USC University of Southern California

ECE 105: Introduction to Electrical Engineering

Lecture 2

System design and intro to Arduino

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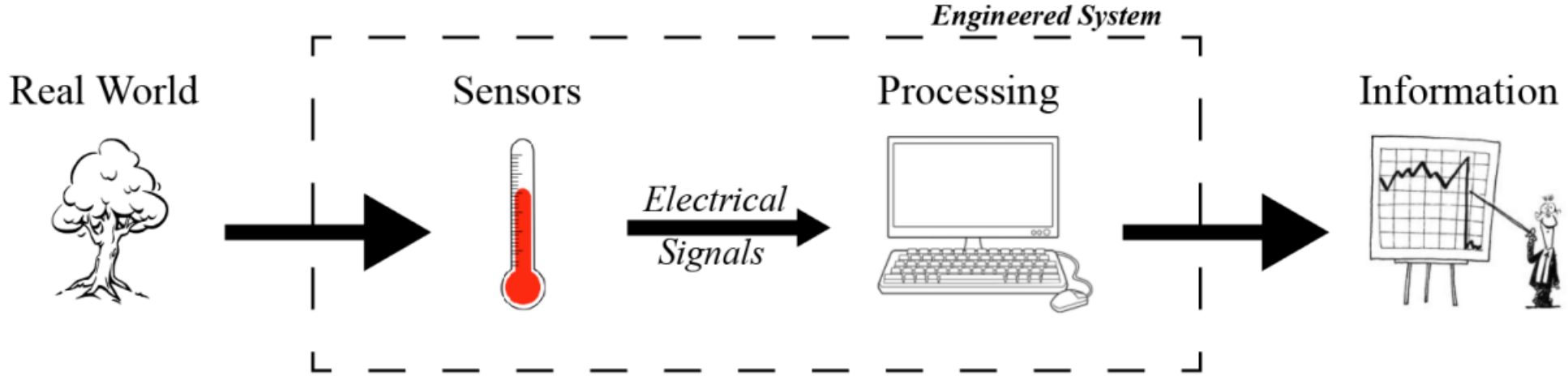
Rehan Kapadia

Breaking down engineering systems



Any signal, for example temperature, touch, brain signal, video inputs, etc.

Temperature sensors, resistive touchscreen, brain electrodes, camera, etc.

Modules in ECE 105: circuits, devices

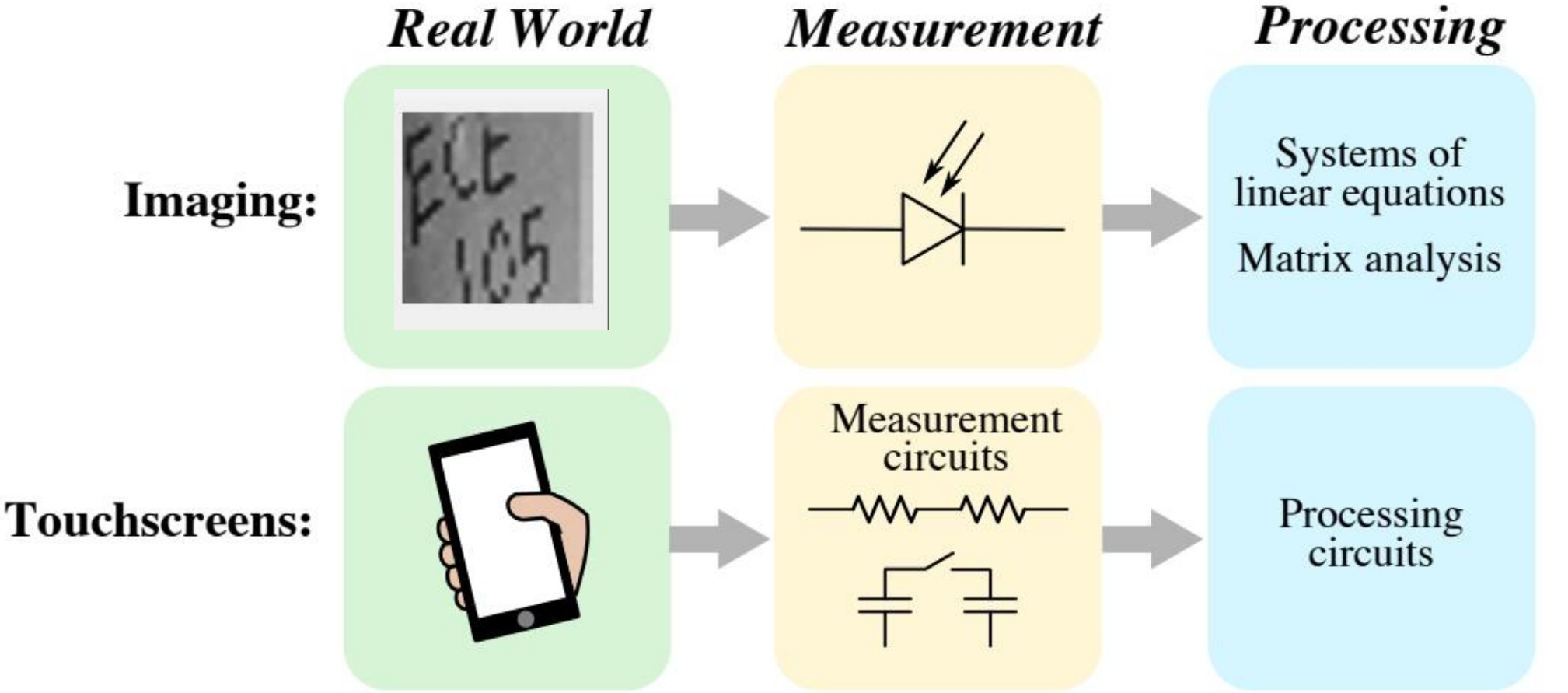
Industry positions in apple, intel, meta, neuralink, etc

Processing circuits, analog and digital computing, etc.

Modules in ECE 105: biosensor, linear algebra, neural network, optical comm

Industry positions in NVIDIA, Raytheon, Qualcomm, etc

Breakdown of hardware and software



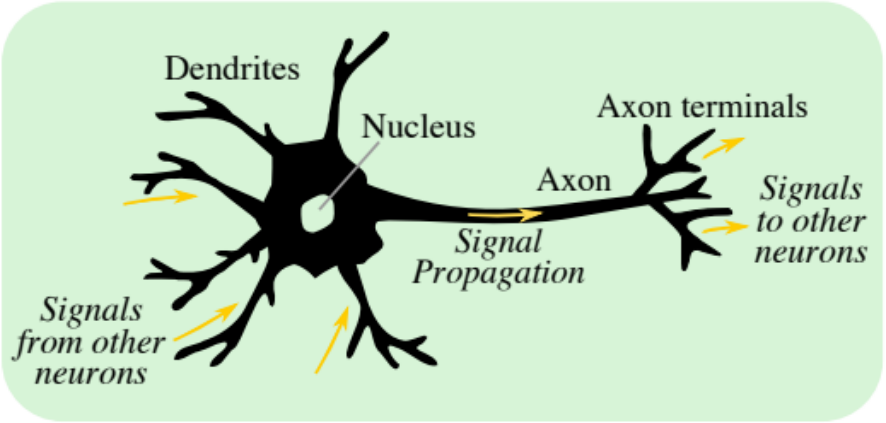
Hardware

Hardware + Software

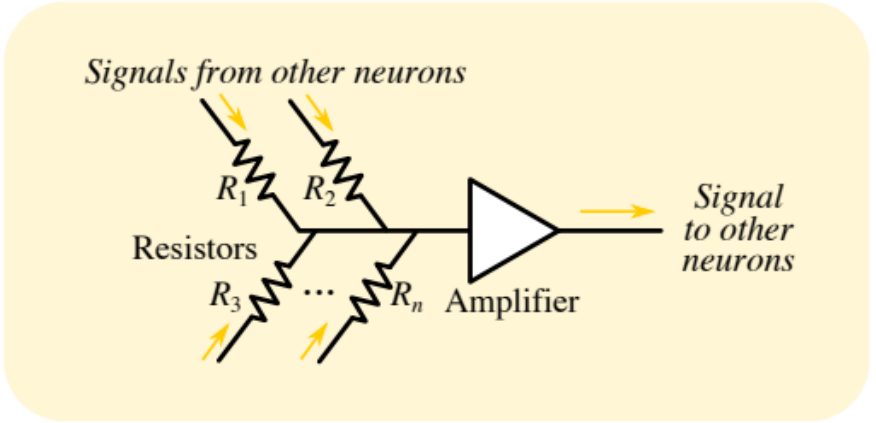
Our own sensors + Arduino

Software running in Arduino + python (jupyter notebook)

