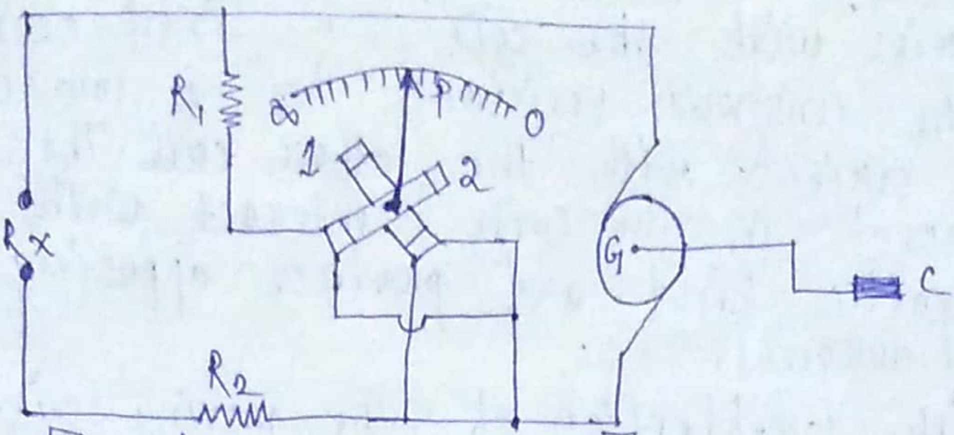
[Measurement]

Ckt diagram of a Megger and the method of measurement of high resistance cable :-

→ Meggers are the instruments which measure the insulation resistance of electric ckts relative to earth and one another.



[Ckt diagram of Megger]

Where,

G = Generator , C = crank , 1,2 = coils

P = pointer , 1 = current coil

2 = pressure/voltage coil

R_x = unknown resistance

R_1 = Fixed Resistance

R_2 = safety resistance

→ A Megger consists of an emf source and a voltmeter. The scale of the voltmeter in calibrated ohms (kilo-ohms or mega-ohms).

→ The emf of self-contained source must be equal to that of source used in calibration.

→ The above figure shows a megger whose readings are independent of the speed of the self-contained generator.

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→ The moving system incorporates two coils 1 (current coil) and 2 (pressure coils) mounted on the same shaft and placed in the field of a permanent magnet.

→ The generator energizes the two coils where the separate wires connected in series with the coil is a fixed resistance.

→ The unknown resistance 'Rx' is connected in series with the other coil. The current in the coils interact with the magnetic field and produce opposing torques.

→ The deflection of the moving system depends on the ratio of the currents in the coils and is independent of the applied voltage. The unknown resistance is read directly from the scale of the instrument.

Q:→ Why an ammeter should be of very low resistance? (2 marks)

Ans:→ When it is connected in series with any circuit, it does not change the current. Consequently, there is a small voltage drop and small power is absorbed. That's why an ammeter should be of very low resistance.

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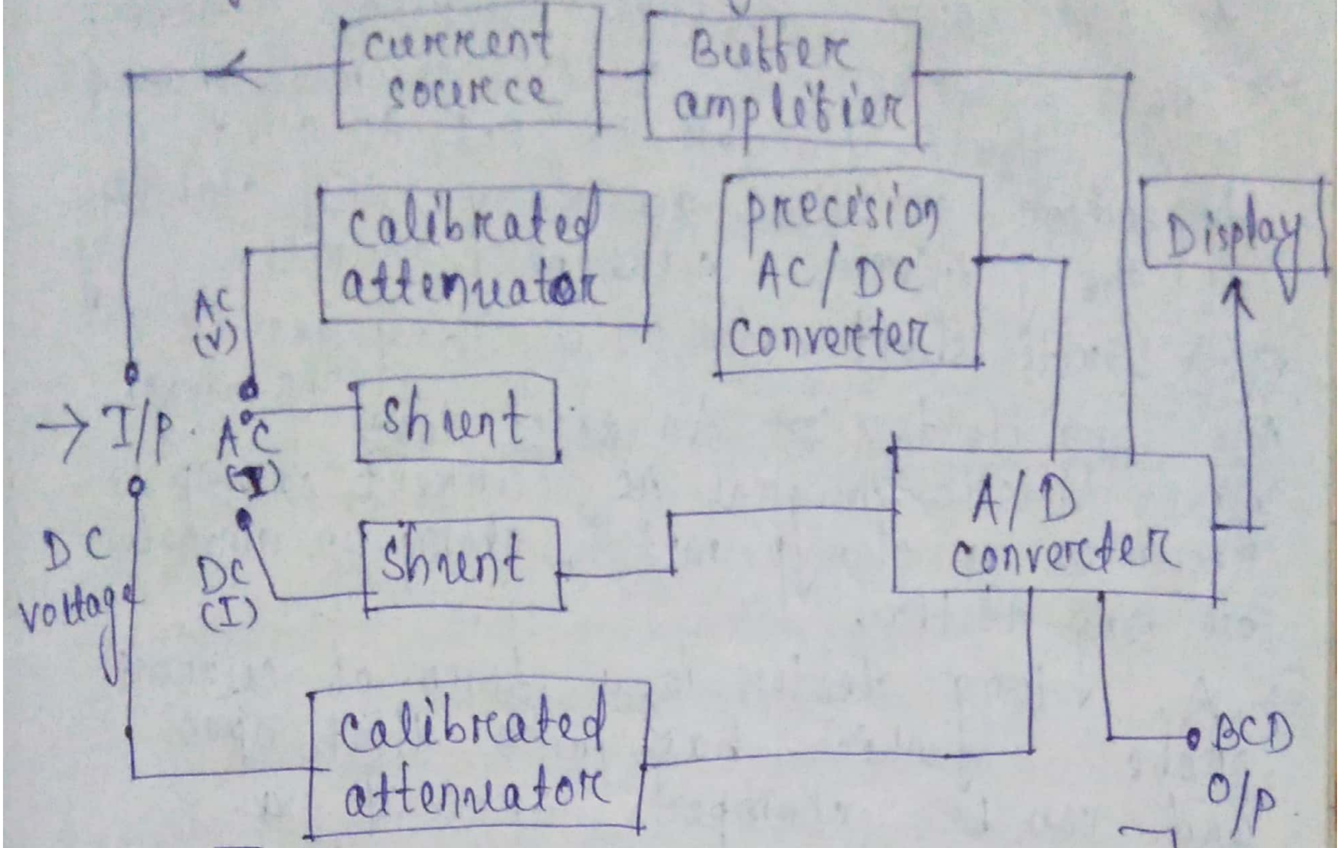
Working principle of Digital Multimeter :→



[Block diagram of Digital Multimeter]

(i) In A.C voltage mode, the applied input is fed through a calibrated, compensated attenuator, to a precession full-wave rectifier ckt followed by a reduction filter. The resulting DC is fed to ADC and the subsequent display system.

(ii) For current measurements, the drop across an internal calibrated shunt is measured directly in the DC current mode. This drop is often in the range of 200 mV corresponding to full-scale.

(iii) In the resistance range the digital multimeter operates by measuring the voltage across the externally connected resistance resulting from a current forced through it from a calibrated internal current source.

→ The accuracy of resistance measurement is of the order of 0.1 to 0.5 %. depending on the accuracy and stability of the internal current sources.

Q:→ Write short notes on a Tong Tester? [8 marks]

Ans Tong Tester :→ An electrical meter with integral AC current clamp is known as a clamp meter, clamp-on ammeter or tong tester.

→ A tong tester is a form of current probe which has jaws that open and can be clamped around a cable. By doing so the jaws form a loop for a transformer which can be used to measure current through the wire.

→ No break of the ckt is required as the probe works by the magnetic field around the wire when current passes through it. There are types for both AC and DC.

→ A tong tester measures the vector sum of the current flowing in all the conductors passing through the probe, which depends upon the phase relationship of the currents.

Instrument Transformers :→

→ Instrument transformers are used to reduce the line current or supply voltage to a value small enough to be easily measured with meters of moderate size and capacity.

→ In other words they are used for extending the range of A.C ammeters and voltmeters. The two basic advantages inherent in the method using instrument transformers for measurement purposes:-

(i) standard rated instruments may be used.

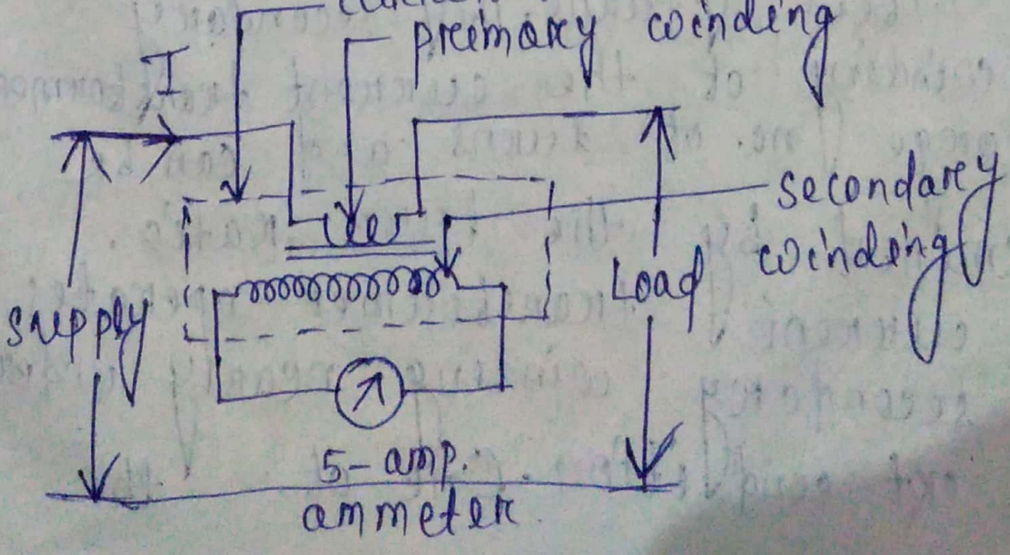
(ii) operating personnel coming in contact with the instruments are not subjected to high voltage and current of the lines and so there is less danger to them.

→ The instrument transformers are classified as follows :-

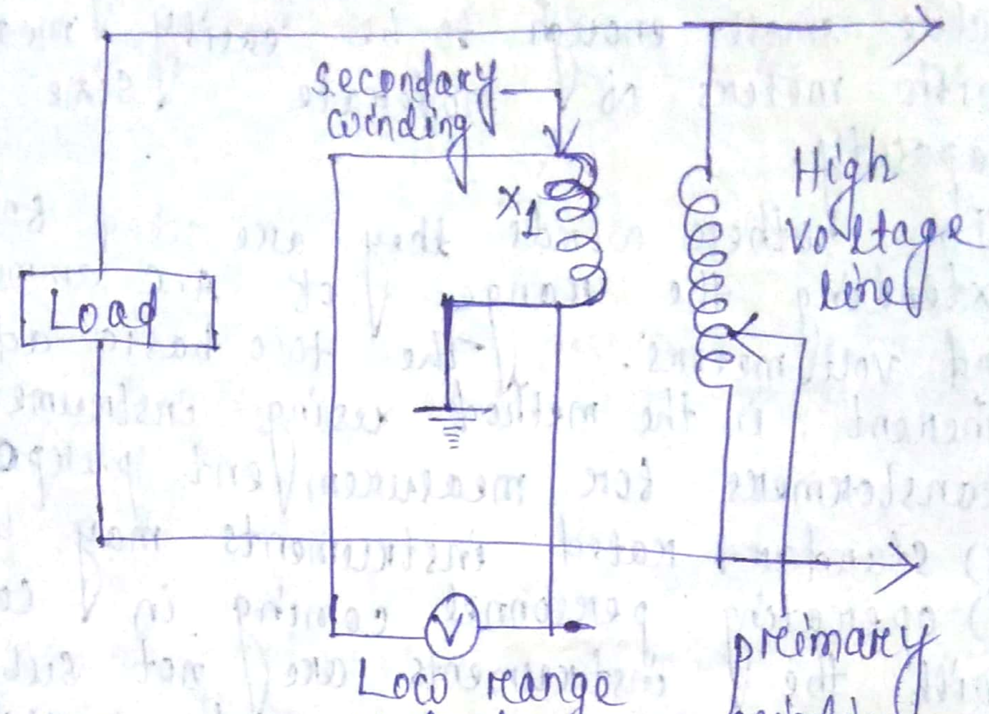
(1) current transformer (CT)

(2) potential transformer (PT)

(1) Current transformer (CT) :→ These are used for the measurement of current.



