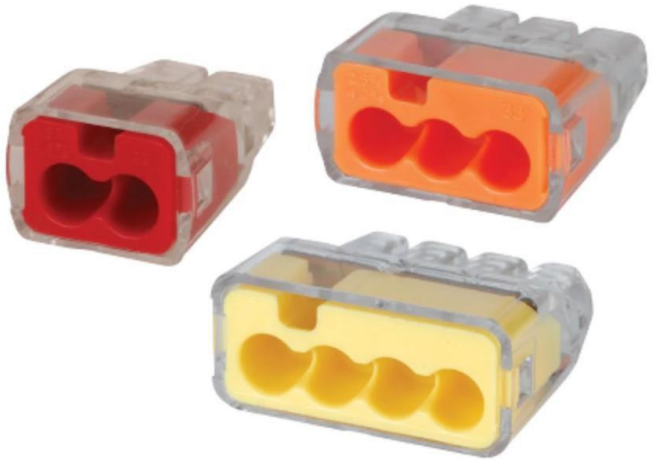
ECOR1044: Devices

Implementation, Input and Output Devices

Implementation: Electrical Connectors



Pressure Fit Connectors

Marrette Connectors

Spade Connectors

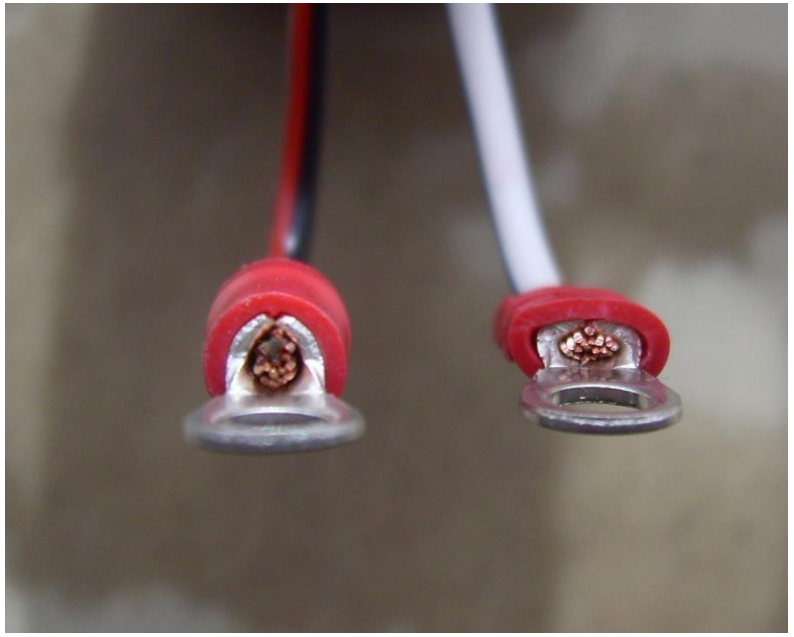
Terminal Block Connectors

Implementation: Wire Gauges

AWG	Diameter [inches]	Diameter [mm]	Area [mm^2]	Resistance [Ohms / 1000 ft]	Resistance [Ohms / km]	Max Current [Amperes]	Max Frequency for 100% skin depth
0000 (4/0)	0.46	11.684	107	0.049	0.16072	302	125 Hz
000 (3/0)	0.4096	10.40384	85	0.0618	0.202704	239	160 Hz
00 (2/0)	0.3648	9.26592	67.4	0.0779	0.255512	190	200 Hz
0 (1/0)	0.3249	8.25246	53.5	0.0983	0.322424	150	250 Hz
1	0.2893	7.34822	42.4	0.1239	0.406392	119	325 Hz
2	0.2576	6.54304	33.6	0.1563	0.512664	94	410 Hz
3	0.2294	5.82676	26.7	0.197	0.64616	75	500 Hz
4	0.2043	5.18922	21.2	0.2485	0.81508	60	650 Hz
5	0.1819	4.62026	16.8	0.3133	1.027624	47	810 Hz
6	0.162	4.1148	13.3	0.3951	1.295928	37	1100 Hz
7	0.1443	3.66522	10.5	0.4982	1.634096	30	1300 Hz
8	0.1285	3.2639	8.37	0.6282	2.060496	24	1650 Hz
9	0.1144	2.90576	6.63	0.7921	2.598088	19	2050 Hz
10	0.1019	2.58826	5.26	0.9989	3.276392	15	2600 Hz
11	0.0907	2.30378	4.17	1.26	4.1328	12	3200 Hz
12	0.0808	2.05232	3.31	1.588	5.20864	9.3	4150 Hz
13	0.072	1.8288	2.62	2.003	6.56984	7.4	5300 Hz
14	0.0641	1.62814	2.08	2.525	8.282	5.9	6700 Hz
15	0.0571	1.45034	1.65	3.184	10.44352	4.7	8250 Hz
16	0.0508	1.29032	1.31	4.016	13.17248	3.7	11 k Hz
17	0.0453	1.15062	1.04	5.064	16.60992	2.9	13 k Hz
18	0.0403	1.02362	0.823	6.385	20.9428	2.3	17 kHz
19	0.0359	0.91186	0.653	8.051	26.40728	1.8	21 kHz
20	0.032	0.8128	0.518	10.15	33.292	1.5	27 kHz
21	0.0285	0.7239	0.41	12.8	41.984	1.2	33 kHz
22	0.0254	0.64516	0.326	16.14	52.9392	0.92	42 kHz
23	0.0226	0.57404	0.258	20.36	66.7808	0.729	53 kHz
24	0.0201	0.51054	0.205	25.67	84.1976	0.577	68 kHz
25	0.0179	0.45466	0.162	32.37	106.1736	0.457	85 kHz

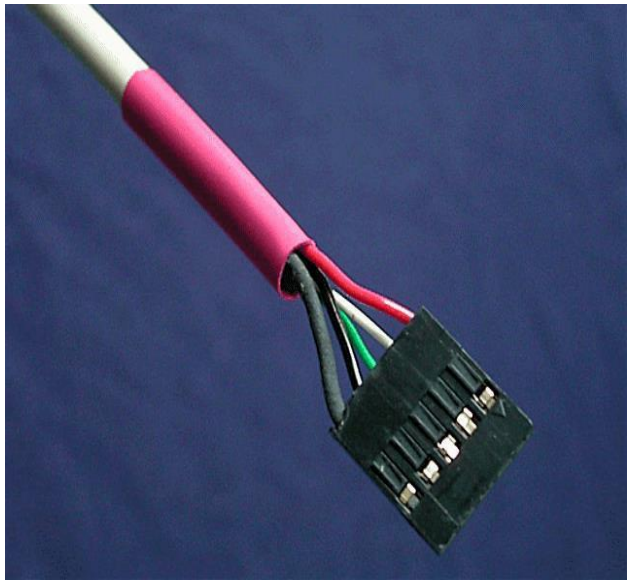
Implementation: Crimping

Crimped Connectors



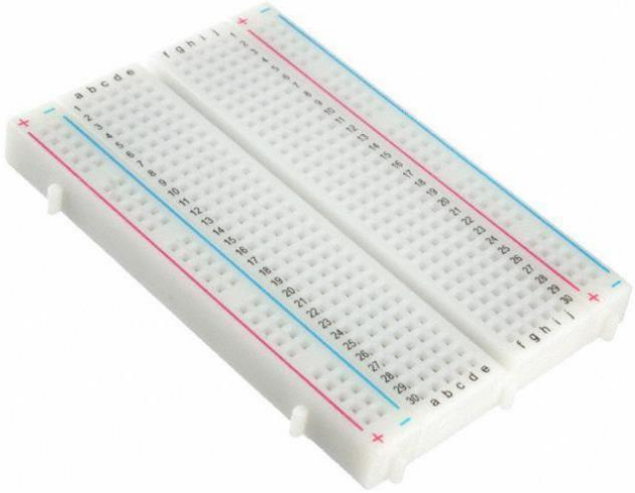
Crimping Tool

Implementation: Heat Shrink

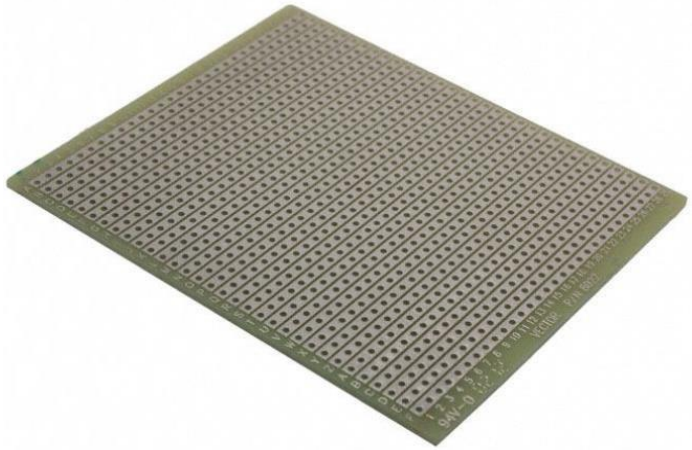


Heat Shrink + Heat Gun

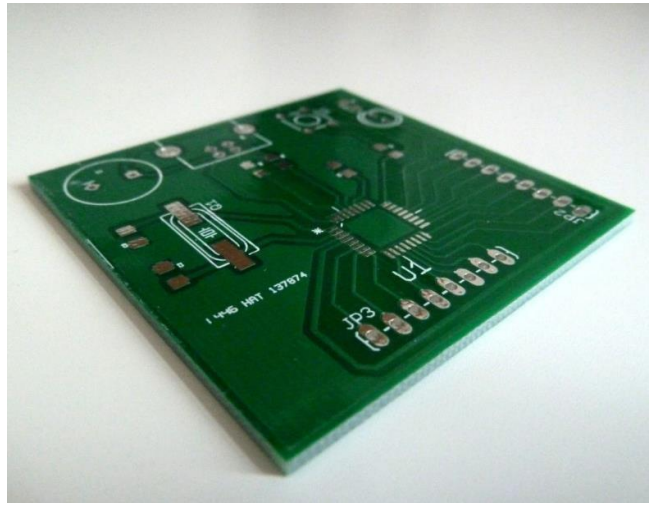
Implementation: Boards



1) Solderless Breadboard



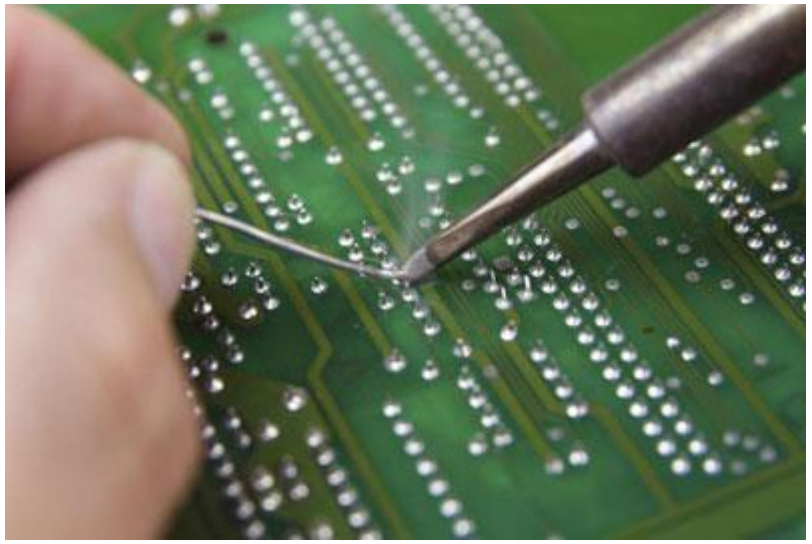
2) Stripboard



3) Printed Circuit Board

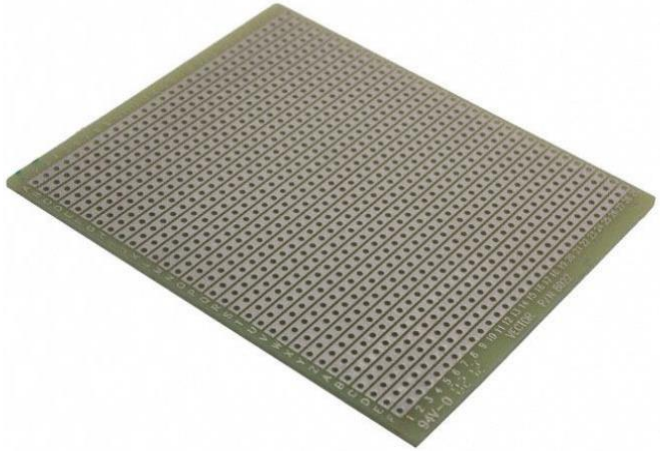
Implementation: Soldering

- Soldering is a process in which two or more metal items are joined by melting and then flowing a filler metal into the joint
- The filler metal has a relatively low melting point.
- Soldering is used to form a permanent mechanical and electrical connection between components.



Implementation: Soldering

- The metal to be soldered is heated with a soldering iron and then solder is melted into the connection.
- Only the solder melts, not the parts that are being soldered.
- Solder is a metallic "glue" that holds the parts together and forms a connection that allows electrical current to flow.



Device Types

- **Analog Devices:**
  - These devices operate using analog signals
  - If we want to interact with them within the Raspberry Pi Typically, we must first **convert** them to a **digital** signal using an external **ADC**.
  - Example: A sensor with a **0 – 3.3 V** or **0 – 5 V** output voltage.

- **Digital Devices:**
  - These devices operate using digital signals, typically through the use of a built-in ADC.
  - Typically, this makes them easier for us to interact with when using the Raspberry Pi
  - It can make debugging more difficult as the device is somewhat abstracted away from the user.
  - Example: A sensor using **communication** to send a **digital** signal.

