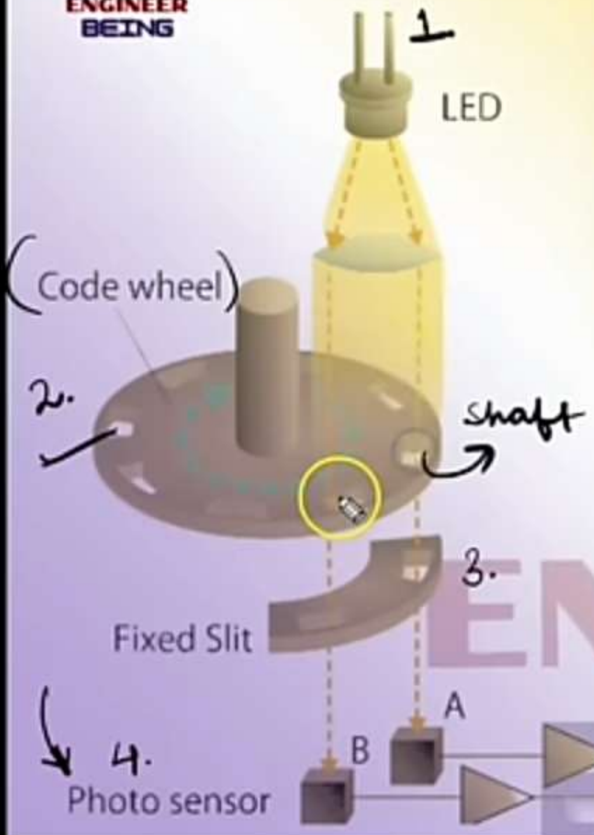
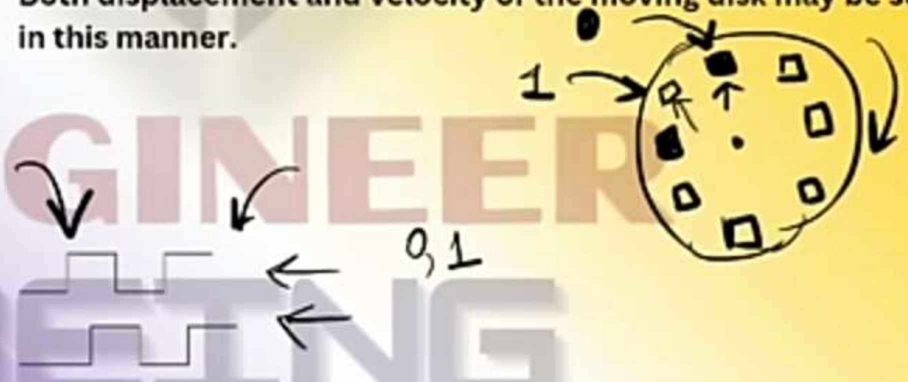
OPTICAL ENCODER

[Digital transducer]

The optical encoder is a transducer commonly used for measuring rotational motion. It consists of a shaft connected to a circular disc, containing one or more tracks of alternating transparent and opaque areas. A light source and an optical sensor are mounted on opposite sides of each track. As the shaft rotates, the light sensor emits a series of pulses as the light source is interrupted by the pattern on the disc. This output signal can be directly compatible with digital circuitry.
Both displacement and velocity of the moving disk may be sensed in this manner.





APPLICATIONS

- It is also used in medical diagnostics.
- It is used in electric lighter used in kitchens. The pressure made on piezoelectric sensor creates an electric signal which ultimately causes the flash to fire up.
- They are used for studying high-speed shock waves and blast waves.
- It is used infertility treatment.
- It is used in inkjet printers.

Advantages :

1. No need for an external emf.
2. Easy to handle and use as it has small dimensions.
3. High-frequency response it means the parameters change very rapidly.

Disadvantages :

1. It is not suitable for measurement in static condition.
2. It is affected by temperatures.
3. The output is low so some external circuit is attached to it.
4. It is very difficult to give the desired shape to this material and also desired strength.

