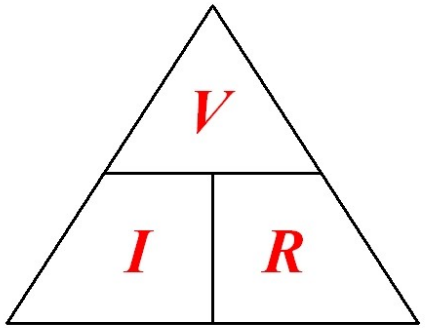
Basic Electronics & analog data

Not just theory……

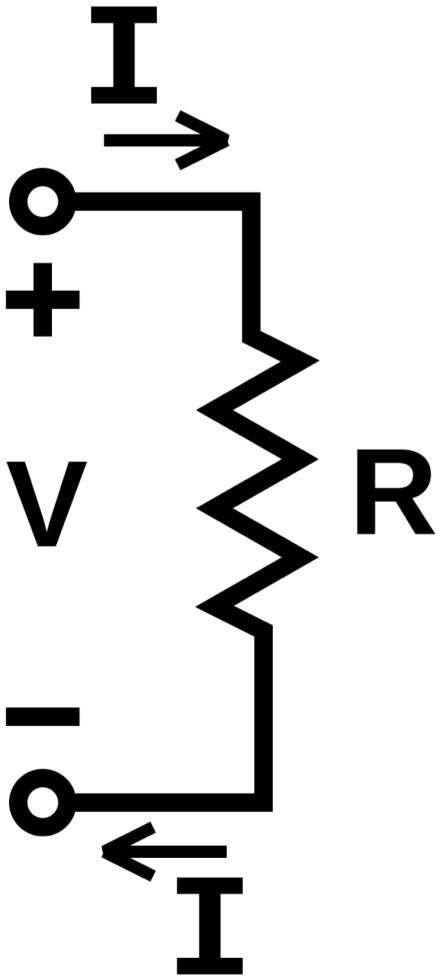
Ohms Law

$$V = I\,R$$

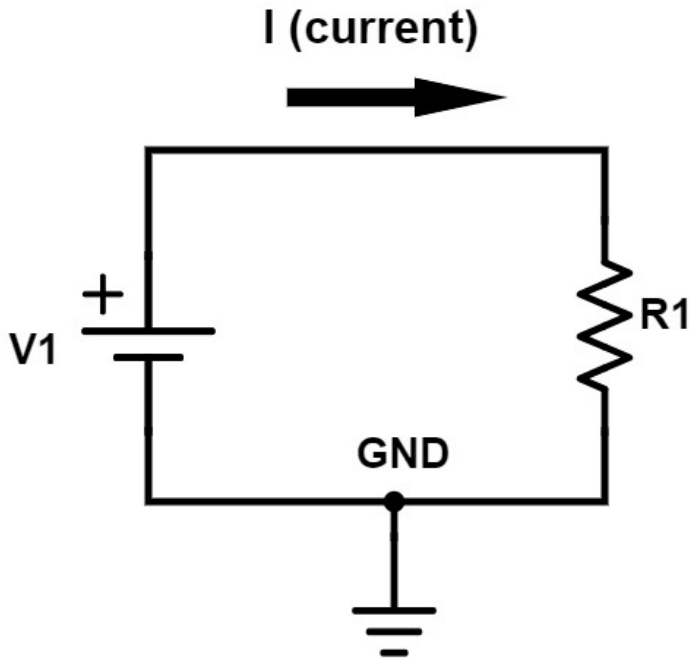


$$I = \frac{V}{R}$$

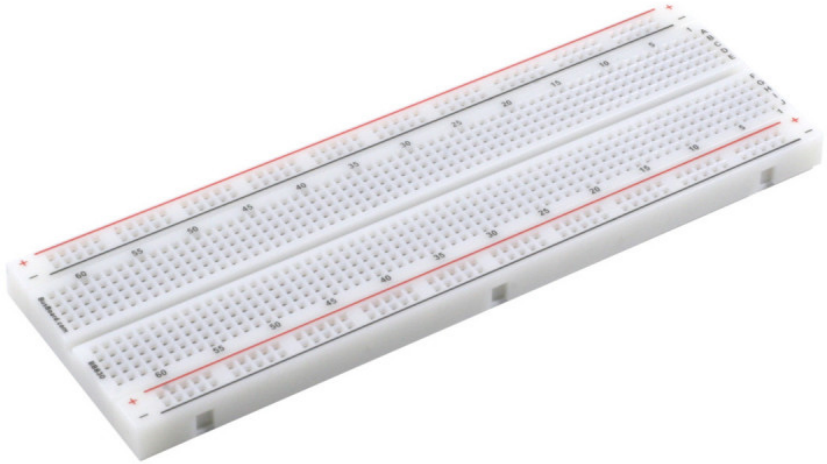
$$R = \frac{V}{I}$$



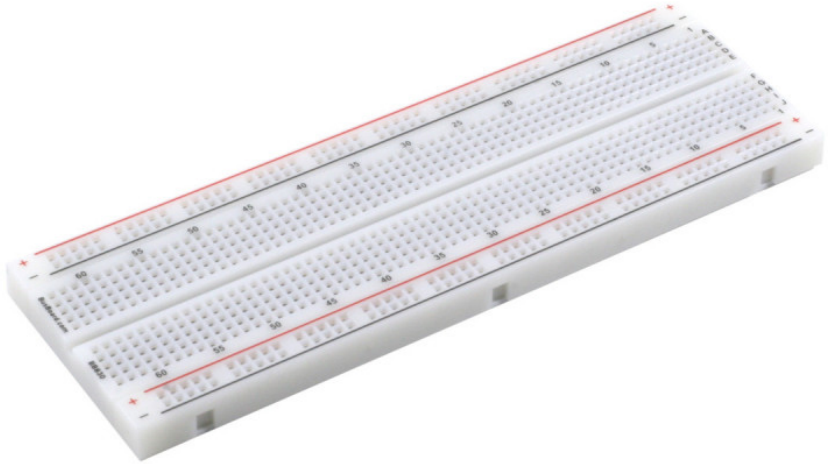
Moving from theory and schematics to actual circuits

