



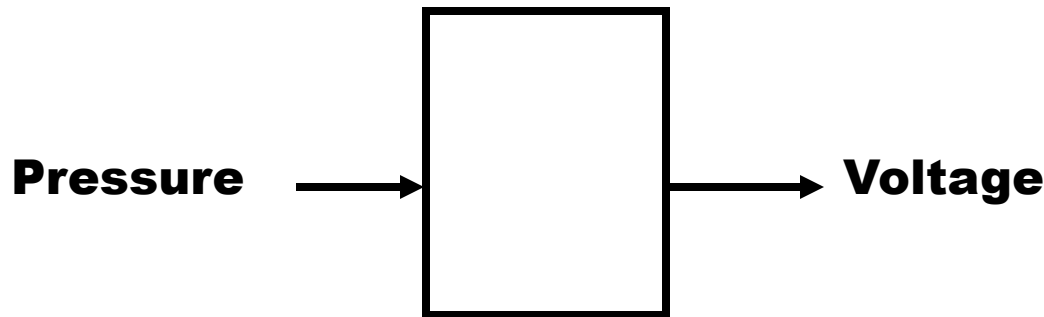
MPHYEC-1F

UNIT-2 TRANSDUCER

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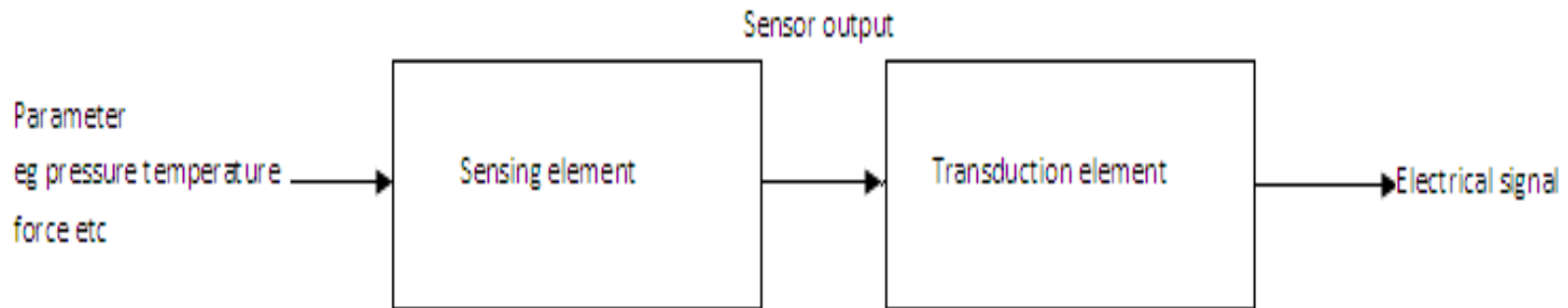
INTRODUCTION OF TRANSDUCERS

- A transducer is a device that convert one form of energy to other form. It converts the measurand to a usable electrical signal.
- In other word it is a device that is capable of converting the physical quantity into a proportional electrical quantity such as voltage or current.
- Energy forms can be mechanical, visual, aural, electrical, thermal, chemical, etc. (examples to follow) • Used to change information into a form that can be easily transferred, stored, processed, interpreted, etc.



BLOCK DIAGRAM OF TRANSDUCERS

- Transducer contains two parts that are closely related to each other i.e. the sensing element and transduction element.
- The sensing element is called as the sensor. It is device producing measurable response to change in physical conditions.
- The transduction element convert the sensor output to suitable electrical form.



CHARACTERISTICS OF TRANSDUCERS

1. Ruggedness
2. Linearity
3. Repeatability
4. Accuracy
5. High stability and reliability
6. Speed of response
7. Sensitivity
8. Small size

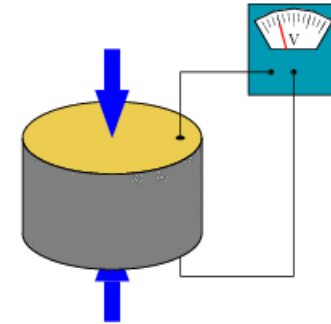
TRANSDUCERS SELECTION FACTORS:

1. **Operating Principle:** The transducer are many times selected on the basis of operating principle used by them. The operating principle used may be resistive, inductive, capacitive , optoelectronic, piezo electric etc.
2. **Sensitivity:** The transducer must be sensitive enough to produce detectable output.
3. **Operating Range:** The transducer should maintain the range requirement and have a good resolution over the entire range.

4. **Accuracy:** High accuracy is assured.
5. **Cross sensitivity:** It has to be taken into account when measuring mechanical quantities. There are situations where the actual quantity being measured is in one plane and the transducer is subjected to variation in another plane.
6. **Errors:** The transducer should maintain the expected input-output relationship as described by the transfer function so as to avoid errors.
7. **Transient and frequency response :** The transducer should meet the desired time domain specification like peak overshoot, rise time, settling time and small dynamic error.
8. **Loading Effects:** The transducer should have a high input impedance and low output impedance to avoid loading effects.
9. **Environmental Compatibility:** It should be assured that the transducer selected to work under specified environmental conditions maintains its input-output relationship and does not break down.
10. **Insensitivity to unwanted signals:** The transducer should be minimally sensitive to unwanted signals and highly sensitive to desired signals.

CLASSIFICATION OF TRANSDUCERS

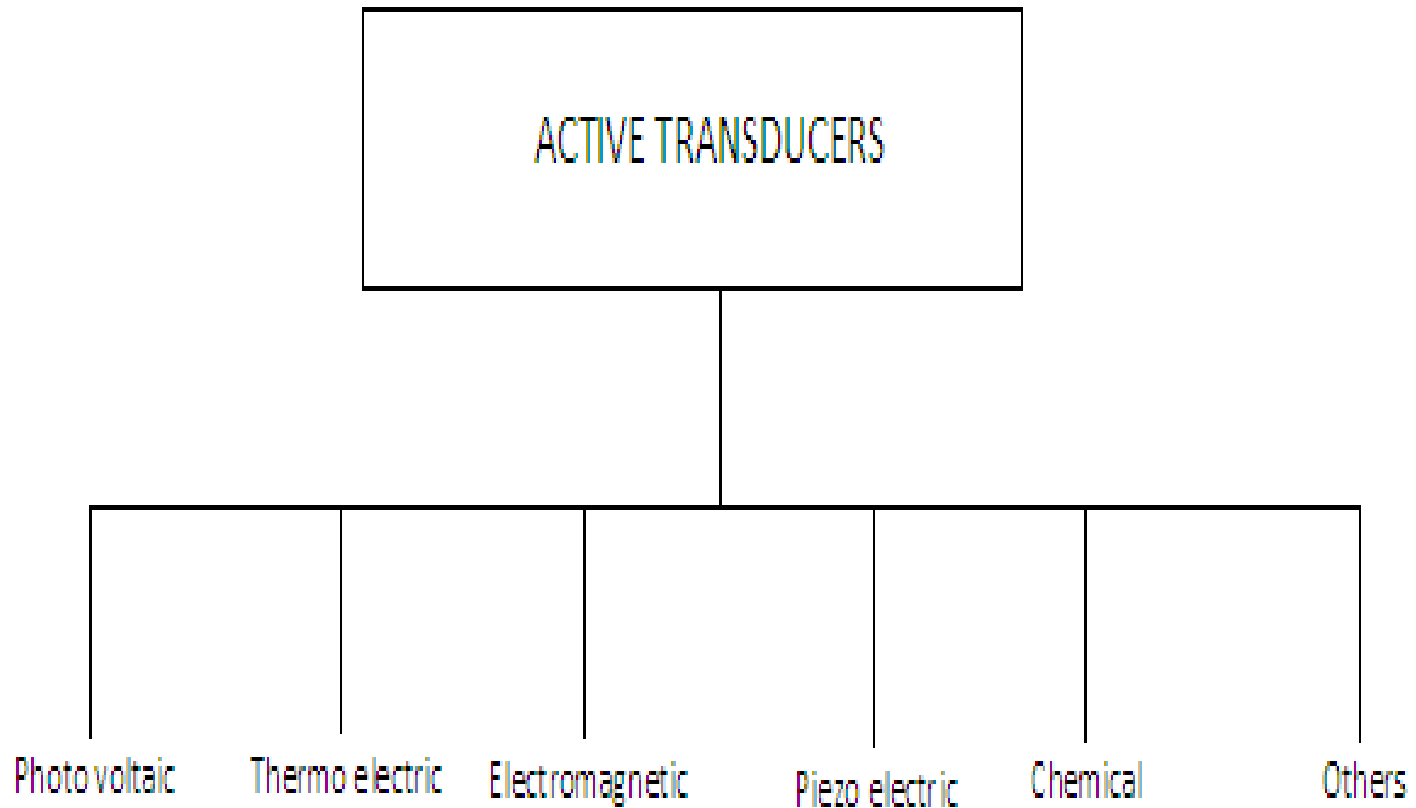
- I. Active and passive transducers.
- II. Analog and digital transducers.
- III. On the basis of transduction principle used.
- IV. Primary and secondary transducer
- V. Transducers and inverse transducers.



