reading to the total:
52   total = total + readings[readIndex];
53   // advance to the next position in the array:
54   readIndex = readIndex + 1;
55
56   // if we're at the end of the array...
57   if (readIndex >= numReadings) {
58     // ...wrap around to the beginning:
59     readIndex = 0;
60   }
61
62   // calculate the average:
63   average = total / numReadings;
64
65   // send it to the computer as ASCII digits
66   Serial.println(average);
67   average = map(average, 60, 230, 0, 255); //we change the range
68   average = constrain(average, 0, 255); //we apply the limits
69
70
71   delay(50); // delay in between reads for stability
72   analogWrite(led_pin, average);
73 }
74
```

08_AnalogSensor_led_blink

Sketches

This is the list of sketches we used in class, some are provided with this presentation, some come from the Example of Arduino IDE.

Control a Led

- 01_blink_Led
- Fade (examples)

Read a Digital Sensor and print the value on the Serial Monitor

- 03_read_DigitalSensor

Control a Led with a Digital Sensor

- 04_button_led_blink
- 04_button_led_on_off

Read an Analog Sensor and print the value on the Serial Monitor

- 05_read_AnalogSensor
- 06_read_AnalogSensor_map
- Smoothing (from Example)

Control a Led with an Analog Sensor

- 07_AnalogSensor_led_fade
- 08_AnalogSensor_led_blink

Workflow

- 1- decide which sensor to make, if it is your first sensor, follow a tutorial. If you already have experience, have fun and try something new or change a sensor already documented.
- 2- Once you have the sensor, test it with the multimeter.