✓ Put value of force in eq^n. ① of charge

$$\boxed{Q = d \times F}$$

$$\boxed{Q = d \cdot A E \frac{\Delta t}{t}}$$

★ $E_p = Q / C_p$ (Capacitance)

$$\frac{d \times f}{\frac{\varepsilon_r \varepsilon_0 A}{t}}$$

Stress or Pressure

$$\boxed{C_p = \varepsilon_r \varepsilon_0 \frac{A}{t}}$$

$$E_p = \frac{Q}{\frac{\varepsilon_r \varepsilon_0 A}{t}} = \frac{d \times F \times t}{\varepsilon_r \varepsilon_0 \times A}$$

$$\boxed{E_p = g \times P \times t}$$

$$\frac{d}{\varepsilon_r \varepsilon_0} \times P \times t$$

Δt  capacitor

$E_0 \propto$ pressure

$\left[E_p = \frac{Q}{C_p}\right]$

* charge(Q) = d × F (1)

d = charge sensitivity

F = Applied force

✓ force causes change in thickness

$$\boxed{F = A \cdot E \cdot \frac{\Delta t}{t}}$$

$$\frac{F}{A \frac{\Delta t}{t}}$$

$$E = \frac{F t}{A \cdot \Delta t}$$

* Young Modulus $E = \frac{\text{Stress}}{\text{Strain}} = \frac{F}{A \frac{\Delta t}{t}} = \frac{F \cdot t}{A \cdot \Delta t}$

$$\boxed{F = A \cdot E \cdot \frac{\Delta t}{t}}$$

PIEZOELECTRIC EFFECT

Explain piezoelectric sensor. 2M 2020-21

What is a piezoelectric sensor? Define one application of the piezoelectric sensor. 10M 2021-22

Piezoelectricity is a phenomena where electricity is generated if the mechanical stress is applied to a material.This piezo electricity produced is proportional to the stress given to substrates Of the strong piezoelectric crystal.

Initially, in a piezoelectric crystal, the charges are exactly balanced the effect of charges cancel out each other and hence no net charge will be Found on the crystal surface.

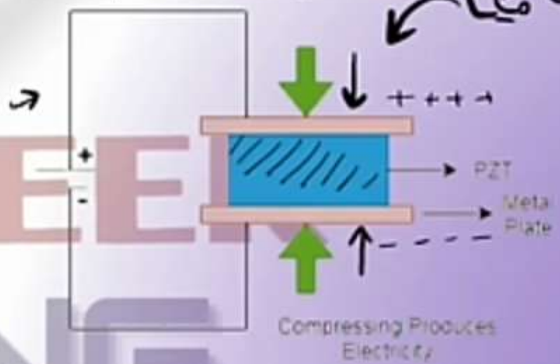
when the crystal is squeezed the charges in crystal become unbalanced which makes net Positive and negative charge to appear on the opposite faces of the crystal.

Therefore, by squeezing the crystal , voltage is produced across the opposite face, and this is known as piezoelectricity.

To make it a complete circuit, two phases are connected together and current is passed through.

[$E \propto P$]

For example, lighters.Gas burners lighter utilizes piezoelectric effect. It produces electric pulse due to the force developed by sudden impact of trigger over the material inside.