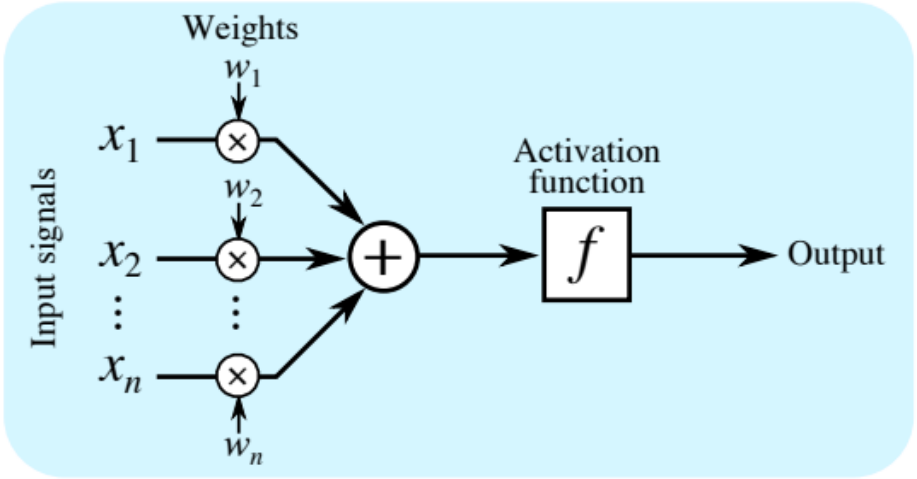
Equivalence to human body



Biological Neuron



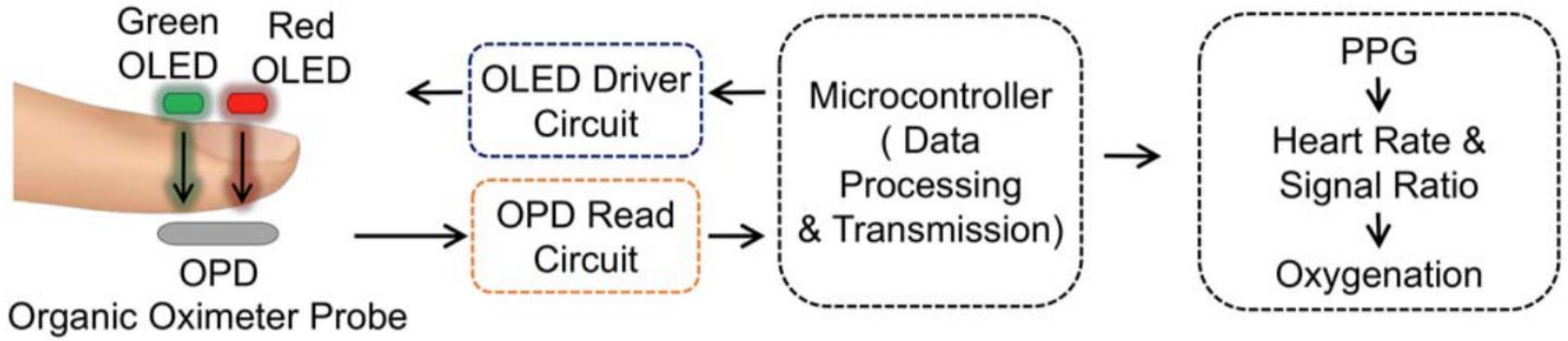
Circuit Model

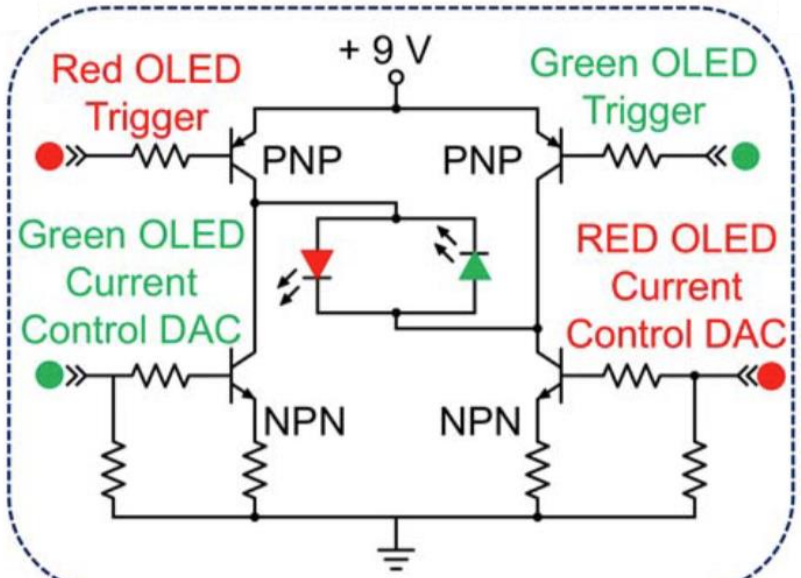


Artificial Neuron Model

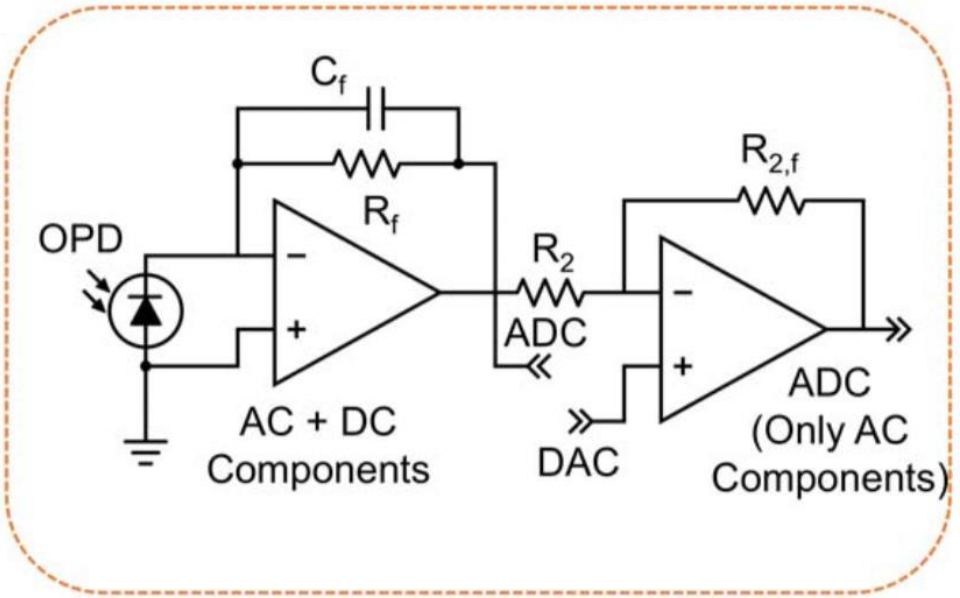
Oximeter system breakdown

Sensors Processing Information





OLED Driver Circuit



OPD Read Circuit

Resistive touchscreen system breakdown

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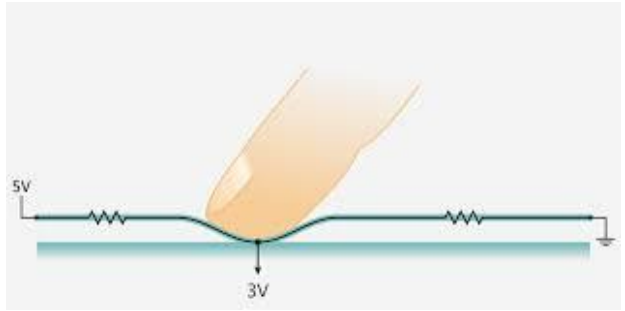
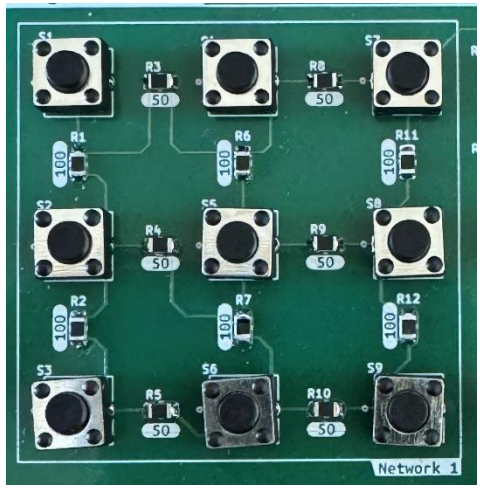
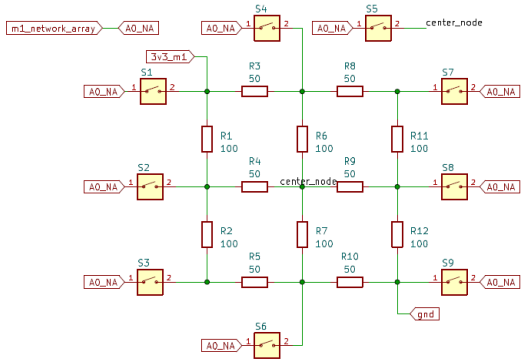
Real world

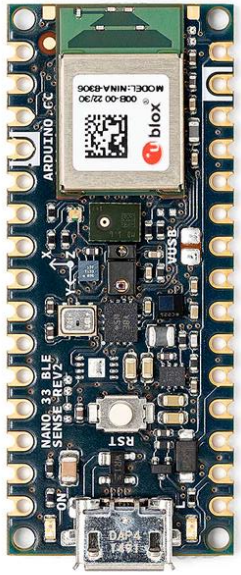


Sensors





Processing



Information

S1 S4 S7

S2 S5 S8

S3 S6 S9

Resistive touchscreen system approach

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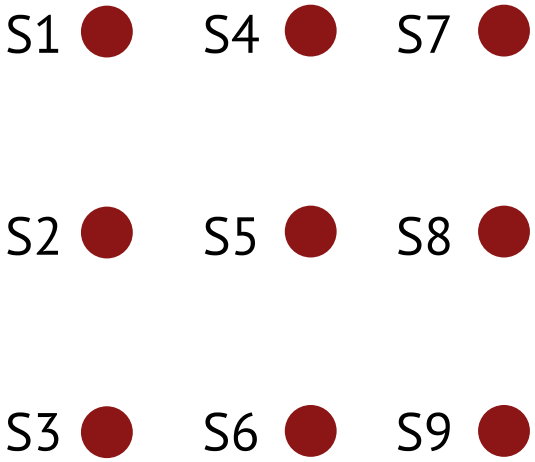
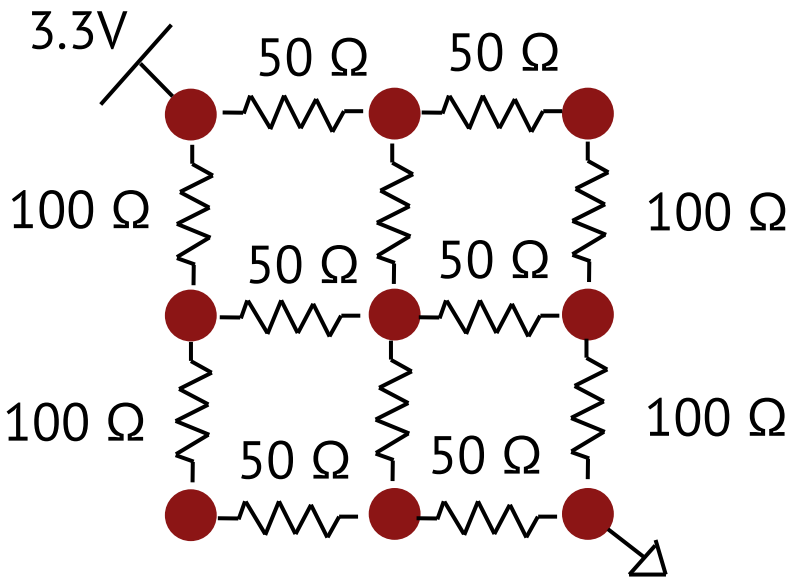
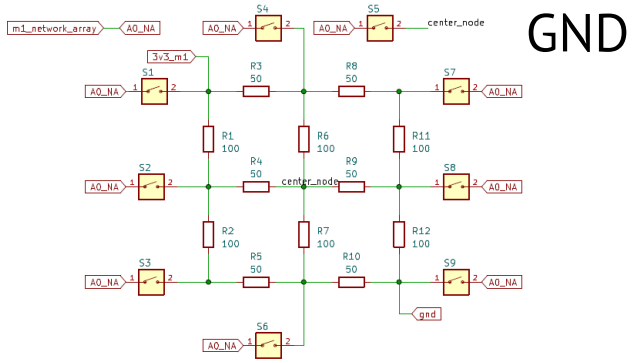
Goal

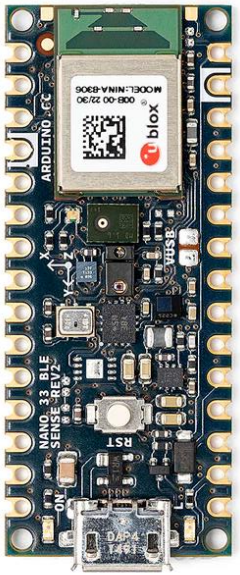


Build a sensor that can detect touch





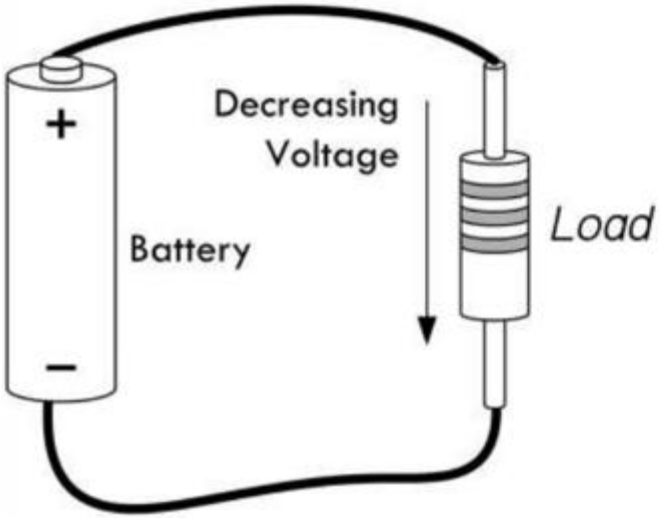
Connect to Arduino for processing

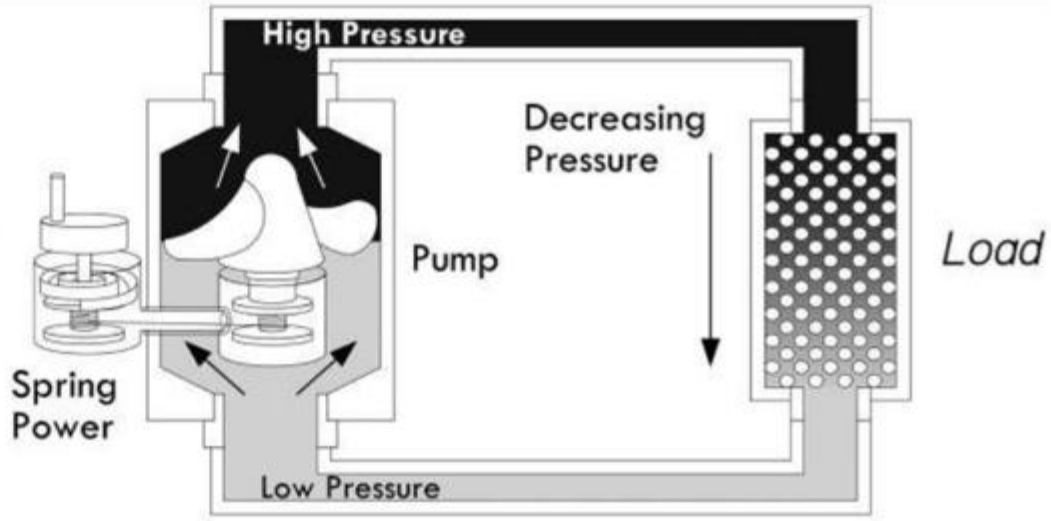


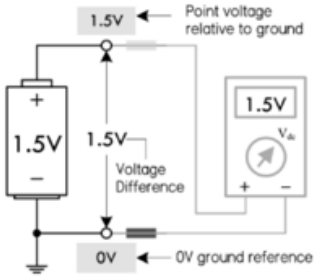
Get location from the voltage measurement

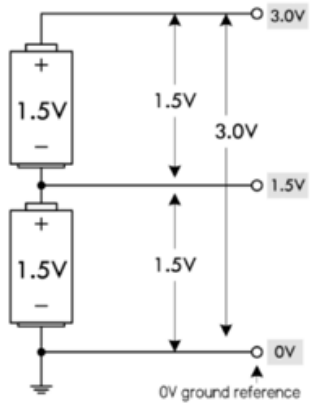
Voltage

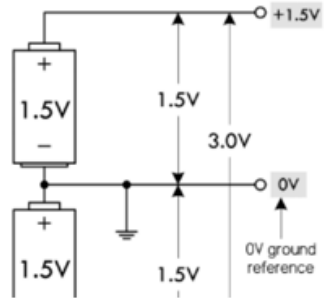
Voltage is the pressure from an electrical circuit's power source that pushes charged electrons (current) through a conducting loop, enabling them to do work such as illuminating a light. In brief, **voltage = pressure, and it is measured in volts (V)**. The term recognizes Italian physicist Alessandro Volta (1745-1827), inventor of the voltaic pile—the forerunner of today's household battery. In electricity's early days, voltage was known as electromotive force (emf).





