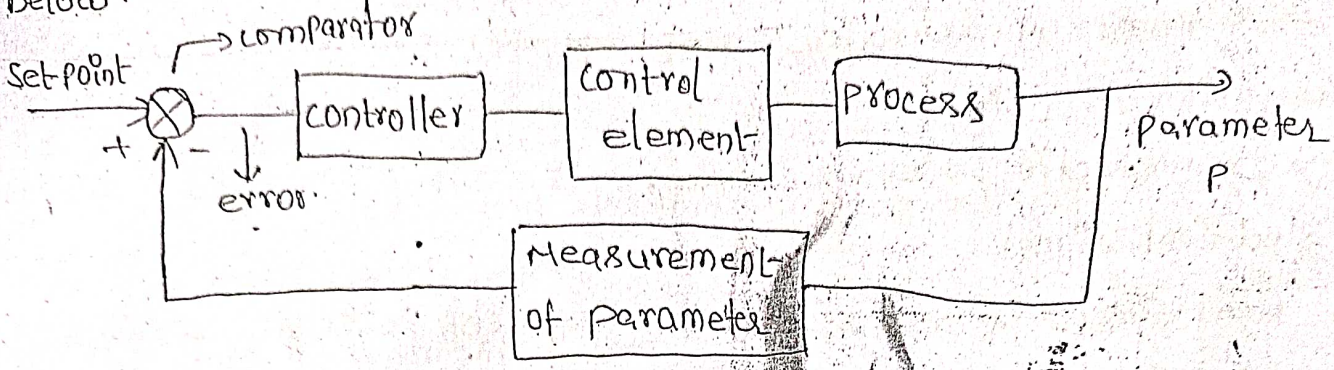
UNIT - IV

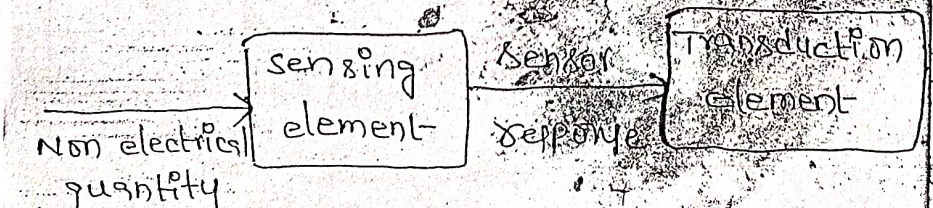
Transducers

The general arrangement of a process loop is as shown below.



For the proper feedback, it is necessary to measure the value of actual parameter P. Most of the controllers are in electronic nature. Therefore it can require electrical signal as feedback. But mostly the o/p is physical parameter like pressure, temperature etc. so a device require to change the physical parameter into electrical parameter is known as transducer.

∴ Tranducer is a device, which converts physical quantity in to the proportional electrical signal called as tranducer. The electrical signal produced may be voltage, frequency, current. The transducer may use some effects for such conversion. The process of transing from one signal to another is known as transduction. transducer also called as "pick up"



A transducer mainly consists of two components.

1) Sensing element (or) detecting element.
2) Transduction element.

→ Sensing element is known as sensor. It is a device which can produce measurable response to a change in physical condition

→ Transduction element changes the o/p of sensor to electrical signal

Many times the transducer is a part of circuit which works with other elements and produces required o/p is known as signal conditioning circuit.

Classification of transducers.

There are two types of trawducers. Mechanical
electrical.

Mechanical transducer:— The mechanical transducers are those primary sensing elements responds to a change in physical condition and gives o/p in mechanical form.

ex:- A bimetallic strip is subjected to a temperature ch then the o/p is mechanical displacement of strip.

electrical transducer:— The electrical transducers a responds to non-electrical quantities but o/p is in el nature. In practically any transducer (i.e) either mecha (or) electrical can be used to measure the physical parameters. But the electrical trawducer is preferre compared to mechanical

Advantages of electrical transducer:-

* The power requirement is very small.
* The controlling of electrical systems can be obtained with small level of power.
* The o/p of electrical transducer can be easily used (i.e) transmitted and amplified with the help of static device
* The effects of friction and non-linearities are reduced.
* Due to integrated circuit technology, the weight of system is less and portable.
* The data transmission through mechanical means is eliminated.

∴ No mechanical failures exist.

* The mass of inertia problems are reduced.

Disadvantages:-

* The cost is high.
* By the circuit deigning the effects of aging can be considered. This can make the circuit complecated.

In general electrical transducers are classified according to their structures, area of applications, o/p signal.

Active & passive.
on the basis of transduction principle.
Analog & digital.
primary & secondary.
Transducer & Inverse transducer.

1) Active & passive transducers:-

Active :- Active transducers are self generating transducers. These transducers doesn't require any external power supply.

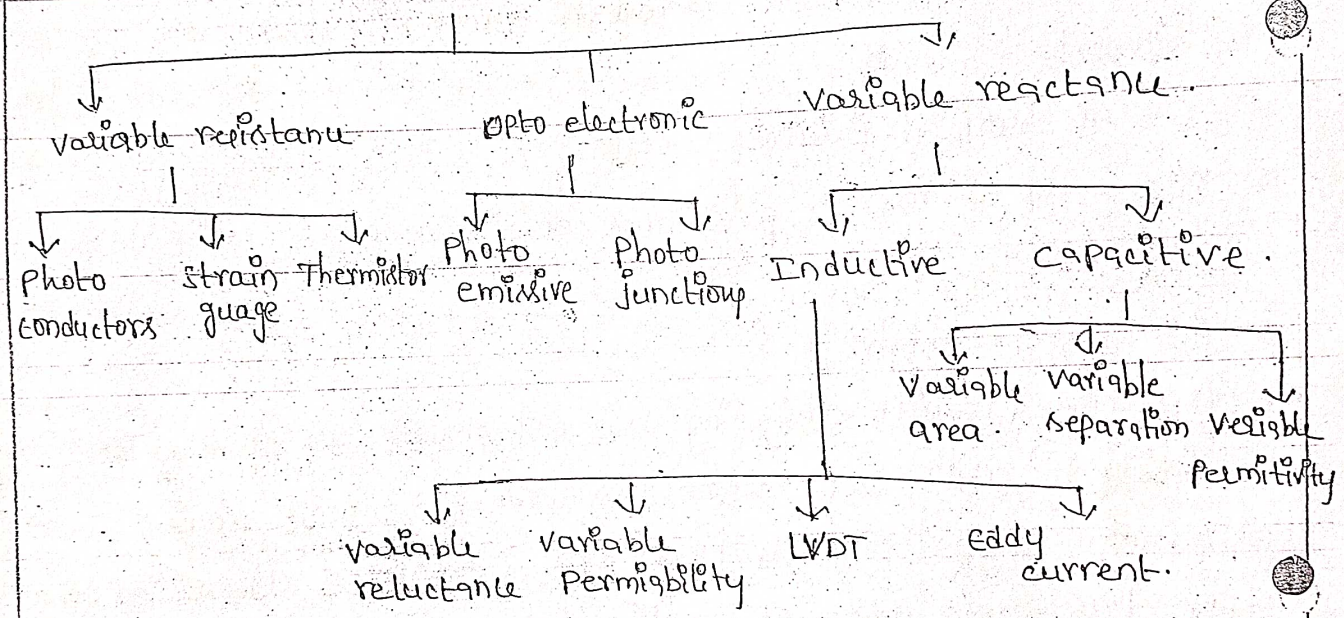


Active

Photo voltaic — Thermo electric — Piezo electric — Electro magnetic.

Passive:- The transducers are not generating power themselves.

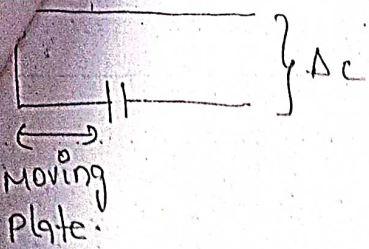
∴ An external source is required. They are also known as externally power driven transducers.

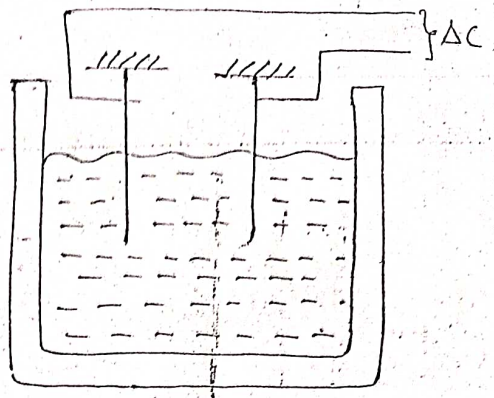


2) According to transduction principle

i) capacitive transduction:- In this one the measurand is converted into change in capacitence. Basically a capacitor consists of two plates. These two are separated by a insulator (dielectric medium).

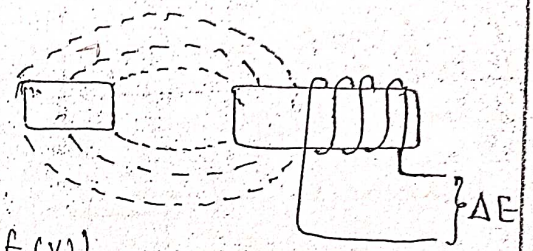
→ The change in capacitor occurs either by changing the distance b/w two plates (or) change in dielectric.





(ii) Electromagnetic transduction:-

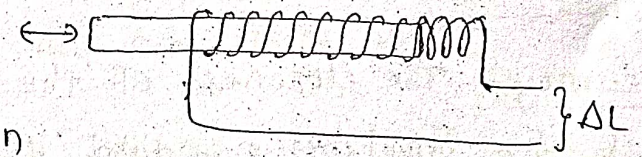
In this one the measurand is converted into electromotive force (emf.(v)) induced by change in flux.



→ The flux change can be occured due to the relative motion b/w magnet & electromagnet.

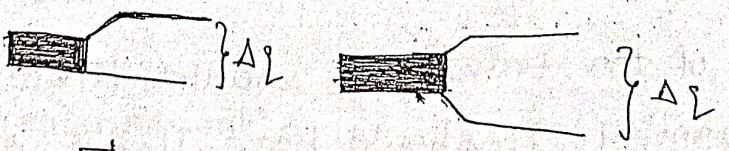
(iii) Inductive transduction:-

In this one, the measurand is converted into change in self inductance of coil.



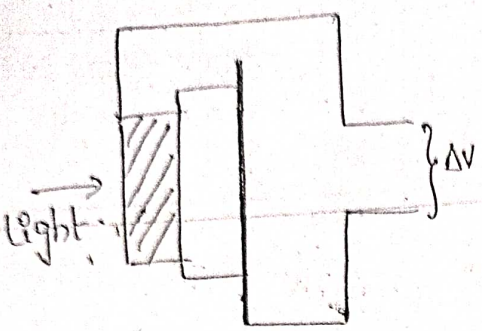
(iv) Piezo electric transduction:-

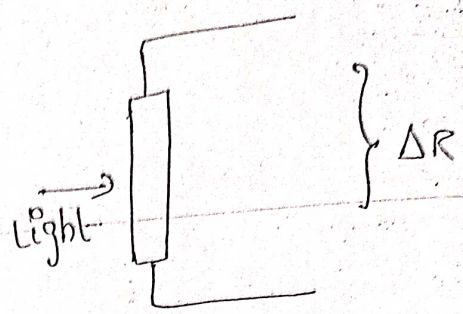
In this one the measurand is converted into change in electrostatic charge(q) and voltage(v) generated by crystals when

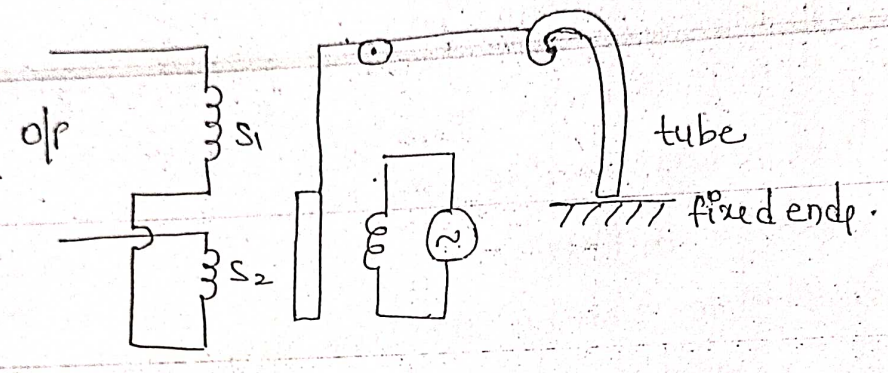


(v) Photovoltaic:- The measurand is converted into voltage generated when two dissimilar junctions are illuminated.