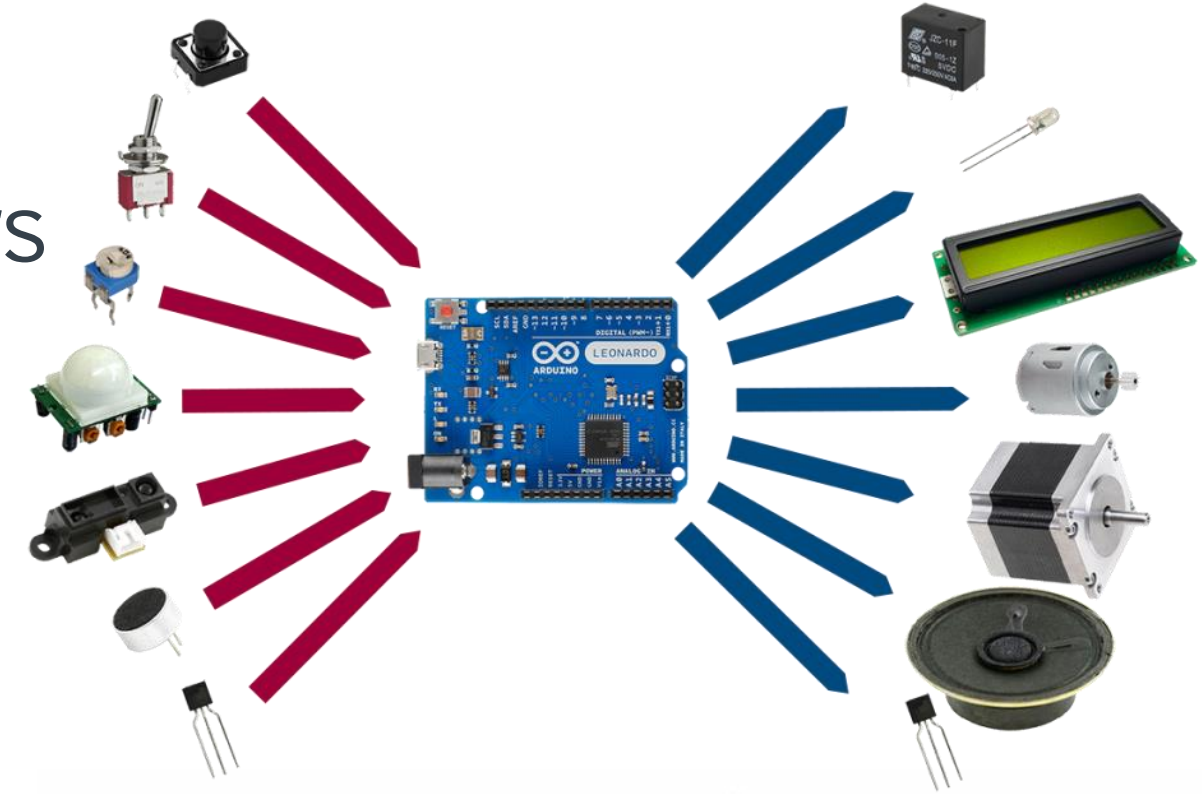
Device Types

- Additionally, these devices can be broken into two other groups:
- **Input Devices:**
  - A hardware or peripheral device used to send data to a computer.
  - These allow users to communicate (directly or indirectly)
  - The communication includes feeding instructions and data to computers for processing, display, storage and/or transmission.
  - **Examples: keyboard, mouse, stylus, touch screen, sensors, etc.**

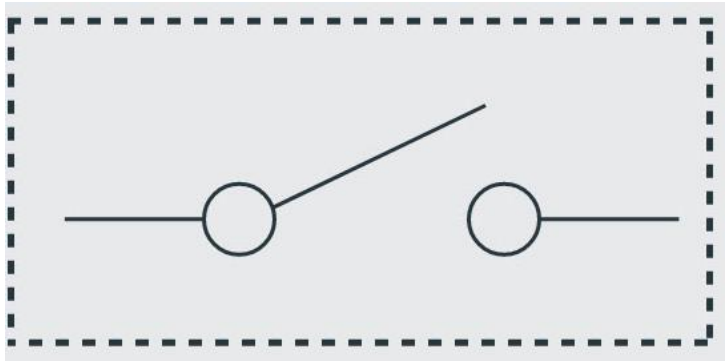
- **Output Devices:**
  - A device used to send data from a computer to another device.
  - Most computer data output that is meant for humans is in the form of audio or visual.
  - **Examples: screen, display, printer, speaker, LED, etc.**

I/O Devices: Sensors

- Mechanical
  - Position
  - Distance
  - Stress
  - Acceleration
  - Rotation
- Environment
  - Temperature
  - Humidity
  - Pressure
  - Light
  - Sound

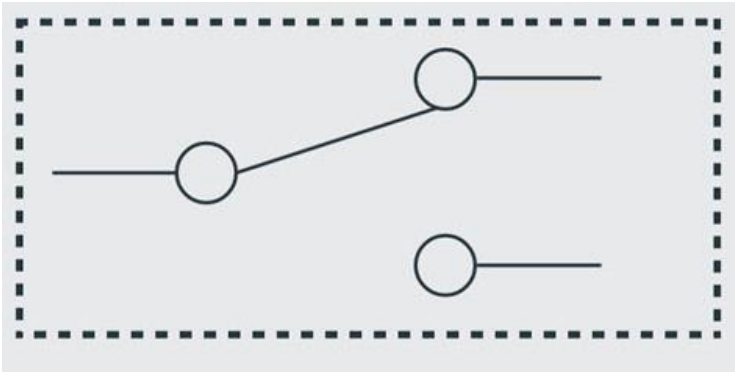


Input Device: Single Pole-Single Throw Switch



- Disclaimer: Do not alter house wiring based off this introduction; code requirements require more in-depth information and any work on house wiring should be done by a licensed electrician.

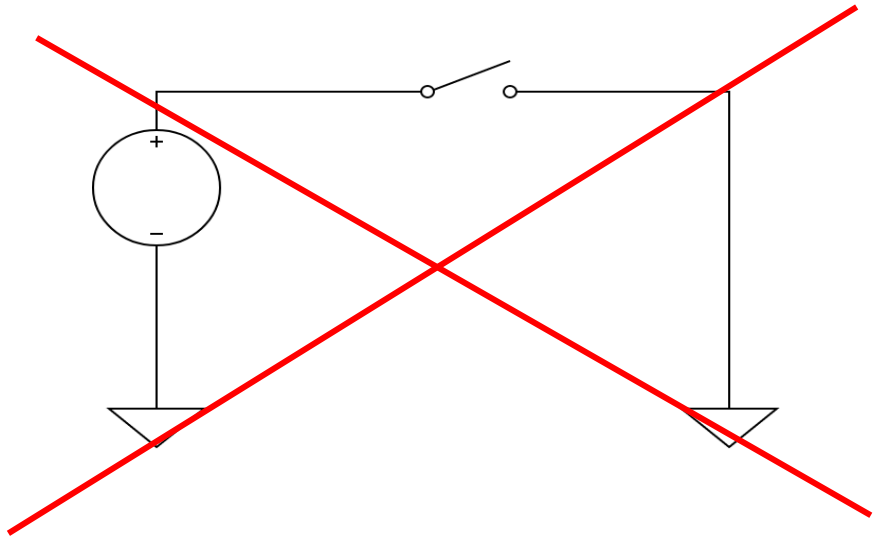
Input Device: Single Pole-Double Throw Switch

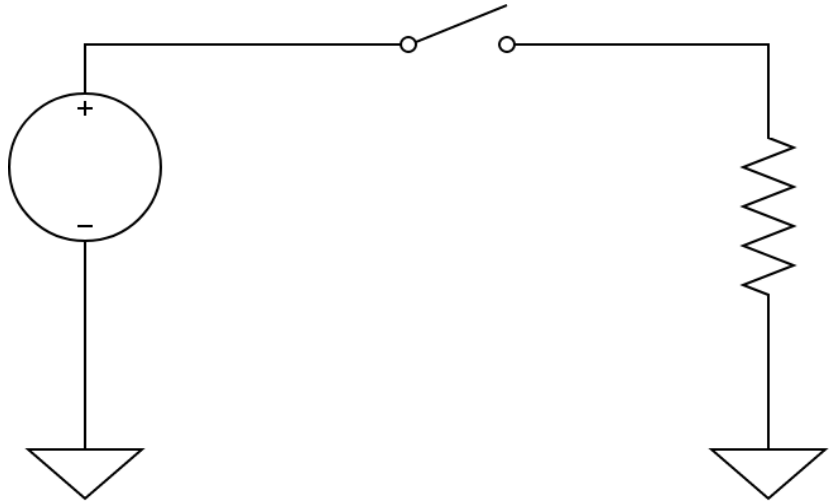


Basic Electrical: Caution!

- When implementing switches, buttons, and other devices we need to make sure we do **not** short circuit the power supply.

- **Very** common error when starting to work with electronics





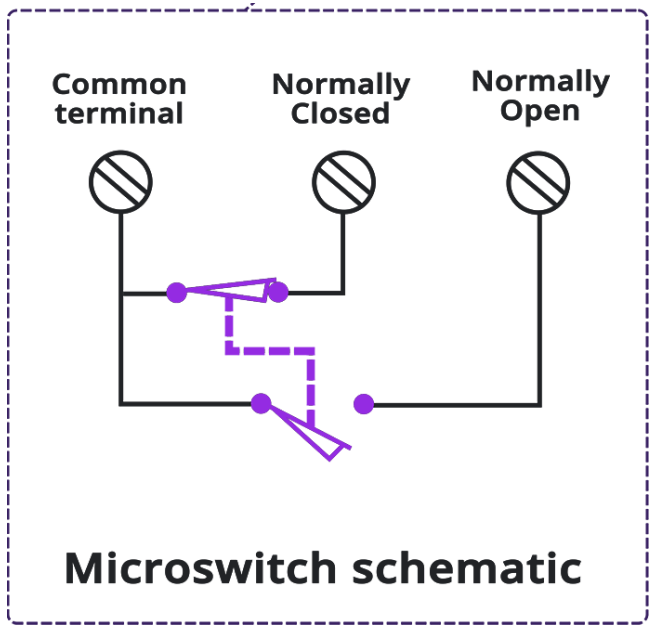
Input Device: Push Button

- The button is primarily be used as an input device, which tells the computer when it has been pressed.
- From an electrical standpoint their functionality is very straightforward; they act as a **momentary switch**.
- Once the button is pressed the voltage on one side of the button will match the other side of the button.

Input Device: Limit Switch

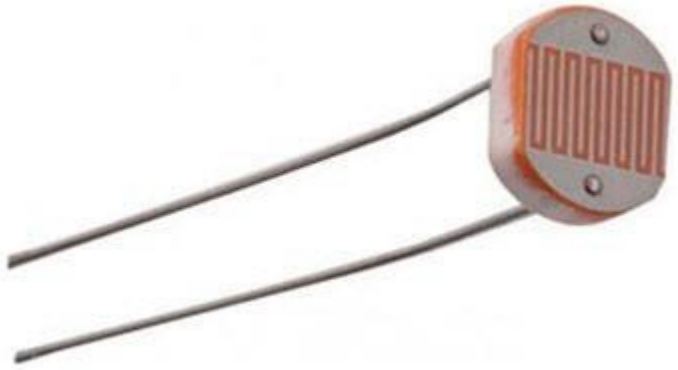
- Works similar to a regular button, with the specific general application of detecting the presence or absence of an object.

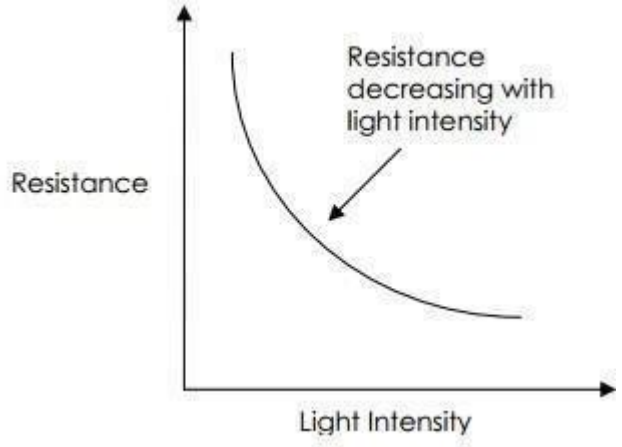
- Were originally used to **define the limits on the range of motion of objects**, therefore a ‘limit’ switch



Input Device: Light Sensors

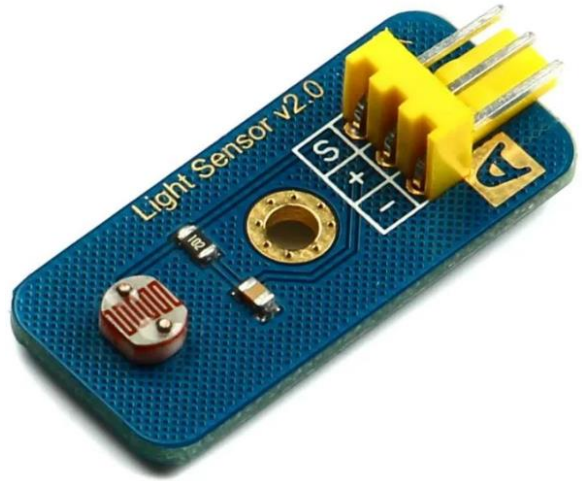
- Sensors that are used for detecting the **amount of light** striking the sensor are called light sensors.
- These light sensors are classified into various types, we will look at the Light **Dependent Resistor (LDR)**.
- An LDR can be used as an analog light sensor, the **resistance** of the LDR **increases** with a **decrease** in light and **decreases** with an **increase** in light.

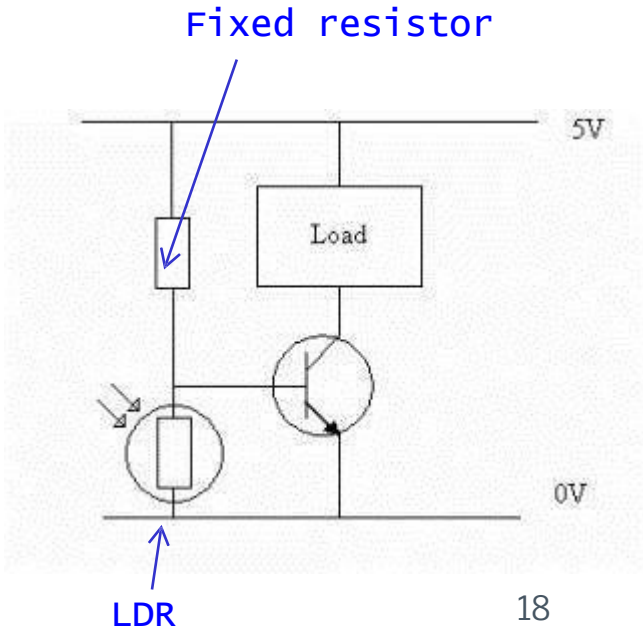




Input Device: Light Sensors

- The circuit below shows a simple way of constructing a circuit that turns on when it goes dark.
- The LDR and the other fixed resistor form a simple ‘voltage divider’ where the center point of the voltage divider is fed to the Base of the Transistor.
- When the light level decreases, the resistance of the LDR increases.
- As resistance increases it causes the voltage dropped across the LDR to also increase.
- **When this voltage is large enough**, it will cause the Transistor to turn on.
- This will make **the current flow through the load**.



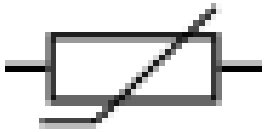


Input Device: Temperature Sensors

A temperature sensor is a device used to measure temperature. This can be air temperature, liquid temperature or the temperature of solid matter. There are different types of temperature sensors available and they each use different technologies and principles to take the temperature measurement.