- 3- Once the sensor looks ok (with the multimeter), connect it to the Arduino and read the value on the Serial Monitor or Serial Plotter.
- 4- Once you can read the values of the sensor with the Arduino, connect the Led and try to control the Led based on the interaction with the sensor.

Arduino Language Reference



HARDWARE

SOFTWARE ▾

DOCUMENTATION ▾

COMMUNITY ▾

BLOG

ABOUT

LANGUAGE

FUNCTIONS

VARIABLES

STRUCTURE

LIBRARIES

IOT CLOUD API

GLOSSARY

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Find anything that can be improved? [Suggest corrections and new documentation via GitHub](#).

Doubts on how to use Github? Learn everything you need to know in [this tutorial](#).

The Arduino® Student Kit:
bring the buzz home

Language Reference

Arduino programming language can be divided in three main parts: functions, values (variables and constants), and structure.

FUNCTIONS

For controlling the Arduino board and performing computations.

Digital I/O

`digitalRead()`

`digitalWrite()`

`pinMode()`

Analog I/O

`analogRead()`

`analogReference()`

`analogWrite()`

Math

`abs()`

`constrain()`

`map()`

`max()`

`min()`

`pow()`

`sq()`

`sqrt()`

Trigonometry

Random Numbers

`random()`

`randomSeed()`

Bits and Bytes

`bit()`

`bitClear()`

`bitRead()`

`bitSet()`

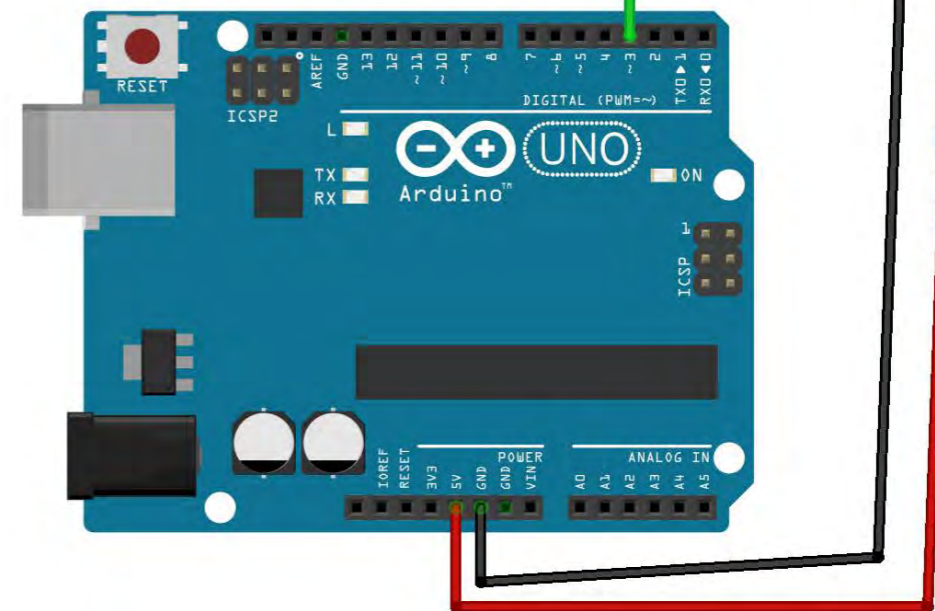
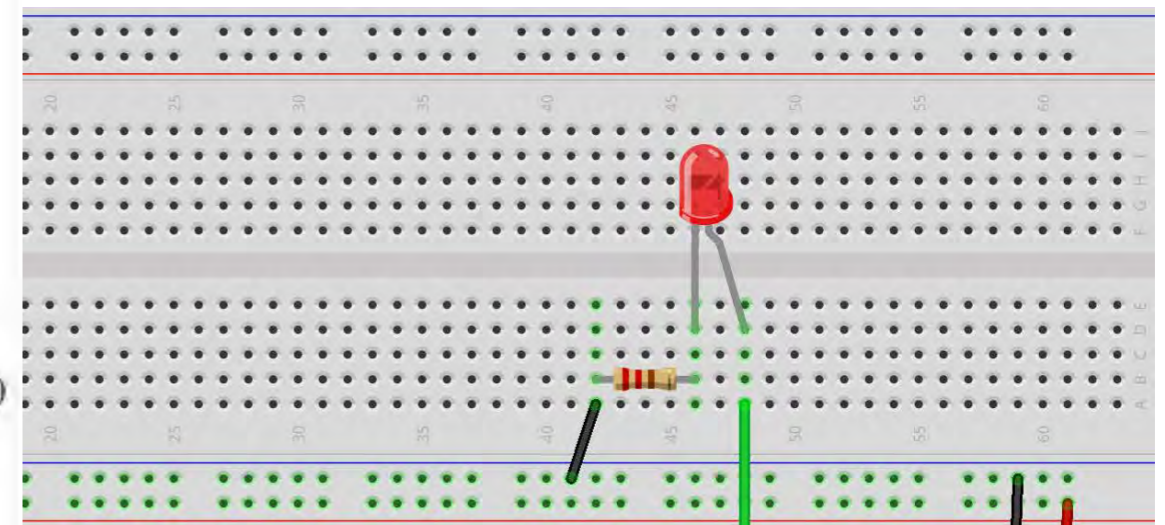
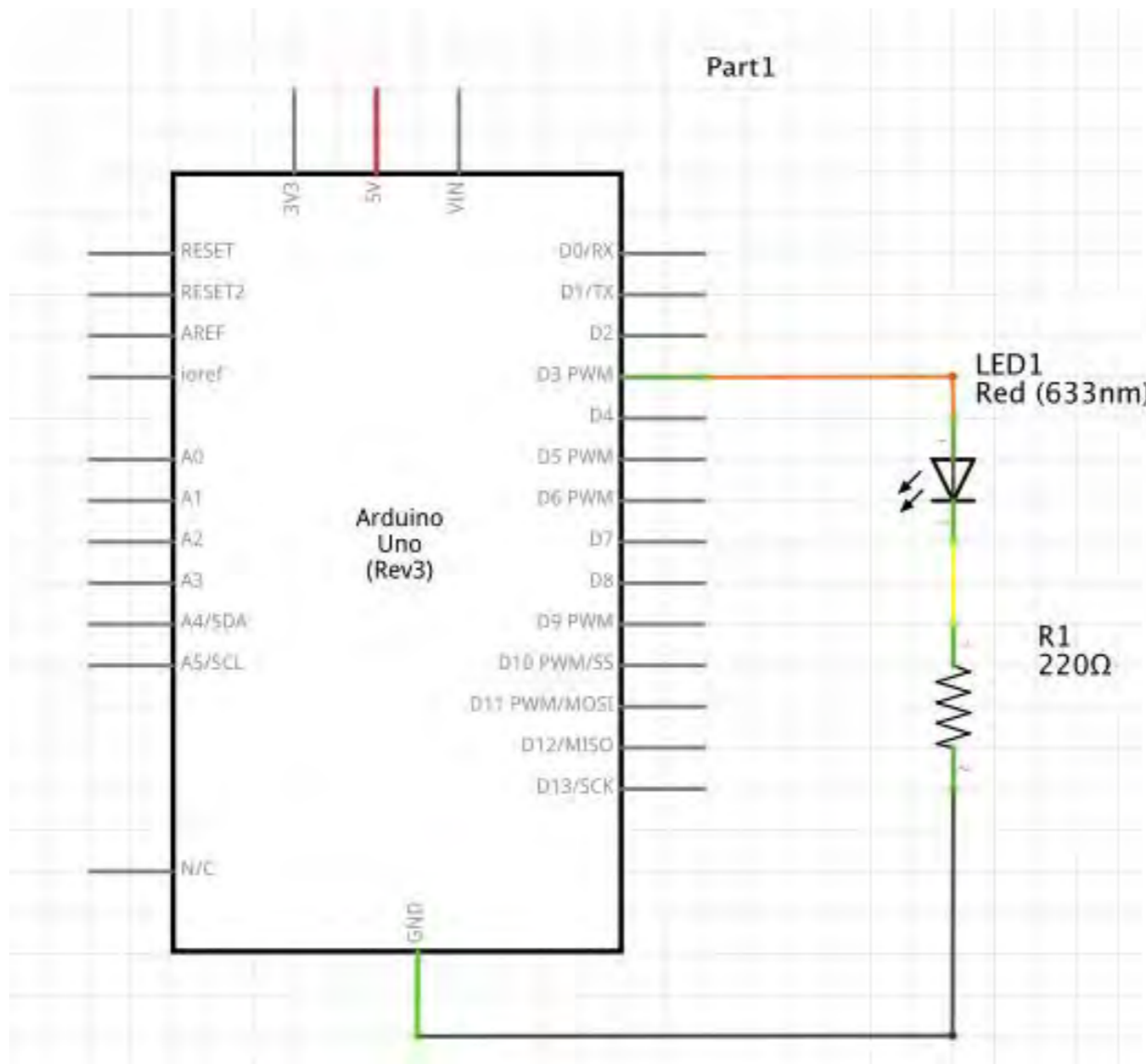
`bitWrite()`

`highByte()`

Help

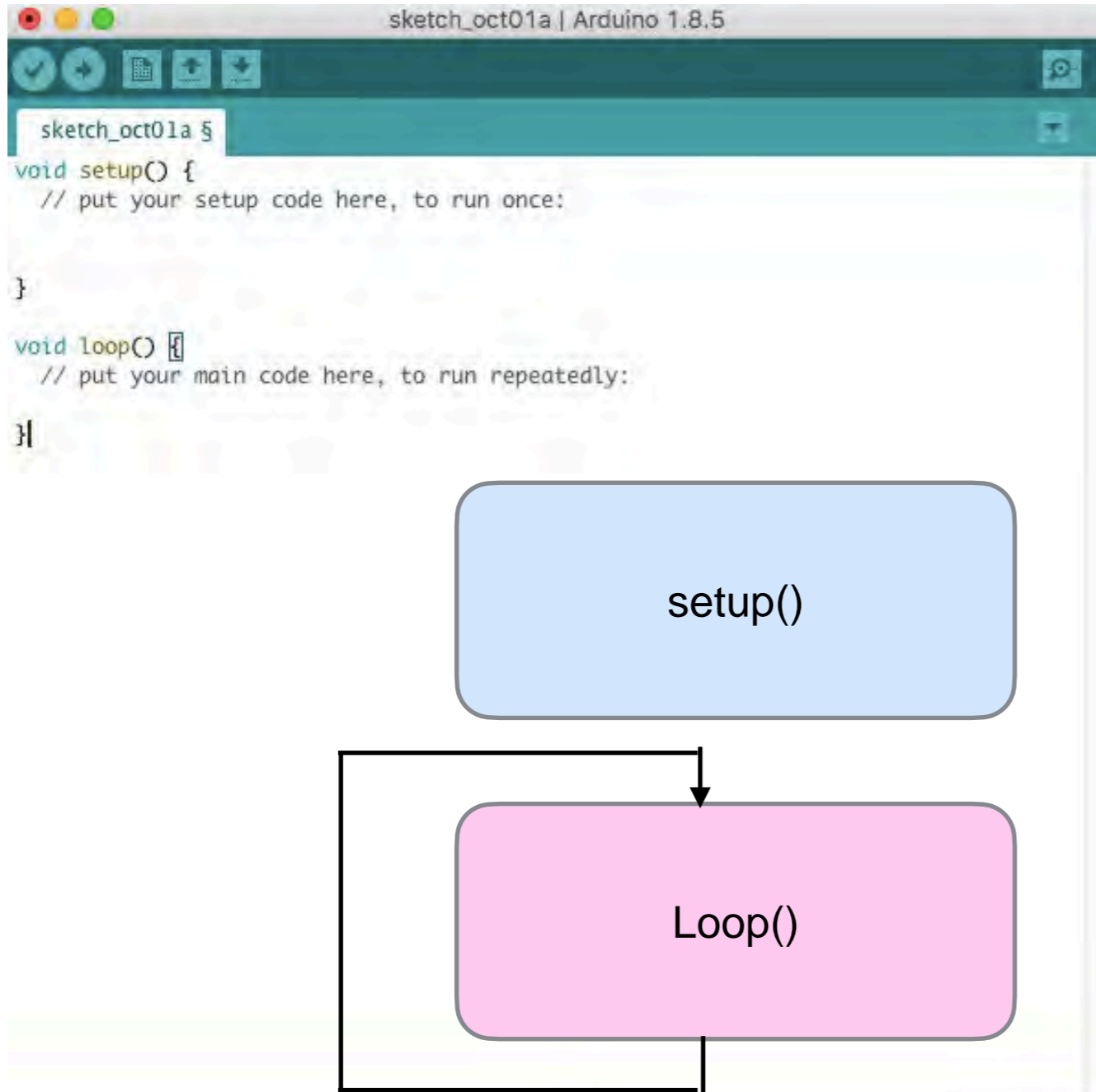
<https://www.arduino.cc/reference/en/>

