HUMBER

ROBOTICS ELECTRICAL SYSTEMS

LESSON 06
ROBOTIC SENSORS

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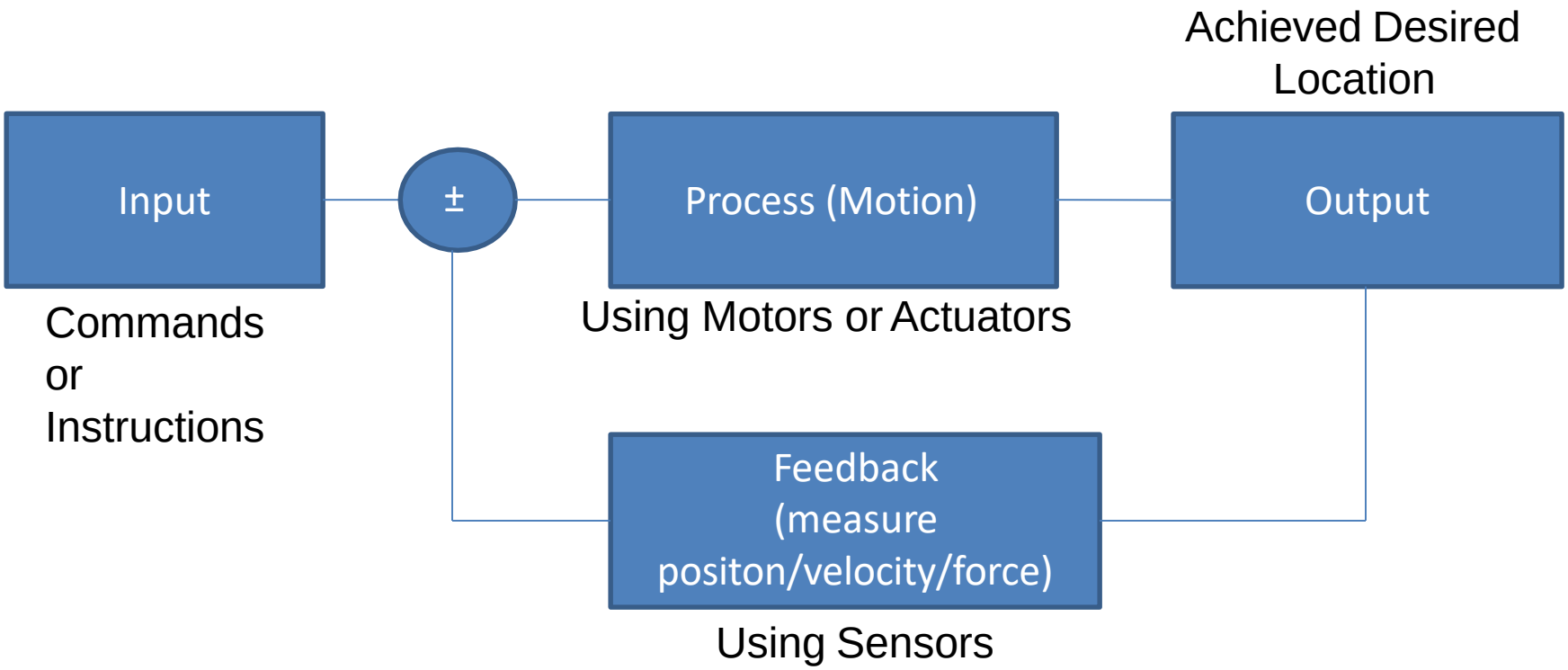
Robotics and Automation

Resources: Text Book: Industrial Robotics (Larry T. Ross)-GW Publisher

Robotic Control System



Importance of Sensors and Actuators

What is Robotic Sensor

Robotic sensors are used to detect the environment and measure the parameters for controlling the robotic manipulator such as position, distance, velocity, pressure, and force etc.

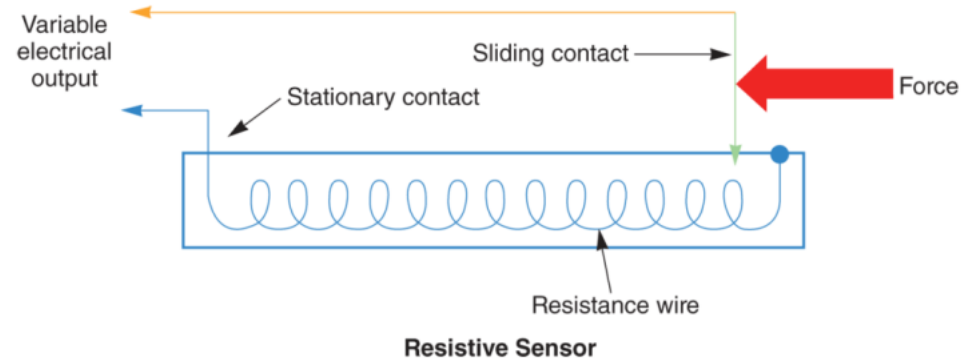
Applications of Sensors in Robotics

- To detect the object in work envelop
- Position and velocity of robotic joint and links
- Pressure and Force measurement in gripper to hold an object
- Allow robots to interact, respond, and determine actions

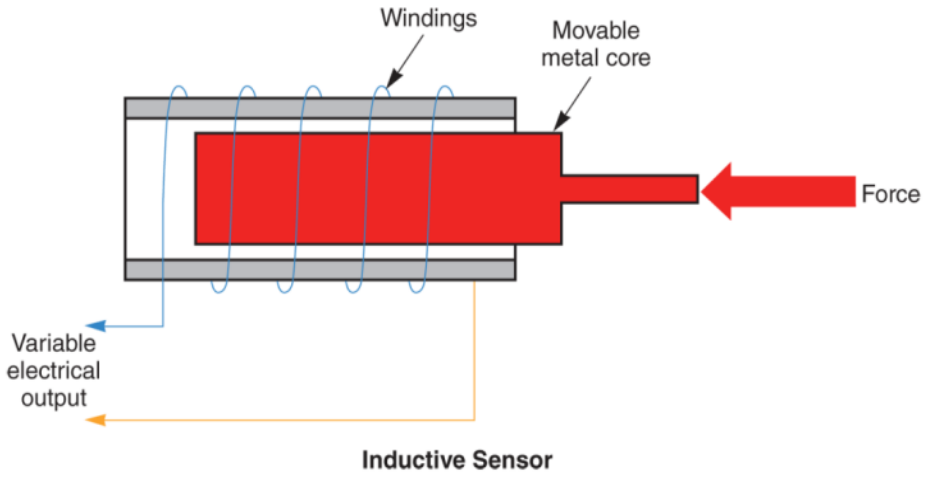
How Sensors Work

Sensor / Transducer convert light, heat, or mechanical energy into electrical energy

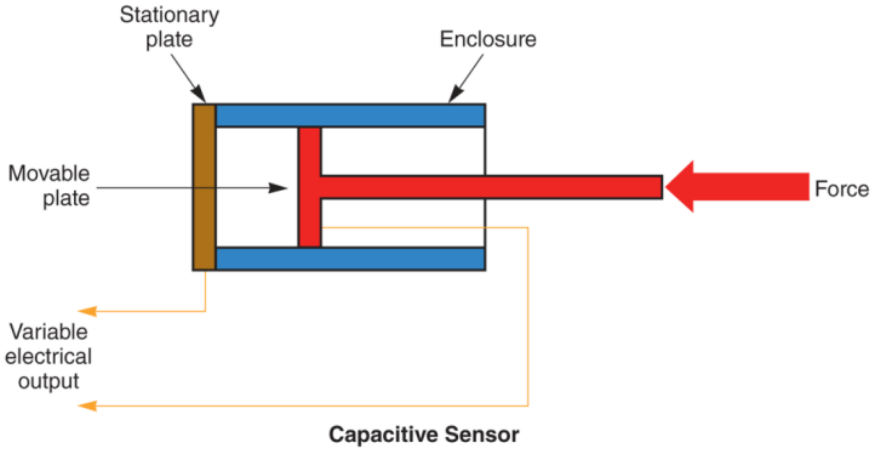
How Sensors Work



Resistive Sensor



Inductive Sensor



Capacitive Sensor

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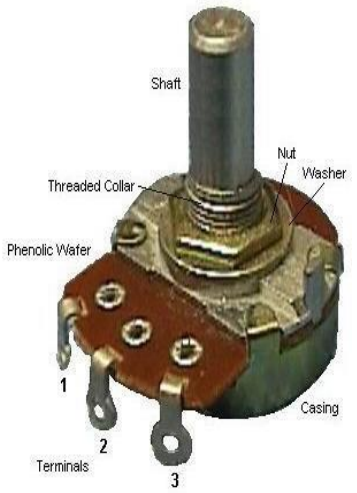
Sensor Types

