CSE444: Introduction to Robotics sensors

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Course Objective

- **At the end of this course, students should be able to:**
  - What are sensors?
  - Detectable Phenomenon.
  - Physical Principles- How do sensors work?
  - Need for sensors.
  - Choosing a sensor.
  - Sensor Descriptions.
    - Temperature sensor.
    - Light Sensor
    - Ultrasonic sensor.
    - Accelerometer.
    - Magnetic field sensor.
    - Photogate.
    - CO_2 Gas sensor.

What are sensors?

- **<u>Definition</u>:** An electrical/ mechanical/ chemical device that sense physical variable(light, heat, etc..) of a physical system or environment.

Q. Why a sensor is called transducer?

Each sensor is based on a transduction principle- conversion of energy from one form to another.

<u>Classifications of sensors:</u>

- **<u>Mechanical Quantities:</u>**
  - displacement, acceleration,
  - weight, force/torque, pressure,
  - flow, rotation velocity.

What are sensors?

- **Electromagnetic/optical quantities:**
  - voltage,
  - current,
  - frequency
  - phase;
  - visual/images,
  - light
  - Magnetism.

- **Thermal quantities:**
  - temperature,
  - heat..

- **Chemical quantities:**
  - moisture,
  - pH value.

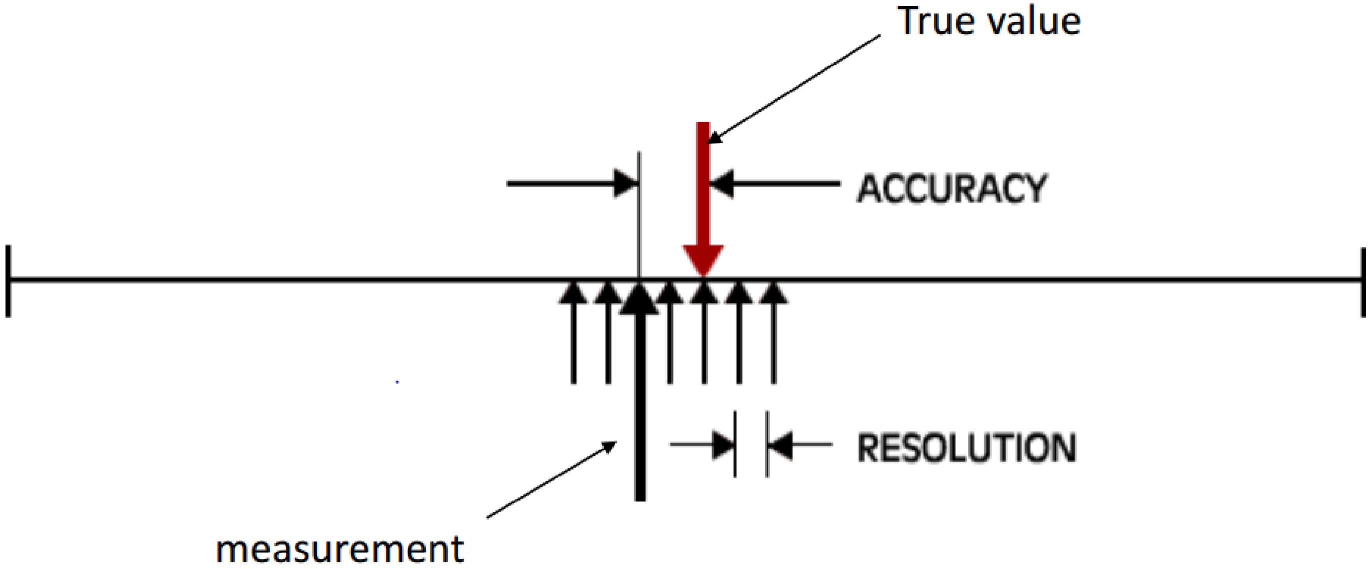
Specifications of Sensor

- **Accuracy**: Error between the result of a measurement and the true value being measured. Or, The error between the real and measured value.

- **Resolution**: The smallest increment of measure that a device can make(step size, $\Delta = 2^* Am/L$).

- **Sensitivity**: The ratio between the change in the output signal to a small change in input physical signal. Slope of the input-output fit line.(slope= $\frac{\Delta Vout}{\Delta Vin}$).

