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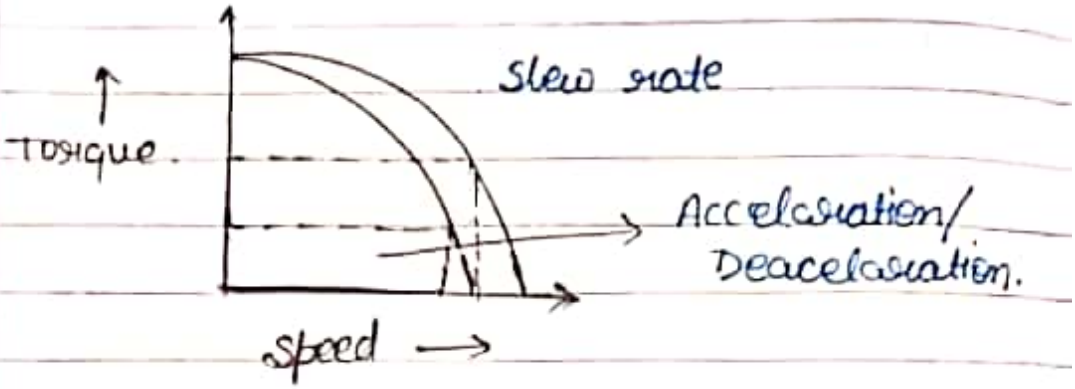
Stepper motor

A stepper motor is a pulse-driven motor that changes the angular position of the rotor in steps. Due to this nature of motor, it is widely used in low cost, open loop position control system.

Types of stepper motor:



(Performance characteristics of stepper motor).

* Types of stepper motor:

1. Permanent magnet.
2. Variable Reluctance. (No parmanent mag)
3.

*: Variable Reluctance motor:

The cylindrical 'rotor' is made up of

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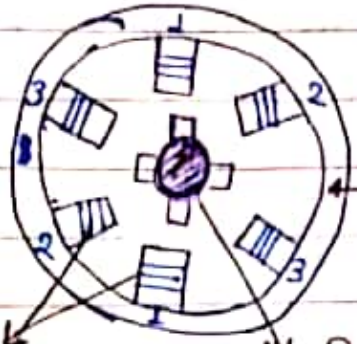
soft steel & has four poles, 90° apart & 6 stator poles 60° apart. Electromagnetic field is produced by activating the stator coil in sequence 2,3,1, it attracts the metal rotor. Now the motor will rotate 30° step angle.



(Variable Reluctance stepper motor).

* Permanent magnet (PM) stepper motor:

In this kind of motor, the rotor is a permanent magnet. Fig. shows the simple, 90° PM motor with four phases (A-D). Applying current to each phase in a sequence will cause the rotor to rotate by Adjusting to the change in magnetic field. Although it operates at low speed, the PM motor have relatively high torque. These are low cost motors with typical step angle rating b/w 7.5° to 15°.

