Unit - 5

Transducers

→ It converts a specified measurand, into usable output, using transduction principle.

→ All sensors are transducers but not vice versa.

→ Transducers can convert mechanical force into electrical signal OR physical parameters like light, flow rate, humidity, pH value into electrical form.

Import Parts of Transducers are

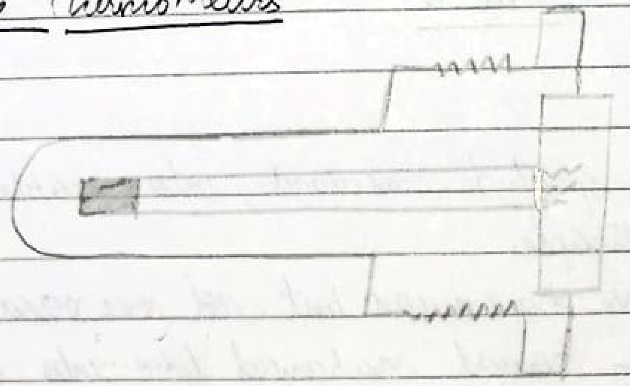
(i) Sensing element

(ii) Transduction element.

Difference betw Active & Passive Transducers

Active Transducers	Passive Transducers
(i) Do not require external power source for operation	(i) Require external power source for operation
(ii) Operate on self-generated voltage/current to produce an output	(ii) Operate on change in Resistance, capacitance/inductance to produce output
(iii) Generate their own electrical signal as output	(iii) Convert an input signal into an output with help of external power.
(iv) Output is directly generated as signal	(iv) Output requires conditioning like amplification
(v) Eg PV cells, Piezoelectric crystals	(v) Eg: Resistive, inductive & capacitive transducers

Resistance Thermometers



→ Resistance thermometer uses the change in electrical resistance of conductor to determine the temperature.

→ The concept of "Resistance of conductor changes when temperature is changed" ~~so~~ it is used here.

$$R_t = R_0 (1 + \alpha_1 T_0 + \alpha_2 T^2 + \cdots + \alpha_n T^n)$$

Reasons why Platinum is used in resistance temperature detectors (PRTD)

(i) Withstand high temp while maintaining stability

(ii) It is a noble metal

(iii) Shows ~~too~~ less susceptibility to contamination.

Requirements of conductor materials to be used in RTDs are

(i) Change in resistance of material/unit change in temperature should be as large as possible

(ii) Material should have high value of resistivity.

(iii) Resistance of material should have a continuous & stable relationship with temp

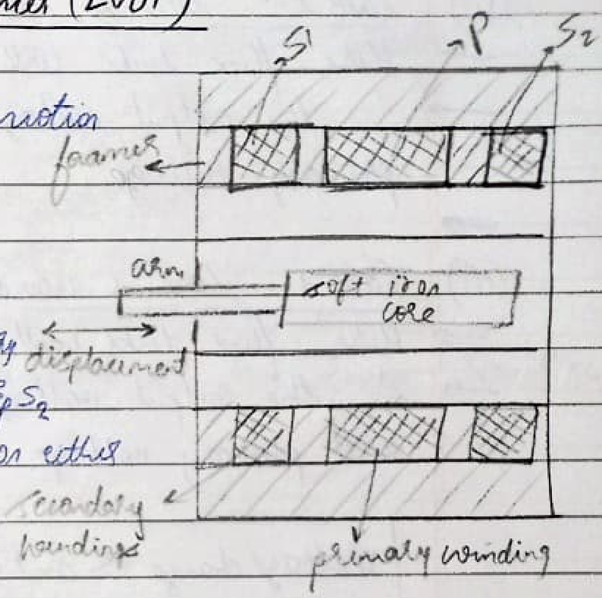
→ Value of RTD is 100 Ω at 0°C, where $\alpha = 3.85 \times 10^{-3}/°C$

→ Materials used for RTDs are ⇒ Pt, Ni, Cu

→ RTD (also called as Pt-100)

Linear Variable Differential Transformer (LVDT)

LVDT is used to convert linear motion into electrical signals.