Input Device: Temperature Sensors

- Sensors that are used for detecting the temperature of their environment are called temperature sensors.
- These sensors are classified into various types, we will look at the thermistor.
- There are **two types** of thermistors:
  - **Negative Temperature Coefficient (NTC)**
  - **Positive Temperature Coefficient (PTC).**



- For an NTC thermistor, when the temperature **increases**, resistance **decreases** and vice versa. Commonly used as temperature sensor or inrush current limiters.
- For a PTC thermistor, when temperature **increases** resistance also **increases**. Commonly used to protect against overcurrent conditions.

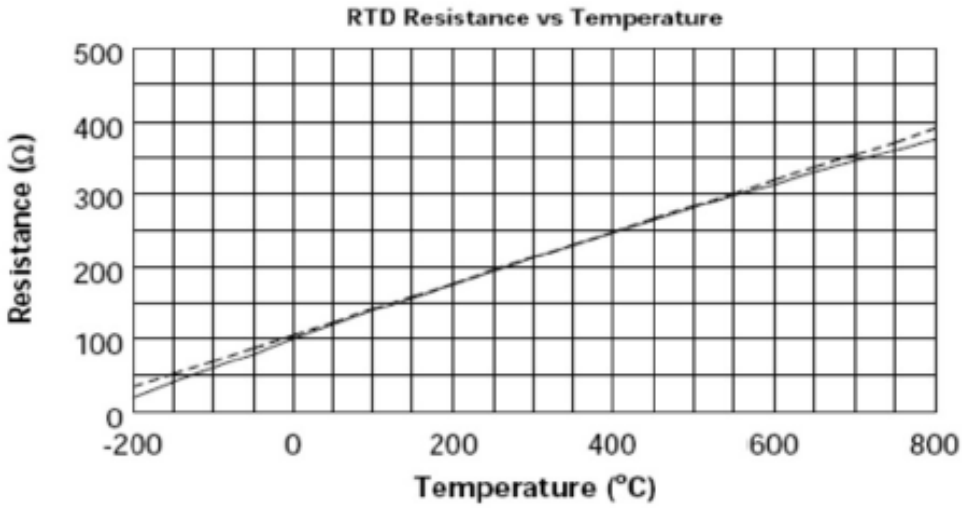
Input Device: Temperature Sensors

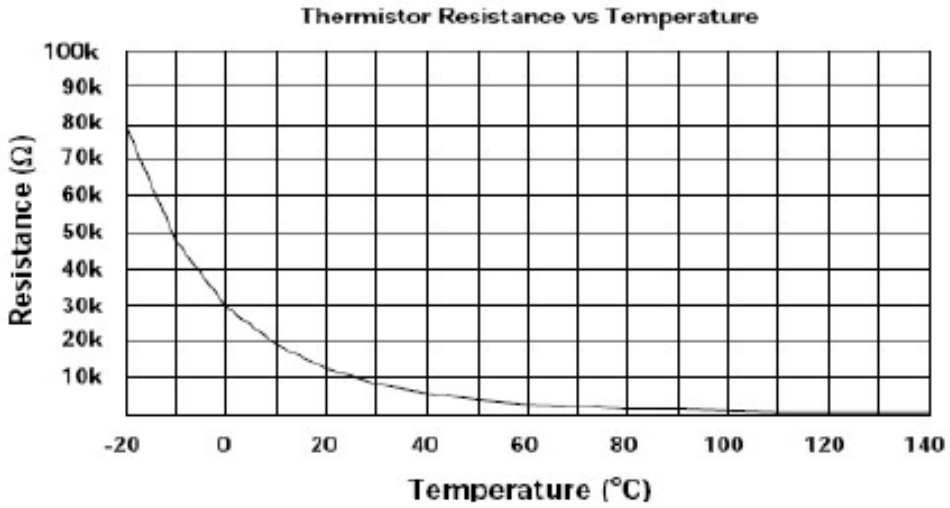
Thermocouples:

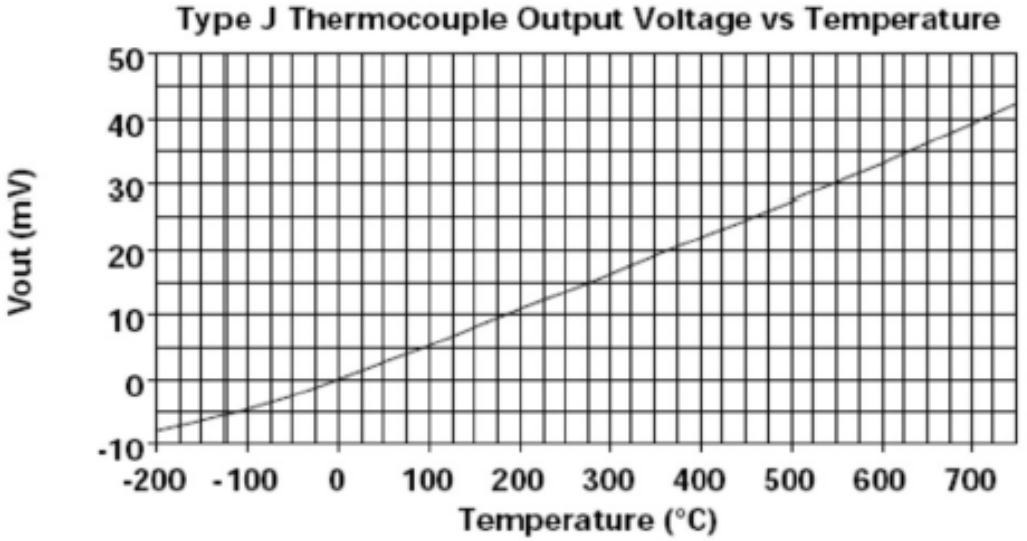
- A thermocouple consists of two different types of metals, joined together at one end. When the junction is heated or cooled, a voltage is created that can be correlated to temperature.
- There are several types of thermocouples. They are classified based on the metals used and temperature range. Common types include:

Types	Metal Used	Temperature Range
Type K	Nickel-Chromium/Nickel-Alumel	-200°C to +1260°C (-328°F to +2300°F)
Type J	Iron/Constantan	-40°C to +750°C (-40°F to +1382°F)
Type T	Copper/Constantan	-200°C to +350°C (-328°F to +662°F)
Type E	Nickel-Chromium/Constantan	-200°C to +900°C (-328°F to +1652°F)

Input Device: Temperature Sensors



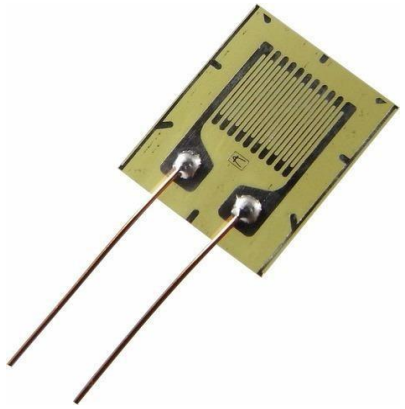


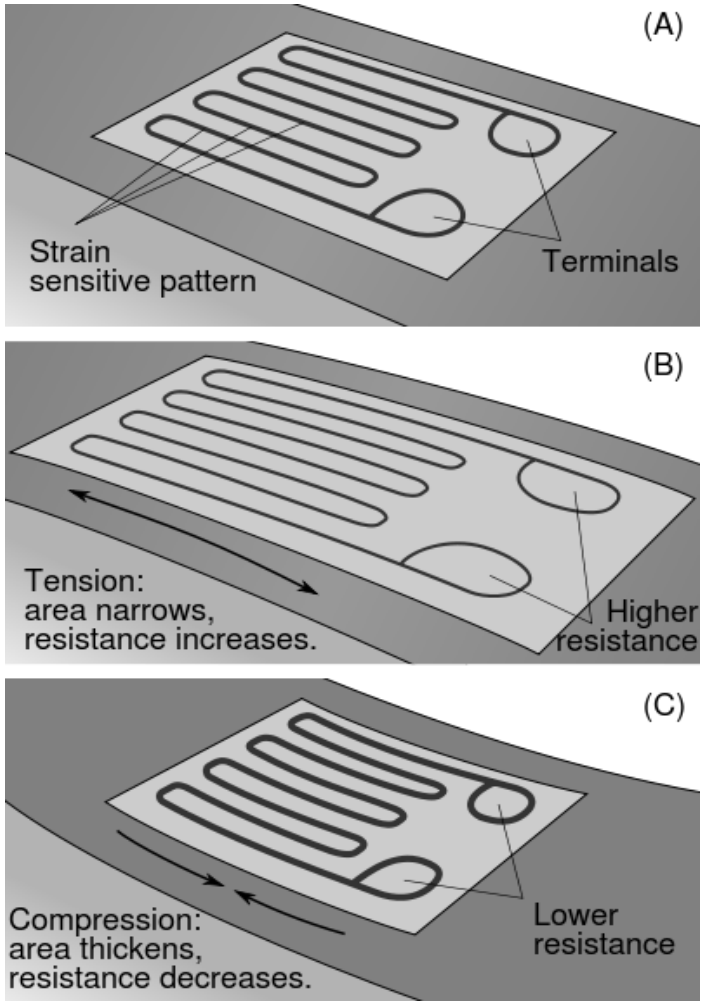


Input Device: Strain Gauges

- A strain gauge is a device that measures **electrical resistance changes** in response to strain applied to the device.

- A strain gauge takes advantage of the physical property of electrical conductance and its dependence on the conductor's geometry.





https://en.wikipedia.org/wiki/Stran_gauge

Input Device: Strain Gauges

- The most common strain gauge is made up of very fine wire, or foil, set up in a grid pattern in such a way that there is a linear change in electrical resistance when strain is applied in one specific direction.

$$\text{Strain} = \frac{\text{Change in resistance}}{\text{Original resistance}}$$

https://en.wikipedia.org/wiki/Strain_gauge

Input Device: Force Sensor

A Force Sensor is defined as a transducer that **converts** an input **mechanical** load, weight, tension, compression or pressure into an **electrical** output signal (load cell definition).

Input Device: Pressure Sensors

- They produce an **output** signal that is **proportional** to the **applied pressure**.
- Types:
  - Absolute pressure sensor: Measures the pressure relative to perfect vacuum.
  - Gauge pressure sensor: Measures the pressure relative to atmospheric pressure.
  - Differential pressure sensor: Measures the difference between two pressures.
  - Sealed pressure sensor: Measures pressure relative to a fixed pressure.

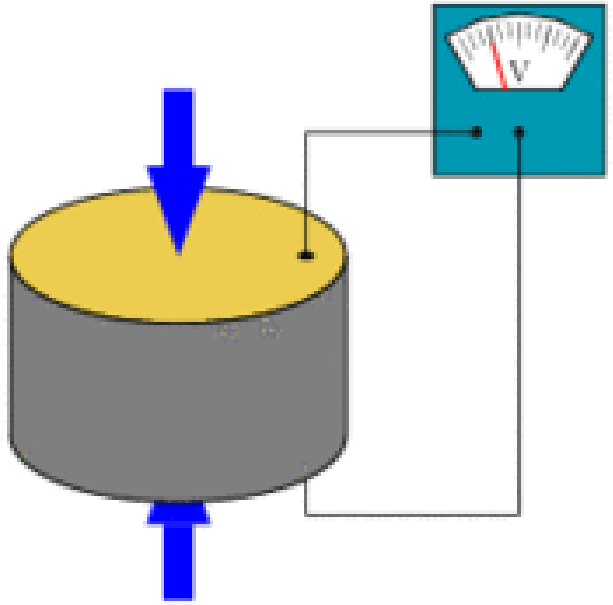
Input Device: Pressure Sensors

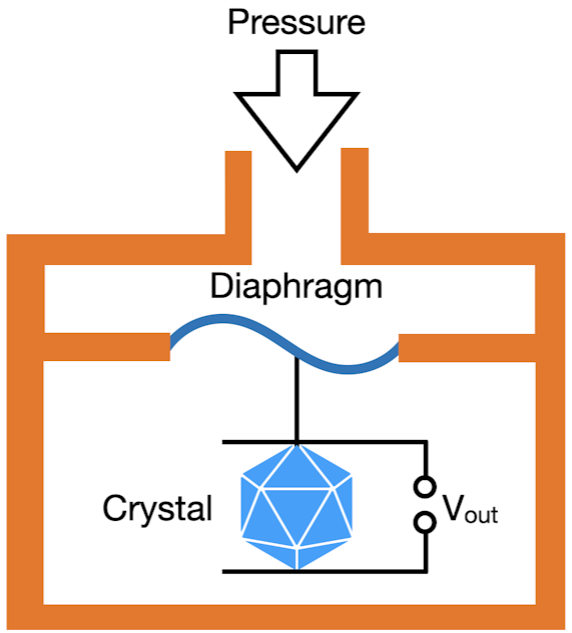
- There are several different designs:
  - **Piezoresistive strain gauge**: Uses the piezoresistive **resistance changes** as pressure deforms the material.
  - **Capacitive**: Uses a variable capacitor to detect strain due to applied pressure, **capacitance decreasing** as pressure deforms the diaphragm.
  - **Electromagnetic**: Measures the displacement of a diaphragm by means of **changes in inductance**.
  - **Piezoelectric**: Uses the piezoelectric effect in certain materials where the **electric charge** accumulates in certain solids in response to applied mechanical stress.

    Piezoelectricity is the charge created across certain materials when a mechanical stress is applied.

Piezoelectric Pressure Sensor

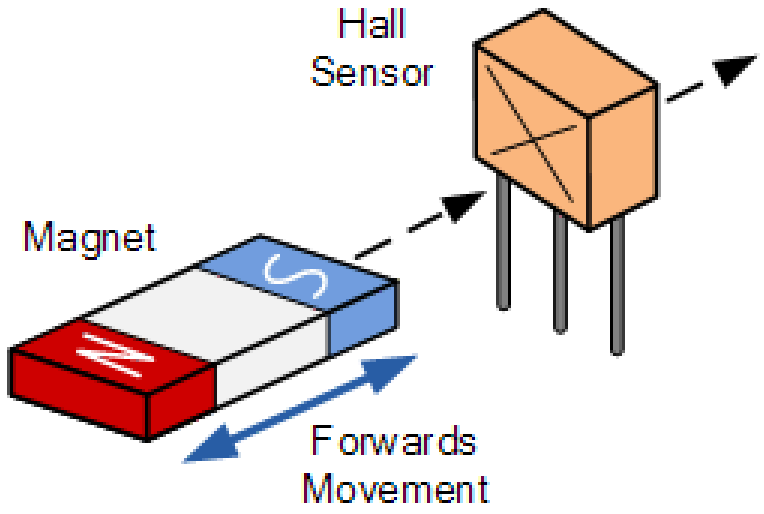
Piezoelectric is used as a micro motion actuator or as a sensor by converting pressure, strain, or force to electric charge.