(2) Potential transformer (PT) :→ These are used for the measurement of voltage.



[Potential T/F connections]

Precautions and uses of CT and PT :→

→ In case of current transformers, the primary winding is connected in series with the line carrying current to be measured.

→ The primary winding consists of very few turns. The secondary winding of the current transformer has large no. of turns and can be determined by the turn ratio.

→ The current transformer operates its secondary winding nearly under short ckt condition. One of the terminals of the secondary winding is earthed so as to protect the equipment.

→ In case of the potential transformer (PT), the primary winding of the transformer is connected across the line carrying the voltage to be measured, and the voltage circuit is connected across the secondary winding.

→ The secondary winding is designed so that a voltage of 100 to 120V is delivered to the instrument load.

→ Current transformer is used for the measurement of current and the potential transformers is used for the measurement of voltage.

→ CT is used both measurement and the protection purposes. It measures very high value of current. Regarding the protection point of view in the H.T and EHT lines and substations they are installed and at the time of fault the heavy fault current is stepped down to a very low value, by using C.T.

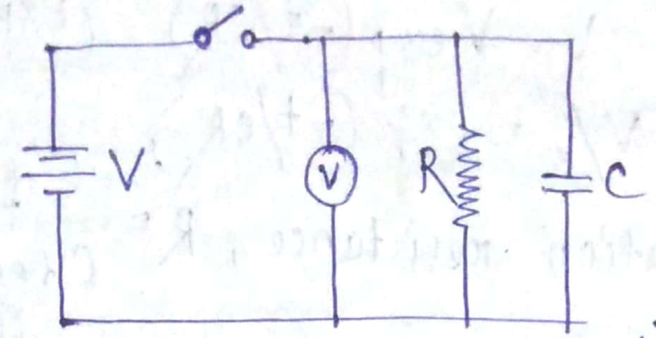
→ When fault occurs, H.V or EHV is induced and the ckt or installation may be damaged. Thus by inserting P.T in that ckt will convert the H.V into L.V and fault is eliminated.

Difference between the operation of C.T & P.T :-

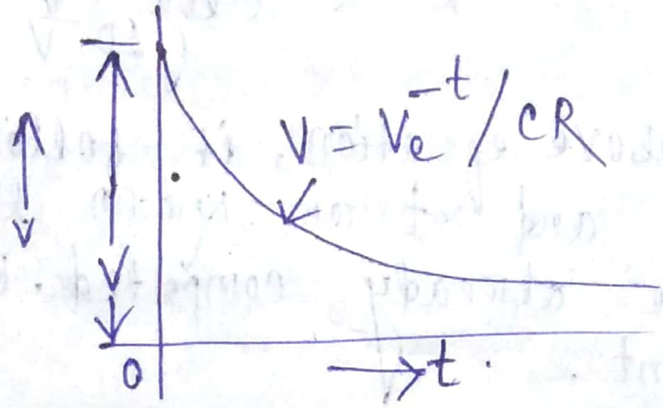
Current Transformer (CT)	Potential transformer (P.T)
(1) secondary must always be shorted.	(1) Secondary is nearly under open ckt conditions.
(2) The winding carries the full line current.	(2) The winding is impressed with the full-line voltage.
(3) The primary current is independent of the secondary ckt conditions.	(3) The primary current depends on the secondary ckt conditions.
(4) It can be treated as series transformers under short ckt conditions.	(4) It can be treated as parallel transformer under open ckt conditions in secondary.
(5) A small voltage exists across its terminals as connected in series.	(5) Full line voltage appears across its terminals.

EM

Measurement of high resistance by loss of charge method :-



[Loss of charge Method]



[Variation of voltage with time]

→ In this method, the insulation resistance 'R' to be measured, is connected in parallel with a capacitor 'C' and an electrostatic voltmeter.

→ The capacitor is charged to some suitable voltage, by means of a battery having voltage 'V' and is then allowed to discharge through the resistance.

→ The terminal voltage is observed over a considerable period of time during discharge.

→ The voltage across the capacitor at any instant 't' after the application of voltage is,

$$V = V \exp(-t/CR) \quad [\text{Exp: Exponential}]$$

$$\text{or, } V/v = \exp(-t/CR)$$

or Insulation resistance, $R = \dfrac{t}{C \log_e \frac{V}{v}}$

$$\Rightarrow R = \frac{0.4343t}{C \log_{10} \frac{V}{v}}$$

→ From the above equation, it follows that if V, v, C and t are known the value of 'R' can be already computed. for this measurement.

→ If the resistance 'R' is very large, the time for an appreciable fall in the voltage is very large and thus, this process may become time-consuming. Also the voltage-time curve will thus be very flat and unless great care is taken in measuring voltages at the beginning and end of the time 't', a serious error may be made in the ratio of V/v causing a considerable corresponding error in the measured value of 'R'.

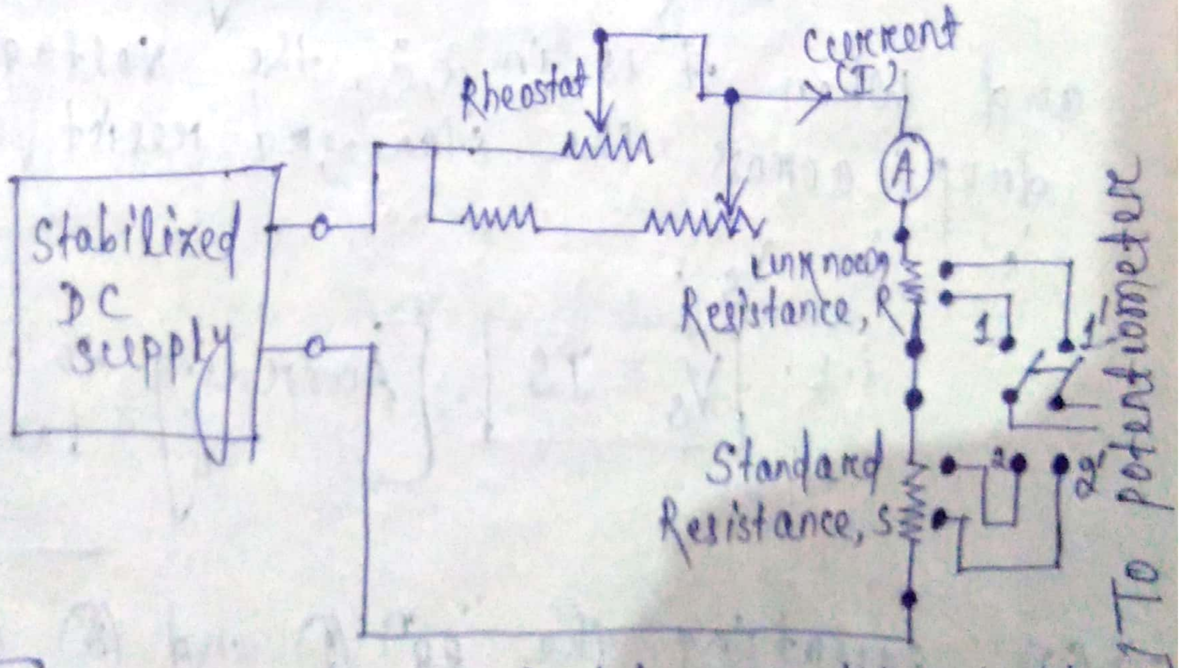
EM

Measurement of low resistance by using potentiometer method :→

→ The DC potentiometer method of measurement of resistance is used for measuring the unknown resistance of low value. This can be done by comparing the unknown resistance with the standard resistance.

→ The voltage drop across the known and unknown resistance is measured and by comparision the value of known resistance is determined.

→ Let understand this with the help of the ckt diagram.



Measurement of Resistance with potentiometer

→ The 'R' is the unknown resistance whose value is needed to be measured.

→ The 's' is the standard resistance from which the value of unknown resistance is compared.

→ The rheostat is used for controlling the magnitude of current in to the ckt.

→ The double pole double throw switch is used in the ckt. The switch when moves to position 1,1, the unknown resistance connects to the ckt and when it moves to position 2,2, the standard resistance connects to the ckt.

→ Consider that, when the switch is in position 1,1 the voltage drop across the unknown resistance is V_R.

i.e. $V_R = IR$ [According to ohm's law] —— (1)

and when it is in 2,2, the voltage drop across the standard resistance 's' is V_S.

i.e. $V_S = IS$ [According to ohm's law] —— (2)

→ On equating the eqn (1) and (2), we get,

$$\frac{V_R}{V_S} = \frac{\cancel{I}R}{\cancel{I}S}$$

$$\Rightarrow \frac{V_R}{V_S} = \frac{R}{S}$$

$$\Rightarrow \boxed{R = \frac{V_R \cdot S}{V_S} \text{ or } \frac{V_R}{V_S} \cdot S}$$

→ The accuracy of unknown resistance depends on the value of standard resistance.

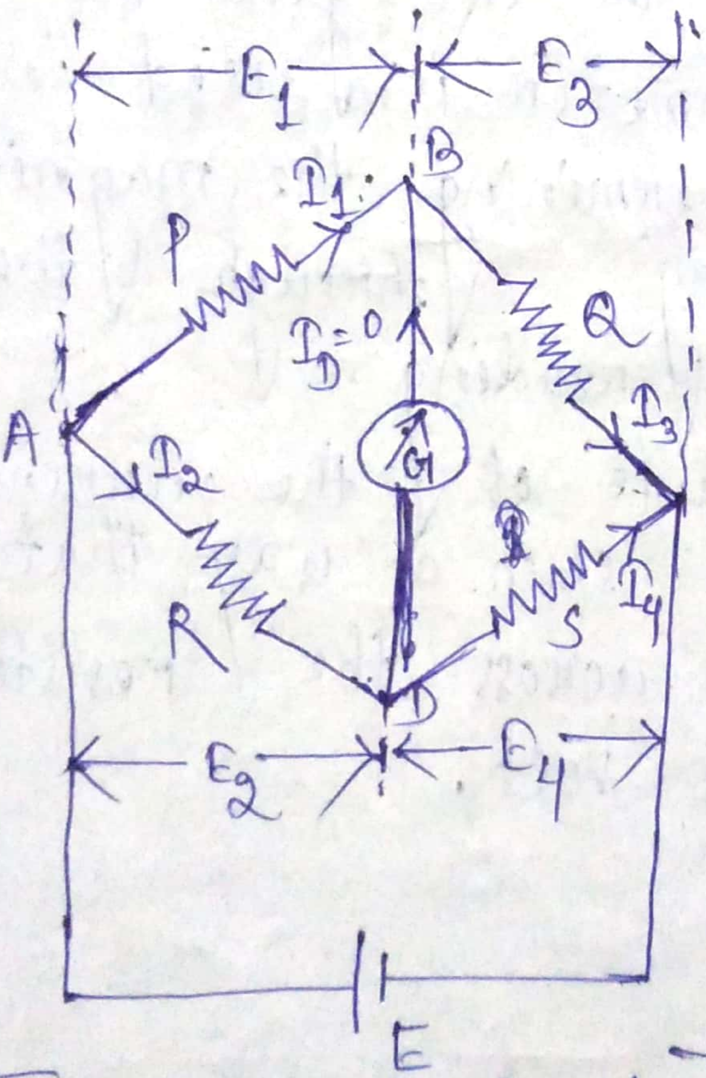
→ The accuracy of the unknown resistance also depends on the magnitude of the current at the time of the readings.

