CHAPTER-THREE

CREDIT HOUR- 12 Hrs

PHYSICAL VARIABLE AND TRANSDUCER

⇒ SENSOR

Sensor may be classified on different basis. One of them is physical principle involve. Hence, on the basis of physical quantity or physical involve. The sensor or ~~transducer~~ transmission is classified as:

1. Resistive Sensor:-

The input being measured is transferred into change in resistance. Example; potentio-meter, resistance thermometer, string gauge etc.

2. Inductive Sensor:-

The input being measured is transferred into change in inductance. Example: LVDT (Linear Variable Differential Transformer).

3. Capacitive Sensor:-

The input being measured is transferred into change in capacitance. Example; capacitive displacement sensor etc.

4. Electromagnetic Sensor:-

This sensor works on the principle of Faraday's law of electromagnetic inductance. Example; Tacno Generator.

5. Thermo-electric Sensor.

The input being thermal energy and the output is electromotive force is termed as thermo-electric sensor or thermo-couple.

6. Piezo-electric Sensor:

Force applied to the crystal displace the atom in the crystal acquiring a surface change and a surface charge; such a sensor used for measurement of transient pressure, acceleration and vibrations.

⇒ HALL EFFECT

The action of magnetic field on a plate carrying an electric current generate a potential difference which is a measure of strength of field.

⇒ CLASSIFICATION OF SENSOR:

Sensor can be classified as
i) Passive Sensor.
ii) Active Sensor.

1. Passive Sensor

Passive sensor are those which require a power supply. Example; potentio-meter.

2. Active Sensor.

Active sensor are those which does not require external power supply. Example; Thermo-couple etc.

⇒ PHYSICAL VARIABLE AND THEIR TYPE:-

[illegible]surend any instrumentation system makes it first contact with a primary detection element or an input device. The physical variable are those quantity required to be measured. All these quantities required primary detection element to be converted into another analogous form which is acceptable by latter stage of measurement system.

There are various type of physical variables such as electrical variable, mechanical bio-physical variable, process variable etc. The measurend include the electrical quantity like current, voltage, resistance, inductance, capacitance, etc are electrical variable.

⇒ The mechanical variable include force, pressure, displacement etc. The process variable are involved in the production plants. Example; flow-rate, velocity, acceleration etc.

⇒ Bio-logical variables are included in the human beings such as blood pressure, body resistance, heart-beat etc.

⇒ TRANSDUCERS

Input (physical form like power, pressure, temperature etc.) → Sensor → Output (Electrical form like voltage, current)

Fig:- Transducer.

A transducer is defined as a device which converts energy from one form to another form. In electrical measurend system, transducer is defined as a device which converts a physical quantity into electrical quantity. The input quantity for most instrumentation system is a non-electrical quantity. In order to use electrical methods and techniques for measurement, manipulation and control non-electrical quantity is generally converted into electrical form by a transducer. Many physical variables such as heat, intensity of light, humidity, liquid level and pH value may be also converted into electrical form by a transducer. A photo conductor converts the light intensity into change of resistance, a thermo-couple converts heat energy into electrical voltage. An acceleration produce a voltage in a piezo-electric crystal etc.

The transducer may consist of two important part:

a) Sensing element and
b) Transduction element.

⇒ A sensing element that part of transducer [illegible]se to a physical phenomenon.

⇒ A transduction element transform the output of a sensing element to an electrical output.

⇒ CLASSIFICATION OF TRANSDUCERS:

Transducers can be classified into four categories:

1. On the basis of principle of transduction
2. Primary and secondary transducer.
3. Active and passive transducer.
4. Transducer and inverse transducer.

1. On the basis of principle of transduction.

Transducer can be classified on the basis of principle of transduction as resistive, capacitive, inductive etc. Depending upon how they converts the input quantity into resistance, inductance or capacitance respectively.

For example; thermister works on the principle that the resistance vary with the temperature, hence used in temperature measurement. The capacitor microphone is a capacitive transducer works on the principle of sound pressure varies the capacitance between fixed plate and diaphragm.

Primary and Secondary Transducer:

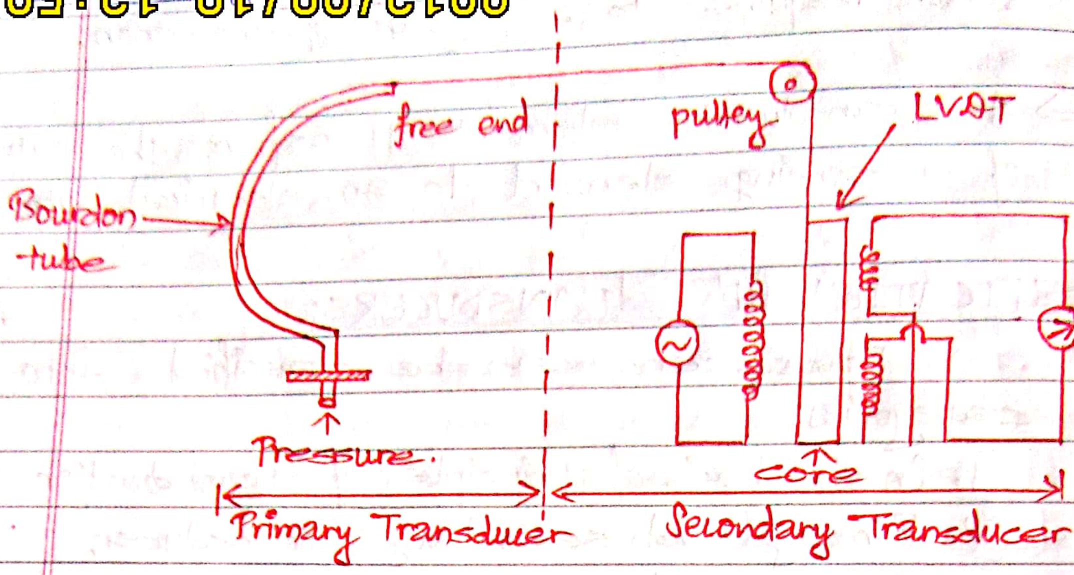

Fig:- Measurement of pressure.