(vi) Photo conductive:- The measurand is converted to change in resistance.







characteristics of transducers:-

Accuracy:- The closeness of the variable being measured with the ideal (or) standard value. The accuracy of transducer is high.

Ruggedness:-

The transducer should be mechanically rugged to withstand overloads. It should have overload protection.

Linearity:-

The o/p of the transducer should linearly proportional to i/p quantity. It should have linear i/p - o/p characteristic.

Repeatability:-

The o/p of transducer is same for same environment,

e quantity (i.e) the i/p can be repeatedly then also is same and

High output:- It can give high o/p which is used to measure and o/p is greater than noise.

High stability & reliability:- The o/p of transducer should be highly stable & reliable the o/p must be uneffected by the environmental conditions.

Sensitivity:- The sensitivity of transducer can be defined as the electrical o/p obtained per unit change in physical parameter. High sensitivity can be occured.

Ex:- temp mv/°c.

Dynamic range:- The operating range for transducer must be wide.

Size:- The size of transducer have small and low weight and small shape. This can make system very compact.

Speed of response:- The speed of response of transducer is high.

Transducer selection factors

For selecting the right or proper transducer for a given measurement we have to consider some factors as listed below.

1) Nature of measurement:-

The selection of transducer will naturally depend on nature of quantity to be measured.

Ex:- Measurement of temperature → temp transducer (or) sensor

2. Loading effect:-

With the loading effects the value of under measurement can change. Therefore errors are introduced. To reduce this type errors the transducer has minimum loading effect.

3. Environmental considerations:-

The troublesome aspects of transducer locations are temperature changes, shocks & vibrations and electro magnetic interfaces.

→ To minimize the errors due to temperature change, some transducers are temp compensated. For this compensation the system design becomes difficult and special materials are used.

→ It is very difficult to reduce complete errors which are due to shocks & vibrations. For this one damping can be done.

→ Transducers are must be operated in strong electromagnetic fields. Transducers with low o/p impedance, high o/p voltage are less susceptible to such interferences.

4. Measuring system compatibility:-

The transducer measurement should be compatible (i.e) the o/p impedance of transducer should not effect the impedance which is imposed by the measuring transducer.

5) availability:-
The cost is low and it must be avilable in market and also some other factors like less maintainence, simplicity and reliability should be considered.
6) less no of moving parts and the operation should be simple.
7) The transducer doesn't have continuous calibration checking.

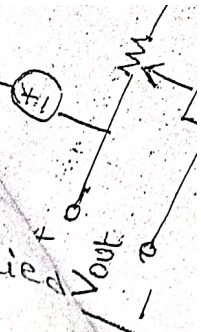
Resistive transducer:-

In general the resistance of a material conductor is given by

$R = \frac{\rho L}{A}$ where ρ - resistivity of conductor (ωm)
L - length of conductor (m)
A - Area of cross section of conductor (m^2)

→ The resistive transducers are designed in such a way that methods of variations of above quantities like ρ, L, A.
→ The resistive transducers are either used as primary (or) secondary
→ The industrial applications are ~~either~~ those
* Both AC & DC voltage of type transducers * and currents are suitable for measuring resistance change.
* The speed of resistive transducers are high.
* They are avilable in various sizes with various wide range of resistance values.
* It has high resolution.

* The change in resistance due to change in length is used in translational (or) rotational potentiometer to measure linear (or) rotational measurement.
* The change in resistance due to change strain applied is used in working principle of strain guage.
* The change in resistivity is used in temperature measurement.

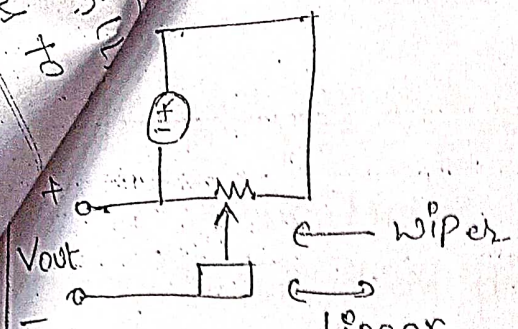


Effect	As primary transducer	As secondary transducer
change in length (L)	Linear displacement. Angular displacement Thickness.	Temperature, pressure, weight, force, velocity, acceleration.
change in area (A)	High pressure strain	Temp, pressure, weight force, acceleration.
change in resistivity	Temperature, magnetic displacement, humidity.	Low pressure, vacuum, displacement.

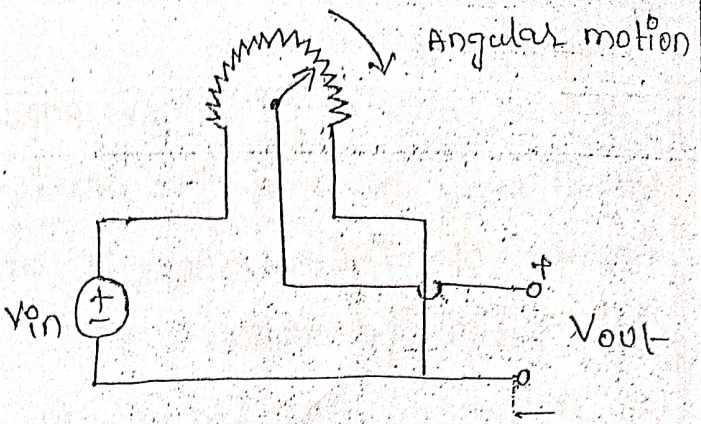
Potentiometric resistance tranducers (potentiometer)

* It is generally used to measure the linear (or) angular displacement.
* It consists of a wire wound resistive element along with a sliding contact is known as wiper.
* The wire is made up of platinum (or) nickel with 0.01 mm diameter.

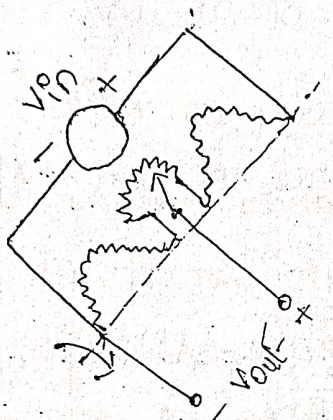
The linear and rotary potentiometer are as shown below.



Linear



Rotary.



Helipot.

→ Using resistance potentiometers the mechanical displacement can be converted into electrical o/p such linear (or) angular displacement is applied to sliding contact and then corrosponding change in registance is converted into voltage.

→ To measure the combination of linear & angular displacement we are using helipots.

Advantages	Disadvantages.
* Simple contruction & operation * In expensive. * useful to measue displacements * High electrical efficiency. * Best suitable to measurements with less equipments.	* Large force is require to move wiper. * Suffer from mechanical wear and missalignment of wiper. * High noise in o/p.

Inductive Transducer:-

It is a simple and most popular type of displacement transducer, in which the variation of inductance as a function of displacement is achived by variation of self (or) mutual inductance.

(a) In general self inductance of an inductor is

$L = \frac{N^2}{S}$ — N - no of turns of coil, S - Reluctance of coil (A/wb)

Reluctance $S = \frac{l}{\mu a}$

$L = \frac{N^2 \mu a}{l}$ — μ - permeability of core, a - Area of magnetic ckt, l - length of magnetic ckt.

Thus variation in self inductance can be obtain by

* change in turn no.
* change in reluctance.
* change in permeability.

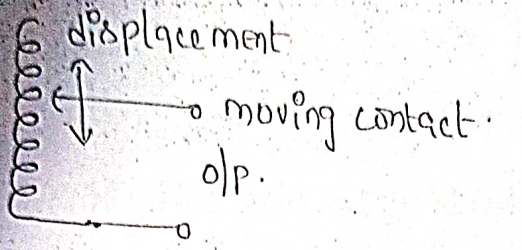
(b) The mutual inductance b/w two coils is

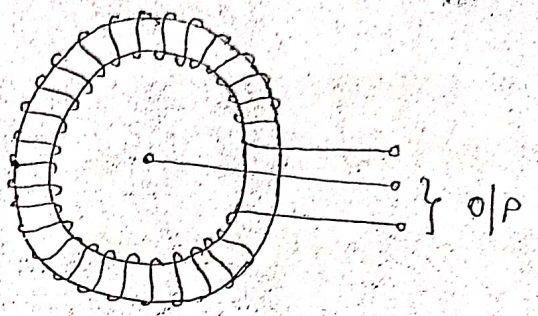
$M = K\sqrt{L_1 L_2}$ — K - coefficient of coupling, M - Mutual inductance.

Thus variation in mutual inductance can be obtained by
* change in coefficient of coupling.
* change in self inductance of two coils.

In practical applications, thye transducers are used to measure physical quantities like force, pressure, velocity, position etc.

Transducer based on principle of change in self inductance with no of turns :-

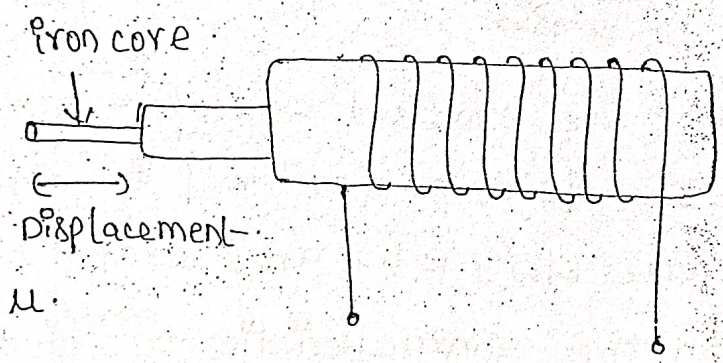




From the definition $L = \frac{N^2}{S}$ i.e $L \propto N^2$

∴ If no of turns can be changed then inductance can also be changed and due to this the o/p voltage can also change

(b) Variable permibility Inductance Transducer :-



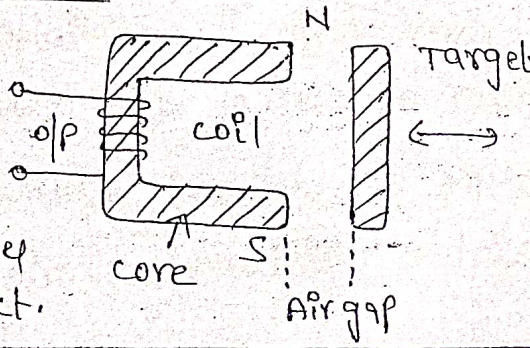
$L \propto \mu$.

In this one the displacement which is to be measured is applied to iron rod which is to be moved in and out of ferrite core according to direction of displacement.

The iron core in → μ is increased. } The o/p voltage changed.
The iron core out → μ is decreased }

(c) Variable Reluctance Inductive transducer :-

$L = \frac{N^2}{S} \Rightarrow L \propto \frac{1}{S}$.



It is a self generating type
The size of air gap determines the reluctance of magnetic ckt.

If s change then L also change.