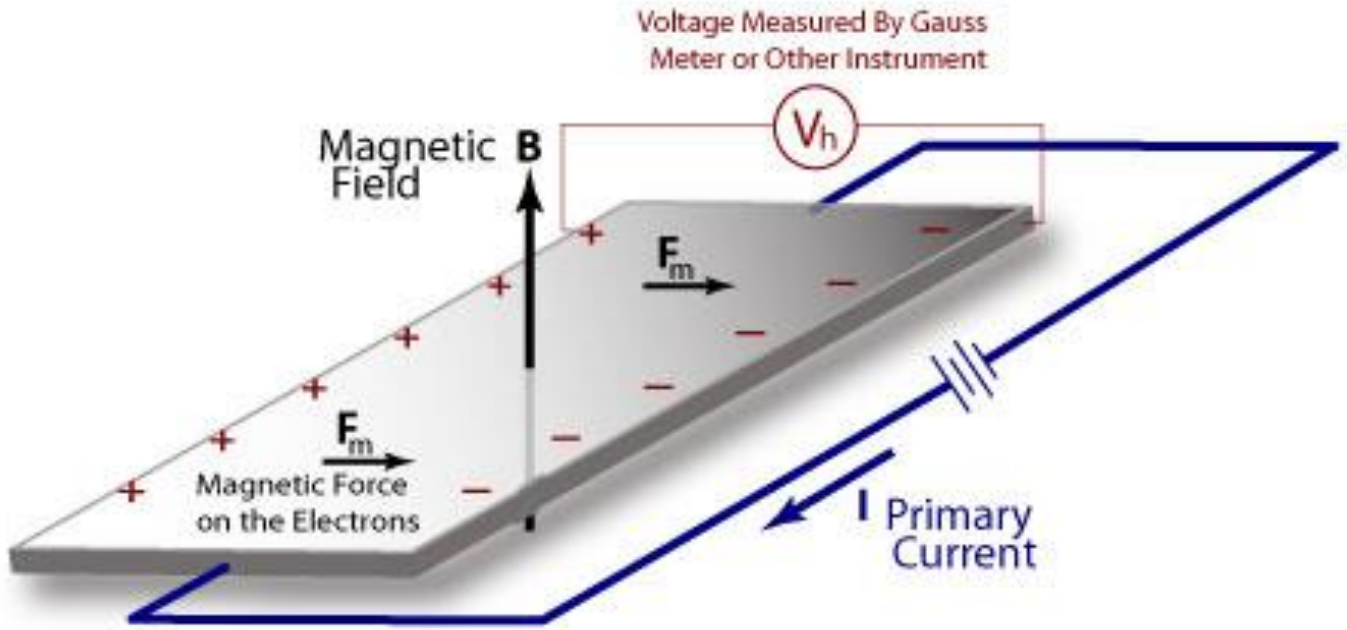




Hall Effect Sensor

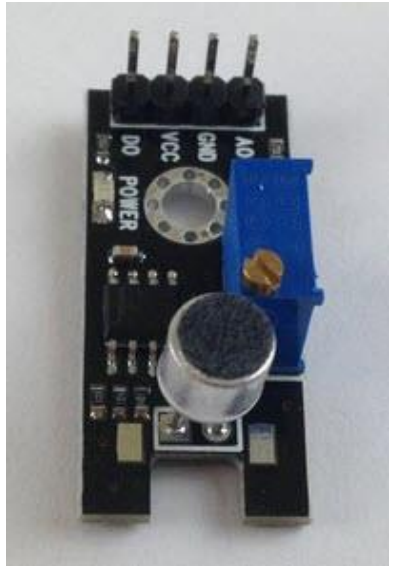
Hall effect is the production of a voltage difference (the **Hall voltage**). It was discovered by Edwin Hall in 1879.





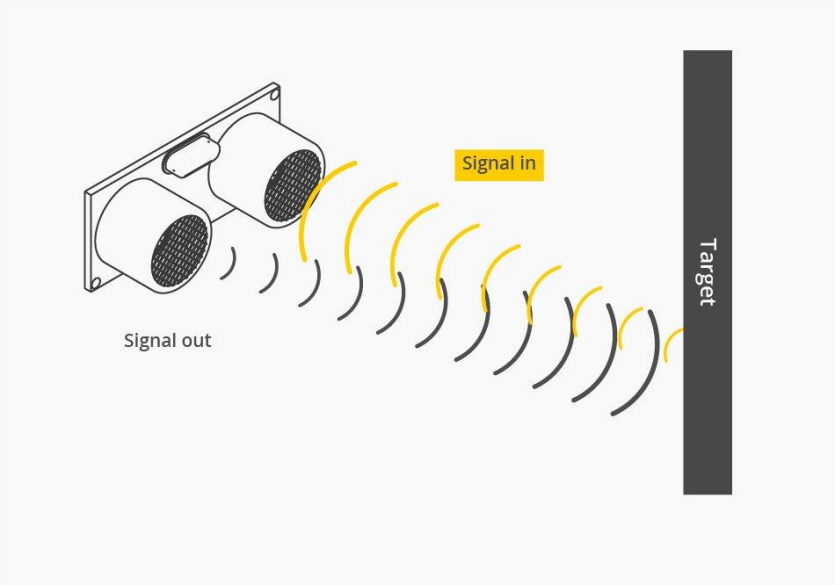
Input Device: Sound Sensors

- Sensors used to sense sound level are called sound sensors.
- These sound sensors **translate** the amplitude of the acoustic volume of the **sound** into an electrical **voltage** for sensing sound level.
- They typically use a thin piece of material, commonly called a diaphragm which generates an electrical signal when it vibrates due to the acoustic waves.



Input Device: Distance Sensors

- There are several methods to determine the distance between a sensor and an object, the type of sensor we will look at uses sound.
- **Ultrasonic sensors:**
  - They emit sound waves at a **frequency** nonaudible to humans.
  - They then wait for the sound to be reflected and received back at the sensor, calculating distance based on the time between **sending** and **receiving** the signal.



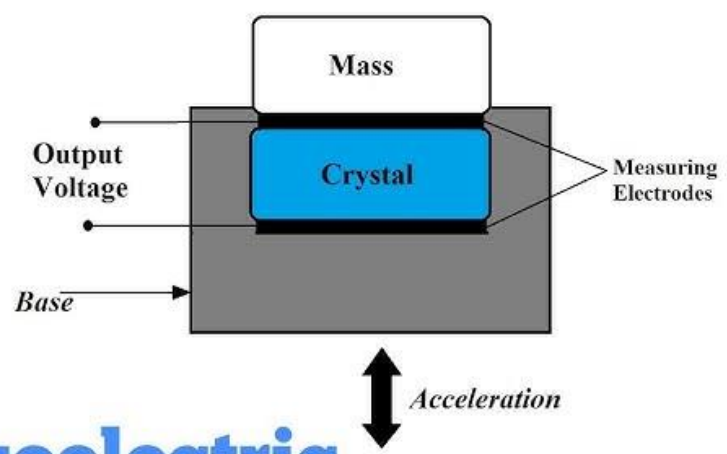
Input Device: Motion Sensors

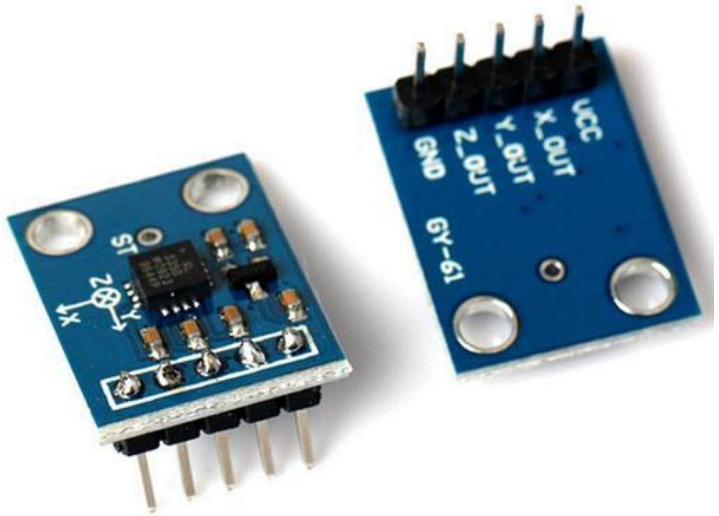
- A motion sensor (or motion detector) is an electronic device that is designed to detect and measure movement.

- They are typically embedded systems with three major components:
  - ✓ A sensor unit, an embedded computer, and hardware (or the mechanical component).

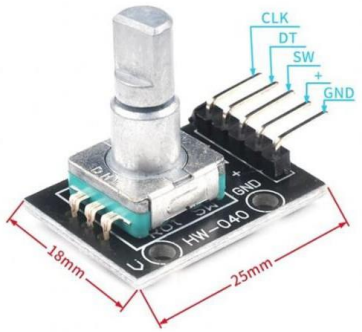
Input Device: Accelerometer

- Sensors that detect changes in acceleration are called accelerometers.
- Accelerometers are available as **analog** and **digital** sensors.
- The analog accelerometer produces a variable **voltage** based on the amount of acceleration applied to the accelerometer which is then converted to an equivalent acceleration.

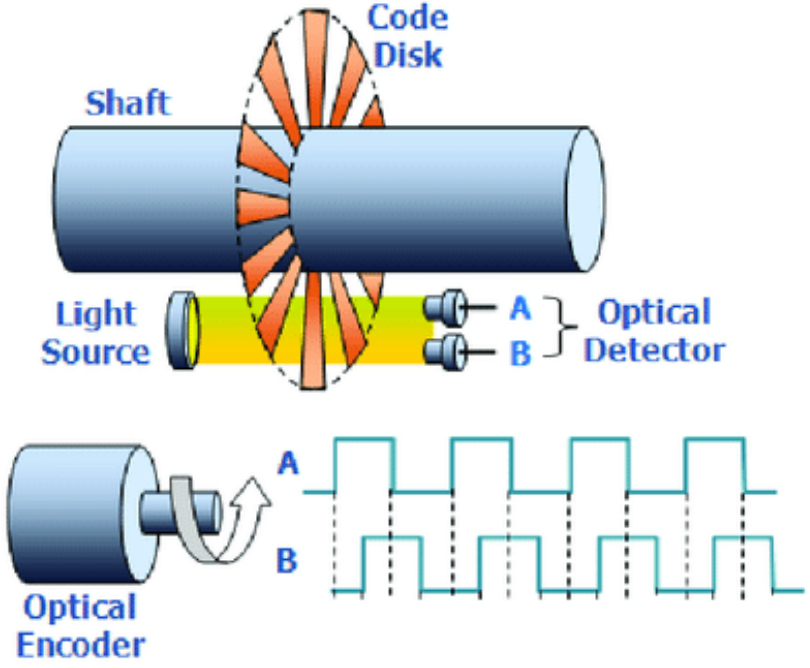


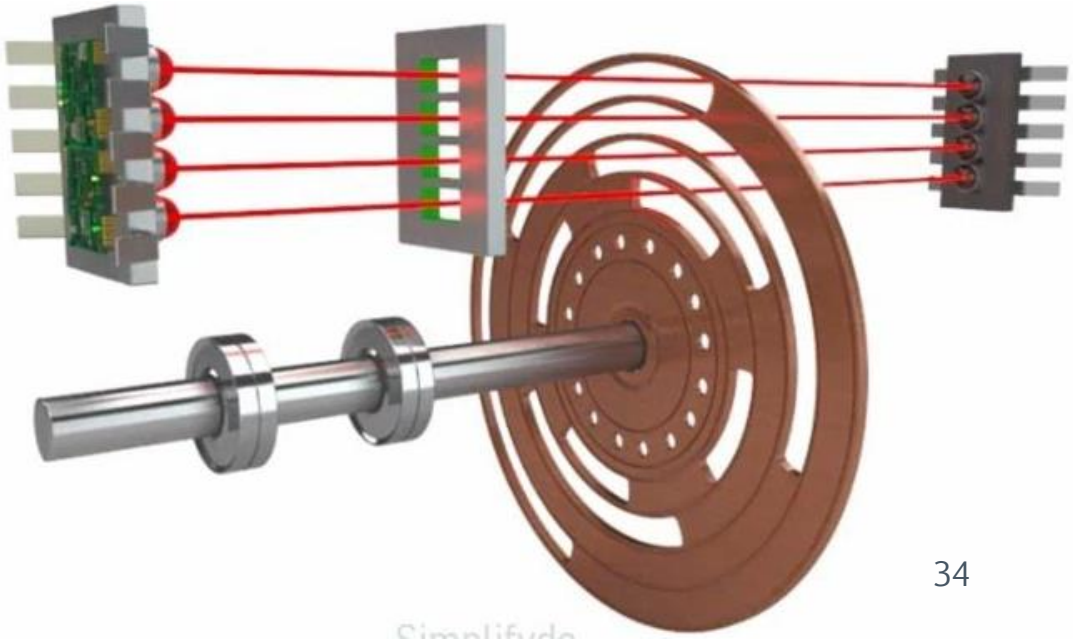


Input Device: Rotary Encoder



- Sensors that detect rotational position (and consequently speed) by converting rotational mechanical displacement into an electrical signal.
- Two types:
  - Incremental Encoders.
  - Absolute Encoders.





Encoder

High Speed Count Configuration

High Speed Count

Up (X002)

DD2 = 1 2 3 4 5 6 7 8

Preset

Edit | Delete

Name HighSpeedCount1 (Max. 16 characters) | Assign Nicknames automatically | Current Count Value DD2

Pulse Input(s)

Type: Up Count

Up: X002 | Count Timing: Rising Edge

Use Reset

You can write a value to DD2 directly.

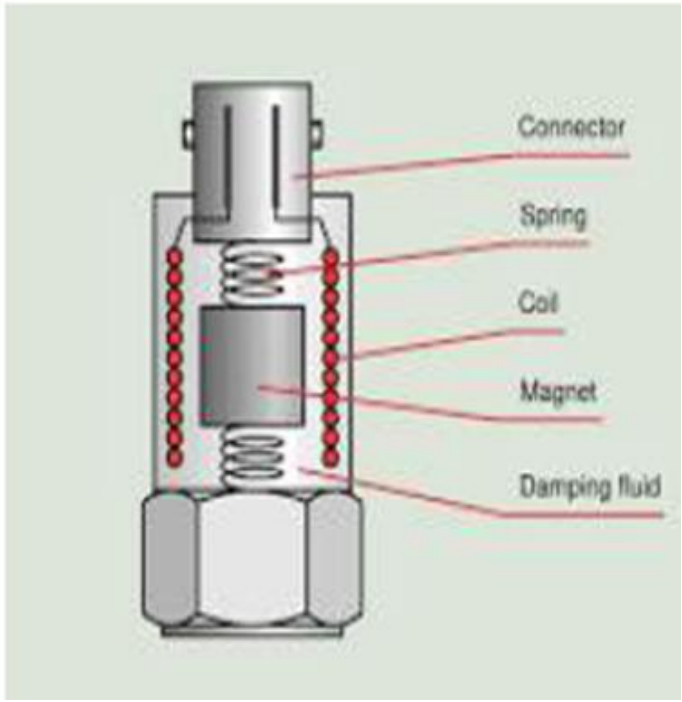
Use Enable

This counter is enabled always.