For Rotational Motion

$$\boxed{V_o = \left(\frac{\theta_i}{\theta_t}\right) V_s}$$

$$V_0 = \frac{\left(\frac{R_p}{x_t} \times x_i\right) V_s}{R_p}$$

$$= \frac{\cancel{R_p}}{x_t} \times x_i \times \frac{V_s}{\cancel{R_p}}$$

$$V_0 = \frac{x_i}{x_t} \times V_s$$

$$\boxed{V_0 \propto x_i}$$

$$\left[\frac{V_0}{x_i} = \frac{V_s}{x_t}\right]$$

★ Sensitivity $= \frac{O/P}{I/P} = \frac{V_0}{x_i} = \frac{V_s}{x_t}$

$$\frac{V_0}{V_s} = \frac{x_i}{x_t}$$

✓ V_s = Input Voltage

✓ V_o = Output Voltage

✓ x_t = Total length

✓ x_i = displacement of slider arm

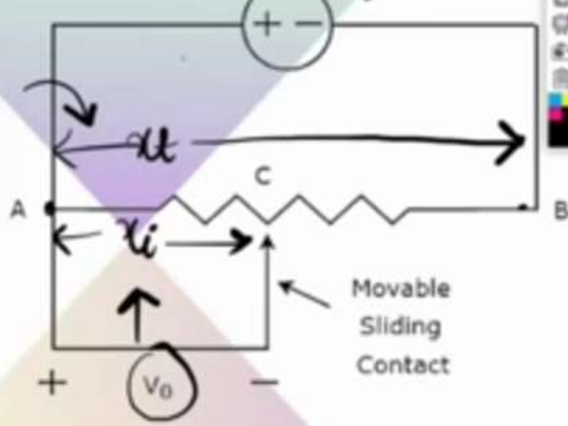
✓ R_p = Total Resistance

✓ Resistance per unit length = $\frac{R_p}{x_t}$

x_t ———— R_p

1 ———— R_p / x_t

x_i ———— $V_s \frac{R_p}{x_t} \times x_i$

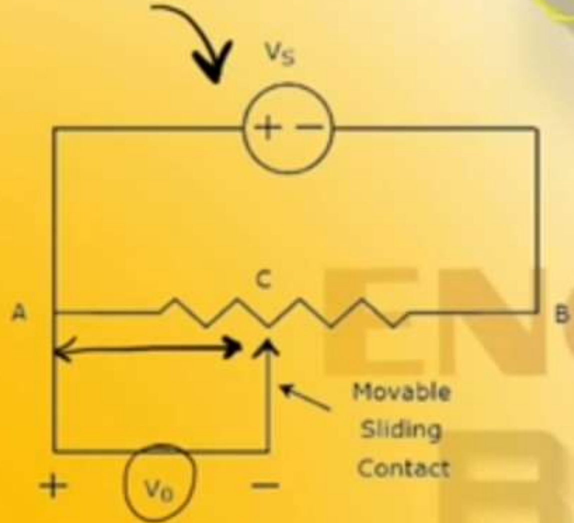


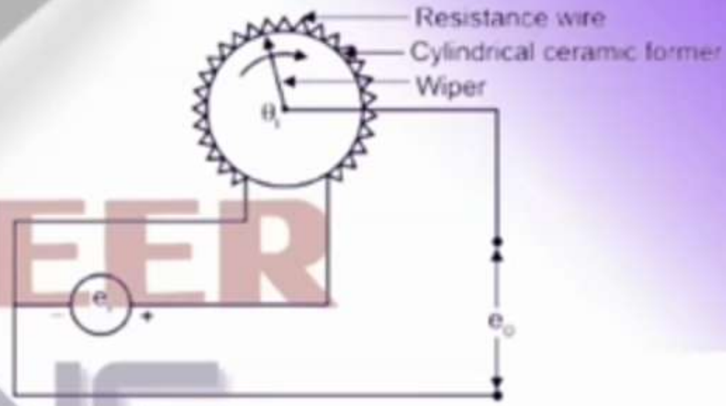
$$V_o = \frac{\text{Resistance at output terminal}}{\text{Resistance at I/P terminal}} \times V_s$$

WORKING

Therefore, we should connect the body whose displacement is to be measured to the sliding contact. So, whenever the body moves in a straight line, the point C also varies. Due to this, the output voltage, V0 also changes accordingly.

we can find the displacement by measuring the output voltage V0.





ENGINEER BEING

$$\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{\partial L}{\partial s} - \frac{2}{D}\frac{\partial D}{\partial s} + \frac{1}{\rho}\frac{\partial \rho}{\partial s}$$

$$\left[\frac{\partial D}{D} = -\nu\frac{\partial L}{L}\right]$$

$$\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{\partial L}{\partial s} - \frac{2\cdot}{\partial s}\left(-\nu\frac{\partial L}{L}\right) + \frac{1}{\rho}\frac{\partial \rho}{\partial s}$$