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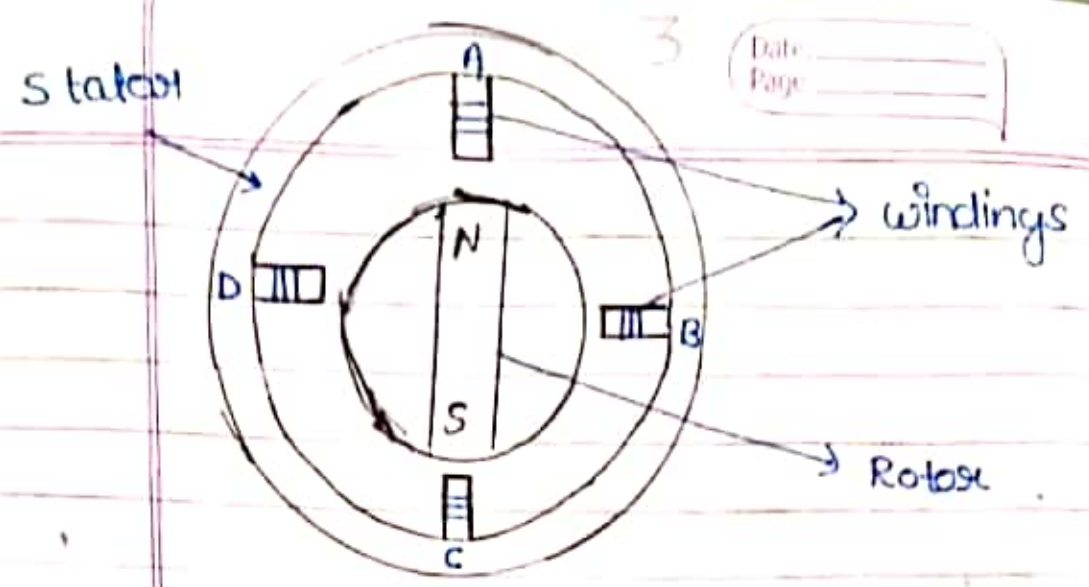
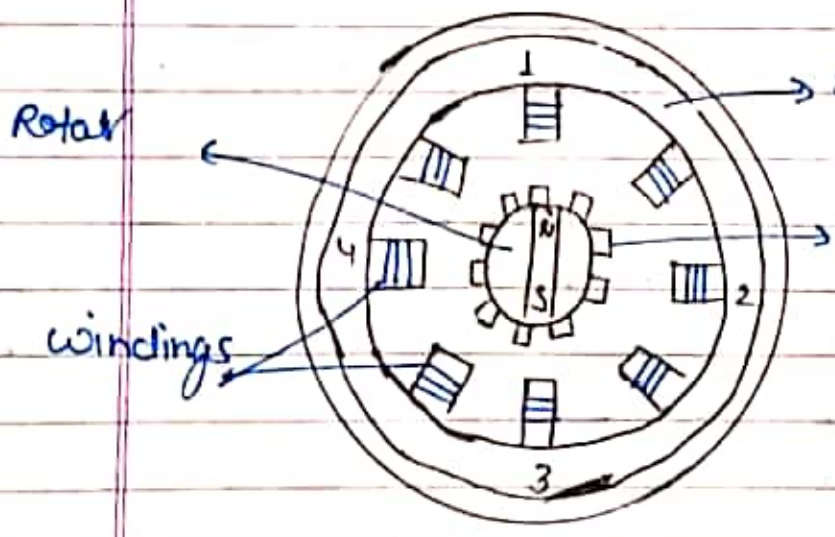


(Permanent magnet stepper)

(3.) Hybrid stepper motor : Hybrid stepper motors combine a permanent magnet & a stator with metal poles to provide features of variable reluctance & permanent magnet motor together.



Hybrid motor are more expensive than motors with permanent magnet, but they use smaller steps, have greater torque, & max. speed.

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Step angle of stepper motor:

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$$\text{Step angle} = \frac{360^\circ}{\text{Number of poles}}$$

★ **Advantages**

1. Low cost
2. Low maintenance
3. Will work in any Environment.
4. Excellent Start - Stop & reversing response

Disadvantages:

1. Low torque capacity compare to DC motor.
2. Limited speed.

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DC MOTORS

A DC motor is a device that converts direct current (Electrical Energy) into rotation of an element (mechanical Energy). These motors are further classified into 2 types:

↳ Brush type DC motor.
↳ Brush less DC motor.

* Brush type DC Motor:

Construction: A typical brushed DC motor consist of an armature coil, slip rings divided into two parts, a pair of brushes & Electromagnet. A simple DC motors have 2 poles namely a north pole & a south pole.

The armature coils is wound around a soft iron core & is placed b/w the magnet poles. The coil Ends are connected to split rings. The carbon brush-es are in contact with the split rings. The Brushes are connected to a DC-Source. Here the split ring rotate with the coil while the Brushes remain Stationary