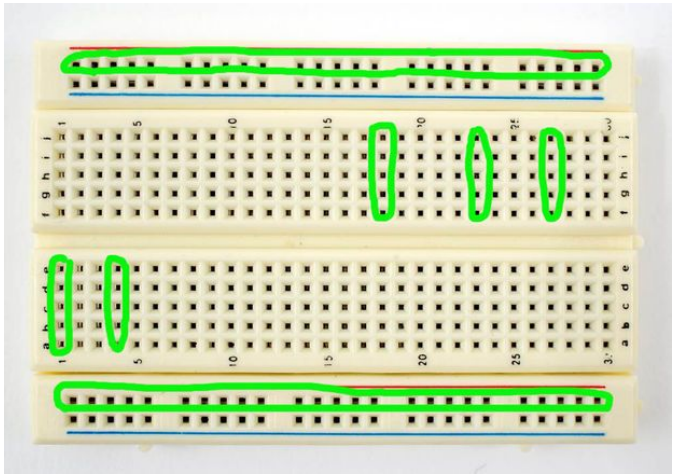


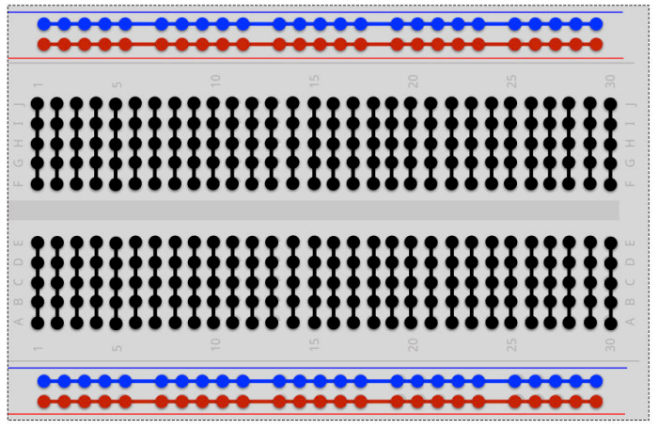
Some basic components



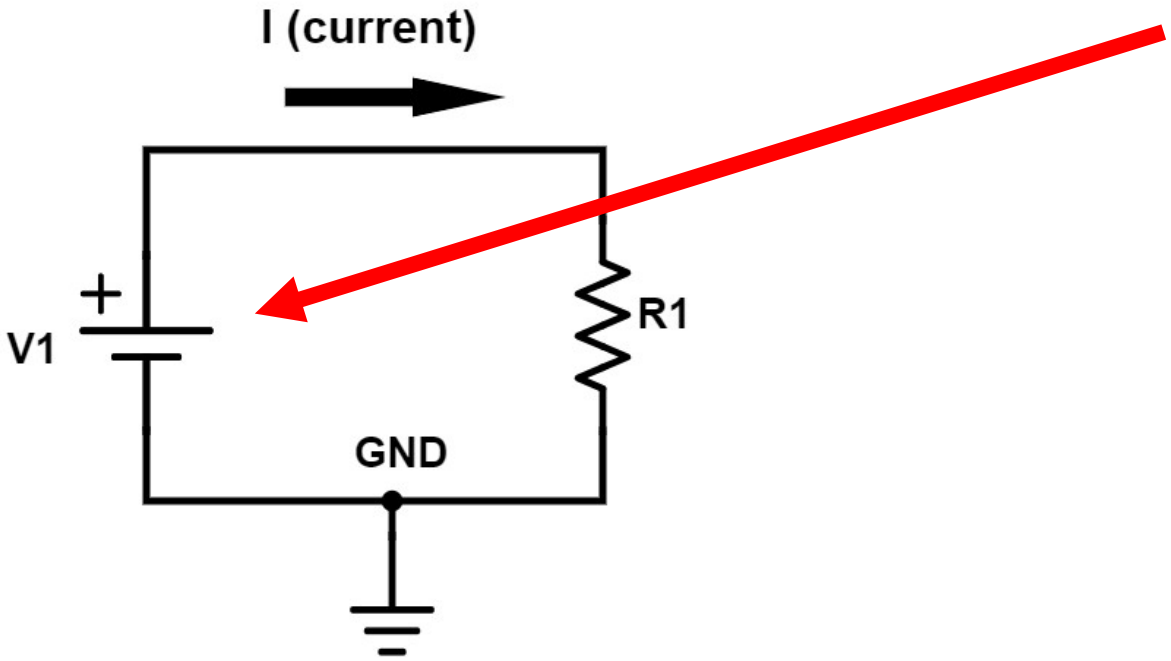
Bread board



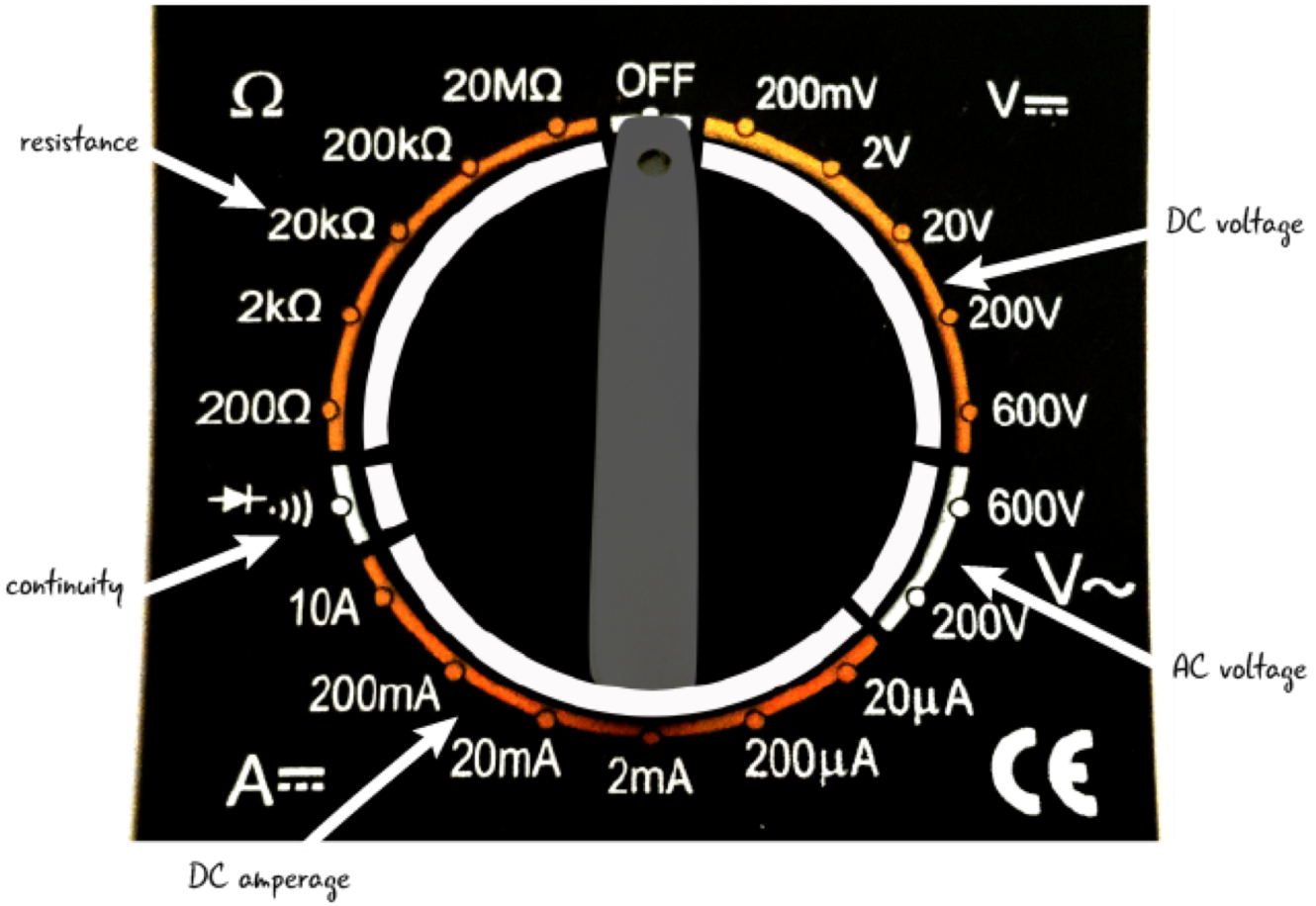




Power supply

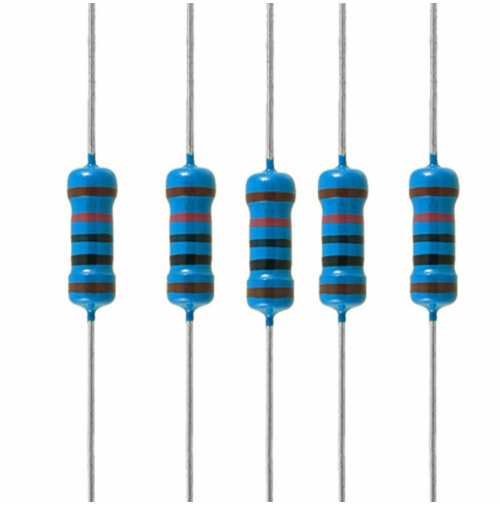


Multimeter


Ω
20MΩ
OFF
200mV
V⎓
200kΩ
2V
20kΩ
20V
2kΩ
200V
200Ω
600V
600V
V~
200V
10A
200mA
20µA
20mA
2mA
200µA
A⎓
CE
resistance
DC voltage
continuity
AC voltage
DC amperage

Resistance & resistors

Each resistor has markings on it stating its resistance but the best way to know is to check with the multimeter.