Piezoelectric Transducer

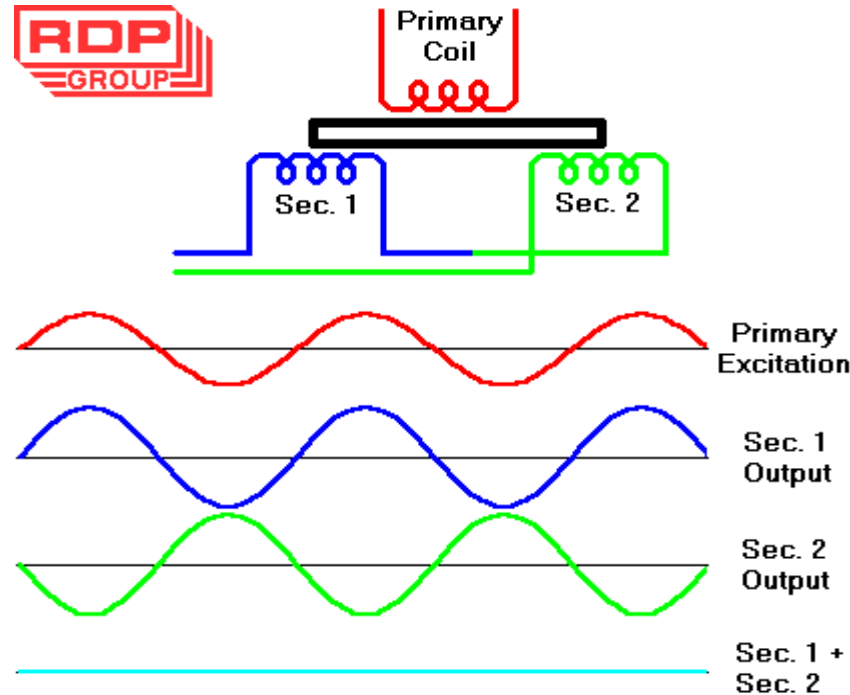
Active transducers : These transducers do not need any external source of power for their operation. Therefore they are also called as self generating type transducers. The active transducer are self generating devices which operate under the energy conversion principle. As the output of active transducers we get an equivalent electrical output signal e.g. temperature or strain to electric potential, without any external source of energy being used.

CLASSIFICATION OF ACTIVE TRANSDUCERS

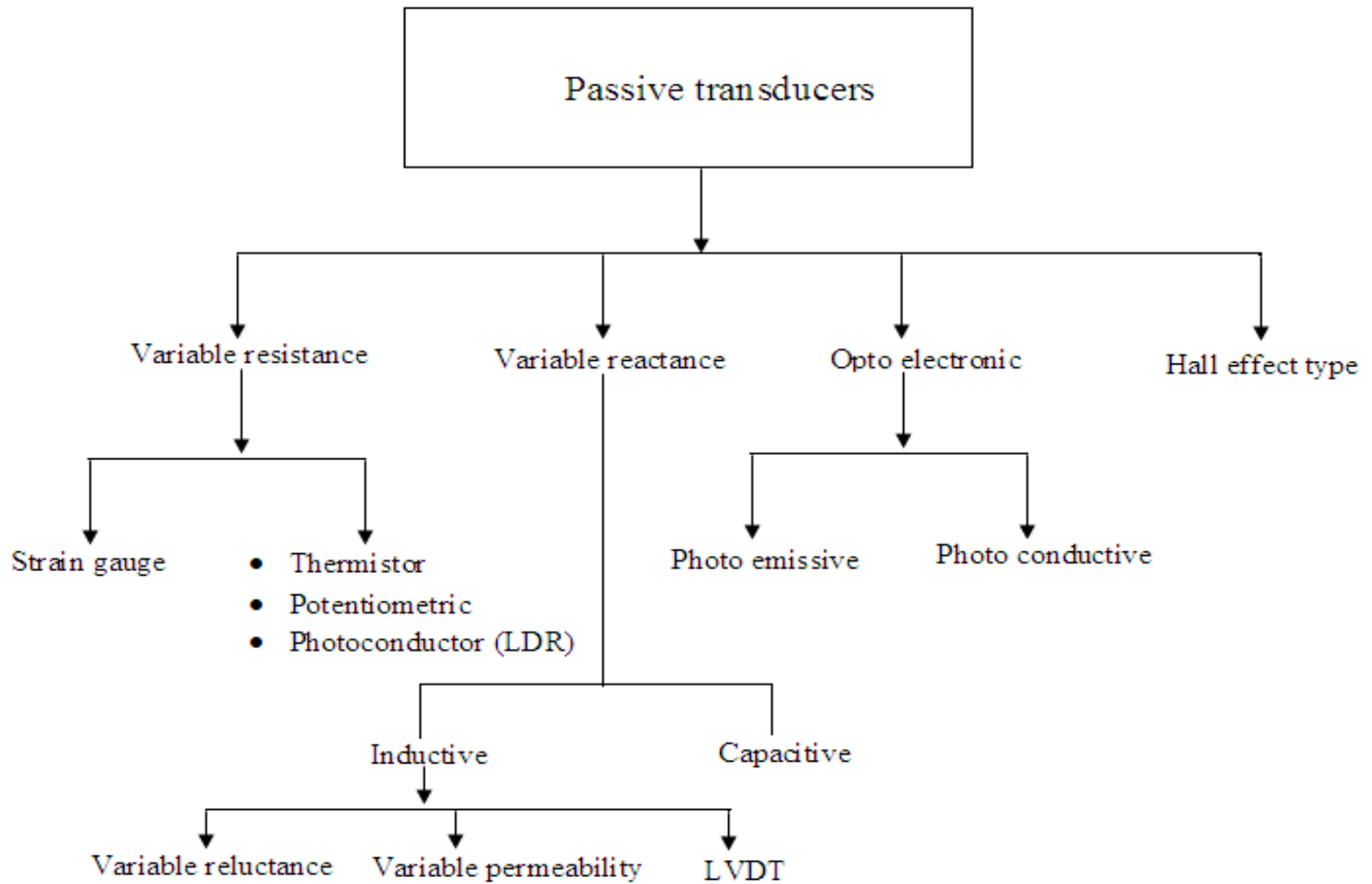


Passive Transducers :

These transducers need external source of power for their operation. So they are not self generating type transducers. A DC power supply or an audio frequency generator is used as an external power source. These transducers produce the output signal in the form of variation in resistance, capacitance, inductance or some other electrical parameter in response to the quantity to be measured.