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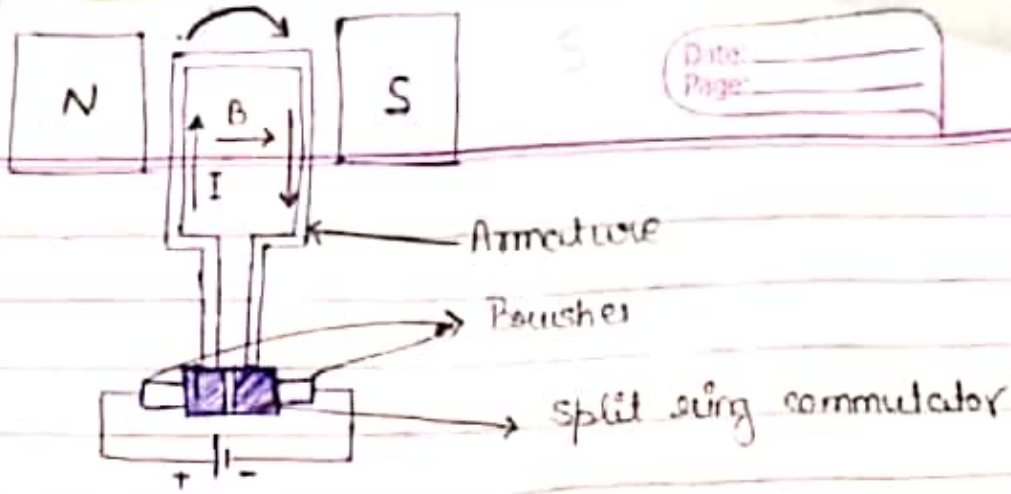

(Brushed DC Motor)

Working : The working is based on the principle that when a current - carrying conductor is placed in a magnetic field, it experiences a mechanical force whose direction is given by Fleming's left hand rule. The magnitude of the force is given by -

$$F = BIL \sin\theta$$

where, B = magnetic field density in weber/m^2
I = current in amperes
l = length of conductor in meter
θ = angle b/w the direction of current in the conductor & Electric field.

If the current & field are perpendicular $\theta = 90°$ & $\boxed{F = BIL}$

⇒ A direct current in a set windings creates a magnetic field. This field produces a force which turn the armature. This force is called torque.

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This torque will allow armature to turn until the it's magnetic field is aligned with the External field.
Once it's aligned the direction of the current in the armature, reverse, thereby reversing the polarity of the Electromagnetic field.
The change in direction of current is given by split ring commutator.
The brush are stationary but in contact with the armature at the commutators, which Rotates with the armature such that at every 180° of rotation, the current in the armature is reversed.
& in this way a torque again exerted on the rotor, & it continues spinning.

Advantages:

- The designe of Brush dc motor is quite simple.
- Controlling the speed is easy.
- Very cost effective.

DisAdvantages:

- High maintenance.
- Performance decreases with dust particle
- less Reliable in control at lower speeds.

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↳ The brushes wear off with usage.

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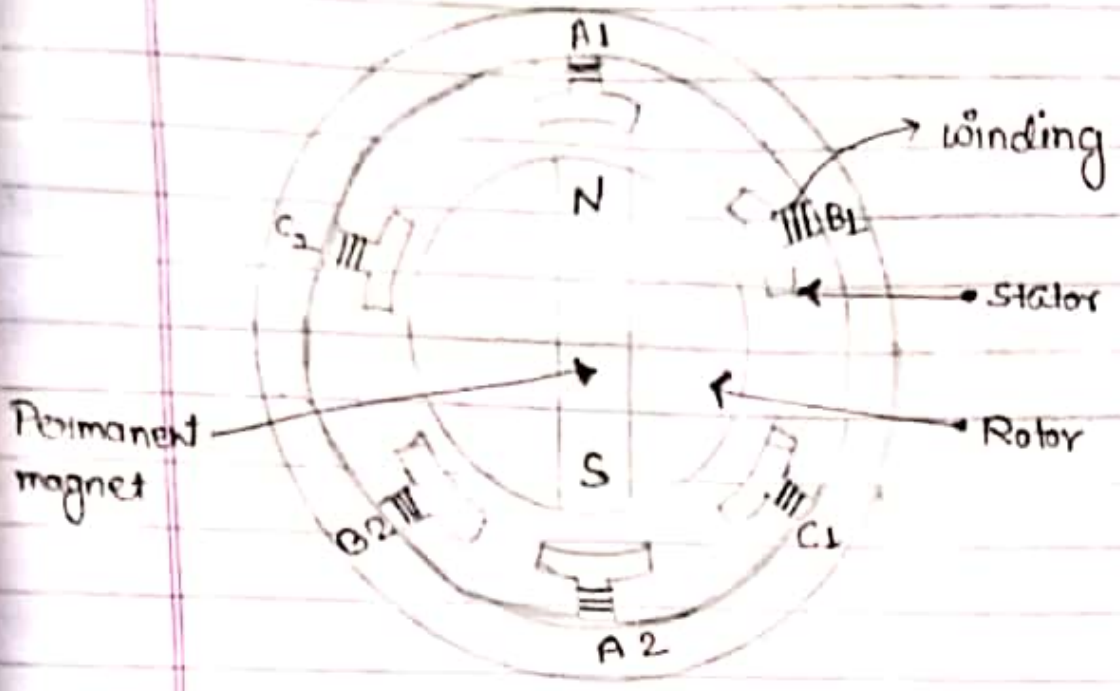
* **Brushless DC motor:**