- Contact or tactile sensors
- Non contact sensors

Contact, tactile sensors

- Potentiometer
- Limit switch (Mechanical Switch)
- Piezoelectric switch

Limit Switch

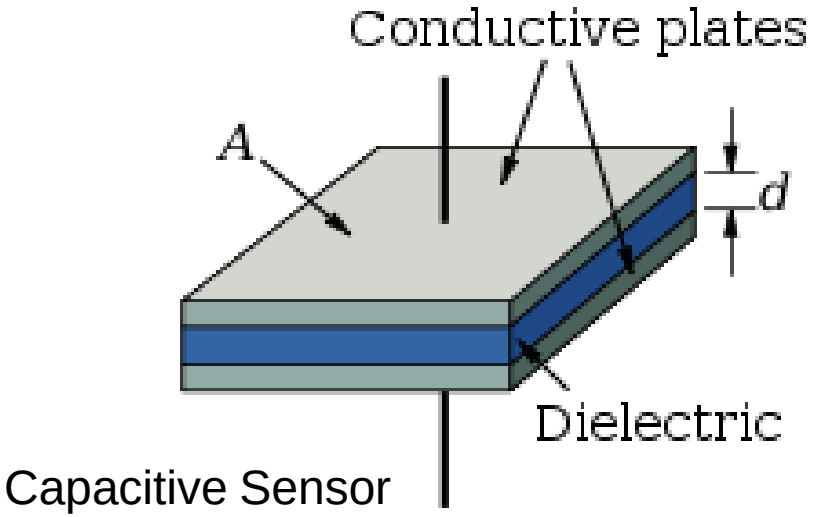


Potentiometer

Non Contact Sensors

- Optical sensors
- Magnetic or Proximity sensors
- Inductive sensors
- Capacitive sensors

Proximity Sensor



Capacitive Sensor

Common Robotic Sensors

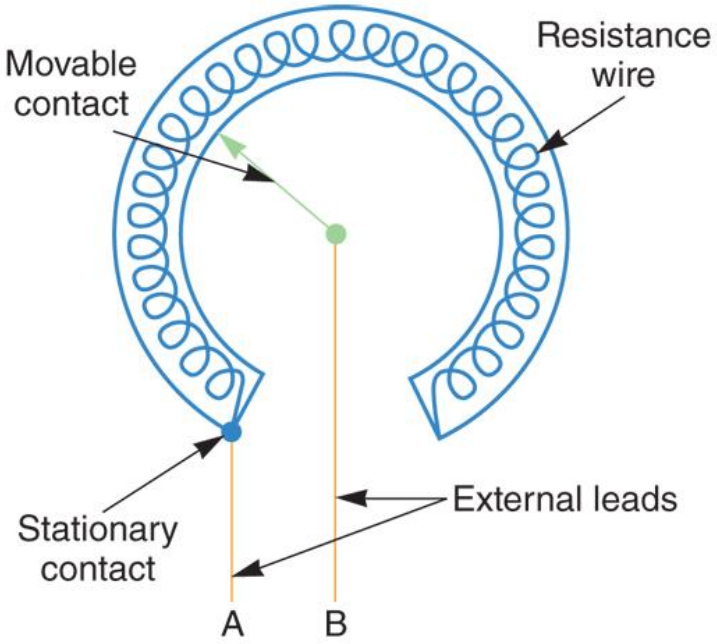
- Position Sensor
- Velocity & Speed Sensors
- Line Follow Sensor
- Vision Sensors
- Balanced Sensors

Position / Displacement Sensors

- Displacement Sensors
  - Potentiometer
  - LVDT
  - Capacitive
- Limit Switch
- Encoders

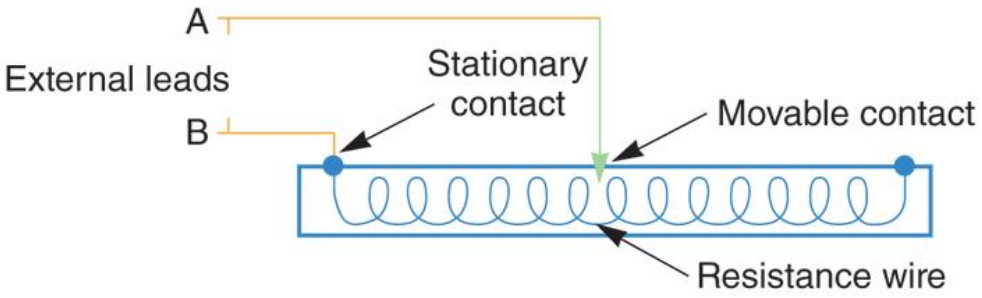
Potentiometer - Resistive Transducers

Works on potentiometer principle



Rotary Potentiometric Transducer

Convert variation in resistance into electrical variations



Flat Potentiometric Transducer

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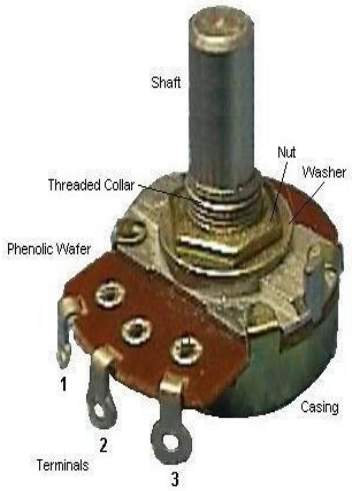
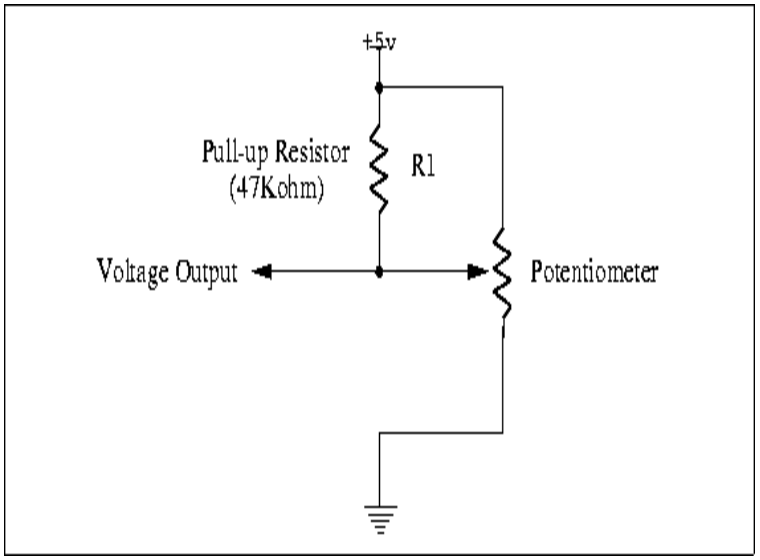
Potentiometer

$$V_0 = V_{in}\left(\frac{R_1}{R_1 + R_{(variable)}}\right)$$



Think, where can you use this sensor in robotics ?