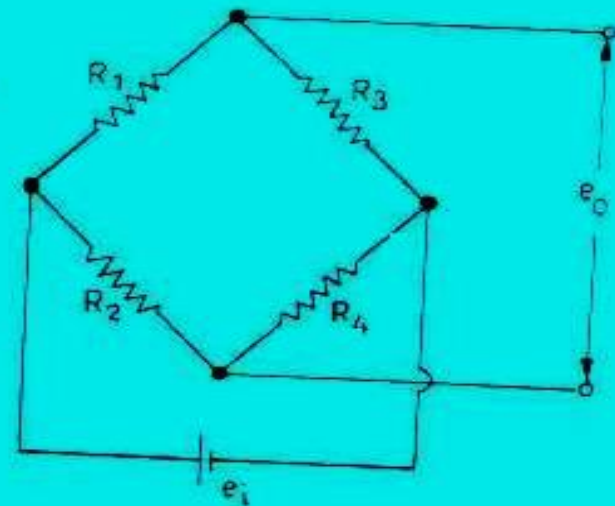
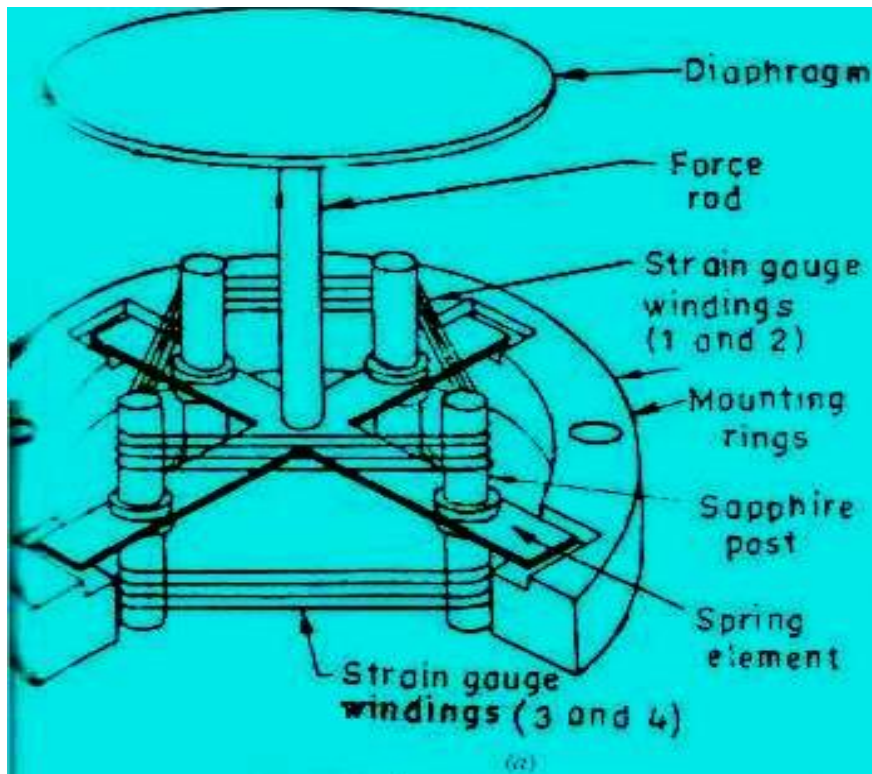
CLASSIFICATION OF PASSIVE TRANSDUCERS



PRIMARY AND SECONDARY TRANSDUCERS

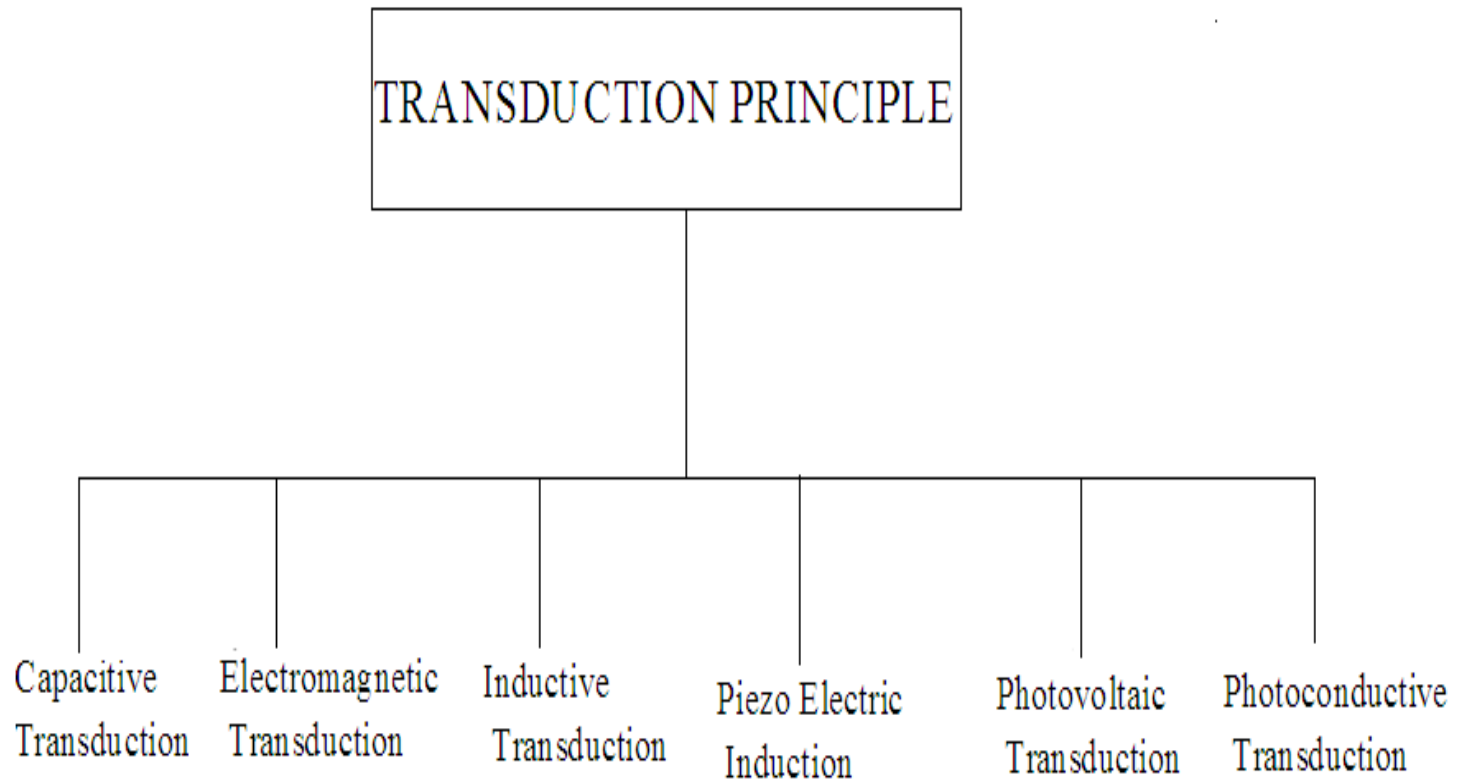
Some transducers contain the mechanical as well as electrical device. The mechanical device converts the physical quantity to be measured into a mechanical signal. Such mechanical device are called as the primary transducers, because they deal with the physical quantity to be measured. The electrical device then convert this mechanical signal into a corresponding electrical signal. Such electrical device are known as secondary transducers. Refer figure below in which the diaphragm act as primary transducer. It convert pressure (the quantity to be measured) into displacement(the mechanical signal).

The displacement is then converted into change in resistance using strain gauge. Hence strain gauge acts as the secondary transducer.