(BRUSHLESS DC motor)

A brushless dc DC motor has a stator with permanent magnet. The brushes & commutator are Eliminated & the winding are conected to the control Electsonics. The control Electronics replace the commutator & brushes & Energize the stator sequentially. Here the conductor is fixed & the magnet moves.

The current supplied to the stator is based on the position of Rotor. The position of the rotor is sensed by Hall effect sensor. Thus a continuous Rotation is obtained.

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- **Robot Sensors -**

Robotic Sensors are used to estimate a robot's condition and environment. These signals are passed to a controller to enable appropriate behaviour. Sensors in robots are based on the functions of human sensory organs. Robots require extensive information about their environment in order to function effectively.

Robot Sensors allow a robot to interact with its environment in a flexible and intelligent manner. A robot that can see and feel is much easier to train and deploy to perform complex tasks.

- **Robot- Sensor Taxonomy -**

* **Internal Sensors** → Position sensors
  - ↳ Velocity sensors
  - ↳ Torque and acceleration sensors

* **External Sensors** → Tactile sensors
  - ↳ Force and torque sensors
  - ↳ Proximity sensors
  - ↳ Range sensors
  - ↳ Vision sensors
  - Others....

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Internal Sensors -

These sensors are used for robot control. It provides position, velocity and acceleration as a continuous stream of feedback signals that possess an integral part of the control loop.

External Sensors -

These sensors are used for robot guidance, obstacle identification and handling. It provides information about the environment and the objects therein. (to avoid collision etc.)

Contact sensors

slip, touch

force/torque

Non-contact sensors

proximity, range

end stage of object handling

- **Sensor Characteristics -**

* **Dynamic Range** - minimum and maximum values of the input signal for which the sensor responds.

* **Response** - sensor should respond to the stimuli almost instantaneously.

* **Sensitivity** - the change in sensor output for the unit change in the input

* **Linearity** - whether the sensor maintains same sensitivity within the entire dynamic range.

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- **Other considerations -**

→ Sensor should not disturb the physical quantity it measures.

→ Sensor should be suitable for the environment it is exposed.

→ Sensor should be isolated from noise, and protected from physical damages.

→ Size, cost and ease of operation

- **Position Sensors and Actuators -**

Sensors and Actuators are the essential elements of the embedded systems. They mainly differ by the purpose they provide, the sensor is used to monitor the changes in the environment by using measurands while the actuator is used when along with monitoring the control is also applied such as to control the physical change.

- **Sensors -** A sensor is an electronic instrument that is able to measure the physical quantity and generate a considerate output. These output of a sensors are usually in the form of electrical signals. Sensors are placed as such they can directly interact with the environment to sense the input energy with the help of sensing element.

There are various types of sensors such as position, temperature, pressure, speed sensors but fundamentally, there are two types - analog and digital. The different types of sensors come under these two basic types.

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- **Actuators** - An actuator is a device that alters the physical quantity as it can cause a mechanical component to move after getting some input from the sensor. In other words, it receives control input (generally in the form of an electrical signal) and generates a change in the physical system through producing force, heat, motion etc.

An actuator can be interpreted with the example of a stepper motor, where an electrical pulse drives the motor. Each time a pulse is given in the input accordingly the motor rotates in a predefined amount. A stepper motor is suitable for the applications where the position of the object has to be controlled precisely, eg. robotic arm.

- **Key Differences between Sensors and Actuators** -

(1) A sensor is a device that changes a physical parameter to an electrical output. As against, an actuator is a device that converts an electrical signal to a physical output.

(2) The sensor is situated at the input port to take the input, whereas an actuator is placed at the output port.

