# Lecture-22

# Sensors

- Human-beings collect information of the surroundings using their sensors, namely eyes, ears, nose, skin etc., in order to perform various tasks.
- A sensor is used to take measurements of physical variables.
- A sensor requires calibration(ie. Comparison with known data)
- Sensors are used to build intelligent robots

# Classification of Sensors

1.

Sensors

**Internal Sensors**
(Used to operate the drive units)
Ex. Position sensors, Velocity Sensors, Acceleration Sensors, Force/ Moment Sensor

**External Sensors**
(used to collect information of the environment)
Ex. Temperature sensors, visual sensor, Proximity sensor, Acoustic sensor

# Classification of Sensors

2.

Sensors

**Contact Sensors**
(Physical Contact between sensor mounted on robot and object)

**Touch sensor/ Tactile Sensor/ binary Sensor**
(indicates presence or absence of an object )
Ex. Micro-switch, limit switch

**Force sensor/ Analog Sensor**
(not only the contact is made but also the force is measured)
Ex. Sensors using strain gauges

**Non-Contact Sensors**
(No physical contact)
Proximity sensors
Visual Sensor
Acoustic Sensor
Range Sensor

# Characteristic of Sensors

**Range:** Difference between the maximum and minimum values of the input that can be measured.

**Response:** should be capable of responding to the changes in minimum time

**Accuracy:** deviation from exact quantity

**Sensitivity**=change in output/ change in input

**Linearity:**constant sensitivity

**Repeatability:** Deviation from reading to reading, when these are taken for a number of times under identical conditions.

**Resolution(least count)**

# Touch Sensor

- Used to indicate whether contact has been made between two objects
- Does not determine the magnitude of contact force
- Ex: Micro-switch, Limit switch

# Connected to robot's wrist

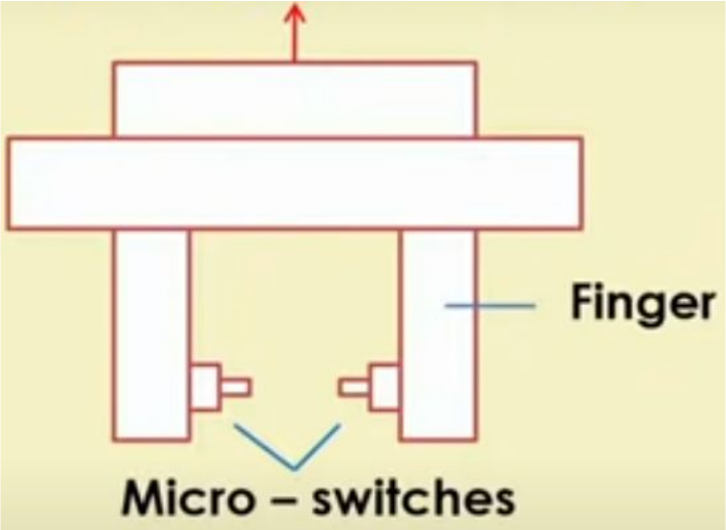



Figure:Micro-switches placed on two fingers of a robotic hand

# Position sensor

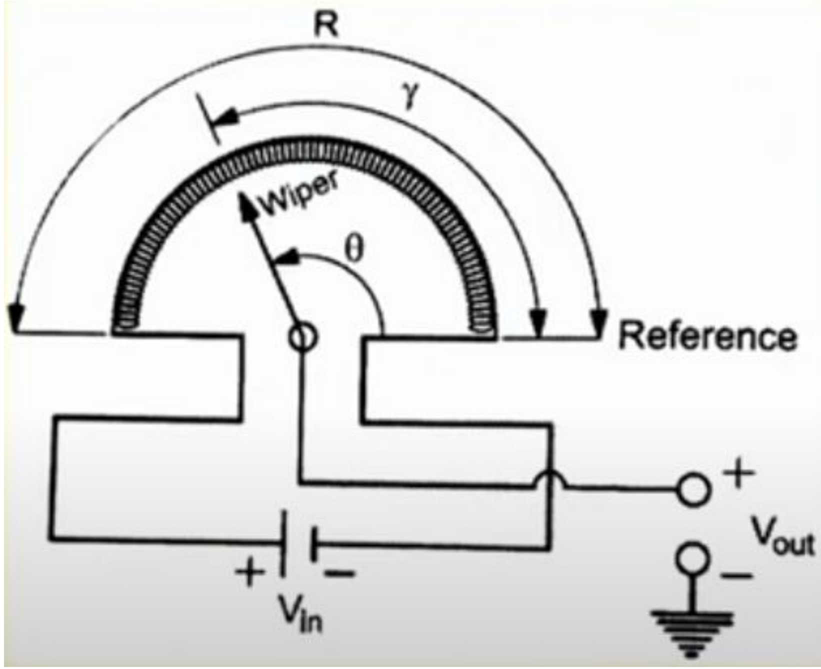
1. Potentiometer

Potentiometer

Potentiometer

**Angular Potentiometer**

**Θ**:Angular displacement of the wiper
With respect to the reference
**R**:Total resistance
**r**:Resistance of the coil between the wiper
and the reference
$\mathbf{V_{in}}$:Input voltage
$\mathbf{V_{out}}$:Output voltage