→ If the magnitude of the current remains same, the ckt gives the accurate result. The ammeter is used in the ckt for determining the magnitude of current passing through the resistor during the reading.

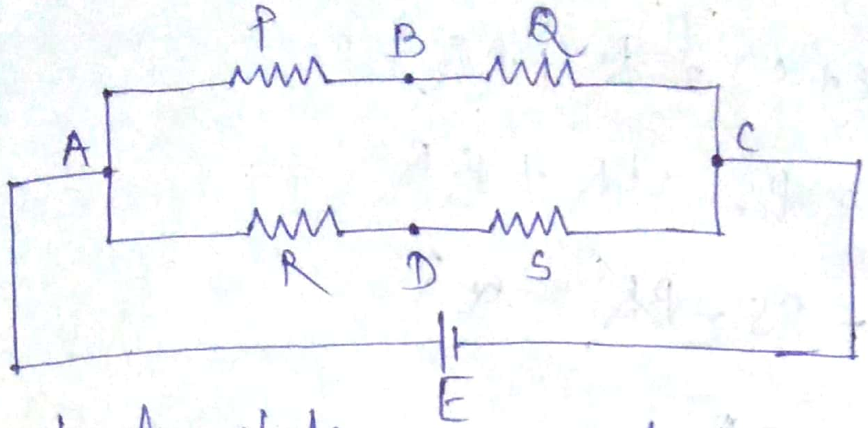
→ The magnitude of the current is adjusted in such a way that the voltage drop across the resistance is equal to 1 volt.

Measurement of Medium resistance by using Wheatstone bridge Method :→

→ It has four resistive arms consisting of resistances P, Q, R and S together with a source of emf and a null detector usually a galvanometer 'G'. The current through the galvanometer depends in the potential difference between the points 'C' and 'D'.



[Wheat stone Bridge]



→ At steady state, 3 conditions are applied,

(1) $I_D = 0$

(2) $V_B = V_D$

(3) $E_1 = E_2$ and $E_3 = E_4$ [∵ voltage drop across the adjacent arm should be equal]

So, for bridge balance,

$I_1 P = I_2 R$ —— (1)

For the galvanometer current to be zero, the following conditions must be satisfied.

Where, $I_1 = I_3 = \frac{E}{P+Q}$

$I_2 = I_4 = \frac{E}{R+S}$

Substituting the value of I_1 and I_2 in eqⁿ (1) we have,

$$\frac{EP}{P+Q} = \frac{ER}{R+S}$$

$$\Rightarrow \frac{P}{P+Q} = \frac{R}{R+S}$$

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$\Rightarrow P(R+S) = R(P+Q)$

$\Rightarrow PR + PS = PR + QR$

$\Rightarrow \cancel{PR} + PS - \cancel{PR} = QR$

$\Rightarrow \boxed{PS = QR}$

i.e. the product of the resistance of the opposite arm should be equal.

As we derive, $PS = QR$

So, $\boxed{R = \frac{PS}{Q}}$

or $\boxed{R = \frac{P}{Q} \cdot S}$

Where, R = unknown Resistance

S = standard arms of the bridge.

P and Q = Ratio arms of the bridge.

→ This wheatstone bridge is also known as the resistance bridge and by using this method we can calculate the medium resistance.

Wheatstone Bridge principle :→

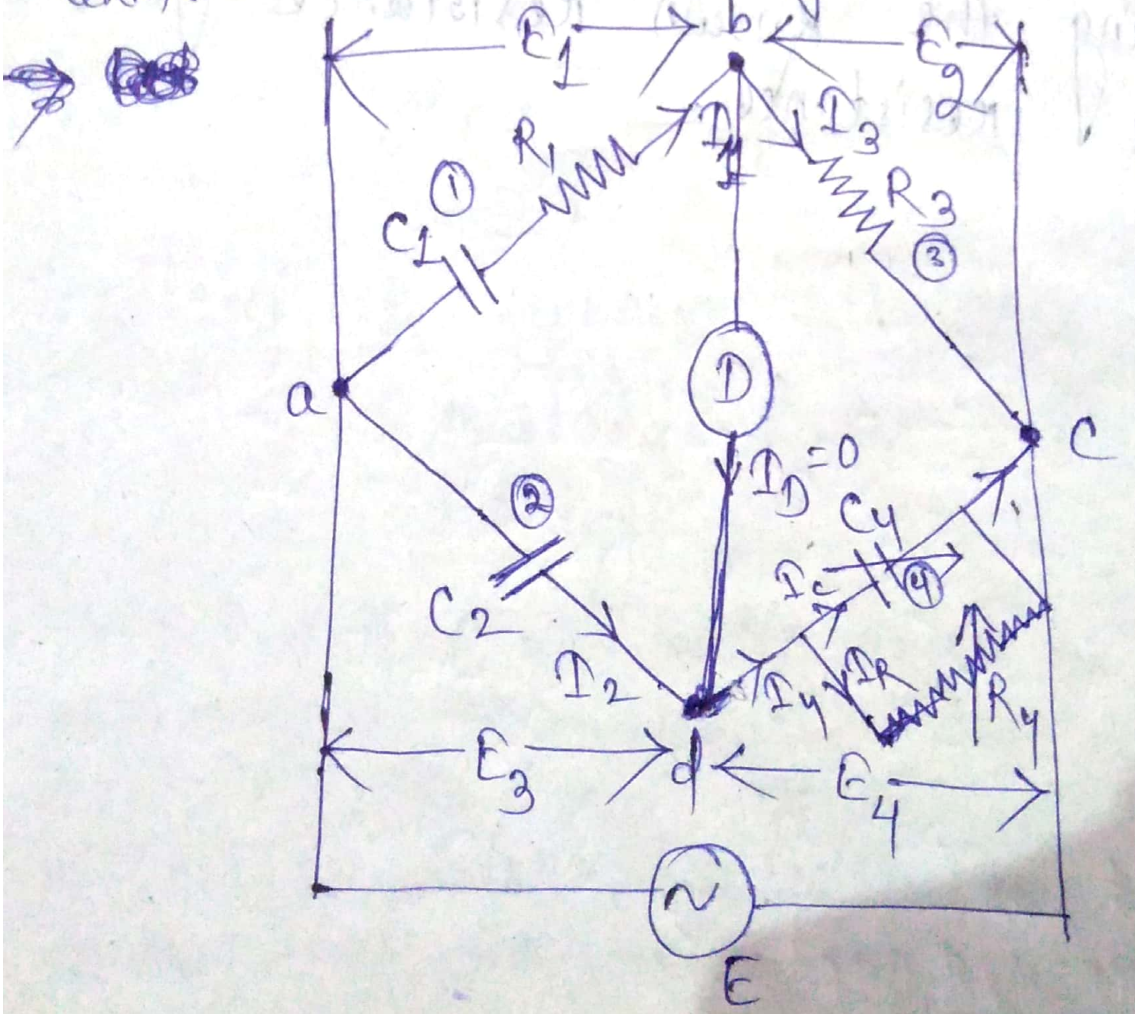
→ It works on the principle of null deflection i.e. the ratio of their resistances are equal and no current flows through the ckt.

→ Under normal conditions, the bridge is in the unbalanced condition where current flows through the galvanometer. The bridge is said to be in a balanced condition when no current flows through the galvanometer.

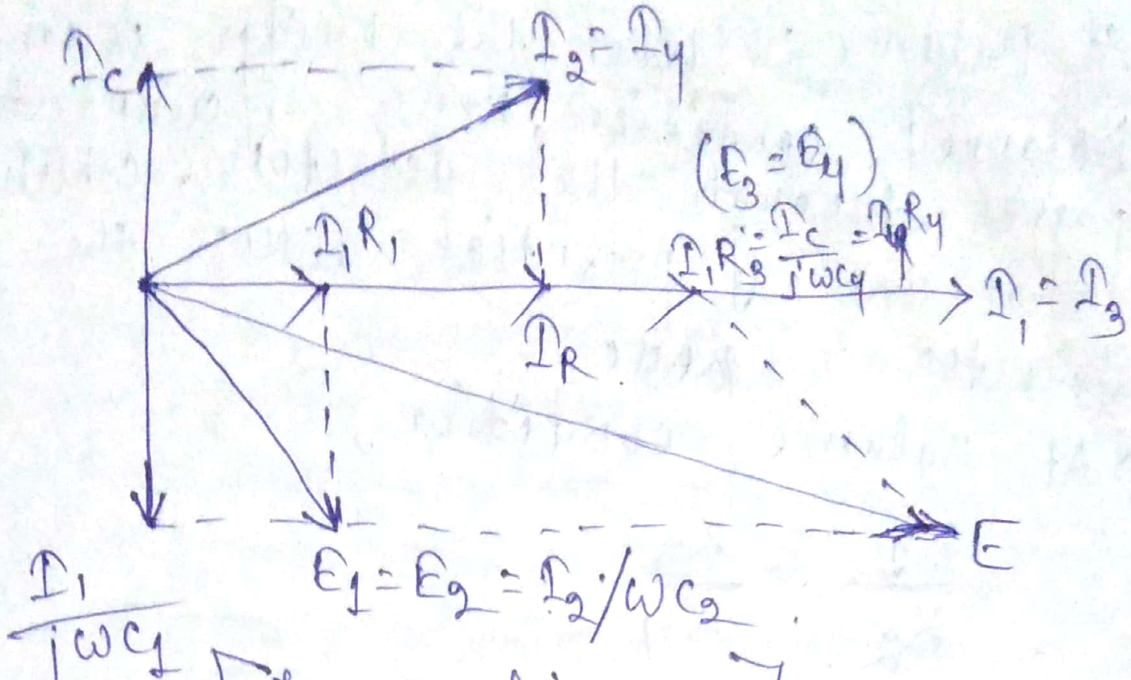
→ This condition can be achieved by adjusting the known resistance and variable resistance.

Measurement of capacitance by schering Bridge Method :→

→ The schering bridge is used for measuring the capacitance of the capacitor, dissipation factor, properties of an insulator, capacitor bushing, insulating oil and other insulating materials. It is one of the most commonly used AC bridge. The schering bridge works on the principle of balancing the load on its arm.



[schering Bridge]



[phasor diagram]

→ In the above ckt diagram, we have,

C_1 = unknown capacitance with its loss component represented as a series resistance 'R_1'.

R_1 = a series resistance, representing the loss of the capacitor C_1.

C_2 = A fixed standard capacitor (The term standard capacitor means the capacitor is free from loss).

R_3 = A fixed non-inductive resistance.

C_4 = A standard variable capacitance or capacitor.

R_4 = A standard variable non-inductive resistance parallel with the variable capacitor C_4.

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At Balance :→ When the bridge is in the balanced condition, zero current passes through the detector, which shows that the potential across the detector is zero.

→ At Balance condition,

$$\frac{Z_1}{Z_2} = \frac{Z_3}{Z_4}$$

$$\Rightarrow Z_1 Z_4 = Z_2 Z_3$$

Here, $Z_1 = R_1 + \frac{1}{j\omega C_1}$, $Z_2 = \frac{1}{j\omega C_2}$, $Z_3 = R_3$

and $Z_4 = \frac{R_4}{1+j\omega C_4 R_4}$

$$Z_1 Z_4 = Z_2 Z_3$$

$$\Rightarrow \left(R_1 + \frac{1}{j\omega C_1}\right) \frac{R_4}{(1+j\omega C_4 R_4)} = \frac{1}{j\omega C_2} \times R_3$$

$$\Rightarrow R_1 R_4 + \frac{R_4}{j\omega C_1} = \frac{R_3}{j\omega C_2} + \frac{C_4 R_3 R_4}{C_2}$$

separating and equating the real and imaginary components in the above expression we have,

$$R_1 R_4 = \frac{C_4 R_3 R_4}{C_2}$$

$$\Rightarrow \boxed{R_1 = \frac{C_4}{C_2} \cdot R_3}$$

and $\frac{R_4}{j\omega C_1} = \frac{R_3}{j\omega C_2}$

$$\Rightarrow \boxed{C_1 = \frac{R_4}{R_3} \cdot C_2}$$

Advantages of schering Bridge :→

(1) Balance equations are free from freqeuency.