Test the random resistor you got.

What is the resistance?

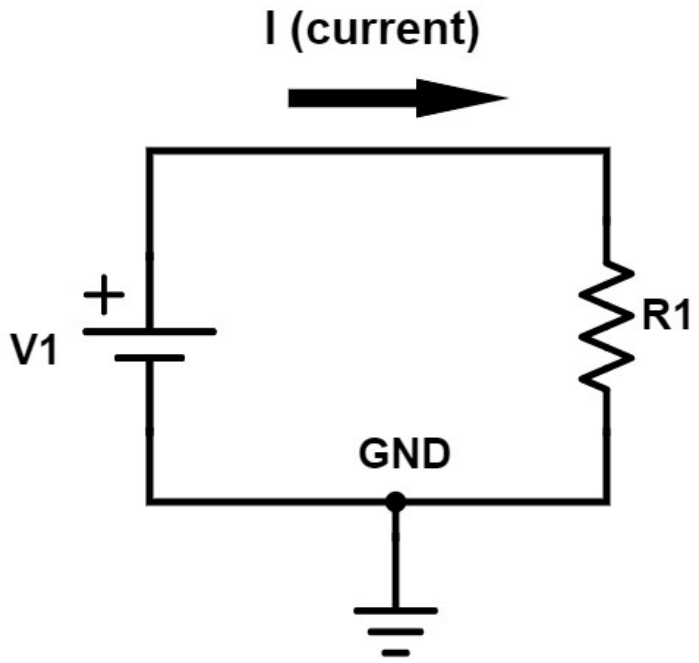
Calculate the current at 5V.

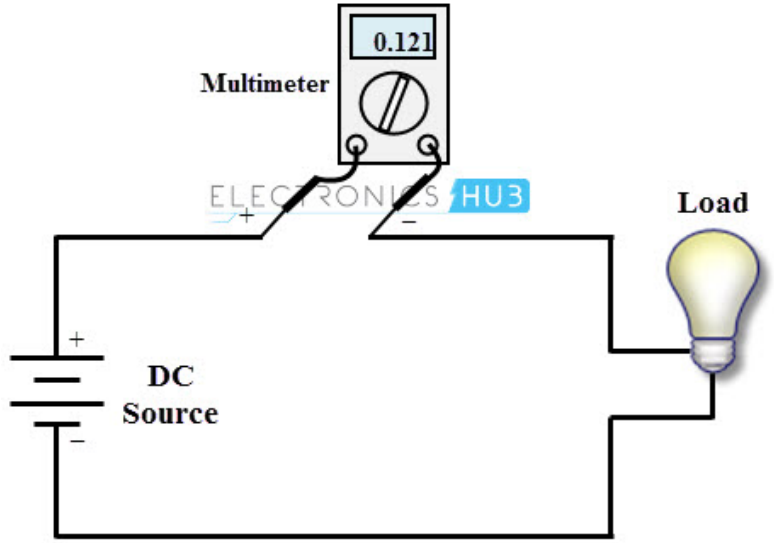
Now let's build a circuit and measure it.

Let’s build this simple circuit

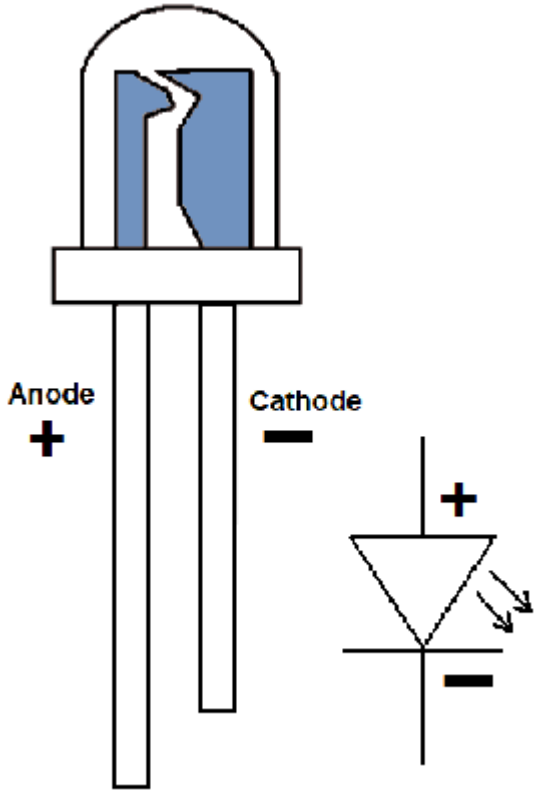
Things to consider:

- Max current in multimeter → don’t burn it
- Resistors are rated 0.25W (reminder W=V*A) → don’t burn them





LED – Light Emitting Diode



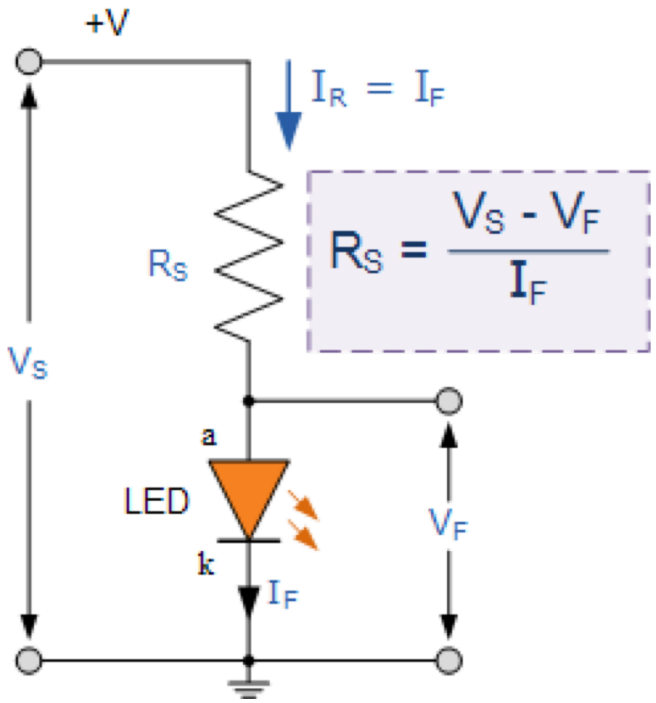
From the datasheet of a standard 5mm LED

ITEMS	Symbol	Absolute Maximum Rating	Unit
Forward Current	I_F	20	mA
Peak Forward Current	I_{FP}	30	mA
Suggestion Using Current	I_{su}	16-18	mA
Reverse Voltage (V_R=5V)	I_R	10	uA
Power Dissipation	P_D	105	mW
Operation Temperature	T_{OPR}	-40 ~ 85	℃
Storage Temperature	T_{STG}	-40 ~ 100	℃
Lead Soldering Temperature	T_{SOL}	Max. 260℃ for 3 Sec. Max. (3mm from the base of the expoxy bulb)	

ITEMS	Symbol	Test condition	Min.	Typ.	Max.	Unit
Forward Voltage	V_F	I_F=20mA	1.8	---	2.2	V
Wavelenength (nm) or TC(k)	$\Delta\lambda$	I_F=20mA	620	---	625	nm
*Luminous intensity	I_V	I_F=20mA	150	---	200	mcd

Good LED tutorials:
https://www.electronics-tutorials.ws/diode/diode_8.html
https://learn.sparkfun.com/tutorials/light-emitting-diodes-leds/all