Set up of an unbonded strain gauge and measurement with a wheatstone bridge

CLASSIFICATION OF TRANSDUCERS (According to Transduction Principle)



CAPACITIVE TRANSDUCER:

- In capacitive transduction transducers the measurand is converted to a change in the capacitance.
- A typical capacitor is comprised of two parallel plates of conducting material separated by an electrical insulating material called a dielectric. The plates and the dielectric may be either flattened or rolled.
- The purpose of the dielectric is to help the two parallel plates maintain their stored electrical charges.
- The relationship between the capacitance and the size of capacitor plate, amount of plate separation, and the dielectric is given by

$$C = \epsilon_0 \epsilon_r A / d$$

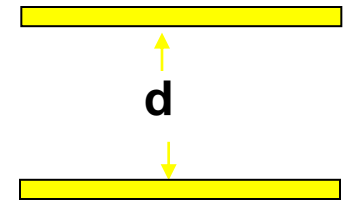
d is the separation distance of plates (m)

C is the capacitance (F, Farad)

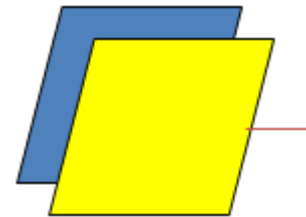
ϵ_0 : absolute permittivity of vacuum

ϵ_r : relative permittivity

A is the effective (overlapping) area of capacitor plates (m²)



Area=A

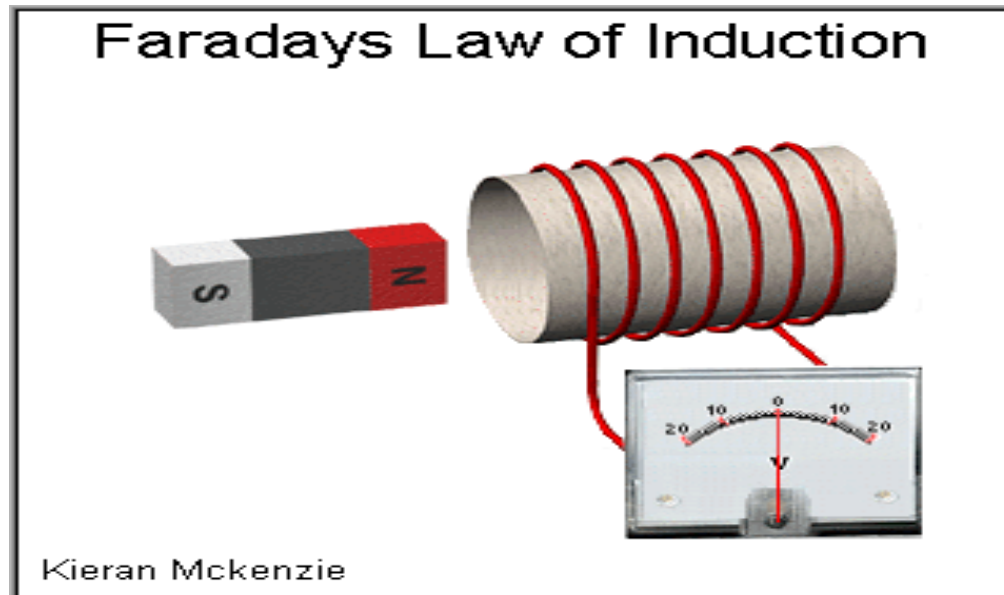


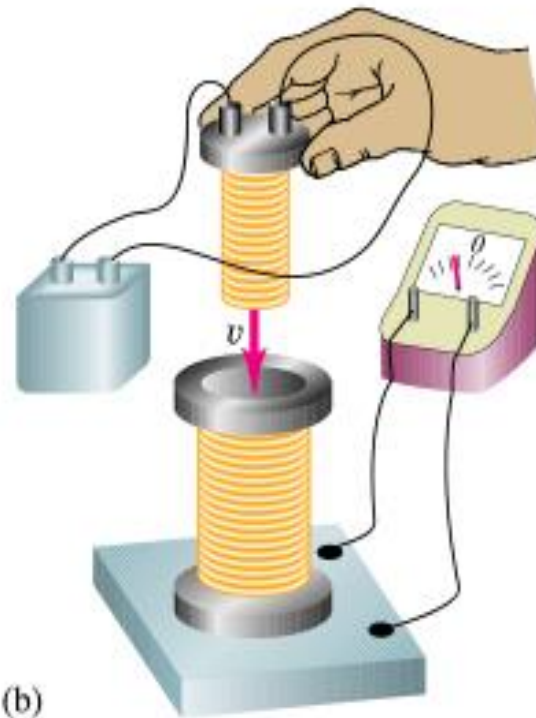
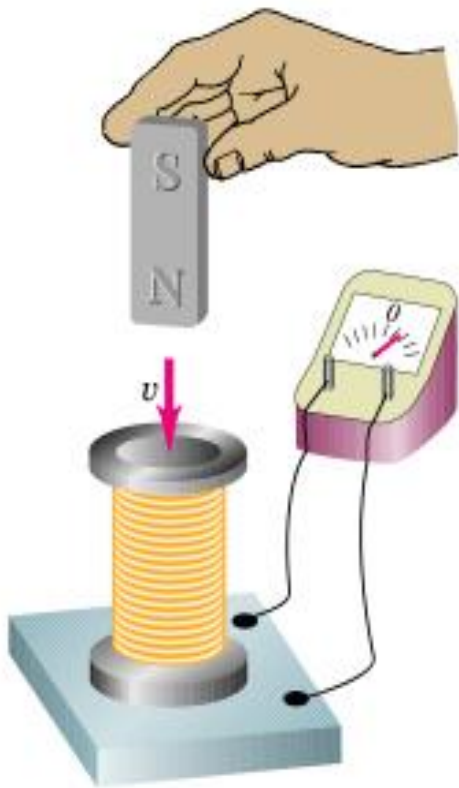
Either A, d or ϵ can be varied.



ELECTROMAGNETIC TRANSDUCTION:

In electromagnetic transduction, the measurand is converted to voltage induced in conductor by change in the magnetic flux, in absence of excitation. The electromagnetic transducer are self generating active transducers. The motion between a piece of magnet and an electromagnet is responsible for the change in flux





(a)

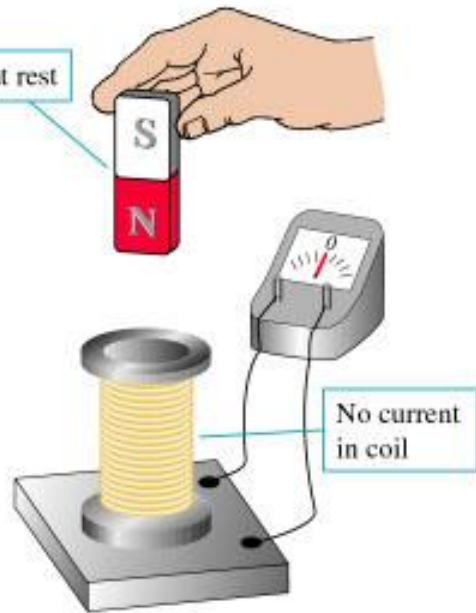
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(b)

(c)

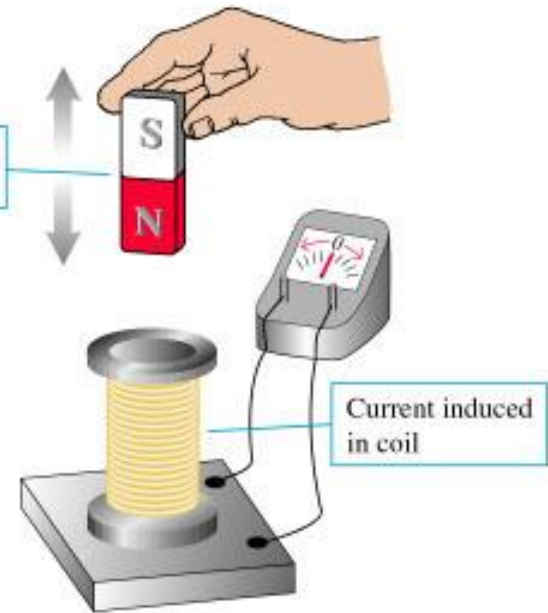
Current induced in a coil.