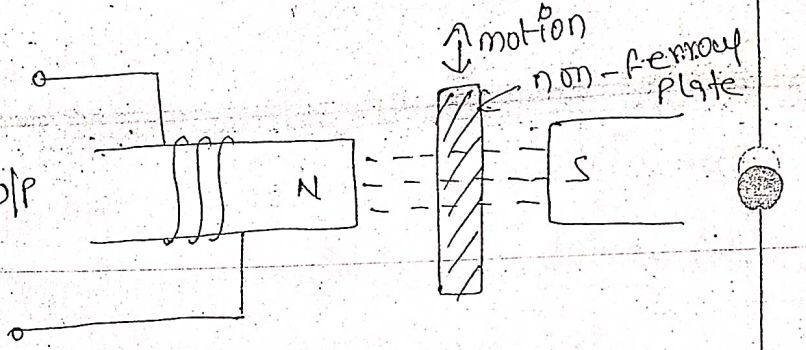
when ever the displacement which is to be measured is applied to target plate then the airgap b/w the core & plate is change (i.e) the reluctance change.

(i.e) the inductance change and also o/p voltage change.

(d) Eddy current type inductive transducers:-

It is also a self generating transducer

A non-ferrous plate is moved ⊥er to lines of flux of magnet.



Due to this one eddy (I) are produced which are proportional to velocity of plate. The o/p is proportional to change in eddy (I). The difference b/w plate and magnets remains constant then the characteristic are linear.

LVDT- Linear variable displacement transducers:-

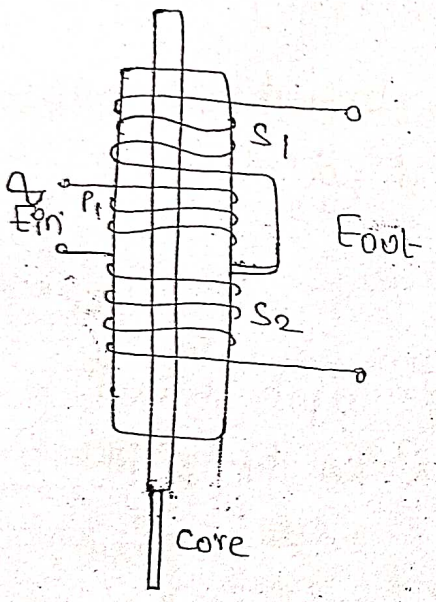
* Displacement is a vector quantity representing a change in position of a body with respect to reference.
* with the help of displacement transducer many other quantities such as force, stress, pressure, velocity can be found.
* The main electrical displacement tranducers work on principle of.

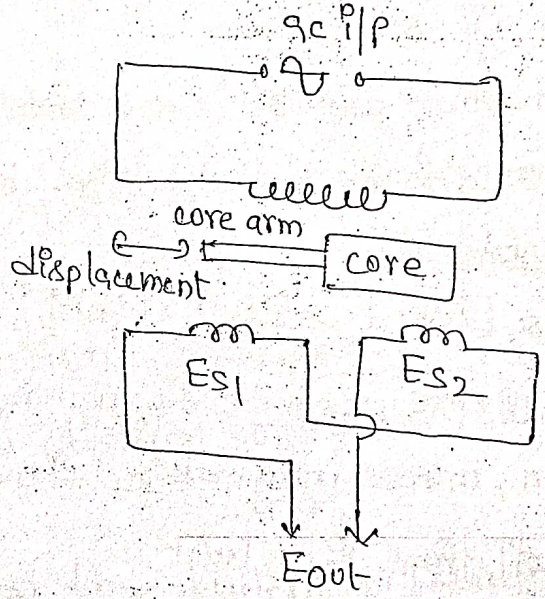
(a) variable resistance: strain guage transducer

variable inductance : Variable difference transducer.
variable capacitence : parallel plate capacitor transducer.
(d) synchros and resolvers: Angular displacement.

* The main popular one is variable inductance type. But for high accuracy, good stability make LVDT most suitable as a position measuring device.

construction & working:-





→ The linear variable differential transformer consists of a single primary wdg P_1 & two secondary wdgs S_1 & S_2. wound on a hollow cylindrical former.
→ A soft iron core is slidy inside the former.
→ * A soft iron core
→ The secondaries have an equal no'of turns but they are connected in series opposition. so that emfs induced in coils oppose each other.
→ The i/p is a.c source, whose frequency is varied from 50Hz - 20KHz

The position of movable core determines the flux linkages of a.c excited primary w/g & each of two secondary w/g o/p variation.

→ The displacement which is to be measured is applied to arm of core.

→ With core at centre position as reference point. the induced emfs in secondaries are equal and opposite to each other

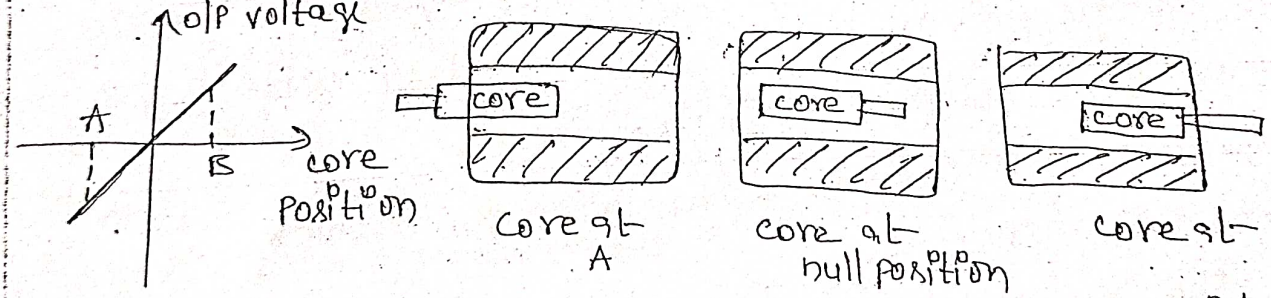
∴ o/p is zero volts.

→ when core can be force moved to left hand position more magnetic flux links the left hand coil than the right hand coil.

∴ E_{s_1} (left) > E_{s_2} (right)

→ when core can be force moved to right hand position, more magnetic flux links the right hand coil than the left.

E_{s_2} (right) > E_{s_1} (left)



Thus LVDT o/p voltage is a function of core position. The core can be placed at center and moved from the center, the greater is the difference in value b/w E_{s_1} & E_{s_2} consequently.

∴ amplitude of o/p voltage is a function of distance

Advantages:
Linearity

core moves.

* o/p of LVDT is linear with in a limited range of motion.

Advantages:-

Linearity:- The o/p of LVDT is linear for 5mm displacement.

* Infinite resolution:- The change in o/p is continuous. stepless.

* High o/p:- LVDT gives high o/p. It requires less i/p

* High sensitivity:- It has high sensitivity of about 300 mv/mm (i.e) 1mm displacement produces 300mv.

* Ruggedness:- LVDT is mechanical rugged one and can withstand the vibrations & shocks.

* Less friction:- There is no sliding contacts. Therefore friction is less.

* Low hysterisis:- LVDT has low hysterisis. Therefore good repeatability.

* low power consumption of 1W power.

* Size:- Less weight and small size.

Disadvantage:-

* large displacements are necessary for differential o/p.

* They are sensitive to stray magnetic fields.

* Temperature effects the transducer.

Applications:-

* The displacement ranging from fractions of a value to a few cm.
* Acting as a secondary transducer, LVDT can be used to measure force, weight, pressure.

(i.e) The force (or) pressure which is to be measured is converted into displacement by using primary transducer and after that by using secondary transducer the displacement is converted into o/p voltage.

Capacitive transducer:-

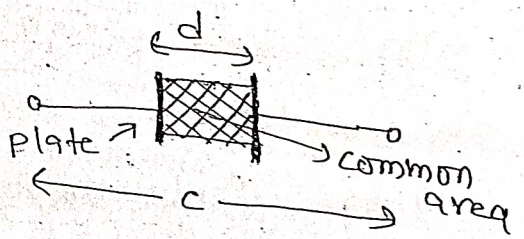
The capacitive transducer works on the fundamental principle of electrical capacitance. The capacitance 'C' of system can be depends on

* Dielectrica medium used.
* Property of a capacitive system.

The important capacitances used in capacitive transducers are.

(i) Parallel plate capacitor:-

The capacitance of a parallel plate capacitor is given by



$$C = \frac{\epsilon A}{d}$$

where ϵ - permitivity.

$\epsilon = \epsilon_0 \epsilon_r$ $\epsilon_0 - 8.85 \times 10^{-12}$ F/m

ϵ_r - relative permitivity.

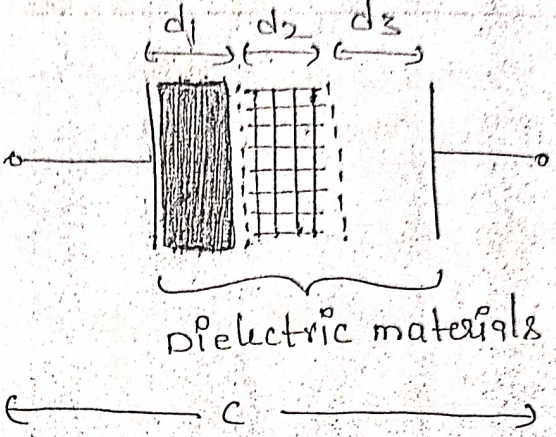
d - distance b/w two plates.

A - Area of cross section of plate.

Easy value of capacitance of capacitor can be changed by simple method.

(2) composite capacitor:-

This capacitor can consists of more than one dielectric medium between two plates as shown in figure

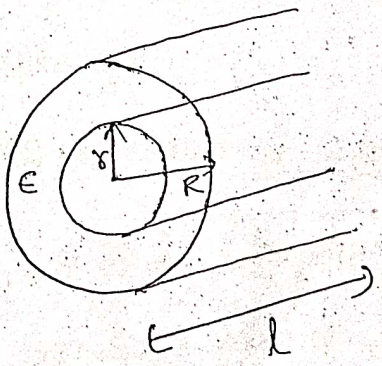


It consists of 3 layers of dielectric having relative permitivities ϵ_1, ϵ_2 & ϵ_3 and layers thickness are d_1, d_2, d_3. The capacitance of system is given by

$$C = \frac{\epsilon_0 A}{\frac{d_1}{\epsilon_1} + \frac{d_2}{\epsilon_2} + \frac{d_3}{\epsilon_3}}.$$

(3) cylindrical capacitor:-

In this one the plates are circular shaped and are separated by a dielectric medium



The capacitance C is given by

$$C = \frac{2\pi\epsilon l}{\ln\left(\frac{R}{r}\right)}$$

r - outer radius of inner circle.

R - inner radius of outer circle.

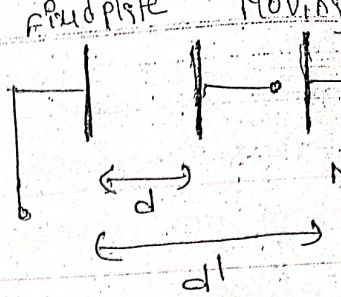
l - length of cylinder.

variation in capacitance

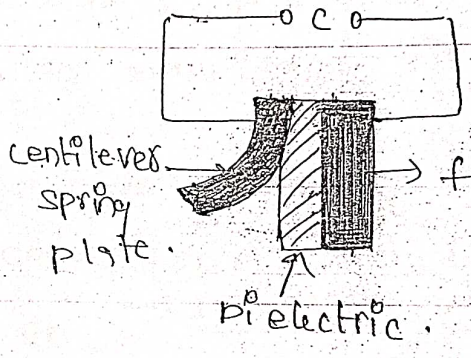
To use the capacitive system as a sensor, it is necessary to change the capacitance. The change in capacitance can be obtained by so many different ways.

a) change of distance b/w plates:-

In this one the distance b/w two plates (i.e) fixed & moving are increased from d to d' then the capacitance can be decreased from c to c'



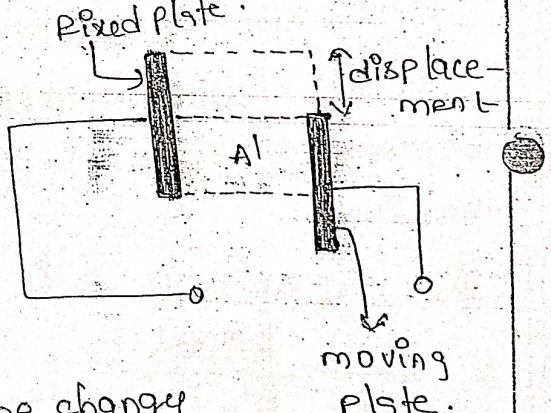
Another method of varying the distance of plates is by using cantilever spring.