Accuracy vs Resolution



Accuracy vs Precision

Accuracy refers to the closeness of a measured value to a standard or known value.

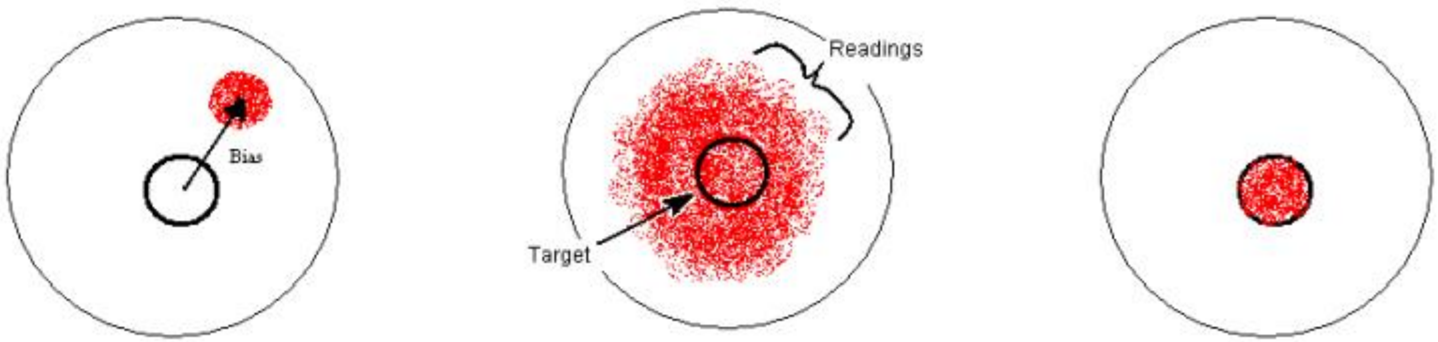
For example, if in lab you obtain a weight measurement of 3.2 kg for a given substance, but the standard or known weight is 10 kg, then your measurement is not accurate.

Precision refers to the closeness of two or more measurements to each other.

if you weigh a given substance five times, and get 3.2 kg each time, then your measurement is very precise.

Summary, if on average, your measurements for a given substance are close to the standard value, but the measurements are far from each other, then you have accuracy without precision.

Accuracy vs Precision



Precision without accuracy

Accuracy without precision

Precision and accuracy

Specifications of Sensor

- **Repeatability/Precision:** The ability of the sensor to output the same value for the same input over a number of trials.
- **Dynamic Range:** the ratio of maximum recordable input amplitude to minimum input amplitude, i.e. D.R. = 20 log (Max. Input Ampl./Min. Input Ampl.) dB
- **Linearity:** the deviation of the output from a best-fit straight line for a given range of the sensor.
- **Transfer Function (Frequency Response):** The relationship between physical input signal and electrical output signal, which may constitute a complete description of the sensor characteristics.

Specifications of Sensor

- **Bandwidth:** The frequency range between the lower and upper cutoff frequencies, Within which the sensor transfer function is constant gain or linear.
- **Noise:** Random fluctuation in the value of input that causes random fluctuation in the output value

Choosing a sensor

Environmental Factors	Economic Factors	Sensor Characteristics
Temperature range	Cost	Sensitivity
Humidity effects	Availability	Range
Corrosion	Lifetime	Stability
Size		Repeatability
Overrange protection		Linearity
Susceptibility to EM interferences		Error
Ruggedness		Response time
Power consumption		Frequency response
Self-test capability		

Types of sensor

- **Active**
  - send signals into environment and measure interaction of signals with environment.
  - e.g. radar, sonar.

- **Passive**
  - record signals already present in environment.
  - e.g. video cameras.

Types of sensor

Exteroceptive

Deal with external world

- Where is something?
- How does is look?

(camera, laser rangefinder)

Proprioceptive

Deal with self

- Where are my hands?
- Am I balanced?

(encoders motor,..)