Construction of LVDT

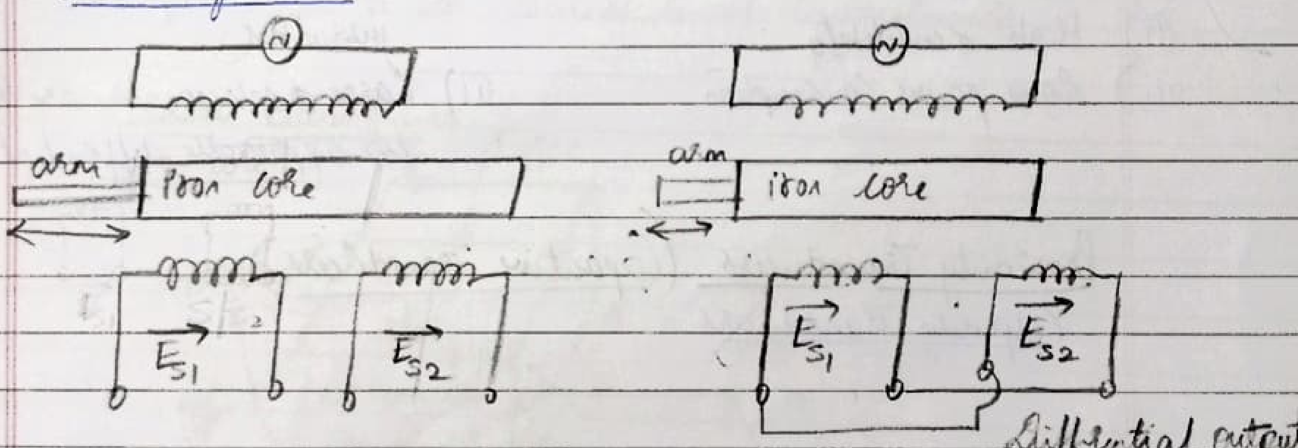
(i) The transformer consists of single primary winding (P) & two secondary windings S_1 & S_2

(ii) ~~All~~ S_1 & S_2 are identical & are placed on either side of (P)

(iii) Primary winding is connected to alternating current source.

(iv) Movable soft iron core is placed in the frames.

Circuits of LVDT



Working

→ The output voltage of transducer depends on 3 cases

(i) Case 1 : When core is at its ~~po~~ normal position

→ The flux linking with both secondary windings is equal & hence equal emfs are induced in them.

→ At null position, $E_{S_1} = E_{S_2}$ & $E_0 = 0$. $(E_0 = E_{S_1} - E_{S_2})$

(ii) Case 2 : Core is moved to left of null point

→ Here, flux links with S_1 is more than that of S_2.

→ ∴ the output voltage will be $(E_0 = E_{S_1} - E_{S_2})$ & is phase with primary voltage.

(iii) Case 3 : Core is moved to right of null point

→ Here, flux links with S_2 is more than that of S_1.

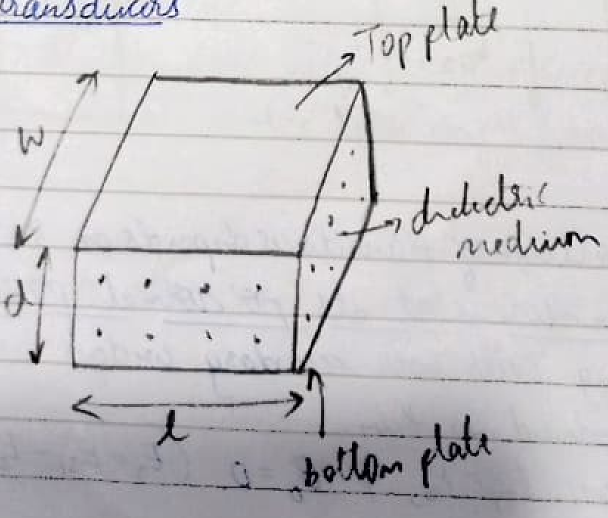
→ ∴ the output voltage will be $(E_0 = E_{S_2} - E_{S_1})$ & is 180° out of phase with primary voltage.

$$\boxed{\text{Voltage change} \propto \text{amt of movement of core} \propto \text{amt of linear motion}}$$

Adv of LVDT
(i) High Range
(ii) High sensitivity
(iii) Low power Consumption

Dis-adv of LVDT
(i) Transducer performance is affected by vibrations
(ii) Large displacements are required for appreciable differential outputs

Proximity Transducers (Capacitive Transducers)
(Capacity Transducers



Principle → change in capacitance of parallel-plate capacitor.