(3) Sensors generates electrical signals while an actuator results in the production of energy in the form of heat or motion.

(4) Magnetometers, cameras, microphones are some of the examples in which the sensor is used. In contrast, actuators are used in LED, loud speakers, motors controllers, laser etc.

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To conclude, we can say that, Sensors present the computer with information about the state of the system. On the other hand, actuators accept commands to perform a function.

- **Position Sensors** -

Most common way of classifying the wide spectrum of sensors is based on the specific application of sensors. Sensors used for measuring humidity is termed as Humidity Sensor; the one used for the measurement of pressure is called a Pressure sensor, sensor used for the measurement of liquid level is called level sensor and so on, though all of them maybe using the same sensing principle. In a similar fashion, sensor used for the measurement of position is called a position sensor.

Position sensors are basically sensors for measuring the distance travelled by the body starting from its reference position. How far the body has moved from its reference or initial position is sensed by the position sensors and often the output is given as a feedback to the control system which takes the appropriate action. Motion of the body can be rectilinear or curvilinear, accordingly, the position sensors are called linear position sensors or angular position sensors.

- **Types of Position Sensors** - Position sensors use different sensing principles to sense the displacement of a body. They can be classified as -

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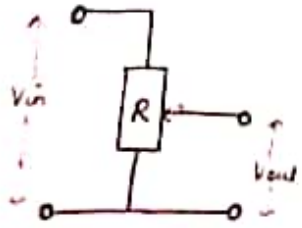
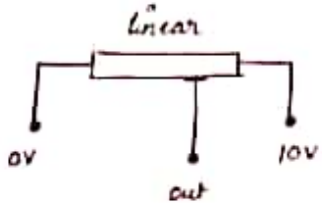
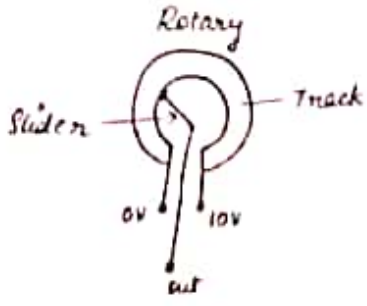
→ Resistance based or Potentiometric Position sensors.
→ Capacitive Position sensors.
→ Linear Voltage Differential Transformers
→ Magnetostrictive linear position sensor.
→ Eddy current based position sensor
→ Hall Effect based magnetic position sensor.
→ Fiber optic Position sensor.
→ Optical position sensors.

- Potentiometric Position Sensor - They use resistive effect as the sensing principle. The sensing element is simply a resistive (or conductive) task track. A wiper is attached to the body or a part of a body whose displacement is to be measured. The wiper is in contact with the track. Resistance, proportional to the wiper position is measured using voltage divider arrangement. A constant voltage is applied across the ends of the track and the voltage across the resistance between the wiper and one end of the track is measured.

The conductive track can be made linear or angular depending upon the requirements. The tracks are made from carbon, resistance wire or piezo resistive material







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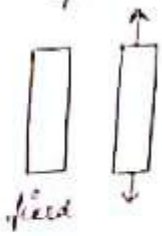
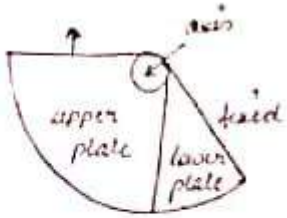
- **Capacitive Position Sensors** - Capacitance between any two plates depends upon the permittivity of the dielectric between the plates, overlapping area between the plates and the distance between the two plates. Any of these three parameters can be varied in order to design a capacitive sensor. It can be based on the following two configurations -

by changing dielectric constant - the changing dielectric constant leads to the change in the capacitance between the plates. This principle is commonly used in level position sensors wherein two concentric tubes are used and fluid acts as the dielectric. The variation in capacitance with the fluid level is linear.

by changing overlapping area - the changing overlapping area between the plates leads to the change in capacitance between the plates. This principle can be employed for both the linear as well as for angular motions.