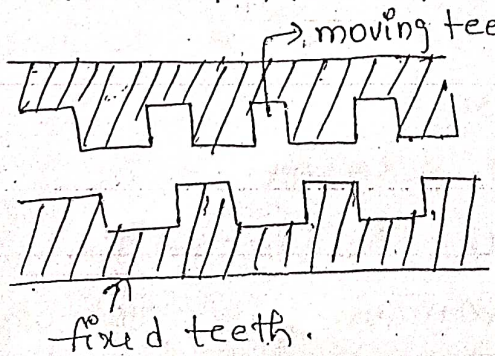


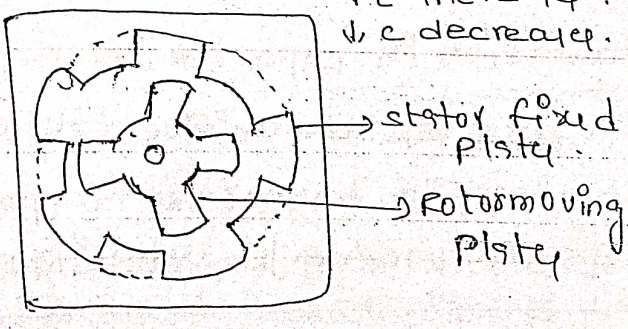
(b) change in common plate area:-

By changing the plates in parallel position, one is fixed and second one is moved then the common area can be changed.

Due to this the capacitance can be changed



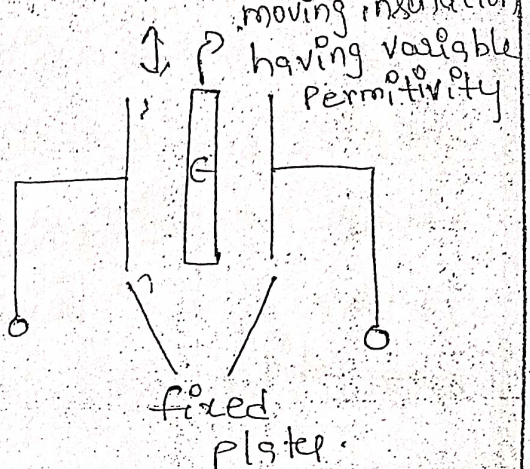




above one is applicable incase of rotational displacement whenever the rotor rotates, the capacitance can be changed directly proportional to angular displacement.

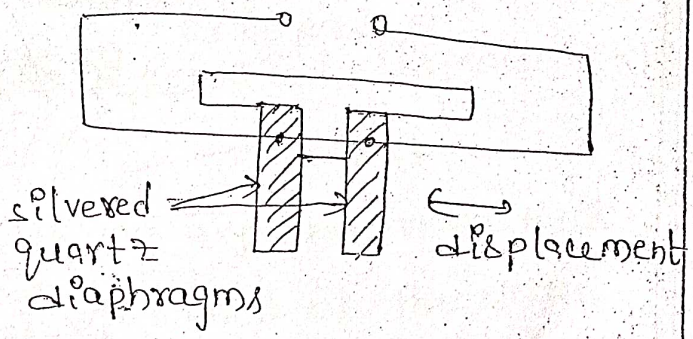
(c) change in dielectric:-

By inserting a plate the capacitance can be varied.



ii) using the quartz diaphragm:-

In this one two silvered quartz diaphragms are used to change the capacitance.



capacitance transducer as level type meter:-

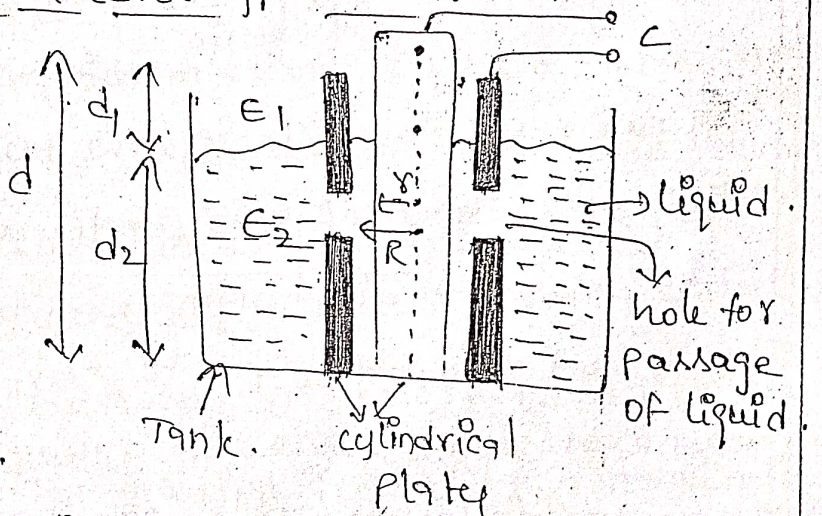
r - radius of inner cylinder.

R - Radius of outer cylinder.

d_1 - level of air.

d_2 - liquid level

d - total level tank.



This type of transducer is used to measure the liquid levels.

The capacitance is given by $C = \frac{2\pi\epsilon_0 [\epsilon_1 d_1 + \epsilon_2 d_2]}{\ln\left[\frac{R}{r}\right]}$

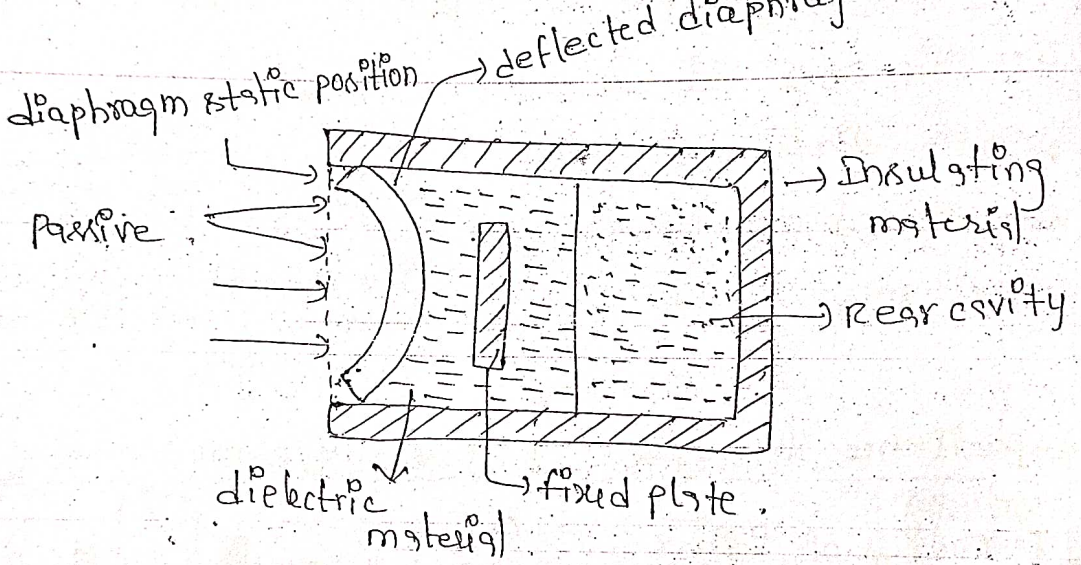
Thy change in liquid level causes the change in capacitance.

ϵ_1 - permitivity of air.

ϵ_2 - permitivity of liquid level.

→ Thy change in capacitance is detected by other circuit which the electrical signal is proportional to the liquid level.

Capacitance pressure Transducer:-



In thy one, the distance b/w two plates are changed, the capacitance of two plates are changed.

In thy one, the diaphragm can be acts as moving plate and the other plate can be acts as fixed plate. whenever some force is applied to diaphragm it can be moved towards fixed plate then the capacitance can be measured by uping oscillator.

Advantages:-

→ They are highly sensitive.

They have good frequency response and very high i/p impedance.
→ The requirement of force is small.

Disadvantages:-
→ The stray capacitance can effect the transducer.
→ proper insulation is required b/w metallic parts of capacitive transducer.
→ The loading effect can reduced sensitivity.

Strainguage transducer:-
It is a passive resistive transducer, which is based on principle of conversion of mechanical displacement into resistance change.

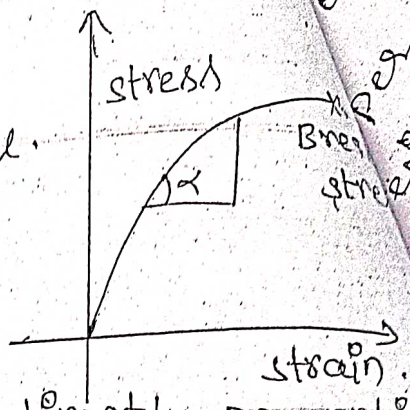
The strength of material is mainly characterised in terms of stress. stress is defined as the force experienced per unit area and expressed in pressure units stress is not measured directly. It normally deduced from mechanical dimensions and load.

The mechanical deformation can be measured with strain guage transducer.

strain is defined as change in length (Δl) per unit length (l) in micro strains i.e $\Delta l / l$ = strain.

The stress - strain curve is as shown below. The curve is linear as long as stress is kept below elastic limits.

A guage which is yeild strain directly is known as strain guage.



Both the stress and strains are directly praportional to the elasticity. But strain can be meaured directly and eaily as compared to stress.

Usually the resistance transducer and resistive tranducer are used as strain guage.

principle of operation of strain guage:-

The basic principle of operation of strain gauge is that the resistance of the wire changes as a function of strain, increasing with tension and reducing with compression.

→ The change in resistance can be measured with the help of wheatstone bridge. The guage is subjected to speciman, Therefore guage can be at the same strain that of speciman.

→ The materials used for strain guage must have the following qualities such as high accuracy, excellent reproducibility good sensitivity, long life and are to operated under required environmental conditions.

→ The most common metals used for strain guage

constantan alloys containing 45% Nickel & 55% copper because of they exhibit high specific resistance and constant guage factor over a wide range, and large temperature range.

→ For dynamic strain measurements, Nichrome alloys, containing 80% Nickel and 20% chromium are used.

→ By bonding cements we are fixing the strain guage into specimen. The cement can served as transmitting the strain from specimen to guage. The improper bonding can caused errors.

→ The cements are classified into 2 types.

→ solvent setting.

→ chemically reacting.

→ Duco cement is example of solvent setting, which is cured by solvent evoperation.

→ Epoxies & phenolic bakelite are examples of chemically reacting which are cured by polymerization.

Gauge factor:-

The guage factor is defined as the unit change in resistance per unit change in length. It is denoted as k or s. It is also called as sensitivity of strain guage.

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

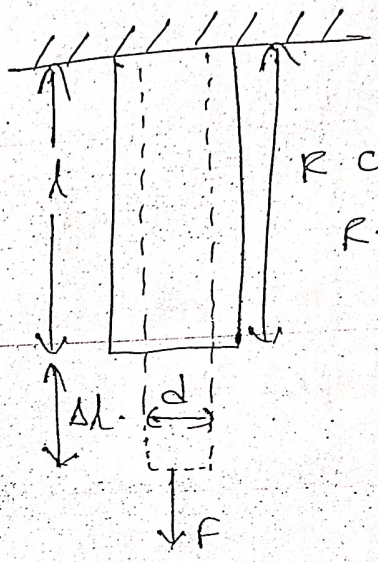
S - guage factor.