Interoceptive

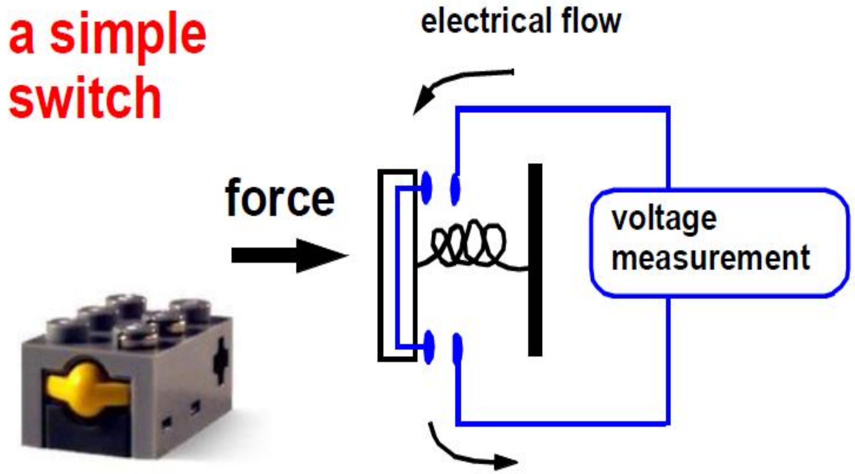
- What is my thirst level?(biochemical)
- What is my battery charge? (voltmeter)

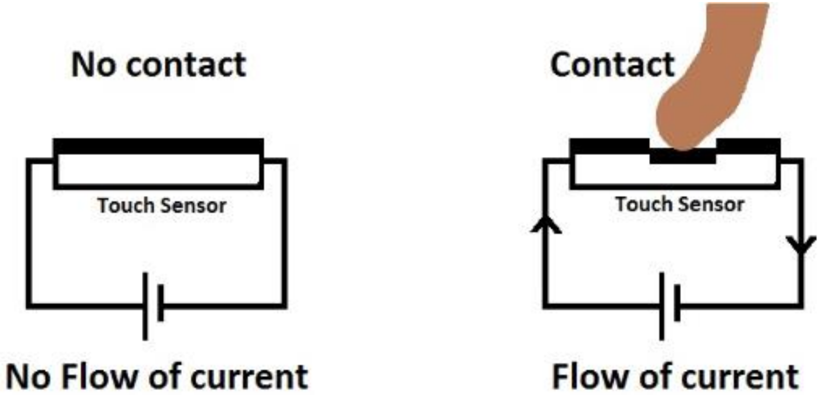
For the most part we will ignore these in this class

Types of sensor

Touch sensor:

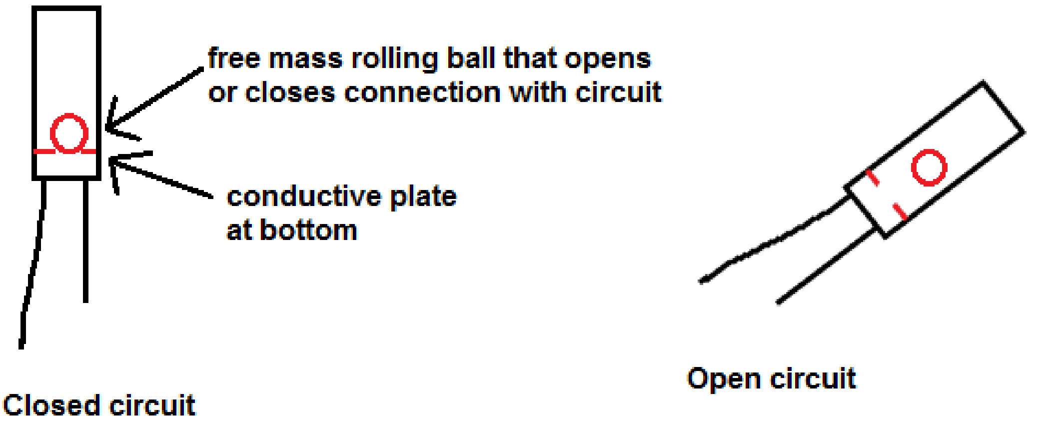
- The Touch Sensor works similar to that of a simple switch.
- When there is contact or a touch on the surface of the touch Sensor. It acts like a closed circuit switch and allows the current to flow through it.
- When the contact is released it acts similar to the opened circuit switch and hence there is no flow of current.