# Angular Potentiometer

$$\frac{V_{\text{in}}}{R} = \frac{V_{\text{out}}}{r}$$

$$r = \frac{RV_{\text{out}}}{V_{\text{in}}}$$

If we know r and nature of wire, we can determine $\theta$

Demerit

- Resistance of the wire is temperature dependent.
- Potentiometer is temperature sensitive

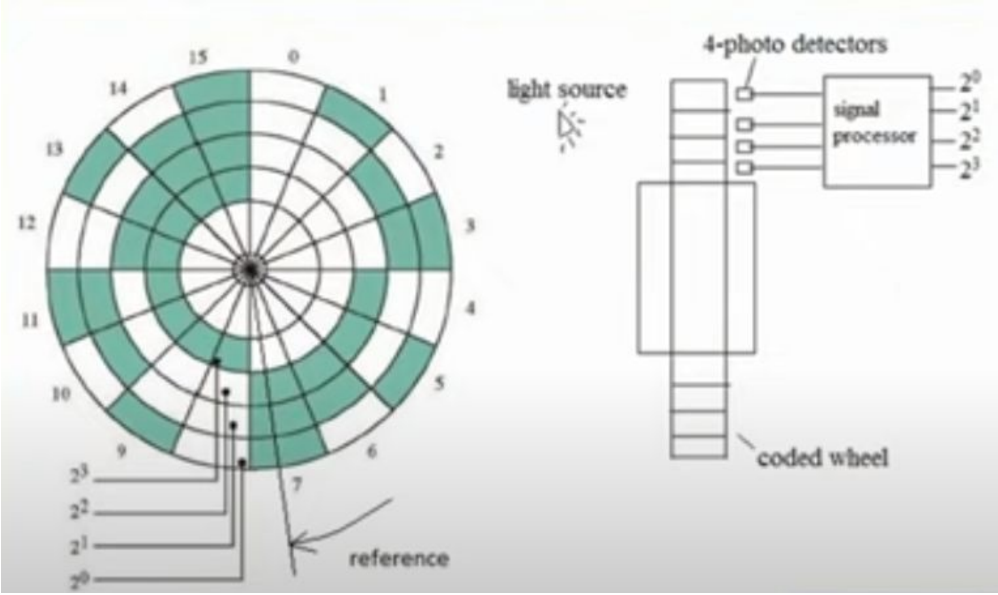
2. Optical Encoder (used as feedback devices)

Absolute Optical encoder

Incremental Optical Encoder

## Absolute Optical Encoder

- **It is mounted on the shaft a rotary device**
- **To generate digital word identifying actual position of the shaft measured from zero position**




What is the angular displacement or what is the rotation of the rotating soft ?

## Absolute Optical Encoder(contd.)

Resolution: 1 part in $2^n$, where n: number of concentric rings(tracks)

| $2^3$ | $2^2$ | $2^1$ | $2^0$ | DV |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 2 |
| 0 | 0 | 1 | 1 | 3 |
| 1 | 1 | 1 | 0 | 14 |
| 1 | 1 | 1 | 1 | 15 |