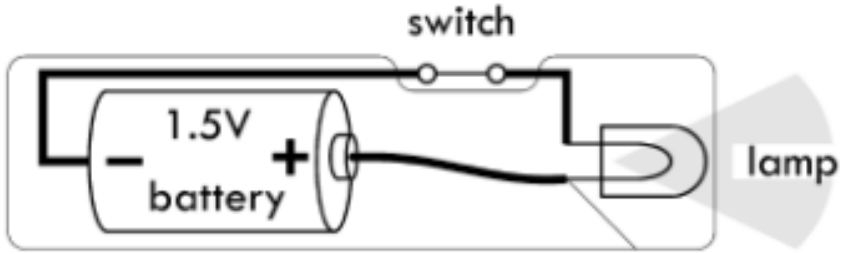




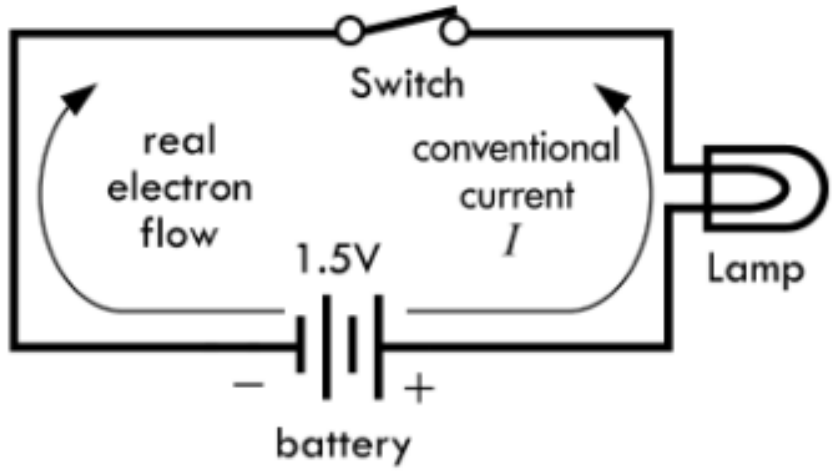


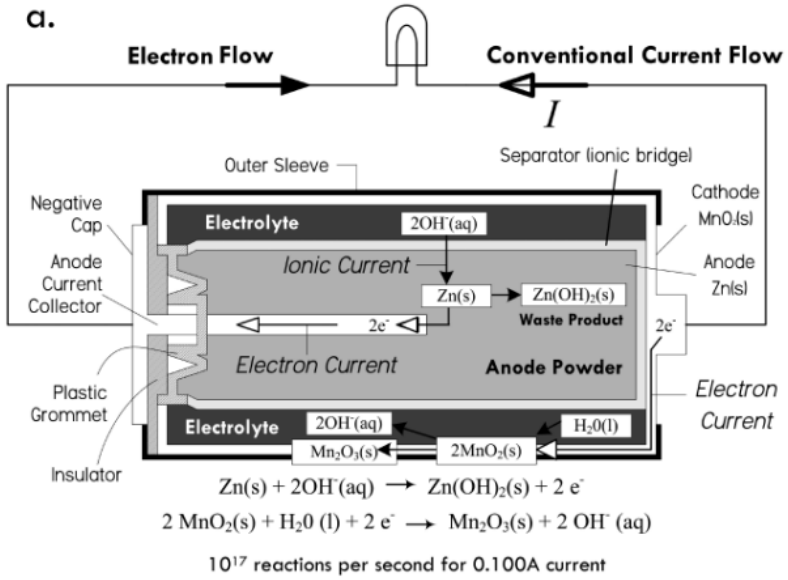
Voltage

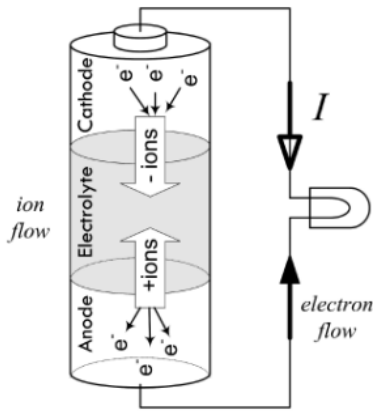
Flashlight

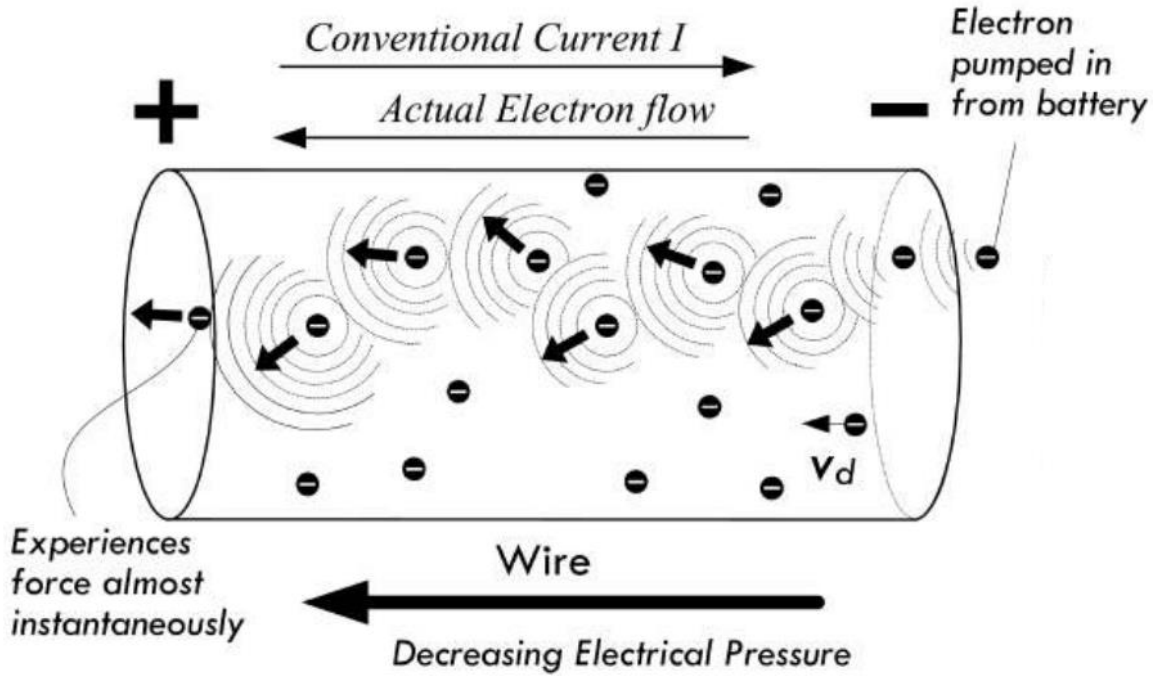


Schematic Diagram



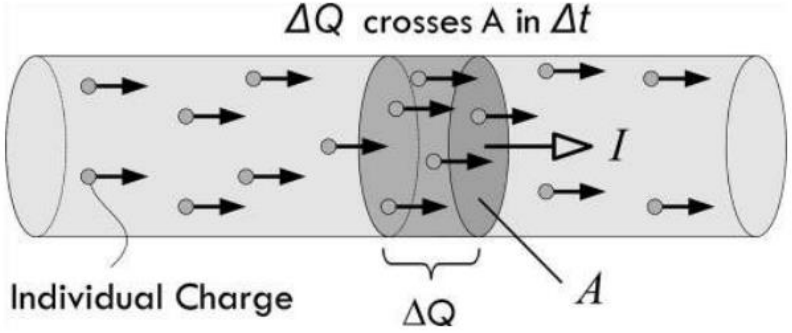


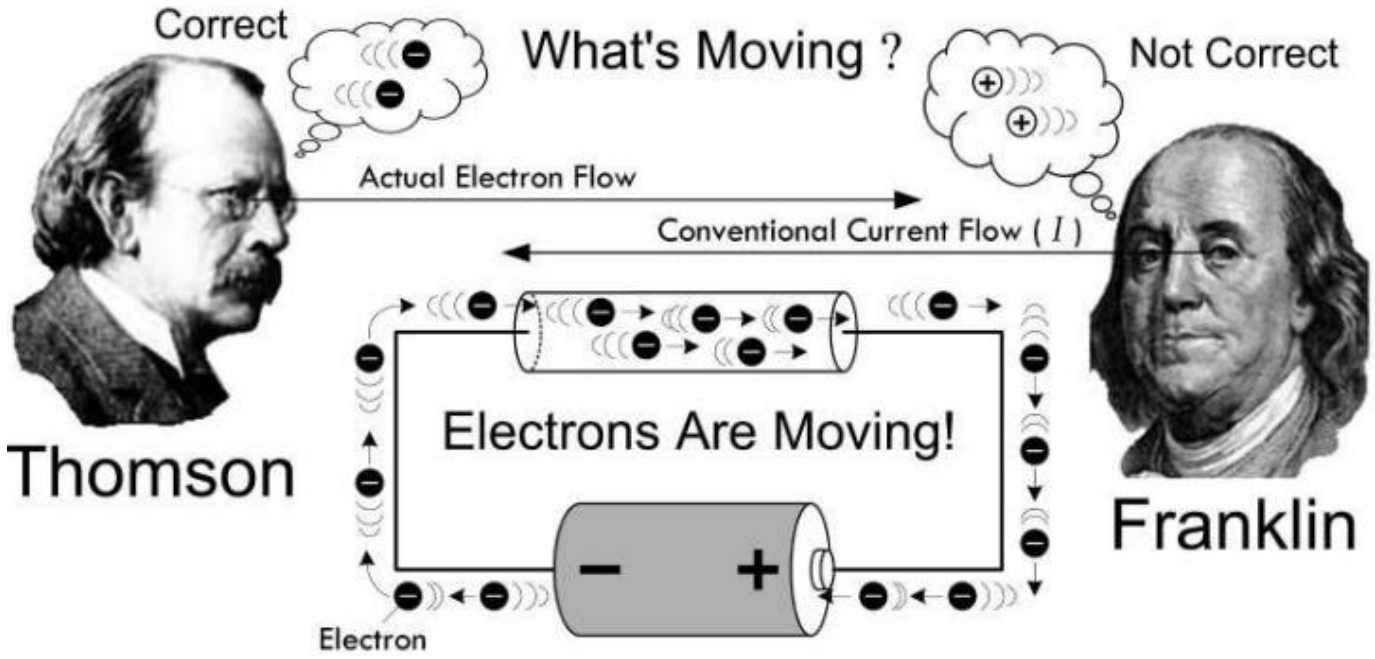




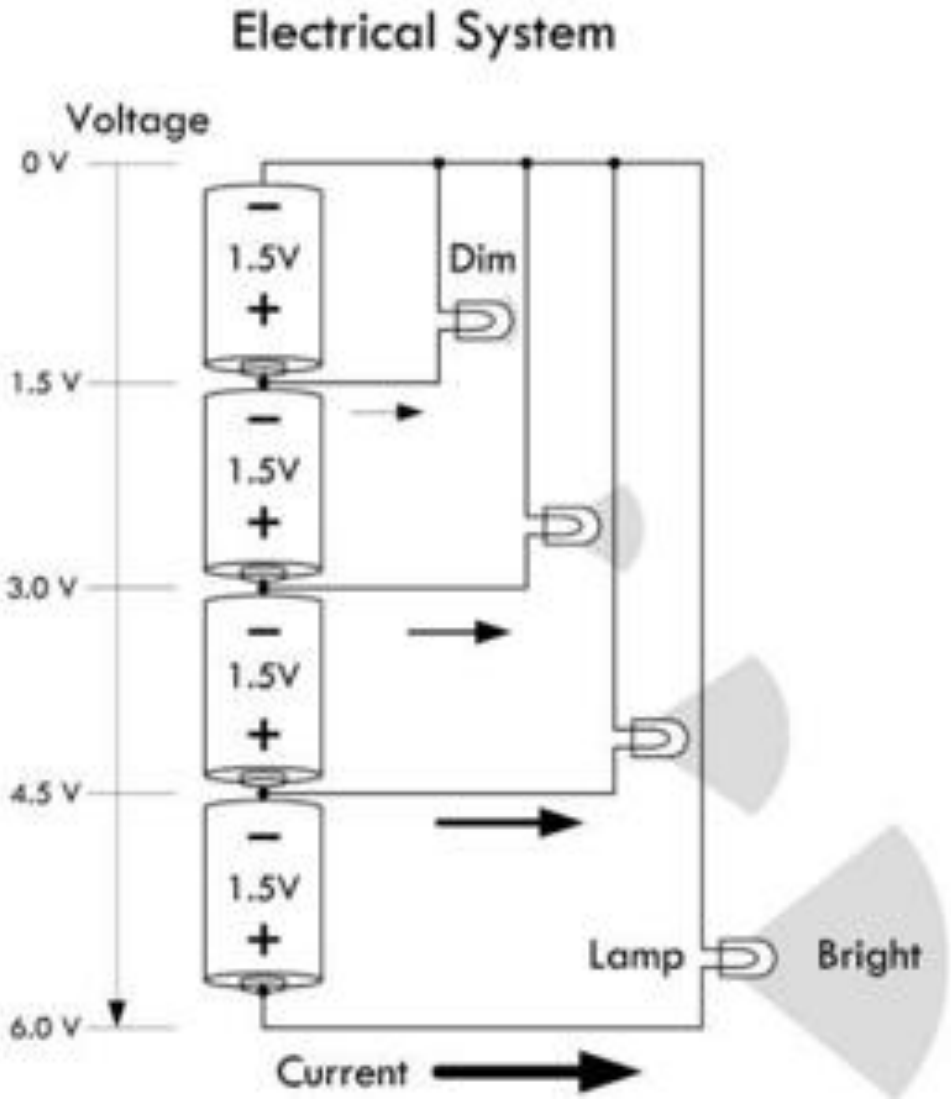
Flow of charge – current

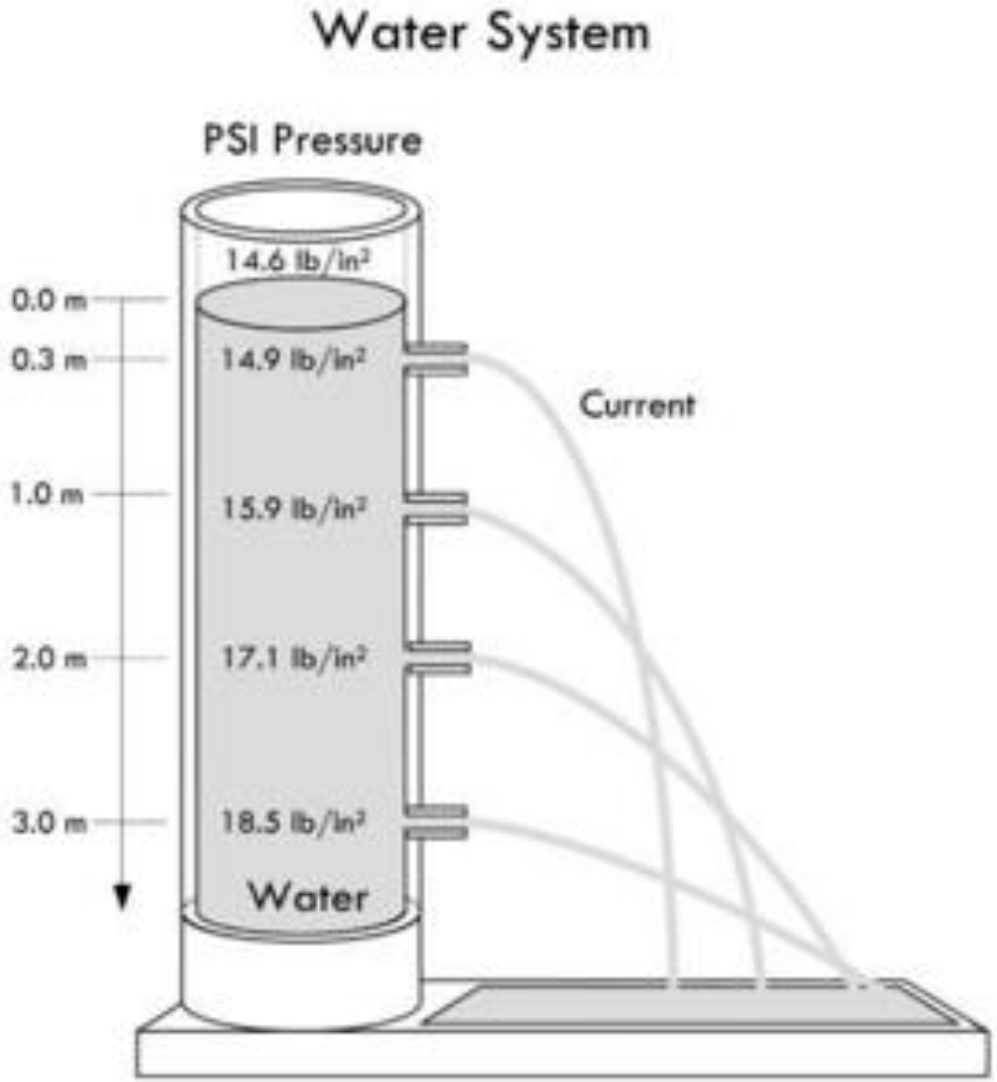
Current is the rate at which electrons flow past a point in a complete electrical circuit. At its most basic, **current = flow.**
An **ampere** (AM-pir), or **amp**, is the international unit used for measuring current. It expresses the quantity of electrons (sometimes called "electrical charge") flowing past a point in a circuit over a given time.
A current of 1 ampere means that 1 **coulomb** of electrons—that's 6.24 billion billion (6.24×10^{18}) electrons—is moving past a single point in a circuit in 1 second.