OK | Cancel | Help

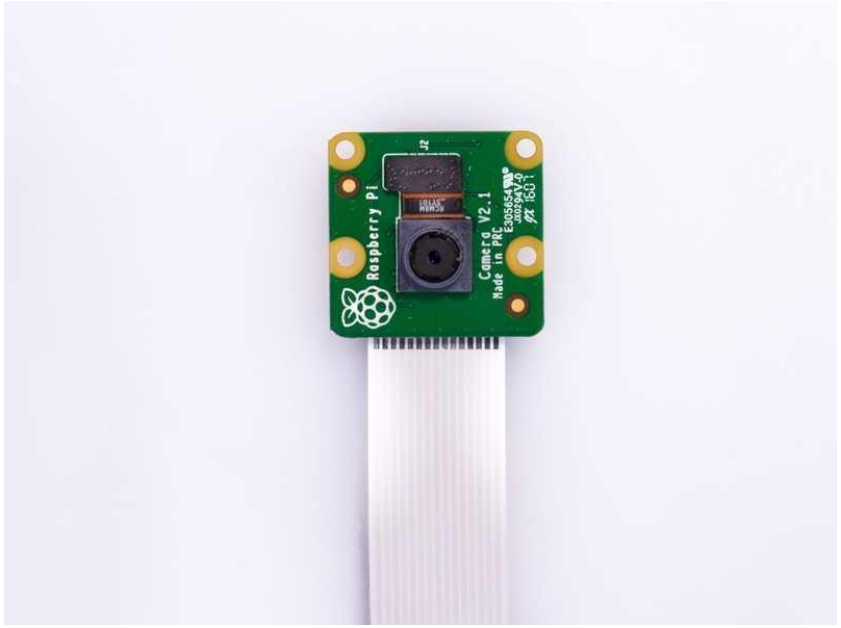
Input Device: Velocity Sensor

A velocity receiver (velocity sensor) is **a sensor that responds to velocity rather than absolute position.** For example, dynamic microphones are velocity receivers. Movement causes the coil to move relative to the magnet, which in turn generates a **voltage** that is **proportional** to the **velocity** of that movement.



Input Device: PI Camera

- The camera module can be used to take high-definition video, as well as still photographs. It supports 1080p30, 720p60 and VGA90 video modes.
- Unlike other devices that use GPIO pins, the camera attaches via a ribbon cable to the **Camera Serial Interface (CSI)** port on the Raspberry PI.

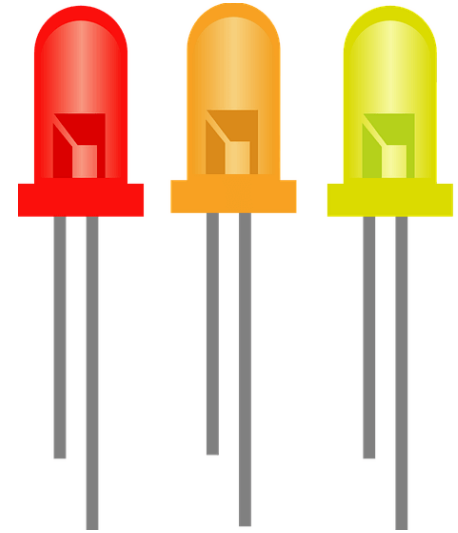


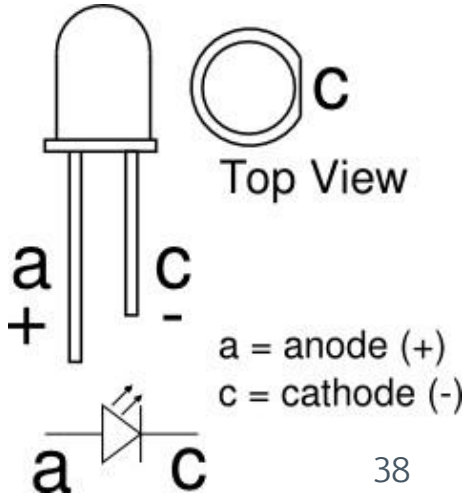
Output Device: Light Emitting Diode

- Light Emitting Diodes (LEDs) are a type of diode that emit a narrow bandwidth of visible light at different colored wavelengths when a forward current is passed through.

- LEDs are two terminal devices; the **negative** terminal is called the **Cathode,** and the **positive** terminal is called the **Anode**.

- Almost all modern light emitting diodes have their cathode identified either by a notch on the side or by the **cathode** lead being **shorter** than the **anode**.



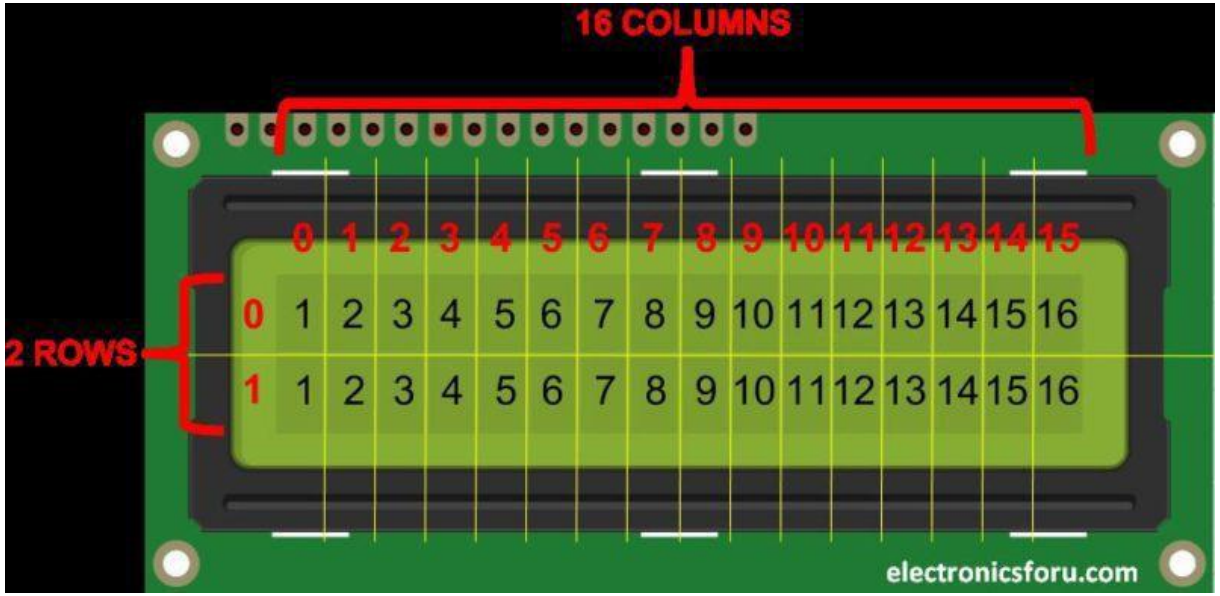


Output Device: Buzzer

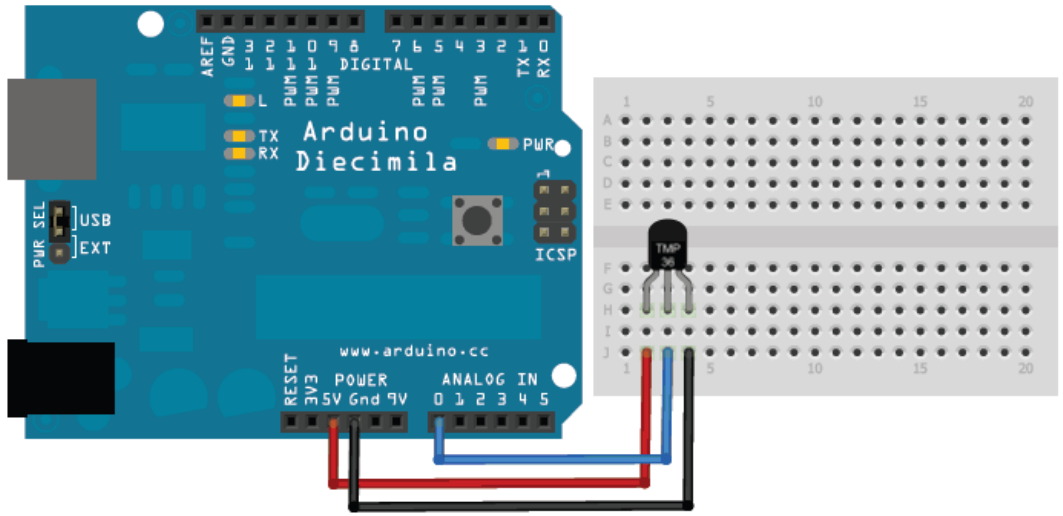
- A buzzer or beeper is an audio signaling device, which may be **mechanical**, **electromechanical**, or **piezoelectric**.
- Typical uses of buzzers and beepers include alarm devices, timers, and confirmation of user input such as a mouse click or keystroke.
- **Piezoelectric** (piezo) buzzers contain a piezo electric vibration within a molded case. Sound is emitted when a **voltage is applied** and the piezo element inside the case **vibrates**.

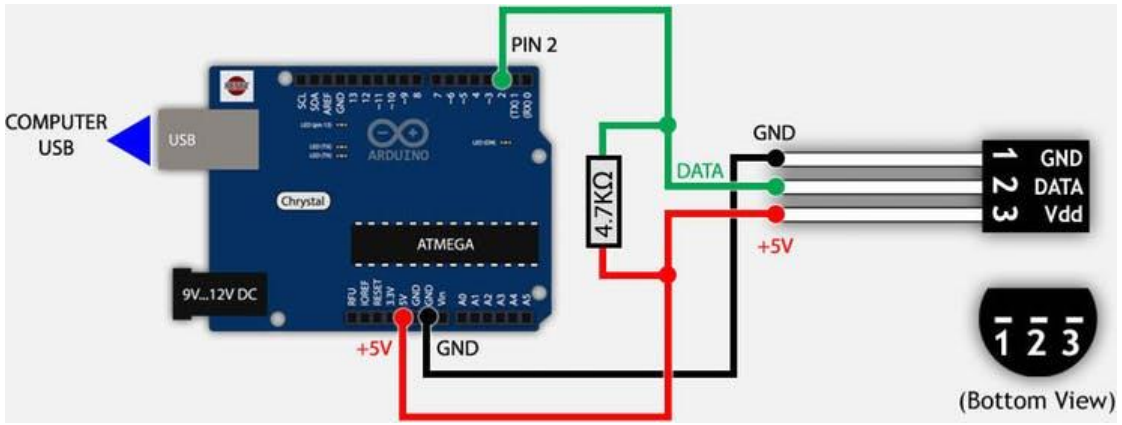
Output Device: Liquid Crystal Display (LCD)

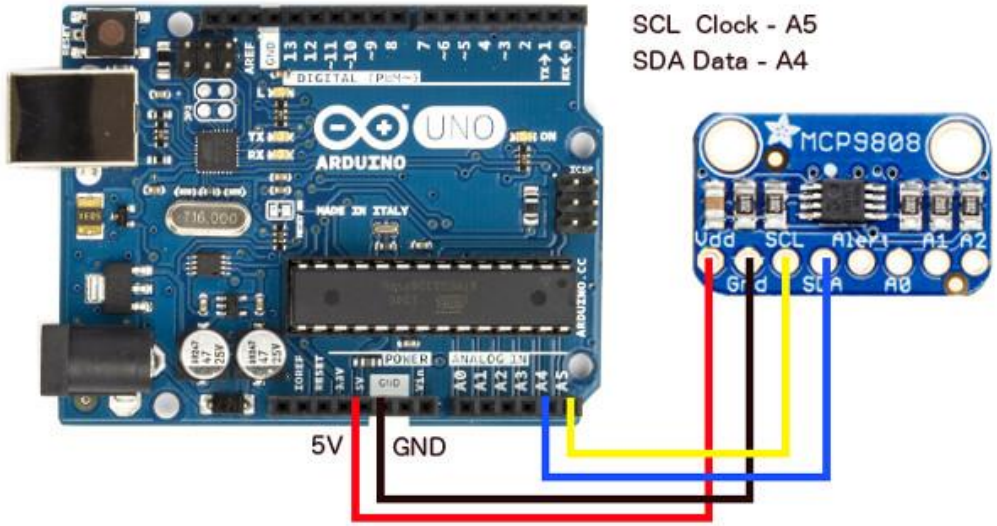
- An LCD is an electronic display module which uses liquid crystal to produce a visible image.
- The 16 × 2 LCD display is a basic module used in the labs.
- The 16 × 2 translates to display 16 characters/line in 2 such lines. In this LCD each character is displayed in a 5 × 7 pixel matrix.