A sensing element converts physical variable into its equivalent electrical output. This response depends upon the sensing element, such type of transducer which converts the physical variable into equivalent quantity is known as primary transducer. In most of the measurement system, there is a suitable working combination where a mechanical device acts as a primary transducer and electrical device acts as a secondary transducer.

The figure shown above is the measurement of pressure. The bourdon tube acts as a primary transducer, sense the pressure and converts it into displacement of its free end. The displacement of free end moves core of LVDT which produces an output voltage proportional to the movement of core of LVDT. The move

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...[illegible] proportional to the displacement of free end of the bourden tube.

There are two stage of transduction, initially pressure converted into displacement by the bourden tube then the displacement is converted into equivalent voltage by the LVDT. So, bourden tube acts as primary transducer and LVDT acts as a secondary transducer.

3. Active and Passive Transducer:

The passive transducer derive the power required for transduction from an auxiliary power source. They also derive part of power required for conversion from the physical quantity under measurement. They are also known as externally powered transducer. The example of passive transducer are resistive, inductive, capacitive transducer. Potentiometer is used for the measurement of displacement, it is resistive transducer powered by a external source, it is used for the measurement of linear displacement.

Active transducer are those which do not requiring auxiliary power source to provide their output, they are also known as self generating type, since they develop their own voltage or current. The energy required for the production of output signal is obtained from the physical quantity being measured. Crystal oscillator is example of active transducer.

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Inverse Transducer:

A transducer can be defined as a device, which converts non-electrical quantity. Example; micro-phone.

And inverse transducer is defined as a device, which converts electrical quantity into non-electrical quantity. Example; Loudspeaker.

⟹ CHARACTERISTICS OF TRANSDUCER:

It can be classified to two classes:

1. Input characteristics
2. Output characteristics

1. Input Characteristics

It has following two types:

a) Type of input and operating range.
b) Load effect.

(A) Type of input and operating range.

Type of input which can be any physical quantity is generally determined. A physical quantity may be measured through the use of transducer, however the choice of particular transducer i.e, selected for the purpose depends upon the useful range of input quantity over which the transducer can be used.

The upper limit is decided by the transducer capability while the lower limit of range is normally decided by the transduction error.

(B) Load Effect:

Ideally the transduction have no loading effect in the input quantity being measured but in actual practice it is impossible. The magnitude of loading effect can be expressed in terms of force, power or energy extracted from the quantity under measurement for the working of transducer. Therefore, the transducer that is selected for particular application should ideally abstract no force, power or energy from the quantity under measurement.

2. Output Characteristics:

It has following three characteristics:

a) Types of output
b) Output impedance.
c) Useful output range.

(A) Types of Output

The type of output which may be available from the transducer may be a voltage, current, impedance etc. These output quantities may or may not be the latter stage of instrumentation system. They may have to be manipulated, calculated that is their magnitude change or they have to be change in their format by signal conditioning equipment.

(B) Output impedance:

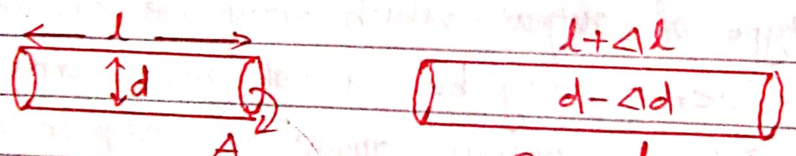
Output impedance determine the amount of power that can be transferred to the successive stage for the given output signal level.

If the output impedance of a transducer is low as compared with load impedance of successive stage, it has the characteristics of constant voltage source. On the other hand, if the output impedance of the transducer is much higher than the load impedance of successive stage, it has the characteristics of constant current source. When the output impedance of the transducer is equal to that of following stage, matching takes place and maximum power transfer from the next stage.

(C) Useful output range.

The output range of a transduce is limited at the lower end by noise signal. The upper limit is set by the maximum useful input level.

⇒ STRAIN GAUGE



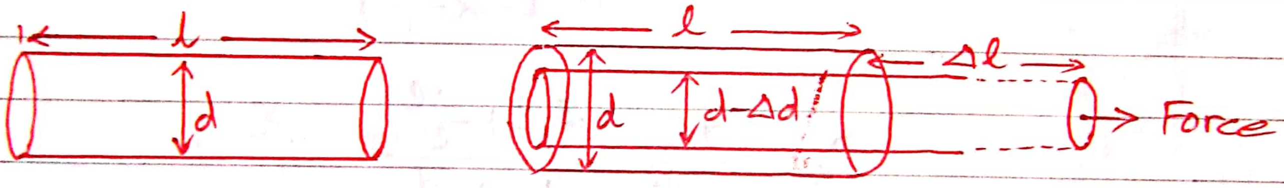
$R = \rho \frac{L}{A}$ where $A = \frac{\pi d^2}{4}$

It converts a mechanical displacement into a change of resistance. If a metal conductor is stressed or compressed, its resistance changes on account of the fact that both length and diameter of the conductor changes. Also there is a change in the value of resistivity of the conductor when it is strained and this ~~property~~ is called piezo- ~~elect~~ resistive effect. So, resistance strain own as piezo-resistive gauge.