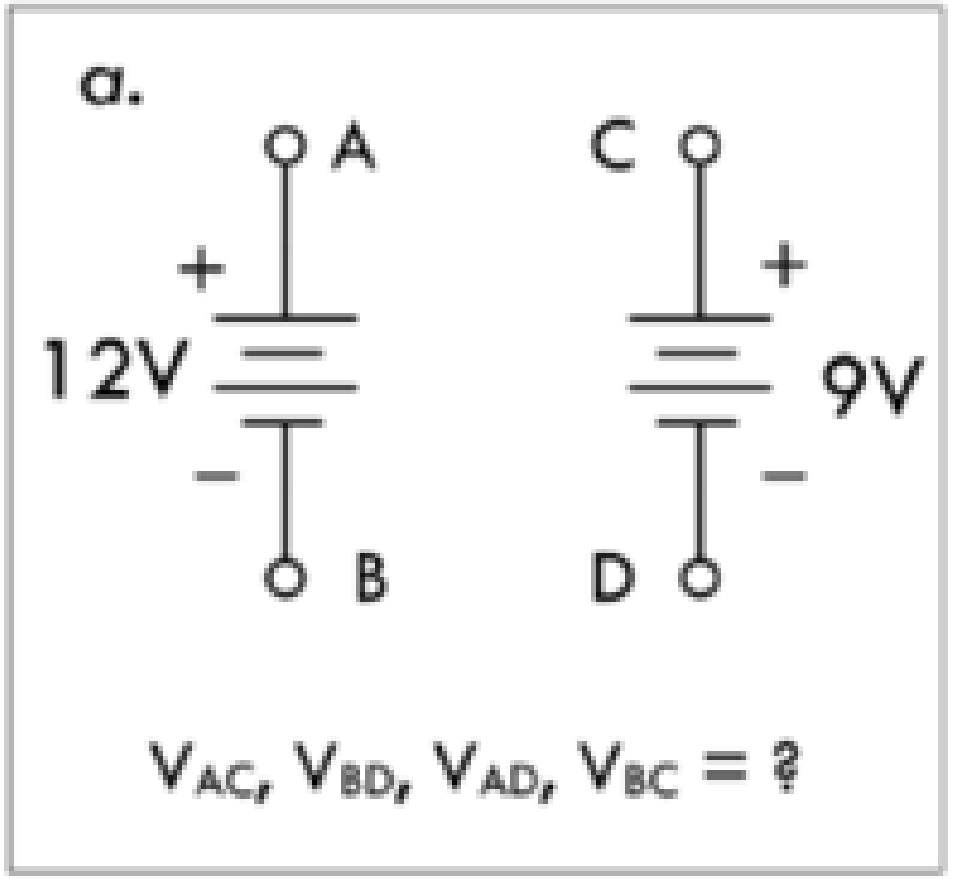


Increasing voltage / increasing water pressure

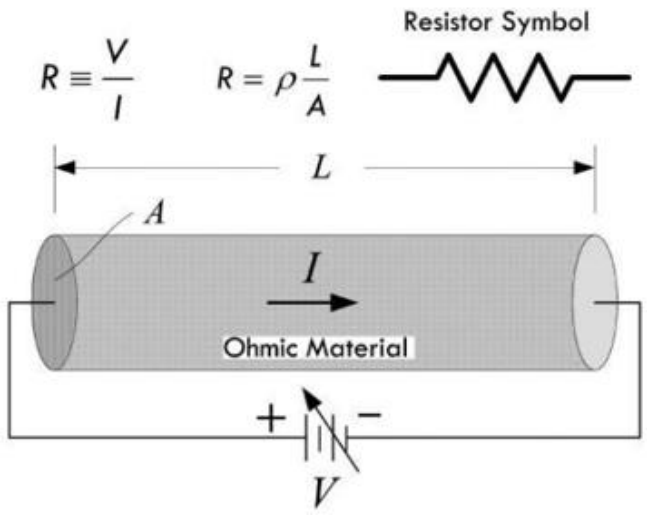


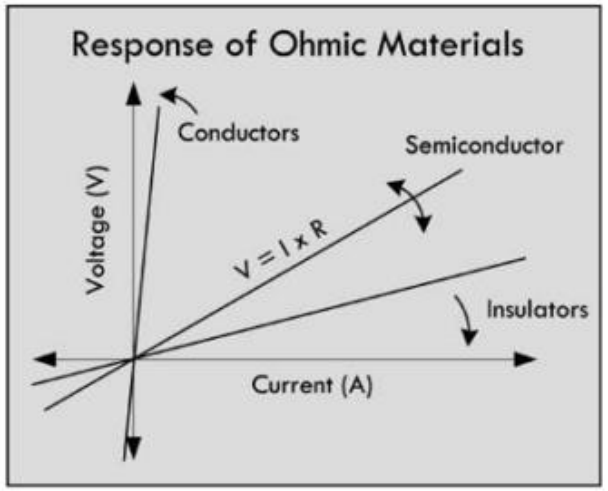


Voltage difference

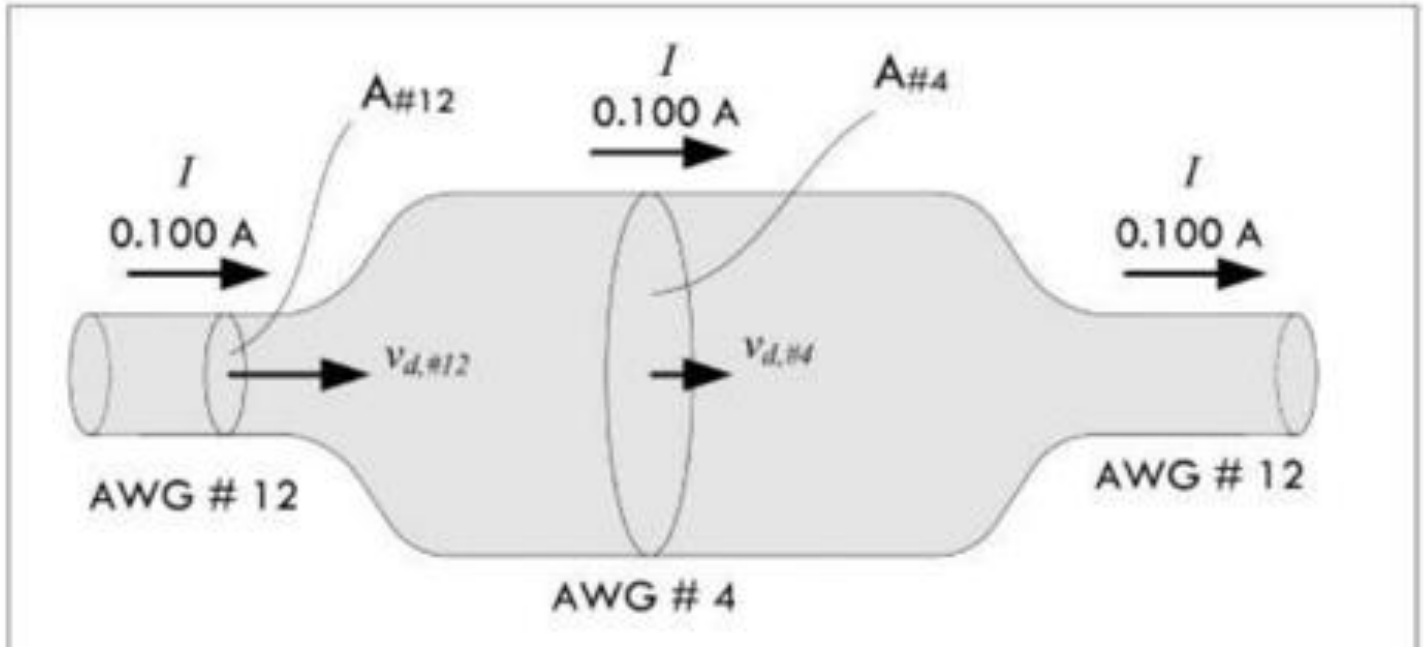


Resistance

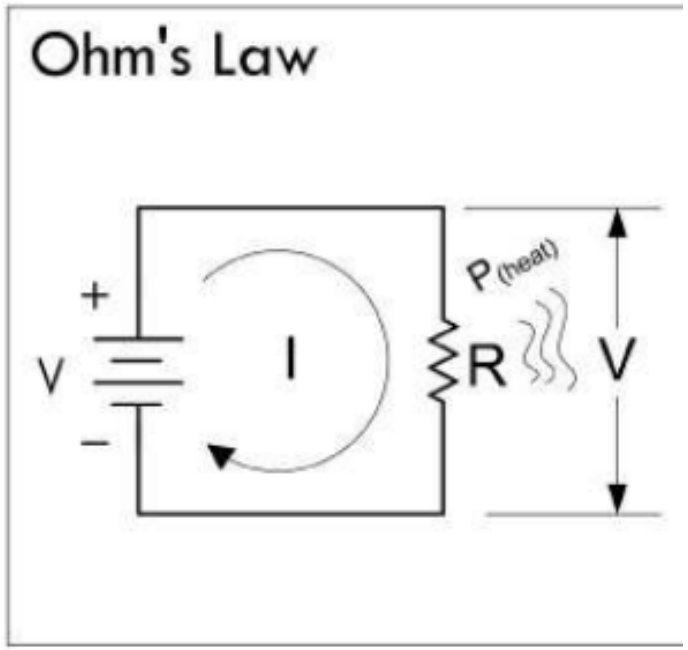


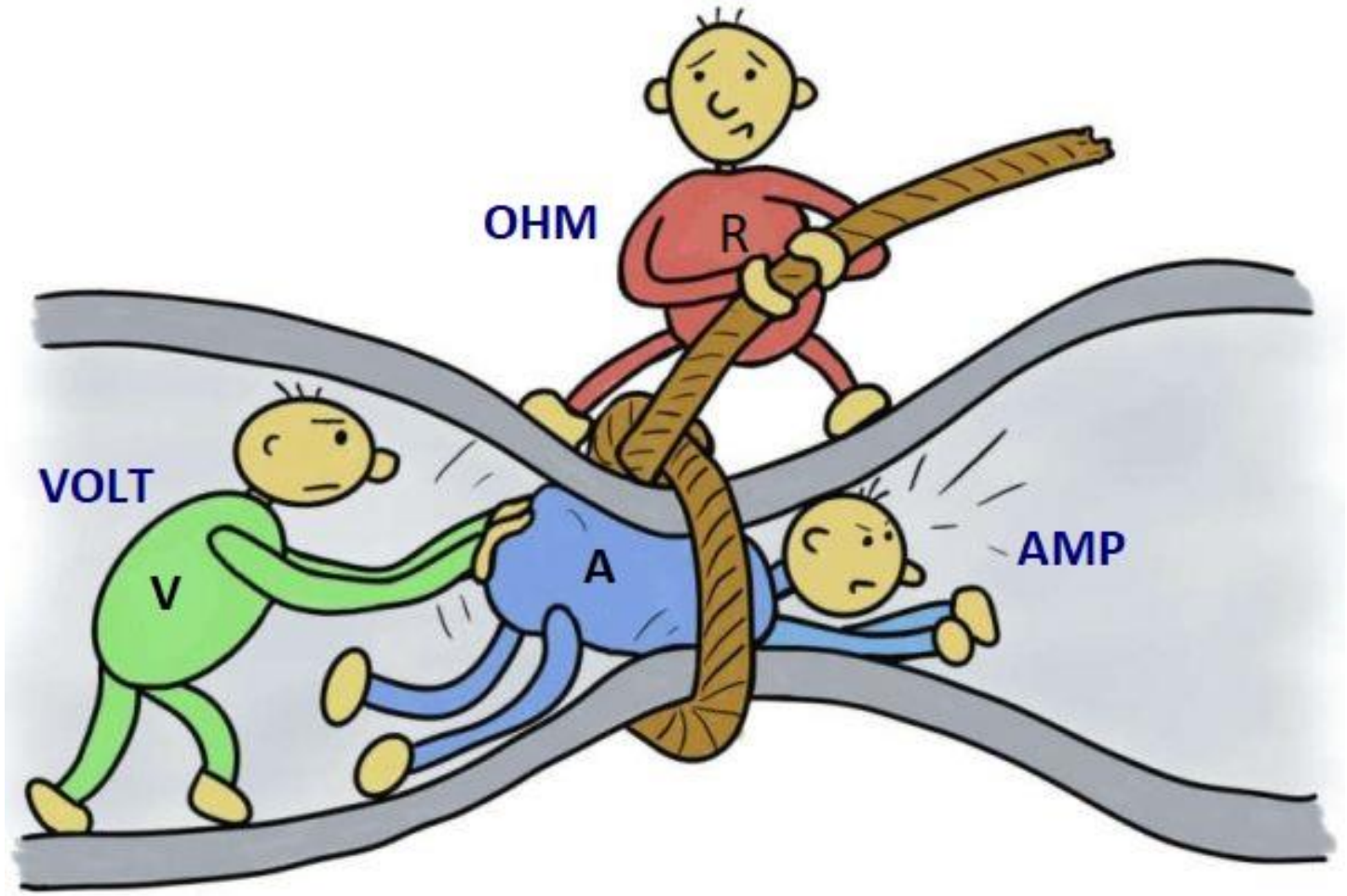


Resistance is a measure of the opposition to the flow of current in an electrical circuit. It is influenced by the material's properties, length, cross-sectional area, and temperature.



Ohm's law





Ohm's law

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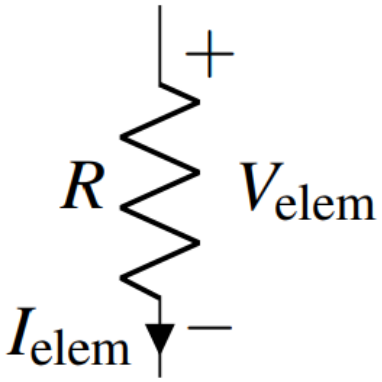
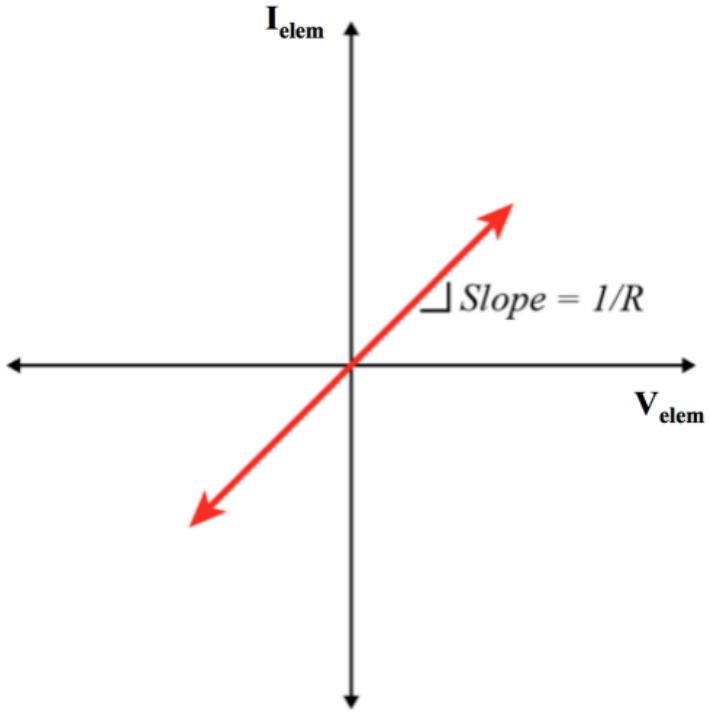
Symbol



IV Relationship



Resistors

- https://www.calculator.net/resistor-calculator.html

Resistor color code calculator

Use this calculator to find out the ohm value and tolerance based on resistor color codes.

Number of Bands: 4 Band

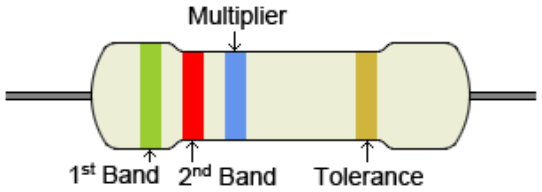