- **Linear Variable Differential Transformer** - This type of positional sensor does not suffers from mechanical wear problems. This is an inductive type position sensor which works on the same principle, as the AC transformer that is used to measure the movement. It basically consists of three coils wound on a hollow tube, former one forming the primary coil and the other two coils forming identical secondaries connected

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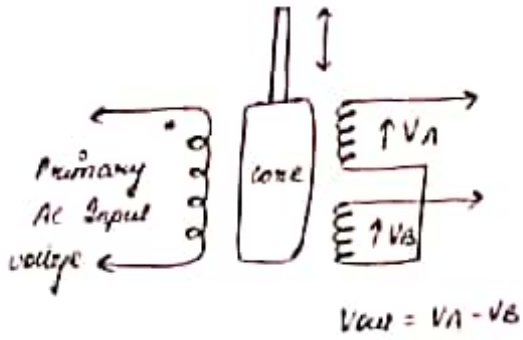
electrically together in series but 180° out of phase, either side of the primary coil. It is an accurate device for measuring linear displacement and whose output is proportional to the position of its moveable core.



- **Velocity Sensors :-**

A velocity or speed sensor measures consecutive position measurements at known intervals and computes the time rate of change in the position values.

It is a sensor that responds to velocity rather than absolute position. for eg.- dynamic microphones are velocity receivers.

- **Types of Velocity Sensors -**
  - → Tachometers
  - → Laser Surface Velocimeter (LSV)
  - → Piezoelectric Sensors
  - → Accelerometer Sensors

- **Tachometers** - A most important device that is used to provide velocity feedback is the tachometer.

It is also known as RPM gauge, and revolution counter.

A tachometer is employed in a motor to calculate the rotational speed of shaft. The output is displayed as RPM

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(revolution per minute) in an analog device.

The two common types of Tachometers are -

- AC Tachometer
- DC Tachometer

AC Tachometer :- It possen primary and secondary stators with fixed windings, and a rotor with permanent magnet. If the rotator is stationary, a constant output voltage is obtained. If the rotator is moving, proportional to the spp speed of the rotor is induced. This type of tachometer cannot provide the information of direction with only one output winding.

DC Tachometer - DC Tachometer is the most commonly used instrument in robotics. It is a DC generator implemented to provide an output voltage that is proportional to the angular velocity of the armature. In this mechanism, the rotor and rotational part will be attached directly. It has a stationary device called as commutator, which is connected with the split slip rings. It is used for picking the induced output signal from the rotating coil.

- Laser Surface Velocimeter - LSV is a non-contact optical speed sensor measuring velocity and length on moving surfaces. Laser surface velocimeters use the laser doppler principle to evaluate the laser light scattered back from a moving object.

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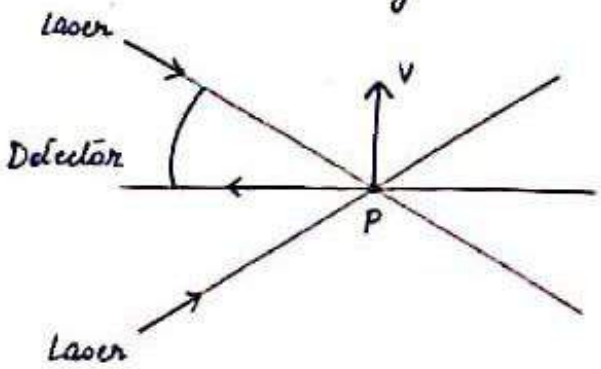
LSV is based on Doppler effect (or Doppler shift) that is the change in frequency of a wave for an observer moving relative to its source.



- Piezoelectric Sensors -

A piezoelectric sensor is a device that uses the piezoelectric effect, to measure the changes in velocity, pressure, acceleration, temperature, strain or force by converting them to an electrical charge.

Principle of Operation - The way a piezoelectric material is cut produces three main operational modes -

- Transverse
- longitudinal
- Shear

These types of sensors are versatile tools for the measurement of various processes. They are used for quality assurance, process control and for research, and development in many industries. Two main groups of materials are used for piezoelectric sensors. Piezoelectric ceramics and single crystal materials.

- Accelerometer Sensors - An accelerometer is a device that measures proper acceleration (time rate of change of velocity). They are typically used in one of the three modes :-

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(1) As an inertial measurement of velocity and position.

(2) As a sensor of inclination, tilt or orientation in 2 or 3 dimensions, as referred from the acceleration of gravity. ($g = 9.8\ m/s^2$).

(3) As a vibration or impact (shock) sensor.