$$\text{Gauge factor} = \frac{\Delta R/R}{\Delta L/L}$$

$$\left[\Delta R/R = G_f \cdot \frac{\Delta L}{L}\right]$$

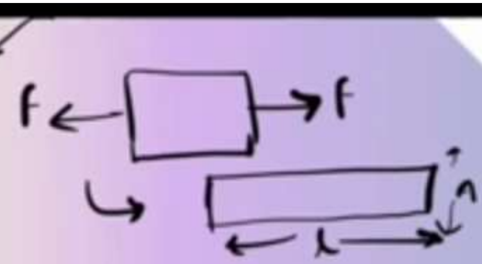
$$\frac{1}{R}\underbrace{\frac{dR}{ds}} = \frac{1}{L}\underbrace{\frac{\partial L}{\partial s}}(1+2\nu) + \frac{1}{\rho}\underbrace{\frac{\partial \rho}{\partial s}}$$

$$\frac{dR}{R} = \frac{\partial L}{L}(1+2\nu) + \frac{1}{\rho}\partial\rho \Rightarrow \frac{\Delta R}{R} = \frac{\Delta L}{L} + 2\nu\frac{\Delta L}{L} + \frac{\Delta\rho}{\rho}$$

$$\frac{\Delta R/R}{\Delta L/L} = \frac{\Delta L/L}{\Delta L/L} + \frac{2\nu\frac{\Delta L}{L}}{\Delta L/L} + \frac{\Delta\rho/\rho}{\Delta L/L} \qquad G_f = 1 + 2\nu + \boxed{\frac{\Delta\rho/\rho}{\Delta L/L}}$$

$$\boxed{G_f = 1+2\nu}$$

$$\text{Strain} = \frac{\text{change in dim}}{\text{Original dim}}$$



Lateral $= \Delta A / A$ Long. $= \dfrac{\Delta l}{l}$

$$R = \frac{\rho l}{A}$$

$$\frac{1}{A} = A^{-1} = (-1)A^{-2} = \frac{-1}{A^2}$$

$$\frac{dR}{ds} = \frac{d}{ds}\left(\frac{\rho l}{A}\right) = \frac{\rho}{A}\left(\frac{\partial l}{\partial s}\right) + \rho l\left(\frac{-1}{A^2}\right)\frac{\partial A}{\partial s} + \frac{l}{A}\frac{\partial \rho}{\partial s}$$

Divide by R

$$\frac{1}{R}\frac{dR}{ds} = \frac{\rho}{AR}\frac{\partial l}{\partial s} + \frac{\rho l}{R}\left(\frac{-1}{A^2}\right)\frac{\partial A}{\partial s} + \frac{l}{RA}\frac{\partial \rho}{\partial s}$$

$$R = \frac{\rho l}{A}$$

$$\frac{1}{R}\frac{dR}{ds} = \frac{\rho}{\cancel{A}\cdot\frac{\rho l}{\cancel{A}}}\left(\frac{\partial l}{\partial s}\right) - \frac{1}{\cancel{A^2}}\frac{\rho l}{\frac{\rho l}{A}}\left(\frac{\partial A}{\partial s}\right) + \frac{l}{\frac{\rho l}{A}\cdot A}\cdot\frac{\partial \rho}{\partial s} = \frac{1}{l}\frac{\partial l}{\partial s} - \frac{1}{A}\frac{\partial A}{\partial s} + \frac{1}{\rho}\frac{\partial \rho}{\partial s}.$$

STRAIN GAUGE

Explain the principle and working of a strain gauge. Derive the expression of gauge factor.10M 2019-20

(Imp.)

$l \uparrow \quad A \downarrow$

ρ

$(F/A) =$ stress.

- Devices to measure these small changes in dimensions are called strain gages. A strain gauge, a device whose electrical resistance varies in proportion to the amount of strain in the device.

[St → ΔR]

Strain = $\frac{\text{change Dim}}{\text{original Dim.}}$

- A strain gauge works on the principle of electrical conductance and its dependence on the conductor's geometry. Whenever a conductor is stretched within the limits of its elasticity, it doesn't break but, gets narrower and longer.

[strain → ΔR]

- Strain gauge is a passive transducer that converts a mechanical elongation or displacement produced due to a force into its corresponding change in resistance, it It uses the variation in electrical resistance in wires to sense the strain produced by a force on the wire.