1st Band Color:
black brown red orange yellow
green blue violet grey white

2nd Band Color:
black brown red orange yellow
green blue violet grey white

Multiplier Color:
black brown red orange yellow
green blue violet grey white
gold silver

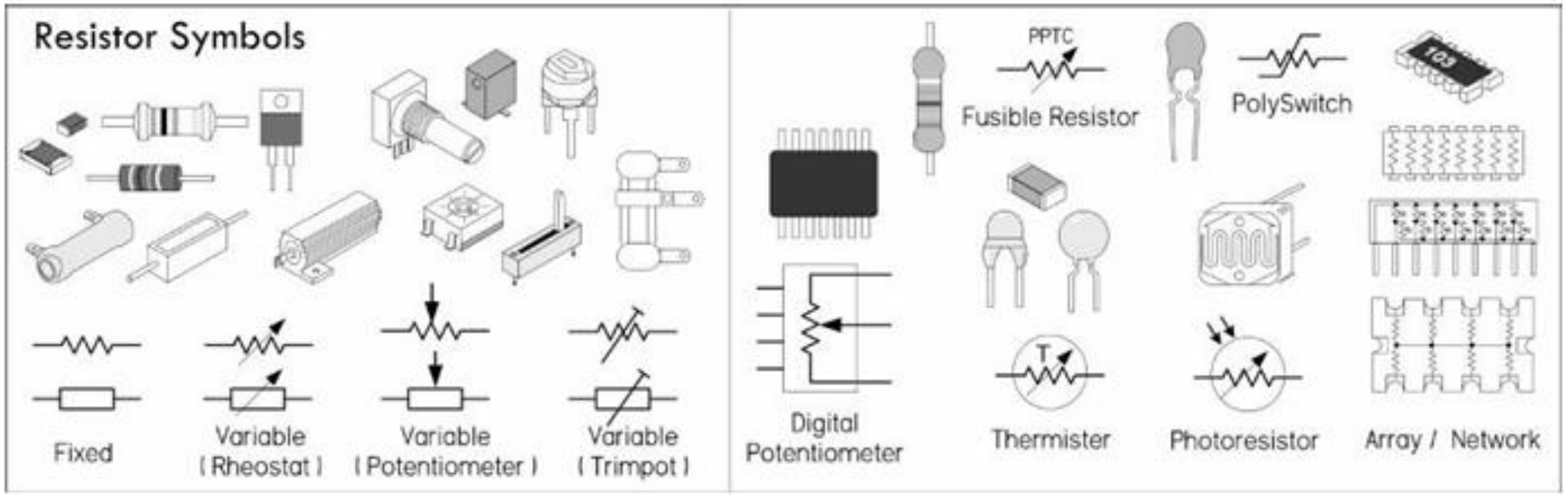
Tolerance Color:
brown red orange yellow green
blue violet grey gold silver

Calculate



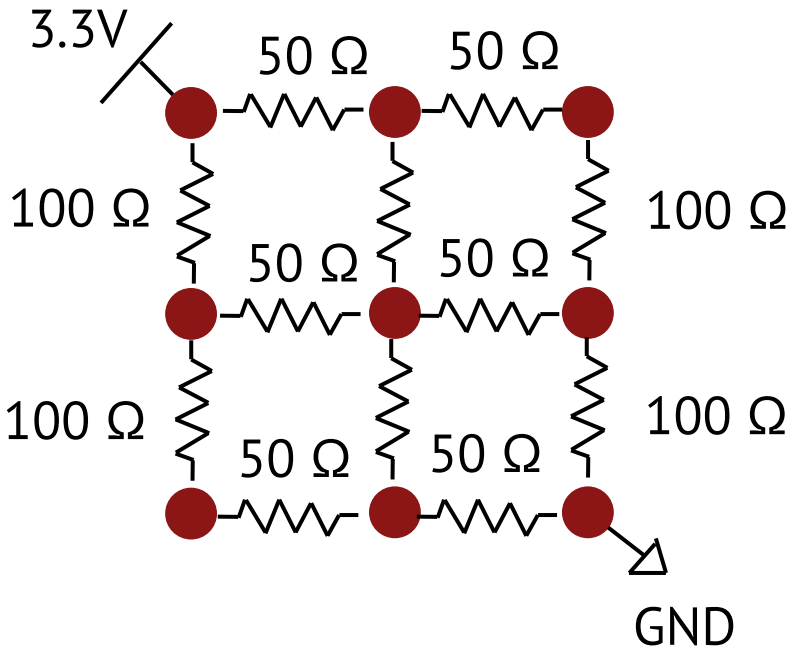
Color	1st, 2nd Band Significant Figures	Multiplier	Tolerance
Black	0	× 1	
Brown	1	× 10	±1% (F)
Red	2	× 100	±2% (G)
Orange	3	× 1K	±0.05% (W)
Yellow	4	× 10K	±0.02% (P)
Green	5	× 100K	±0.5% (D)
Blue	6	× 1M	±0.25% (C)
Violet	7	× 10M	±0.1% (B)
Grey	8	× 100M	±0.01% (L)
White	9	× 1G	
Gold		× 0.1	±5% (J)
Silver		× 0.01	±10% (K)

Resistors


Resistor Symbols
Fixed
Variable
(Rheostat)
Variable
(Potentiometer)
Variable
(Trimpot)
Digital
Potentiometer
PPTC
Fusible Resistor
PolySwitch
Thermister
Photoresistor
Array / Network