Formula

$C = \frac{\epsilon_r \epsilon_0 A}{d}$

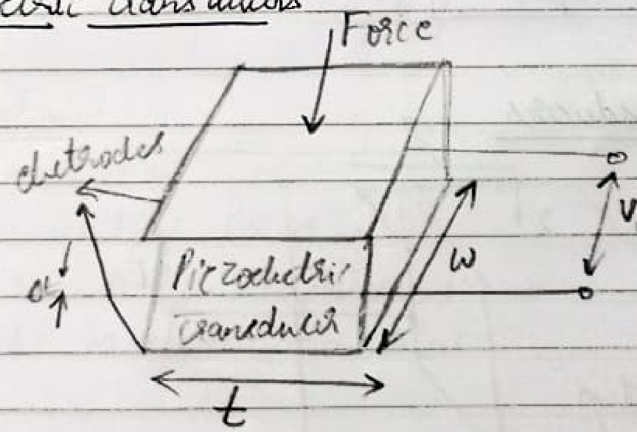
$A \rightarrow$ area of plates (m^2)
$d \rightarrow$ dist betw two plates (m)
$\epsilon_r \rightarrow$ relative permittivity
$\epsilon_0 \rightarrow$ permittivity of free space (8.85×10^{-12} F/m)

Causes of change in capacitance
(i) Change in overlapping Area (A)
(ii) Change in distance betw plates (d)
(iii) Change in dielectric medium.

Output Impedance = $X_C = \frac{1}{2\pi f C}$

Application → used to measure linear displacements

Piezoelectric Transducers



Piezoelectric materials
They are substances that generate electric charge when subjected to mechanical stress & deform when exposed to E.F.
Eg:- Rochelle's salt.

Principle → Piezoelectric effect.

Construction

(i) Piezoelectric material → substance that generates electrical signal.
(ii) Electrodes → the conducting layers attached to the material for collecting electric signals
(iii) Base → A structure on which mechanical force is applied.

Working

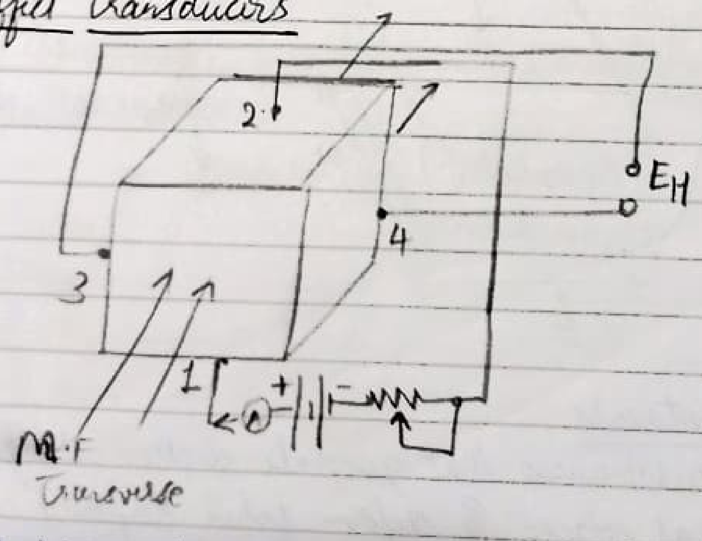
(i) When mechanical force is applied to the material, it deforms
(ii) The deformation, causes re-arrangement of charges which leads to potential diff betw electrodes
(iii) This potential diff generates electric signal.

CONVERSELY

(i) When E.F is applied, the piezoelectric material deforms.
(ii) This application is used in speakers, & Ultrasonic devices.

$$\boxed{V_0 = \frac{dt}{\epsilon_r \epsilon_0} \cdot P}$$

Hall effect Transducers



Hall effect Transducers

It is a device that uses Hall effect to measure magnetic field, electric currents & other physical quantities.

Principle → Hall effect

Construction

(i) Hall element → made up of semiconductor material ~~who~~ that exhibits hall effect. Eg. GaAs.
(ii) Electrodes → Used for measuring hall voltage.
(iii) Encasing → shields transducer from environmental damage
(iv) Mag field source → generates M.F ⊥ to current.

Working

(i) When M.F is applied ⊥ to current, charges experience Lorentz force, which causes them to accumulate on one side of material.
(ii) The charge seperation generates voltage across material
(iii) Voltage generated ∝ M.F strength & current
(iv) The voltage is measured at terminals.

$$\boxed{E_H = \frac{R_H I_B}{t}} \quad \boxed{V_H = \frac{R_H \cdot I \cdot B}{t}}$$

Application

(i) Measurement of current
(ii) Measurement of Power.
(iii) Measurement of Displacement
(iv) Magnetic to electric transducer

Sensors

It is a device that measures physical input from the environment and converts it into data that can interpreted by a human / another machine.

Need for sensors

(i) They provide vital information & exchange data with other devices
(ii) Sensors are ~~even~~ Omnipresent. They can be embedded in very machine as well as human body.