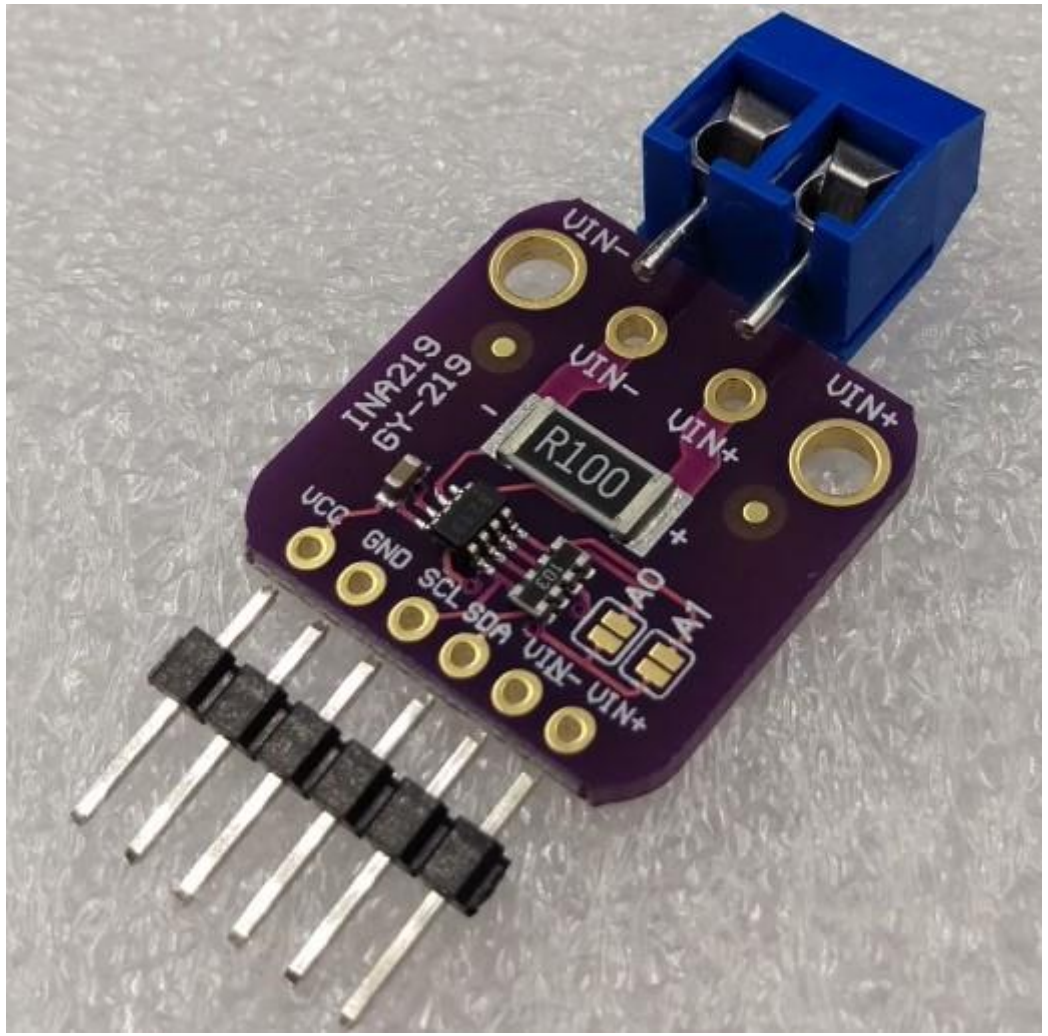
Sensors: Types

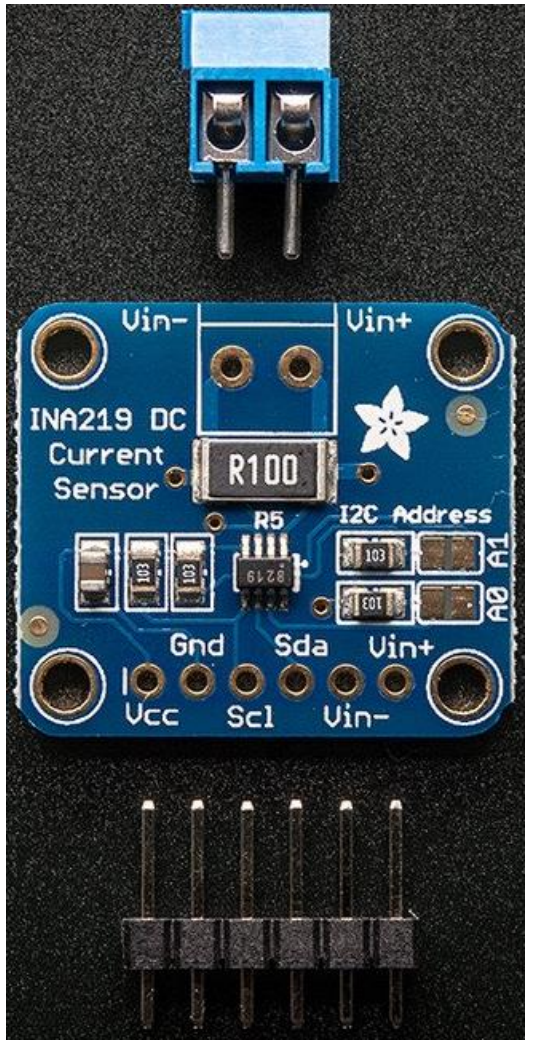






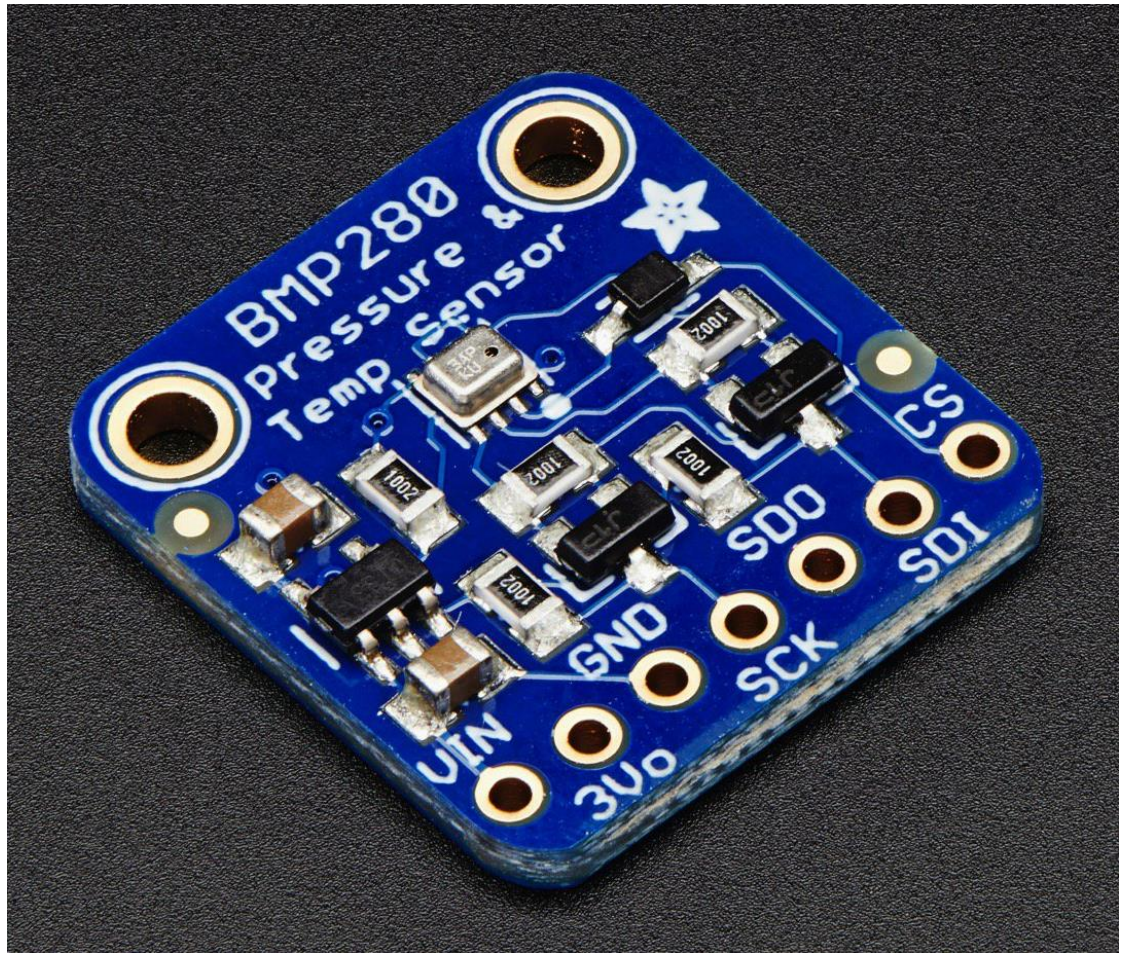
I²C Current Sensor





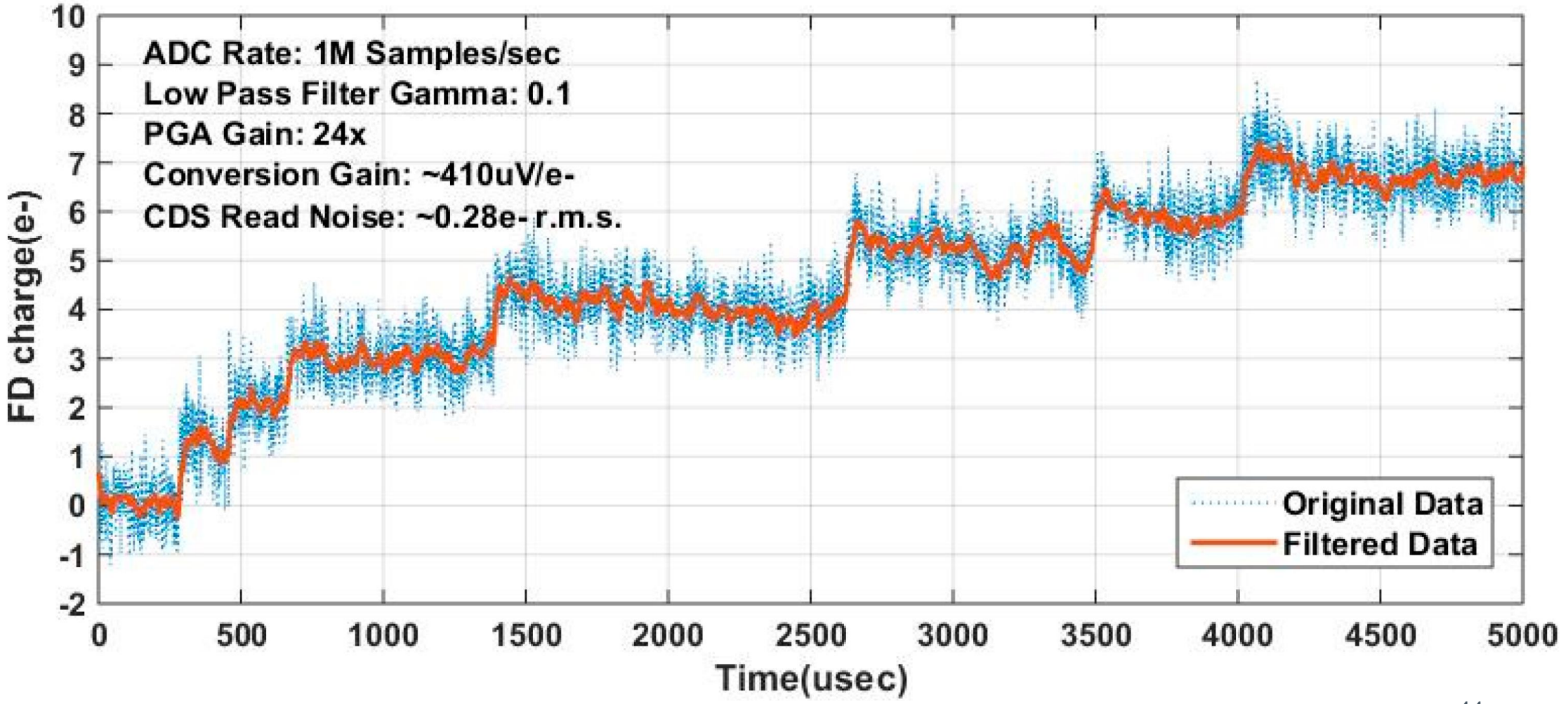
https://cdn-learn.adafruit.com/downloads/pdf/adafruit-ina219-current-sensor-breakout.pdf

SPI Pressure, Altitude & Temperature Sensor

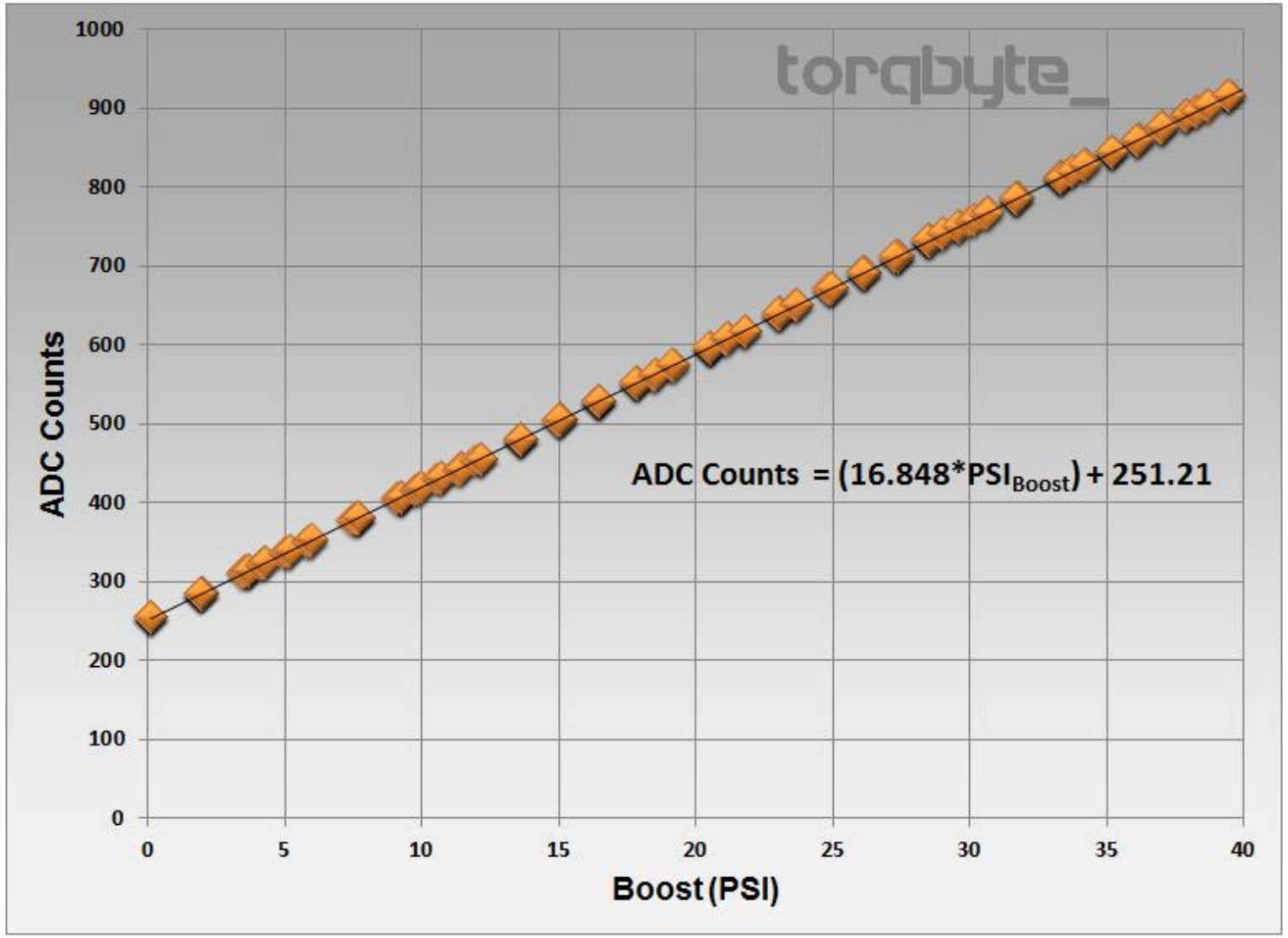


https://cdn-learn.adafruit.com/downloads/pdf/adafruit-bmp183-spi-barometric-pressure-and-altitude-sensor.pdf

