Physical Variables and transducers

Page No.
Date : / /

Sensor :

Sensor are the electrical devices which has capability of sensing different physical variables.

Sensors May be classified ~~as~~ on different basis, one of them is physical quantity, Hence on the basis of physical quantity or physical vibration involved the sensors are classified as ;

(i) Resistive Sensor :

The input being measured is transferred into change in resistance.
example: potentiometer, resistance, thermometer, Strain guage etc.

ii) Inductive Sensor :

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

iii) Capacitive Sensor :

The input being measured is transferred into change in capacitance.
eg: Capacitive Displacement Sensor.

Page No.
Date: / /

(iv) Electromagnetic Sensor

This sensor works on the principle of Faraday's Law of Electromagnetic Induction.

Eg: technometer or techno-generator.

(v) Thermo-electric Sensor

The input of this sensor is thermal energy and the output is electromotive force (emf)

It is also known as thermo-couple.

(vi) Piezo-electric Sensor:

Force applied to the crystal displac the atoms in the crystal acquiring a surface change and a surface charge. Such a sensor is used for the measurement of transient pressure, acceleration & vibration.

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

(i) Passive Sensor :

Passive Sensor are those which require a power Supply. eg : potentio-meter.

(ii) Active Sensor :

Active Sensor are those ~~which~~ which doesn't require external power Supply. eg : Thermo-couple etc.

Page No.
Date : / /

PHYSICAL VARIABLE AND THEIR TYPES :

The measurement of any instrumentation system makes its first contact with primary sensing element or an input device.

The physical variables are the quantities required to be measured. All these quantities require primary detection element to be converted into another anologous form which is acceptable by later stage of measurement system.

There are various types of physical variables such as electrical variable, mechanical, bio-physical, process variable etc.

The measurend including electrical quantity like current, voltage, resistance, inductance, capacitance etc are electrical variables.

The mechinical variable include force, pressure, displacement etc.

Bio-physical variables are included in

human beings such as blood pressure, heart-beat.

The process variable are involved in the production plants.

Transducer

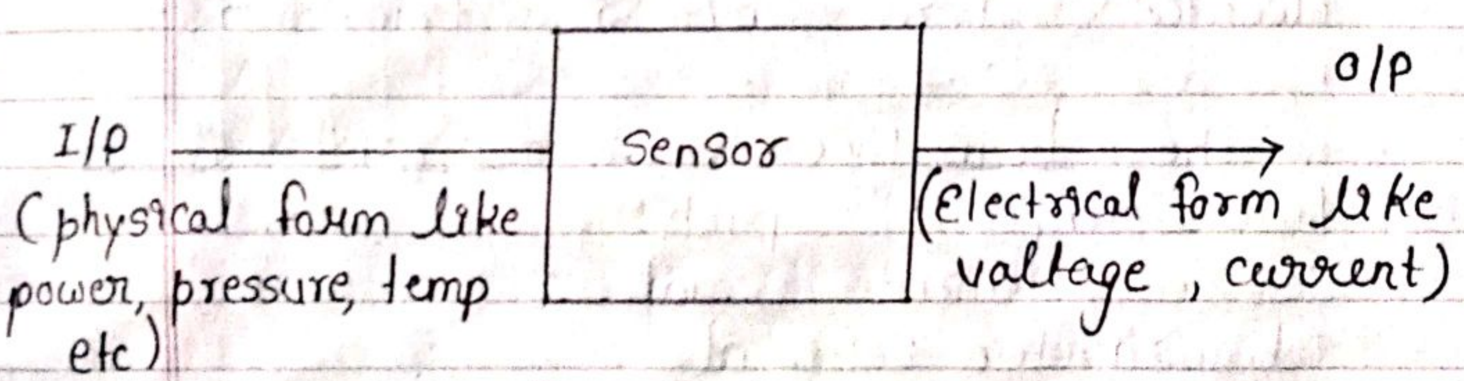


fig: Transducer

A transducer is defined as the device which converts energy from one form to another. In electrical measurent system transducer is defined as a device which converts a physical quantity into electrical quantity.

The input quantity for most instrumentation system is 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 variable such as intensity of light, humidity heat, liquid level and PH value may also be converted into electrical form by a transducer.

The transducer may consist of two important parts:

- Sensing element and
- transduction element

→ A sensing element is that part of transducer which respond to a physical phenomenon.

→ The transduction element transforms the output of a sensing element to an electrical output.

Classification of Transducer

Transducers can be classified into four categories:

i) On the basis of principle of transduction.
ii) Primary and secondary transducer
iii) Active and Passive transducer.
iv) Transducer and inverse Transducer.

(i) 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 convert the input quantity into resistance, capacitance or inductance respectively.

For example: thermistor works on the principle that the resistance vary with the temperature hence used in temperature measurement.

The capacitor microphone is a capacitive transducer which works on the principle of sound pressure varies the capacitance between fixed plate and diaphragm.

(ii) Primary and Secondary Transducer :