Types of sensor

- **Tilt sensor:**



e.g. Aircraft flight Controls, gravity

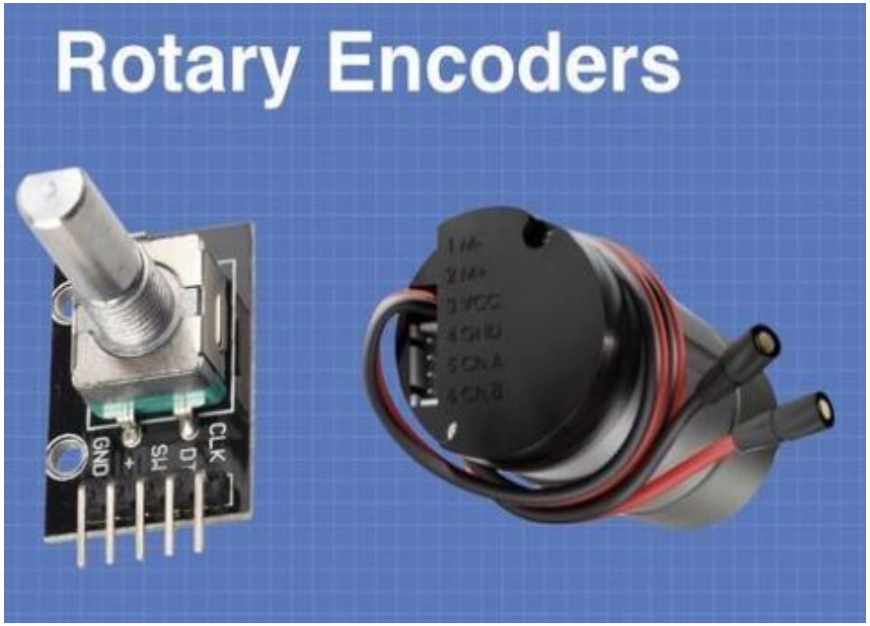
- Tilt sensors are devices that produce an electrical signal that varies with an **angular movement**.
- These sensors consist of a **rolling ball** with a conductive plate beneath them. When the sensor gets power, the rolling ball **falls to the bottom** of the sensor to **form an electrical connection**.
- When the **sensor is tilted**, the rolling ball doesn't fall to the bottom so that the **current cannot flow** the two end terminals of the sensor.

Types of sensor

❑ Encoders sensor:

- Encoders can be used to measure the rotation of a wheel.

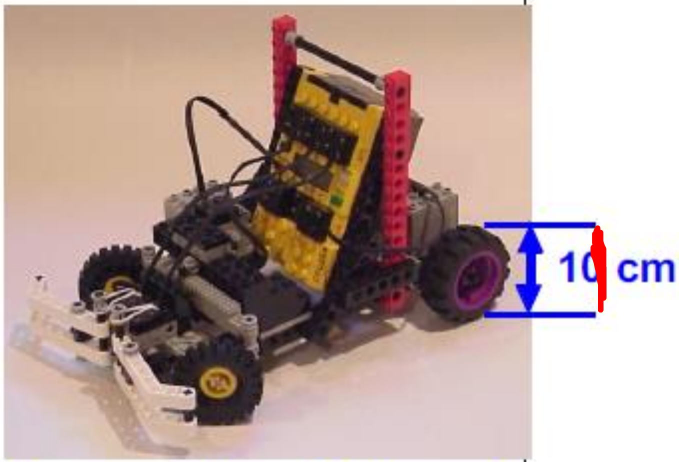
- **Servo motor:** used in conjunction with an electric motor to measure the motors position and, in turn, control its position.



Types of sensor

Sample problems

Sensor Analysis



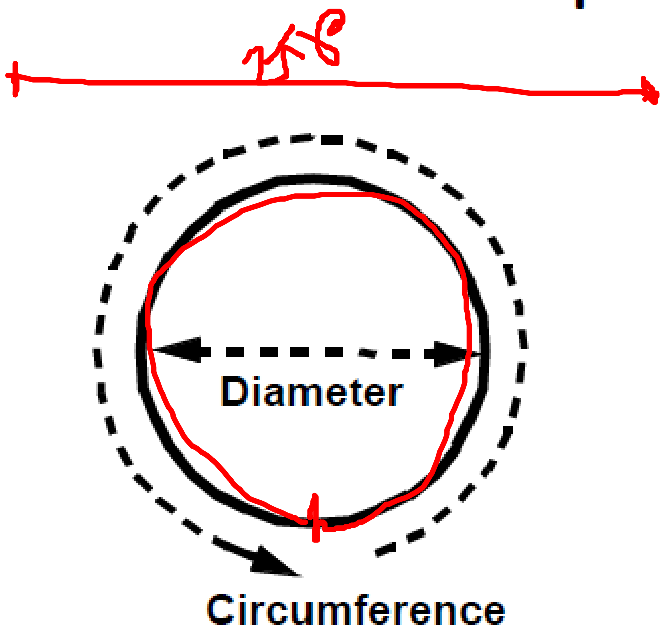
16 counts per rev.