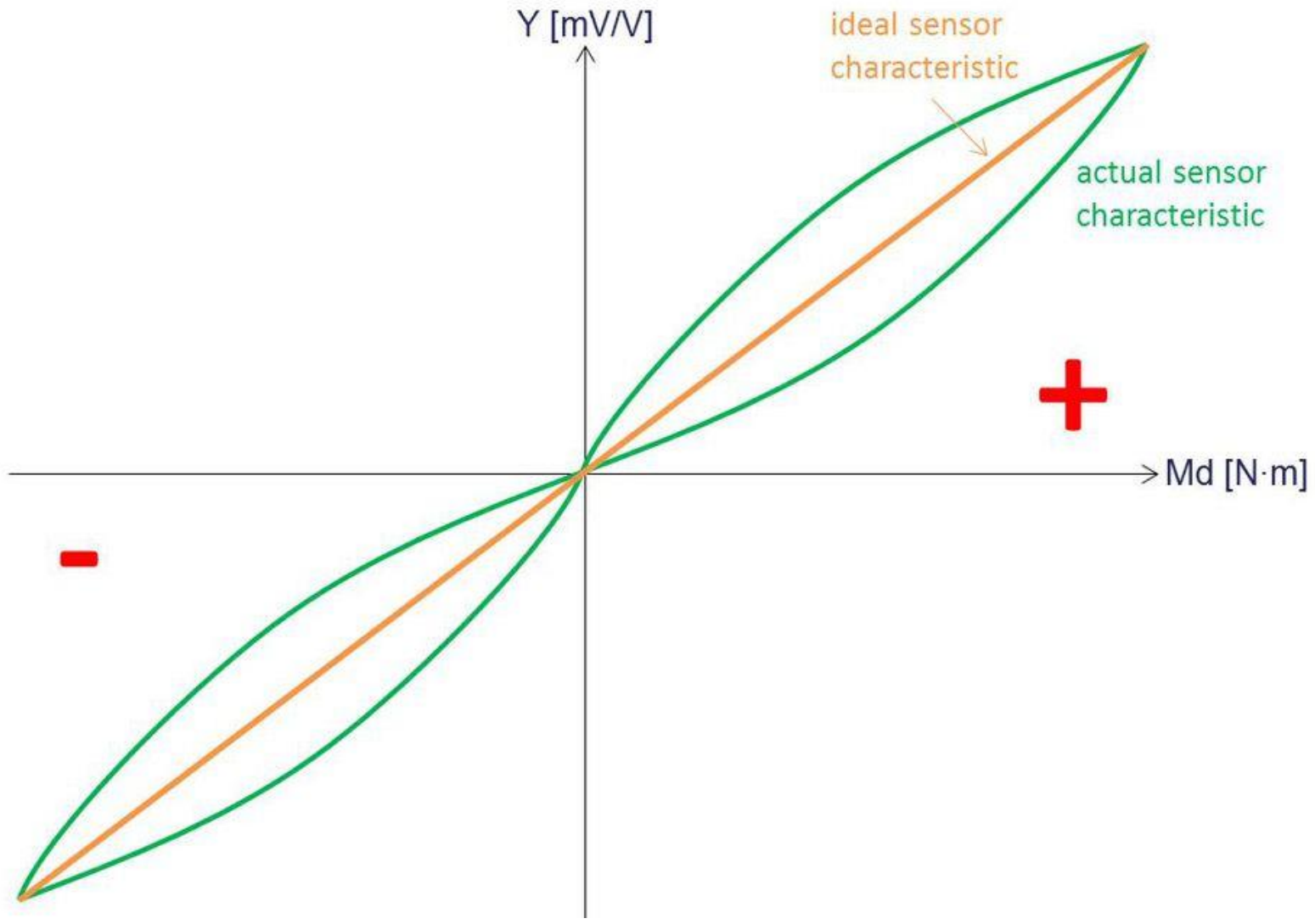
Sensors: Noise



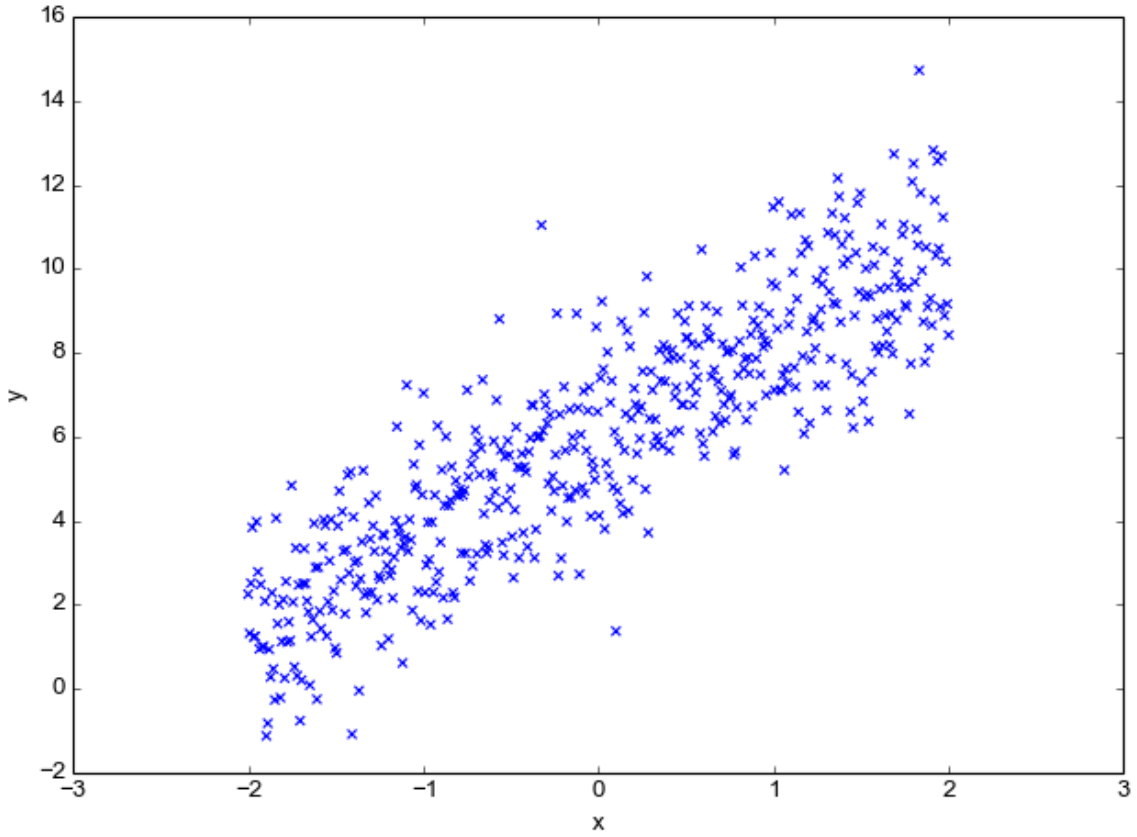
Sensors: Ideal Case

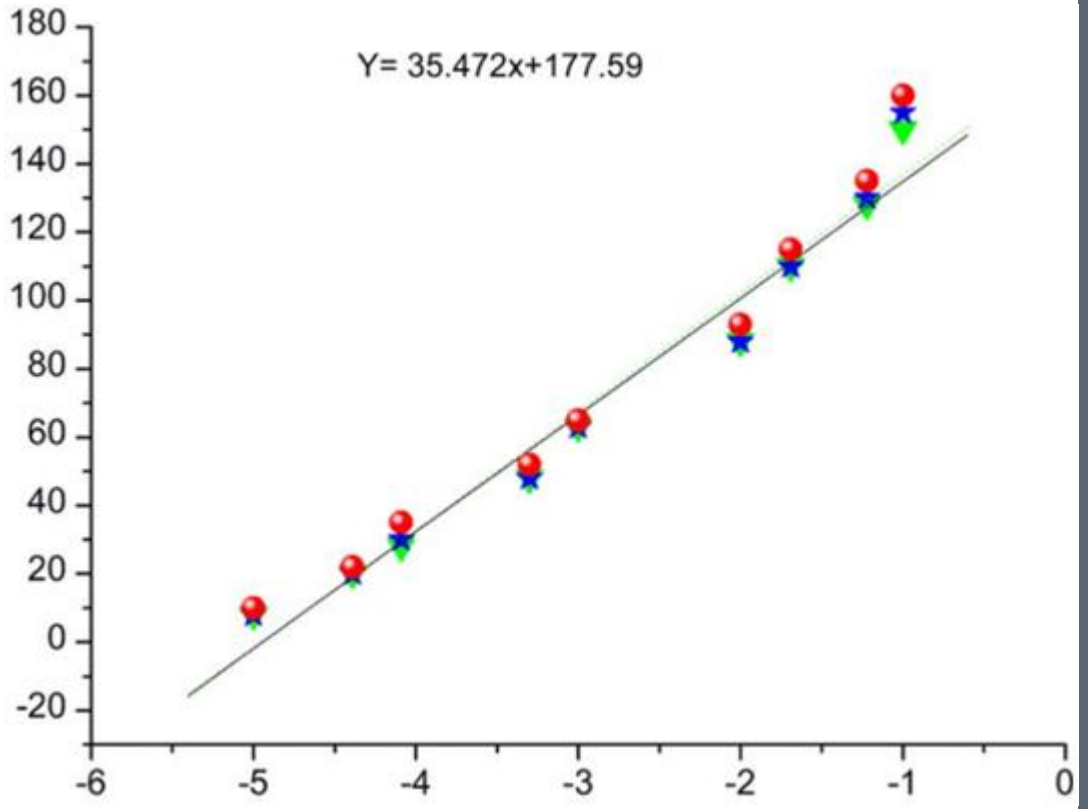


Sensors: Identification

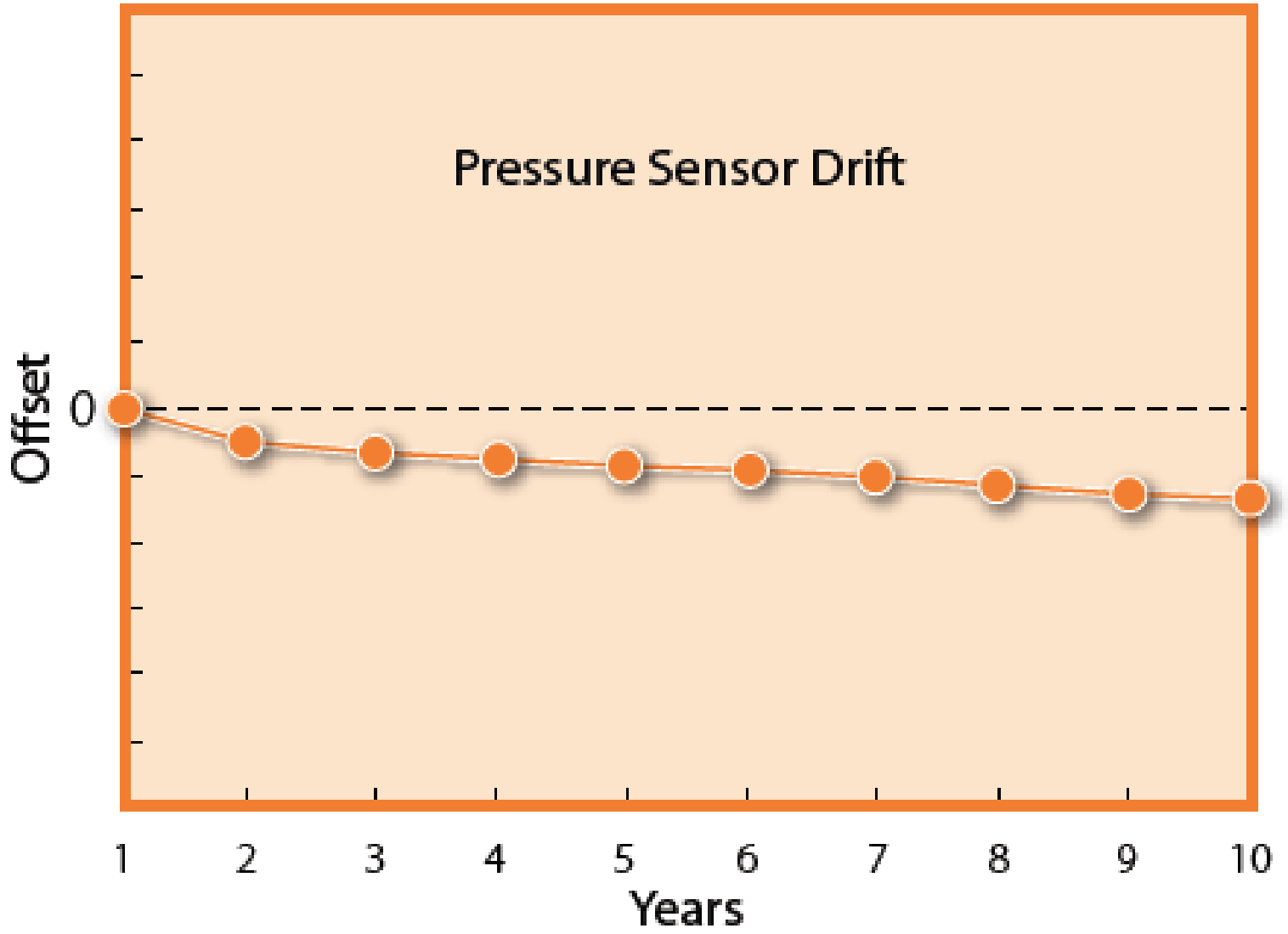


Sensors: Repeatability

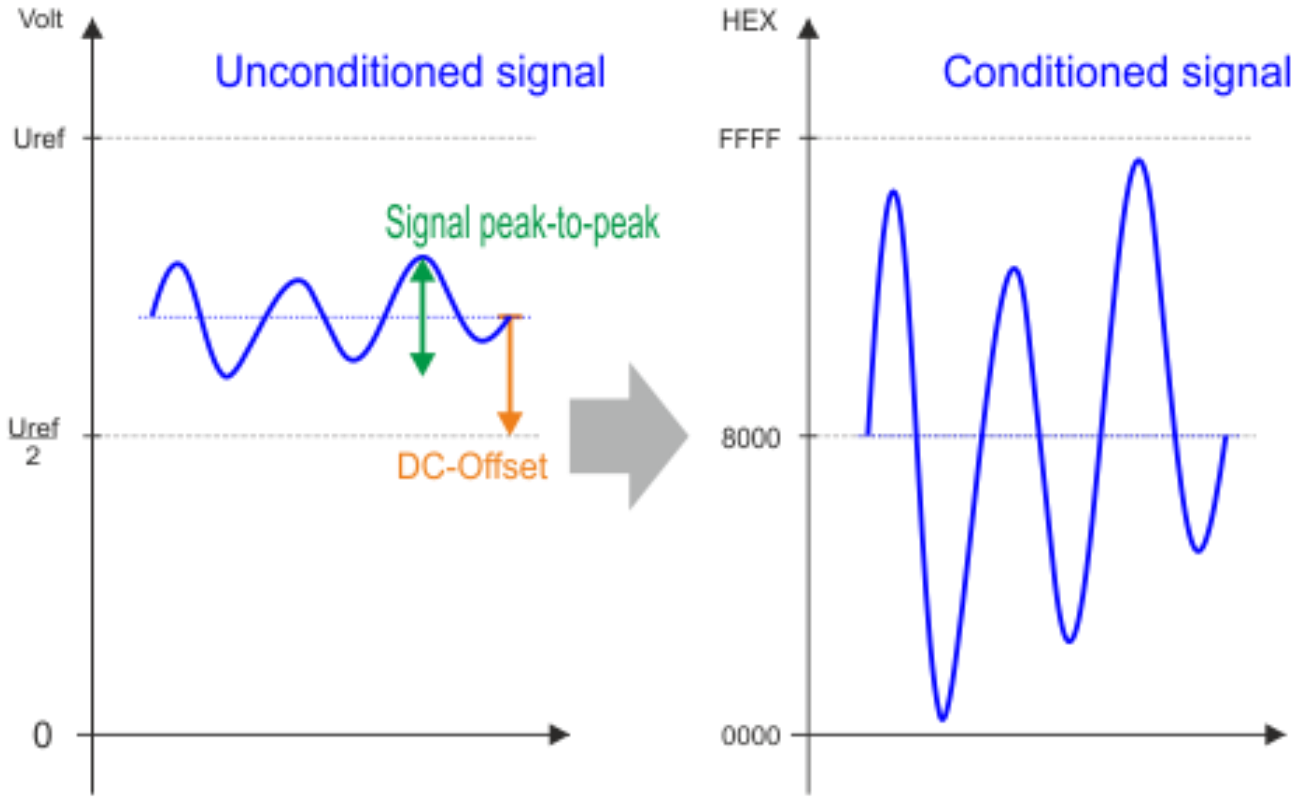




Sensors: Offset



2 vs. 3-Axis Gyro (MD0520 vs. MMA7361L)



http://www.mouser.com/catalog/specsheets/TinkerKitGyroscope2Axis4X.pdf
https://www.nxp.com/docs/en/data-sheet/MMA7361L.pdf