R - guage wire resistance.

ΔR - change in wire resistance

l - length of guage wire.

Δl - change in length of guage wire



consider the resistance wire is under tensile stress and it is deformed by ΔL.

Let P = specific resistance of wire.

l = length of wire.

A = cross section of wire.

when uniform stress (σ) is applied to the wire along length the resistance R changes to R+ΔR because of change in length and cross sectional area.

σ = stress = $\frac{\Delta L}{L}$

Generally $R = \frac{Pl}{A}$.

$$\frac{dR}{d\sigma} = \frac{d\left(\frac{Pl}{A}\right)}{d\sigma} = \frac{P}{A}\frac{\partial l}{\partial \sigma} + \frac{l}{A}\frac{\partial P}{\partial \sigma} - \frac{Pl}{A^2}\frac{\partial A}{\partial \sigma}.$$

Multiply both sides by $\frac{1}{R}$.

$$\Rightarrow \frac{1}{R}\frac{dR}{d\sigma} = \frac{P}{RA}\frac{\partial l}{\partial \sigma} + \frac{l}{RA}\frac{\partial P}{\partial \sigma} - \frac{Pl}{RA^2}\frac{\partial A}{\partial \sigma}$$

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

$\Rightarrow \frac{1}{R}\frac{\partial dR}{d\sigma} = \frac{1}{l}\frac{\partial l}{\partial \sigma} + \frac{1}{\rho}\frac{\partial \rho}{\partial \sigma} - \frac{1}{A}\frac{\partial A}{\partial \sigma}$ $\qquad \frac{\rho l}{RA} = 1$

cancelling $d\sigma$ on both sides.

$\Rightarrow \frac{dR}{R} = \frac{\partial l}{l} - \frac{\partial A}{A} + \frac{\partial \rho}{\rho}$.

$\Rightarrow \frac{\Delta R}{R} = \frac{\Delta l}{l} - \frac{\Delta A}{A} + \frac{\Delta \rho}{\rho}$ ——(1)

Thus for finite stress, the total change in resistance is due to fractional change in length, Area and resistivity.

For a circular wire

$$A = \frac{\pi}{4} d^2$$

$$\frac{\partial A}{\partial S} = \frac{\pi}{4}(2d)\frac{\partial d}{\partial S}$$

$$\frac{1}{A}\frac{\partial A}{\partial S} = \frac{\pi}{4}\frac{2d}{A}\frac{\partial d}{\partial S}$$

$$= \frac{1}{d^2}\frac{2d}{4}\frac{\partial d}{\partial S}$$

$$\frac{1}{A}\frac{\partial A}{\partial S} = \frac{2}{d}\frac{\partial d}{\partial S}$$

$$\frac{\Delta A}{A} = 2\frac{\Delta d}{d} \quad \text{——(2)}.$$

The poissions ratio for the wire is defined as ratio of strain in lateral direction to strain in axial direction.

$$\mu = \frac{-\Delta d/d}{\Delta l/l}$$. poissions ratio.

$$\frac{\Delta d}{d} = -\mu\left(\frac{\Delta l}{l}\right) \quad \text{---} \quad (3)$$

Substitute (2) & (3) in (1)

$$\Rightarrow \frac{\Delta R}{R} = \frac{\Delta l}{l} - 2\frac{\Delta d}{d} + \frac{\Delta \rho}{\rho}$$

$$= \frac{\Delta l}{l} - 2\left[-\mu\frac{\Delta l}{l}\right] + \frac{\Delta \rho}{\rho}$$

$$= \frac{\Delta l}{l} + 2\mu\frac{\Delta l}{l} + \frac{\Delta \rho}{\rho}$$

$$\frac{\Delta R}{R} = \frac{\Delta l}{l}[1 + 2\mu] + \frac{\Delta \rho}{\rho}$$

$\therefore$ Gauge factor $S = \dfrac{\Delta R/R}{\Delta l/l} = \dfrac{\frac{\Delta l}{l}[1+2\mu] + \frac{\Delta \rho}{\rho}}{\Delta l/l}$

$$S = 1 + 2\mu + \frac{\Delta \rho/\rho}{\Delta l/l}$$

This is due to piezo electric effect.

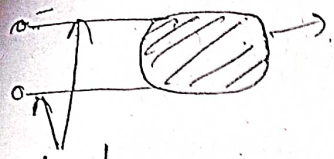
Thermistors:-

Basically the thermistors are as thermal resistors The resistors, which are depending on temperature are known as thermal resistors. They having +ve temperature coefficients. But in general the resistors having NTC - Negative temperature coefficient are called thermistors.

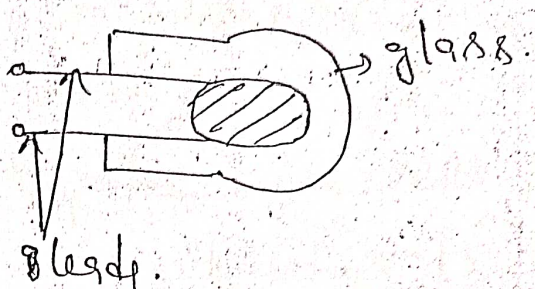
As temp increases, the resistance of thermistor can decreases. The thermistors are large (or) small

it can measure both low & high temperature range.

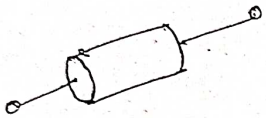
Construction of Thermistors :-



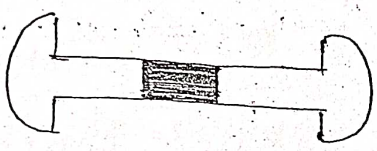
(i) Disc.



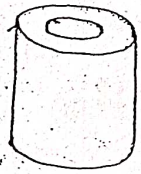
(ii) Probe.



(iii) Bead



(iv) Rod.



(v) Washer type.

Thermistors are composed of manganese, nickel, cobalt, copper, iron and uranium. Their resistance at ambient temperature may range from 100Ω to 100kΩ. They are available in wide range & variety shapes.

→ The smallest thermistors are beads of 0.15mm – 1.25mm.

→ They beads are sealed in tips of solid glass to form a probe.

→ Discs & washers can be made by pressing thermistor material at high pressure into cylindrical shape.

→ The washer can be placed in series (or) parallel for power dissipating

→ Thermistors are used in temperature measurem temp control because of their very large in resistan with temperature.

The operating range are −100°c to +200°c. The change in resistance with temp is carried out by a wheat-stone bridge.

characteristics

(a) Resistance temperature characteristics:-

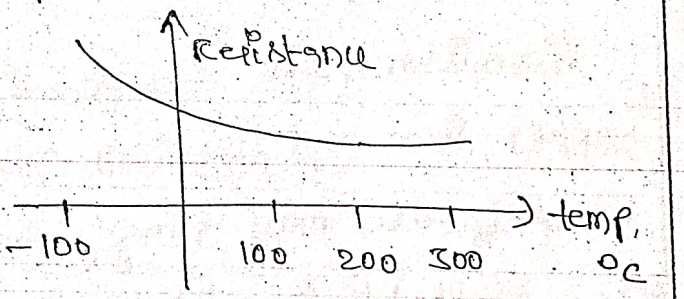
$$R_{T_1} = R_{T_2} e^{\left[\beta\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]}$$

R_{T_1} - resistance at T_1°k

R_{T_2} - resistance at T_2°k.

β - constant 3500 - 4500°k.

The equation shows that an exponential term and shows that a highly non linear in nature. It has high negative temperature coefficient.

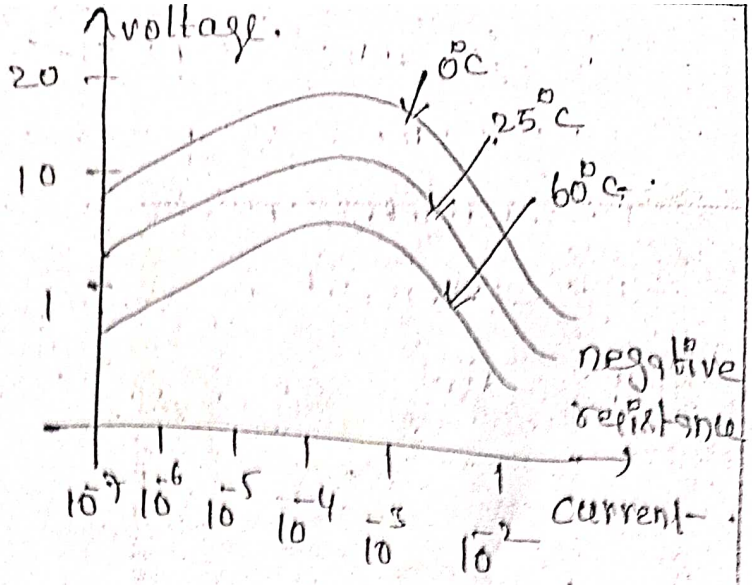


The characteristics are non linear and type characteristics are linear for small range.

(b) voltage current characteristics:-

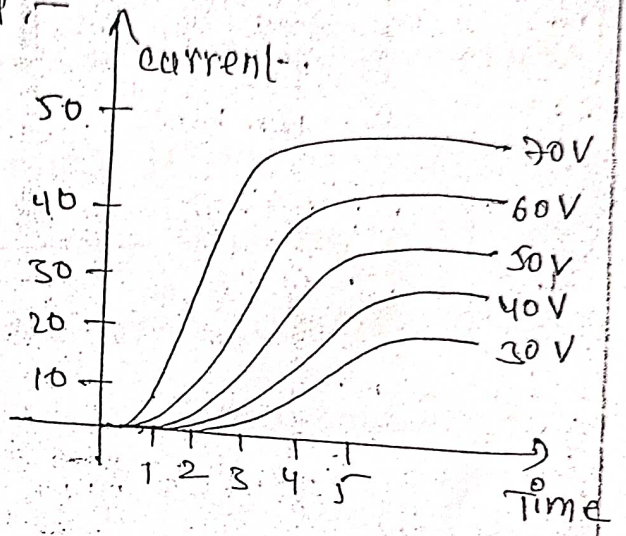
It can be seen that current increases, the voltage across thermistor increases up to a peak level and then decreases

⇒ when it can decreases the negative resistance region



Whenever low voltage is applied to thermistor, small current can flows. This does not produce heat as so as to change resistance of thermistor.

(c) current - time characteristics:-



At low voltage thermistor take large time to reach peak current at voltage increases the time required is decreased.

Advantages:-

→ Small size, low cost, fast response.
→ Large change in resistance for small change in temp.
→ Signal conditioning circuit required is simple.
→ Stable response.

Disadvantages:-

→ The R-temp characteristics are non-linear.
→ Not suitable over a wide temp range.

Applications:-

→ useful for temperature transducer.

→ Ideal for remote control.
→ Measurement of power at high frequencies.
→ Measurement of thermal conductivity.
→ Measurement of vacuum.
→ providing time delays.
→ pressure, flow and liquid level measurements.

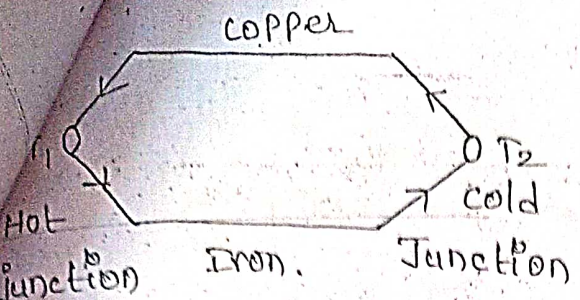
Thermocouple

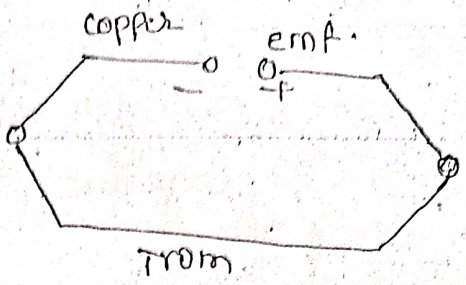
Thermo electric transducer is a temperature transducer which can converts thermal energy into electrical energy. The mostly common used one is "thermocouple". It is a primary transducer which can converts the temp directly into electrical signal. The behaviour of thermocouple can be explained on the basis of:

1) seebeck effect.
2) peltier effect
3) Thompson effect.