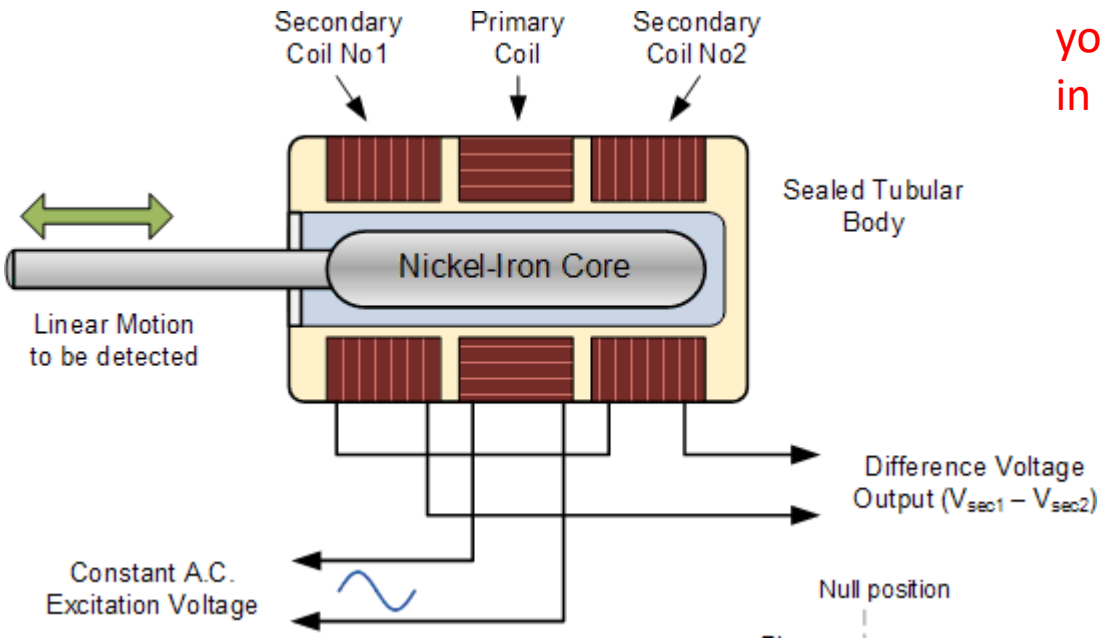


$$R_{variable} \propto Length of resistive wire$$

$$R_{variable} = (cons)\,L$$

$$R_{variable} = L$$

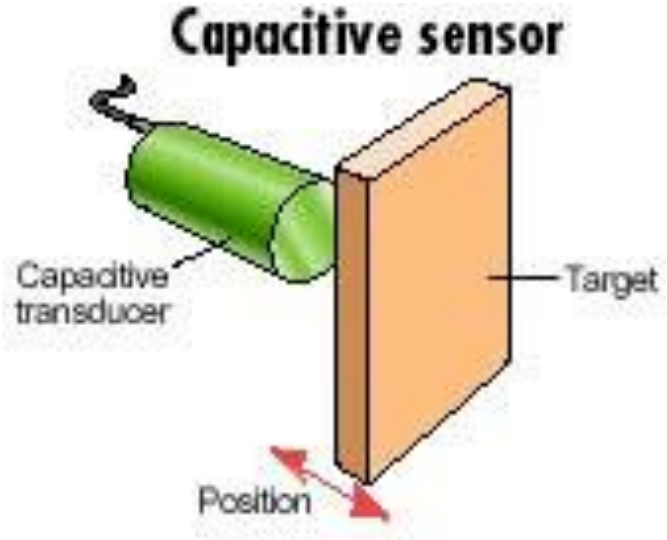
Linear Variable Differential Transformer (LVDT)

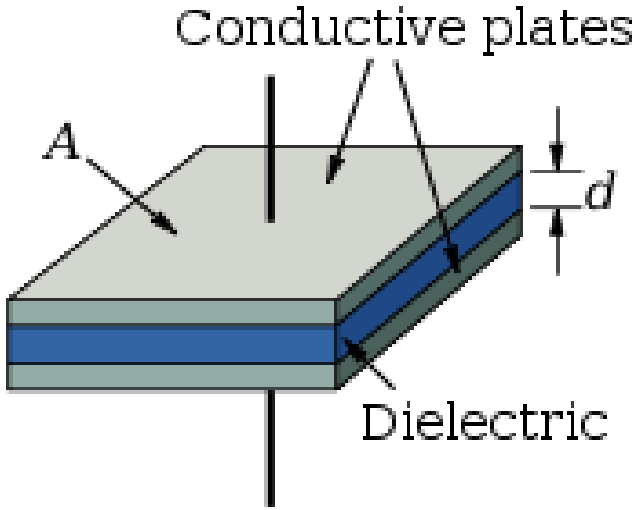


Think, where can you use this sensor in robotics ?

$$\Delta V \alpha \Delta X$$

Capacitive Sensors





Capacitance exists when two conductive materials (plates) are separated by insulating material

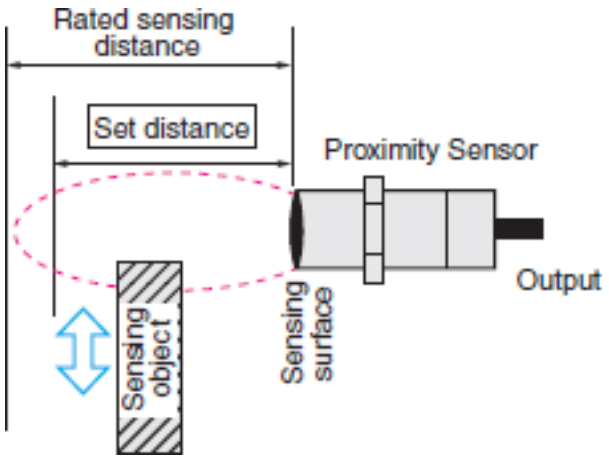
$$C = \varepsilon_0 \varepsilon_r \frac{A}{d}$$

Think, where can you use this sensor in robotics ?

Proximity Sensors

A **proximity sensor** often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal.

Think, where can you use this sensor in robotics ?