10 cm wheel diameter

- How far does the wheel travel for 1 encoder count?
- What happens if we change the wheel diameter?
- How many counts are there per meter of travel?

Types of sensor

Sample problems



$$C = \pi D$$

$$C = 10\pi \text{ cm}$$

$$\frac{10\pi \text{ cm}}{1 \text{ rev}} \times \frac{1 \text{ rev}}{16 \text{ counts}} = \frac{1.96 \text{ cm}}{\text{count}}$$

Types of sensor

Sample problems

Suppose I want 1.0 cm / count.

What should my wheel diameter be?

$$\frac{1.0\text{ cm}}{\text{count}} \times \frac{16\text{ counts}}{1\text{ rev}} = \frac{16\text{ cm}}{\text{rev}}$$

$$C = 16\text{ cm}$$

$$D = \frac{C}{\pi} = \frac{16}{\pi} = 5.09\text{ cm}$$

Types of sensor

Sample problems

For my 10 cm wheel, how many encoder counts will there be for 1 meter of travel?

$$\frac{1.96 \text{ cm}}{\text{count}} \times \frac{1 \text{ meter}}{100 \text{ cm}} = \frac{0.0196 \text{ m}}{\text{count}}$$

$$\frac{1}{0.0196 \text{ m/ct}} = 51 \text{ counts/m}$$

Types of sensor

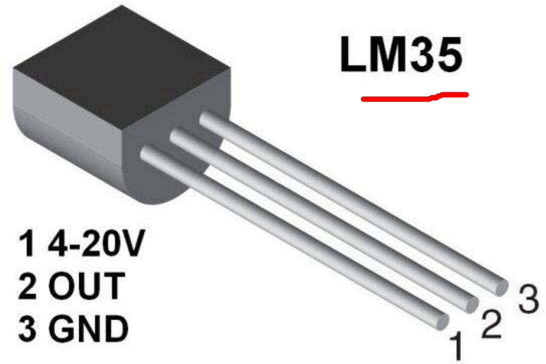
Temperature Sensor:

- **Temperature sensor** is an analog, linear temperature sensor whose output voltage varies **linearly** with change in temperature.