Magnet at rest



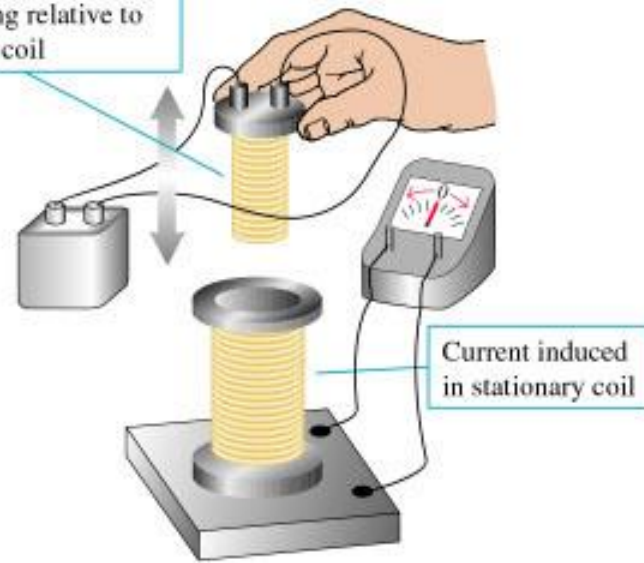
(a)

Magnet moving relative to coil



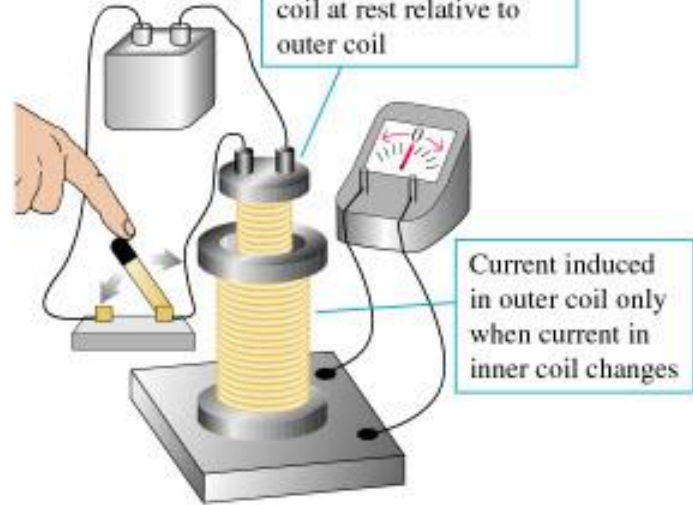
(b)

Second, current-carrying coil moving relative to stationary coil



(c)

Second, current-carrying coil at rest relative to outer coil



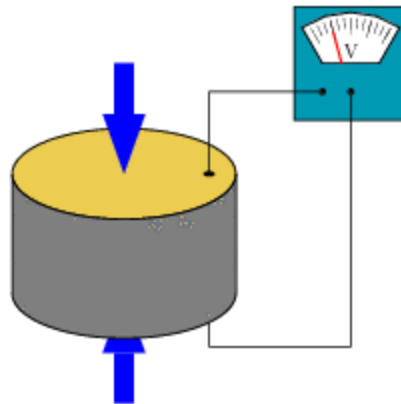
(d)

INDUCTIVE TRANSDUCER:

In inductive transduction, the measurand is converted into a change in the self inductance of a single coil. It is achieved by displacing the core of the coil that is attached to a mechanical sensing element.

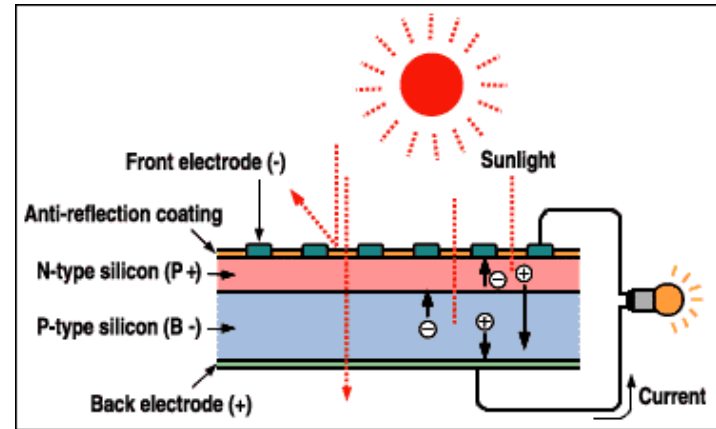
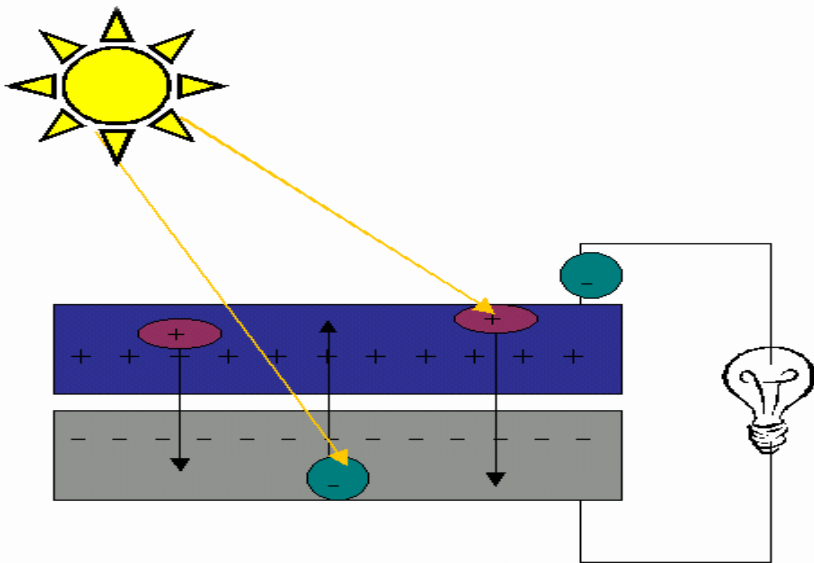
PIEZO ELECTRIC INDUCTION :

In piezoelectric induction the measurand is converted into a change in electrostatic charge q or voltage V generated by crystals when mechanically it is stressed as shown in fig.



PHOTOVOLTAIC TRANSDUCTION :

In photovoltaic transduction the measurand is converted to voltage generated when the junction between dissimilar material is illuminated as shown in fig.



Physics of Photovoltaic Generation

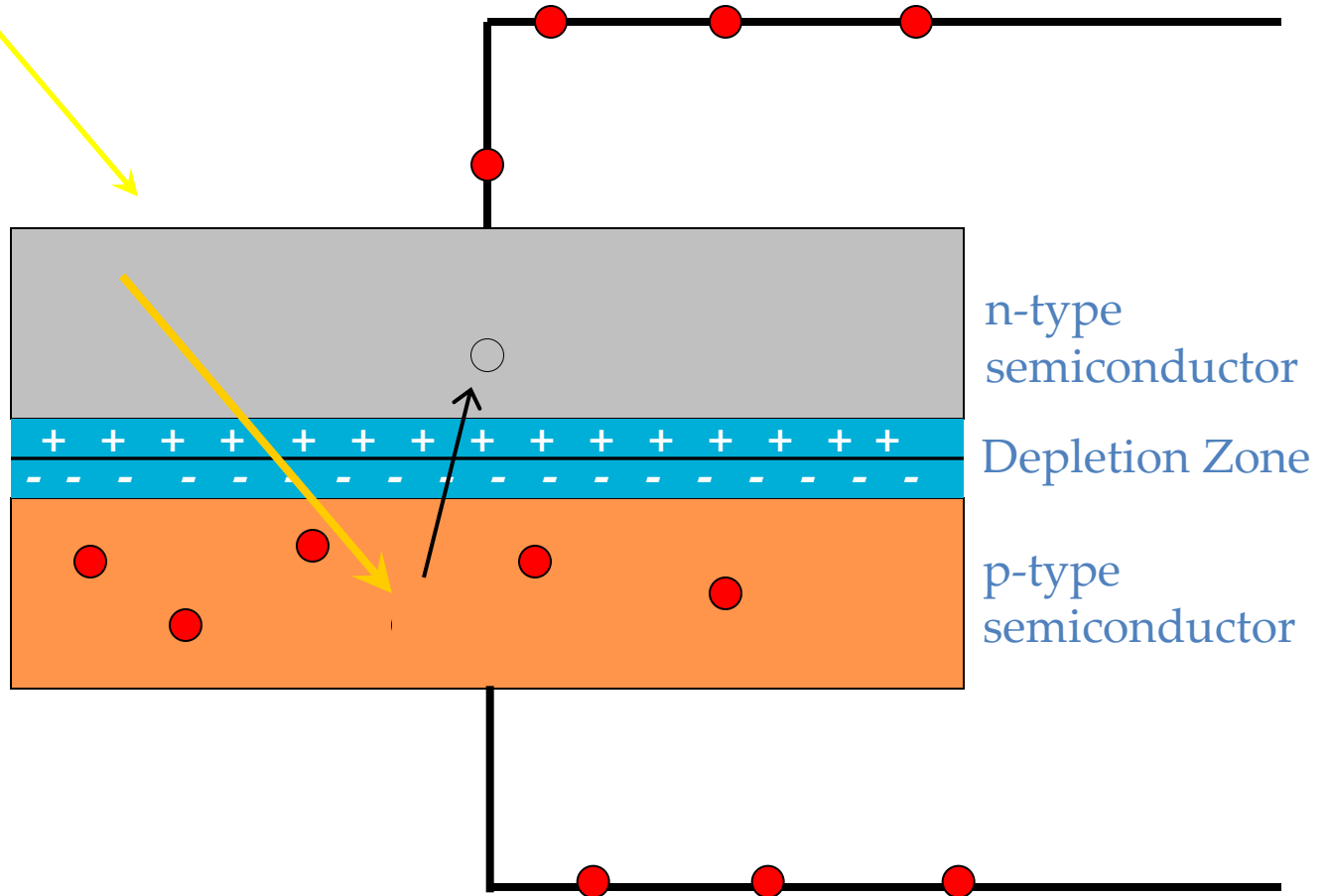
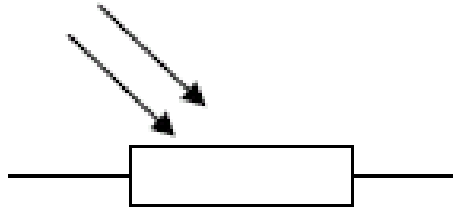