$R = \frac{\rho l}{A}$

Piezo resistive Effect

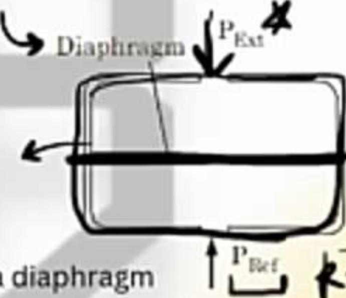
ENGINEER BEING

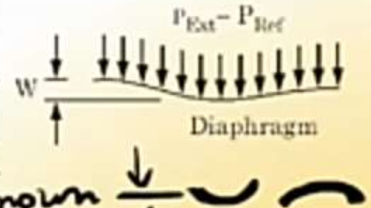
Measurement of pressure using LVDT

What is an LVDT and how it is arranged for measuring pressure? 10m 2021-22

[Pext → Diaphragm → LVDT disp. → emf]

disp → emf

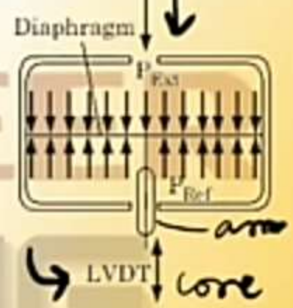


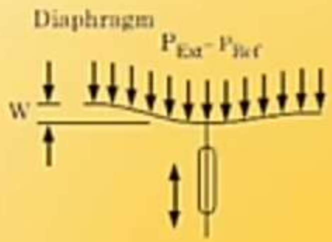


1. The diaphragm pressure gauge uses the elastic deformation of diaphragm (i.e. membrane) instead of a liquid level to measure the difference between the unknown pressure and a reference pressure.

2. A typical diaphragm pressure gauge contains a capsule divided by a diaphragm

3.One side of diaphragm is open to the external targeted pressure, PExt., and the other side is connected to a known pressure, PRef . The pressure difference PExt − PRef, mechanically deflects the diaphragm.





4. The membrane of the diaphragm is connected to LVDT. Due to application of pressure on diaphragm, a displacement is applied on core or primary winding of LVDT. As a result a voltage is induced in the secondary winding of LVDT. This induced voltage is directly proportional to applied pressure

[Pext → Emf]

ENGINEER BEING

Advantages :

1. High output and high sensitivity : The LVDT gives a high output and a high sensitivity.
2. Ruggedness : These transducers can usually tolerate high degree of shock and vibrations especially when the core is spring loaded without any adverse effects.
3. Low hysteresis : LVDTs show a low hysteresis and hence repeatability is excellent under all conditions.
4. Low power consumption : Most of LVDTs consume power which is less than 1 W. B.

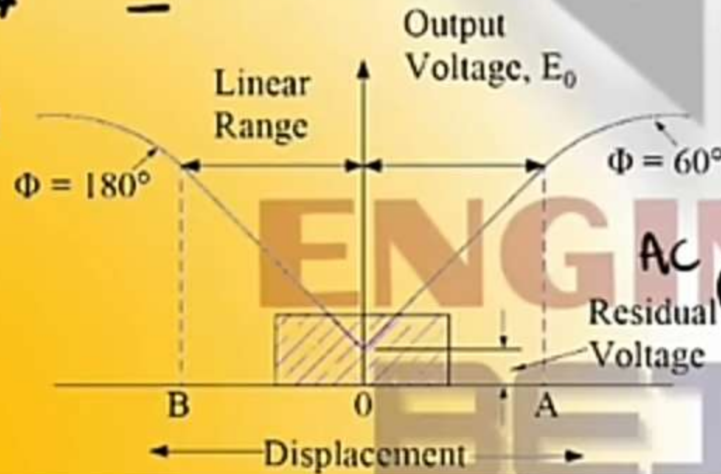
Disadvantages :