(2) The arrangement of the bridge is less costly as compared to the other bridges.

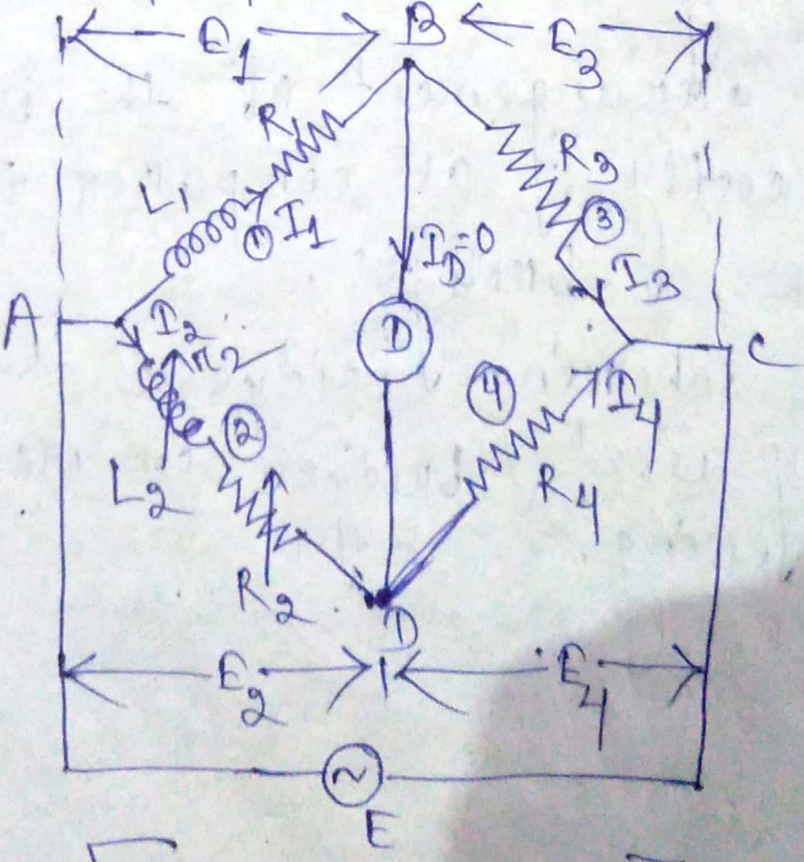
(3) The schering bridge is the most widely used bridge in electrical engineering.

Measurement of Inductance by Maxewell's Bridge Method :→

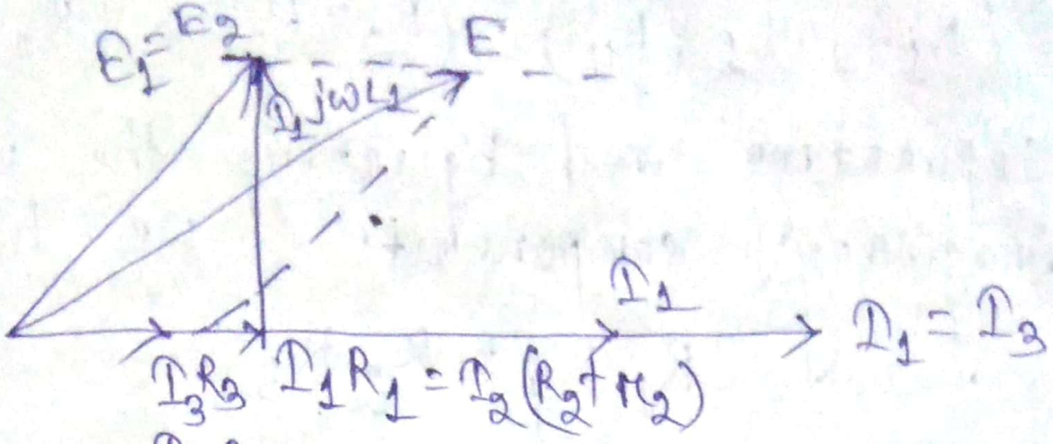
Definition :→ This bridge is used for the measurement of self-inductance of the ckt is known as the Maxwell bridge. It is the advanced form of the wheatstone bridge.

→ The Maxwell bridge works on the principle of the comparision i.e., the value of unknown inductance is determined by comparing it with the known value or the standard value.

→ In such type of bridges, the value of unknown resistance is determined by comparing it with the known value of the standard self-inductance.



[Maxwell's Bridge]



[phasor diagram]

→ In the above ckt diagram, we have,

L_1 = The unknown self inductance with an internal resistance R_1.

L_2 = A standard variable inductance of fixed resistance R_1.

R_2 = A standard variable resistance connected in series with the inductor L_2.

R_3, R_4 = Fixed known non-inductance resistance.

At Balance, we have,

$$Z_1 Z_4 = Z_2 Z_3$$

Where, $Z_1 = R_1 + j\omega L_1$, $Z_2 = R_2 + j\omega L_2$,

$Z_3 = R_3$, $Z_4 = R_4$

We have,

$$(R_1 + j\omega L_1)(R_4) = (R_2 + j\omega L_2)(R_3)$$

separating and Equating the real and imaginary components we have,

$$R_1 \cdot R_4 = R_2 R_3$$

$$\Rightarrow \boxed{R_1 = \frac{R_2 R_3}{R_4}} \quad \text{———} \quad (1)$$

and

$$\omega L_1 R_4 = \omega L_2 R_3$$

$$\Rightarrow \boxed{L_1 = \frac{R_3}{R_4} \cdot L_2} \quad \text{———} \quad (2)$$

→ The value of the R_3 and R_4 resistance varies from 10 to 1000 ohms with the help of the resistance. Sometimes for balancing the bridge, the additional resistance is also inserted in to the circuit.

Advantages of the Maxwell's Bridges :→

(1) The balance equation of the ckt is free from frequency.

(2) Both the balance equations are independent of each other.

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SENSORS AND TRANDUCER

Transducer :→ A transducer is a device that converts energy from one form to another. These are often employed at the boundaries of automation, measurement and control systems, where electrical signals are converted to and from other physical quantities (energy, force, torque, light, motion, position etc.).

→ The device which converts the one form of energy into another is known as the transducer. The process of conversion is known as transduction. The conversion is done by sensing and transducing the physical quantities like temperature, pressure, sound etc.

→ The electrical transducer converts the mechanical energy in to an electrical signal. The electrical signal may be voltage, current and frequency. The production of the signal depends on the resistive inductive and capacitive effects of the physical input.

→ A transducer receives sequences of high voltage electrical pulses called the transmit pulses from the ecosounder. When the wave of the sound bounces back, the transducer acts as a microphone.

It receives the sound wave during the time between each transmit pulse and converts it back into electrical energy.

Needs of Transducer :→

→ It is quite difficult to determine the exact magnitude of the physical forces like temperature, pressure etc. But, if the physical force is converted in to an electrical signal, then their value is easily measured with the help of the meter. The transducers convert the physical forces into an electrical signal which can easily be handled and transmitted for the measurement.

Physical quantity → Transducer → Electrical signal.

Advantages of converting the physical quantity into an electrical signal :→

(1) The amplification of the electrical signals are very easy.

(2) The electrical signal produces less friction error.

(3) The small power is required for controlling the electrical systems.

(4) The electrical signals are easily transmitted and processed for the measurement.

(5) The electrical signals are used in telemetry.

(6) The component used for measuring the electrical signal is very compact and accurate.

Parts of Transducer :→

→ The transducer consists of two important parts. These are :→
(1) Sensing Element
and (2) Transduction Element

→ The transducer has many other parts like amplifiers, signal processing equipment, power supplies, calibrating and reference sources etc.

(1) Sensing or Detector Element :→ It is the part of the transducers which give the response to the physical sensation. The response of the sensing element depends on the physical phenomenon.

(2) Transduction Element :→ The transduction element converts the output of the sensing element in to an electrical signal. This element is also called the secondary transducer.

Factors Influencing the choice of the transducer :→ The choice of the transducers used for measuring the physical quantity depends on the following factors :-

(1) operating principle (2) sensitivity
(3) operating range (4) Accuracy.
(5) cross sensitivity.
(6) Errors
(7) Loading Effect.
(8) Environmental compatibility
(9) Insensitivity to unwanted signals.
(10) usage and Ruggedness
(11) stability and Reliability
(12) static characteristic.

Applications of Transducer :→ The following are the application of the transducers.

(1) It is used for detecting the movement of muscles which is called accelerомyograph.

(2) The transducer measures the load on the engines.

(3) It is used as a sensor for knowing the engine knock.

(4) The transducers measure the pressure of the gas and liquid by converting it into an electrical signal.

(5) It converts the temperature of the devices into an electrical signal or mechanical work.

(6) The transducer is used in the ultrasound machine. It receives the sound waves of the patient by emitting their sound waves and pass the signal to the CPU.

(7) The transducer is used in the speaker for converting the electrical signal in to acoustic sound.

(8) It is used in the antenna for converting the electromagnetic waves in to an electrical signal.

The classifications of the transducers depend on the various factors like by transduction, the converting electrical signal from AC or DC etc.

Types of Transducer :→ The transducer changes the physical quantity in to an electrical signal. It is an electronic device which has two main functions i.e. sensing and transduction. It senses the physical quantity and then converts it into mechanical works or electrical signals.

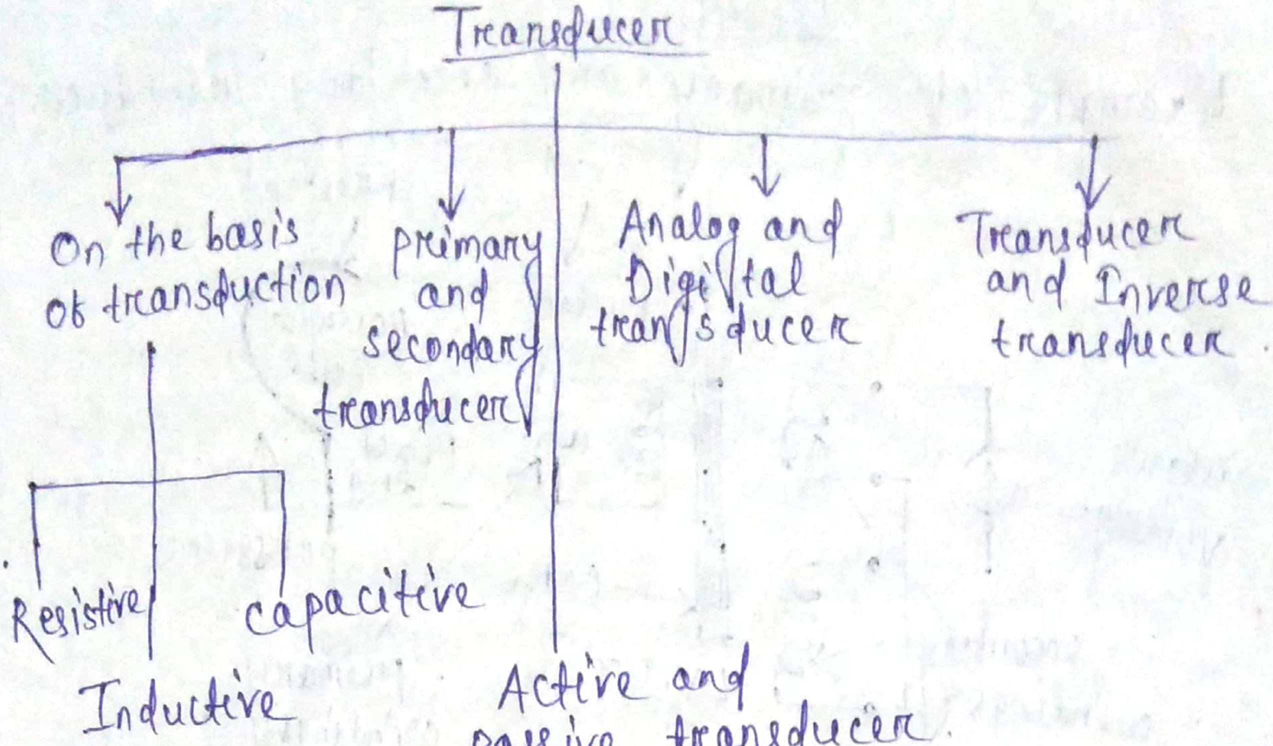
→ The transducer is of many types, and they can be classified by the following criteria :

(1) By transduction used.
(2) as a primary and secondary transducer.
(3) as a passive and active transducer.
(4) as analogue and digital transducer.
(5) as the transducer and inverse transducer

→ The transducer receives the measurand and gives a proportional amount of output signal. The output signal is sent to the conditioning device where the signal is attenuated, filtered, and modulated.