PHOTO CONDUCTIVE TRANSDUCTION :

In photoconductive transduction the measurand is converted to change in resistance of semiconductor material by the change in light incident on the material.



TRANSDUCER AND INVERSE TRANSDUCER

TRANSDUCER:

Transducers convert non electrical quantity to electrical quantity.

INVERSE TRANSDUCER:

Inverse transducers convert electrical quantity to a non electrical quantity

PASSIVE TRANSDUCERS

- **Resistive transducers :**

- Resistive transducers are those transducers in which the resistance change due to the change in some physical phenomenon.

- The resistance of a metal conductor is expressed by a simple equation.

- $R = \rho L/A$

- Where R = resistance of conductor in Ω

L = length of conductor in m

A = cross sectional area of conductor in m^2

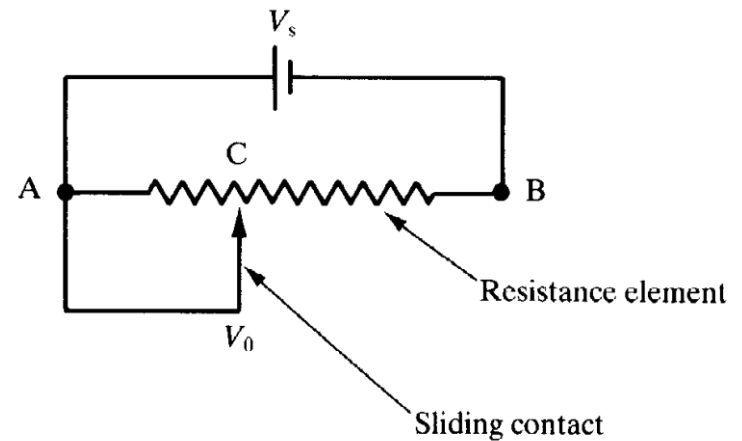
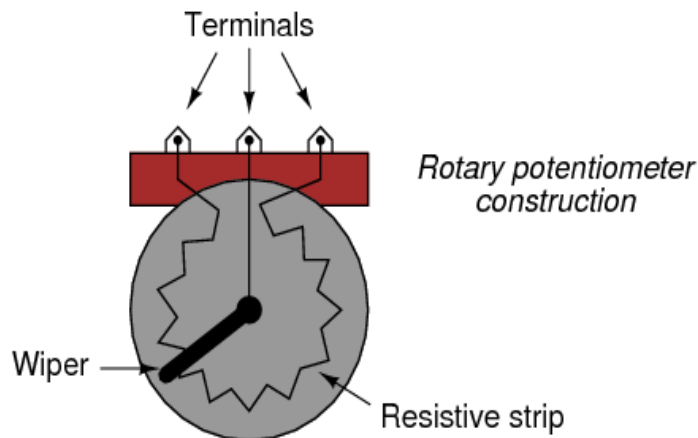
ρ = resistivity of conductor material in Ω -m.

There are 4 type of resistive transducers.

1. Potentiometers (POT)
2. Strain gauge
3. Thermistors
4. Resistance thermometer

POTENTIOMETER

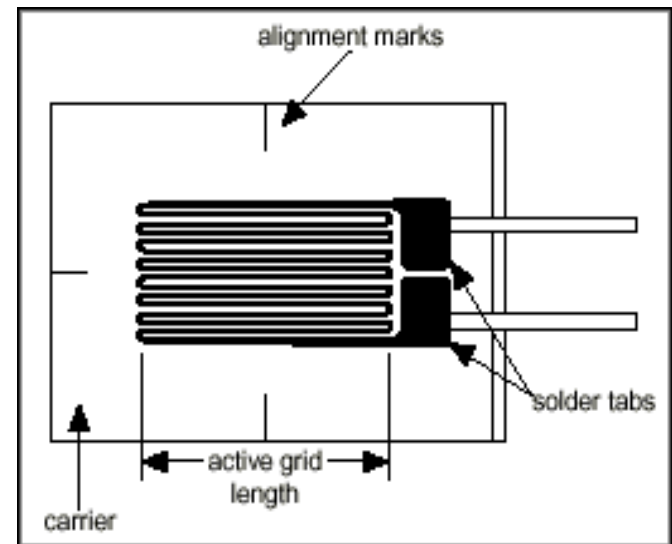
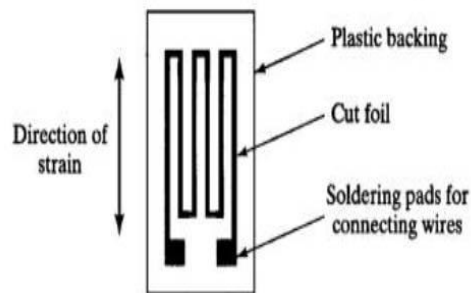
- The potentiometer are used for voltage division. They consist of a resistive element provided with a sliding contact. The sliding contact is called as wiper.
- The contact motion may be linear or rotational or combination of the two. The combinational potentiometer have their resistive element in helix form and are called helipots.
- Fig shows a linear pot and a rotary pot.



STRAIN GAUGE

- The strain gauge is a passive, resistive transducer which converts the mechanical elongation and compression into a resistance change.
- This change in resistance takes place due to variation in length and cross sectional area of the gauge wire, when an external force acts on it.

FIGURE 8.2
Foil strain gage.