Seebeck effect:-

If two wires of difference material are joined together and forming a closed ckt and if two junctions are at different temperatures, An electric current flows around closed ckt. This is called seebeck effect (i.e) If copper and iron are two materials, the current flows from copper to iron at hot junction and from iron to copper at cold junction.

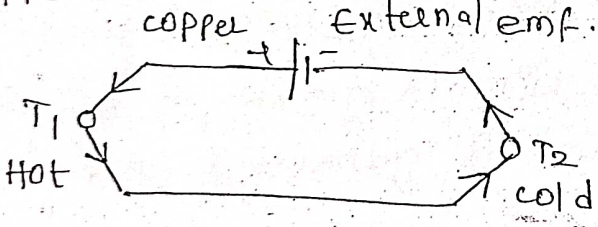




If the copper wire can be cut, if emf appears across open circuit. This emf is known as seebeck effect.

Peltier effect:-

prof. peltier discovered a reverse phenomenon when two dissimilar metals from two junctions and an external emf is connected then current flows through the junctions. The current from copper-iron makes T_1 as hot by absorbing. The current from iron-copper makes T_2 as cold by liberating. This is called peltier effect.

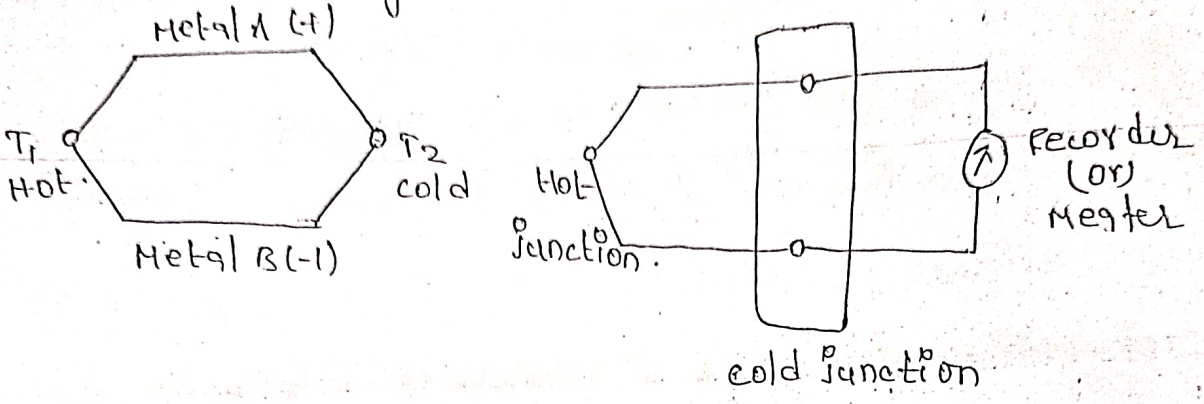


Thompson effect:-

According to prof. Thompson when a current flows through a copper conductor. Heat is released at a point where current is in direction same as heat flow and heat is absorbed when current is opposite direction of heat flow. This is known as thompson effect.

Construction of thermocouple:-

Thermo couple is made up of two wires of dissimilar metals joined together to form two junctions.



Out of two junctions T_1 & T_2. T_2 is kept at constant temperature. Hence it is referred as cold junction and temperature change which is to be measured is subjected to T_1 is known as Hot junction.

∴ Hot junction is known as measuring junction and cold junction is known as reference junction.

The temperature of Hot wire is greater than the temp of cold wire then emf is generated and the magnitude of generated emf is depends on materials used and temperature difference between two junctions. The two wires of thermo couple are twisted and welded together.

A general junction can be formed by 2 methods

1) Butt weld
2) twisted weld.

In case of butt weld, two wires are fused into a round bend.

In case of twisted weld first wires are twisted and then welded.

To measure high temperature the wire should be heavier. But if the size of wire increases then the response time can be increased. Therefore Moderate can be taken.

Materials used for thermo couples:-

Material used	Type of Thermocouple	Temperature range.
Copper-constantan	T	-250°c to 400°c.
Iron-constantan	J	-200°c to 850°c.
chromel-Alumel	K	-200°c to 110°c.
chromel-constantan	E	-200°c to 850°c.
Platinum-platinum -rhodium	S	0°c to 1400°c.
Tungston-Molybdenum	—	0°c to 2700°c.
Tungston-Rhenium	—	0°c to 2600°c.

The two junctions are insulated to each other and the type of insulating material can be depend on the temp range.

Insulating material	Temp range.
Enamel & cotton	250°F
Asbestos	900°F
Glass	900°F
ceramic insulators	2600°F.

Advantages:-

→ It is rugged in contruction.
→ It's temperature is a wide range -270°c to 2700°c.
→ It's coast is low
→ calibration can be easily checked.
→ Good reproducibility.
→ High speed respose.
→ Accuracy is high.

Disadvantages:-

→ For accurate measurement, cold junction is compensated necessarily.
→ In many applications, amplification is necessary
→ The emf & temp characteristics are non-linear.

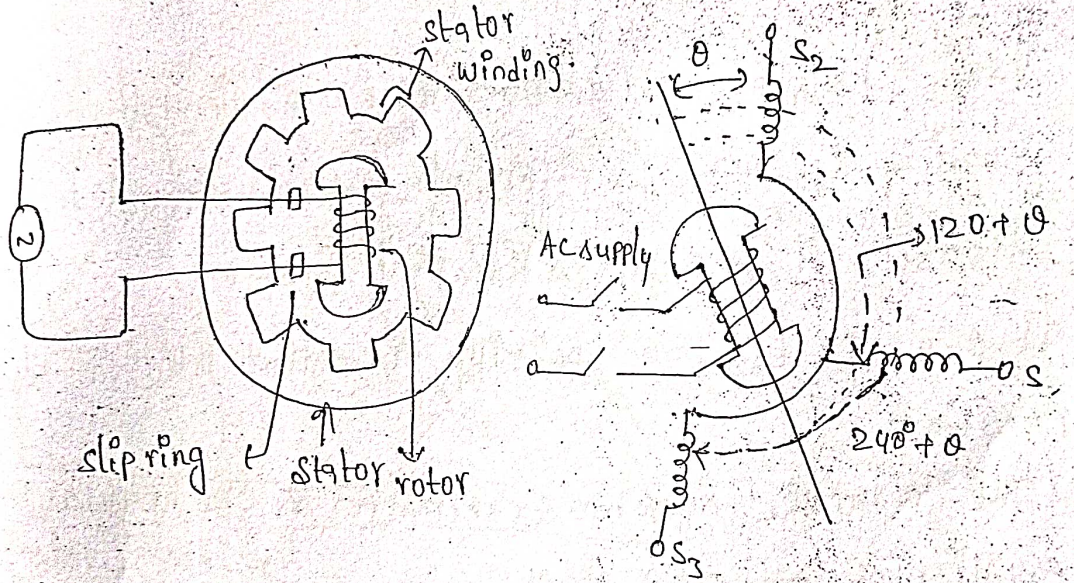
characteristics:-

→ The temp-emf characteristics are reasonably linear.
→ The cost should be reasonable.
→ The material should be able to withstand high temp, and effects of corrosive atmosphere.

are widely used in control systems as detectors encoders because of its rigidness and high reliability chro is a rotary devici, an electromagnetic trawducer ich operates on same principle that of trawformer i.e nverts angular of shaft into electrical signal.

Synchro Transmitter:-

Its construction is similar to that of 3-ϕ alternator.



The stator part is made up with laminated steel. This part is slotted and 3-ϕ wdg is placed in it and the wdg should be star connection.

The rotor part is a dumb-bell shaped magnet with a single wdg.

A 1-ϕ Ac voltage is applied to rotor through slip rings.

$$e_r(t) = E_r \sin \omega_0 t$$

when θ=0°. the voltage induced in S_2 wdg will be

maximum, and position is called as electric zero.

The applied voltage in rotor coil produces sinusoidal varying flux. This flux is distributed in airgap. Because of transformer action voltage gets induced in wdg.

$E_{S1n} = K E_r \cos(\theta - 240) \sin\omega_0 t$

$E_{S2n} = K E_r \cos\theta \sin\omega_0 t$

$E_{S3n} = K E_r \cos(\theta - 120) \sin\omega_0 t$

Terminal voltage are,

$E_{S12} = E_{S1n} - E_{S2n} = \sqrt{3} K E_r \sin(\theta + 240^\circ) \sin\omega_0 t$

$E_{S23} = E_{S2n} - E_{S3n} = \sqrt{3} K E_r \sin(\theta + 120^\circ) \sin\omega_0 t$

$E_{S31} = E_{S3n} - E_{S1n} = \sqrt{3} K E_r \sin\theta \sin\omega_0 t$

If $\theta = 0$, the $E_{S3S1} = 0$, position is called electric zero position

∴ The i/p to the synchro transmitter is the angular position of its rotor shaft.

The o/p is a set of three 1-ϕ voltage.

(2) Synchro control transformer:-

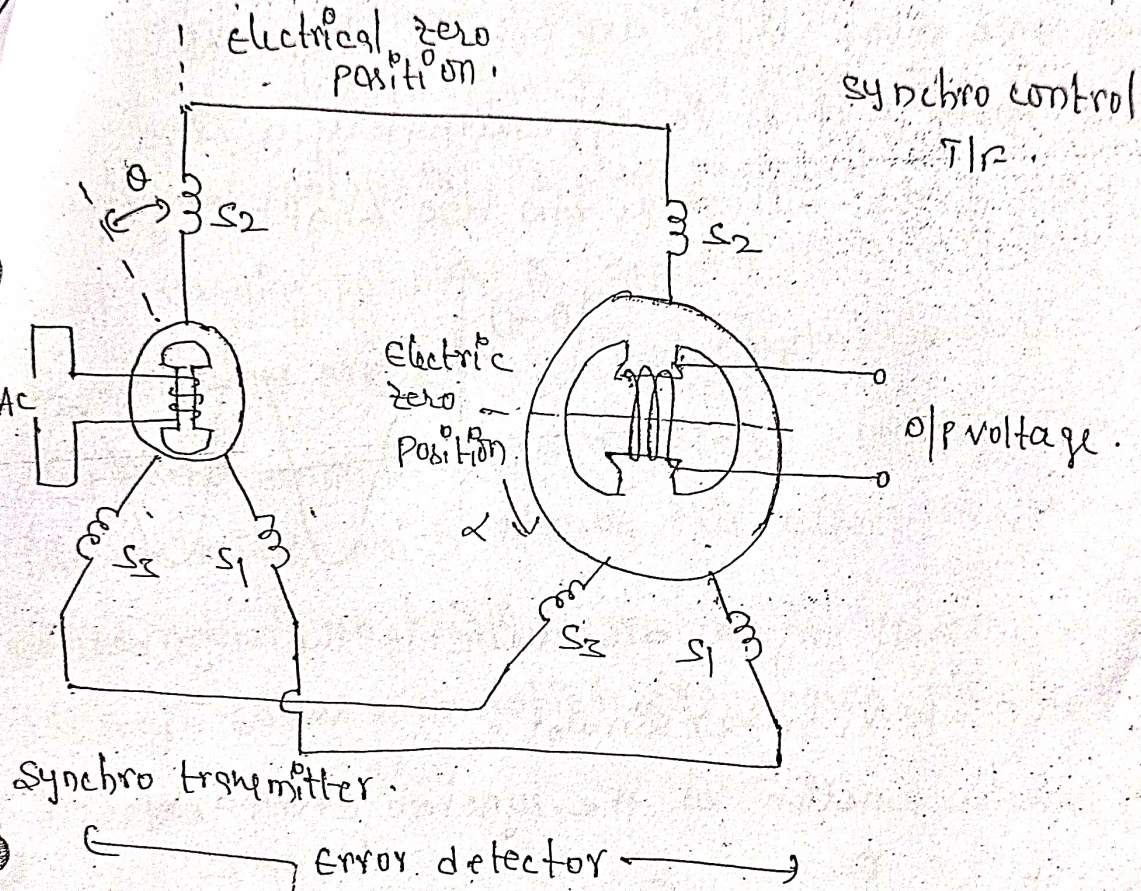
The error detector is used to convert the difference of two shaft positions into an electrical signals by using synchro transmitter and synchro control transformer.