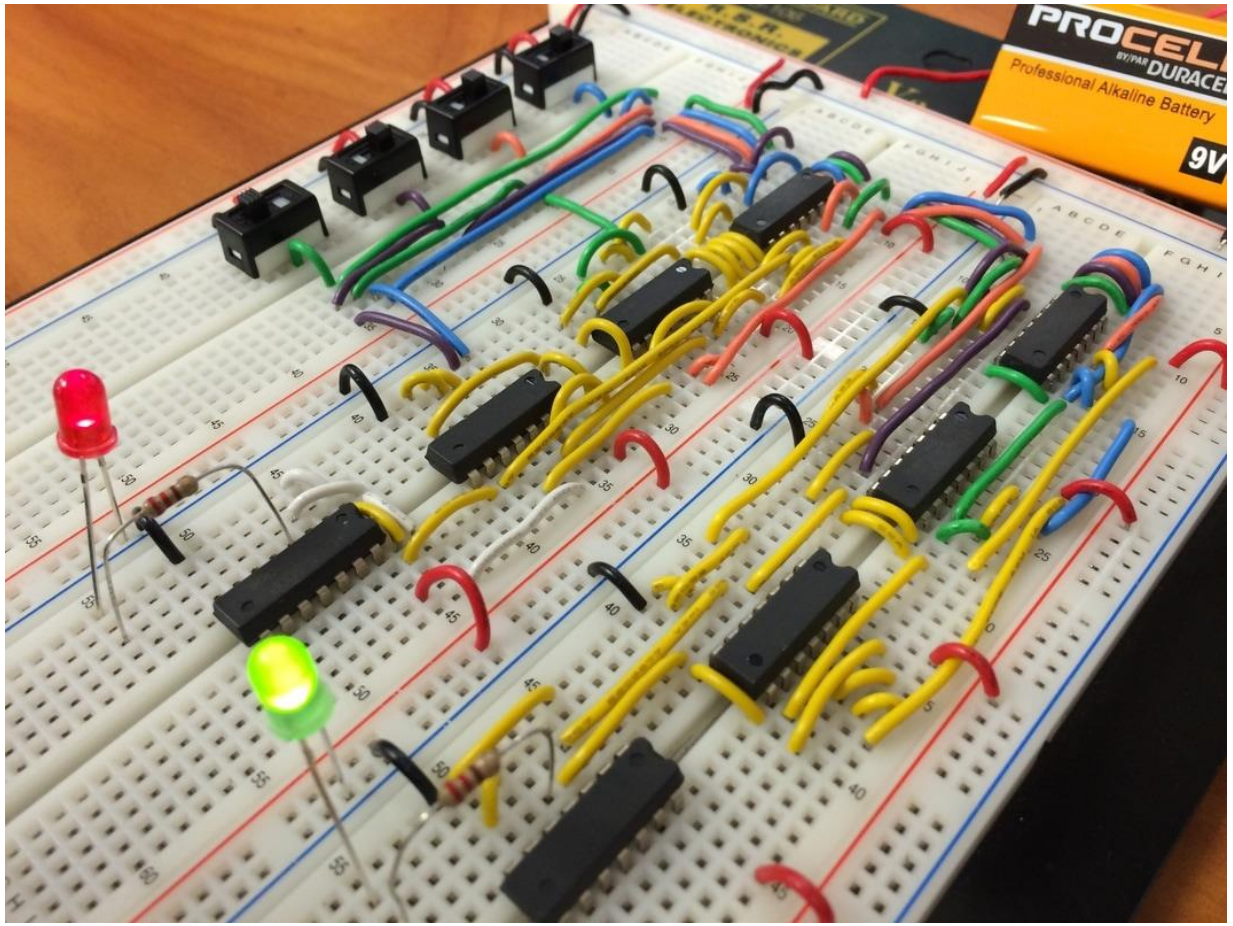
Going back to the touchscreen

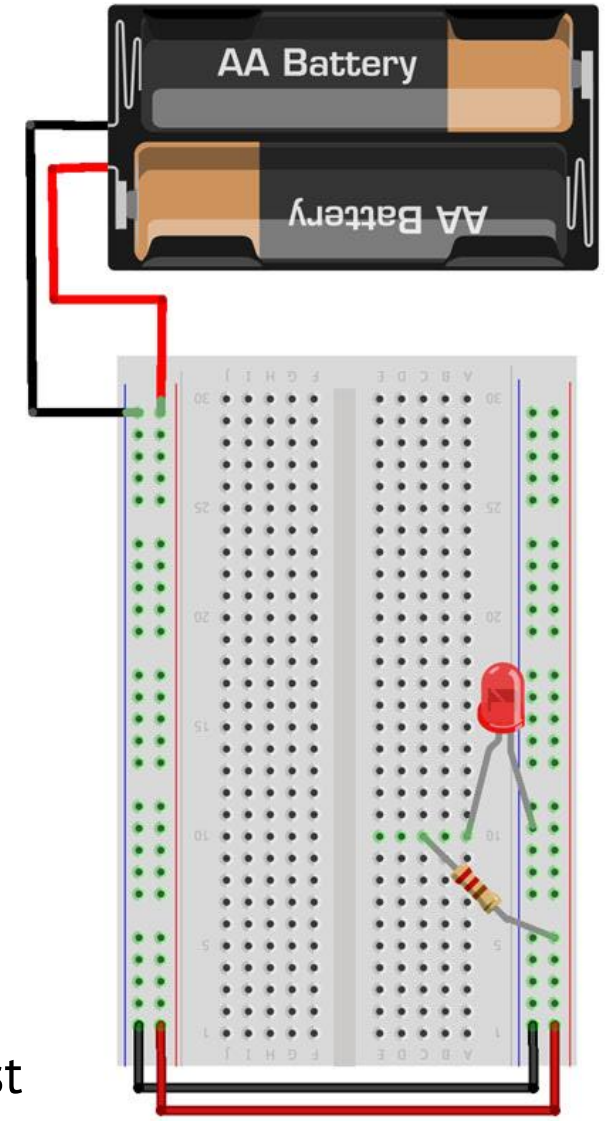
Build a sensor that can detect touch



Connect to Arduino for processing

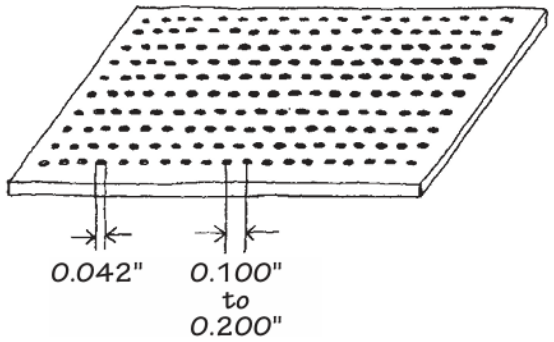
Step 1/a: Breadboarding

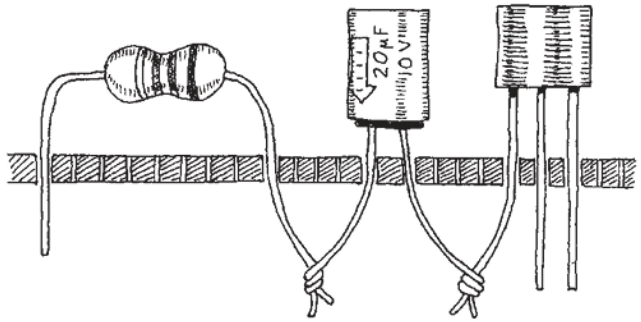




The electronic components are inserted in the breadboard to test the prototype circuit

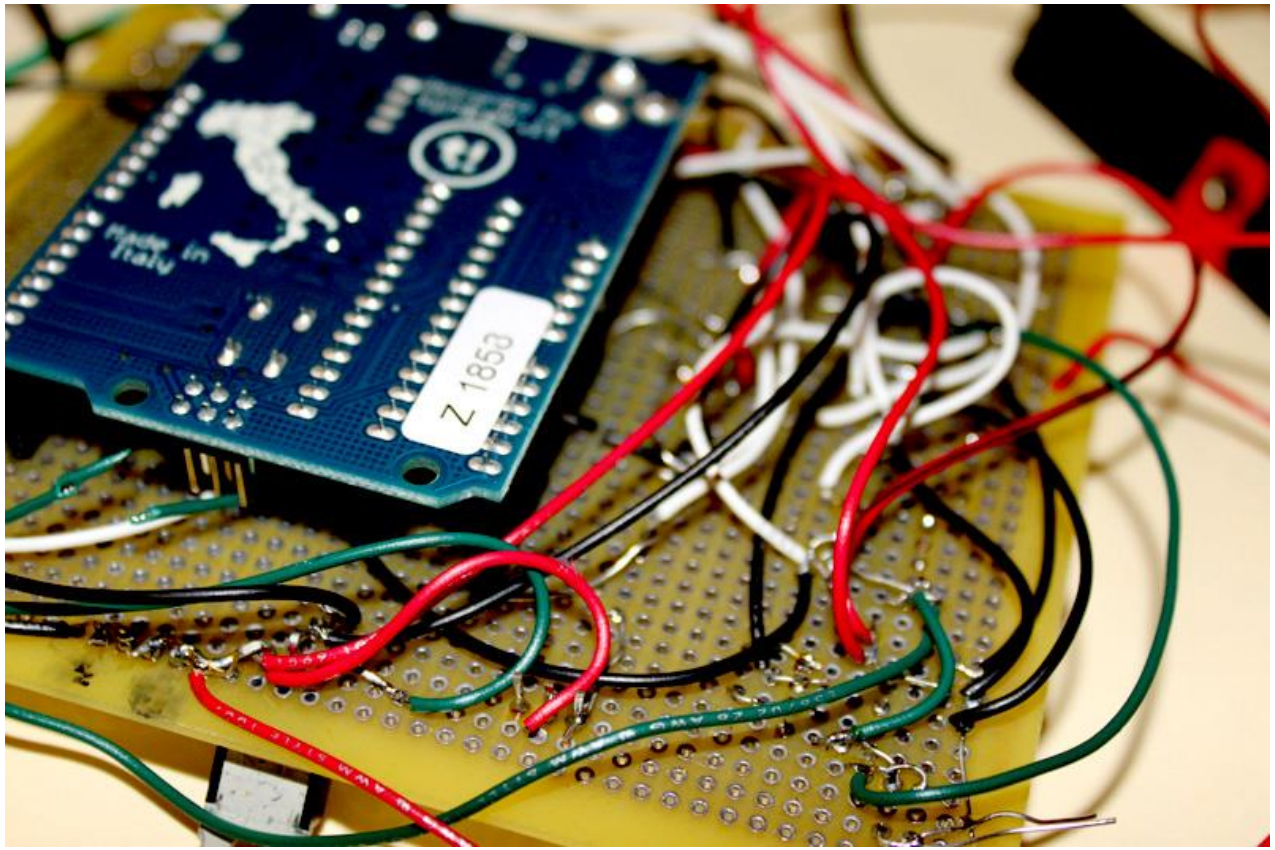
Step 1/b: Protoboards



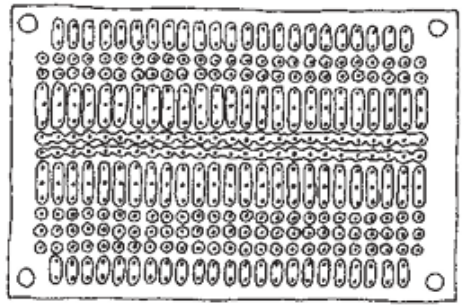


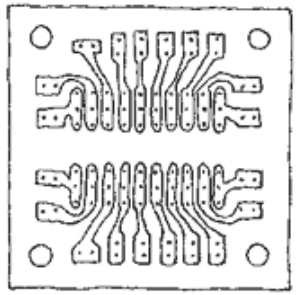
Protoboards are perforated boards with copper plated holes where wire can be connected and soldered

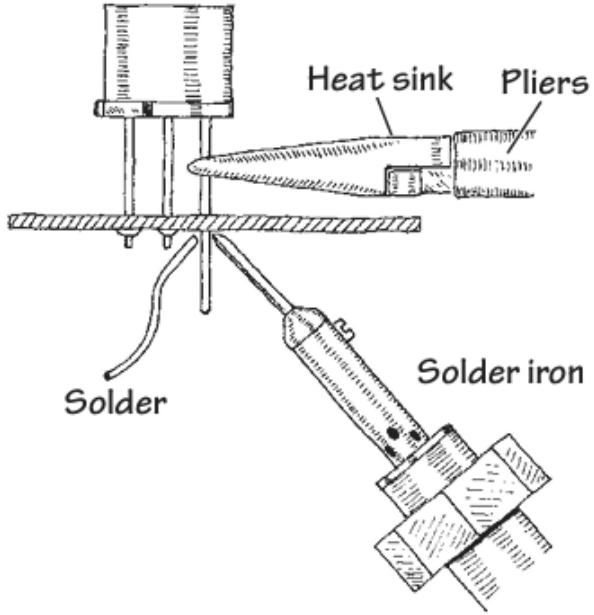
Yasser's first protoboard project (2010)

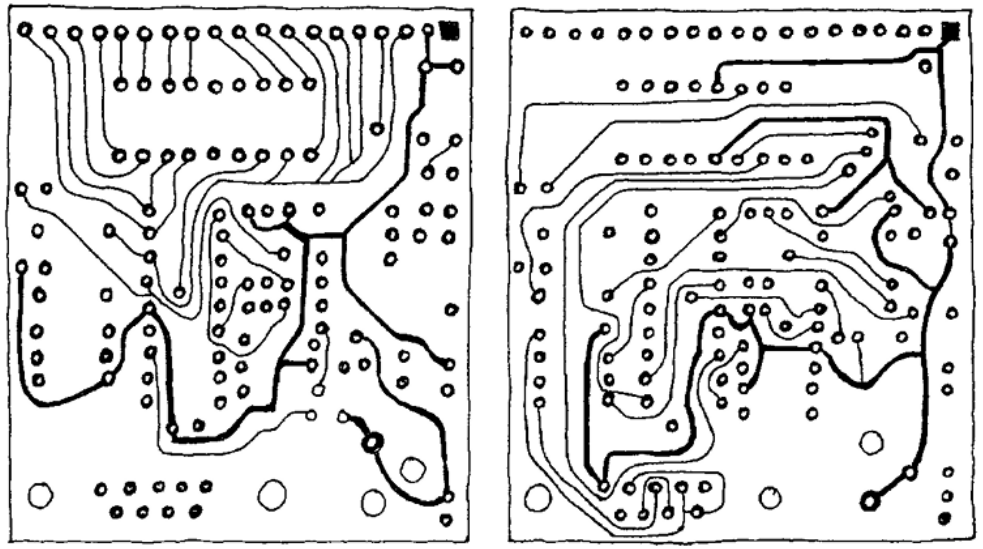


Protoboard soldering and connection

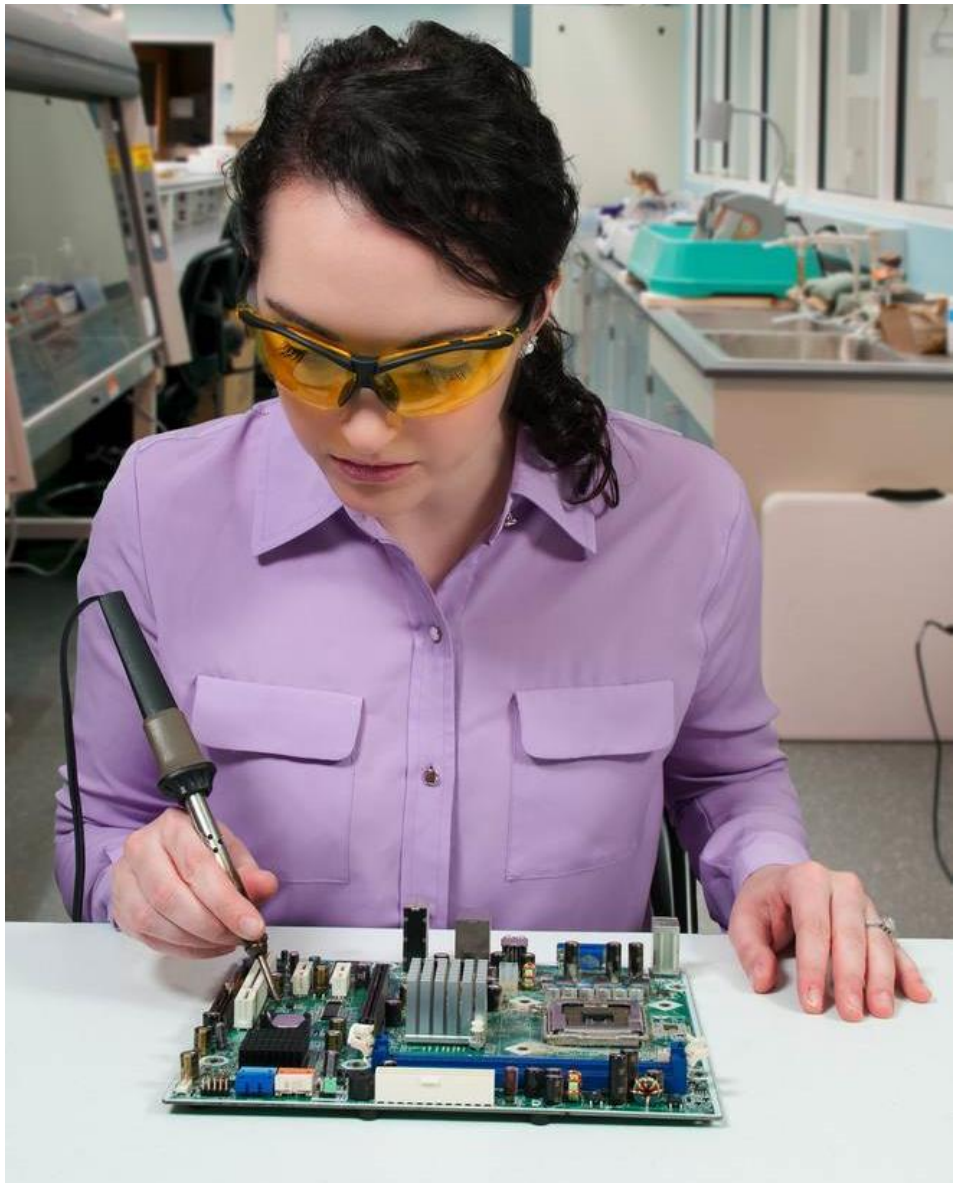








What is happening here 🤔?