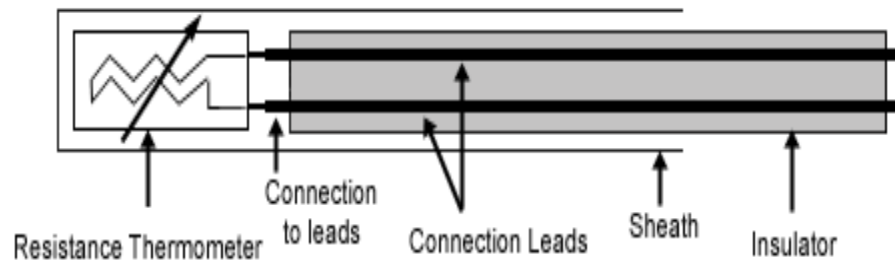
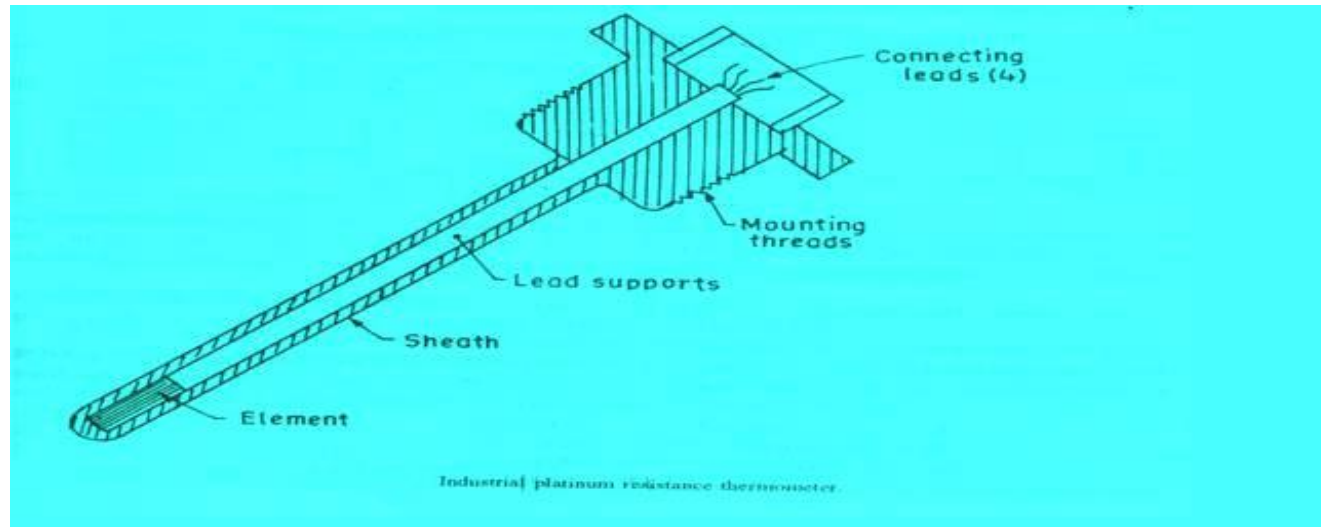
TYPES OF STRAIN GAUGE

- The type of strain gauge are as
 1. Wire gauge
 - a) Unbonded
 - b) Bonded
 - c) Foil type
 2. Semiconductor gauge

RESISTANCE THERMOMETER

- Resistance of metal increase with increases in temperature. Therefore metals are said to have a positive temperature coefficient of resistivity.
- Fig shows the simplest type of open wire construction of platinum resistance thermometer. The platinum wire is wound in the form of spirals on an insulating material such as mica or ceramic.

- This assembly is then placed at the tip of probe
- This wire is in direct contact with the gas or liquid whose temperature is to be measured.



The resistance of the platinum wire changes with the change in temperature of the gas or liquid

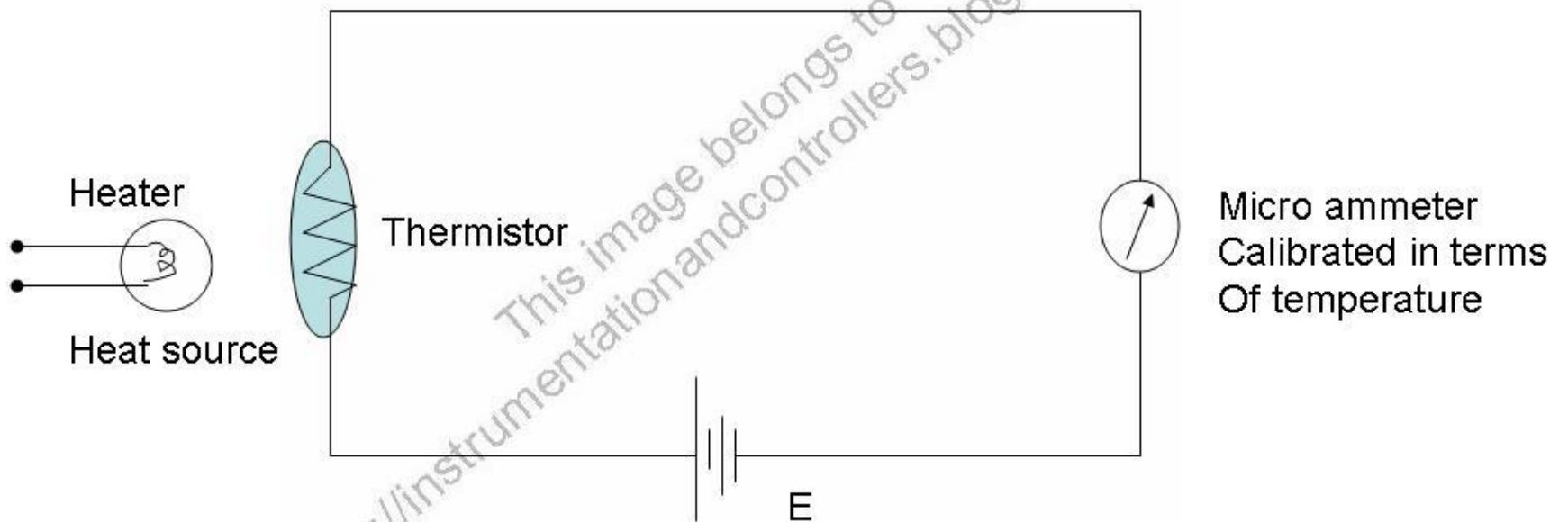
This type of sensor have a positive temperature coefficient of resistivity as they are made from metals they are also known as resistance temperature detector

Resistance thermometer are generally of probe type for immersion in medium whose temperature is to be measured or controlled.