⇒ Theory of Strain Gauge

OR, prove that $G = 1 + 2\mu$ or $K = 1 + 2\mu$

The change in value of resistance by straining a gauge may be explained by the normal dimensional behaviour of elastic material. If a stripe of elastic material is subjected to tension its longitudinal direction, dimension increases while its cross-sectional area increases. Since the resistance of a conductor is directly proportional to its length and inversely proportional its cross-sectional area, the resistance of gauge increases with positive strain.



Let us consider a strain gauge made up of circular wire. The wire has three dimension, length, diameter and cross-sectional. The material having resistivity 'ϱ' then the resistance unstrained wire is

$$R = \rho \frac{l}{A} \quad \text{---------- (i)}$$

Let a tensile stress, the applied to the wire, this produces strain, causing the length increase, diameter decrease and cross-sectional area also decreases. Tension on the conductor causes an increase it Δl of its length and simultaneously

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...d in its diameter. The resistance of conductor after stressing then.

$$R_S = \frac{\rho(l+\Delta l)}{\frac{\pi(d-\Delta d)^2}{4}}$$

where, $l+\Delta l \rightarrow$ new length

$d-\Delta d \rightarrow$ new diameter.

or, $$R_S = \frac{4\rho(l+\Delta l)}{\pi(d-\Delta d)^2}$$

$$R_S = \frac{4\rho(l+\Delta l)}{\pi(d^2 - 2d.\Delta d + \Delta d^2)}$$

$$R_S = \frac{4}{\pi}\rho\frac{(l+\Delta l)}{(d^2 - 2d\Delta d)}$$

$$R_S = \frac{4}{\pi}\rho\frac{l(1+\frac{\Delta l}{l})}{d^2(1-2\frac{\Delta d}{d})}$$

$$R_S = \frac{4\rho l}{\pi d^2}\frac{(1+\frac{\Delta l}{l})}{(1-2\frac{\Delta d}{d})}$$

$$R_S = \frac{\rho l}{\frac{\pi d^2}{4}}\frac{(1+\frac{\Delta l}{l})}{(1-2\frac{\Delta d}{d})}$$

$$R_S = R\frac{(1+\frac{\Delta l}{l})}{(1-2\frac{\Delta d}{d})} \qquad \text{(ii)}$$

Poission's ratio is given by

$$\mu = \frac{\Delta d/d}{\Delta l/l}$$

$$\therefore \frac{\Delta d}{d} = \mu \cdot \frac{\Delta l}{l}$$

Then equation (ii) becomes.

$$R_s = \frac{R\left(1+\frac{\Delta l}{l}\right)}{\left(1-2\mu\frac{\Delta l}{l}\right)}$$

$$R_s = \frac{R\left(1+\Delta l/l\right)\left(1+2\mu\,\Delta l/l\right)}{\left[1-\left(2\mu\frac{\Delta l}{l}\right)^2\right]}$$

$$R_s = R\left(1+\frac{\Delta l}{l}\right)\left(1+2\mu\frac{\Delta l}{l}\right)$$

$$R_s = R\left[1+\frac{\Delta l}{l}+2\mu\frac{\Delta l}{l}+2\mu\left(\frac{\Delta l}{l}\right)^2\right]$$

$$R_s = R\left(1+\frac{\Delta l}{l}+2\mu\frac{\Delta l}{l}\right)$$

$$R_s = R\left[1+\frac{\Delta l}{l}(1+2\mu)\right]$$

$$R_s = R + R\frac{\Delta l}{l}(1+2\mu)$$

or $$\cancel{R}+\Delta R = \cancel{R} + R\frac{\Delta l}{l}(1+2\mu)$$

or $$\frac{\Delta R}{R} = \frac{\Delta l}{l}(1+2\mu)$$

$$\Rightarrow \frac{\Delta R/R}{\Delta l/l} = 1+2\mu$$

$$\therefore G = 1+2\mu$$

Q. A resistance strain gauge with a gauge factor 2 is fastened to a steel member subjected to a stress of $1050\ kg/cm^2$. The modulus of elasticity of steel is $2.1 \times 10^6\ kg/cm^2$. Calculate change in resistance ΔR of strain gauge element due to applied stress.

⇒ solution,

we have,

Gauge factor $(K) = G = 2$.

Modulus of elasticity $(E) = 2.1 \times 10^6\ kg/cm^2$

Applied stress $= 1050$

Change in resistance$(\Delta R) = ?$

Now,

$$\text{Elasticity} = \frac{\text{Stress}}{\text{Strain}}$$

$$\Rightarrow \text{Strain} = \frac{\text{Stress}}{\text{Elasticity}}$$

$$\Rightarrow \text{Strain} = \frac{1050\ kg/cm^2}{2.1 \times 10^6\ kg/cm^2}$$

$$\Rightarrow \text{Strain} = 5 \times 10^{-4}$$

$$\therefore \frac{\Delta l}{l} = 5 \times 10^{-4}$$

Again,

Gauge factor G of strain gauge is given by

$$G = 1 + 2\mu = \frac{\Delta R/R}{\Delta l/l}$$

or, $$G = \frac{\Delta R/R}{\Delta l/l}$$

or, $$\frac{\Delta R}{R} = G \times \frac{\Delta l}{l}$$

$= 2 \times 5 \times 10^{-4}$

$\frac{\Delta R}{R} = 10^{-3}$

or, $\Delta R = 0.001 R$

i.e, $\Delta R = 0.1\%$ of R

Hence, resistance is changes by 0.1% of original resistance.

