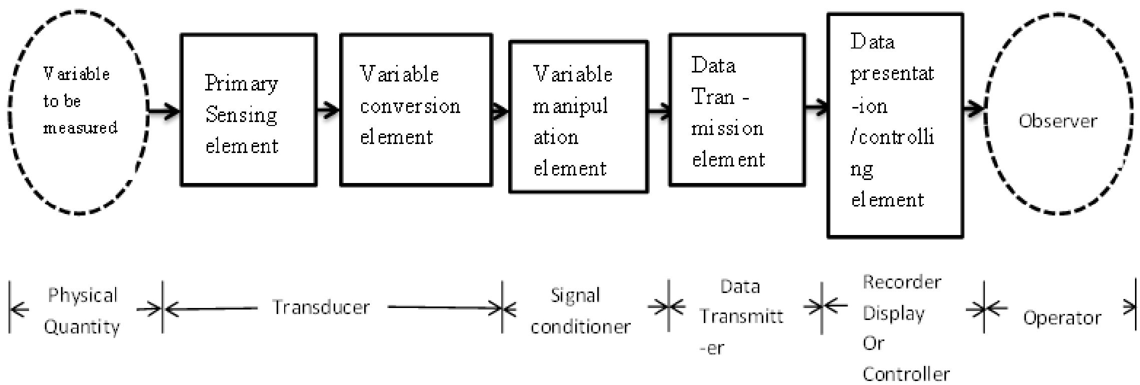
UNIT 1

INTRODUCTION TO TRANSDUCER (14 marks)

1.1 Transducer: Need of sensor or transducer, Classification: Active and Passive, Analog and Digital, Primary and Secondary, Mechanical and Electrical
1.2 Mechanical transducer: Bellows, diaphragm, bourdon tube, bimetallic strip
1.3 Electrical Transducer: resistive transducer- linear and Angular Potentiometers, Strain gauge-types, gauge factor
1.4 Capacitive Transducer
1.5 Inductive transducer -LVDT, RVDT, Magneto strictive
1.6 Piezoelectric transducer
1.7 Selection criterion of transducers

Introduction

Block diagram of instrumentation system



Functions of each block:

• **Primary sensing element:** This first receives energy from the measured medium and produces an output depending on measured quantity.

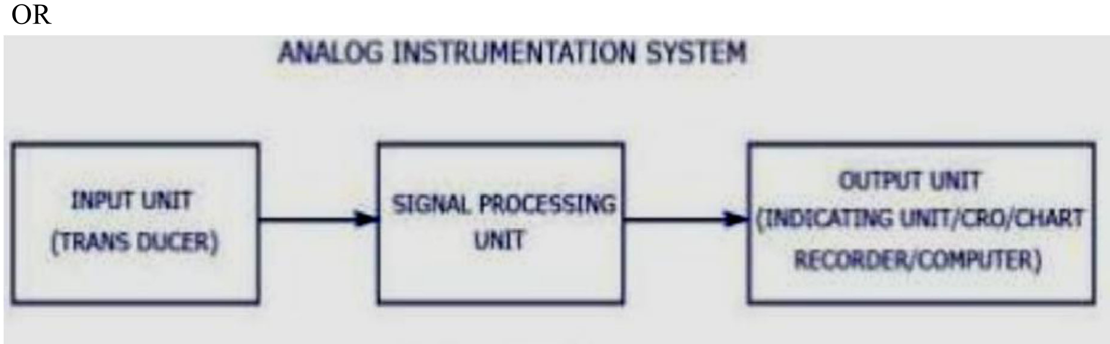
• **Variable conversion element:** Converts the output signal of the primary sensing element into a more suitable variable or condition useful to the function of the instrument.

• **Variable manipulation element:** Manipulates the signal represented by some physical variable, to perform the intended task of an instrument. In the manipulation process, the physical nature of the variable is preserved.

• **A data transmission element:** Transmits the data from one element to the other.