Torque

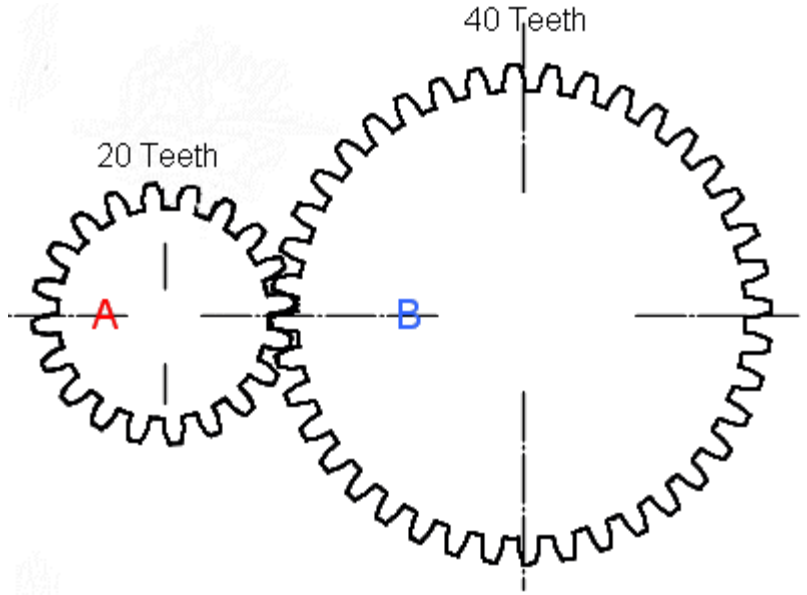
- Also known as moment of force, or moment, torque is the rotational equivalent of a linear force.

- It can be calculated by: $M = F \cdot D$

Gear Ratios

- It can be used to change direction of rotational motion or converting one set of rotational speed and torque to a different set of rotational speed and torque.

$$GR = \frac{T_2}{T_1}$$

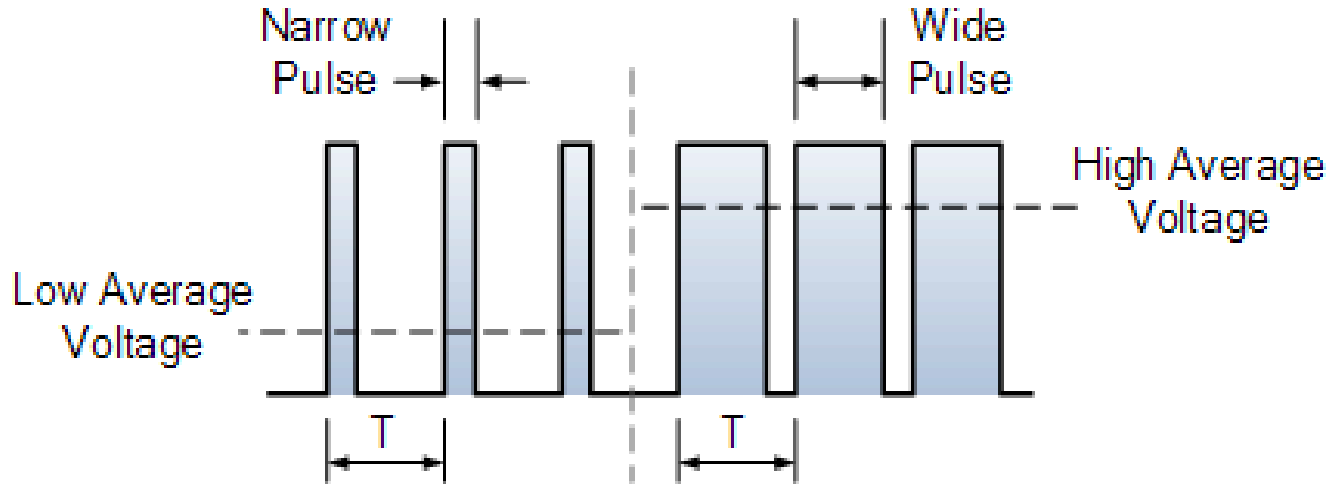


- To convert the torque from a motor using a gearbox, the original torque and gear ratio are required:

$$\tau_{new} = GR * \tau_{OG}$$

Pulse-Width Modulation

- Pulse width modulation (PWM) is a method of reducing or increasing the average power delivered by an electrical signal. By effectively breaking it into discrete parts of varying durations.
- The average value of voltage fed to a load is controlled by turning the switch between the supply and load on and off at a fast rate.
- The longer the switch is ‘ON’ compared to ‘OFF’, the higher the total power supplied to the load and vice versa



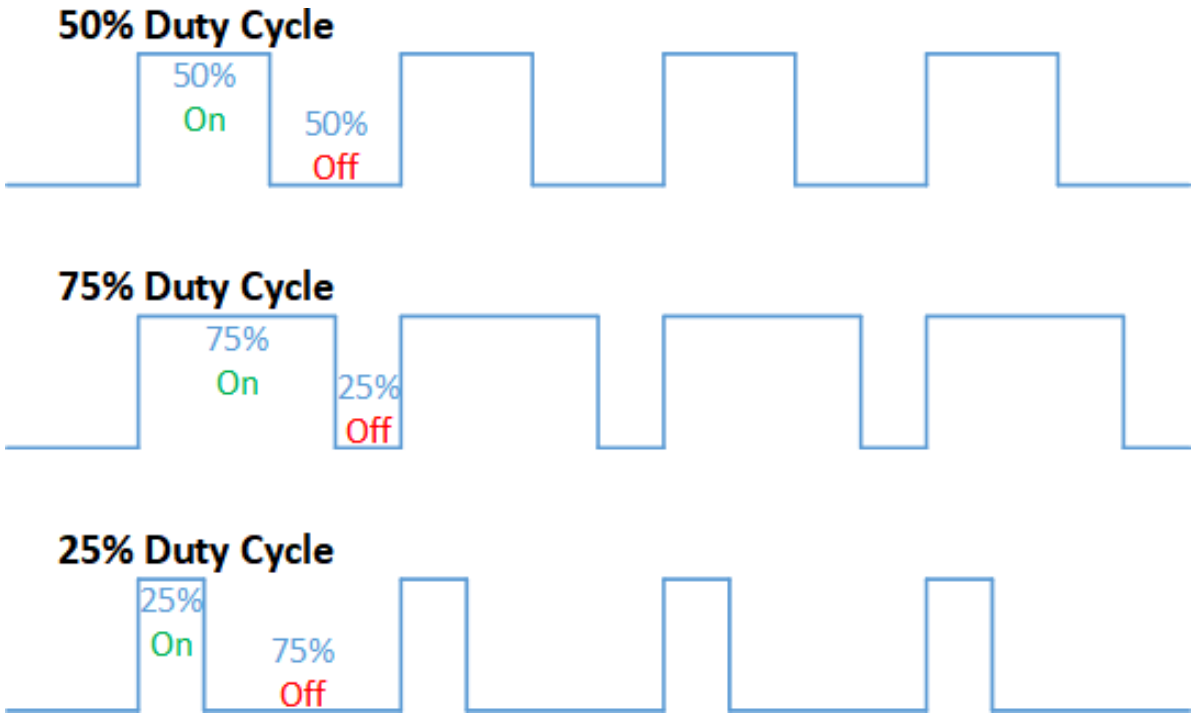
Pulse-Width Modulation

- PWM signals are often used for driving DC or servo motors and for other simple tasks like controlling the brightness of a LED.

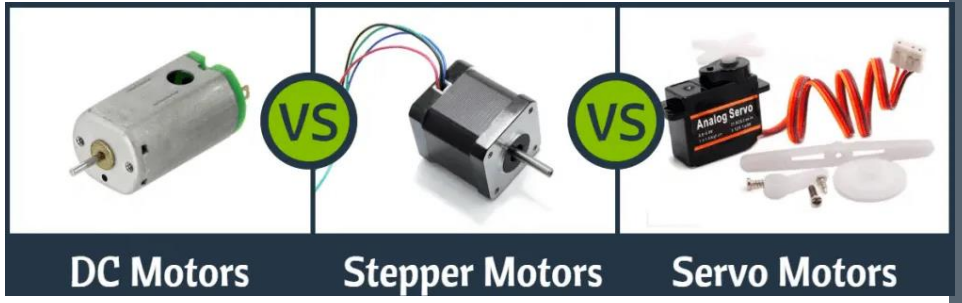
$$Duty\ Cycle = \frac{TON}{TON + TOFF}$$

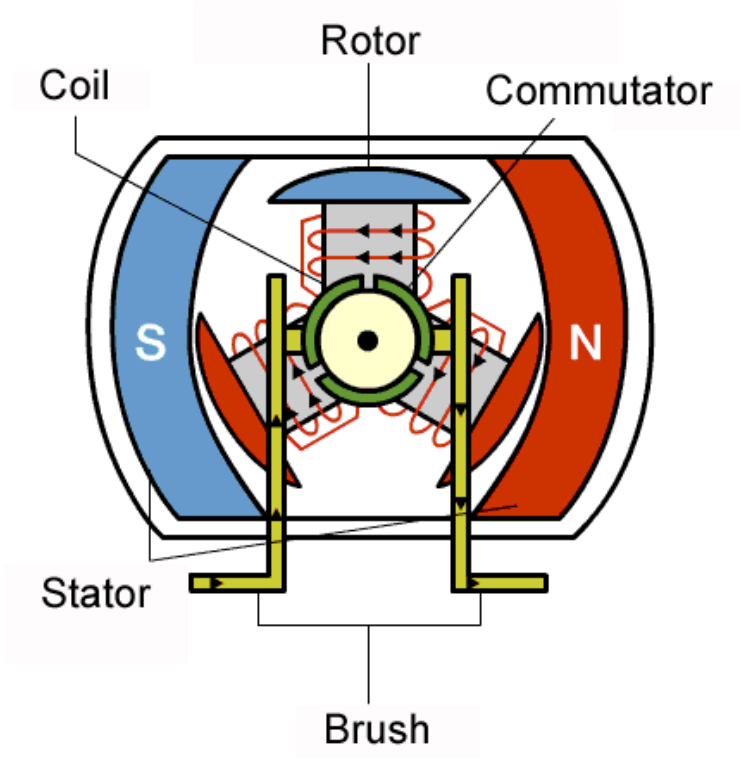
$$Duty\ Cycle\ (\%) = \frac{TON}{TON + TOFF}\ X\ 100$$

$$D = \frac{PW}{T} \cdot 100$$

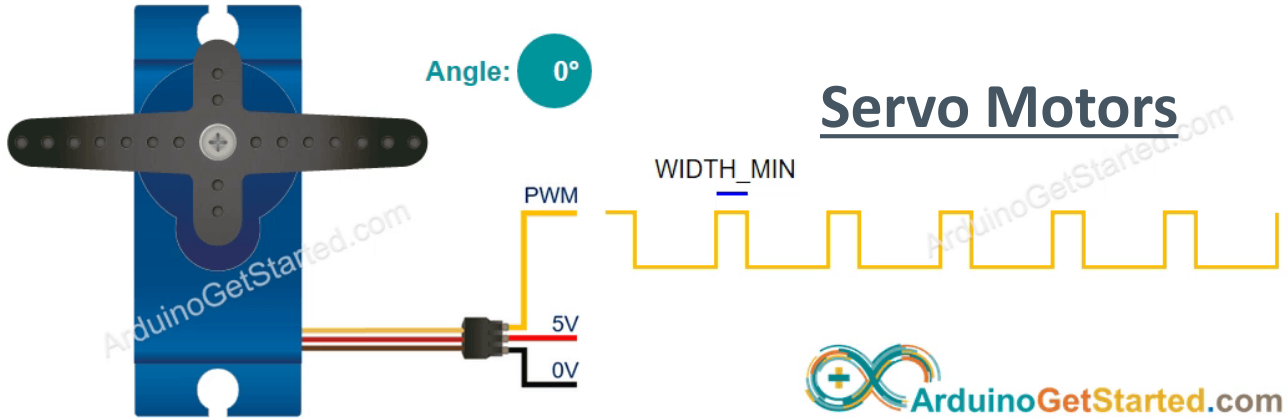


Output Device: Motors

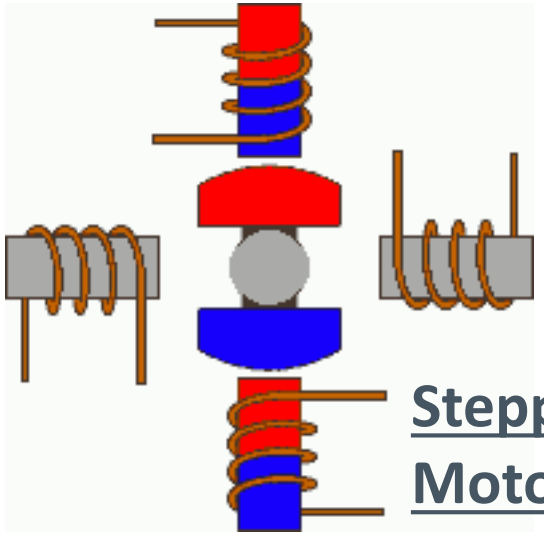




DC Motors



Servo Motors



Stepper Motors

Questions?