⇒ Resistance Transducer

They are used to measure the physical quantity on the basis of change in resistance. There are number of way in which resistance can be changed by a physical phenomenon. The resistance of metal conductor is given by:

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

where,

$\rho \rightarrow$ resistivity of materials
$L \rightarrow$ Length
$A \rightarrow$ cross-sectional area
$R \rightarrow$ resistance (Ω)

⇒ Resistive Sensor (or potentiometer)

Potentiometer is used for the measurement of displacement. It consist of resistive element wound on a ceramic materials. This resistive element is always in contact with sliding contact known as wiper. Generally there are two types of potentiometer i.e linear and ~~rot~~ rotatory linear potentiometer as shown in figure:

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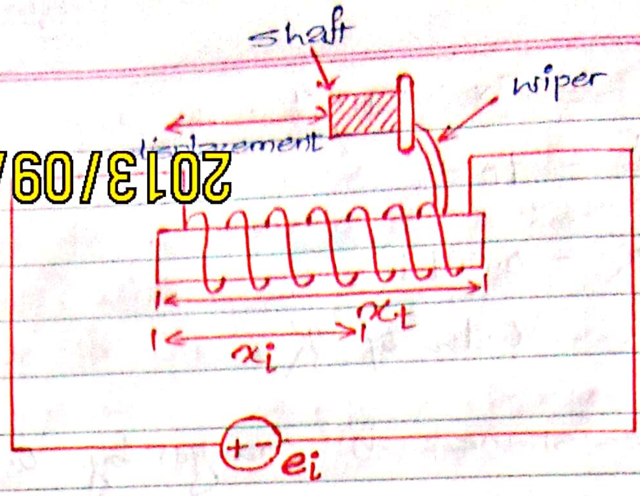


Fig:-(a)

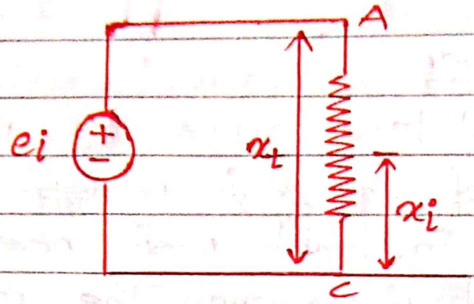


Fig:-(b)

Let us consider DC-excited linear potentio-meter having input voltage e_i and output voltage 'e_o'.

Let $R_p \rightarrow$ total resistance of potentiometer

$x_t \rightarrow$ total length of resistive element.

$x_i \rightarrow$ displacement of wiper from its initial element or, position.

Now,

Let us consider the resistance of the potentio-meter is uniformly distributed.

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

Hence, resistance of displacement is given by:

$$R_{BC} = \frac{R_P}{x_t} \times x_i$$

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

$$\therefore R_{BC} = K \cdot R_p \quad \text{——— (1)}$$

Also,

$$e_o = \frac{R_{BC}}{R_{AB}+R_{BC}} \times e_i \quad \left[\text{By voltage divider rule}\right]$$

$$\text{or, } e_o = \frac{K \cdot R_p}{R_p} \times e_i \quad [\text{from (1)}]$$

$$\therefore e_o = K e_i \quad \text{——— (2)}$$

Hence,

This equation shows that there exist a linear relationship between input and output.

The same expression is used for the rotatory potentiometer where x_i is replaced by θ_i and x_t is replaced by θ_t.

$$\therefore e_o = K e_i = \frac{\theta_i}{\theta_t} \times e_i$$

$$\therefore \boxed{\frac{e_o}{e_i} = \frac{\theta_i}{\theta_t}}$$

The potentiometer is a device for dividing the potential in the ratio determined by the position of sliding contact.

$$\text{Sensitivity} = \frac{\text{Output}}{\text{input}} = \frac{e_o}{e_i} = \frac{x_i}{x_t} = \frac{\theta_i}{\theta_t}$$

$$\therefore \boxed{\frac{e_o}{x_i} = \frac{e_i}{x_t}}$$

⇒ Inductive Transducer:-

In the inductive transducer, the measurement of force is accomplished by the change in the inductive ratio of a pair of a coil or by the change of inductance of a single coil. The change in air gap is varied by a change in position of armature of diaphragm. The resultant change in inductance is a measure of magnitude of applied force. The coil can be used as a component of LC oscillation, the frequency then varies with a applied force. This type of transducer is used the telementry system.