- Resistance temperature device,

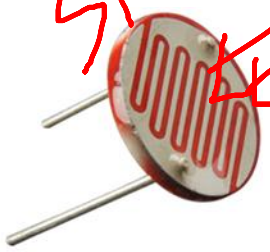
$$R = R_0[1 + \alpha(T - T_0)]$$

$$R = R_0 e^{\gamma\left[\frac{1}{T} - \frac{1}{T_0}\right]}$$

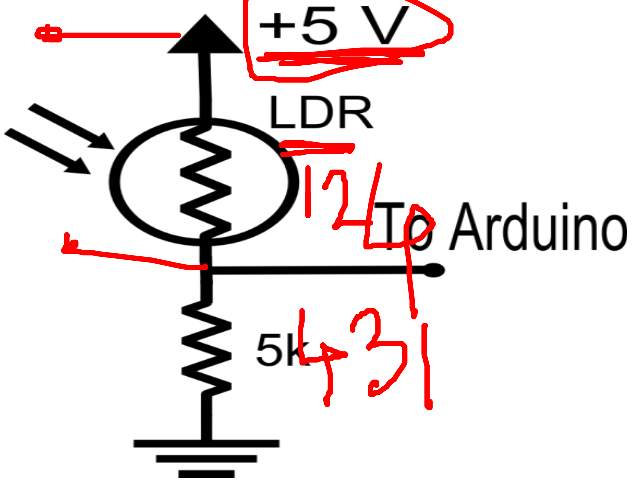


Types of sensor

❑ <u>LDR(Light Dependent Resistor):</u>



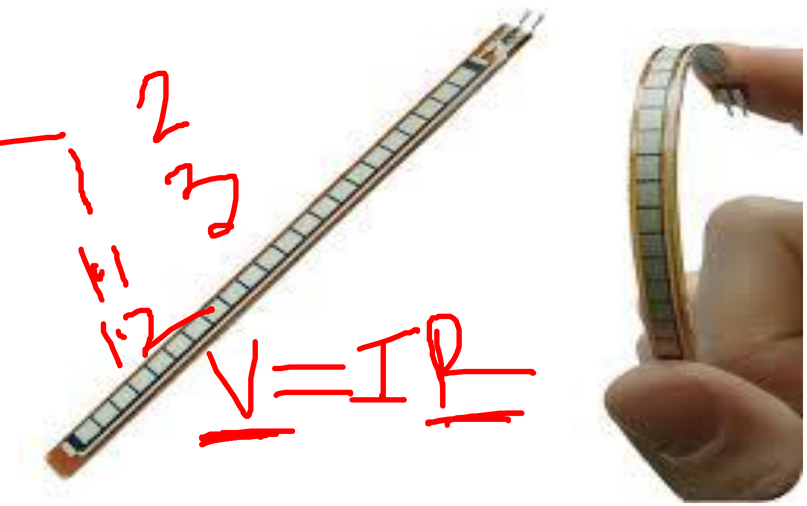
- A ***Light Dependent Resistor (LDR)*** senses light levels.
- The LDR resistance varies with Light.
- The value of resistance decreases with light and vice-versa.
- We do that by using the LDR and a Resistor in a **Potential Divider circuit.**



Types of sensor

❑ Bend sensor:

- **Bend sensor** changes in resistance depending on the amount of bend on the sensor.
- They convert the change in bend to electrical resistance - **the more the bend, the more the resistance value**.
- When the sensor **straightens** out again, the resistance returns to the **original value**.
- By measuring the resistance, you can determine how much the sensor is being bent.

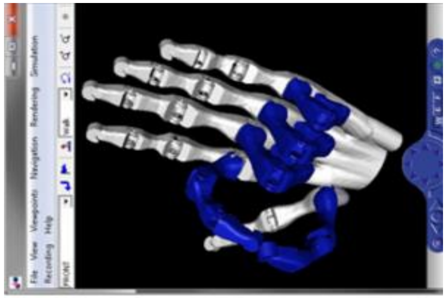


Where it is used?

- gaming gloves,
- measuring devices(weight machines),
- musical instruments,
- Joysticks.

Types of sensor

❑ Bend sensor(cont.):



Types of sensor

- **<u>Bend sensor(cont.):</u>**

Sample problem

Bend sensor specs:

100 Ω when straight

1000 Ω when bent

$$V = I \times R$$

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

Given a 5 V source, what is the min. and max. current that is drawn?

$$\text{min} = \frac{5}{1000} = 5\ \text{mA}$$

$$\text{max} = \frac{5}{100} = 50\ \text{mA}$$

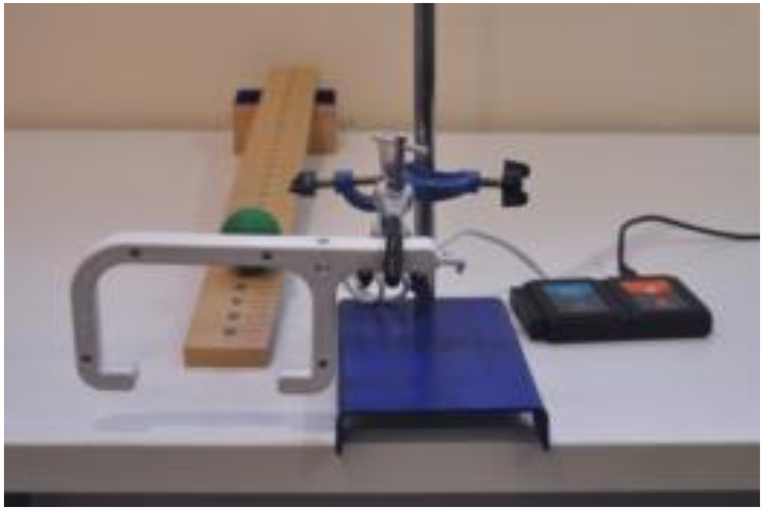
Type of sensor

❑ Photogate Sensor:

- **Photogates** are used in counting applications (e.g. finding period of motion).

- Infrared transmitter and receiver are at opposite ends of the sensor.