Control a Led with Arduino



fritzing

Time to Program



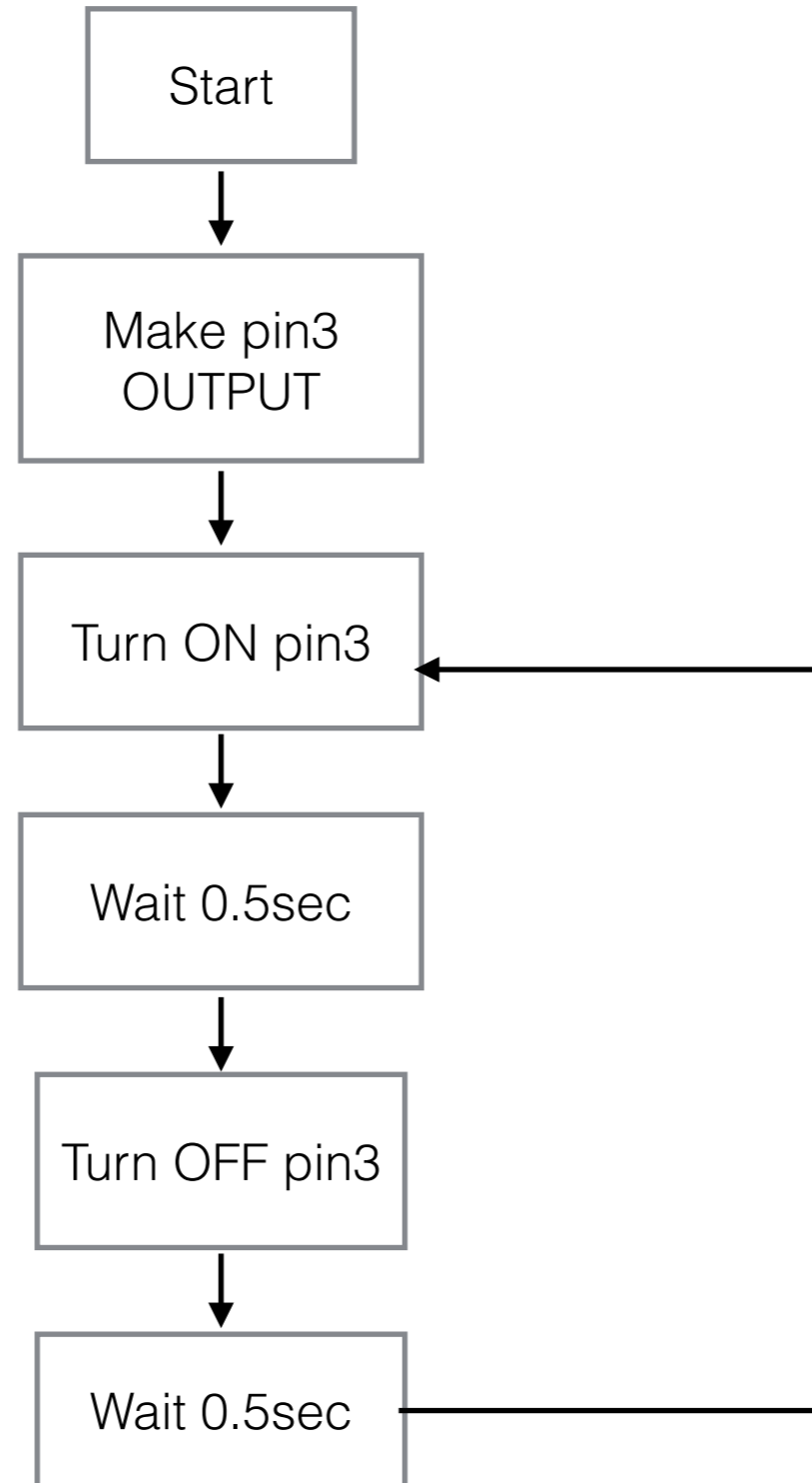
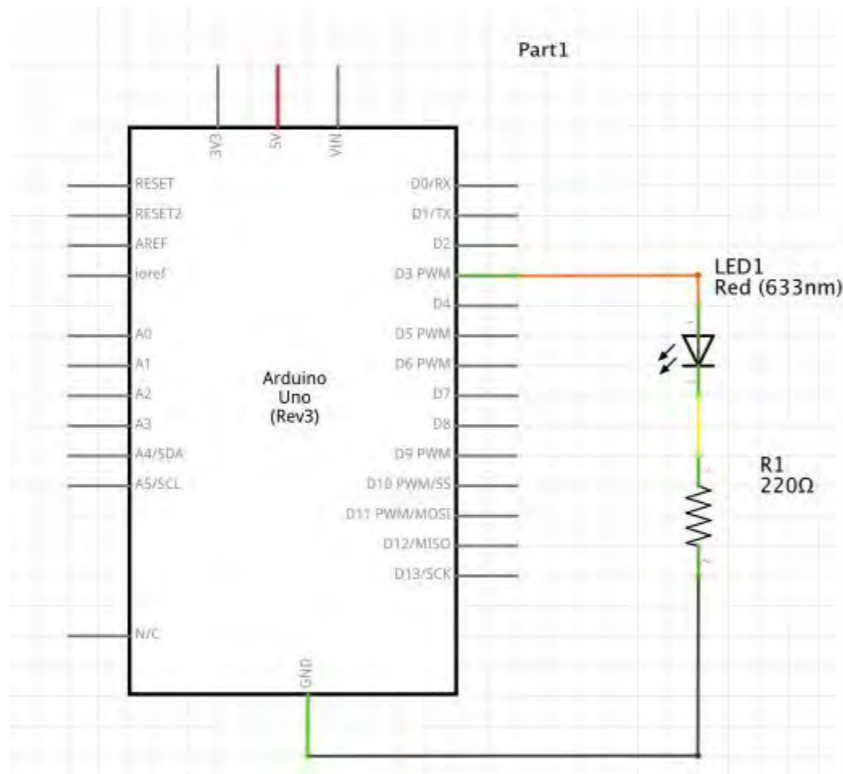
Initialise

Runs once, at the beginning when the Arduino is powered on.
Define the pins.

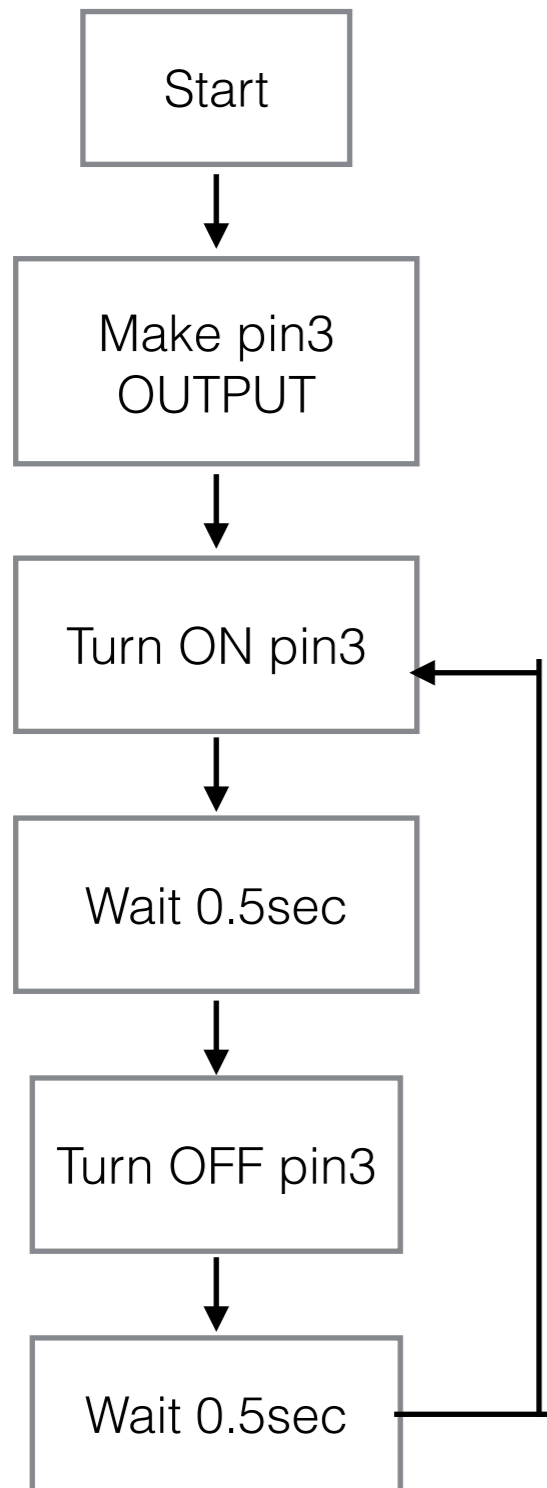
Running

Run repeatedly, after setup.

Control Flow



Control Flow

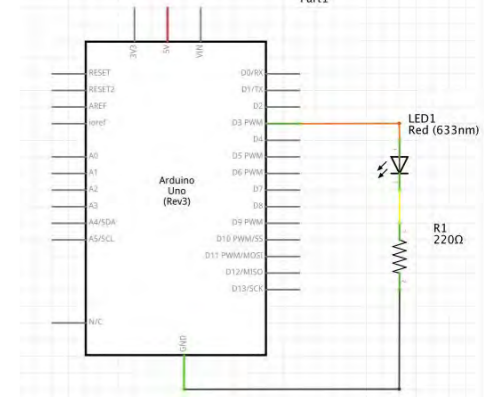


In human language

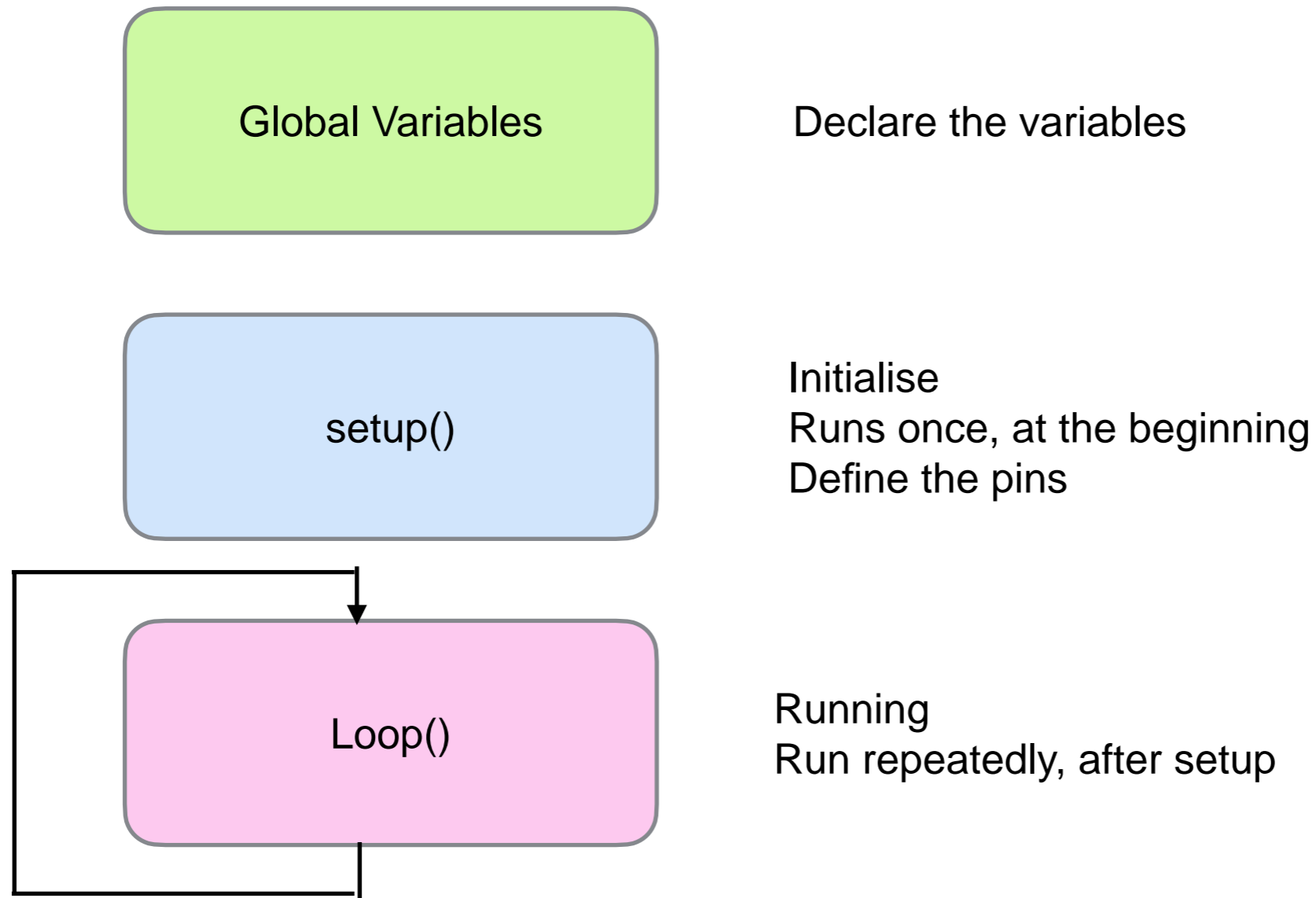
```
void setup() {  
  make the pin 3 an OUTPUT  
}  
  