Detect absence or presence of an object

Optical proximity sensors

Measure light reflected from an object

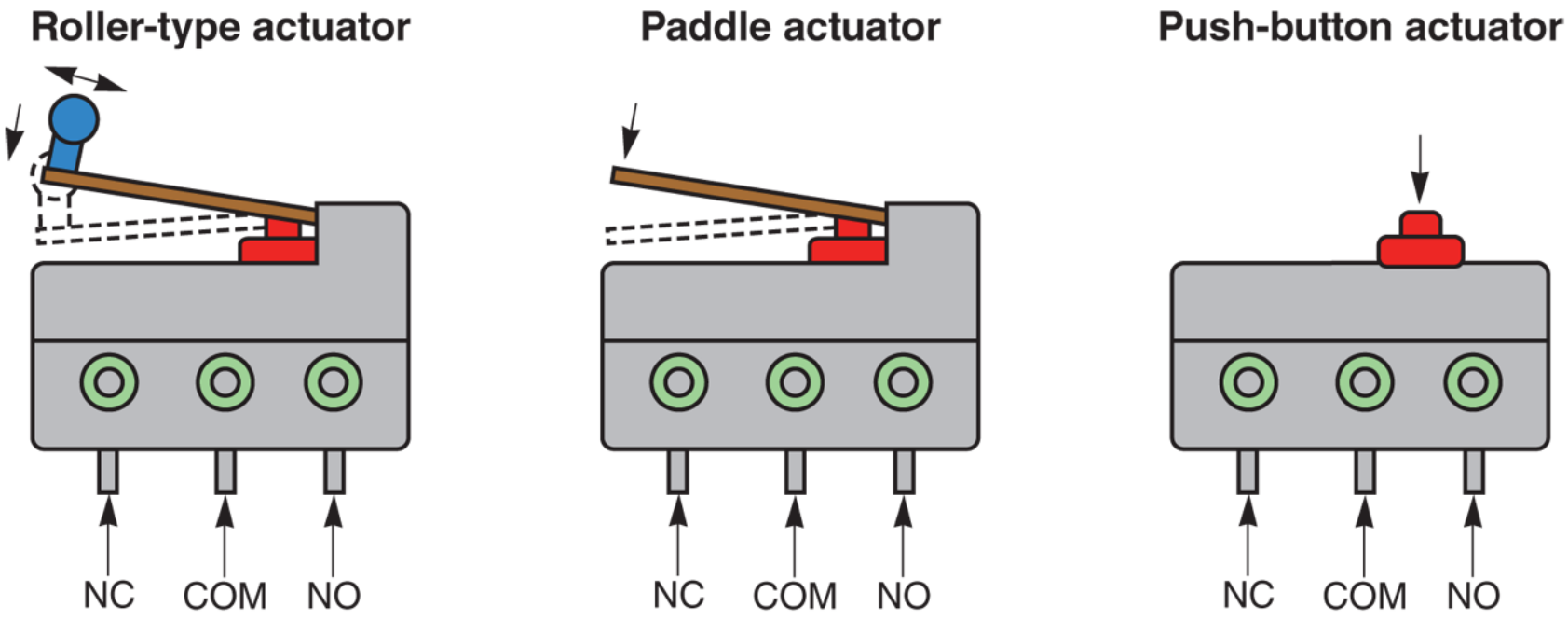
Use incandescent lights or *light-emitting diodes (LEDs)*

Limit Switch

Think where can you use this sensor in robotics ?

Limit Switch

Types of limit switches



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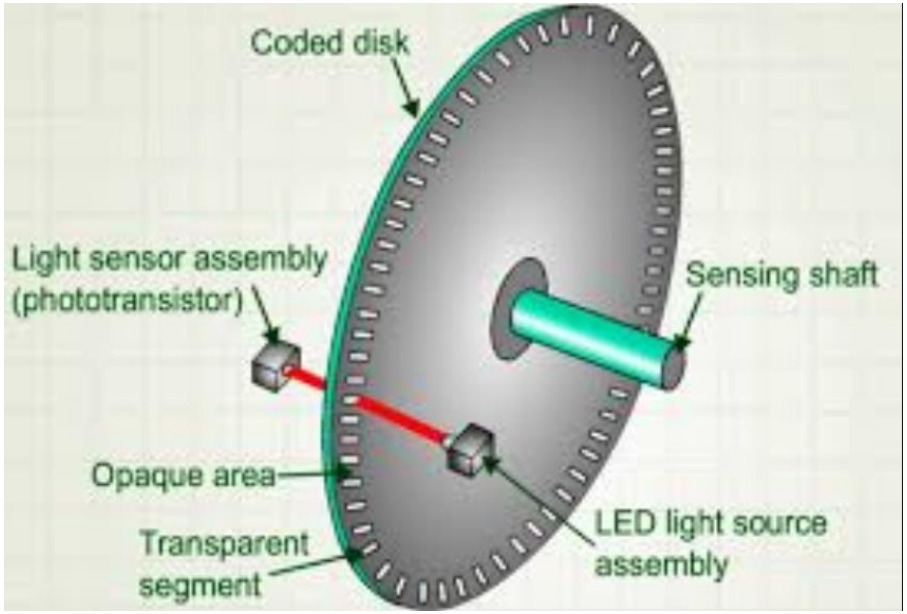
Angular Position and Velocity Sensors

- Encoders
  - Incremental Encoders
  - Absolute Encoders

Encoders - Angular Position and Velocity Sensors

Incremental Encoders

Incremental Encoder consists of a disk which has number of slits. The light passes through the slit and hits the light sensor. In result a single pulse is generated.



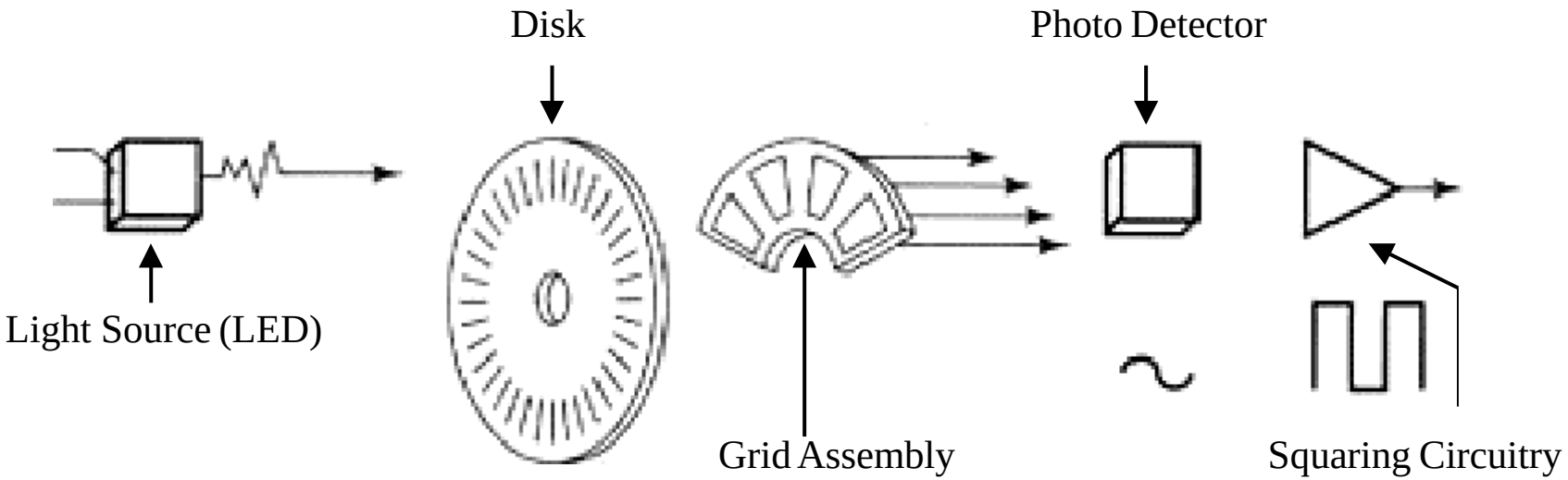
Think, where can you use this sensor in robotics ?