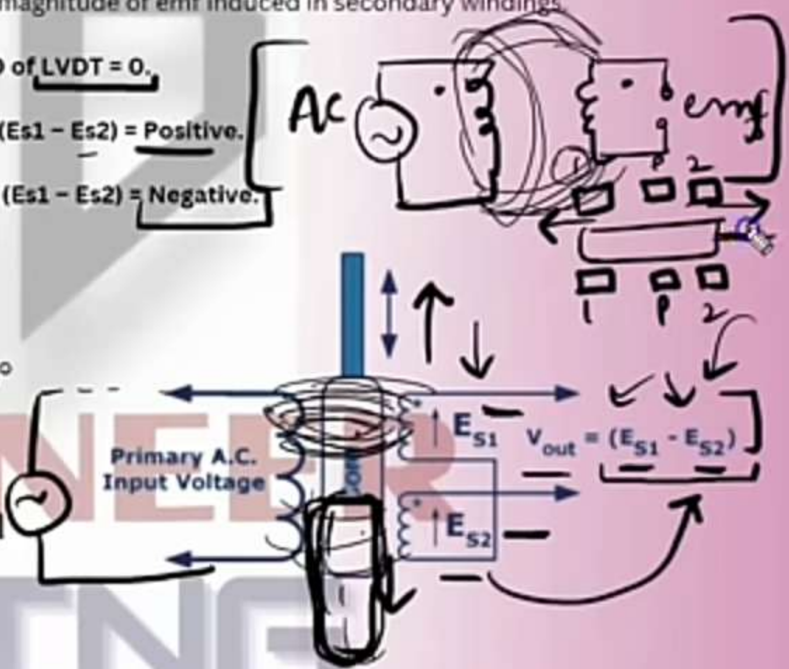
- Very high displacement is required for generating high voltages.
- Shielding is required since it is sensitive to magnetic field.
- The performance of the transducer gets affected by vibrations.
- It is greatly affected by temperature changes.

Working:

Since the primary winding of Linear Variable Differential Transformer (LVDT) is supplied with AC supply, it produces an alternating magnetic flux in the core which in turn link with the secondary winding S1 and S2 to produce emf due to transformer action.
the emf produced in secondary winding S1 is Es1 and that in S2 is Es2. The magnitude of Es1 and Es2 will depend upon the magnitude of rate of change of flux **(dØ / dt) acc to faradays law**
Thus faster the movement of core, the greater will be the magnitude of emf induced in secondary windings.
net output voltage E0 of the LVDT is : **E0 = Es1 – Es2**

- **Core at center : Es1 = Es2 and hence net output voltage E0 of LVDT = 0.**
- **Core at left Es1 > Es2 and net output voltage voltage E0 = (Es1 – Es2) = Positive.**
- **Core at right Es2 > Es1 and hence net output voltage E0 = (Es1 – Es2) = Negative.**





LVDT

(10M) imp.

[disp → emf]

Measurement of displacement using LVDT With the help of a neat sketch explain the working of a 'LVDT'. What are its advantages and disadvantages? 10M 2021-22

Linear Variable Differential Transformer is a common type of electromechanical transducer that can convert the rectilinear motion of an object to which it is coupled mechanically into a corresponding electrical sign

Construction:

LVDT is a transformer consisting of one primary winding P and two secondary winding S1 & S2 mounted on a cylindrical former.

A movable soft iron core is placed inside the former. Actually the movable core made of nickel - iron.