→ The input quantity is the non-electrical quantity, and the output electrical signal or the output electrical signal is in the form of the current, voltage or frequency.

→ The transducer is classified as the following diagram :-



(1) Classification based on the principle of Transduction :→ The transducer is classified by the transduction medium. The transduction medium may be resistive, inductive or capacitive depends on the conversion process that how input transducer converts the input signal in to resistance, inductance and capacitance respectively.

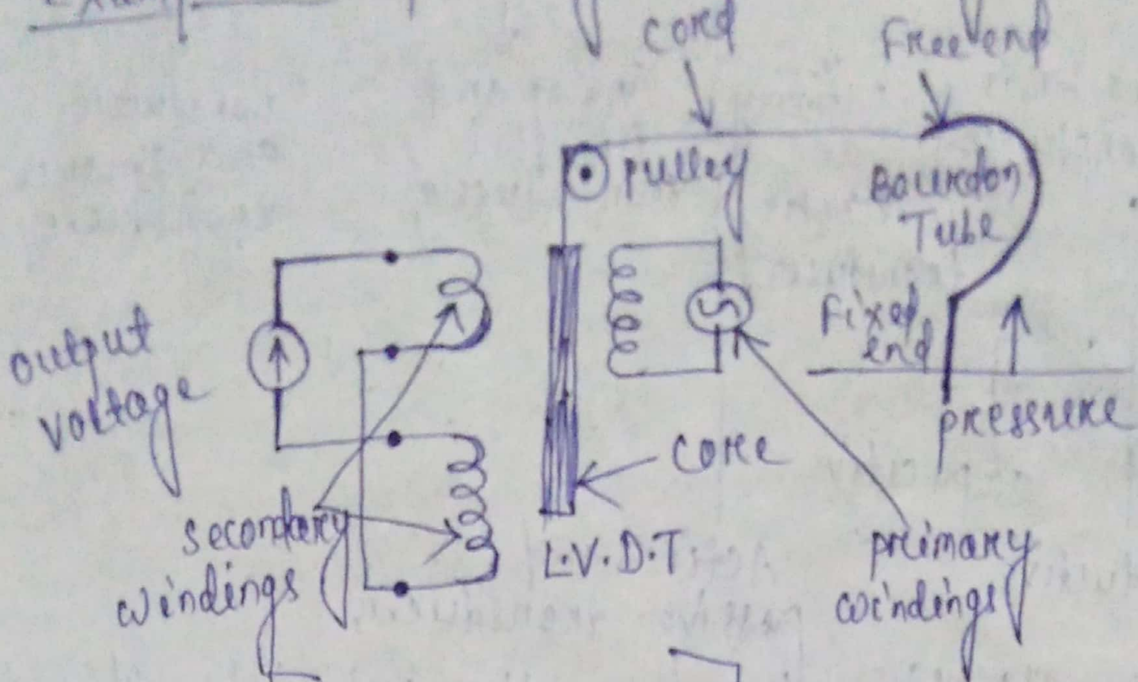
(2) Primary and Secondary Transducer :→

Primary Transducer :→ The transducer consists the mechanical as well as the electrical devices. The mechanical devices of the transducer change the physical input quantities in to a mechanical signal. This mechanical device is known as the primary transducers.

Secondary Transducer :→ It converts the mechanical signal in to an electrical signal. The magnitude of the output signal depends on the input mechanical signal.

EM

Example of primary and secondary Transducers



Bouredon's Tube

→ Consider the Bouredon's tube shown in the figure below. The tube act as a primary transducer. It detects the pressure and converts it into a displacement from its free end. The displacement of the free ends moves the core of the linear Variable displacement transformer (LVDT). The movement of the core induces the output voltage which is directly proportional to the displacement of the tube free end.

→ Thus, the two type of transduction occurs in the Bouredon's tube. First, the pressure is converted into a displacement and then it is converted into the voltage by the help of the L.V.D.T.

→ The Bouredon's tube is the primary transducer, and the L.V.D.T is called the secondary transducer.

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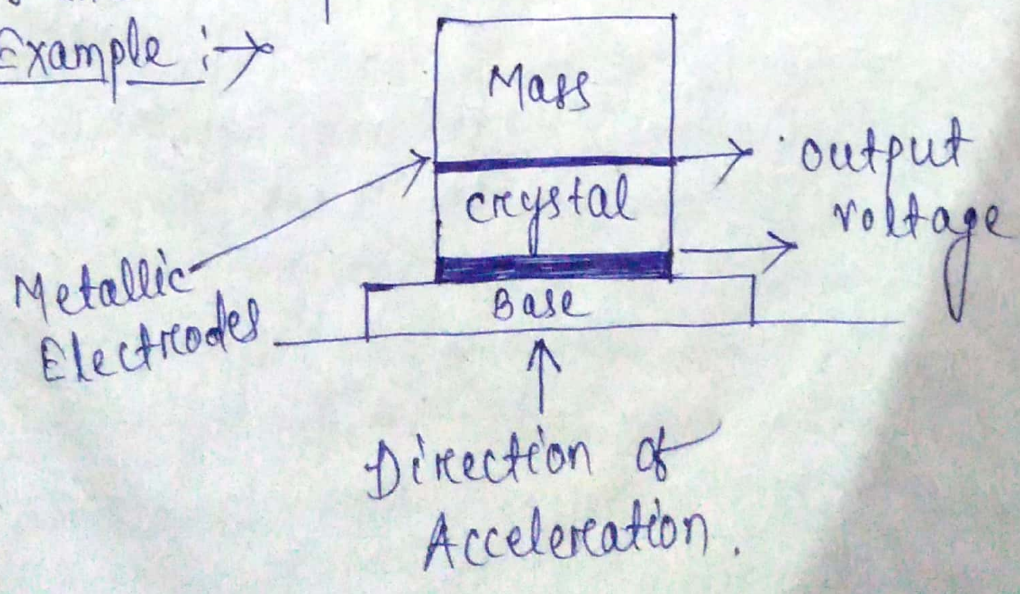
(3) Passive and Active Transducer :→

Passive Transducer :→ The transducer which requires the power from an external supply source is known as the passive transducer. They are also known as the external power transducer. The capacitive, resistive and inductive transducers are the example of the passive transducer.

Active Transducer :→ The transducer which does not require the external power source is known as the active transducer. Such type of transducer develops their own voltage or current, hence known as a self-generating transducer. The output signal is obtained from the physical input quantity.

→ The physical quantity like velocity, temperature, force and intensity of light is induced with the help of the transducer. The piezo-electric crystal, photo-voltaic cell, tacho-generator, thermocouples, photovoltaic cell are the examples of the active transducers.

Example :→



→ Consider the examples of a piezoelectric crystal. The crystal is sandwiched between the two metallic electrodes, and the entire sandwiched is fastened to the base. The mass is placed on the top of the sandwiched.

→ The piezocrystal has the special property because of which when the force is applied to the crystal, they induce the voltage. The base provides the acceleration due to which the voltage is generated. The mass applies on the crystals induces an output voltage. The output voltage is proportional to the accelaration.

→ The above mention transducer is known as the accelerometer which converts the acceleration into an electric voltage. The transducer does not require any auxillary power source for the conversion of the physical quantity in to an electrical signal.

(4) Analog and Digital Transducer :→

The transducer can also be classified by their output signals. The output signal of the transducer may be continuous or discrete.

Analog Transducer :→ The analog transducer changes the input quantity in to a continuous function. The strain gauge, L.V.D.T thermo-couple, thermistor are the examples of the analog transducer.

Digital Transducer :→ These transducers convert an input quantity in to a digital signal or in the form of the pulse. The digital signals work on high or low power.

(5) Transducer and Inverse Transducer :→

Transducer :→ The device which converts the non-electrical quantity in to an electric quantity is known as the transducer.

Inverse Transducer :→ The transducer which converts the electric quantity in to a physical quantity, such type of transducers is known as the inverse transducer. The transducer has high electrical input and low non-electrical output.

Difference between Sensor and Transducer :→

→ One of the significant difference between the sensor and the transducer is that the sensor senses the physical changes occur in the surrounding whereas the transducer converts the physical quantity or the non-electrical in to another signal or electrical signal.

→ The transducer and sensor both are the physical devices used in electrical and electronic instruments for measuring the physical quantities. The sensor detects the energy level and changes it into an electrical signal which is easily measured by the digital meters, the transducer transfers the energy either in the same form or another.

Key differences between sensor and Transducer :→

(1) The sensor senses the physical change across the surrounding whereas the transducer transforms the one form of energy into another.

(2) The sensor itself is the major component of the sensor, whereas the sensor and the signal conditioning are the major elements of the sensor.

(3) The primary function of the sensor is to sense the physical changes, whereas the transducer converts the physical quantities in to an electrical signal.

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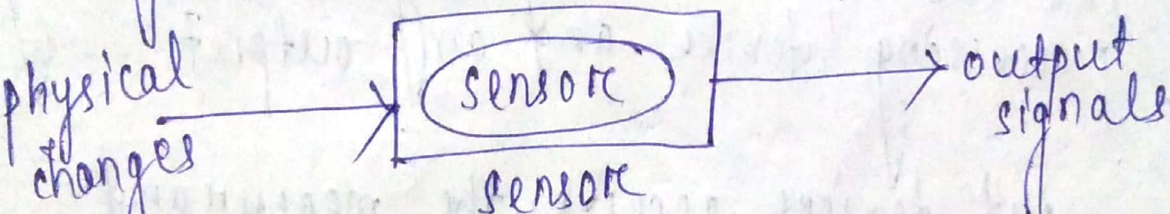
(4) The accelerometer, barometer, gyroscope are the examples of the sensors whereas the thermistor, and thermocouple is the examples of the transducer.

<u>Defination of sensor</u> :→ The sensor is a device that measures the physical quantity (i.e. Heat, Light, sound etc.) in to an easily readable signal (voltage, current etc.). It gives accurate readings after calibration.

<u>Examples</u> :→ The mercury used in the thermometer converts the measurand temperature in to an expansion and contraction of the liquid which is easily measured with the help of a calibrated glass tube. The thermocouple also converts the temperature to an output voltage which is measured by the thermometer.



→ The sensors have many applications in the electronics equipment.

(i) The motion sensors are used in the home security system and the automation door system.

(ii) The photo sensor senses the infrared or ultraviolet light.