Classification of sensors

(i) Principle of Transduction → Resistive, Capacitive, Inductive
(ii) Primary & secondary sensor
(iii) Passive & active sensors
(iv) Analog & Digital sensors

Active sensors	Passive sensors
(i) Emit their own energy	(i) Depend on external energy sources
(ii) Can work in both day & night	(ii) Specifically used depending on the condition
(iii) More complex & expensive	(iii) Simple & cheap
(iv) Can cause interference with other sensors	(iv) Do not interfere with other sensors
Eg: Radar, sonar	Eg:- Camera, thermal imager

Transducer	Sensor
(i) Convert one form of energy into another	(i) Detect & respond to physical changes in the environment
(ii) Focused on energy conversion	(ii) Focused on detecting & measuring parameters
(iii) Provides output in diff energy form	(iii) Provides a direct measurement of parameter
(iv) More complex as they convert energy	(iv) Simple as they only sense & measure changes.
Eg. Piezoelectric transducer	Eg: temp sensor.

Humidity Sensor

→ It is a device that detects & measures water vapor.
→ It works by detecting changes, that alter electrical currents/ temp in the air.
→ types of Humidity sensor
(a) Capacitive
(b) Resistive
(c) ~~Inductive~~ Thermal

Capacitive Humidity sensor

→ Sensing element = capacitor
→ It measures the change in electrical permittivity of dielectric material to calc relative humidity values

Resistive humidity sensor

→ Sensing element = Low (P) materials
→ It measures the change in ~~resistive material~~ resistivity value of the material to measure change in humidity.

Applications

→ Printer, oven, Automobiles

Biomedical sensor

→ They are used to detect change in biological, chemical & physical ~~processor~~ processes of the body, report these changes & use them for medical applications.

Applications

Blood pressure detection, blood flow, bone growth etc.

Ultra-sonic sensor

→ It is a device that uses sound waves to detect the presence & proximity of ~~of~~ objects.

→ It sends out high-f sound waves that bounce off objects & then measures the time it takes for the sound waves to return.

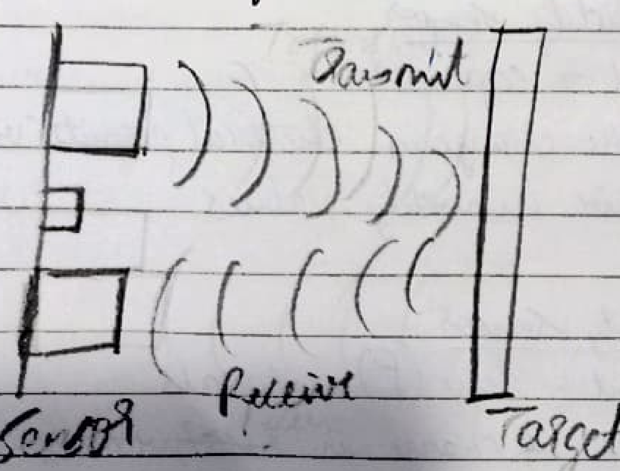
Range of Ultra-sonic sensors

(i) For air-coupled application, f range = 30-500 KHz

(ii) Ultra sonic frequency $\propto$ rate of attenuation.

(iii) Low (f) sensors (30-80 KHz) are better for long range

Q1) Explain the working of Ultrasonic sensor with digram



It is an electronic device that uses high (f) sound waves to measure dist betw objects

Principle → echo-location

$$\boxed{S = \cancel{\quad} \frac{\text{speed of sound} \times \text{time taken}}{2}}$$

Construction

(i) Transmitter → converts electrical signal to ultra sonic sound waves
(ii) Receiver => captures the reflected waves & converts to electrical signals.
(iii) Micro-controller => sends & receives signals to external controllers.

Working

(i) The microcontroller sends a short pulse to the ultrasonic sensor
(ii) Transmitter converts the pulse into ultrasonic sound waves. & sends them out
(iii) The sound waves travel through air, hit the target & bounce back to the receiver.
(iv) Receiver converts the signal to electric signals.
(v) Control Unit calc the time diff betw transmission & reception

Application

(i) Distance measurement
(ii) Parking sensor
(iii) Obstacle detection

Q2) Explain the Working of the Humidity sensor

It is a electronic device that used to measure moisture present in the air. It converts relative humidity into electrical signals.

Principle → Hygroscopic nature

Construction
(i) Sensing element → moisture sensitive material like polymer/ceramic
(ii) Electrodes → helps to measure change in capacitance/resistance
(iii) Substrate → holds sensing element & electrodes
(iv) Encapsulation → shields the sensor from contaminants & mechanical damage.

Working
(i) sensor absorbs moisture from surrounding air
(ii) Absorbed moisture changes either capacitance, resistance / thermal properties of sensing material
(iii) sensor converts these variations into an electrical signal
(iv) The rawdata is processed using a microcontroller / signal processing element.

Applications
(i) Weather monitoring
(ii) Agriculture
(iii) HVAC systems