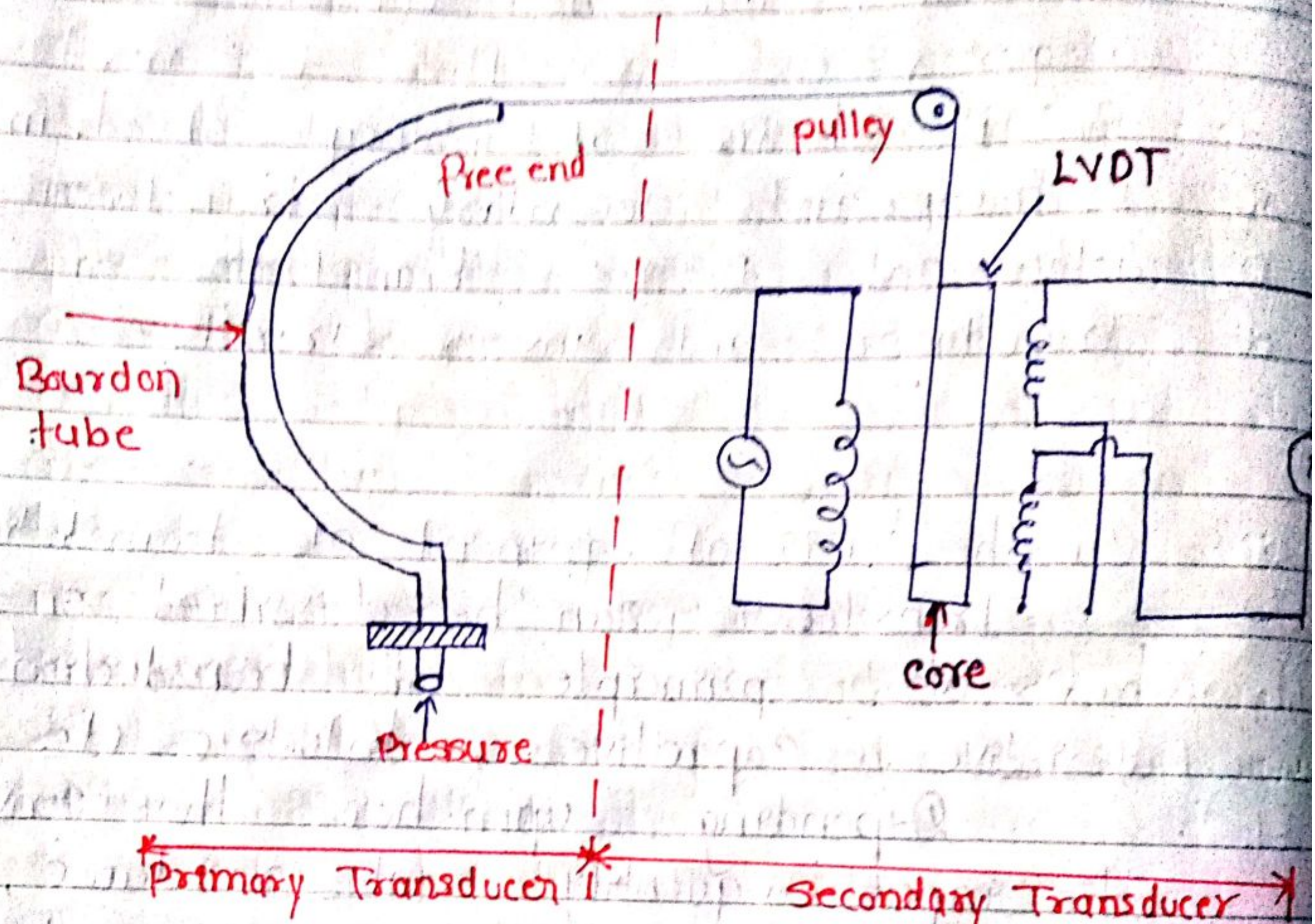


fig: Measurement of pressure

A sensing element converts physical variable into its equivalent electrical output. This response depends upon the sensing element. Such type of transducer which converts physical variable into equivalent electrical 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 act as a primary transducer sense the pressure and convert it into displacement of its free end. The displacement of free end moves the core of LVDT which produces an output voltage proportional to the movement of core of LVDT.

The movement of core is proportional to the displacement of free end of Bourdon tube.

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

Page No
Date : / /

iii) <u>Active and Passive Transducer</u> :
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 require auxiliary power source. They are also known as self-generating transducer since they develop their own voltage or current.

The energy required for the production of output signal is obtained from the physical quantity they measure. Examples of active transducers are tachogenerators, thermocouples, photovoltaic cells, Crystal Oscillators.

(iv) Transducer and Inverse Transducer :
Transducer can be defined as the device which converts non-electrical quantity into electrical form.
eg : microphone
Inverse transducer is a device which converts electrical quantity into non-electrical form.
eg : loud speaker.

characteristics of Transducer :
It can be classified into two types:
(i) Input characteristics
(ii) Output characteristics

(i) Input characteristics :
It has following two types :
ⓐ Types of input and operating range.
ⓑ Load effect.

ⓐ Types 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 transduction capability while the lower limit of range is normally decided by the transduction error.

(b) Load effect :

Ideally the transducer have no ~~legreatly~~ 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 the particular application should ideally abstract no force, power or energy from the quantity under measurement.

(ii) output characteristics

It has following three characteristics:

ⓐ Types of output.
ⓑ output impedance.
ⓒ useful output range.

ⓐ Types of output

The type of output may be available from the transducer is in the form of 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 i.e their magnitude changes or they have to be change in their format by signal conditioning equipment.

ⓑ Output Impedance

It determines 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 the load impedance of successive stage, it has the characteristics of constant voltage.

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

(c) Useful operating Range :

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

Page No.
Date : / /

Types of Transducer :

(1) **Resistive Transducer**

They are used to measure the physical quantity on the basis of change in resistance.

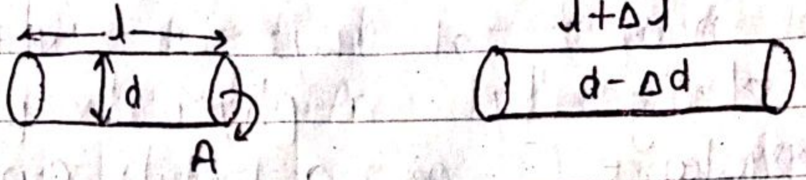
There are number of ways in which resistance can be changed by a physical phenomenon. The resistance of a metal conductor is given by,

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

where,
$\rho \rightarrow$ resistivity
l = length
A = Cross-Sectional Area.

eg : Potentiometer, strain guage, resistance thermometer, photoconductive cell.

(a) Strain Guage :
A strain Guage is a thin, wafer like device that can be attached to a variety of materials to measure applied strain.



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

~~The change in value of Resistance by~~
It converts mechanical displacement into change in resistance. If a metal conductor is stressed or compressed, its resistance changes on account of fact that both length and diameter of the conductor changes.
Also there is change in the value of resistivity of the conductor and this property is also known as piezo resistive effect.
So, resistance strain gauge is also known as (piezo - resistive gauge).

Theory of Strain Guage Gauge :
OR prove that $G = 1 + 2\mu$ or $K = 1 + 2\mu$

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

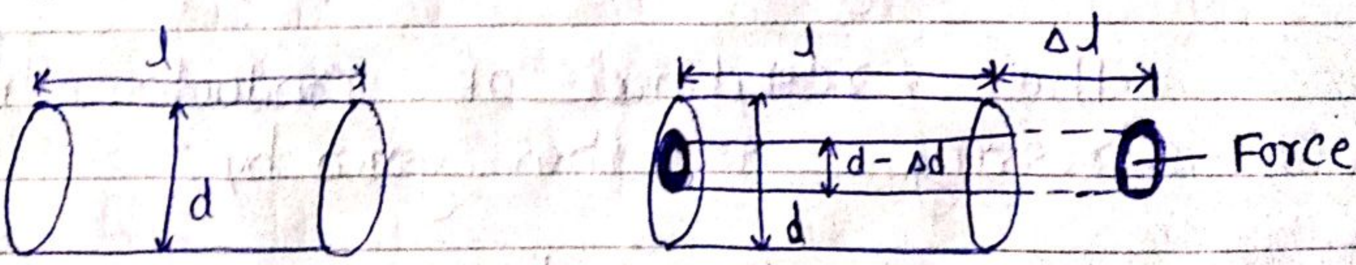


fig: An electrical conductor being stretched on the application of stress (force).

Page No
Date : / /

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

$$R = \rho \frac{l}{A} \quad \text{— (P)}$$

Let a tensile stress 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 in Δl of length and simultaneously decrease in Δd of its diameter.

The resistance of conductor after stressing is then given by;

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

where, $l + \Delta l$ = change in length
$d - \Delta d$ = change in diameter.