Both the secondary winding are connected in series But in phase opposition

C A

E_1 E_2

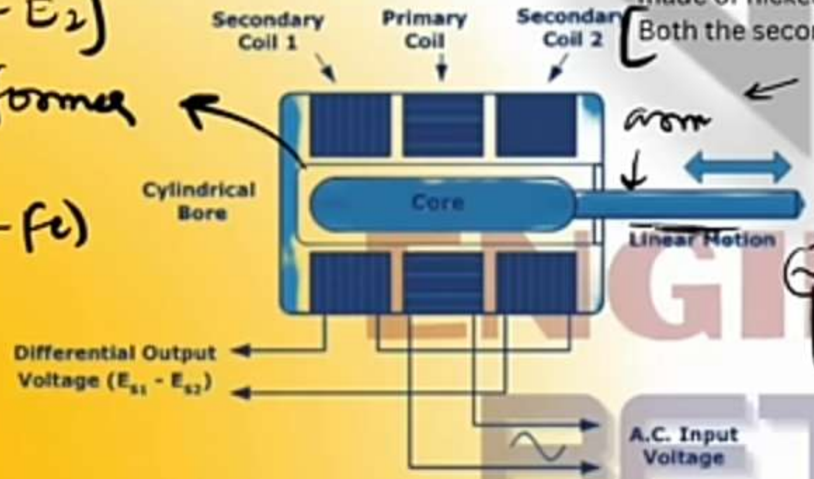
$[E_1 - E_2]$

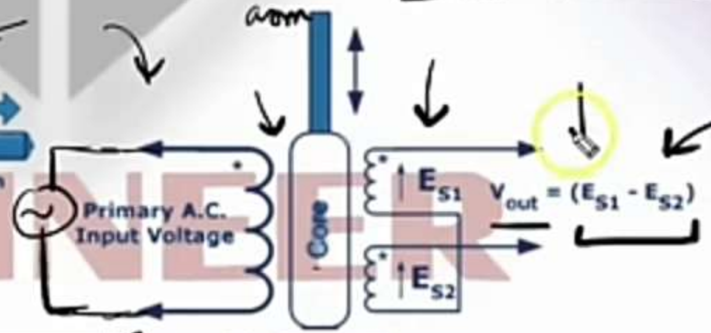
former

(Ni-Fe)

arm

Construction of LVDT





Secondary transducer :

The secondary transducer converts the mechanical signal into an electrical signal.

Passive and active transducer :

Passive transducer

The transducer which requires the power from an external supply sourceis known as the passive transducer.

Active transducer :

The transducer which does not require the external power source is known as the active transducer.

Analog and digital transducer :

Analog transducer :

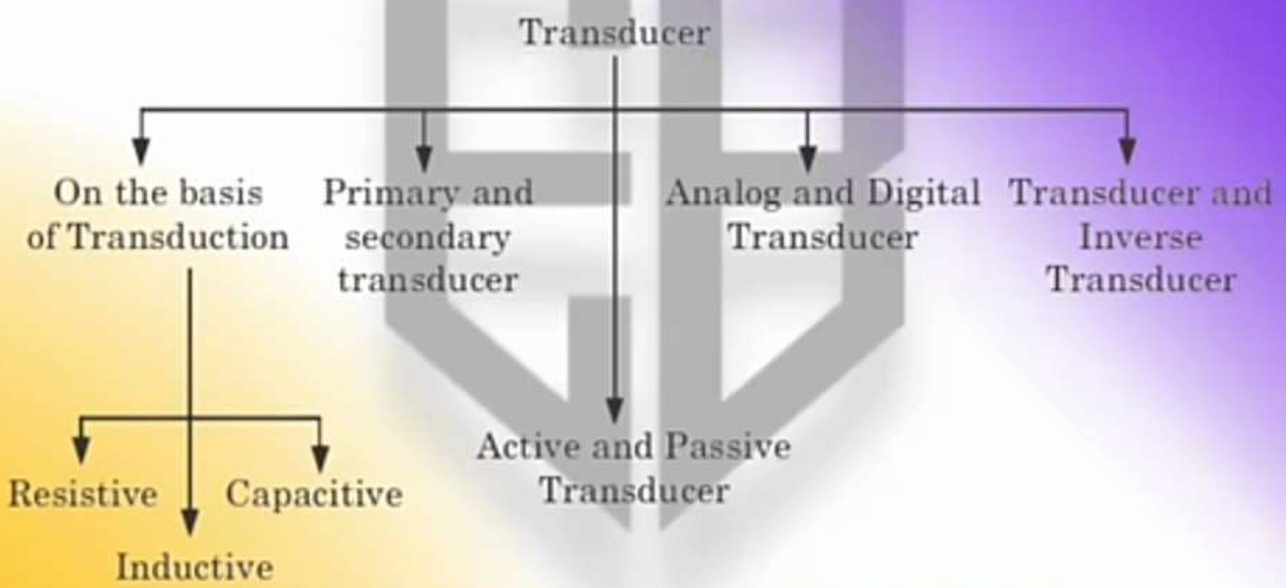
The analog transducer changes the input quantity into a continuous function.