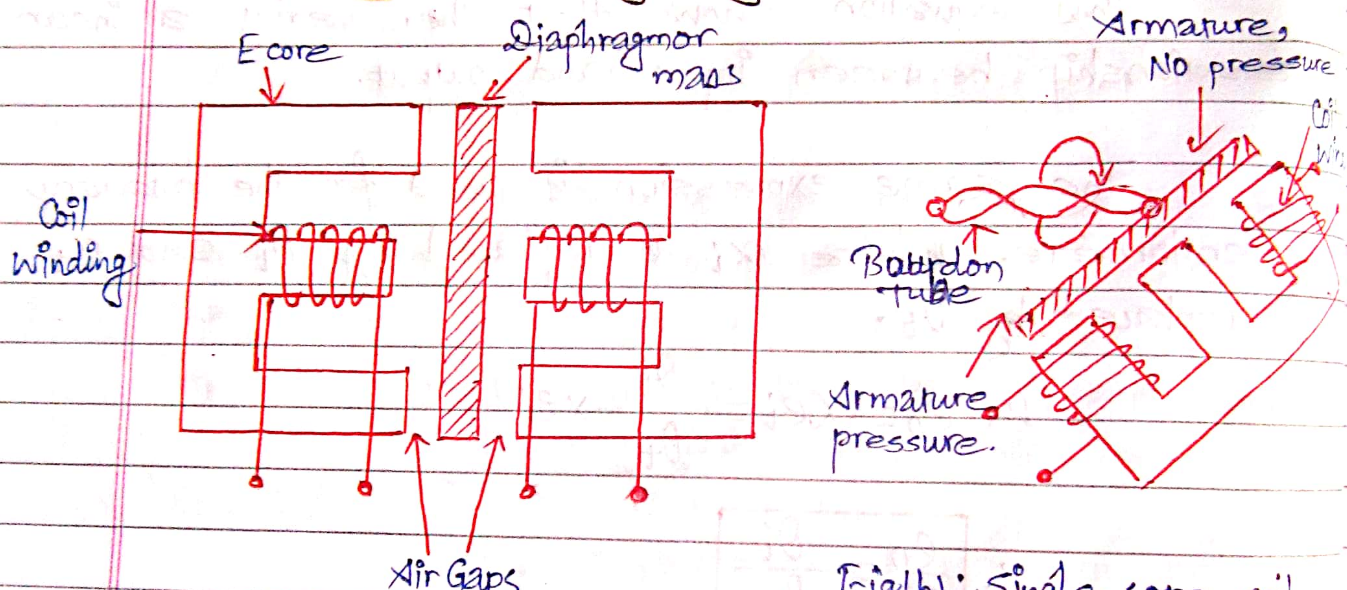


Fig (a) Double Coil

Fig(b): Single core coil.

Fig:- Inductive Transducers.

⇒ Capacitive Transducers:-

The capacitance of a parallel-plate capacitor is given by.

$$C = \frac{K\epsilon_0 A}{d} = \text{(Farads)}$$

Where, $K \rightarrow$ Dielectric constants.

$A \rightarrow$ Area of plates

$d \rightarrow$ Distance between two plates

[illegible] 10^{-12} (F/M)

since, k, ϵ_0, A are constant in same extent

then,

$$C \propto \frac{1}{d} \quad \text{——} \quad (1)$$

Again charge stored in capacitor is given by

$$q = CV$$

$$V = \frac{q}{C}$$

$$V \propto \frac{1}{C} \quad \text{——} \quad (2)$$

$$\Rightarrow V \propto d \quad [\text{From (1) and (2)}]$$

Since, the capacitance is inversely proportional to the spacing of the parallel plates. Any variation in distance 'd' causes the corresponding variation in capacitance. A force applied to a diaphragm that function as one plate of a simple capacitor, changes the distance between diaphragm and the static plate. The resultant change in capacitance could be measure with an AC-bridge

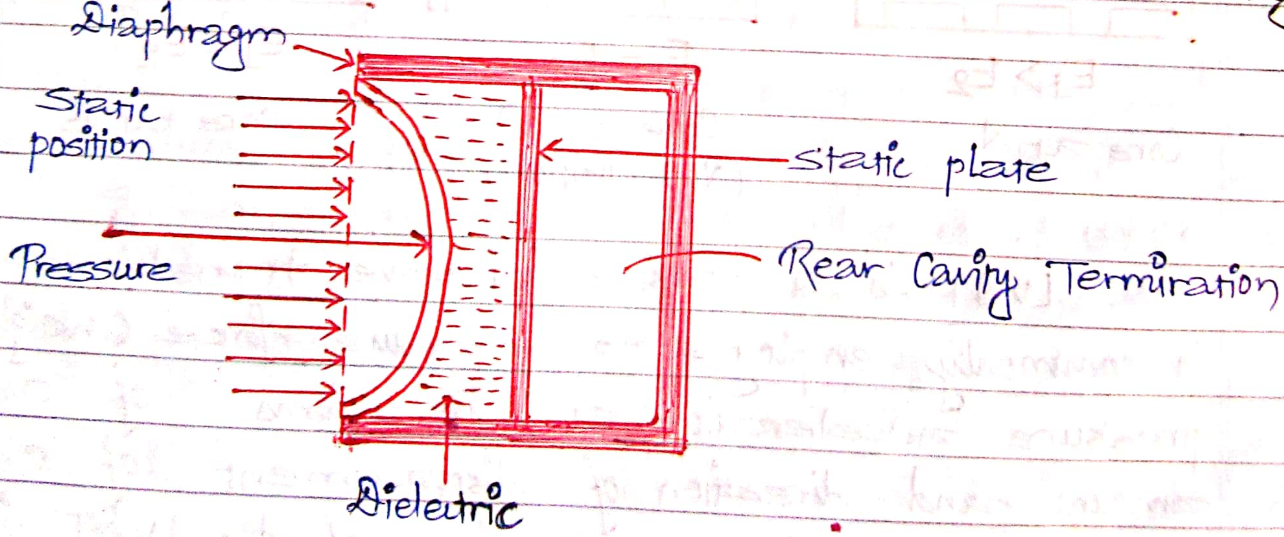


Fig:- Capacitive Transducer

⇒ LVDT (Linear Variable Differential Transformer)