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

$$= \frac{4\rho}{\pi} \left(\frac{l + \Delta l}{d^2 - 2\Delta d . d} \right)$$ [Δd^2 is neglected due to smallest value]

$$= \frac{4\rho}{\pi} . \frac{l \left(1 + \Delta l / l \right)}{d^2 \left(1 - 2\frac{\Delta d}{d} \right)}$$

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

$$R_s = R \frac{\left(1 + \Delta l / l \right)}{\left(1 - 2\Delta d / d \right)} \quad \text{—— ②}$$

Poisson's ratio is given by

$$\mu = \frac{\Delta d / d}{\Delta l / l}$$ ($\frac{\text{change in dia}}{\text{change in length}}$

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

from (19)

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

$$= R\frac{(1+\Delta l/l)}{(1-2\mu\,\Delta l/l)}\cdot \times \frac{(1+2\mu\,\Delta l/l)}{(1+2\mu\,\Delta l/l)}$$

$$= \frac{R\left(1+\Delta l/l + 2\mu\Delta l/l + 2\mu(\Delta l/l)^2\right)}{1-4\mu^2\frac{\Delta l^2}{l^2}}$$

$$= \frac{R.\left(1+\frac{\Delta l}{l}(1+2\mu)+2\mu\frac{\Delta l^2}{l^2}\right)}{\left(1-4\mu^2\frac{\Delta l^2}{l^2}\right)}$$

Neglecting the terms having $\left(\frac{\Delta l}{l}\right)^2$.

Page No.
Date: / /

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

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

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

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

$\therefore G = 1 + 2\mu$

Where,

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

= Gauge factor.

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

Page No

Date / /

Que. 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 modolous of elasticity of steel is 2.1×10^6 kg/cm^3. Calculate the change in resistance of strain gauge element due to applied stress.

Solution:

Gauge factor $G = 2$

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

Stress $= 1050\ kg/cm^2$.

$$Y = \frac{\text{stress}}{\text{strain}}$$

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

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

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

Again,

Gauge factor G of strain guage is given by,

Page No.
Date : / /

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

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

$$\Delta R = 1 \times 10^{-3} R$$
$$= 0.001 R$$

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

Hence, resistance changes by 0.1% of original resistance.

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Page No.
Date : / /

(b) Resistive Sensor (or potentiometer) :
It is one of the example of resistive transducer and is used for the measurement of displacement. It consists of a resistive element wound on a ceramic material.
This resistive element is always in contact with the sliding contact known as wiper. Generally there are two types of potentiometer i.e;
(linear potentiometer and rotatary potentiomet as shown in figure :)

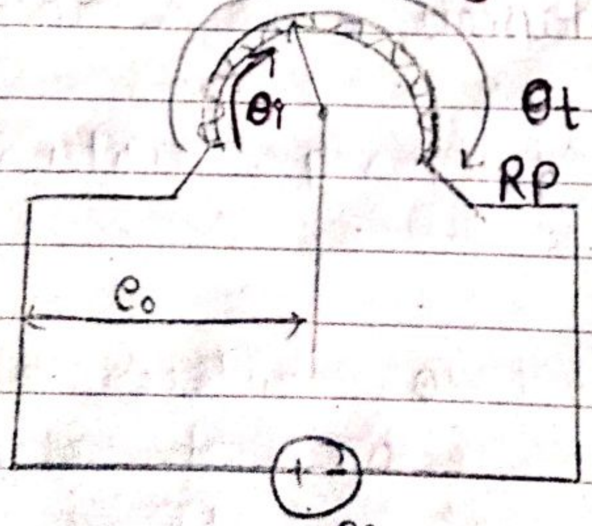


fig : Rotary potentiometer

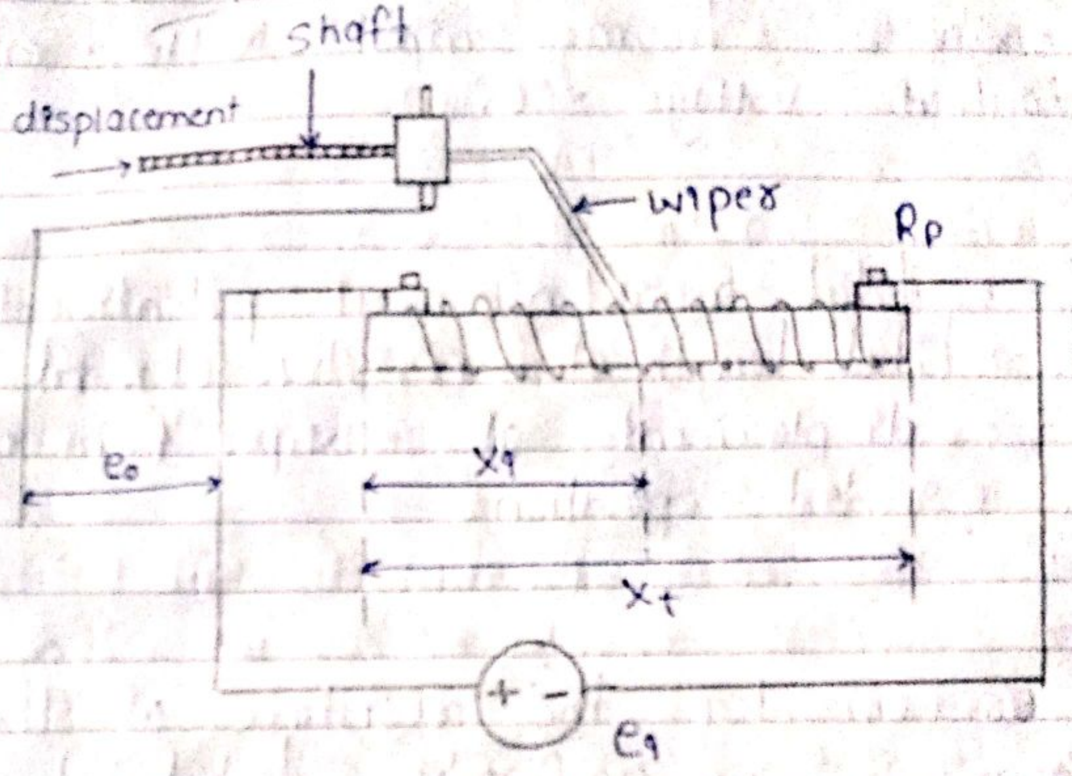


Fig: Linear potentiometer (a)

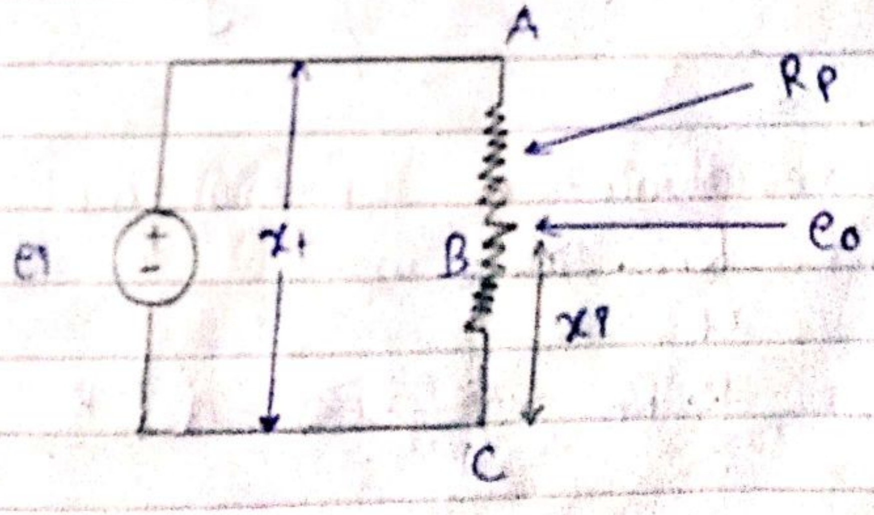


fig b) Electrical equivalent of (a)

Let us consider DC- excited linear potentiometer 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.