Correct way to hold soldering iron

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Very old way of making printed circuit boards

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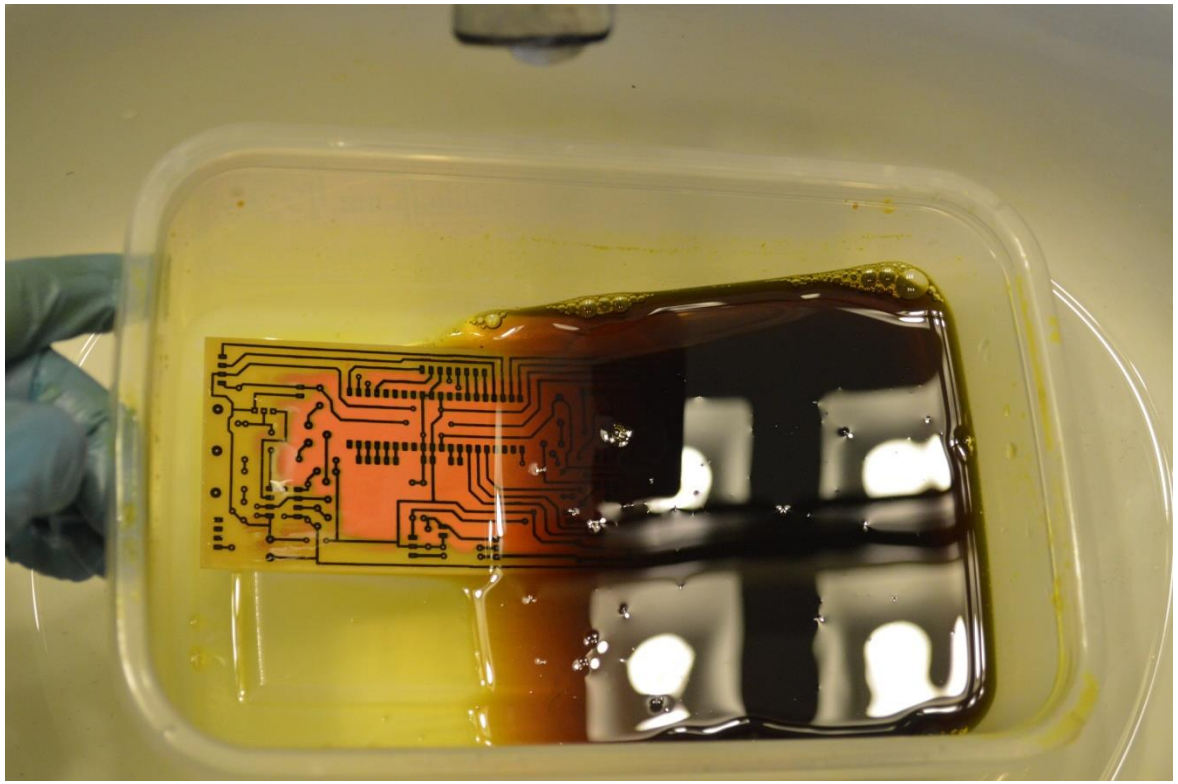

Ferric chloride etching of copper boards

Use of PCB design tools such as eagle / kicad

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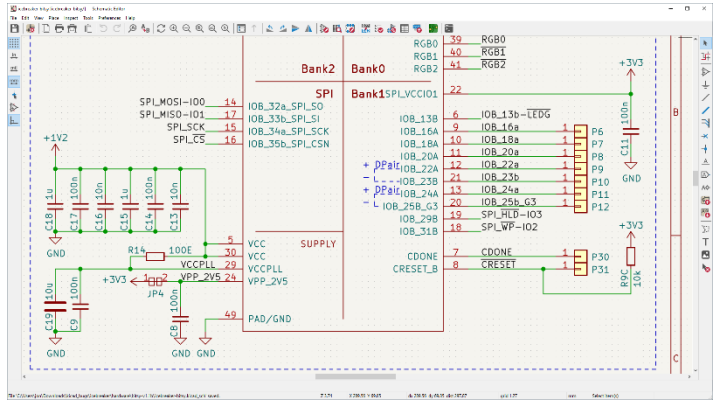
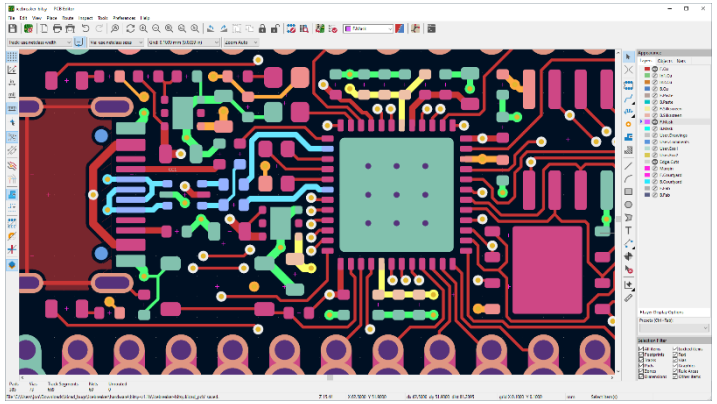
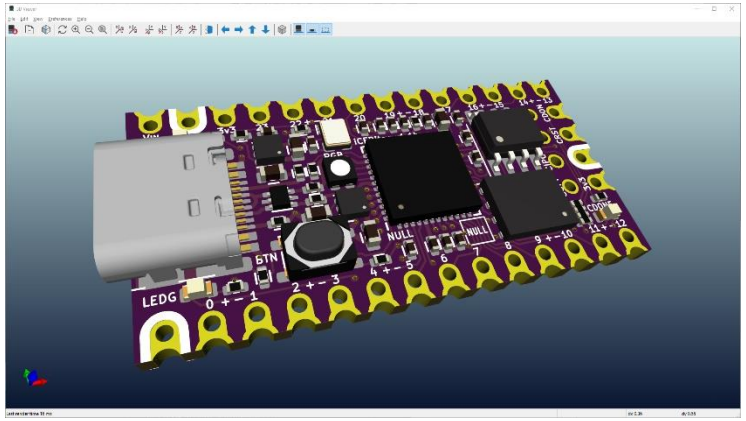


1. Schematic design



2. Board layout



3. Fabrication

Yasser's first electronics project (14 years ago)

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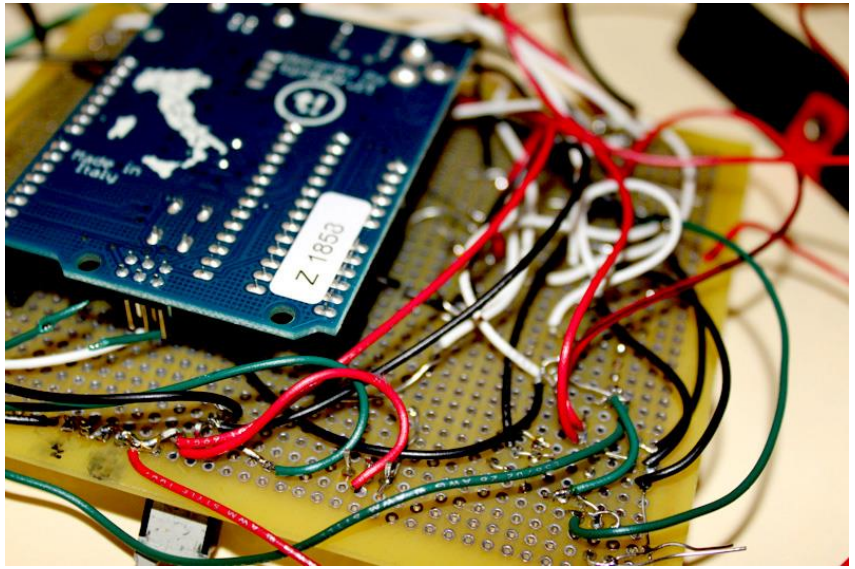
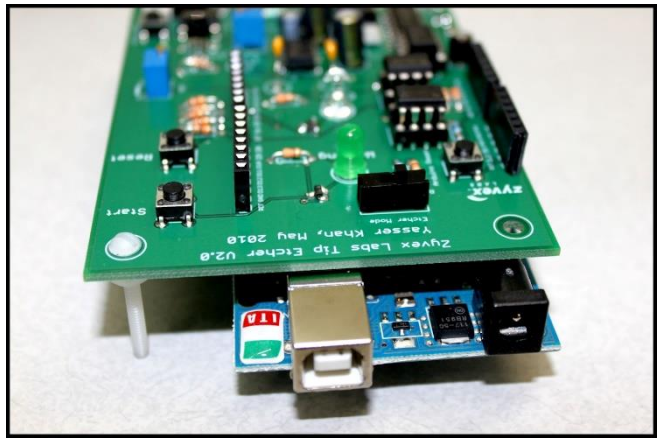
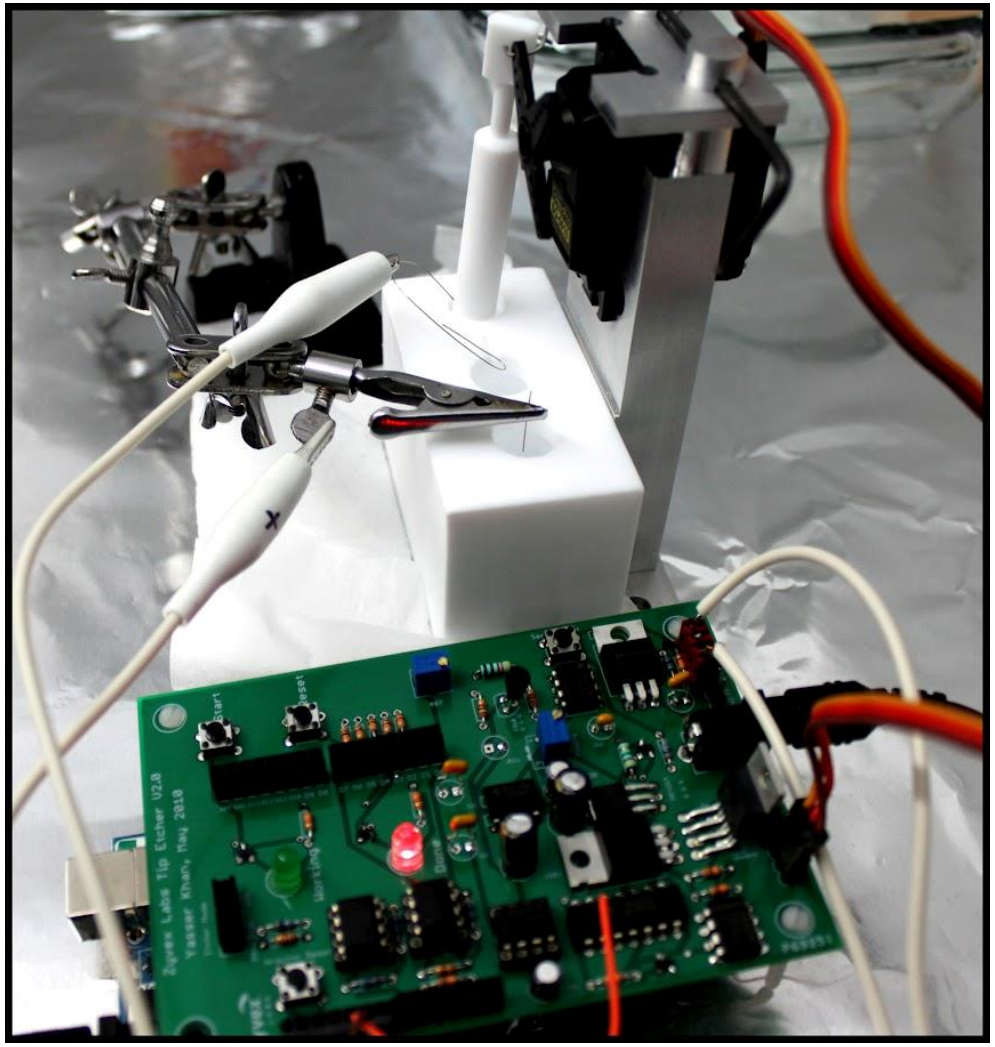