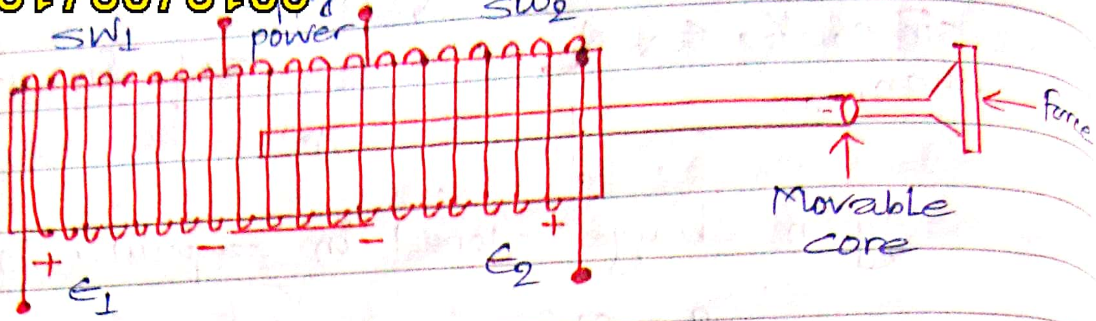
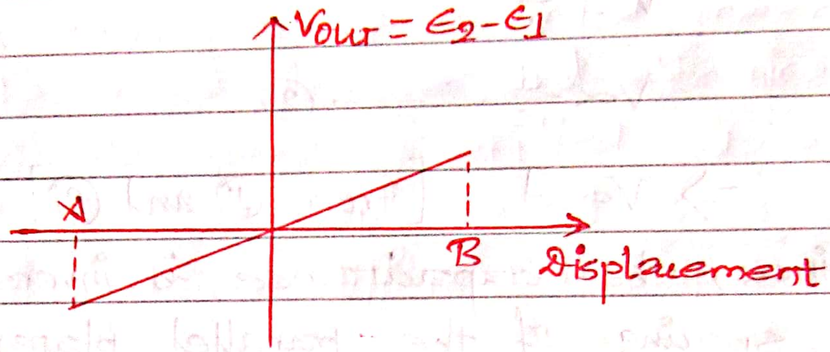
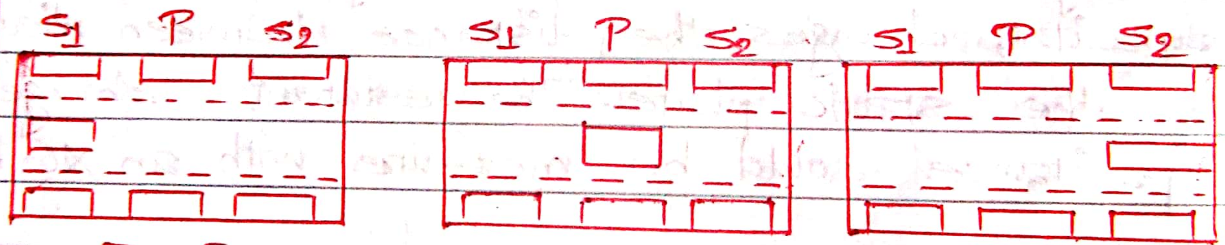


Fig (a):- Essential components of the LVDT



Fig(b): Related position of the core generate the indicated output voltages.



$E_1 > E_2$	$E_1 = E_2$	$E_1 < E_2$
Core at A	Core at O (Null position)	Core at B

LVDT is a passive inductive transducer and is commonly employed to measure force (weight, pressure acceleration, etc) in terms of an amount and direction of displacement of an object. The basic construction of the LVDT is given in above figure.

Construction

It consists of one primary winding (PW) and two secondary winding (SW_1 and SW_2) which are placed on the either side of the primary mounted on same ~~magnitude~~ magnetic core. The magnetic core is free to move axially inside the coil assembly and the motion being measured is mechanically coupled to it. The two secondary coil S_1 and S_2 have equal number of turns but are connected in series possition or opposition, so that emf ϵ_1 and ϵ_2 induced in them are 180° out of phase with each other. The primary winding is energized or supplied from a suitable AC-source.

Working

When the core is in centre, the induced voltage ϵ_1 and ϵ_2 are equal and opposite, hence output voltage, Vout is zero. When the external force moves the core towards S_2, ϵ_2 is increased but ϵ_1 is decreased in magnitude then the net output voltage, Vout is

$$V_0 = \epsilon_2 - \epsilon_1$$

which is positive.

Similarlly when the movable core moves towards core S_1, ϵ_1 is greater than ϵ_2. Hence, in this case, output voltage is negative.

Advantages of LVDT

a) Th[illegible] have a high sensitivity.

b) Consumes less power.

c) Less friction and noise for the point, it from $-265°C$ to $600°C$.

d) Less hysteresis loss.

Dis-advantages of LVDT

a) Transducer performance is attached by vibration.

b) The dynamic response is limited mechanically by the mass of core and electrically by means of frequeny of applied voltage.

c) Relatively large displacement was required for appreciable differential output.

⇒ Piezo-Electric Transducer.

A piezo-electric material is one which an electric-potential appears across certain surface of a crystal, if the dimension of the crystal are changed by the applications of the mechanical. Crystal are produced an emf when they are placed under stress. The effect is reversible that is conversely, if a varying potential is applied to the proper axis of a crystal, it will change the dimension of the crystal near by deforming it. This effect is called piezo-electric effect. This property is used in piezo-electric transducer where crystal is placed between a solid base and force summing members.

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The potential developed across the crystal is proportional to the magnitude of applied force.