Example

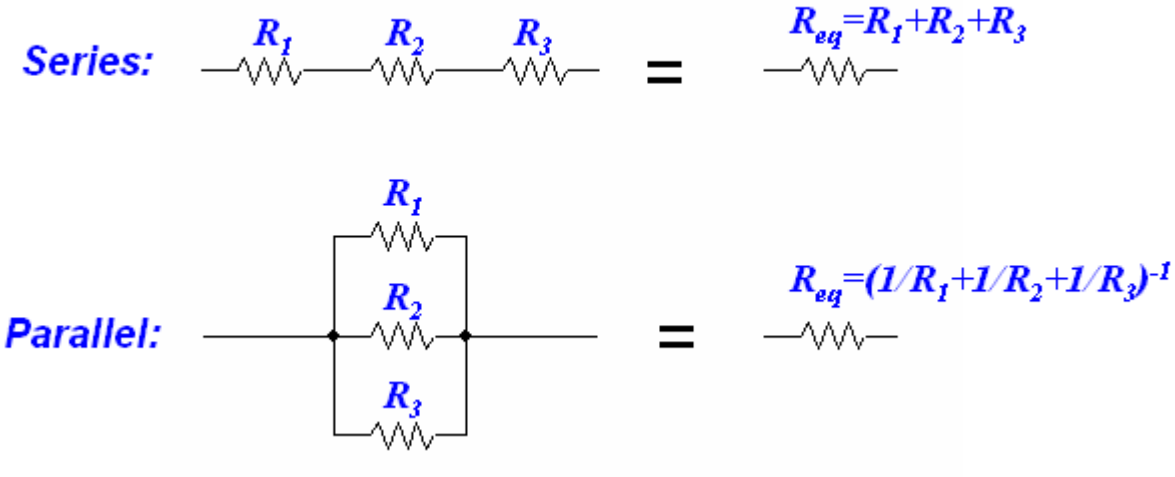


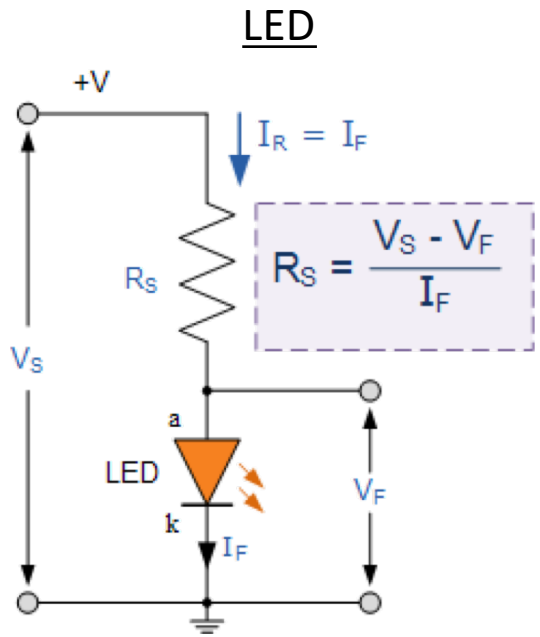
$$R_S = \frac{V_S - V_F}{I_F} = \frac{5v - 2v}{10mA} = \frac{3}{10 \times 10^{-3}} = 300\Omega$$

What resistor will you use for a 12V power supply?
Try it…

Exercises:

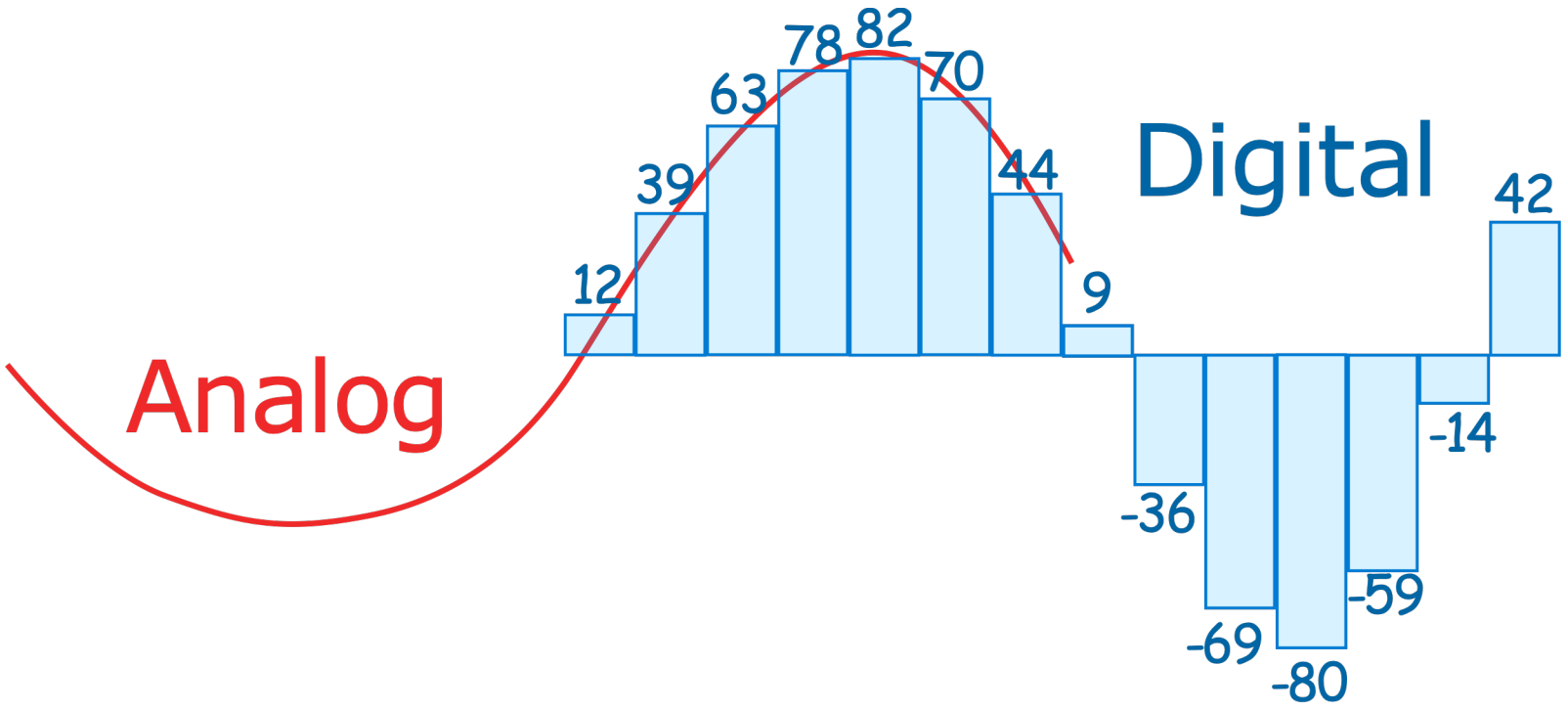
- Plan and create a circuit with 50uA current
- Play with resistors in series and in parallel to create unique resistance values
  - Reminder:





Test and see if its true……

Analog signal, sensors and measurement



ESP32/Arduino measures voltage using an ADC

Sensors

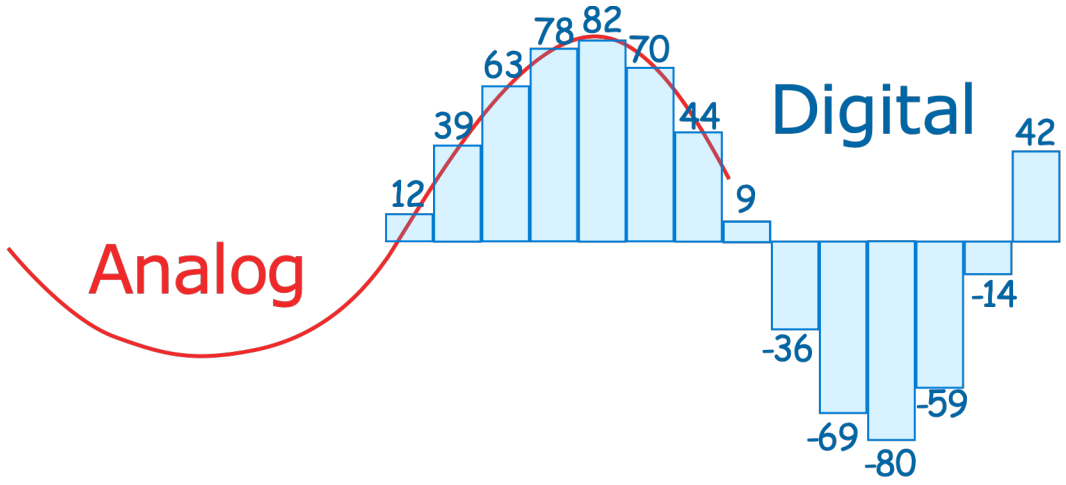
A sensor is a device that responds to any change in physical phenomena or environmental variables like heat, pressure, humidity, movement etc. This change affects the physical, chemical or electromagnetic properties of the sensors which is further processed to a more usable and readable form. Sensor is the heart of a measurement system. It is the first element that comes in contact with environmental variables to generate an output.

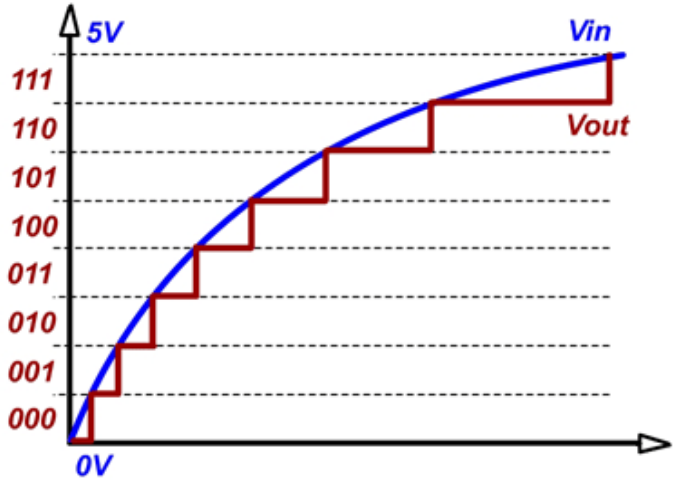
For us we will be working mostly with sensors that change in their electromagnetic properties:

- Change in voltage
  - Example: thermocouple / radiation sensors
- Change in resistance
  - Example: Thermistors / photoresistor / potentiometer
- Change in current
  - Example: Some light sensors
- Change in capacitance
  - Example: Humidity and Soil moisture
- Open/close electrical circuit – Pulse
  - Exsample: wind sensor (anemometer), switches

ESP32/Arduino measures only voltage and it does so using an Analog to Digital Converter (ADC)