$BC = x_i \rightarrow$ displacement of wiper from it's initial position.

Now,

Let us consider the resistance of the potentiometer is uniformly distributed.

then,

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

Here, resistance of displacement

$$R_{BC} = \frac{R_p}{x_t} \cdot x_i$$

$$\therefore R_{BC} = K \cdot R_p \quad \text{——— (1)} \quad \left(\because K = \frac{x_i}{x_t}\right)$$

Also, output voltage $(e_o) = \dfrac{R_{BC}}{R_{AB} + R_{BC}} \times e_i$

(By voltage divider rule)

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

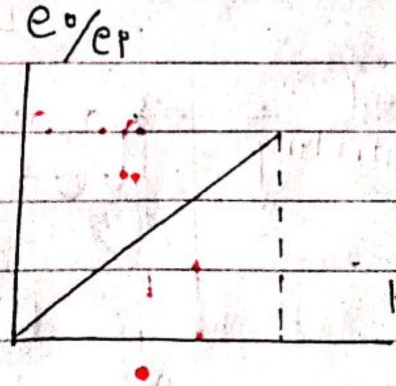
$\therefore \boxed{e_o = K e_i}$ — ②

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

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'.

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

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



$K = \frac{x_i}{x_t}$ or $\frac{\theta_i}{\theta_t}$

fig: output voltage versus linear displacement or angular displacement.

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

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

(2) Inductive Transducer

In inductive transducer, the input being measured is transformed into change in inductance.

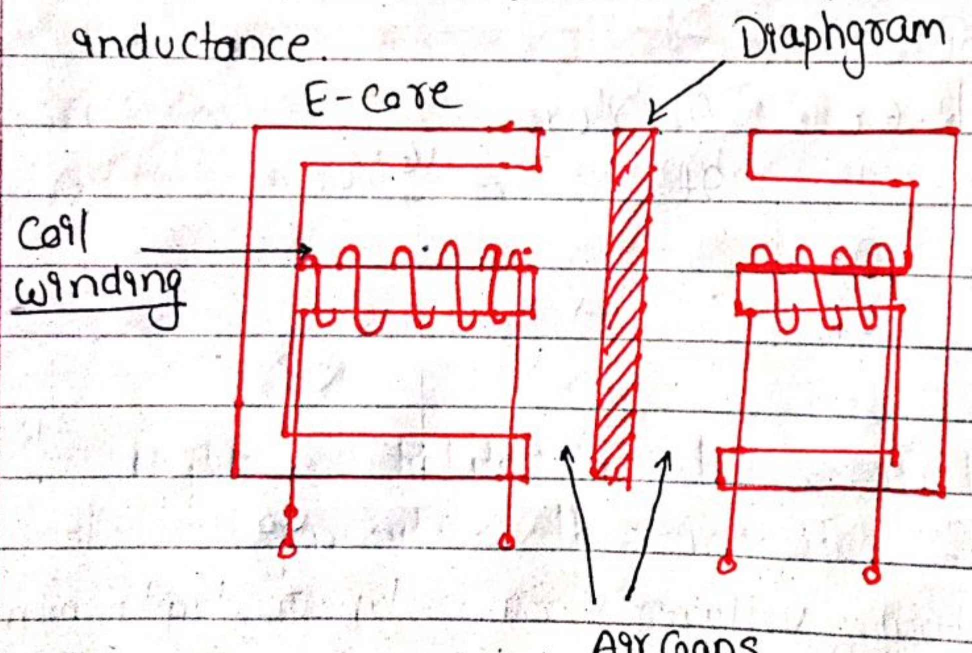


Fig (a) Double Coil

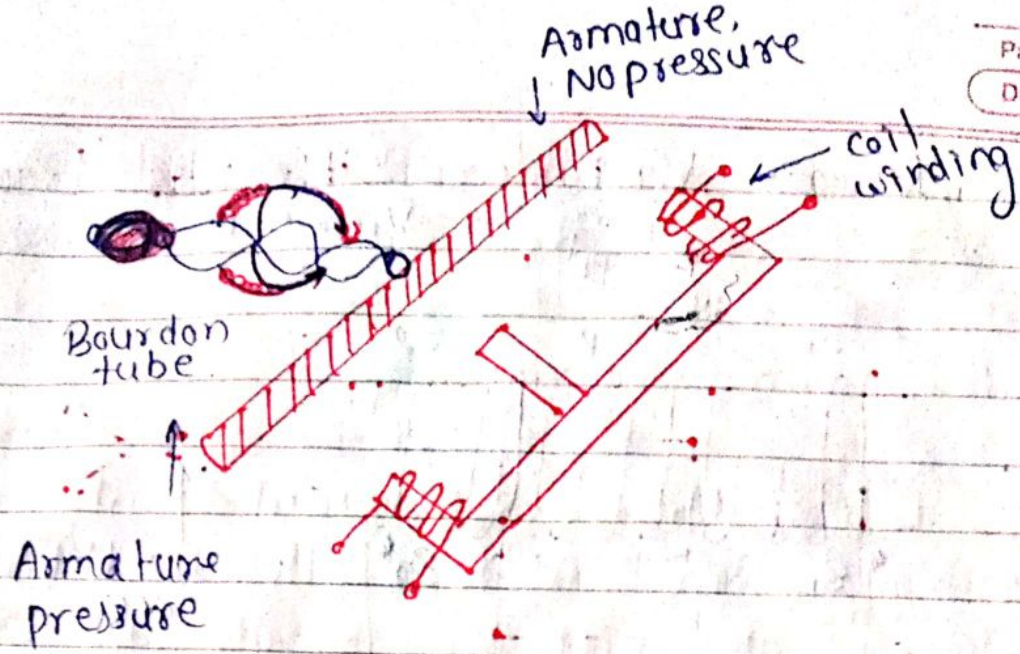


fig (b) : Single core coil.

fig : Inductive Transducers :

In the inductive transducer the measurement of force is accomplished by the change in inductive ratio of a pair of a coil or by the change of inductance of a single coil.