$$\text{if } 4 \text{ concentric rings } \; 2^4 = 16$$

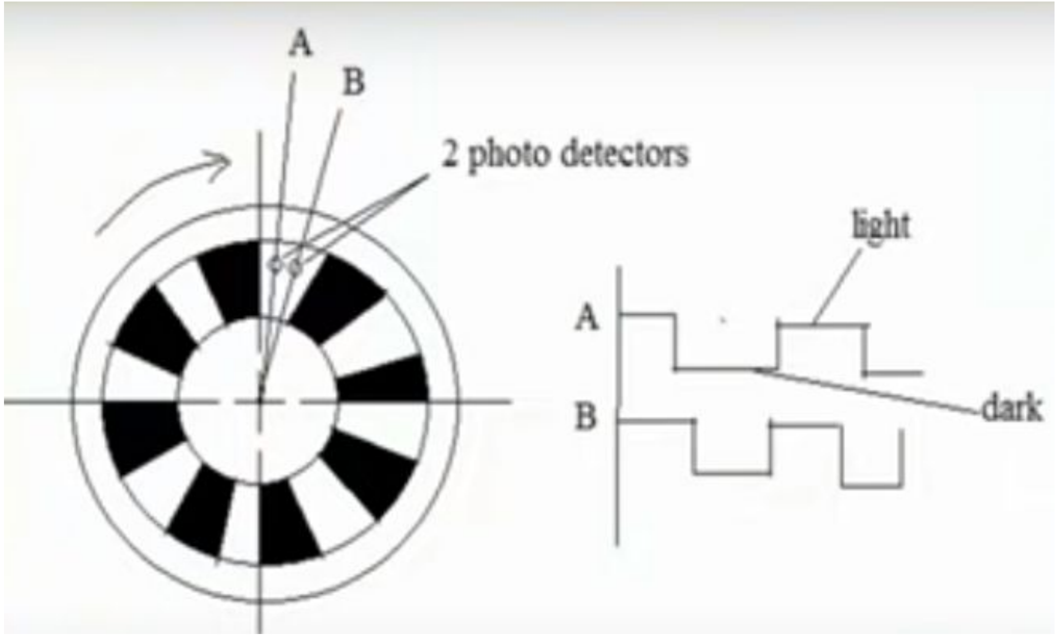
$$Then\ \frac{360^0}{16} = \text{Resolution}$$

$$\text{if } n \text{ concentric rings } \; 2^n$$

$$\frac{1}{2^n}$$

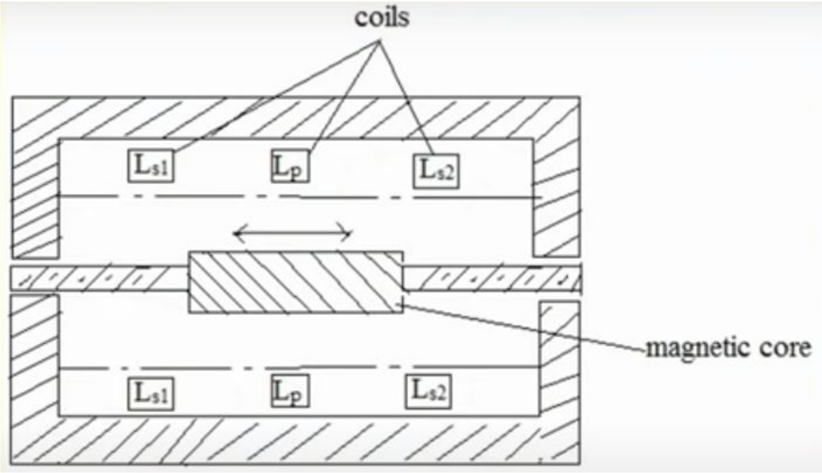
# Incremental optical encoder

- Consists of one coded disc and two photo-detectors
- By counting the number of light and dark zones, angular displacement can be measured with respect to known starting position.
- It can determine the director of rotation also
- It is construction-wise simpler, less accurate and less expensive.



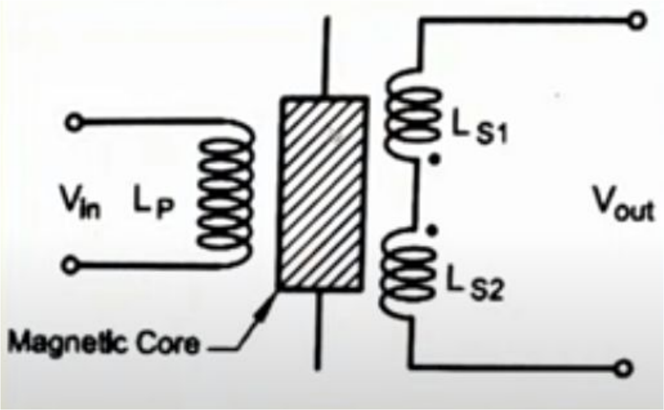
# Linear Variable Differential Transformer(LVDT)

- It consists of two parts: fixed casing and moving magnetic core
- In-between the fixed casing and magnetic core, there are one primary(LP) and two secondary (Ls1, Ls2) coils
- Produced voltage output is proportional to the displacement of moving part relative to the fixed one