ADC – Analog to Digital Converter





1 Bit

can be 0 or 1

2 Bits = 4 States

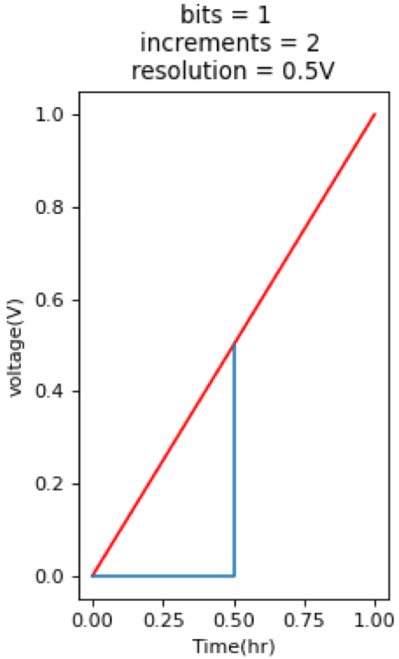
0 0 | 0 1 | 1 0 | 1 1

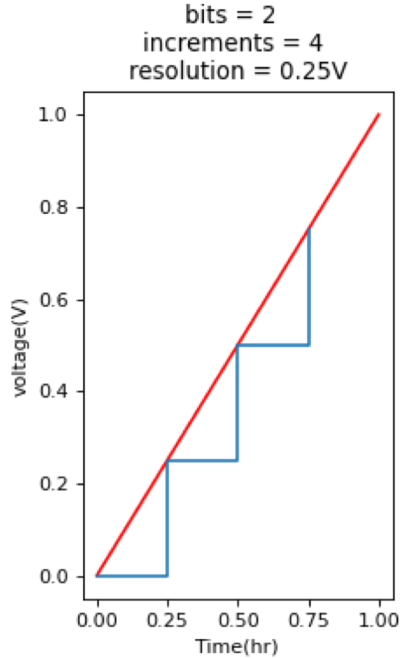
3 Bits = 8 States

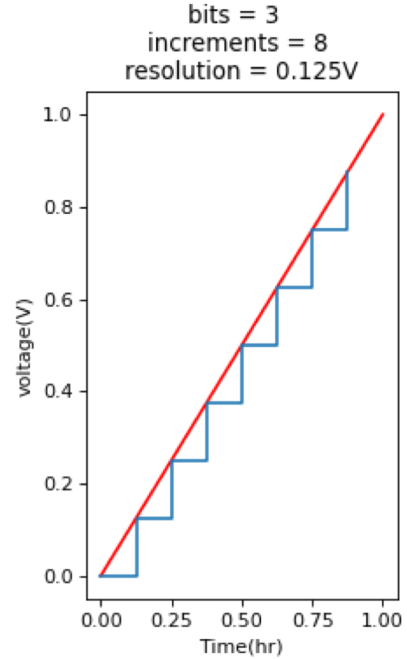
0 0 0 | 0 0 1 | 0 1 0 | 0 1 1

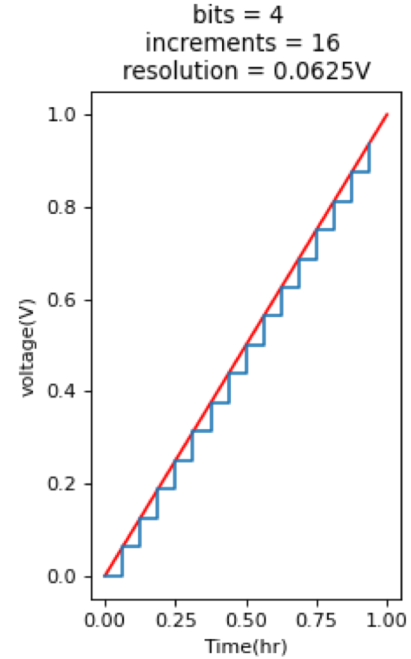
1 0 0 | 1 0 1 | 1 1 0 | 1 1 1

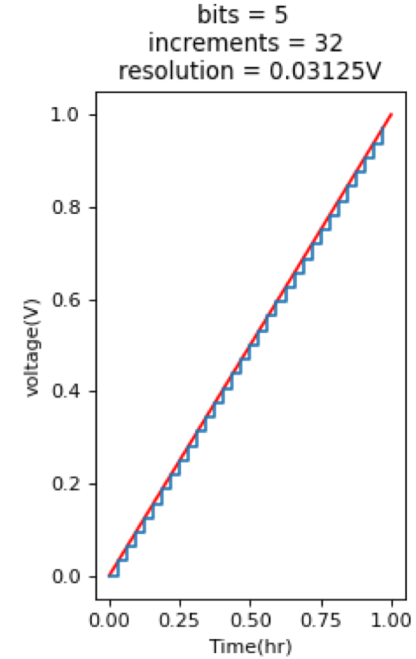
$$Number\ of\ states = 2^{bit}$$

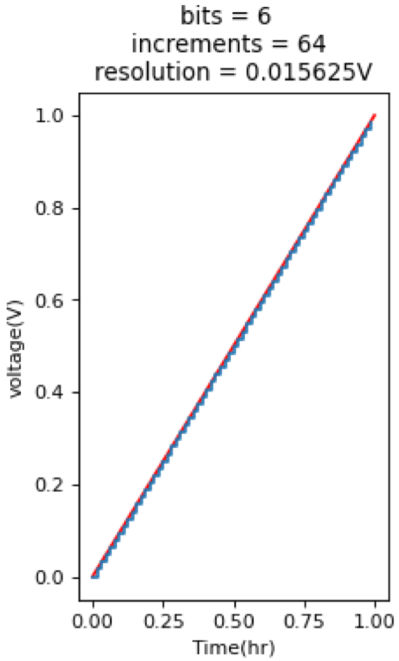

bits = 1
increments = 2
resolution = 0.5V
voltage(V)
Time(hr)

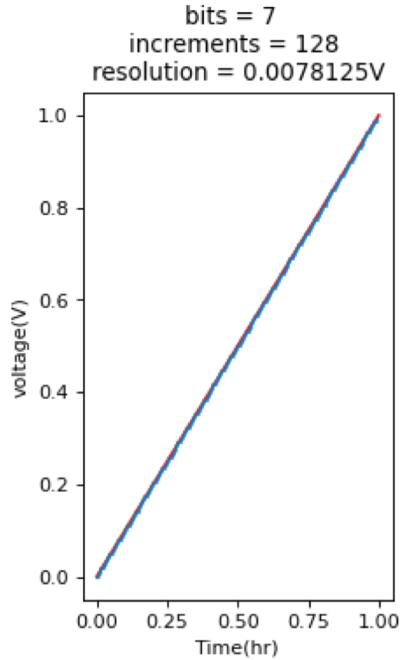

bits = 2
increments = 4
resolution = 0.25V
voltage(V)
Time(hr)

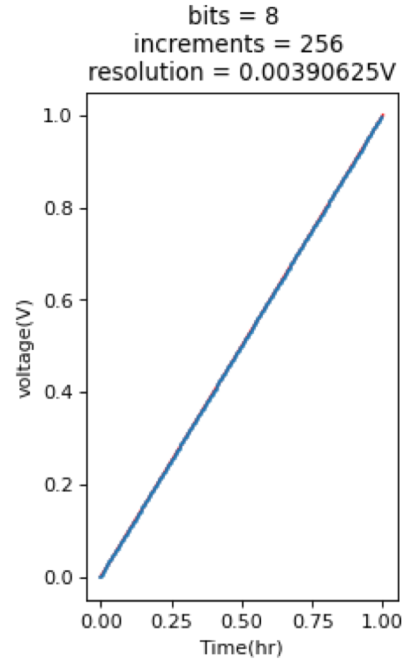

bits = 3
increments = 8
resolution = 0.125V
voltage(V)
Time(hr)

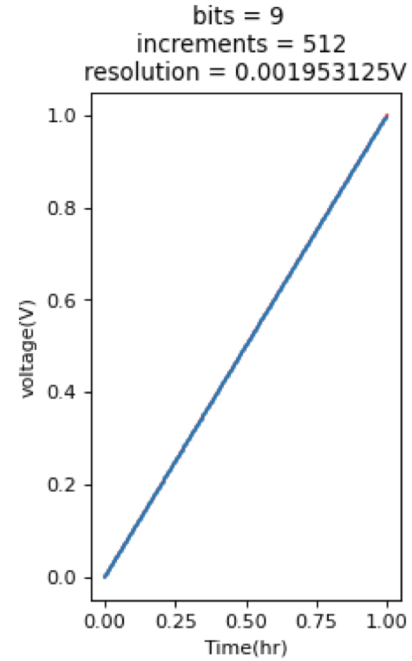

bits = 4
increments = 16
resolution = 0.0625V
voltage(V)
Time(hr)

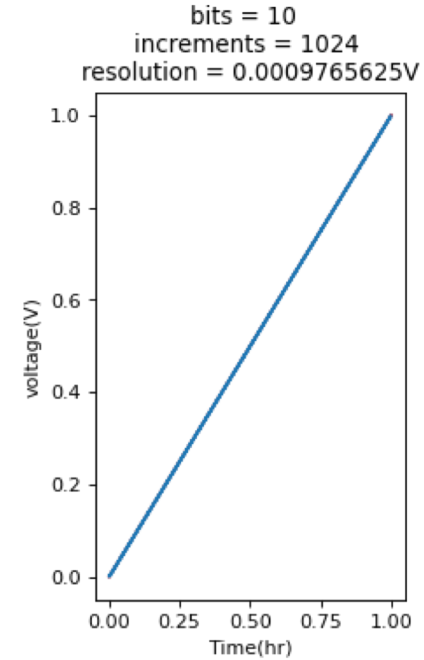

bits = 5
increments = 32
resolution = 0.03125V
voltage(V)
Time(hr)


bits = 6
increments = 64
resolution = 0.015625V
voltage(V)
Time(hr)


bits = 7
increments = 128
resolution = 0.0078125V
voltage(V)
Time(hr)


bits = 8
increments = 256
resolution = 0.00390625V
voltage(V)
Time(hr)


bits = 9
increments = 512
resolution = 0.001953125V
voltage(V)
Time(hr)


bits = 10
increments = 1024
resolution = 0.0009765625V
voltage(V)
Time(hr)

What ADCs we have

Module:	Arduino	ESP32	ADS1115
ADC bits	10	12	16
Range (V)	0-5 0-1.1 0-reference (<5)	0-3.3	+/- 6.144V +/- 4.096V +/- 2.048V +/- 1.024V +/- 0.512V +/- 0.256V
Accuracy	Good	Bad (noisy & no- linear)	excelent
Max resolution?			

Try calculating the max resolution

$$Resolution = \frac{Range}{2^{bit}}$$

What ADCs we have

Module:	Arduino	ESP32	ADS1115
ADC bits	10	12	16
Range (V)	0-5 0-1.1 0-reference (<5)	0-3.3	+/- 6.144V +/- 4.096V +/- 2.048V +/- 1.024V +/- 0.512V +/- 0.256V
Accuracy	Good	Bad (noisy & no- linear)	excellent
Max resolution	1.07mV	0.805mV	0.0078125mV

Devices only measure voltage, so how do we convert to voltage?