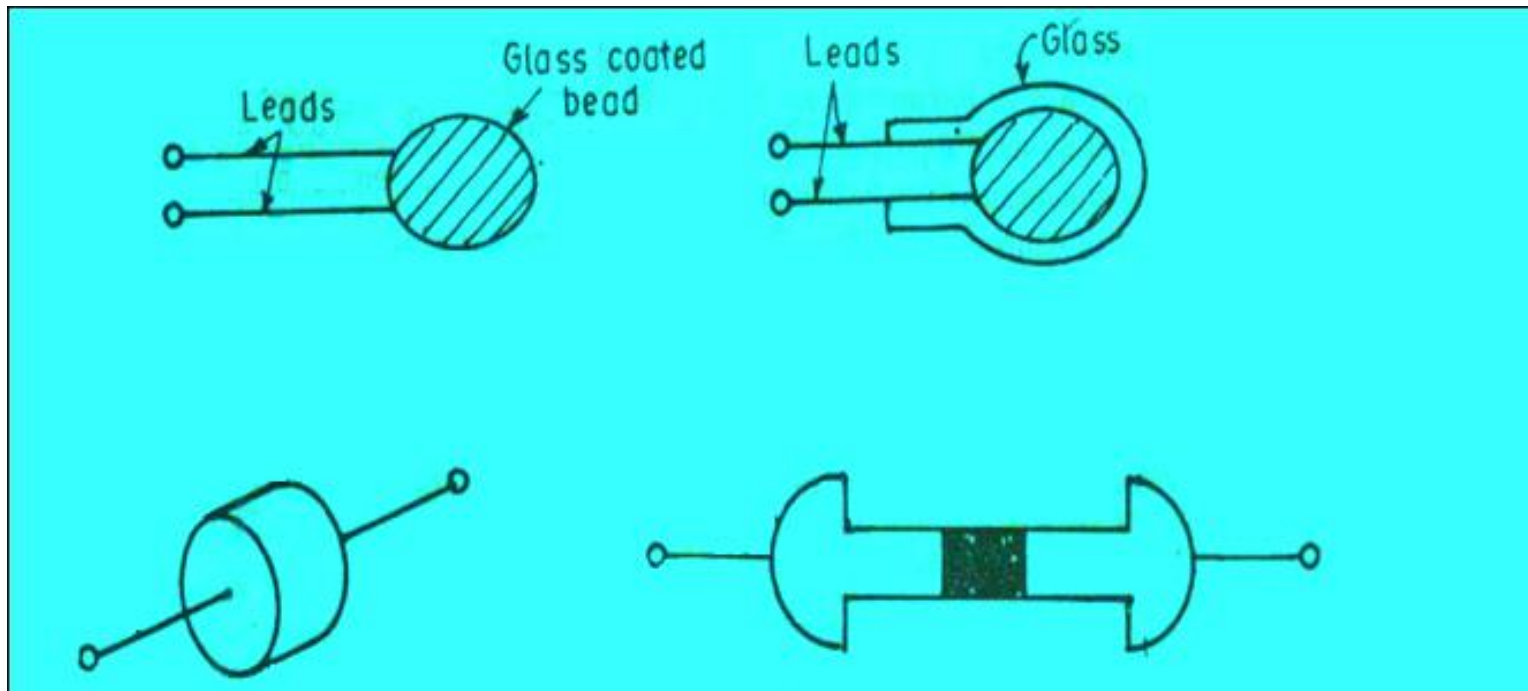
THERMISTOR

- Thermistor is a contraction of a term “thermal resistor”.
- Thermistor are temperature dependent resistors. They are made of semiconductor material which have negative temperature coefficient of resistivity i.e. their resistance decreases with increase of temperature.
- Thermistor are widely used in application which involve measurement in the range of 0-60° Thermistor are composed of sintered mixture of metallic oxides such as manganese, nickel, cobalt, copper, iron and uranium

Temperature measurement using thermistor



- The thermistor may be in the form of beads, rods and discs.
- The thermistor provide a large change in resistance for small change in temperature. In some cases the resistance of themistor at room temperature may decreases as much as 6% for each 1°C rise in temperature.

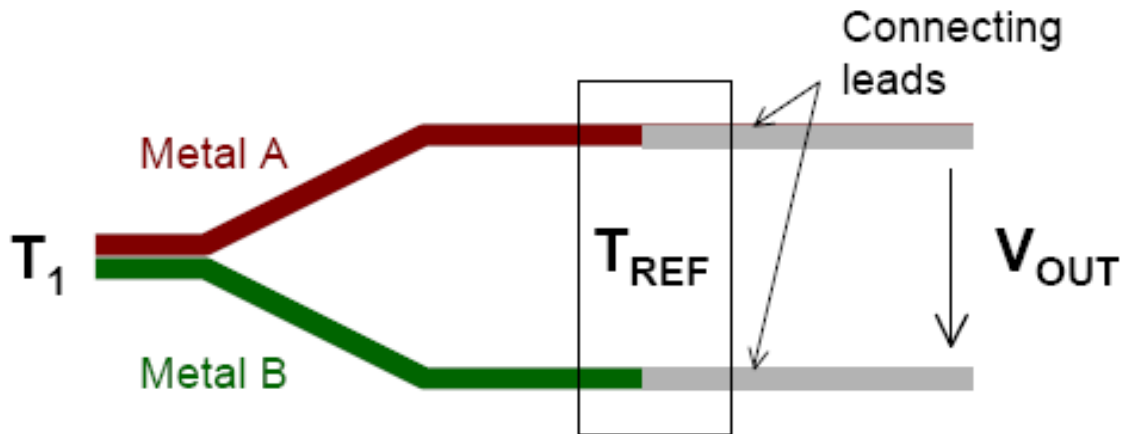


Thermocouples

Seebeck Effect

When a pair of dissimilar metals are joined at one end, and there is a temperature difference between the joined ends and the open ends, thermal emf is generated, which can be measured in the open ends.

This forms the basis of thermocouples.

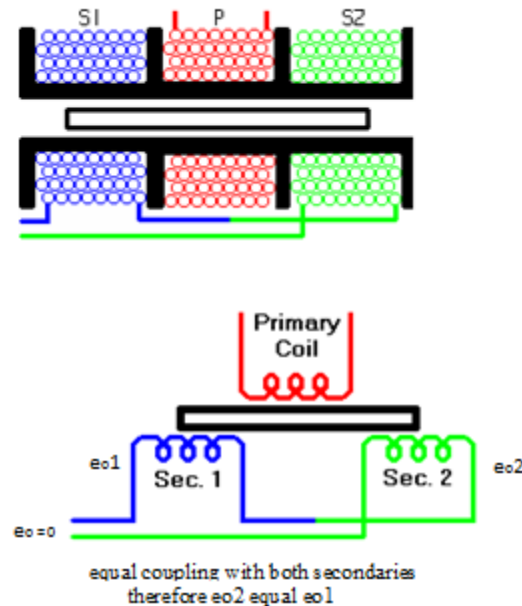


VARIABLE-INDUCTANCE TRANSDUCERS

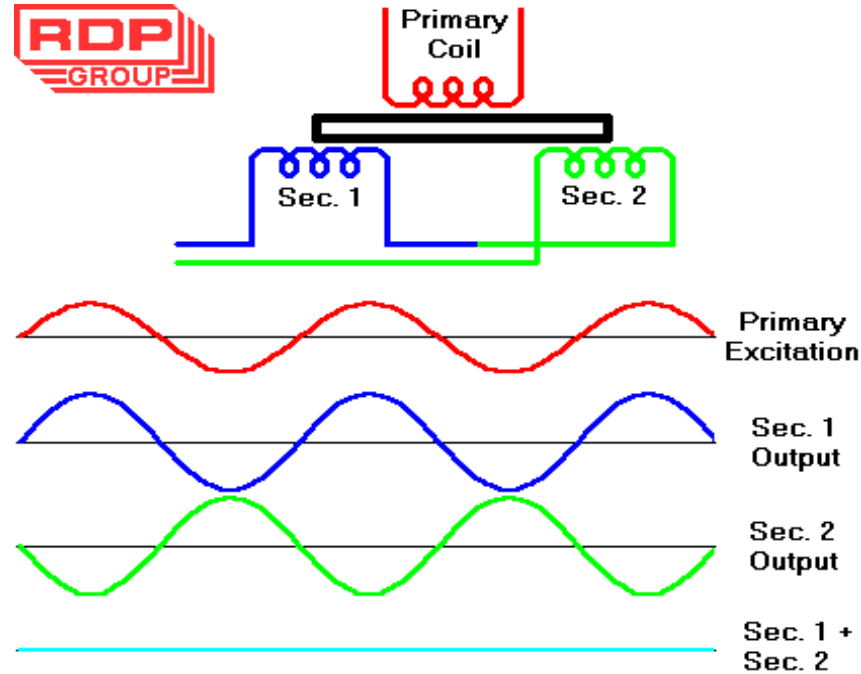
- An inductive electromechanical transducer is a transducer which converts the physical motion into the change in inductance.
- Inductive transducers are mainly used for displacement measurement.

LINEAR VARIABLE DIFFERENTIAL TRANSFORMER(LVDT)

- AN LVDT transducer comprises a coil former on to which three coils are wound.
- The primary coil is excited with an AC current, the secondary coils are wound such that when a ferrite core is in the central linear position, an equal voltage is induced in to each coil.
- The secondary are connected in opposite so that in the central position the outputs of the secondary cancels each other out.



- The excitation is applied to the primary winding and the armature assists the induction of current in to secondary coils.
- When the core is exactly at the center of the coil then the flux linked to both the secondary winding will be equal. Due to equal flux linkage the secondary induced voltages (e_{o1} & e_{o2}) are equal but they have opposite polarities. Output voltage e_o is therefore zero. This position is called “null position”



- Now if the core is displaced from its null position toward sec1 then flux linked to sec1 increases and flux linked to sec2 decreases. Therefore $e_{o1} > e_{o2}$ and the output voltage of LVDT e_o will be positive
- Similarly if the core is displaced toward sec2 then the $e_{o2} > e_{o1}$ and the output voltage of LVDT e_o will be negative.

REFERENCE :-

Electrical Measurement & Measuring Instrument

By A. K. Sawani