Synchro control TF is a electro mechanical device, which produces a 1-ϕ voltage whose magnitude

proportional to sine of the angle of rotation of PTs with respect to stator magnetic field.

Principle of operation of synchro control TIF is same synchro transmitter.

Error detector using synchros:-



The o/p of synchro transmitter is connected to the synchro control TIF when the rotor positions of two synchros are in perfect alignment, the voltage generated across terminals of rotor of control TIF are zero. This position is called electrical zero position.

Let, the transmitter rotate through an angle 'θ' as shown in fig. Then the synchro control TIF rotor can

rotated in same direction of angle γ

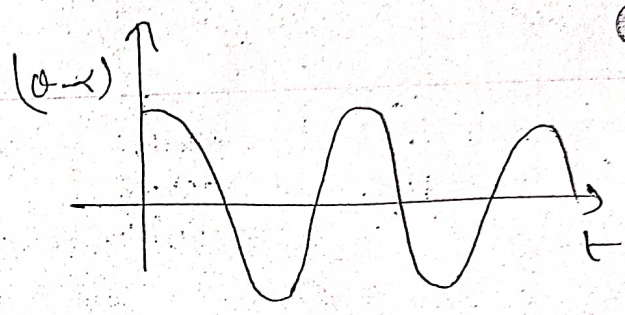
$\therefore$ Net angular separation of two rotors $= (90^\circ - \theta + \gamma)$

The voltage across terminals of control TF are

$$e(t) = k' V_r \cos\phi \sin\omega_0 t.$$

sub $\phi \Rightarrow e(t) = k' V_r \sin(\theta - \gamma) \sin\omega_0 t.$

when two rotor shafts are not in alignment, the rotor voltage of CT is approximately a sine function of the difference b/w two shaft angles.



for very small angular displacement the eqn becomes

$$e(t) = k' V_r (\theta - \gamma) \sin\omega_0 t.$$

The transfer function of the synchro error detector is

$$K_s = \frac{E}{\theta_r - \theta_e} = \frac{E}{\theta_e}.$$

K_s - sensitivity of error detector.

Features of control transformers (CT)

→ The rotor is in cylindrical shape, air gap is uniform so change in rotor o/p impedance with of shaft gets minimised.

→ stator wdg has higher impedance per phase.

electric transducers:-

two opposite faces of thin slice of certain crystals applied to a mechanical force, then opposite charges are developed on two faces of slice. The magnitude of the electric potential between two faces is directly proportional to deformation produced.

If the deformation is reversed then also the polarity of potential is also reversed.

If varying potential is applied to axis of crystal, the dimensions are changed and crystal deforms.

This phenomenon is called as piezo electric effect and the materials which shows this effect are known as piezo electric materials.

The main substances which can shows piezo electric effects are

- → quartz.
- → Rochelle salts.
- → tourmaline.

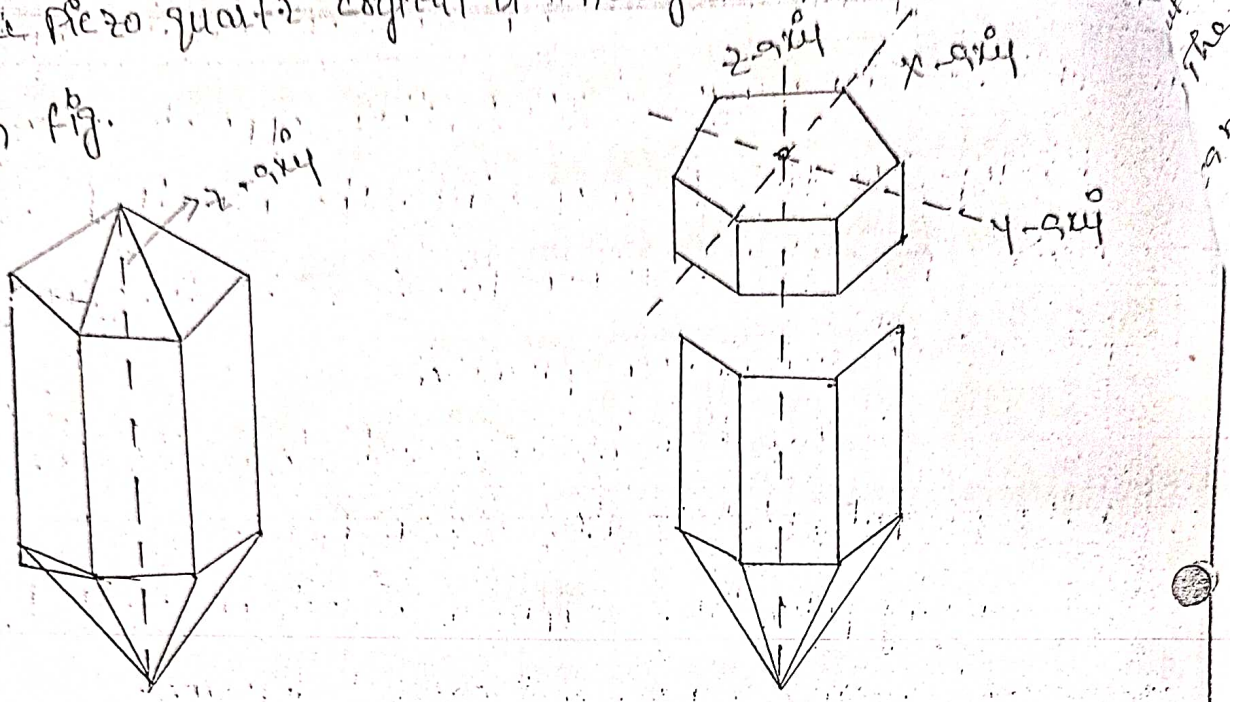
→ Rochelle salts shows great piezo-electric activity and weakest one.

→ Tourmaline is the strong one but has low piezo-electric activity.

→ Quartz is a compromise b/w the above two (ie) piezoelectric activity of Rochelle salts and strength

of tourmaline.

The piezo quartz crystal of hexagonal prism is as shown in fig.

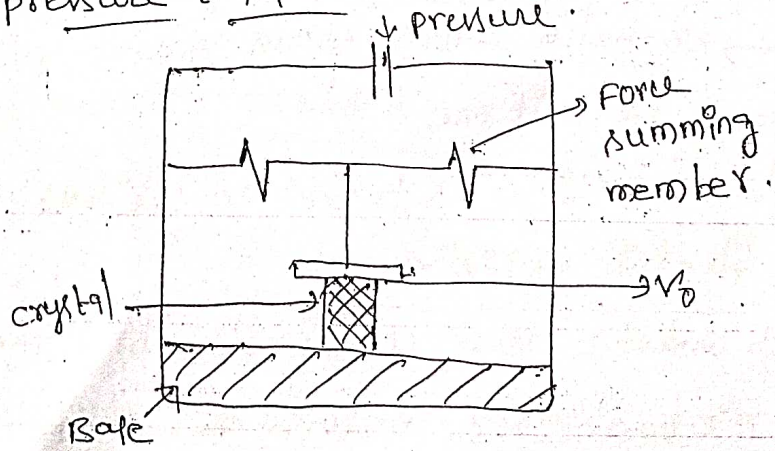


The above one has pyramid. The axis passing through the end points of pyramid is called optic axis (or) z-axis.

The axis passing through corners is called electrical axis (or) x-axis.

The axis passing through mid points of opposite sides is called mechanical axis (or) y-axis

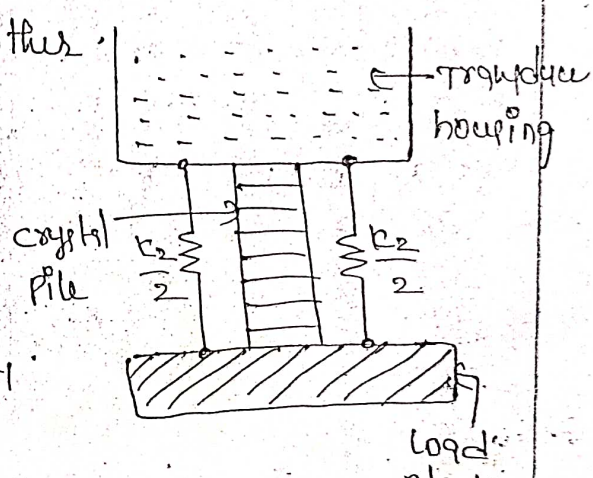
Basic piezo electric pressure transducer



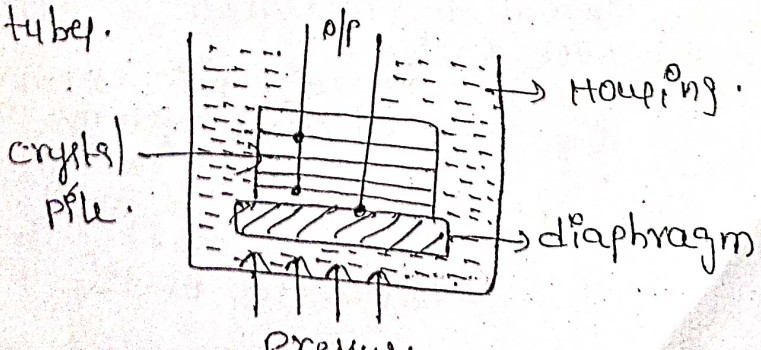
crystal is placed b/w solid base and force summing member
Metal electrode plates on the crystal are used to take output.
The electrodes are act as capacitor plates and it can be consider as charge generator.

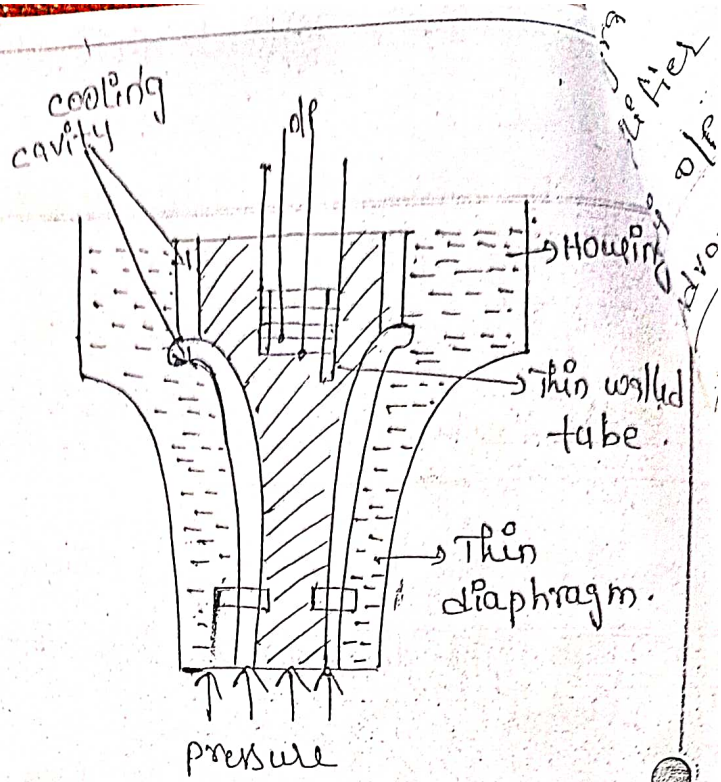
o/p $V_0 = Q/C$.