The change in the air gap is varied by a change in position of armature of diaphgram. The resultant change in inductance is a measure of magnitude of the applied force.

The coil can be used as a component of LC Oscillation ; the frequency then varies with the applied force. This type of transducer is used in telemetry system.

eg: LVDT.

Q7. **LVDT (Linear Variable Differential Transformer)**

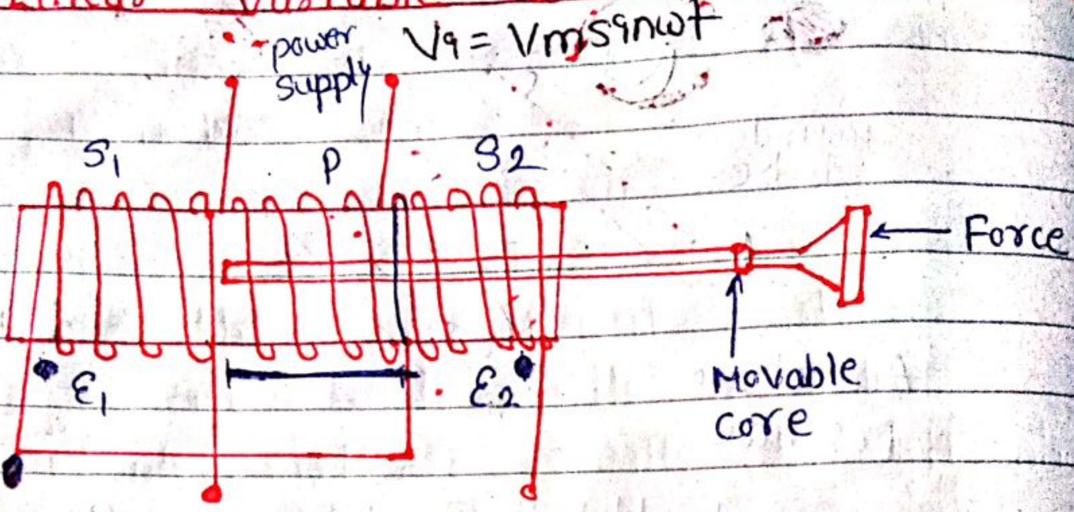


fig (a) Essential Component of LVDT

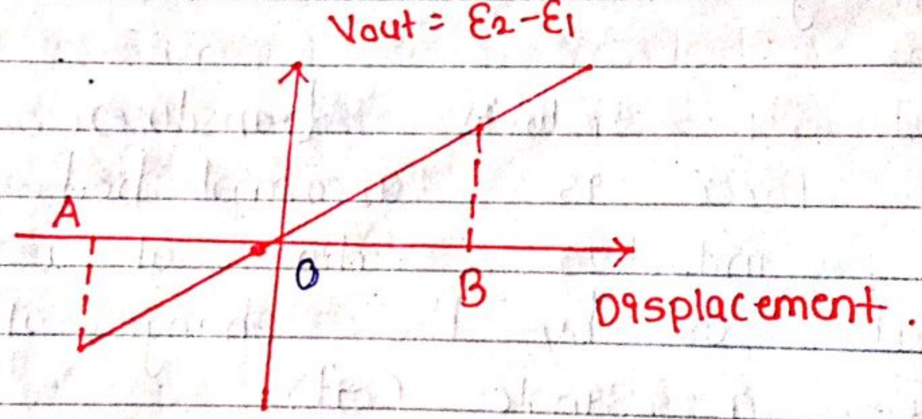
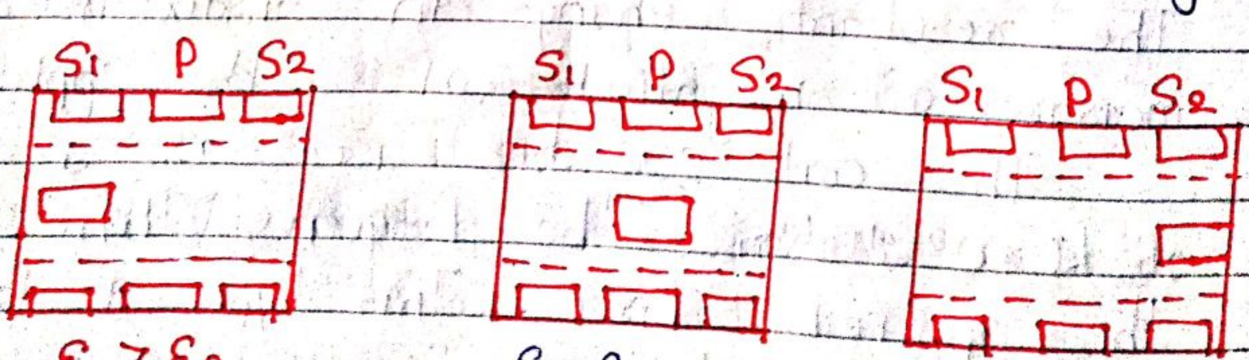


fig (b) : Related position of the core generate the indicated output voltages.



$E_1 > E_2$ — Core at A

$E_1 = E_2$ — Null position

$E_1 < E_2$ — Core at B

LVDT is a passive inductive transducer and is commonly used to measure force, weight, pressure acceleration etc in terms of an amount & direction of displacement of an object.

The basic construction of LVDT is as shown in figure above:

Construction :

~~When the core is in centre the~~

It consists of one primary winding and two secondary windings, which are placed on either sides of the primary winding mounted on the same 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 coils S_1 and S_2 have equal number of turns but are connected in series opposition so that emf E_1 and E_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 principle : (after operation)

Operation

Case I : When the core is at centre

→ The flux linkage with both S_1 and S_2 will be same ideally. Hence, ideally the differential output $\Delta E = E_2 - E_1 = 0$. But in actual practice, there will be some differential output due to harmonics. These differential output is known as residual voltage as shown in figure (A).