Change in voltage

No problem

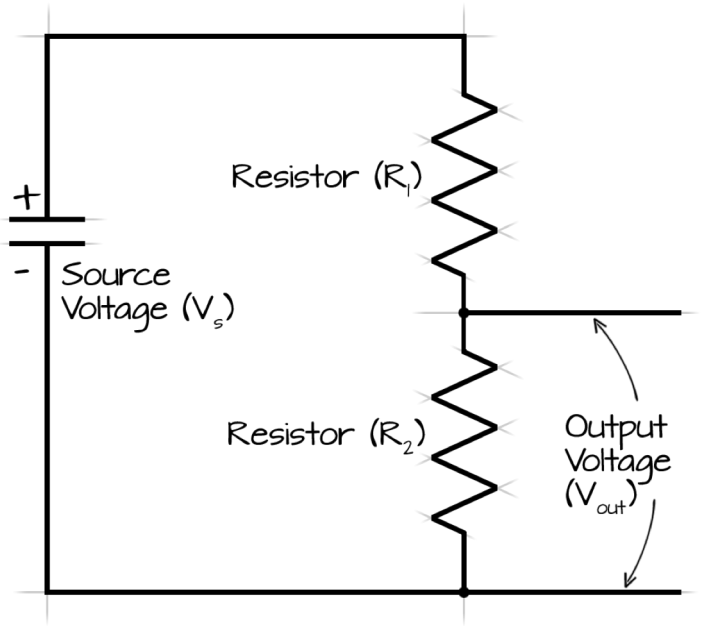
Change in current

Add resistor with known value

V = I * R

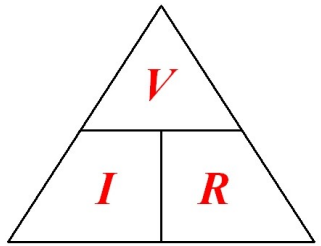
Change in resistance

Voltage divider



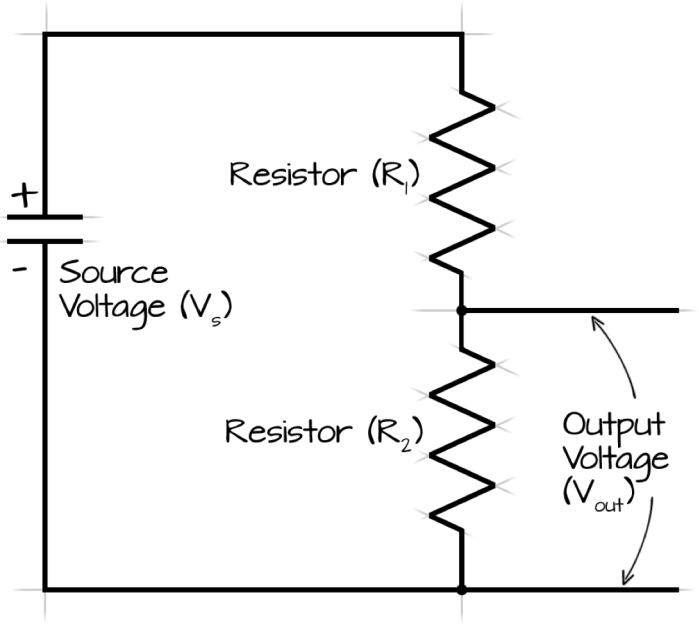
What is the relation between R2 and Vout?

$$V = I\,R$$



$$I = \frac{V}{R} \qquad R = \frac{V}{I}$$

Voltage divider



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

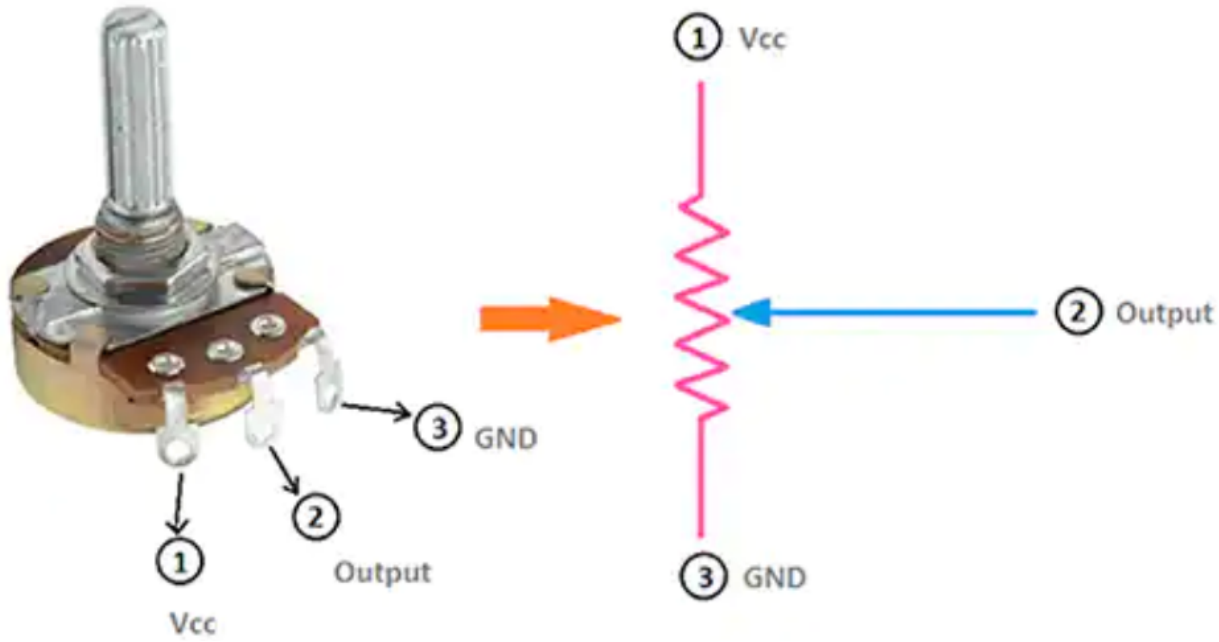
$$if\, R_1 = R_2 : V_{out} = V_{in} \cdot \frac{R}{2R} = \frac{V_{in}}{2}$$

$$if\, R_2 \gg R_1 : V_{out} \approx V_{in} \cdot \frac{R_2}{R_2} = V_{in}$$

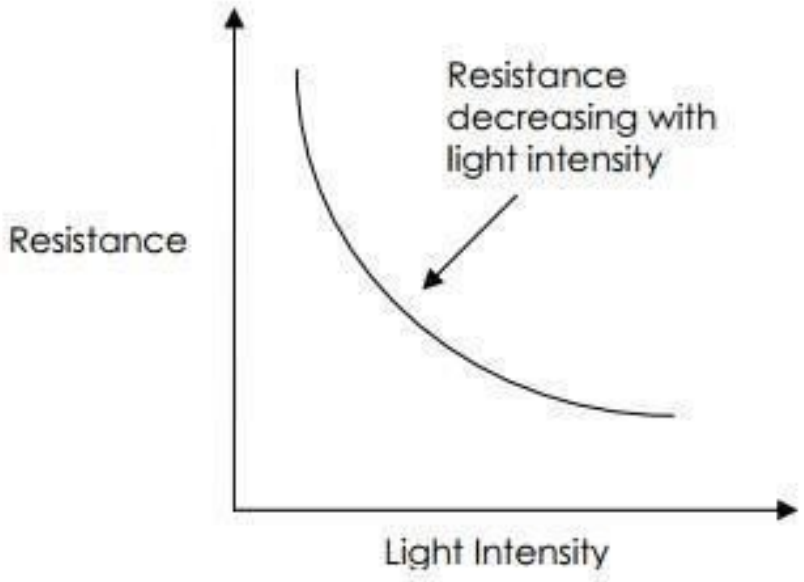
$$if\, R_2 \ll R_1 : V_{out} \approx V_{in} \cdot \frac{0}{R_1} = 0$$