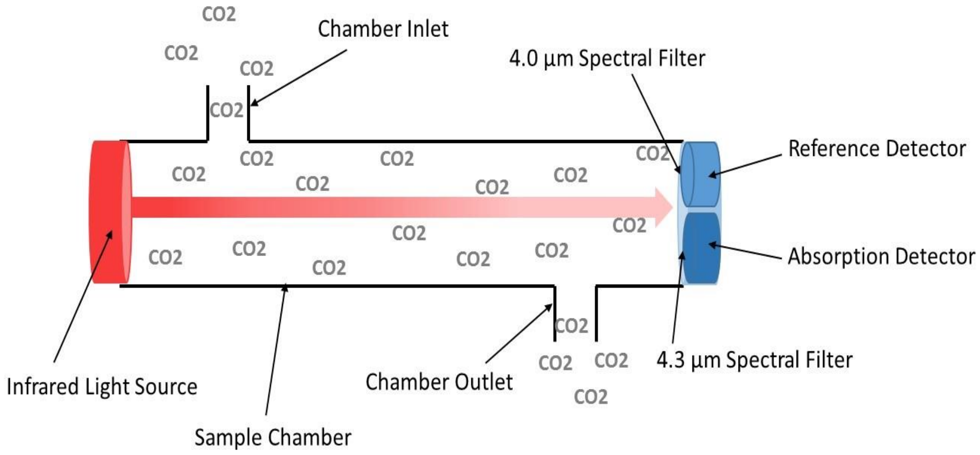
- Measured time, at which light is broken.



Types of sensor

❑ CO_2 Gas Sensor:

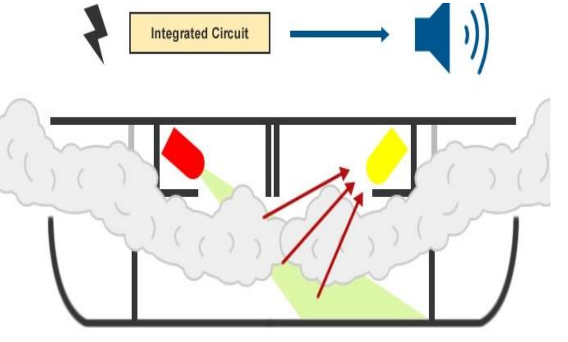
- CO2 sensor measures gaseous CO2 levels in an environment
- Measures CO2 levels in the range of 0-5000 ppm
- Monitors how much infrared radiation is absorbed by CO2 molecules



Types of sensor

❑ **<u>Smoke Sensor</u>**:

- A smoke detector is a device that senses smoke, typically as an indicator of fire.
- Uses a light beam(infrared LED) and electrical photocells (photodiodes) to track smoke particles.
- When smoke particles enter the optical chamber, these particles interfere with the light beam (i.e. the lights reflects off of the smoke particles) and then make contact with the electrical photocells
- This contact increases the electrical charge in the detector to a threshold level, which initiates an alarm signal.
- details://www.safelincs.co.uk/smoke-alarm-types-optical-alarms-overview/

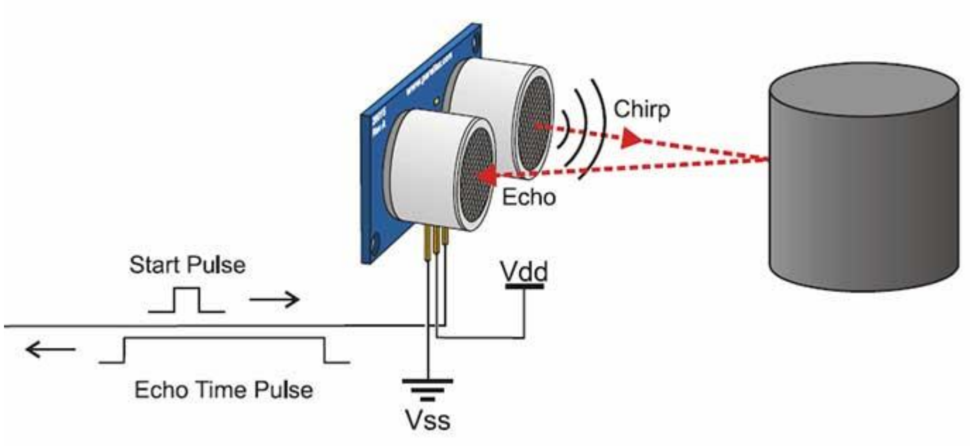


Types of sensor

❑ Ultrasonic sensor:

- The transmitter sends a high-frequency sound triggered by a signal pulse of 10µs at it's trig pin.
- When the signal finds an object, it is reflected.
- The receiver receives it and generates an output signal on its eco pin.