Incremental Encoder

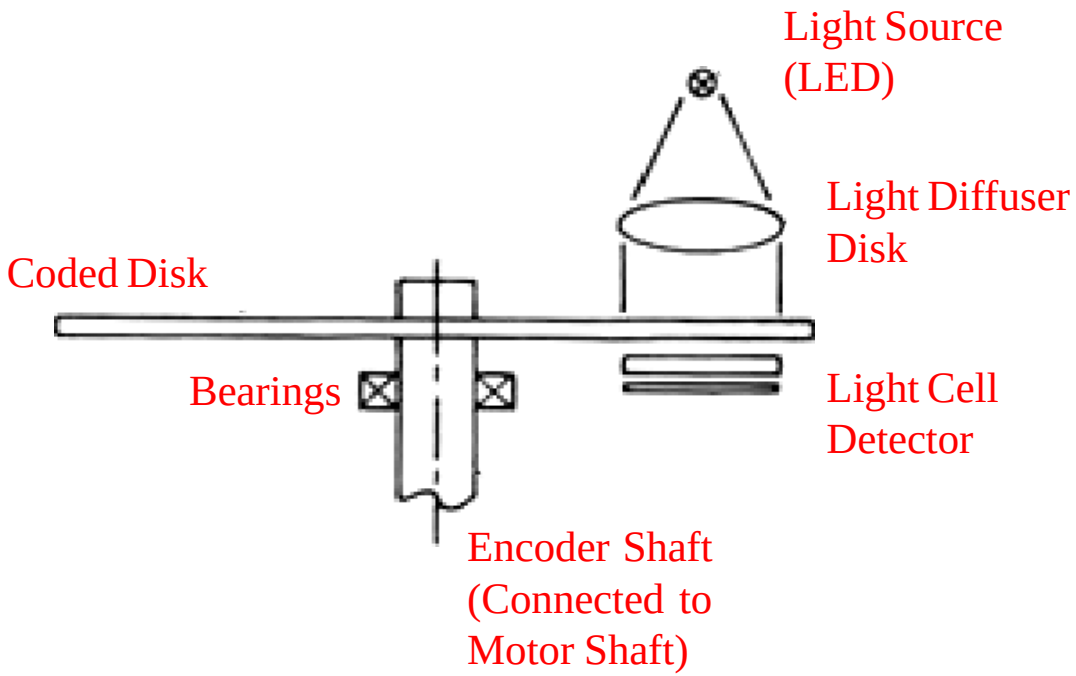
Source: ResearchGate (Dipam Chakrabowti)

Feedback Devices, Encoders

The diagram shows that the disk is very thin, and a stationary light-emitting diode (LED) is mounted so that its light will continually be focused through the glass disk. A light-activated transistor is mounted on the other side of the disk so that it can detect the light from the LED. The disk is mounted to the shaft of a motor or other device whose position is being sensed, so that when the shaft turns, the disk turns. When the disk lines up so the light from the LED is focused on the phototransistor, the phototransistor will go into saturation and an electrical square wave pulse will be produced. This figure shows an example of the square wave pulses that are produced by the rotary encoder.

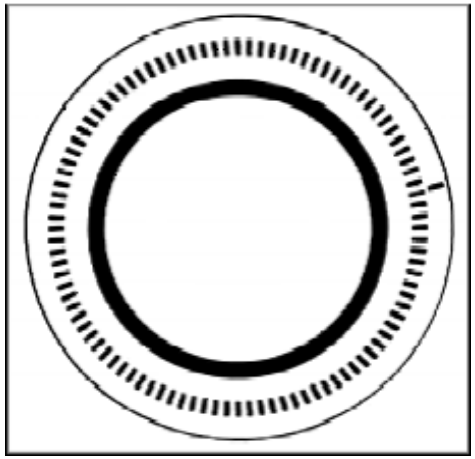


Incremental Rotary Encoder



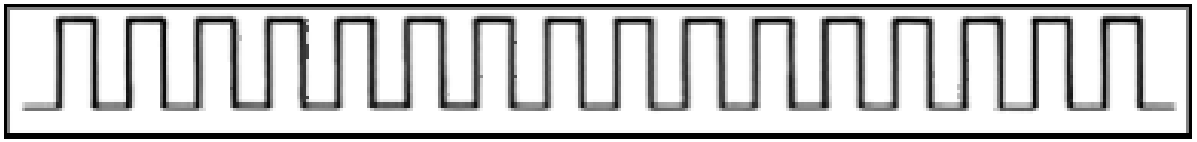
An incremental rotary encoder generates a square wave pulse pattern as the encoder disk turns. The disk is coupled directly to the motor shaft. If the motor turns so does the encoder, producing a square wave signal. If the square wave is monitored we can determine both the speed of motor rotation and amount of motor rotation.

This information can then be used to calculate the manipulator location.

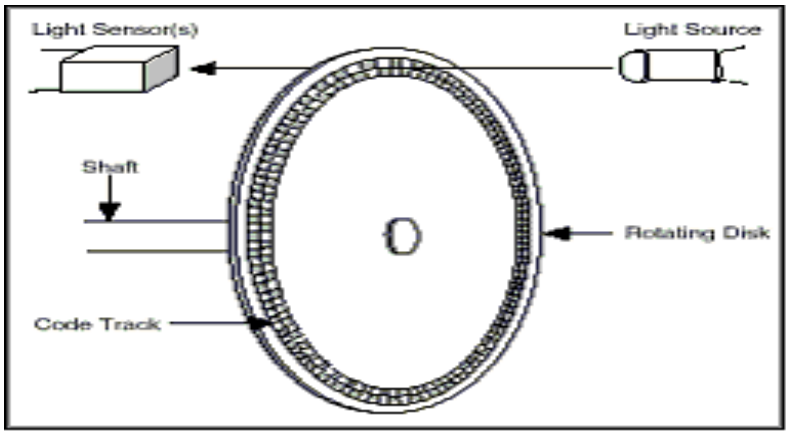


Shown is an example of a simplified basic incremental encoder construction, a coded disk and the produced square wave.

Incremental Rotary Encoders are sometimes called Pulse Generators.



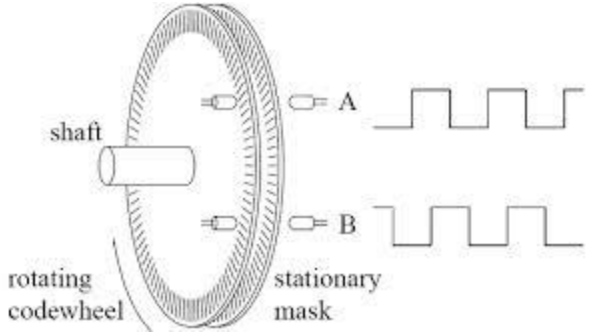
Incremental Encoders



Key elements of incremental encoder setup

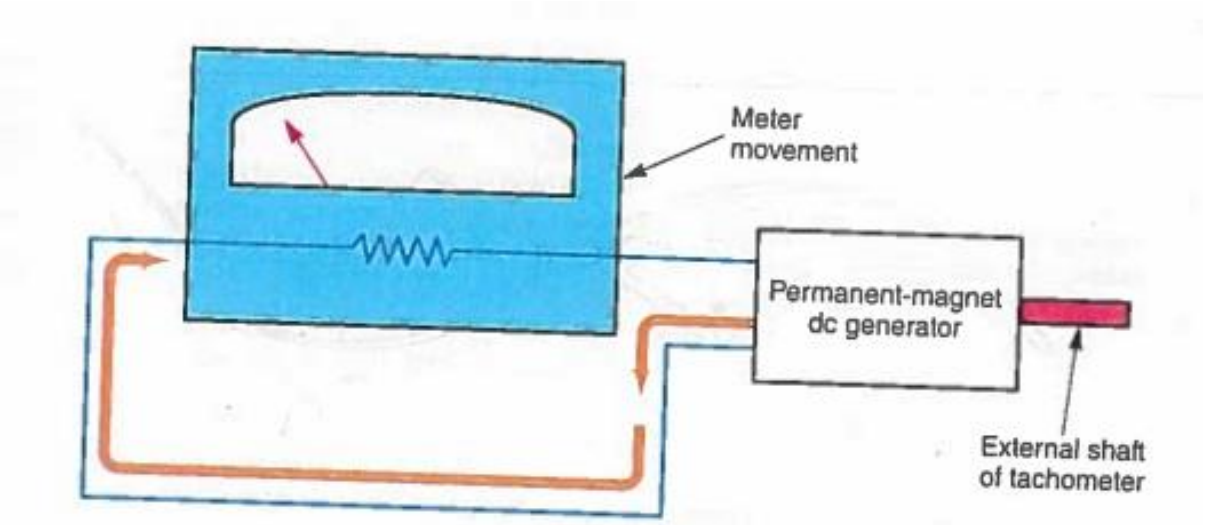
1. Optical disk with slits
2. Light source (Emitter)
3. Light sensor (Receiver)

$$S = \frac{Total\ no's\ \ of\ \ pulses\ in\ one\ \min}{number\ of\ \ slits}\ \ rpm$$



Other Speed Sensors - DC Tachometer

A DC tachometer, is connected directly to a rotating shaft. The rotation turns the shaft of the small dc generator, creating voltage. The generator's voltage output is directly related to the rotation rate of the shaft.