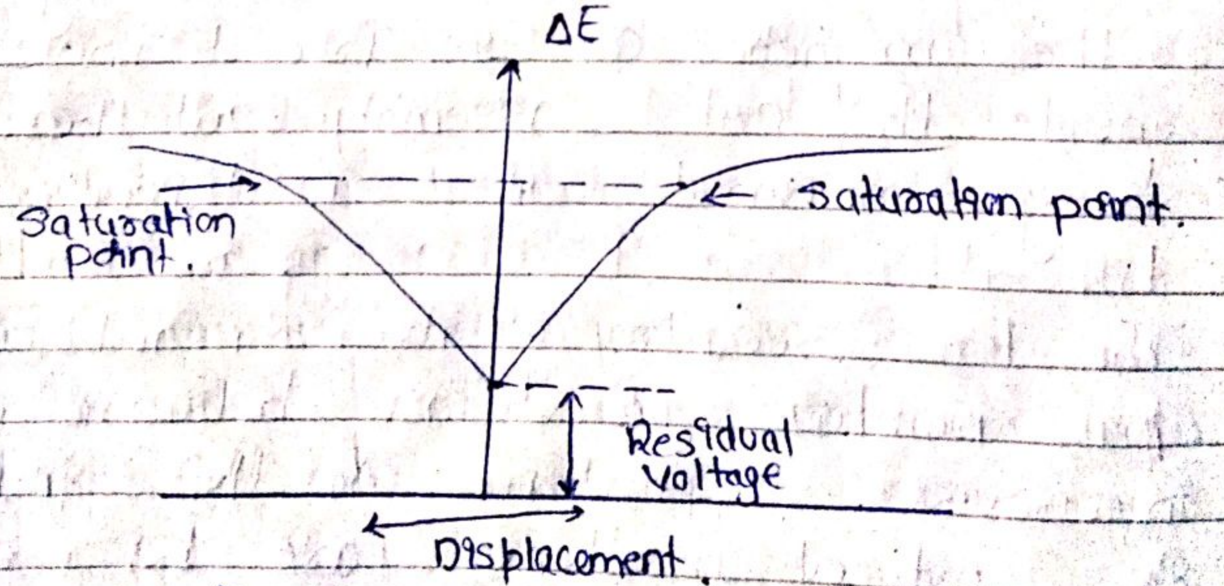


Fig (A) variation of output voltage with linear displacement.

Page No.
Date: / /

Working principle:

(When a sinusoidal input $V_i = V_m \sin\omega t$ is applied to the primary winding, a sinusoidal flux will link with primary winding as well as secondary windings S_1 and S_2.
This flux will induce emf E_1 and E_2 in S_1 and S_2 respectively. As S_1 and S_2 are connected in series opposition, the differential output, $\Delta E = E_2 - E_1$. The differential output ΔE will be either in phase with input voltage (V_i) or it will be 180° out of phase with (V_i).)

Case II: Core moving towards S_2.

When the external force moves the core towards 'S_2', 'E_2' is increased and 'E_1' is decreased in magnitude. Then, the net output voltage, Vout is

$$V_{out} = E_2 - E_1$$

Which is positive.

This means the differential output, $\Delta E = E_2 - E_1$ increases. There exist linear relation between the differential output and the displacement upto saturation and beyond the saturation point, the relation will be no more linear as in A.

Case III : Core moving towards S_1.
Similarly, when the core moves towards S_1, $E_1 > E_2$ hence in this case output voltage is negative.
That means the differential output $\Delta E = E_1 - E_2$ increases.

Advantages of LVDT :
(i) The transducer have a high sensitivity.
(ii) Consumes less Power.
(iii) It can operate on the temperature range of $-265°c$ to $600°c$.
(iv) It has less hysteresis loss, minimum friction and noise.

Disadvantages :
(i) Transducer performance is attached by the vibration.
(ii) The dynamic response is limited mechanically by the mass of core and electrically by means of frequency of applied voltage.
(iii) Relatively large displacement is required for appreciable differential output.

Page No.
Date : / /

Applications :

(i) used to Control Jet engine.
(ii) measurement of weight on highways.
(iii) measurement of thickness and weight on steel mills.

3. Capacitive Transducers

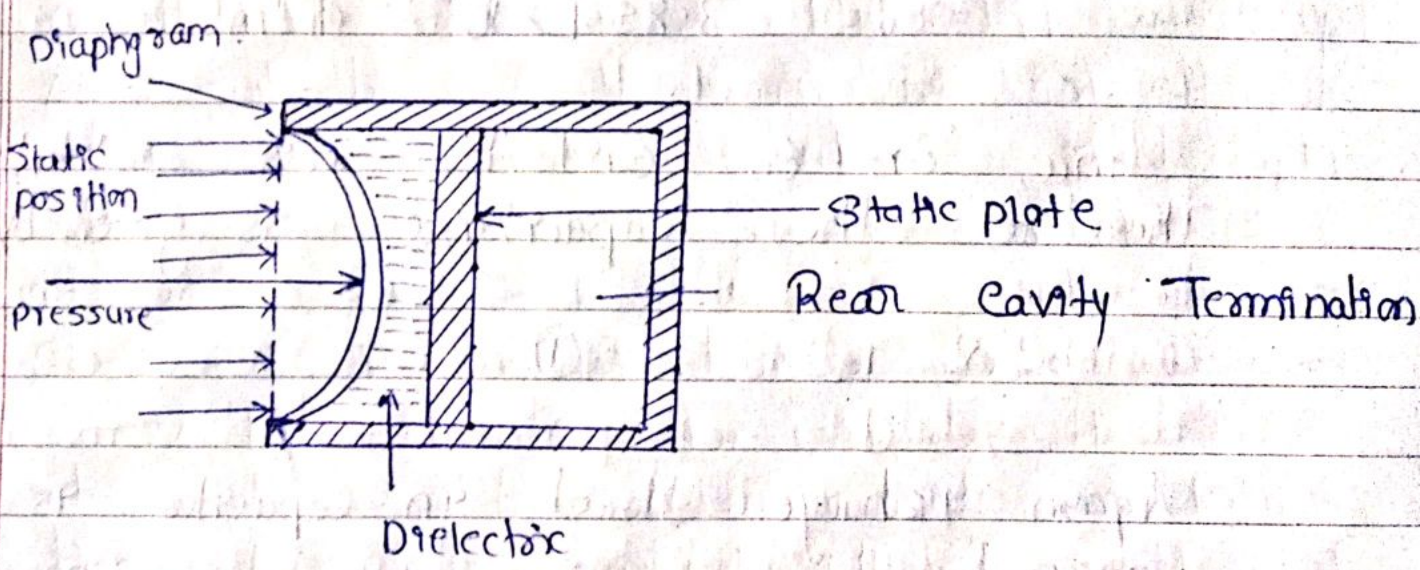


Fig : Capacitive Transducer

In Capacitive transducer, the input being measured is transformed into change in Capacitance. eg : Capacitive displacement transducer

Page No.
Date : / /

The Capacitance of a parallel plate capacitor is given by,

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

Where, ε_r = Dielectric Constant.
A = area of plate.
d = distance between two plates.
ε = permittivity of medium.
$\varepsilon_0 = 8.854 \times 10^{-12}$ F/m.

Since, ε_r, ε_0 and A are constants.
Therefore, the capacitance is given by,

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

Again charge stored in capacitor is given by

$$q = CV$$

$$V = q/C$$

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

$$\Rightarrow V \propto d \quad (\text{from (1) and (2)})$$

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 diaphgram that function as one plate of a simple capacitor, changes the distance between diaphgram and the static plate. The resultant change in capacitance could be measure with an AC-bridge.