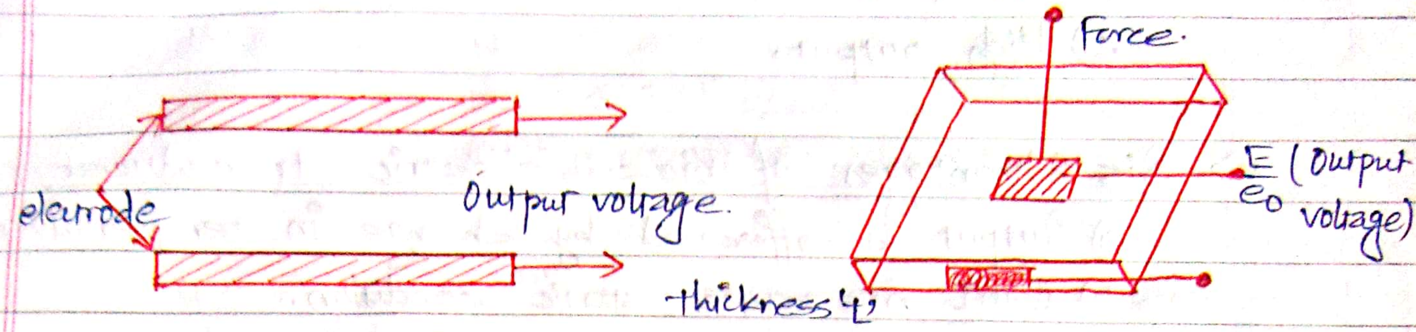

Fig:- Piezo-electric Transducer.

Here,

The output is given by

Output voltage (E) $= \dfrac{gtF}{A}$ ——— ①

Where, $E \rightarrow$ Output voltage
$g \rightarrow$ Voltage sensitivity
$t \rightarrow$ thickness of a crystal
$F \rightarrow$ Force
$A \rightarrow$ Area of crystal.

Also, $g = \dfrac{k}{t}$ ——— ②

$k = gt$

Where k = piezo-electric constant and

$p = \dfrac{F}{A}$

Then, output voltage from equation ① comes as

$$\boxed{E = kp}$$

where, $k = gt$ and

$p = \dfrac{F}{A}$

⇒ Advantages of piezo-electric transducers:

a) High frequency response.

b) [illegible]ze.

c) High output.

⇒ Dis-advantages of piezo-electric transducer

a) Output is affected by change in temperature.

b) Can't measure static condition.

⇒ Application Areas:

It is used in pressure cells, force cells, ceramic microphone, etc.

Numerical-1:

A piezo-electric crystal measuring 6mm × 6mm × 1.8mm is used to measure a force and its voltage sensitivity is 0.055 Vm/N. Calculate the force, if the voltage developed is 120V.

⇒ Solution,

Here, we have given,

Voltage sensitivity $(g) = 0.055\ Vm/N$

Voltage developed $(E) = 120V$

Dimension of crystal $= 6mm \times 6mm \times 1.8mm$

Area of crystal $(A) = 6mm \times 6mm$

$= 36 mm^2$

$= 36 \times 10^{-6} m^2$

Thickness $(t) = 1.8mm$

$= 1.8 \times 10^{-3} m$

Force $(F) = ?$

We know that,

Output voltage (E) is given by

$$\epsilon = \frac{gtF}{A}$$

$$\epsilon \times A$$

$$\text{or, } F = \frac{120V \times 36\times 10^{-6} m^2}{0.055\ Vm/N \times 1.8\times 10^{-3} m}$$

$$\therefore \ F = 43.64 N$$

Thus, required force on a crystal is 43.64 N.

Question 2

The following data related to a $BaTiO_3$ pick up dimension 6mm × 6mm × 1.5mm. The force acting on the pick up is 6N, charge sensitivity is 150 PC/N, permitivity is 12.5×10^{-9} F/m and modulus of elasticity is 12×10^6 N/m². Calculate strain and charge and capacitance.

=> Solution,

Here, we have given

Force acting on pick up $(F) = 6N$

Pick up dimension of $BaTiO_3$ $= 6mm \times 6mm \times 1.5mm$

Charge sensitivity $= 150$ PC/N

Permitivity $= 12.5 \times 10^{-9}$ F/m

Modulus of elasticity $= 12 \times 10^6 N/m^2$

Area of pick up $(A) = 6mm \times 6mm$

$= 36 mm^2$

$= 36 \times 10^{-6} m^2$

Thickness $(t) = 1.5mm$

$= 1.5 \times 10^{-3} m$

To find

i) Strain = ?

ii) Charge (Q) = ?

iii) Capacitance (C) = ?

Now, we know that

$$\text{Stress} = \frac{\text{Force (F)}}{\text{Area (A)}}$$

$$= \frac{6N}{36 \times 10^{-6} m^2}$$

$$= 1.67 \times 10^{5} \ N/m^2$$

Then,

$$\text{strain} = \frac{\text{stress}}{\text{Modulus of elasticity}}$$

$$= \frac{1.67 \times 10^{5} N/m^2}{12 \times 10^{6} N/m^2}$$

$$= 1.389 \times 10^{-2}$$

ii) Charge (Q)

$$= \text{charge sensitivity} \times \text{Force (F)}$$

$$= 150 \ pC/N \times 6N$$

$$= 900 \ pC$$

iii) Capacitance $(C) = \frac{Q}{\epsilon} = \frac{900 \ PC}{\epsilon}$ ———— ①

Then

$$\text{Voltage Sensitivity } (g) = \frac{\text{charge sensitivity}}{\text{permitivity}}$$

$$= \frac{150 \times 10^{-12}}{12.5 \times 10^{-9}}$$

$$g = 12 \times 10^{-3} \ Vm/N$$

So,

$$\epsilon = \frac{gtF}{A} = \frac{12 \times 10^{-3} \times 1.5 \times 10^{-3} \times 6}{36 \times 10^{-6}}$$

$$\epsilon = 3V$$

Thus, equation ① comes as

$$\text{capacitance } (C) = \frac{900 \ PC}{3V} = 300 \ pF$$

Temperature Measurement :

This can be classified into following parts as below

1. Resistance Thermometer
2. Thermo-Couples
3. Thermister

1. Resistance Thermometer

Resistance thermometer or RTD employee a sensitive element of extremely pure platinum, copper or nickel wire that provide a definite resistance at each temperature within its range. The relationship between temperature and resistance of a conductor can be calculated from given equation

$$R_t = R_{ref}(1 + \alpha \Delta t)$$

Where,

$R_t \rightarrow$ Resistance of conductor at $t°C$.