→ It's size is small and high o/p at 1-50mV.
→ The o/p is effected by temp change. It is a water soluble.
→ Practically piezo electric element of a piezo electric transducer is a pile of pairs of quartz discs.
→ Thye faces are parallel to load plate face.
→ one side is load plate and other side is ~~connected~~ transducer housing thye two are connected by preloading spring of stiffness K_2. The stiffness of crystal is K_1.



⇒ In olden days preloading diaphragm are used, but thye are effected by temperature change so those are replaced by load tubes.





→ The force which is produced by external pressure is P. This can be devided into two parts.

(1) Force in crystal pike (P_1)

(2) Force in preloading thin walled tube (P_2)

$\therefore P = P_1 + P_2 = K_1 \Delta x + K_2 \Delta x$.

$= \Delta x (K_1 + K_2)$

$\Rightarrow \frac{P_1}{P} = \frac{K_1 \Delta x}{(K_1 + K_2)\Delta x} = \frac{K_1}{K_1 + K_2} = \frac{1}{1 + \frac{K_2}{K_1}}$

$\frac{K_2}{K_1}$ is decreased due to this $\frac{P_1}{P}$ is increased.

→ The linear operation is possible only when $\frac{K_2}{K_1}$ is constant over range.

→ To do this the bending systems are spot welded and proper cooling system is used.

→ the natural frequencies of this one is 30-50 KHz

→ The o/p of crystal is inform of charge 'Q' and

...ration of charge a given current. The charge ...plifier is integrate f/r charge and produces some o/p. ...'s o/r is amplified by voltage amplifier.

Advantages

→ Rugged and small coustruction
→ High o/p.
→ Excellent frequency response.

Disadvantages

→ Temp sensitive.
→ It can be used for dynamic measurements only.

Applications:-

→ For non electrical quantity measurements like acceleration, vibration, sound.
→ It is used in ultrasonic flow meters.
→ It is also used in electrostatic dust filters
→ It is used in aerodynamics, bomb blast, supersonic wind tunnels.

photovoltaic transducers:-

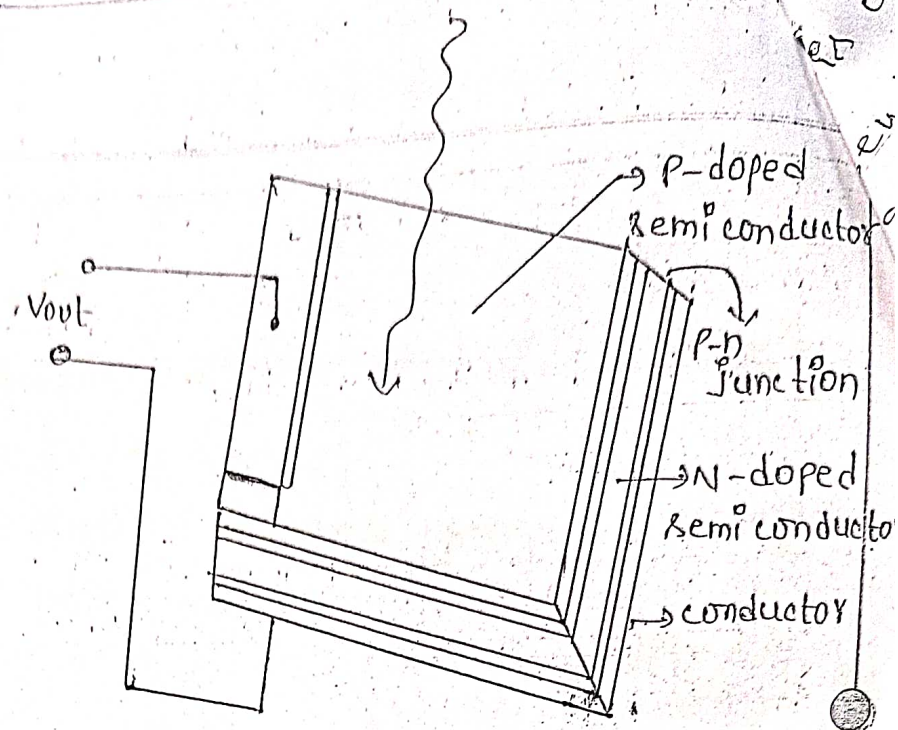
when an open circuited p-n junction is illuminated, large no'of electron-hole pairs are generated in region near junction.

A small voltage appears across its terminals. Hence acts as voltage source. This phenomenon (i.e) in which light energy is converted into electrical energy is called photovoltaic effect.

Ex:- photovoltaic cell.

photo voltaic-cell:

The cell is actually a P-N junction with doped semiconductors.



when photons strikes on thin P-doped layer, they are absorbed by electrons in n-layer, due to this formation of conduction electrons and holes.

The conduction electrons and holes are separated by depletion region potential of P-n junction. when a load is connected across cell, the depletion region potential causes a photo current to flow through load.

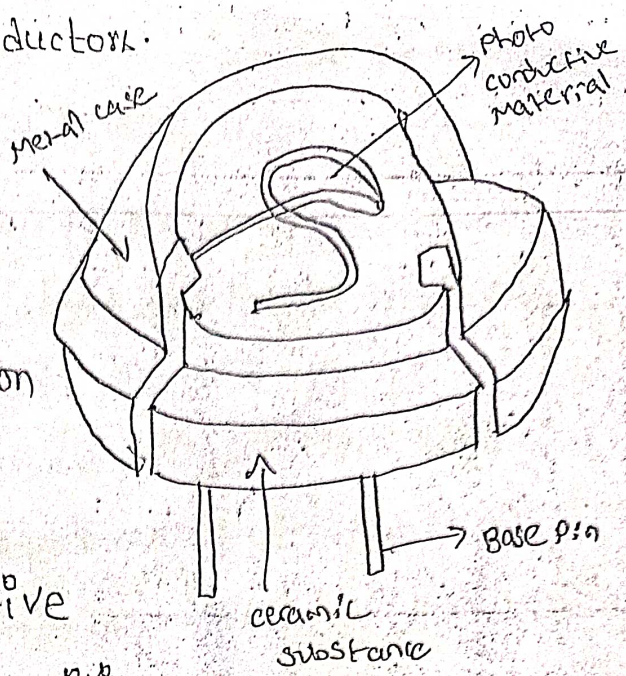
photo conductive cells:-

when light falls on a material, the energy in radiation ionizes the covalent bonds. Thus the bonds are broken and large no of electron-hole pairs are generated. This can increases no of current carrier and decreases resistance of material. This phenomenon is known as photo conductive effect. The devices are called as

...resistors (or) photo conductors.

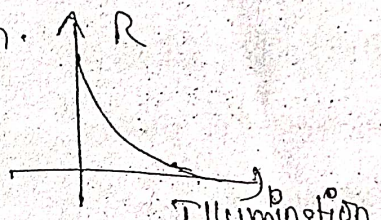
→ commonly used photo sensitive element in relays and proximity switches.

→ It is also used in population alarms and counters of persons.



→ In this one photo sensitive element is placed in zig zag position.

→ The symbol is as shown.





→ The most commonly used materials are cadmium sulphide (CdS) and cadmium selenide (CdSe)

→ The peak spectral response occurs ~~the no of~~ for

CdS at 5100 A°

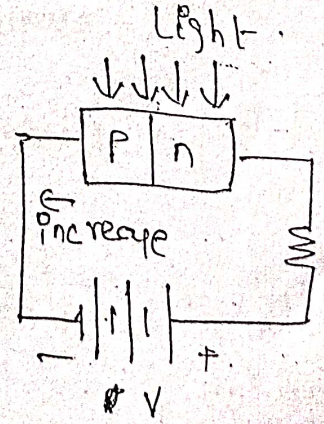
CdSe at 6150 A°

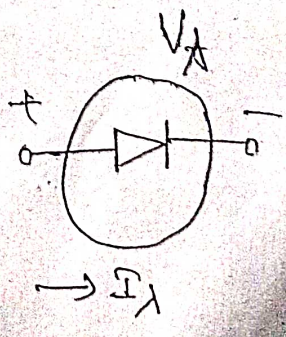
→ The illumination increases, the no of photons increases and giving large no of free electrons.

∴ Resistance decreases.

Photo diode:-

It is a diode which is used to detect and its operation is limited in reverse bias region only.

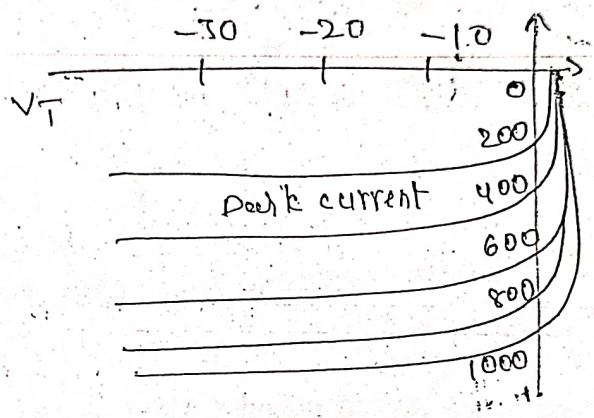




In case of normal diode, under reverse biased cond the reverse current is due minority charge carriers in P-type & n-type regions (μA).

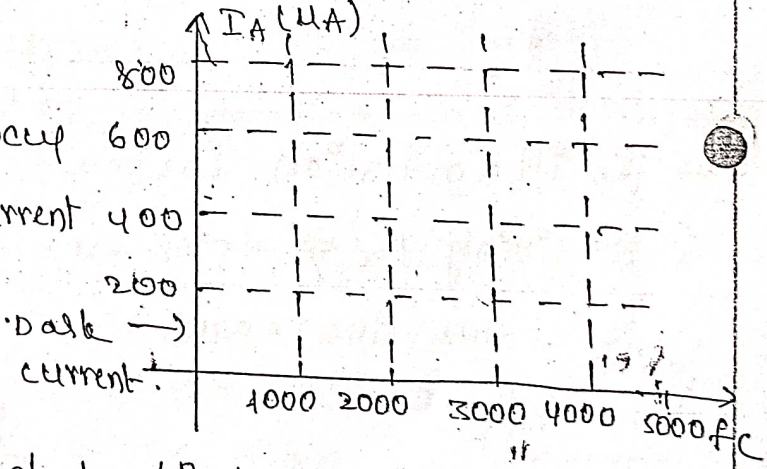
In case of photo diode, when light fall on it the energy in the form of photons is transform into atomic structure. They can increase no of minority charge carriers in both p & n regions.

∴ Reverse current can increase with increasing light intensity as shown below.



→ Dark current is the reverse current in photo diode when there is no illumination.

→ From the characteristics it is seen that for increment in luminous focus same in increment in current (i.e) linear characteristics.



→ The rise & fall time in photo diode is very small (nano seconds)

→ They are mostly used in high speed switching and counting applications.

semi conductors used are Ge and Si out of
Ge has wide wavelength
can be used to detect infrared light.
also has high level of reverse current as compare
Si.
but the dark current in Ge is higher than Si.
when a photo diode is illuminated without applying
reverse biasing voltage, it acts as voltage source
P-region (+ve) n-region (-ve).
→ In this mode of operation it is called photo
voltaic diode (or) solar cell.
→ The materials which are used in solar cells are

* Silicon
* selenium.
* Gallium arsenide.
* cadmium sulphide.
* Indium arsenide.