The strain gauge, LVDT, thermocouple and thermistor are the examples of the analog transducer

Digital transducer :

These transducers convert an input quantity into a digital signal or in the form of the pulse. The digital signals work onhigh or low power.

CLASSIFICATION OF TRANSDUCER



Primary and secondary transducer :

Primary transducer :

The mechanical devices of the transducer change the physical input quantities into a mechanical signal. This mechanical device is known as the primary transducers.

Define different categories of sensors and the process to select a sensor for any process 10M 2021-22

When selecting a sensor for a particular application, it is important to consider the following factors:

1. Type of Sensing: The parameter that is being sensed like temperature or pressure

2. Operating Principle: The principle of operation of the Transducer/Sensor.

3. Power Consumption: The power consumed by the Transducer/sensor will play an important role in defining the total power of the system.

4. Accuracy: The accuracy of the Transducer/sensor is a key factor in selection.

5.Resolution and Range: The smallest value that can be sensed and the limit of measurement are important.

6.Cost: Depending on the cost of application, a low cost Transducer/Sensor or high cost sensor can be used.

Based on the quantity being measured

Classification of sensors 2M 2021-22
How can you classify sensors? Explain each of them in detail.

Temperature: Resistant temperature detector RTD, Thermistor thermocouple.
Pressure: Bourdon tube, diaphragm.
Force or torque: Strain gauge.

Active & passive sensors :

Based on the power requirement, sensors can be classified as active and passive. Active sensor are those which do not require external power source for their functioning. They generate power within themselves to operate and hence called as self generating type. The energy for functioning is derived from the quantity being measured. For example piezoelectric crystal generate Electrical output when subjected to acceleration.

Passive sensors require external power Source for their functioning. Most of the resistive, inductive and capacitive sensors are passive, just as resistors, inductors and capacitors are called passive devices.

Analog and digital sensors :

An analogue sensor converts the physical quantity being measured to the analog form.That is continuous in time.Thermocouple RTD strain gauge are called analogue sensors.
A digital sensor produces output in the form of Pulse. Encoders are example of digital sensor.

Inverse sensors.

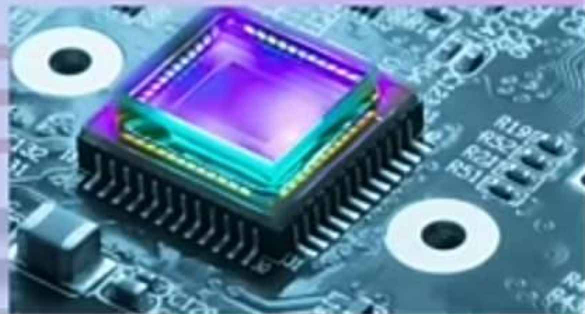
There are some sensors which are capable of sensing a physical quantity to convert it to other forms and also sense the output signal Form to get back the quantity in original form. For example, piezoelectric crystal when subjected to vibration generates voltage. At the same time when Piezo Crystal is subjected to varying voltage, they begin to vibrate. This property makes them suitable to use in microphone and speakers.

Sensors & Transducer

Define the term sensors
2m 2021-22

A sensor is a device that detects and responds to some type of input from the physical environment. The input can be light, heat, motion, moisture, pressure or any number of other environmental phenomena. The output is generally a signal that is converted to a human-readable display at the sensor location

Define the term Transducer
2m 2021-22



A transducer is a device that converts one form of energy into another, typically converting a physical quantity into an electrical signal

Calculate the gauge factor of the strain gauge if the value of resistance is 152 ohm with changes by 5 ohms for 5000 microstrain.

$$g_f = \frac{(\Delta R/R)}{(\Delta L/L)}$$

strain

$R = 152\,\Omega$

$\Delta R = 5\,\Omega$

strain $= 5000 \times 10^{-6} = 5 \times 10^{-3}$

$$g_f = \frac{(5/152)}{5 \times 10^{-3}} = \frac{5 \times 1}{152 \times 5 \times 10^{-3}} = \boxed{6.57}$$