- **Proximity Sensors** -

A Proximity sensor is a sensor that is able to detect the presence of nearby objects without any physical contact. A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation and looks for changes in the field of return signal. The object being sensed is often referred to as Proximity sensor's target. Different proximity sensor targets demands different sensors. for eg - a capacitive proximity sensor or a photoelectric sensor might be suitable for a plastic target, an inductive proximity sensor always require a metal target. These type of sensors can have a high reliability and long functional life because of the absence of mechanical parts and the lack of physical contact between the sensor and the sensed object.

- **Types of Sensors** - The different types of proximity sensors are -
  - ↳ Inductive sensors
  - ↳ Capacitive sensors
  - ↳ Capacitive displacement sensors

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- Doppler effect based sensors
- Eddy current sensors
- Magnetic sensors
- Optical sensors
  - Photoelectric
  - Photocell
  - Passive thermal infrared
  - Laser range finder
- Ultrasonic sensors
- Fiber optic sensors
- Hall effect sensors
- Radar sensors

- **Operating Principles of Proximity sensors -**

Inductive and Capacitive - This operating principle is based on the high frequency oscillator that creates a field in the close surroundings of the sensing surface. The presence of a metallic object (inductive) or any material (capacitive) in the operating area causes a change of the oscillation amplitude. The rise or fall of such oscillations is identified by a threshold circuit that changes the output state of a sensor.

Photoelectric - These sensors use light sensitive elements to detect the objects and are made up of an emitter (light source) and a receiver. Three types of photoelectric sensors are available -

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Direct reflection - emitter and receiver are housed together and uses the light reflected directly off the object for detection.
Reflection with reflector - emitter and receiver are housed together and requires a reflector.
Thru Beam - emitter and receiver are housed separately and detects an object when it interrupts the light beam between them

Magnetic - Magnetic sensors are actuated by the presence of a permanent magnet. Their operating principle is based on the use of reed contacts.

- Applications of Proximity Sensors -
  - Parking sensors, systems mounted on car bumpers that sense distance to nearby cars for parking.
  - Ground proximity warning system for aviation safety.
  - Sheet break sensing in paper machine.
  - Anti-aircraft warfare
  - Roller coasters
  - Conveyor systems
  - Mobile devices
  - Automatic faucets.

- Acceleration Sensors -

Acceleration Sensor is used for measuring acceleration and tilt. An accelerometer is a device used for measuring acceleration. Static force - It is the frictional force between any two objects. By measuring this gravitational force, we can

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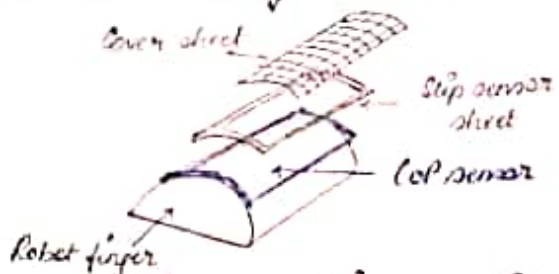
determine that how much the robot is tilting.

Accelerometer is an electromechanical device that measures acceleration and tilt angles by using the MEMS (Micro Electro Mechanical Systems) technology, where acceleration is the rate of change of velocity with respect to time. Acceleration forces may be static or dynamic depending upon the way one uses the accelerometer. The change in the acceleration leads to the change in the voltage output of the accelerometer.

Accelerometers have been extensively used in the field of automation and robotics. They detect vibrations and can be used for testing car engine. They can sense the car crashes and push out the air bags at the right time.

- **Slip Sensors-**

Humans can grasp an object without information such as a coefficient of friction or weight. To implement this grasping motion with the base robot hand, sensors have been proposed that detect an incipient slip within the contact surface or slick slip.



The slip of an industrial robot finger means the relative motion of an object with respect to the finger in the direction vertical to the grasping finger force. The travelling distance of the grasping point is called the slip displacement.

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The proposed slip sensor detects the slip displacement through the rotating motion of rollers contacting the object.

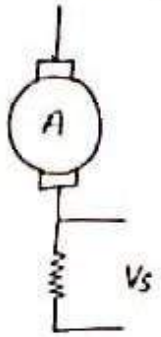
Slip motion causes forced vibrations in pierodectric crystal.