Bats, Dolphins, RADAR works same principles



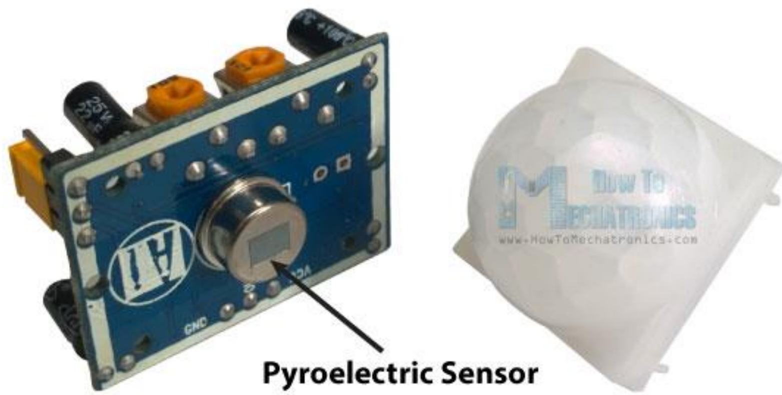
Pyro-electric Infra-Red(PIR) sensor

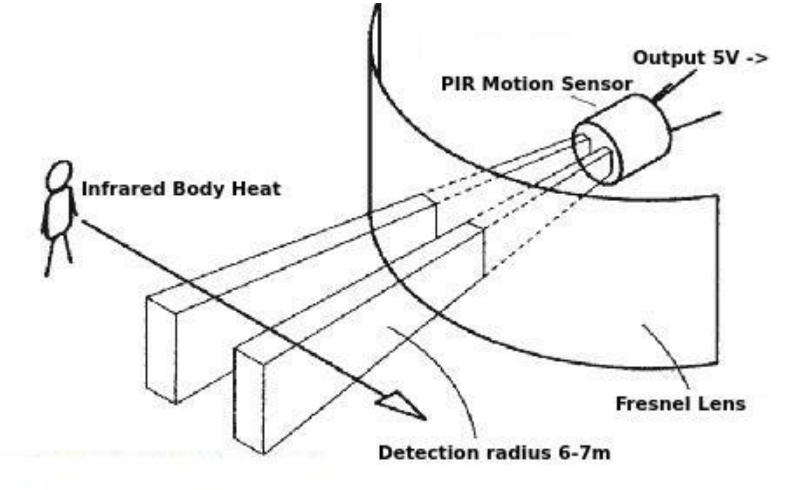
- **'''What is a PIR sensor?''‘:**
  - PIR sensors allow you to **sense motion**, almost always used to detect whether a human has moved in or out of the sensors range.

  - For that reason they are commonly found in appliances and gadgets used in homes or businesses. They are often referred to as PIR, “**Passive Infrared**", "**Pyro-electric Infrared**", or "**IR motion**" sensors.

Pyro-electric Infra-Red(PIR) sensor

- This motion sensor consists of a Fresnel lens, an infrared detector (Pyro-electric Sensor), and supporting detection circuitry.





- The lens on the sensor focuses any infrared radiation present around it towards the infrared detector (Pyro-electric sensor).
- Our bodies generate infrared heat and as a result, this gets picked up by the motion sensor.
- The sensor outputs a 5V signal for a period of one minute as soon as it detects the presence of a person.
- It offers a tentative range of detection of about 6-7 m and is highly sensitive

Types of sensor

Gyroscope Sensor:

- A gyroscope is a device used for measuring or maintaining orientation and angular velocity.
- When the external rotational force is applied to the sensor vertical vibrations are caused on Drive arms.
- This leads to the vibration of the Drive arms in the upward and downward directions due to which a rotational force acts on the stationary part in the center.
- Rotation of the stationary part leads to the vertical vibrations in sensing arms.
- These vibrations caused in the sensing arm are measured as a change in electrical charge.
- This change is used to measure the external rotational force applied to the sensor as Angular rotation.