(4) Piezo-electric Transducer

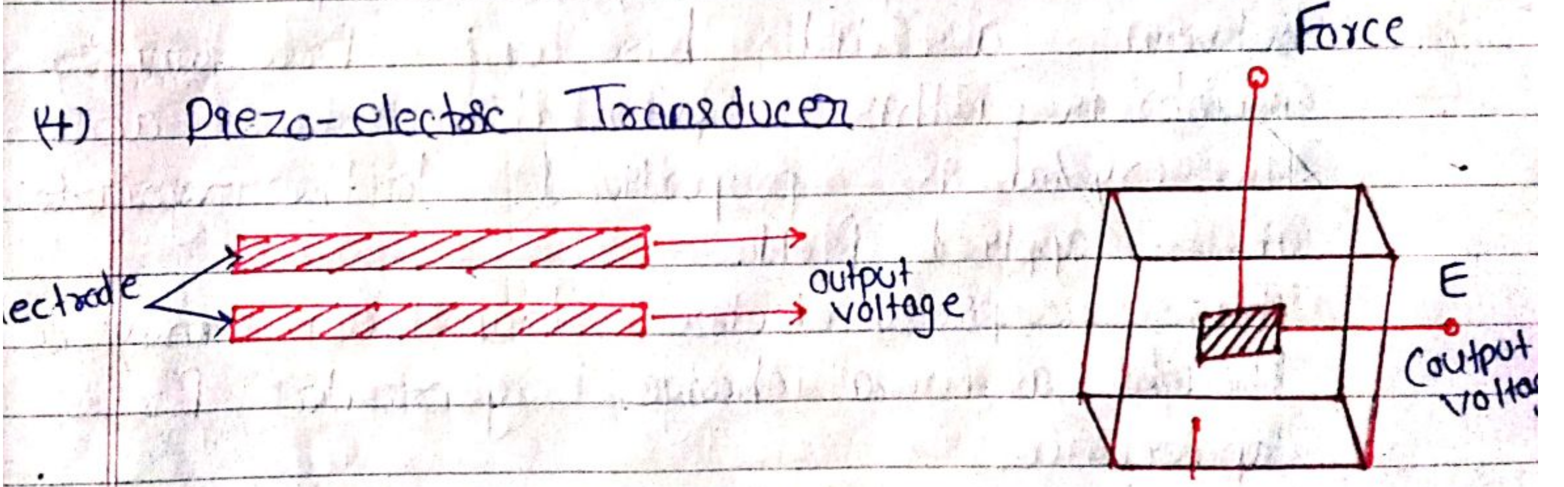


Fig: Piezo-electric Transducer

(A piezoelectric material is one in which an electric potential appears across certain surface of crystal, if the dimension of a crystals are changed by the application of mechanical force.)

Page No.
Date : / /

(Crystal produces an electromotive force when they are placed under stress. Thus, potential is produced as these materials generate an electric charge within them when deformed. This effect is reversible i.e conversely if a varying potential is applied to the proper axis of a crystal, it will change the dimension of crystal nearby deforming it. This effect is called piezo-electric effect.

This property is used in piezo-electric transducer. ~~crystal~~ Crystal is placed between a solid base and force summing membrane. This potential developed across the crystal is proportional to the magnitude of applied field.

Thus, a piezo-electric transducer may be thought as a charge generator for a capacitance.

The charge generated is directly proportional to the force applied.

i.e $Q \propto F$

or, $Q = dF$ —— (i)

where 'd' is charge sensitivity $\left(\frac{C}{N}\right)$ $\left(\frac{\text{charge}}{\text{force}}\right)$

The capacitance formed is given by,

$$C_p = \frac{\varepsilon A}{t} = \frac{\varepsilon_0 \varepsilon_r A}{t} \quad \text{--- ②}$$

where, A = area of the crystal,
t = thickness of the crystal, $\varepsilon = \varepsilon_0\varepsilon_r$ is permittivity of crystal.

The Voltage generated is,

$$E = \frac{Q}{C_p}$$

or, $$E = \frac{dF}{\varepsilon_0 \varepsilon_r \frac{A}{t}}$$

or, $$E = gPt \quad \text{--- ③}$$

where, $g = \frac{d}{\varepsilon_0 \varepsilon_r}$ = Voltage Sensitivity.

Also, $$g = \frac{k}{t}$$

$$k = gt \quad \text{--- ④}$$

where k is piezo-electric constant

from ③ and ④

$$\boxed{E = kP}$$

Advantages :
i) High frequency response
ii) Small in size
iii) High output.

Disadvantages :
→ Output is affected by change in temperature.
→ Can't measure static condition.

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

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Temperature measurement

Resistance Thermometer

It is one of the example of resistive transducer. It is used for measurement of temperature.

(i) Metal resistance thermometer

(ii) Semi-conductor resistance thermometer (thermistor).

(i) Metal resistance thermometer (RTD)

Resistance temperature detectors or resistance thermometers employ a sensitive element of extremely pure plantinum, copper or nickel wire that provides a difinite resistance value at each temperature within its range.

The relationship between temperature and resistance of conductors in the temperature range from 0°c can be calculated by the equation :

$$R_t = R_{ref}\,(1 + \alpha \Delta t) \quad \text{— (i)}$$

Where,
R_t = resistance of conductor at temp. t.
R_{ref} = resistance of reference temp. $0^\circ c$.
$\alpha \rightarrow$ temperature coefficient of resistance.
$\Delta t \rightarrow$ Difference between operating & reference temperature.

A high value of 'α' is desirable in a temperature sensing element so that a substantial change in resistance occurs for a relatively small change in temperature.
This change in resistance (ΔR) can be measured with a wheatstone bridge which may be calibrated to indicate temperature that caused the resistance change rather than the resistance change itself.
The sensing element of a resistance thermometer is selected according to the intended application. A typical sensing element for a probe-type thermometer is constructed by coating a small platinum or silver tube with ceramic material, winding the resistance wire over the coated tube and coating the finished winding again with ceramic.

The resistance thermometer method is so accurate that it is one of the standard methods of temperature measurement within the range about -183 to 630°c

Thermistor (Thermal Resistor)

Thermistor are semi-conductor device that behaves as resistors with a high usually negative, temperature coefficient of resistance. They are made from oxide of chromium, cobalt, nickel, etc. These oxide oxides are semiconductor in nature. So, as temperature increases, resistance decreases. The relation between resistance and temperature is given by,

$$R_T = R_0 e^{\beta}\left[\frac{1}{T} - \frac{1}{T_0}\right]$$

Where,

β = Constant that depends upon the types of the materials used,

T and T_0 are temperatures in kelvin.

Page No.
Date : / /

The high sensitivity to temperature change makes the thermistor 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 thermistor are:

(i) Very high negative temperature coefficient of resistance. (Resistance-temp Characteristics)

(ii) The voltage drop across the thermistor increases with increase in current until it reaches peak value. Beyond which the voltage drop decreases as ↑ current ~~decreases~~ increases. (Voltage-current character)

(iii) Current-Time characteristics:

→ The current-time characteristics curve indicates the time delay to reach maximum current as a function of applied voltage.

When the self heating effect occurs in a thermistor network, a certain finite time is required for the thermistor to read and current to built of to a maximum steady state value.