void loop() {  
  turn Led ON  
  wait 0.5 sec  
  turn Led OFF  
  wiat 0.5 sec  
}
```

In Arduino language

```
void setup() {  
  // put your setup code here, to run once:  
  pinMode(3, OUTPUT);  
}  
  
void loop() {  
  // put your main code here, to run repeatedly:  
  digitalWrite(3, HIGH);  
  delay(500);  
  digitalWrite(3, LOW);  
  delay(500);  
}
```



SKETCH



01_blink_led Sketch

Global variables

setup()

loop()



```
01_blink | Arduino 1.6.9
_01_blink
/*Emma Pareschi 25 September 2017
 * I turn on a led and I turn it off
 */

int led_pin = 3; //defin the pin where the Led is connected

void setup() {
  pinMode(led_pin, OUTPUT); //define pin of the Led as an output
}

void loop() {
  digitalWrite(led_pin, HIGH); //turn the Led on
  delay(100); //wait 100millisecond
  digitalWrite(led_pin, LOW); //turn the Led off
  delay(100); //wait 100millisecond
}

Done Saving.
The sketch name had to be modified. Sketch names can only consist
of ASCII characters and numbers (but cannot start with a number).
They should also be less than 64 characters long.

20 ATtiny25/45/85, ATtiny85, Internal 16 MHz on /dev/cu.usbserial-FTXH0
```

Blink Sketch

setup()
Define the function of the pin
`pinMode(pin, function);`

The pin is 'led_pin
The functionality is Output



```
_01_blink | Arduino 1.6.9
_01_blink
/*Emma Pareschi 25 Spetmber 2017
 * I turn on a led and I turn it off
 */

int led_pin = 3; //defin the pin where the Led is connected

void setup() {
  pinMode(led_pin, OUTPUT); //define pin of the Led as an output
}

void loop() {
  digitalWrite(led_pin, HIGH); //turn the Led on
  delay(100); //wait 100millisecond
  digitalWrite(led_pin, LOW); //turn the Led off
  delay(100); //wait 100millisecond
}

Done Saving.
The sketch name had to be modified. Sketch names can only consist
of ASCII characters and numbers (but cannot start with a number).
They should also be less than 64 characters long.

20 ATtiny25/45/85, ATtiny85, Internal 16 MHz on /dev/cu.usbserial-FTH9HXH0
```


Blink Sketch

Loop()

The list of commands that arduino runs repeatedly.

DigitalWrite(pin, level);

we control the voltage on the pin

HIGH: high voltage (5V)

LOW: low voltage (ground)

Delay(time);

We add a delay in millisecond

```
_01_blink | Arduino 1.6.9
_01_blink
/*Emma Pareschi 25 Spetmber 2017
 * I turn on a led and I turn it off
 */

int led_pin = 3; //defin the pin where the Led is connected

void setup() {

  pinMode(led_pin, OUTPUT); //define pin of the Led as an output
}

void loop() {

  digitalWrite(led_pin, HIGH); //turn the Led on
  delay(100); //wait 100millisecond
  digitalWrite(led_pin, LOW); //turn the Led off
  delay(100); //wait 100millisecond
}

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```