Before learning PCB design

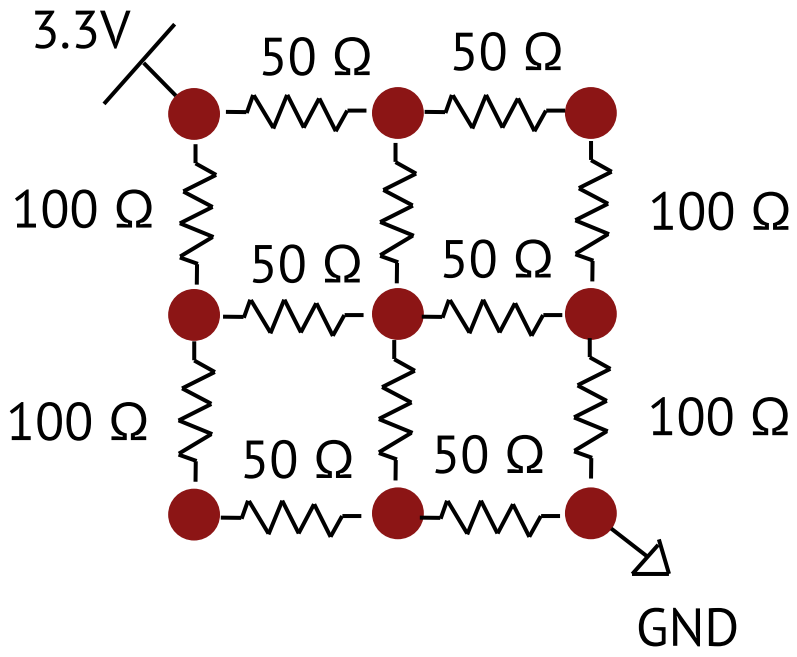


After learning PCB design



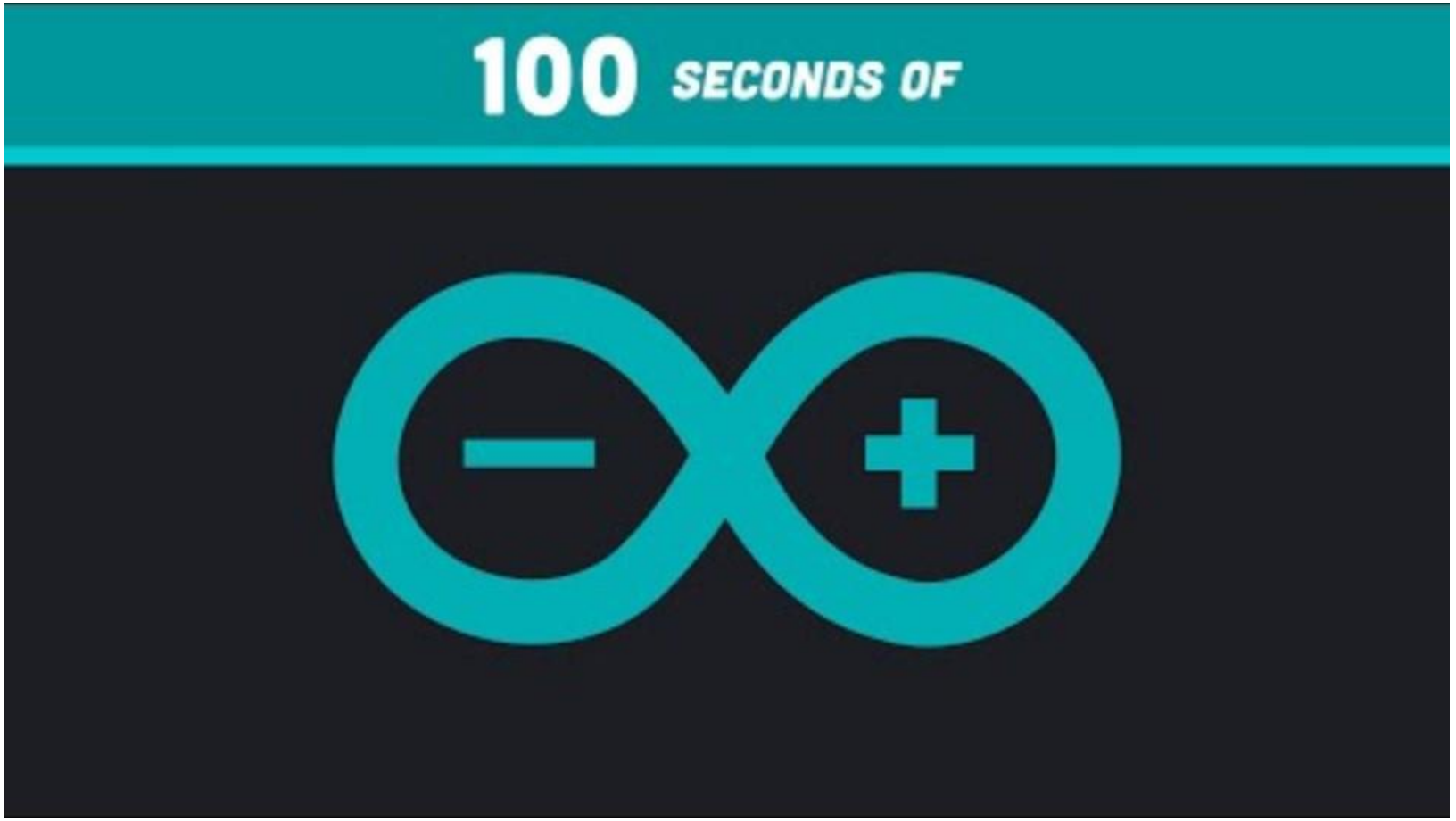
What's remining now?

Build a sensor that can detect touch



Connect to Arduino for processing

Arduino



https://www.youtube.com/watch?v=1ENiVwk8idM

Arduino Nano 33 BLE

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

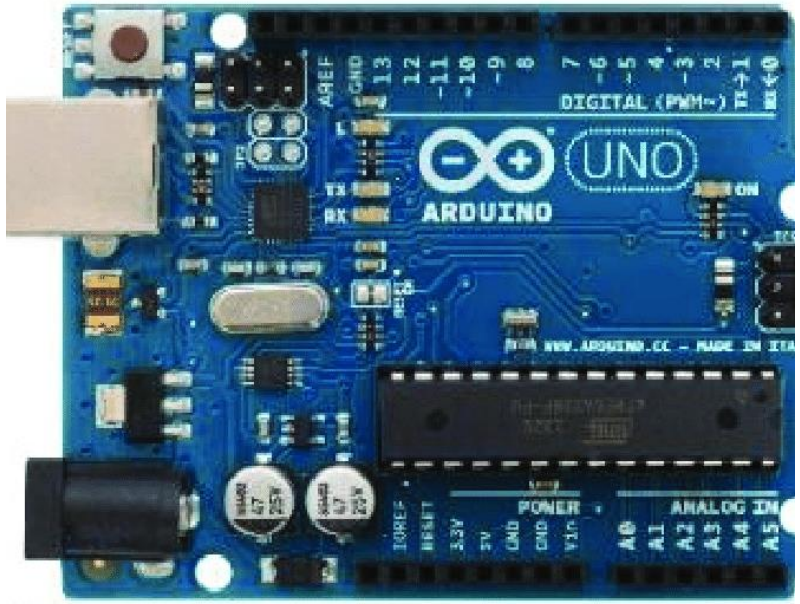
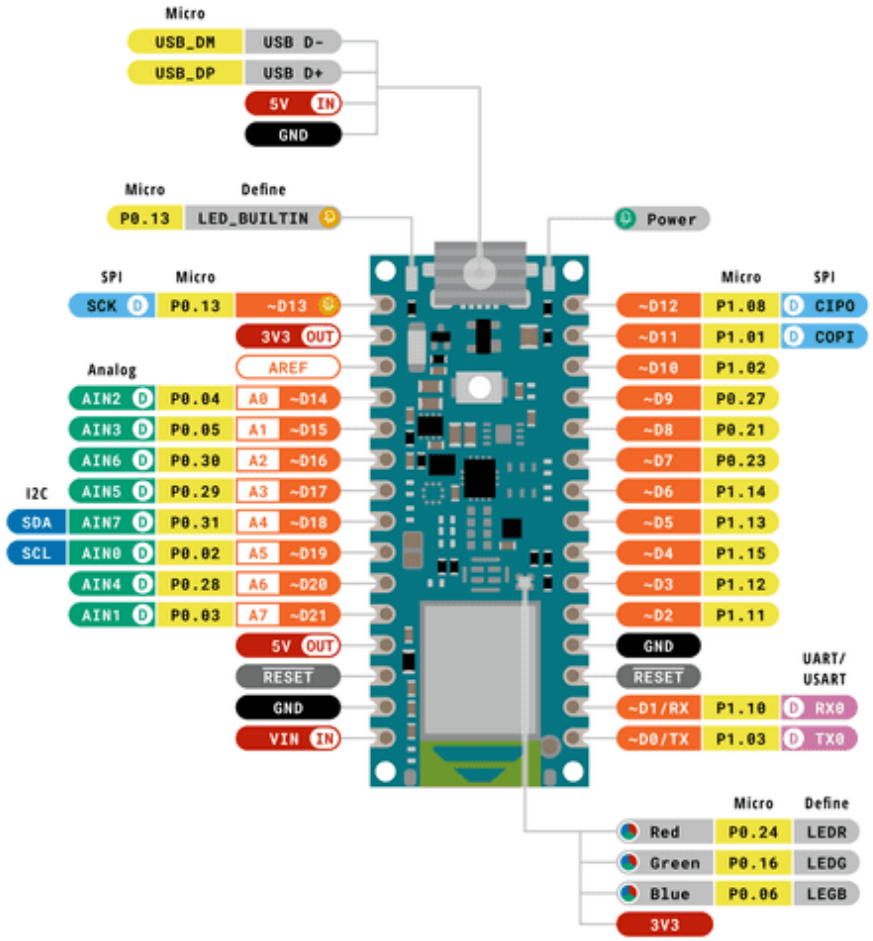
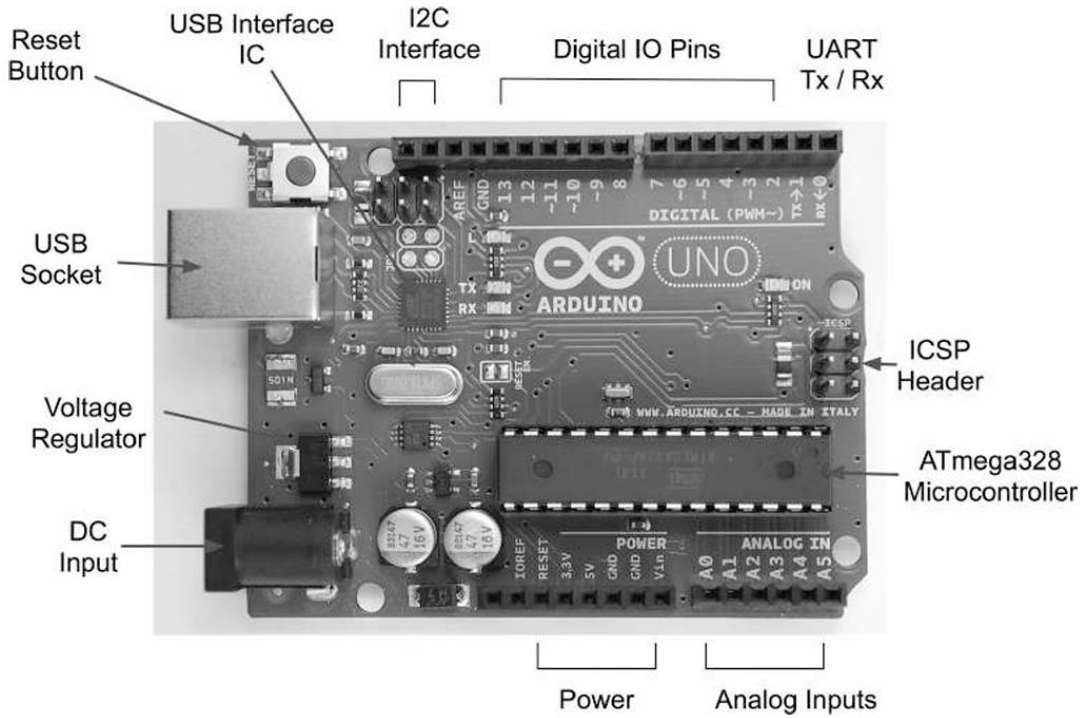


Figure. 1 Arduino Uno

Parameters	Arduino Nano 33 BLE
View	
COST	22.20 USD
Processor	nRF52840
Processor Description	32-bit ARM Cortex-M4F
Clock Speed	64MHz
CPU Flash Memory	1 MB
SRAM	256 KB
EEPROM	No EEPROM
Wireless Protocols	Bluetooth 5
Inbuilt Sensors	IMU(LSM9DS1)
Operating Voltage	3.3 v
DC Current input output pin	15 mA
UART	1
SPI	1
I2C	1
PWM Channels	All Digital Pins
Analog Input Pin	8
Analog Output Pins	Only through PWM (no DAC)
Digital I/O Pins	14

Arduino pinout





Installing and running examples on Arduino

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- Demo 1: Blink the LED
- Demo 2: Wireless data transfer to a web app