Other Speed Sensors

Electronic tachometer

A reflective material is placed on the surface of the rotation portion of the equipment. Light emitted from the tachometer is reflected back when it encounters the reflected material. The photocell on the tachometer converts reflected light energy into electrical signals to measure the speed

Source: Oriental (otdl.com)

Quiz (Incremental Encoders)

Question 1

If an optical encoder has 8 slits and it gives 5 output pulse signals then determine the resolution of the encoder and angular displacement of the joint where the encoder is attached.

Solution:

Resolution= $\mathrm{R} = \frac{360}{number\ of\ slits} = \frac{360}{8} = 45°$

Angular displacement = R x number of slits = $45°$ x 5 = 225°

Quiz (Incremental Encoders)

Question 2
If an optical encoder has 10 slits and it is giving 200 output pulses in 2 minutes then determine the speed of the joint in rpm and rps.

Solution:
In one minute: 200/2 = 100 pulses / min.

In one complete revolution total pulses : 10 Therefore,

10 pulses = 1 rev.
1 Pulse = 1/10 rev.
100 pulses = $\frac{1}{10} x\ 100 = 10\ rpm$

In rps : $\frac{10}{60}$=0.16 rps

Quiz 3

Question 3

An optical disk (with 8 slits) is mounted on a mobile robot. If the diameter of the optical disk is 100 mm and the output pulses are counted as 300, then calculate the linear displacement of the mobile robot. (Assume the wheel diameter is same as the optical disk diameter)

Solution:

Data:

Number of slits: 8

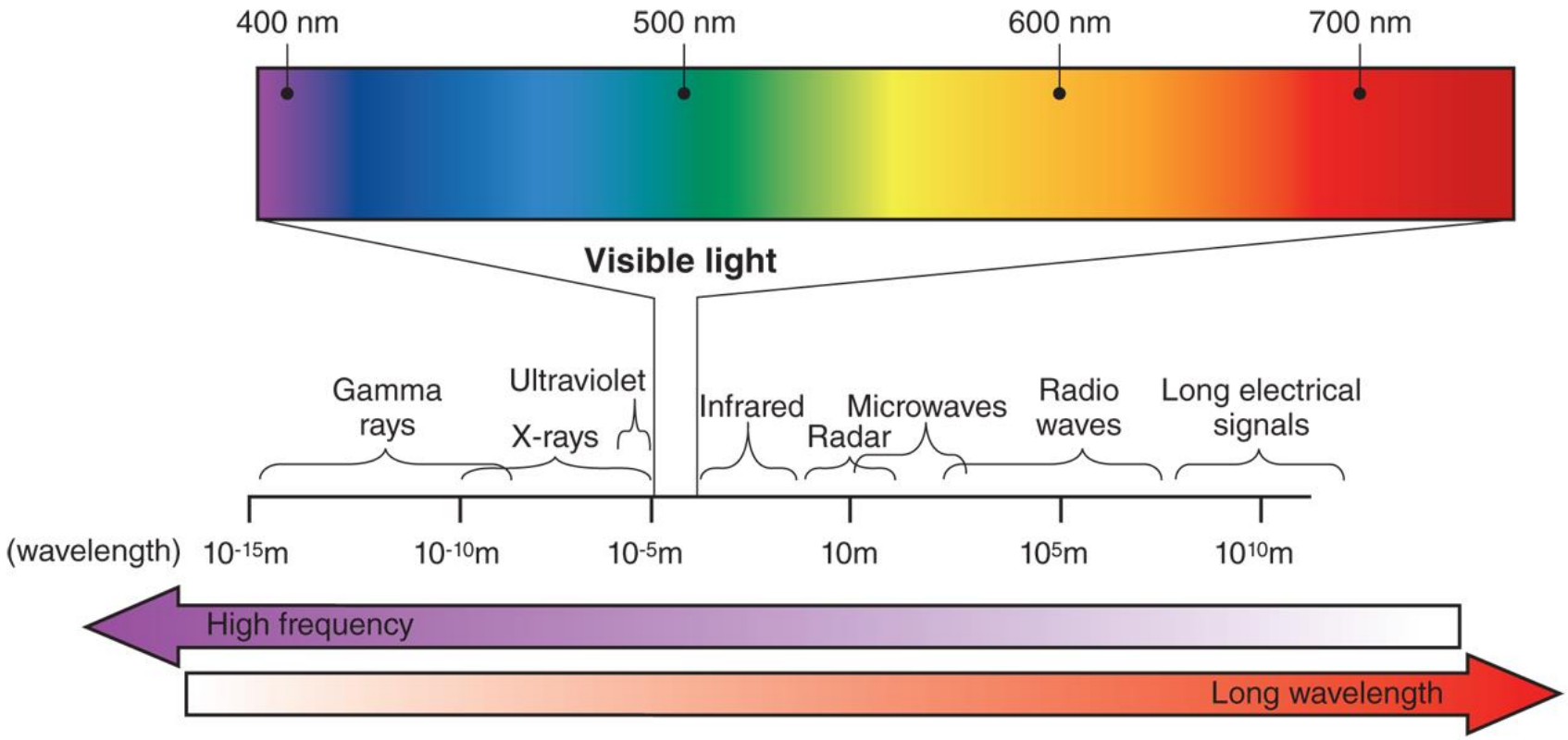
Disk diameter:100 mm

Output pulses: 300

Linear Displacement: ?

Light Sensors

LIGHT IS AN ELECTROMAGNETIC SPECTRUM WAVES ELECTROMAGNECTIC WAVES HAVE WIDE RANGE OF FREQUENCY – Visible light range is 400 nm to 700 nm



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Light Sensors

Measuring wavelengths of light

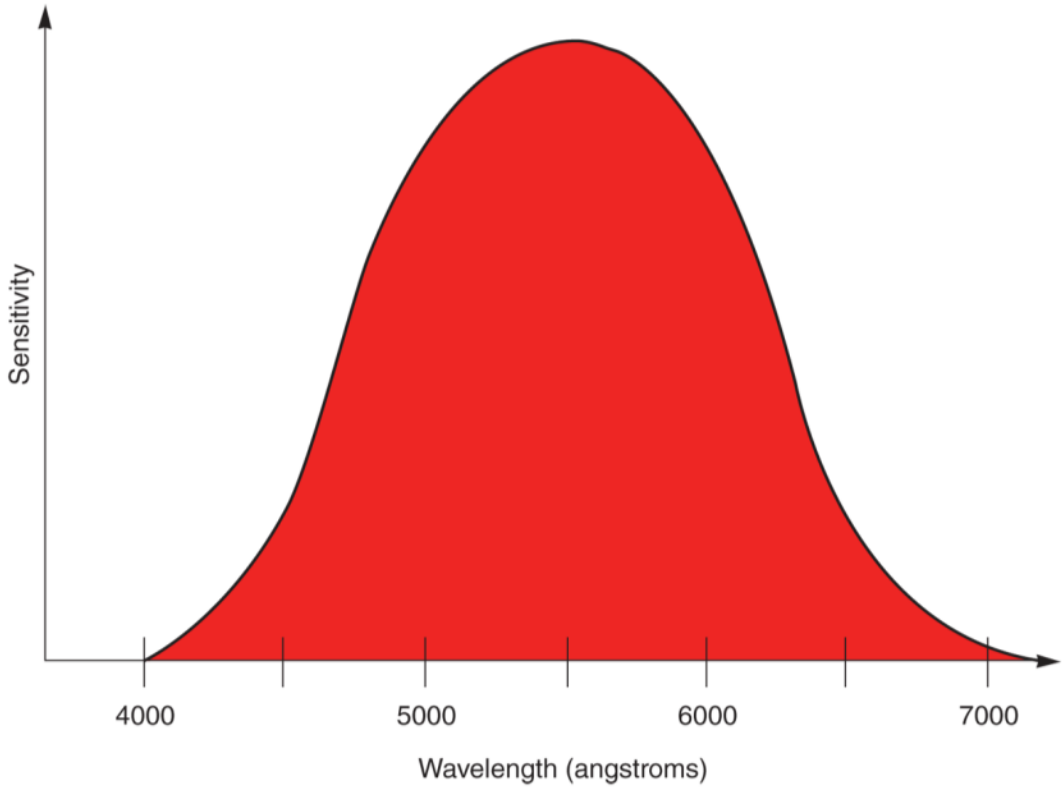
Nanometers (nm) are one-billionth of a meter
Angstrom (Å) unit is one-tenth of a nanometer