• **A data presentation element:** Performs the translation function, such as the simple indication of a pointer moving a scale or the recording of a pen moving over chart.

OR



• The Primary Element/Transducer: The input receives the quantity whose value is to be measured and is converted into its proportional incremental electrical signal such as voltage, current, resistance change, inductance or even capacitance. Thus, the changed variable contains the information of the measured variable. Such a functional element or device is called a transducer.

- The Secondary Element/Signal Processing Unit: The output of the transducer is provided to the input of the signal processing unit. This unit amplifies the weak transducer output and is filtered and modified to a form that is acceptable by the output unit. Thus, this unit may have devices like: amplifiers, filters, analog to digital converters, and so on.
- The Final Element/Output Unit: The output from the signal processing unit is fed to the input of the output unit. The output unit measures the signal and indicates the value to the reader. The indication may be either through: an indicating instrument, a CRO, digital computer, and so on

1.1 Transducer: Need of sensor or transducer, Classification: Active and Passive, Analog and Digital, Primary and Secondary, Mechanical and Electrical

A) Transducer

Definition:

Device which converts one form of energy to another form. Or, the device which converts nonelectrical energy to electrical energy. i.e. physical to physical, physical to electrical.

Examples:

a) Thermocouple b) Piezoelectric transducer c) Strain gauge d) Bellows
e) Diaphragm f) RTD g) Thermistor h) Bimetallic strips
i) Bourdon Tube

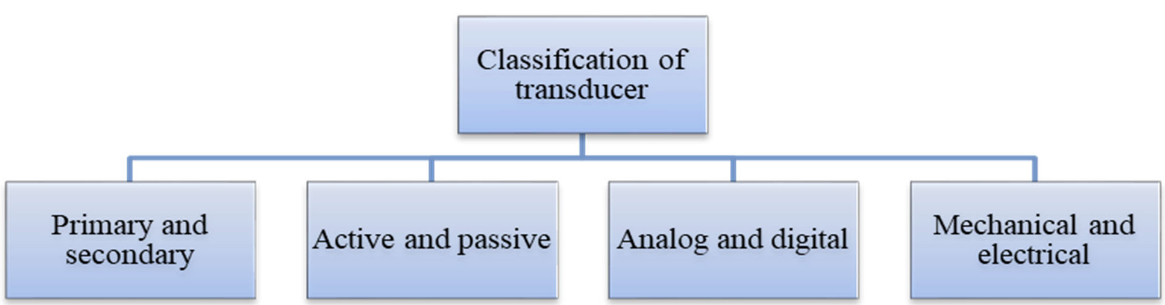
B) Need Of Transducers.

Input quantity for most of the Instrumentation systems is non – electrical quantity. To convert non- electrical quantities like heat, pressure, level, flow rate, humidity, temperature, etc. into electrical quantities in order to use electrical methods and techniques for measurement, manipulation and control, transducers are required.

C) Transducer Classification

Transducer is classified as:

1. Active transducer and passive transducer
2. Analog transducer and digital transducer.
3. Primary Transducer and Secondary Transducer
4. Mechanical transducer and Electrical transducer



(i) Active and Passive Transducers:

Active transducers:

Active transducers are also known as **self-generating** type transducers. They do not require an external power source to produce the output. They work under energy conversion principle. Active transducers develop their own voltage or current. The energy required for the production of the output signal is obtained from the physical phenomenon being measured.
Example: piezoelectric transducer, thermocouple.

Passive transducers:

Passive transducers are also known as **externally powered** transducers. They require an external power source to produce the output. They work under energy controlling principle.
Example: resistive, capacitive, inductive transducer.

Comparison of active and passive transducers.