$R_{ref} \rightarrow$ Resistance of conductor at reference temperature.

$\alpha \rightarrow$ Temperature coefficient of resistance.

$\Delta t \rightarrow$ Difference between operating and reference temperature.

The resistance thermometer uses the change in electrical resistance of conductor to determine the temperature. The requirement of conductor material to be used in resistance temperature detector or RTD are

↳ The change in resistance of material per unit change in temperature should as large as possible.

↳ Material at high value of resistivity.

↳ The resistance of material should have a continuous and stable relationship with temperature.

Platinum wire is used for most laboratory work for industrial measurement of high accuracy. RTD are generally of the probe type for immersion in the medium whose temperature is to be measured or controlled. A typical sensing element for a probe-type thermometer is constructed by coating a small platinum or silver tube with ceramic materials, winding the resistance wire over the coated tube and coating the finished winding again with ceramic. The probe is protected by sheath to produce the complete sensing element.

Practically all resistance thermometer for industrial application are mounted in a tube or well to provide protection against mechanical damage and to guard against contamination ~~of~~ and eventual failure.

2. Thermo-Couples:

In 1821 Thomas Seeback discovered that when two dissimilar metals were in contact, a voltage is generated where the voltage was a function of temperature. The device, consisting of two dissimilar material joined together is called as thermocouple and the voltage is called Seeback voltag. For example; joining of two materials copper and constantion produce a voltage on the order of few 10th of milli-volts with positive potential at copper side. An increase in temperature causes an increase in voltage.

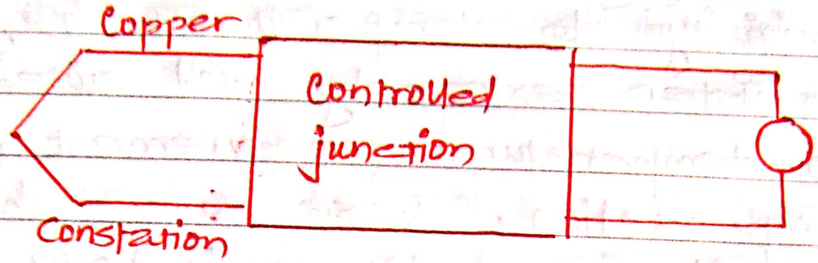

Fig:- Thermo-couple

Thermocouple are normally not installed in the pipeline vessel and other equipments directly but they are usually placed inside the protected wall. So, that they may be easily remove or replace without any interruption. The output of emf of thermo-couple is the difference between temperature of measuring junction and difference junction can be measured by following methods

i) Measuring the output voltage directly with the PMMC instrument.

ii). Measuring the output voltage with the help of DC- potentiometer.

iii) Measuring the output voltage after amplifying it.

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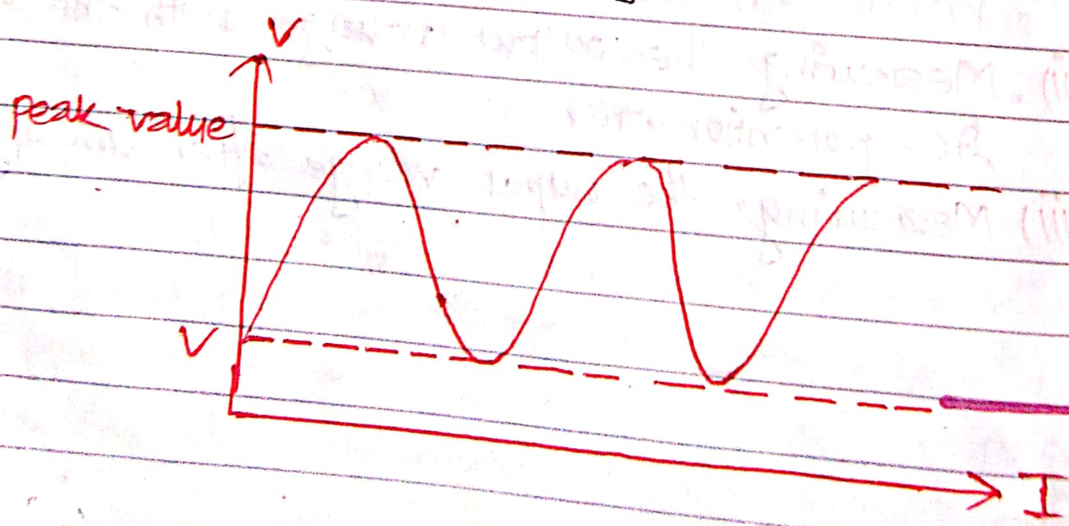
3. Thermister:

Thermister or thermal resistance are device that behaves as a resistor. They are usually negative temperature coefficient of resistance composed of a mixture of metallic oxide such as nickel, cobalt, copper etc. There resistance range from 0.5 Ω to 75 MΩ. The high sensitivity to temperature change makes the thermister extremely well suited to precision temperature measurement, control and compensation. These are therefore widely used in such application especially in the lower temperature range of −100°C to 300°C.

The characteristics of thermister are.

i) Very high negative temperature coefficient of resistance.

ii) The voltage drop across the thermister increases with increase in current until it reaches of peak value beyond which the voltage drop decreases as current decreases.



The time delay to reach maximum current as a function of applied voltage. When the self heating effect occurs in a thermister network, a certain finite time is required for the thermister to read and current to built of to a maximum steady state value. Thermister are best known from their funution in the measurement of controlled of temperature.