Grasping strategy -

↳ Determine min and max force that can be applied on a part

↳ Use min force to start with

↳ Increase the force if slip is detected subject to limit the max force / displacement



- **Touch Sensors** -

The sense of touch is an important sensor channel in many animals and plants. Computer input devices are different to human contact. Thus touch sensing input devices offers numerous possibilities to connect with softwares.

- **Principle of Working** - Touch sensors are also called tactile sensors and are sensitive to touch, force and pressure. The working of a touch sensor is similar to that of a simple switch. When there is contact with the surface of the touch sensor, the circuit is closed inside and there is a flow of current. When the contact is released, the circuit is open and no current flows.

The pictorial representation of the working of a touch sensor is shown below -

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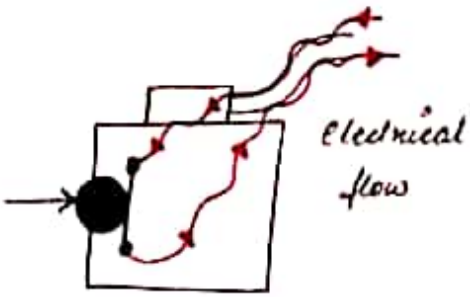
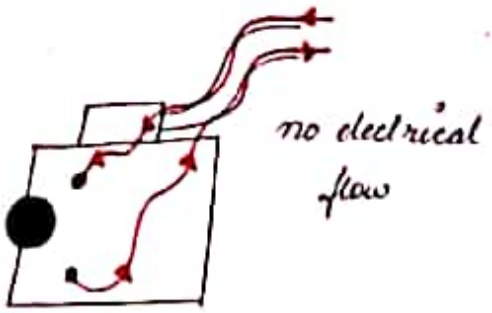


Touch sensor pressed



Touch sensor released

- Types of Touch Sensors - The two types of touch sensors are -

  Capacitive Touch sensor

  Resistive Touch sensor

* Capacitive Touch Sensor - These sensors are widely used in most of the portable devices like mobile phones, MP3 player etc.

The principle of a capacitive touch sensor is defined by two conductors separated by an insulator. Metal plates can be considered as conductors. The formula of capacitance is shown below -

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

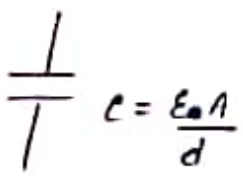
where,

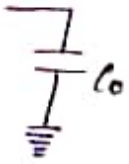
$\varepsilon_0 \rightarrow$ permittivity of free space

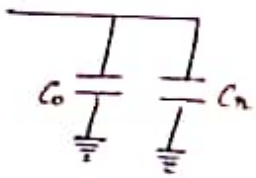
$\varepsilon_r \rightarrow$ Relative permittivity

$A \rightarrow$ area of the plate

$d \rightarrow$ distance between them







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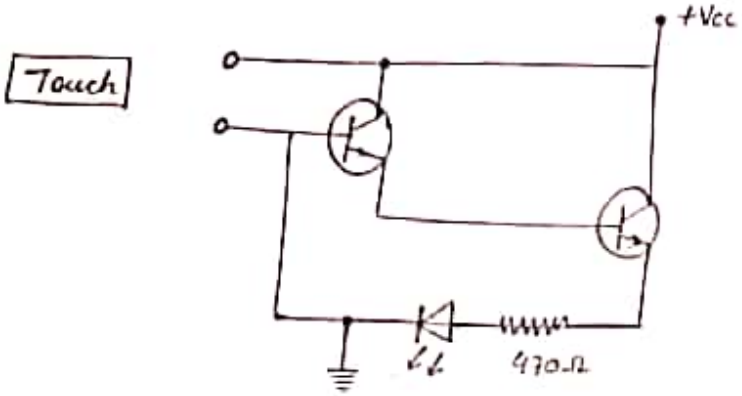
* **Resistive Touch Sensor** - Unlike the capacitive touch sensor, the resistive touch sensor does not depends upon the electrical properties such as conductivity. The resistive sensor work with the by sensing the pressure when applied on the surface.

The resistive touch sensor consists of two conductive layers separated by a very small distance or dots. The two layers are made up of film. The film is generally coated by Indium Tin oxide.
A constant voltage is applied opp across the surface of two films. When the pressure is applied with the help of a finger, the sensor is activated and senses the touch.



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