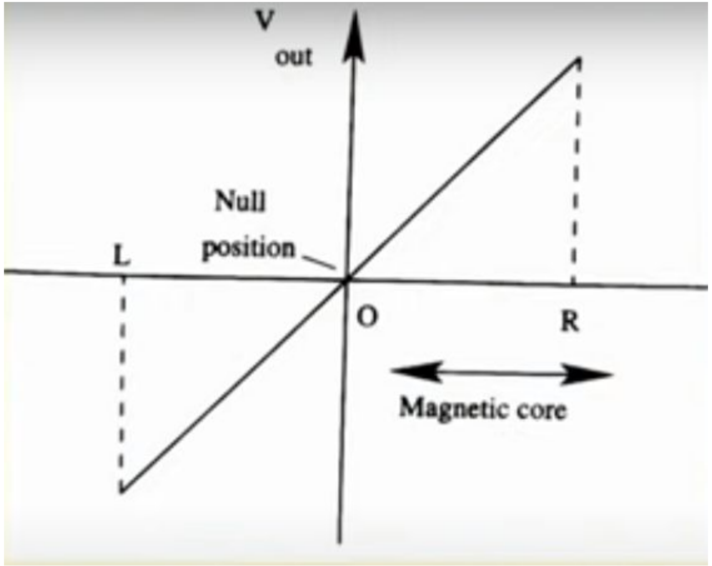


# LVDT(Contd.)

- Ac voltage is applied to $L_p$
- $L_{S1}$ and $L_{S2}$ are connected in series
- $V_{\text{out}} = VL_{s2} - VL_{s1}$

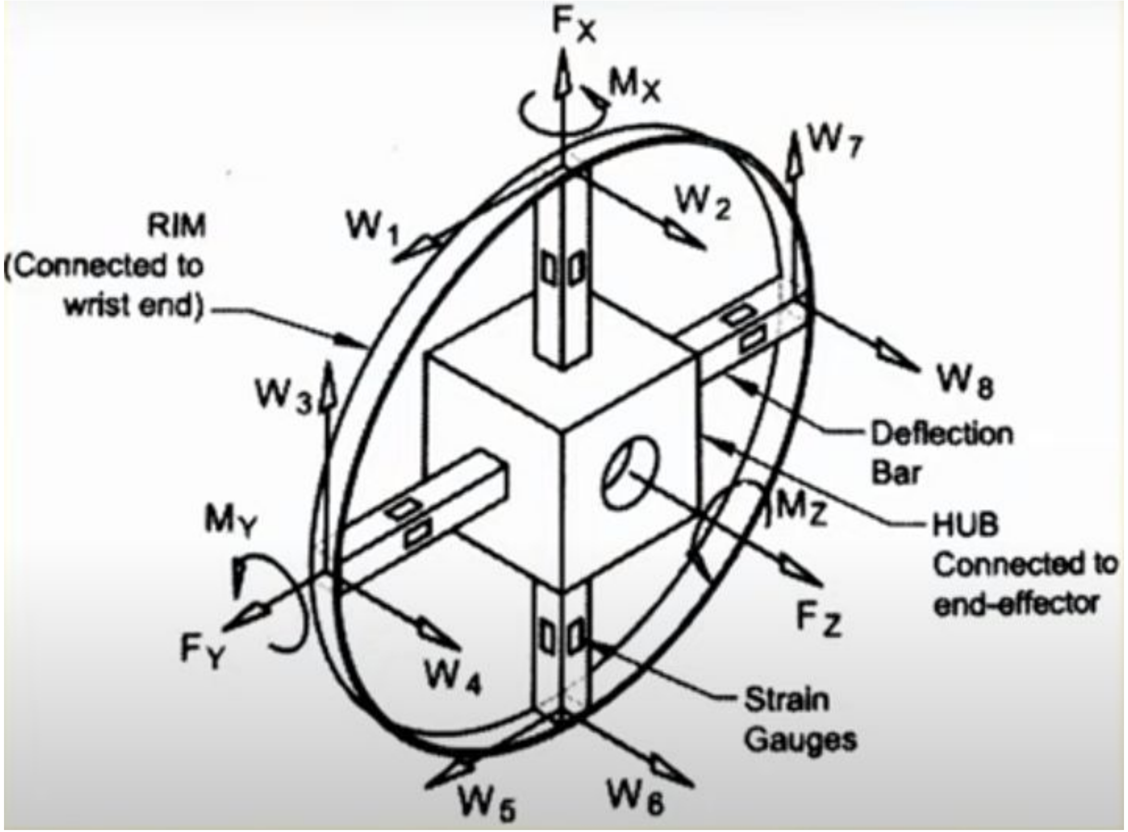



LVDT:equivalent electrical circuit




Calibration curve

# Force/Moment Sensor



# Force/ Moment Sensor(Contd.)

- It is placed between the wrist and end-effector end
- It consists of 4 deflection bars. Two paris of strain gauges are mounted on each deflection bar. One end of each deflection bar is rigidly supported by a hub, which is connected to the end-effector end. The other ends of the deflection bars are supported by a common rim, which is connected to the wrist end.
- External forces cause deflection of the mechanical structure, which are measured using strain gauges