(iii) The accelerometer sensor used in the mobile for detecting the screen rotations.

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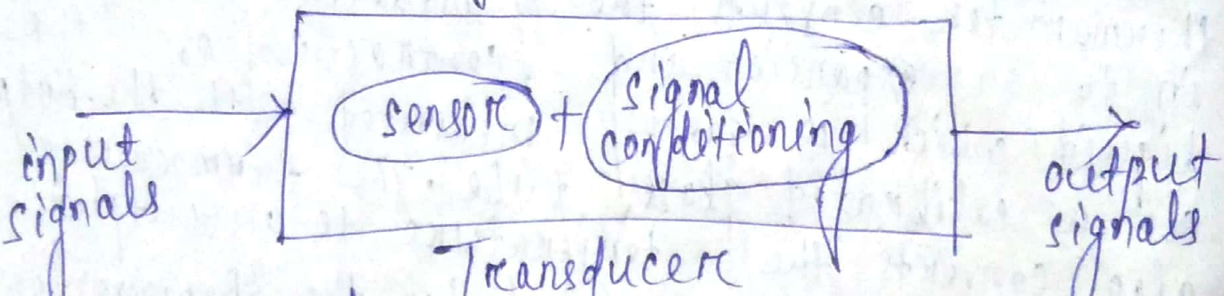
Defination of Transducer:→ It is a device that changes the physical attributes of the non-electrical signal into an electrical signal which is easily measureable. The process of energy conversion in the transducer is known as the transduction. The transduction is completed into two steps. First by sensing the signal and then strengthening it for further processing.



→ The transducer has 3 major components; they are the input device, signal conditioning or processing device and an output device.

→ The input devices receive the measurand quantity and transfer the proportional analogue signal to the conditioning device. The conditioning device modified, filtered, or attenuates the signal which is easily acceptable by the output devices.

Conclusion:→ The sensor and the transducer both are the physical devices used for measuring the physical quantities like the temperature, displacement, heat, etc. which are difficult to measure.

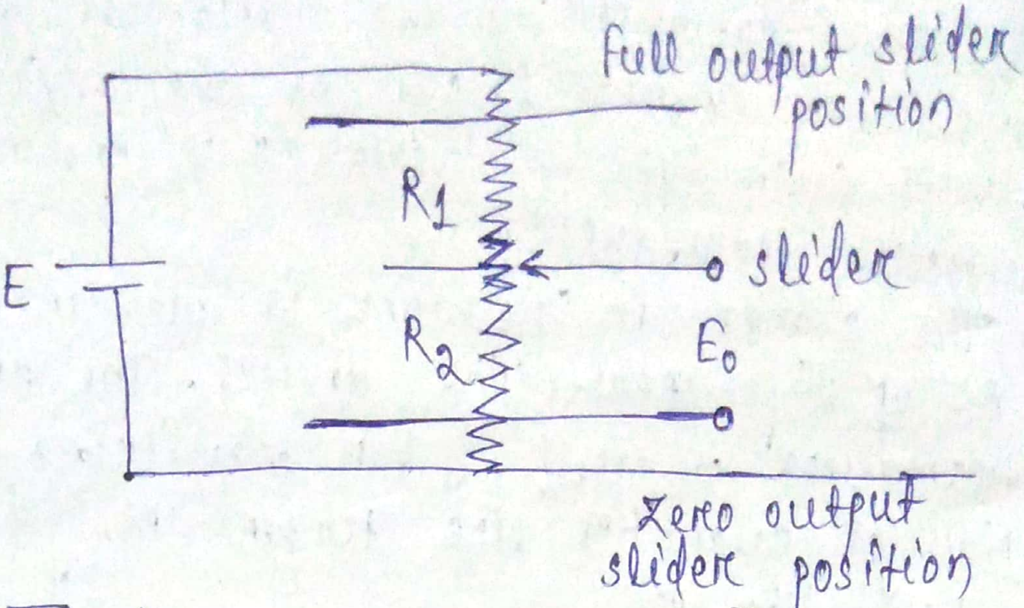
Resistive Transducer :→ The transducer whose resistance varies because of the environmental effects such type of transducer is known as the resistive transducer.

→ The change in resistance is measured by the AC or DC measuring devices. The resistive transducer is used for measuring the physical quantities like temperature, displacement, vibration etc.

→ The measurement of the physical quantity is quite difficult. The resistive transducer converts the physical quantities in to the variable resistance which is easily measured by the meters. The process of variation in resistance is widely used in the industrial applications.

→ The resistive transducer can work both as the primary as well as the secondary transducer. The primary transducer changes the physical quantities in to a mechanical signal, and secondary transducer directly transforms it into an electrical signal.

Example :→ The ckt of the sliding resistive transducer is shown in the figure below. The sliding contacts are placed on the resistive element. The slider moves horizontally. The movement of the slider changes the value of the resistive element of the transducer, which is measured by the voltage source E.



Sliding Resistive Transducer

→ The displacement of the slider is converted in to an electrical signal.

Advantages of Resistive Transducer :→

(1) Both the AC and DC, current or voltage is appropriate for the measurement of the variable resistance.

(2) The resistive transducer gives the fast response.

(3) It is available in various sizes and having a high range of resistance.

Working principle of Resistive Transducer :→

→ The resistive transducer element works on the principle of that the resistance of the element is directly proportional to the length of the conductor and inversely proportional to the area of the conductor.

→ It is given by,

$$R = \rho L/A$$

Where, R → Resistance in ohms.
A → cross-section area of the conductor in meter square (m^2).
ρ → The resistivity of the conductor in materials in ohm meter (Ωm).
L → Length of the conductor in m^2.

→ The resistive transducer is designed by considering the variation of the length, area and the resistivity of the metal.

Applications of Resistive Transducer :→

(1) potentiometer (2) strain gauges
(3) Resistance Thermometer.
(4) Thermistor

→ A resistive transducer is an electronic device that is capable of measuring various physical quantities like temperature, pressure, vibration, force, etc. These physical quantities are otherwise extremely difficult to measure as they can change easily.

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Applications of Resistive Transducer :→

(1) Potentiometer :→ The translation and rotary potentiometer are the examples of the resistive transducers. The resistance of their conductor varies with the variation in their lengths which is used for the measurement of displacement.

(2) strain gauges :→ The resistance of their semiconductor material changes when the strain occurs on it. This property of the metals is used for the measurement of the pressure, force - displacement etc.

(3) Resistance Thermometer :→ The resistance of the metals changes because of changes in the temperature. This property of conductor is used for measuring the temperature.

(4) Thermistor :→ It works on the principle that the temperature coefficient of the thermistor material varies with the temperature. The thermistor has the negative temperature coefficient. The negative temperature coefficient means the temperature is inversely proportional to the resistance.

→ There are a number of ways because of which the resistance of the metal changes with the changed in the physical phenomenon. And this property of conductors is used for measuring the physical quantities of the material.

Inductive Transducer :→ It is the self-generating type otherwise the passive type transducer. The first type like self-generating uses the principle of fundamental electrical generator. The electric generator principle is when a motion among a conductor as well as magnetic field induces a voltage within the conductor.

→ It works on the principle of inductance change due to any appreciable change due to any change in the quantity to be measured i.e. measured. For example :- LVDT, a kind of inductive transducers, measures displacement in terms of voltage difference between its two secondary voltages. Secondary voltages nothing but the result of induction due to flux change in the secondary coil with the displacement of the iron bar.

→ The inductive transducers work on the principle of the electromagnetic induction. Just as the resistance of the electric conductor the depends on the number of factors, the induction of the magnetic material depends on a number of variables like the number of turns of the coil on the material, the size of the magnetic material, and the permeability of the flux path.

→ In the inductive transducers, the magnetic materials are used in the flux path and there are one or more air gaps.

→ The change in the air gap also results in change in the inductance of the ckt and in most of the inductive transducers, it is used for the working of the instrument.

→ There are 2 common types of inductive transducers. These are:-

(1) Simple Inductance type

and (2) Two-coil mutual inductance type.

→ Hence, the inductive transducers use one of the following principles for their working. These are:-

(i) change of self-inductance

(ii) change of mutual inductance

(iii) production of eddy current.

Here, the transducers, which work on the change of mutual inductance principle, use multiple coils.

→ The active transducer is also called as self generating type transducer. The passive transducer is also called as the externally powered transducer. Example of passive transducer is LVDT (Linear Variable differential Transformer). It generates the electric current or voltage directly in response to the environmental stimulation.

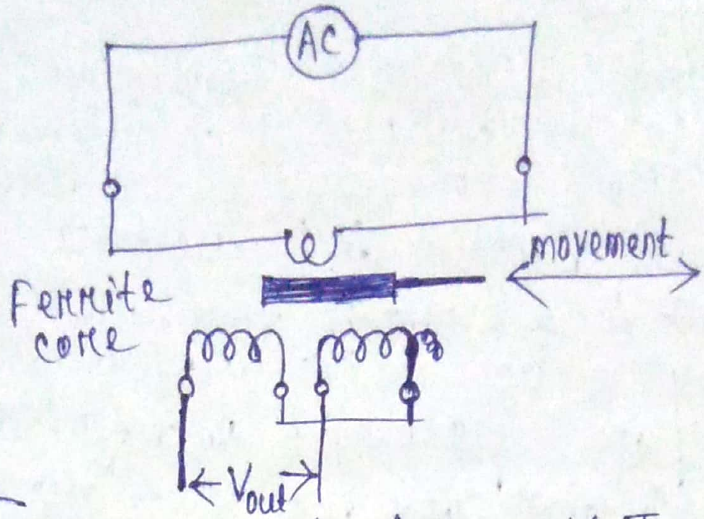
Linear variable Differential Transformer (LVDT):→

→ The linear variable differential transformer (LVDT) is the most widely used inductive transducer to translate linear motion in to electrical signal.

Construction:→ A differential transformer consists of a primary winding and two secondary windings. The windings are arranged concentrically and next to each other. They are wound over a hollow bobbin which is usually of a non-magnetic and insulating material.

→ A ferro-magnetic core (armature) in the shape of a rod of the cylinder is attached to the transducers sensing shaft. The core slides freely within the hollow portion of the bobbin. In the simplex winding configuration, the LVDT is shown in the figure below.

→ There is one primary and two secondary windings. The secondaries are connected so their outputs are opposite. If an AC excitation is applied across the primary winding then voltages are induced in the secondaries. A movable core varies the coupling between it and the two secondary windings. When the core is in the centre position, the coupling to the secondary coils is equal. As the core moves away from the centre position, the coupling to one secondary becomes more and hence its output voltage increases, while the coupling and the output voltage of the other secondary decreases.

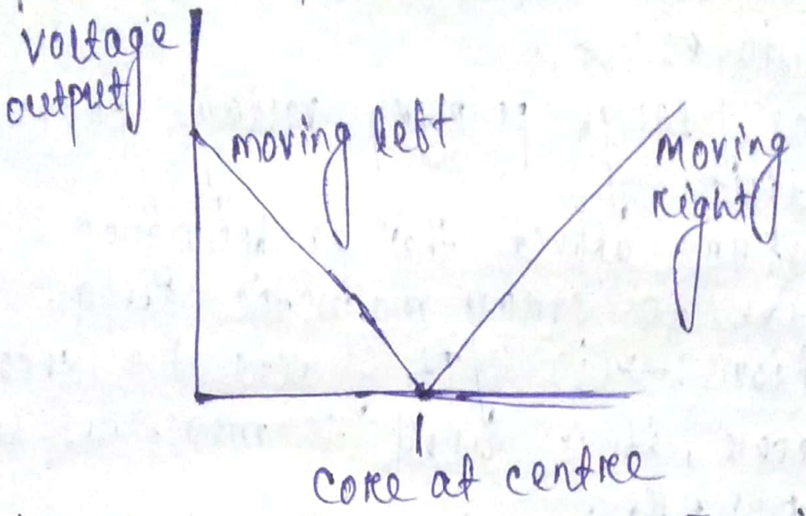


[Linear Variable Differential Transformer]

Working Principle:→ Any physical displacement of the core causes the voltage of one secondary winding to increase while simultaneously, reducing the voltage in the other secondary winding. The difference of the two voltages appears across the output terminals of the transducer and gives a measure of the physical position of the core and hence the displacement.