Page No.
Date: / /

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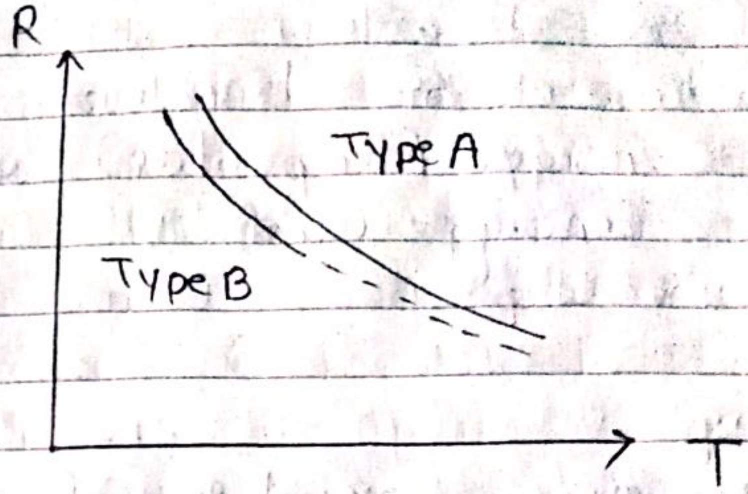

Fig: RT-characteristics

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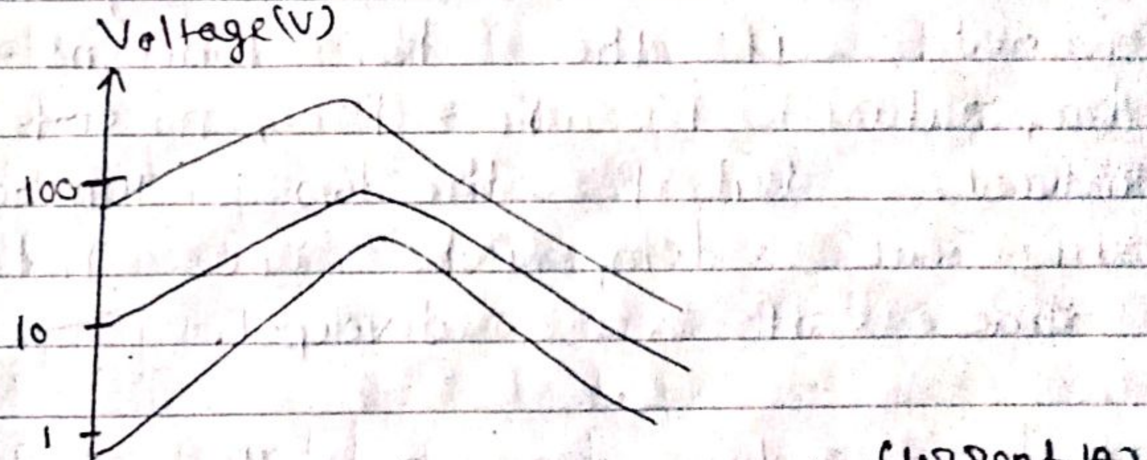

Fig V-C characteristics

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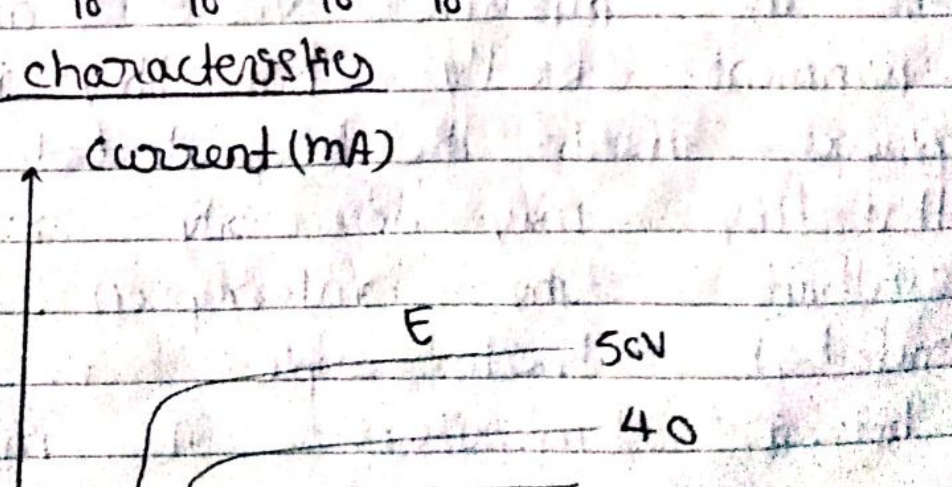

Thermo-electric Transducer

For thermo-electric transducer, input is thermal energy (temperature) output is electrical energy (emf).
eg : Thermo-couple.

→ Thermo-Couple :

A thermocouple circuit is formed by connecting two metal wires A and B end to end such that two junctions are formed. If the two junctions are at same temperature i.e $T_1 = T_2$; no emf is induced. But if the two junction are at different temperature i.e, $T_1 \neq T_2$, then some emf is developed.

Thermo couples 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 removed 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.

Page No.
Date: / /

Numerical

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

Here,
Voltage sensitivity (g) = 0.055 Vm/N.
Voltage developed (E) = 120 V

Dimension = 6mm X 6mm X 1.8 mm.

Area of crystal = 6mm X 6mm
= $36\ mm^2$
= $3.6 \times 10^{-5}\ m^2$.

Thickness (t) = 1.8 mm
= 1.8×10^{-3} m

Force (F) = ?
We have,

$$E = gtp$$

or, $$120 = \frac{0.055 \times 1.8 \times 10^{-3}\ F}{3.6 \times 10^{-5}}$$

$\therefore$ F = 43.64 N.

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(8) The following data related to a $BaTiO_3$ pick up dimension $6mm \times 6mm \times 1.5mm$. The force acting on the pick up is 6N, charge sensitivity is 150 pC/N, permittivity is 12.5×10^{-9} F/M and Modulus of elasticity is 12×10^{6} N/m^2. Calculate strain and charge and capacitance.

Here,

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

dimension = $6mm \times 6mm \times 1.5mm$.

charge sensitivity = 150 pC/N.

permittivity = 12.5×10^{-9} F/M.

Modulus of elasticity = 12×10^{6} N/m^2

Area of pick up (A) = $36\ mm^2$

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

thickness (t) = 1.5×10^{-3} m.

We have, Stress = $\frac{F}{A}$

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

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

Date : / /

(i) 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) = charg sensitivity × F

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

$$= 900\ pC.$$

(iii) Capacitance (C) = $\frac{Q}{E}$

$$= \frac{900\ pC}{E}$$

$$g = \frac{\text{Charge sensitivity}}{\text{permittivity}}$$

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

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

So, E = gpt

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

$= 3V$

$\therefore$ from ①

$$C = \frac{900\,pC}{3V} = 300\,PF$$

→ The signal conditioning equipment may be required to do linear process like

→ Amplification

Attenuation

Integration

Differentiation

Addition

Subtraction.

And non-linear processes like modulation, demodulation, shamping, filtering, clippling, squaring, linearising and multiplication by another function.

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