Respond to light energy changes

Opto-electronic devices combine optical and electronic

Light Sensors

Visible light wavelengths between 4000 and 7000 angstroms



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Light Sensor

- Work in the range of 400 nm to 700 nm wavelength

Opto –Electronic Devices

Photoemmisive device: emit electron in the presence of light

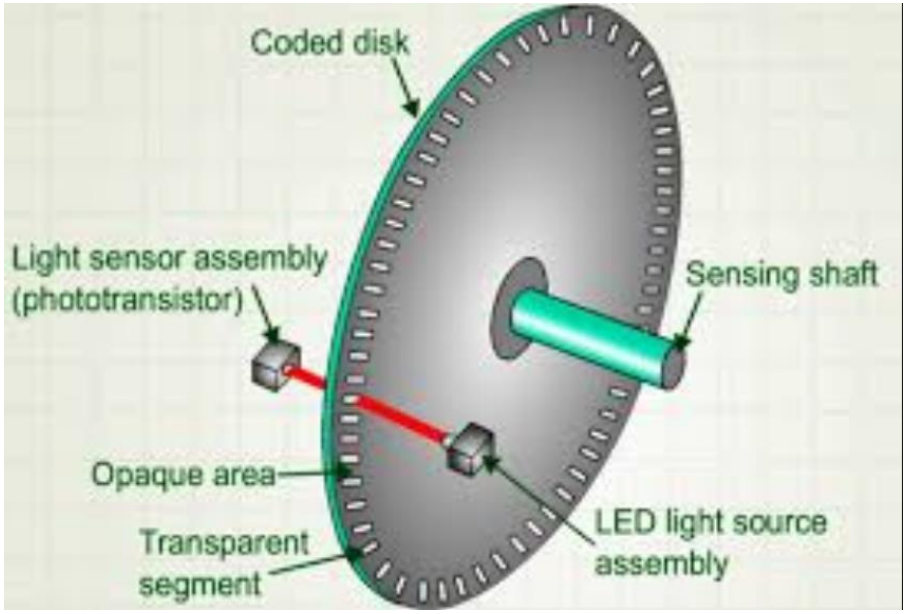
Example: using in Encoders

Photoconductive devices: varying in conduction according to fluctuation in light. The electrical resistance decrease when light is more intense and increases when light intensity decreases. Example: LDRs (Light dependent resistors)

Photovoltaic devices: create electrical voltage when light energy falls on photovoltaic devices. Example Solar cells

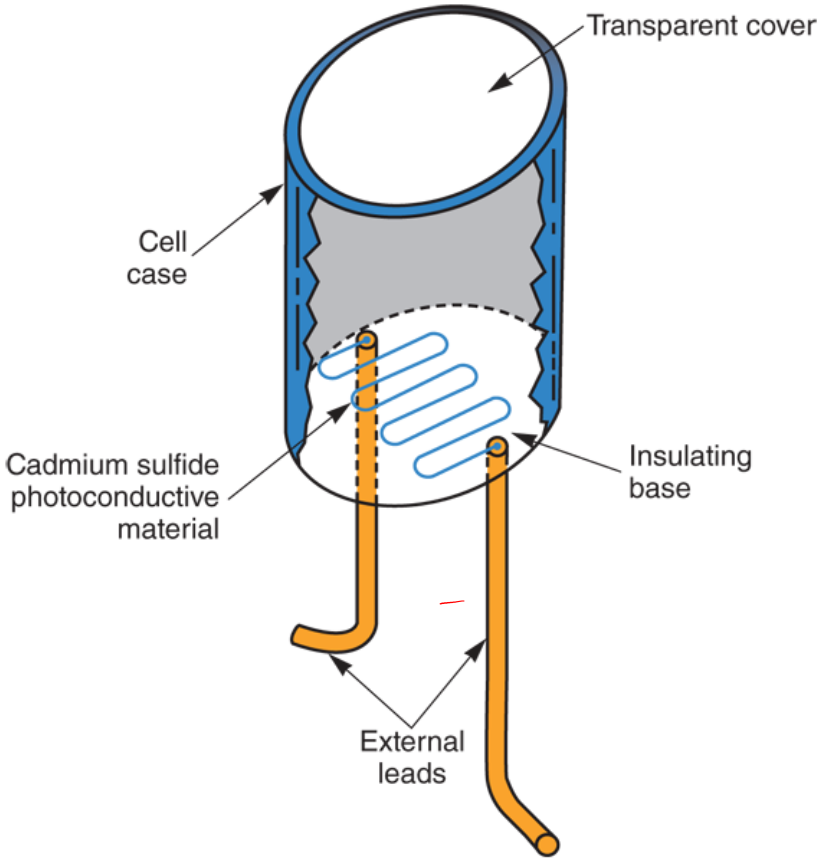
Light Sensor - Photoemissive devices

Emit electrons in presence of light. Encoder uses photo emissive sensors



Light Sensors- Photoconductive device

Cadmium sulfide cell is photoconductive device



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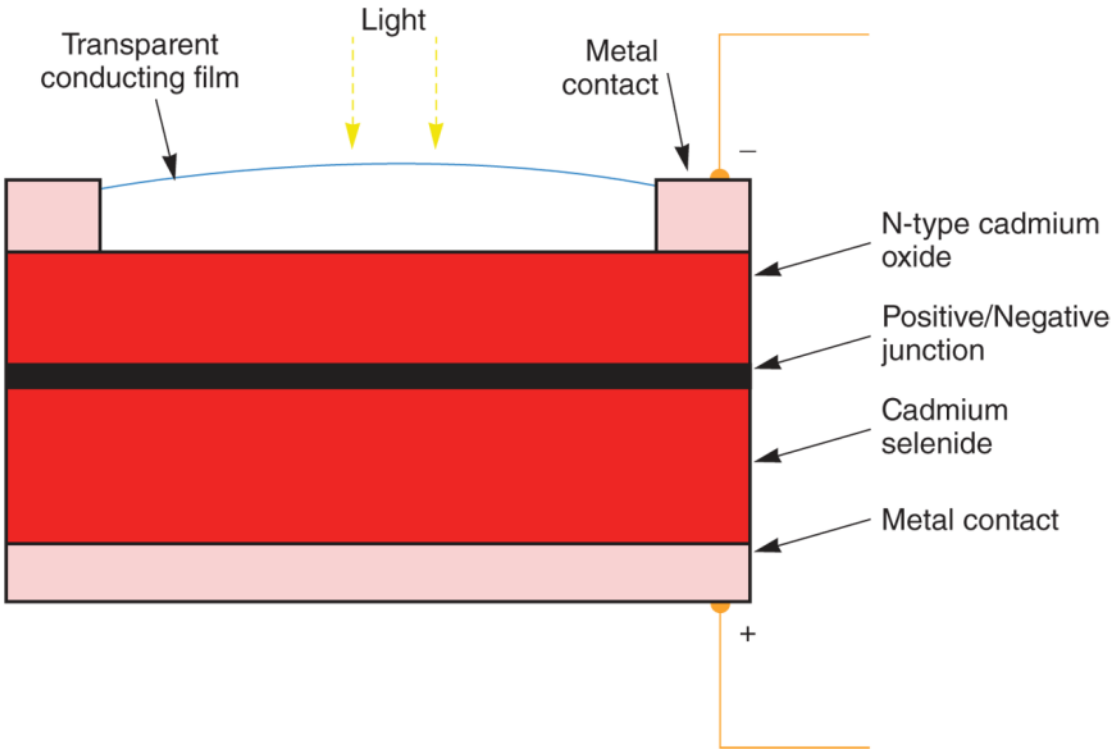
Light Sensors - Photovoltaic device