→ When the core is in the neutral or zero position, voltages induced in the secondary windings are equal and opposite and cancel out. The net output is negligible. As the core is moved in one direction from the null position, then there will be more voltage in one secondary than the other. The voltages will not cancel out and there will be an AC signal at the output proportional to the distance the core has moved. The differential voltage, i.e., the difference of the secondary voltages, will increase while maintaining an in-phase relationship with the voltage from the input source.

→ In the other direction from the null position, the differential voltage will again increase, but will be 180°C out of phase with the voltage from the input source. Using a phase detector ckt it is also possible to indicate the direction the core has moved. By comparing the magnitude and phase of the output (differential) voltage with the input source, the amount and the direction of movement of the core and hence of displacement may be determined. Variation of output voltage with core position is shown in the figure below :-



[Variation of output voltage in LVDT with core position]

→ The output voltage of these transducers is practically linear for displacement up to 5mm. The transducer has infinite resolution and a high sensitivity. It is simple, light in weight, and easy to align and maintain. These transducers can usually tolerate a high degree of shock and vibration without any adverse effects. In addition to this they have low hysteresis and hence repeatability is excellent under all conditions.

→ The disadvantages of LVDT include their relatively large displacements are requirement for appreciable differential output. They are sensitive to stray magnetic fields but this can be overcome by providing the appropriate shielding. Temperature affects the performance of the transducer.

Advantages :→ There are some advantages of LVDT which are given below :→

(i) The LVDT has low power consumption.
(ii) It has higher sensitivity.
(iii) It has ruggedness.
(iv) It has wide range
(v) It has low hysteresis.

Disadvantages :→

(i) It has large primary voltage produce distortion in output.
(ii) Temperature affects the performance.
(iii) Sensitive to stray magnetic field.

Applications :→ (i) It acts as a secondary transducer, it is used to measure force, weight and pressure.
(ii) The LVDT can be used for displacement measurement ranging from fraction of mm to few cm.
(iii) The LVDT sensor works as the main transducer, and that changes dislocation to electrical signal straight.
(iv) Some of these transducers are used to calculate the pressure and load.
(v) LVDT's are mostly used in industries as well as servomechanisms.
(vi) Other applications like power turbines, hydraulics, automation, aircraft, and satellites, nuclear reactors, Factory automation, weight sensitive applications, General industrial applications, process and control and Materials testing etc.

<u>Capacitive Transducer</u> :→ The capacitive transducer is used for measuring the displacement, pressure and other physical quantities. It is a passive transducer that means it requires external power for operation. The capacitive transducer works on the principle of variable capacitances. The capacitance of the capacitive transducer changes because of many reasons like overlapping of plates, change in the distance between the plates and dielectric constant.

→ The capacitive transducer contains two parallel metal plates. These plates are separated by the dielectric medium which is either air, material, gas or liquid. In the normal capacitor the distance between the plates are fixed, but in capacitive transducer the distance between them are varied.

→ The capacitive transducer uses the electrical quantity of capacitance for converting the mechanical movement in to an electrical signal. The input quantity causes the change of the capacitance which is directly measured by the capacitive transducer.

→ The capacitors measure both the static and dynamic changes. The displacement is also measured directly by connecting the measurable devices to the movable plate of the capacitor. It works on with both the contacting and non-contacting modes.

<u>Principle of operation</u> :→ The equations below express the capacitance between the plates of a capacitor.

$$C = \varepsilon A/d$$

$$\Rightarrow C = \varepsilon_r \varepsilon_0 A/d$$

Where, A = overlapping area of plates in m^2.

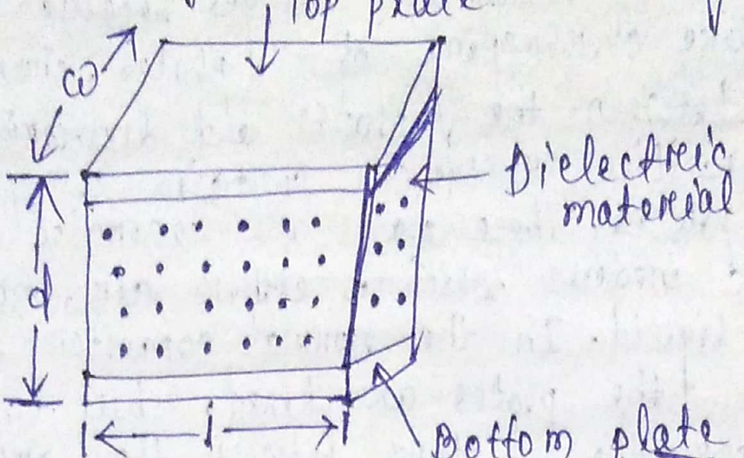
d = the distance between two plates in meter.

ε = permitivity of the medium in F/m.

ε_r = relative permitivity.

ε_0 = the permitivity of free space.

→ The schematic diagram of a parallel plate capacitive transducer is shown in the figure below.



(parallel plate capacitive transducer)

→ The change in capacitance occurs because of the physicals variables like displacement, force, pressure etc. The capacitance of the transducer also changes by the variation in their dielectric constant which is usually because of the measurement of liquid or gas level.

→ The capacitance of the transducer is measured with the bridge ckt. The output impedance of the transducer is given as,

$$X_C = 1/2\pi f C$$

Where, C = capacitance in Farad (F)

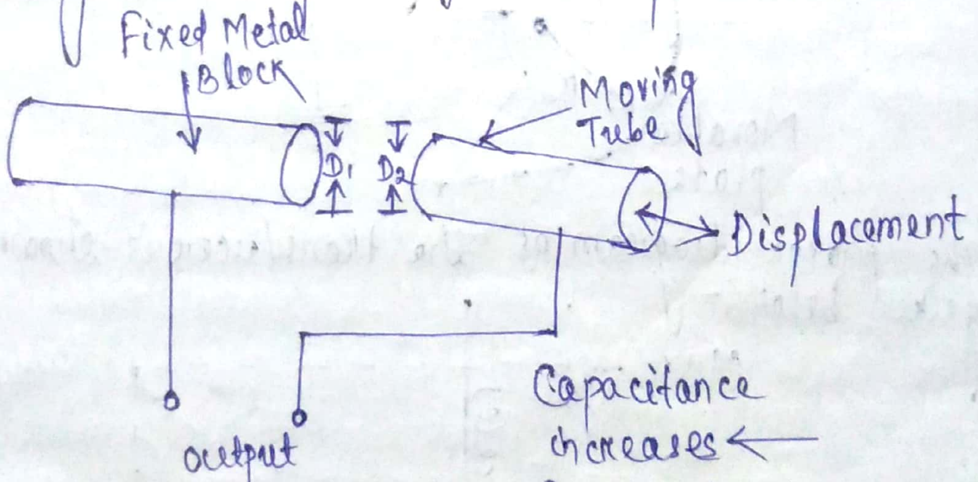
f = frequency of excitation in Hz

→ The capacitive transducer is mainly used for measurement of linear displacement. The capacitive transducer uses the following three effects :-

(1) Variation in capacitance of transducer is because of the overlapping of capacitor plates.
(2) The change in capacitance is because of the change in distance between the plates.
(3) The capacitance changes because of dielectric constant.

→ The following methods are used for the measurement of displacement :-
(1) A transducer using the change in the area of plates.
(2) The transducer using the change in distance between the plates.

(1) <u>A transducer using the change in the area of plates</u> :→ The equation below shows that the capacitance is directly proportional to the area of the plates. The capacitance changes correspondingly with the change in the position of the plates.



[Capacitive Transducer]

→ The capacitive transducers are used for measuring the large displacement approximately from 1mm to several cms. The area of the capacitive transducer changes linearly with the capacitance and the displacement. Initially, the nonlinearity occurs in the system because of the edges. Otherwise, it gives the linear response.

The capacitance of the parallel plates is given as,

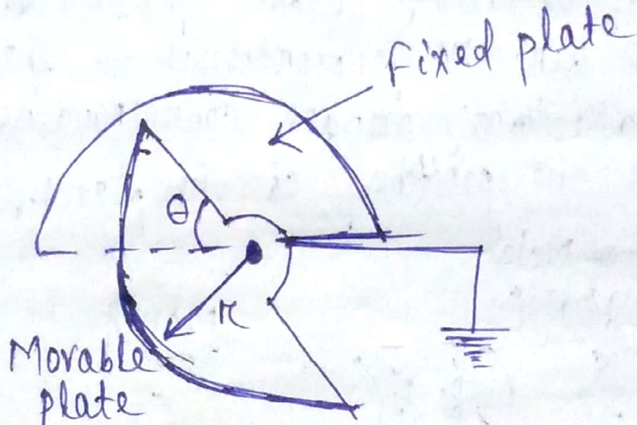
$$C = \frac{\epsilon A}{d} = \frac{\epsilon x \omega}{d} \; F$$

Where, x = the length of overlapping part of plates.
ω = the width of overlapping part of plates.

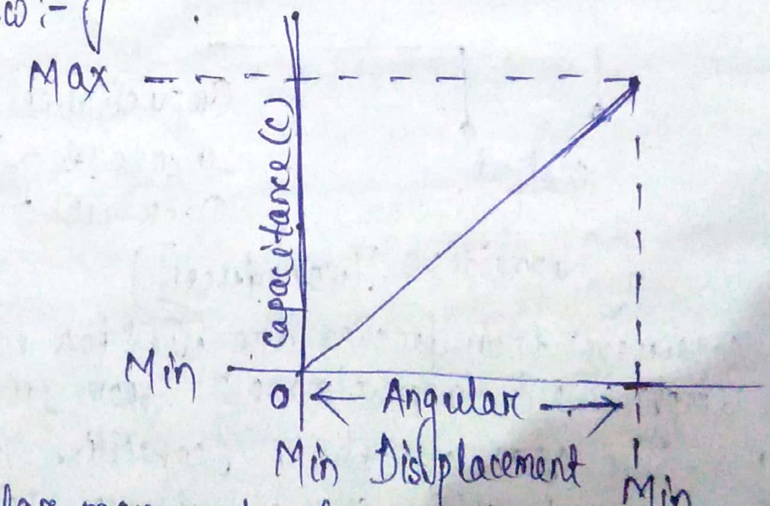
→ The sensitivity of the displacement is constant, and therefore it gives the linear relation between the capacitance and the displacement.

$$\text{Displacement} = S = \frac{\partial C}{\partial x} = \epsilon \frac{\omega}{d} \; F/m.$$

→ The capacitive transducer is used for measuring the angular displacement. It is measured by the movable plates shown below. One of the plates of the transducer is fixed, and the other is movable.