Potentiometer

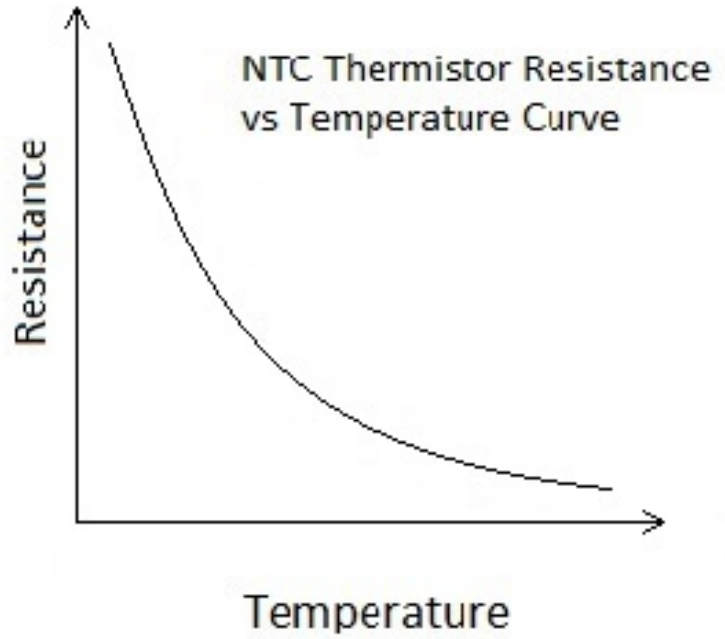
Has “built in” variable voltage divider

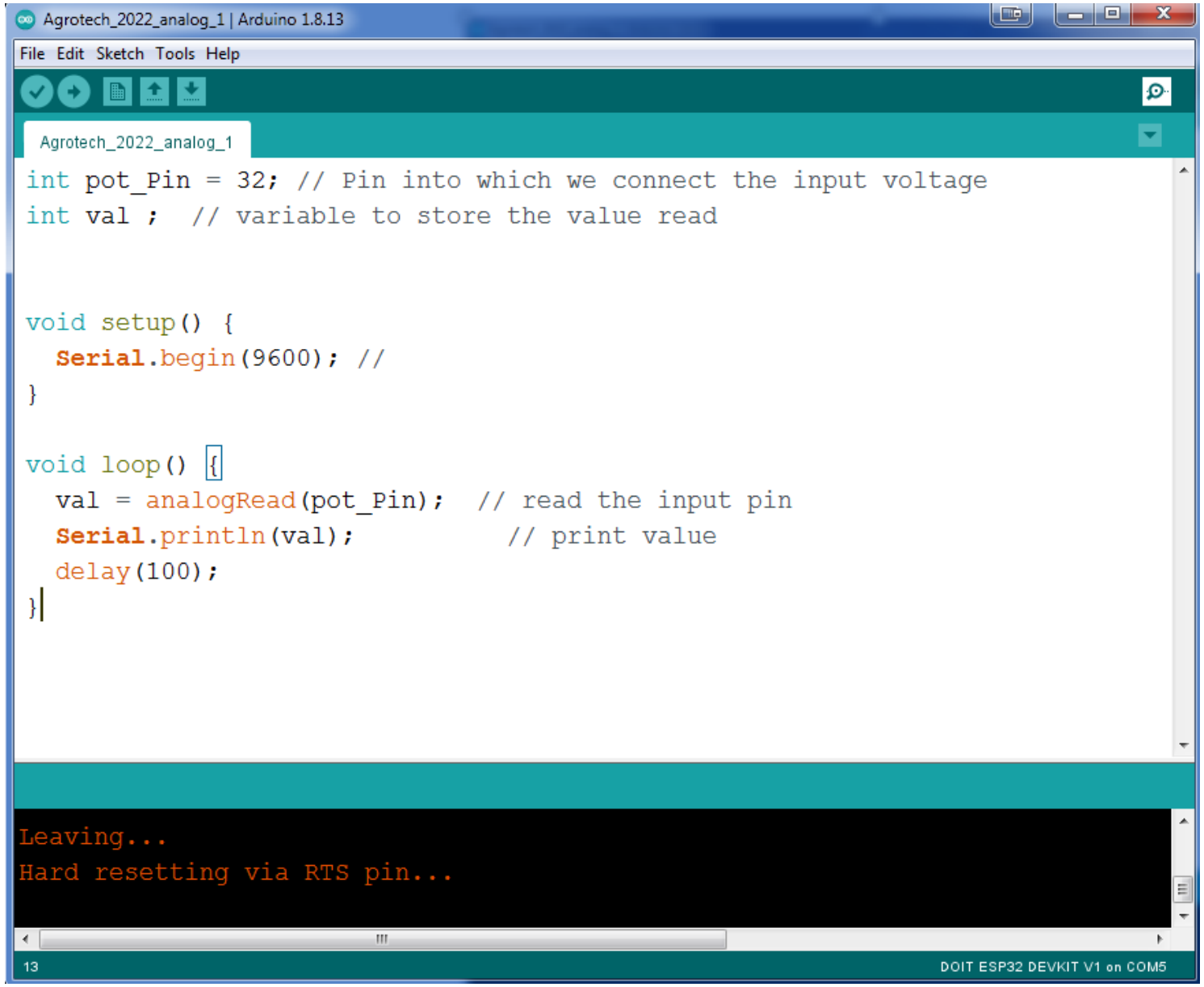


Photoresistor



Thermistor





Class work

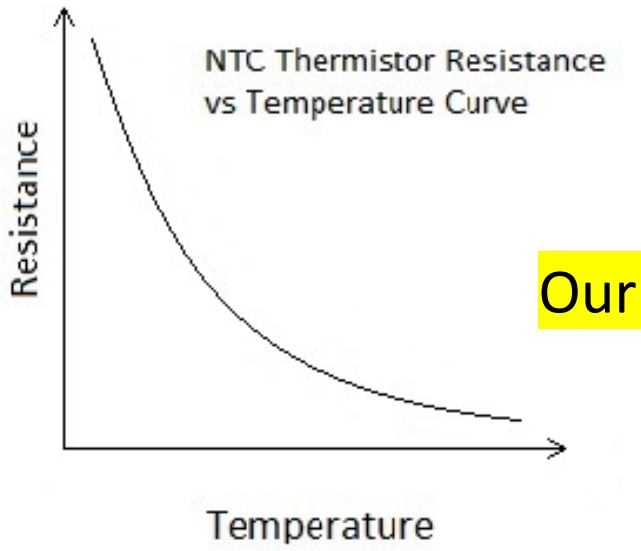
Upload the code and connect:

1. Potentiometer
2. Photoresistor
3. Thermistor

Turn ADC value into:

1) Voltage (V2)
2) R2 value
3) bonus - convert resistance to Temperature

From resistance to temperature



Our B value = 4150

Model equations and calculator of constants for thermistors:
https://www.thinksrs.com/downloads/programs/therm%20calc/ntccalibrator/ntccalculator.html

Thermistor tutorial:
https://learn.adafruit.com/thermistor/using-a-thermistor?gclid=CjwKCAjw8sCRBhA6EiwA6_IF4aVJKhNGZ1uXLi9KoB-jvnO2kBAEfc7wec8Rc3JcZuQGs_f4GHzYKRoCxxoQAvD_BwE

Temp(C)	min(Ω)	center(Ω)	max(Ω)
9	21.311	21.694	22.081
10	20.334	20.690	21.049
11	19.287	19.613	19.944
12	18.356	18.658	18.962
13	17.475	17.753	18.034
14	16.641	16.898	17.157
15	15.852	16.088	16.327
16	15.104	15.322	15.541
17	14.396	14.596	14.798
18	13.724	13.909	14.094
19	13.088	13.257	13.428
20	12.484	12.640	12.796
21	11.912	12.055	12.198
22	11.369	11.500	11.631
23	10.853	10.973	11.093
24	10.364	10.474	10.583
25	9.900	10.000	10.100
26	9.450	9.549	9.649
27	9.022	9.122	9.222
28	8.617	8.716	8.815
29	8.232	8.330	8.429
30	7.866	7.964	8.062
31	7.518	7.615	7.712
32	7.188	7.284	7.380
33	6.874	6.968	7.064
34	6.575	6.669	6.763
35	6.291	6.383	6.476
36	6.021	6.112	6.203
37	5.763	5.853	5.943
38	5.518	5.607	5.695
39	5.285	5.372	5.459
40	5.063	5.148	5.234
41	4.851	4.935	5.020
42	4.650	4.732	4.815