Light energy creates electrical voltage in photovoltaic device



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Infrared Sensors

- Infrared sensors respond to radiation in the infrared region of the electromagnetic wave. It detect this radiation in darkness and also work for heat control system

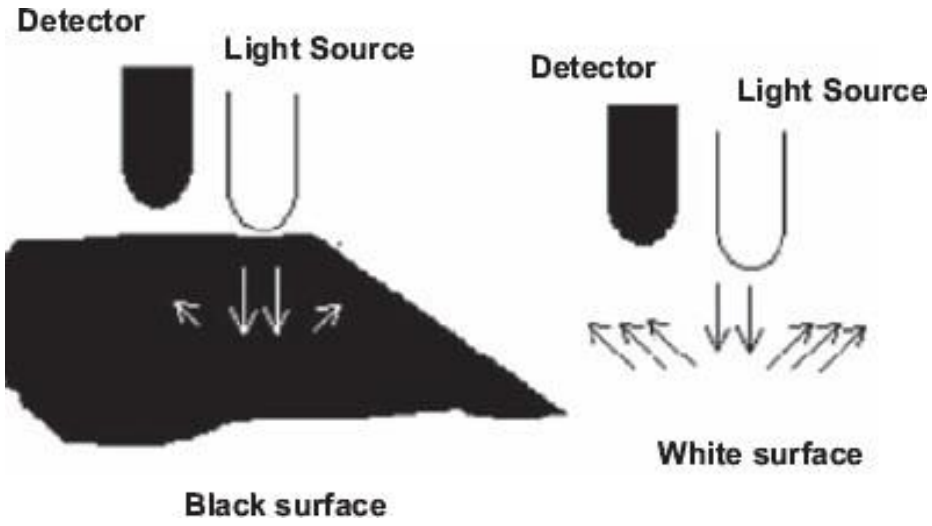
Infrared Light Sensors

Infrared sensors respond to radiation in infrared region spectrum

Infrared Cameras, Inc.

Walking Robot - Line Follow Sensors

- Infra Red Sensors are used to following the line path



Ultraviolet Sensors

Ultraviolet sensors respond to radiation in ultraviolet range

Color measurement, leak detection, impurity detection, and other precision measurements

Flying Robots – Gyroscope

A **gyroscope** is a device used for measuring or maintaining orientation and angular velocity.

Gyroscope is used to detect the rotational velocity in all three axes

Vision Sensors / Visual Servoing

Recognize objects or measure characteristics

Detect spatial relationships, provide depth information (how the object is located in space)

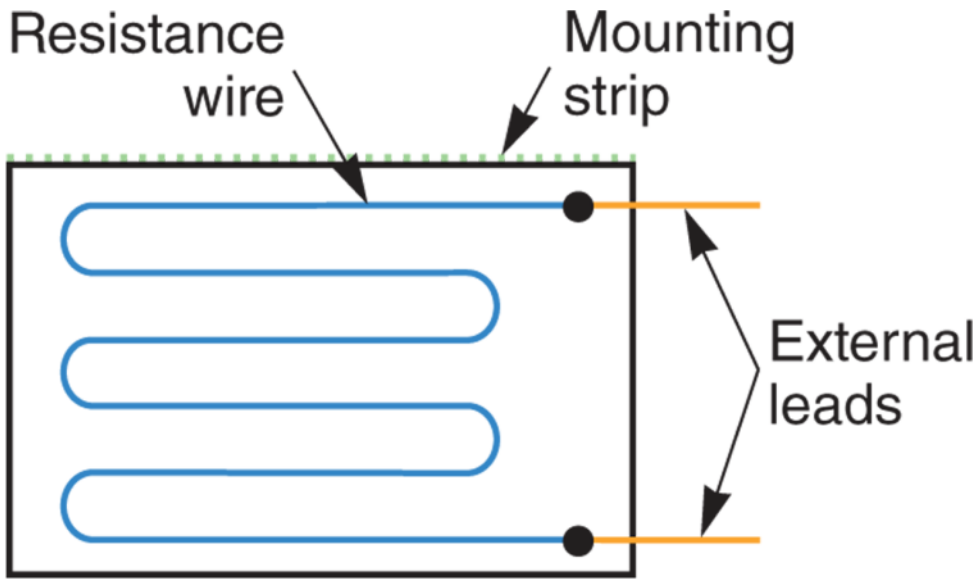
Provide feedback to guide end effector

This process is referred to as visual servoing

We have Baxter Robot with visual servoing system

Mechanical Movement Sensors

Strain gauge is used to measure stress on the surface. In robotics, It can be used measure the force on the gripper to hold an object.



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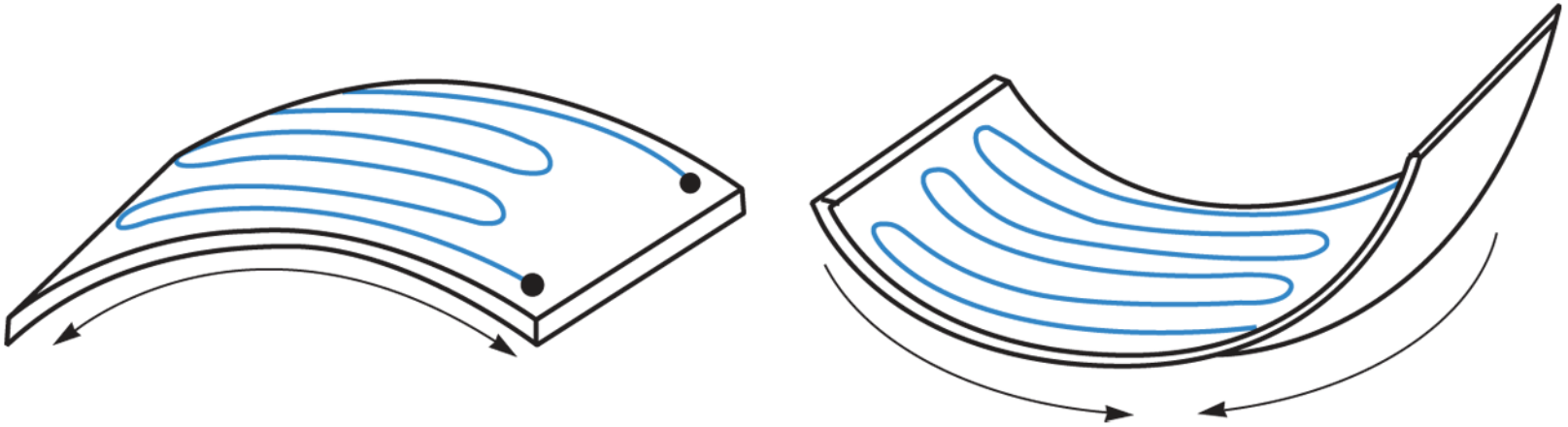
Mechanical Movement Sensors

Resistance increases under tension and decreases under compression



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