$$\delta = \frac{PL^3}{3EI}$$

# Force and Moment Sensor

- Strain gauge is connected to potentiometer circuit, whose output voltage is proportional to the deflection and hence, force.
- Three components of force (F) and moment (M) each are determined by adding and subtracting the respective components of force

$$F = C_M W$$

Calibration matrix

Forces/moments

$$\begin{bmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{bmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & - & - & - & C_{18} \\ C_{21} & C_{22} & C_{23} & - & - & - & C_{28} \\ & & & & . & & \\ & & & & . & & \\ & & & & . & & \\ C_{61} & C_{62} & C_{63} & - & - & - & C_{68} \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \\ . \\ . \\ . \\ W_8 \end{bmatrix}$$

Reading of the strain gauges

$$F_X = W_3 + W_7$$

$$F_Y = W_1 + W_5$$

$$F_Z = W_2 + W_6 + W_4 + W_8$$

$$M_X = W_4 + W_8$$

$$M_Y = W_2 + W_6$$

$$M_Z = W_1 + W_5 + W_3 + W_7$$

$$F_X = W_3C_{13} + W_7C_{17}$$

$$F_Y = W_1C_{21} + W_5C_{25}$$

$$F_Z = W_2C_{32} + W_6C_{36} + W_4C_{34} + W_8C_{38}$$

$$M_X = W_4C_{44} + W_8C_{48}$$

$$M_Y = W_2C_{52} + W_6C_{56}$$

$$M_Z = W_1C_{61} + W_5C_{65} + W_3C_{63} + W_7C_{67}$$

Precautions:

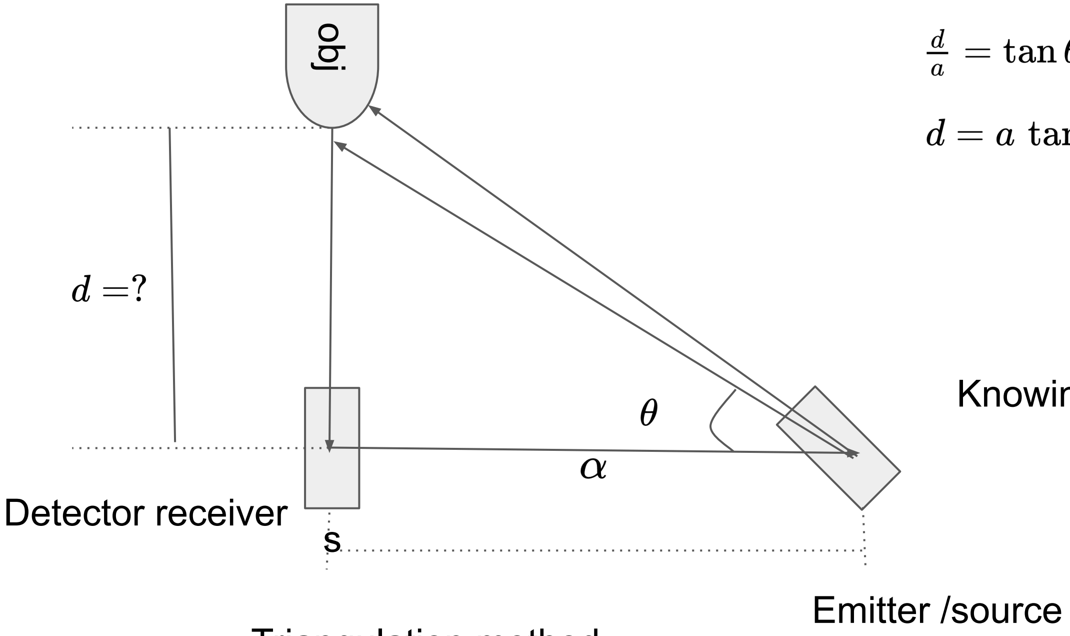
- Strain gauges are to be properly mounted on the deflection bars
- Sensor should be operated within the elastic limit of its material (Deflection bars)

# Range Sensor

It measures the distance between the sensor (detector) mounted on the robot's body and the object

$\frac{d}{a} = \tan\theta$

$d = a\ \tan\theta$




Knowing the values of $\alpha$ and $\theta$, $d$ can be calculated

Triangulation method