→ The phasor diagram of the transducer is shown in the figure below:-



→ The angular movement changes the capacitance of the transducers. The capacitance between them is maximum when these plates overlap each other. The maximum value of capacitance is expressed as,

$$C_{max} = \frac{\varepsilon A}{d} = \frac{\pi \varepsilon r^2}{2d}$$

→ The capacitance at angle θ is given expressed as,

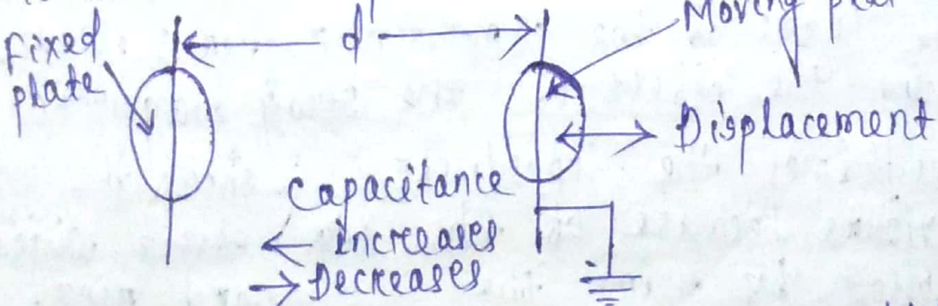
$$C = \frac{\varepsilon \theta r^2}{2d}$$

where, θ = angular displacement in radian. The sensitivity for the change in capacitance is given as,

$$S = \frac{\partial C}{\partial \theta} = \frac{\varepsilon r^2}{2d}$$

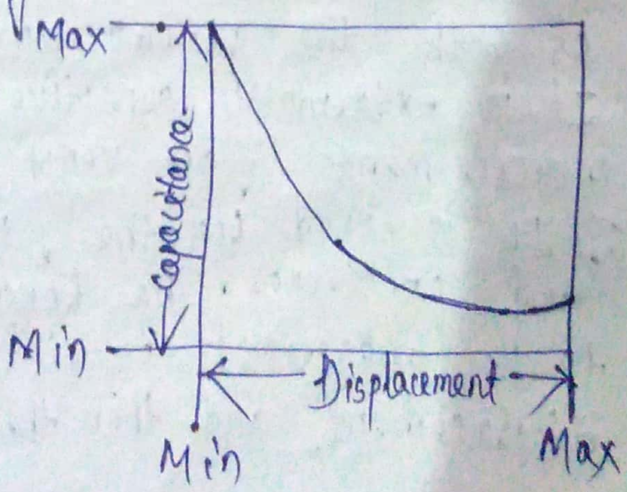
→ The 180° is the maximum value of the angular displacement of the capacitor.

(2) The transducer using the change in distance between the plates:→ The capacitance of the transducer is inversely proportional to the distance between the plates. The one plate of the transducer is fixed, and the other is movable. The displacement which is to be measured links to the movable plates.



→ The capacitance is inversely proportional to the distance because of which the capacitor shows the non-linear response. Such type of transducer is used for measuring the small displacement. The phasor diagram of the capacitor is shown in the figure below:-

→ The sensitivity of the transducer is not constant and vary from places to places.



Advantages of capacitive Transducer :→

→ The following are the major advantages of the capacitive transducers.

(1) It requires an external force for operation and hence very useful for small systems.

(2) The capacitive transducer is very sensitive.

(3) It gives good frequency response because of which it is used for the dynamic study.

(4) The transducer has high input impedance hence they have a small loading effect.

(5) It requires small output power for operation.

Disadvantages :→ The main disadvantages of the transducer are as follows :-

(1) The metallic parts of the transducers require insulation.

(2) The frame of the capacitor requires earthing for reducing the effect of the stray magnetic field.

(3) Sometimes the transducer shows the non-linear behaviours because of the edge effect which is controlled by using the guard ring.

(4) The cable connecting across the transducer causes an error.

Uses of capacitive Transducer :→

(1) The capacitive transducer uses for measurement of both the linear and angular displacement. It is extremely sensitive and used for the measurement of very small distance.

(2) It is used for the measurement of the force and pressures. The force or pressure, which is to be measured is first converted into a displacement, and then the displacement changes the

capacitances of the transducer.

(3) It is used as a pressure transducer in some cases, where the dielectric constant of the transducer changes with the pressure.

(4) The humidity in gases is measured through the capacitive transducer.

(5) The transducer uses the mechanical modifier for measuring the volume, density, weight etc.

→ The accuracy of the transducer depends on the variation of temperature to the high level.

<u>Piezo - Electric Transducer</u> :→ It is an electroacoustic transducer used for conversion of pressure or mechanical stress in to an alternating electric force. It is used for measuring the physical quantity like force, pressure, stress etc. which is directly not possible to measure.

→ The piezo transducer converts the physical quantity into an electrical voltage which is easily measured by analogue and digital meter. The piezoelectric transducer uses the piezoelectric material which has a special property i.e. the material induces voltage when the pressure or stress applied to it. The material which shows such property is known as the electro-resistive element.

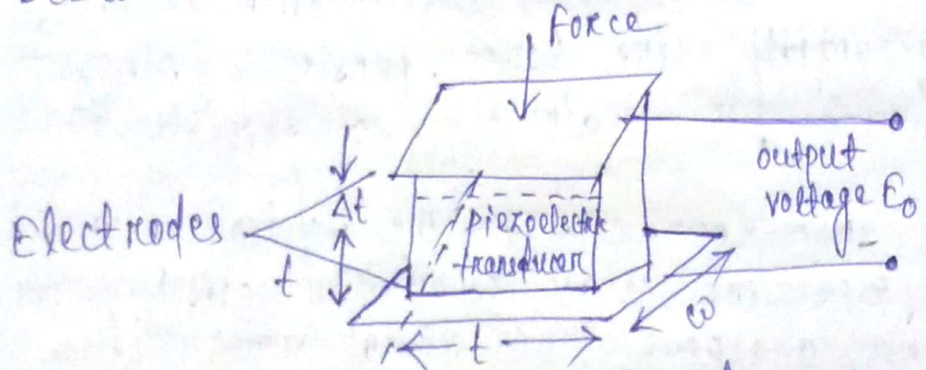
→ The ceramic material does not have the piezoelectric property. The property is developed on it by special polarizing treatment. The ceramic material has several advantages. It is available in different shapes and sizes. The material has the capability of working at low voltages, and also it can operate at the temperature more than 3000°c.

Piezoelectric Effect :→ The emf develops because of the displacement of the charges. The effect is changeable i.e. if the varying potential applies to a piezoelectric transducer, it will change the dimension of the material or deform it. This effect is known as the piezoelectric effect.

→ The pressure is applied to the crystals with the help of the force summing devices for examples the stress is applied through mechanical pressure gauges and pressure sensors etc. The deformation induces the emf which determines the value of applied pressure.

Theory of Piezoelectric Transducer :→

→ A piezoelectric crystal is shown in the figure below.



→ The polarity of the charge depends on the direction of the applied forces.

$$\text{charge } Q = d \times F \text{ coulomb}$$

Where, $d \rightarrow$ charge sensitivity of the crystals.

$F \rightarrow$ applied force in Newton.

and $E = \frac{\text{stress}}{\text{strain}}$

properties of piezoelectric crystal :→

(1) The piezoelectric material has high stability.

(2) It is available in various shapes and sizes.

(3) The piezoelectric material has output insensitire to temperature and humidity.

Uses of piezoelectric crystal :→

(1) The piezoelectric material has high stability and hence it is used for stabilizing the electronic oscillator.

(2) The ultrasonic generators use the piezoelectric material. This generator is used in SONAR for underwater detection and in industrials apparatus for cleaning.

(3) It is used in microphones and speakers for converting the electric signal into sound.

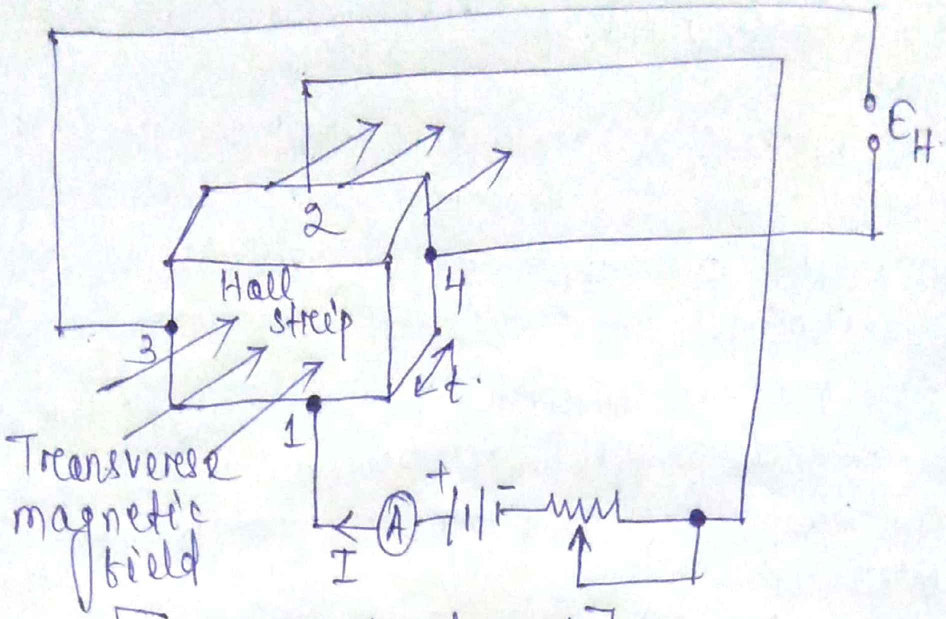
(4) The piezoelectric material is used in electrical lighter.

The transducer has low output, and hence external ckt is associated with it.

Hall effect transducer :→ The hall effect element is a type of transducer used for measuring the magnetic field by converting it into an emf. The direct measurement of the magnetic field is not possible. Thus the Hall effect transducer is used. The transducer converts the magnetic field into an electric quantity which is easily measured by the analogue and digital meters.

Principle of Hall effect Transducer :→ The principle of hall effect transducer is that if the current carrying strip of the conductor is placed in a transverse magnetic field. then the emf develops on the edge of the conductor. The magnitude of the develop voltage depends on the density of flux, and this property of a conductor is called the Hall effect. The Hall effect element is mainly used for magnetic measurement and for sensing the current. The metal and the semiconductor has the property of hall effect which depends on the densities and the mobility of the electrons.

→ Consider the hall effect element shown in the figure below.



Hall effect element

→ The current supply through the lead 1 and 2 and the output is obtained from the strip 3 & 4. The lead 3 and 4 are at same potential when no field is applied across the strip. When the magnetic field is applied to the strip, the output voltage develops across the output leads 3 & 4. The developed voltage is directly proportional to the strength of the material.

→ The output voltage is, $E_H = K_H IB/t$

where, K_H → Hall effect coefficient.

t → thickness of strip; m

I → current in amp.

B → Flux densities in wb/m^2.

→ The current and the magnetic field strength both can be measured with the help of the output voltages. The Hall effect EMF is very small in conductors, because of which it is difficult to measure. But semiconductors like germanium produces large emf which is easily measured by the moving coil instrument.

(b) **State the characteristics of digital meters.**

Ans. Characteristics of Digital Meters :

(i) In digital meters there are binary systems 0 or 1 and thus the mechanism of measurement is some what easier and better.

(ii) They have better accuracy and precision is also better.

(iii) There are no mechanical contact and they have very less maintenance problem and wear, tear.

(iv) They are not expensive.

(v) They can be made to any degree of desired accuracy provided that the sector is made large enough to accommodate the required number of binary numbers and are quite adequate for slowly moving systems.

(vi) The resolution of these meters depend upon the number of digits comprising the binary number.

The resolution is $\frac{1}{2^n}$ of full scale. Where n = number of digits.

(vii) The range is set up to several meters with an accuracy of 1 part in 20,000 of full scale.

(viii) They have faster response.

(ix) These meters are less effected by noise.

(x) More digital circuitry can be fabricated on IC chips.

(xi) Information storage is easy with digital meters and circuits.

(xii) They are easy to design.

(xiii) They are reliable and power requirement are very low.

3.(a) Discuss burden in instrument transformer.

Ans. The rated burden is the volt - ampere loading which is permissible without errors exceeding the limits for the particular class of accuracy.

Total secondary burden

$$= \frac{(\text{Secondary winding induced voltage})^2}{(\text{Impedance of the secondary winding circuit including impedance of secondary winding})}$$

= (Secondary winding current)^2 × (Impedance of secondary winding circuit including secondary winding).