Sr. No.	Parameter	Active Transducer	Passive Transducer
1	**Definition**	Do not require external power supply for its operation	Require external power supply for its operation
2	**Another name**	It is also called self-generating transducer	It is also called Externally powered transducer.
3	**Circuit**	Circuit is simple.	Circuit is complex
4	**Application**	Used for measurement of surface roughness in accelerometers & vibration pickups.	Used for measurement of power at high frequency
5	**Output form**	They produce an electrical signal proportional to the input physical quantity.	They produce an output signal in the form of some variation in resistance, capacitance or any other electrical parameter, which has to be converted to an equivalent current or voltage signal.
6	**Active bridge**	Not required	Required.
7	**Working Principle**	Operate under energy conversion principle	Operate under energy controlling principle
8	**Example**	Thermocouple, Piezoelectric transducer, Solar Cell, Tachogenerator, Photovoltaic cell, etc.	Thermistors, Strain gauges ,LVDT, RTD, potentiometer, capacitive transducer etc

(ii) Analog and Digital transducers

The output signal of the transducer may be continuous or discrete. Based on this, the transducers are classified by their output signals as Analog and Digital transducers.

Analog Transducer:

The Analog transducer changes the input quantity into a continuous function.
Example: strain gauge, L.V.D.T, thermocouple, thermistor, Solar Cell/ Photovoltaic cell

Digital Transducer:

These transducers convert an input quantity into an electrical signal which is in digital form or in the form of the pulse.
Example: Tachometer, shaft encoder, Optical encoder

(iii) Primary & secondary transducer

Primary Transducer:

The detector or sensing element which senses the physical phenomenon and converts it into a measurable quantity, whose output forms the input of another transducer is called a primary transducer.

i.e. Primary transducers are the sensors which comes in contact with the measurement medium, senses it and gives the output in nonelectrical form

Secondary Transducer:

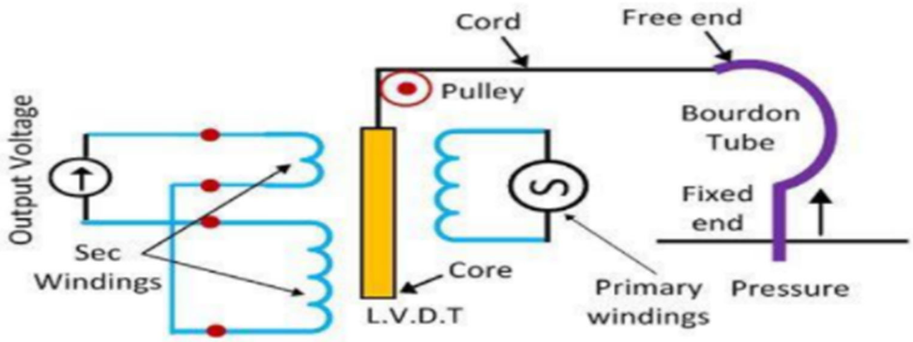
A transducer which converts analogous output of primary transducer into an electrical quantity is called a secondary transducer.
i.e. Secondary transducers convert the nonelectrical output of primary transducer to electrical form.

Comparison Of Primary transducer and Secondary transducer:

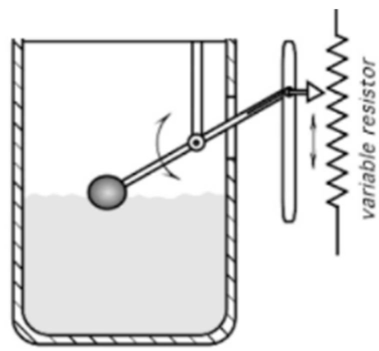
Sr. No.	**Primary transducer**	**Secondary transducer**
1	The Mechanical device which converts physical quantity to be measured into a mechanical signal	The Electrical device which converts this mechanical signal to the electrical signal
2	Primary transducer is that which comes in contact with the medium being measured	The secondary transducer does not come in direct contact with the medium being measured
3	Output of primary transducer will not directly used in process system	Output of secondary transducer directly used in process system
4	It is mechanical device	It is electrical device
5	Example :- Bourdon tube, bellows, Load cell	Example :- LVDT, Strain Gauge

Example of primary and secondary transducer:

(a) Bourdon tube with LVDT for pressure measurement:



(b) Float with potentiometer for level measurement:



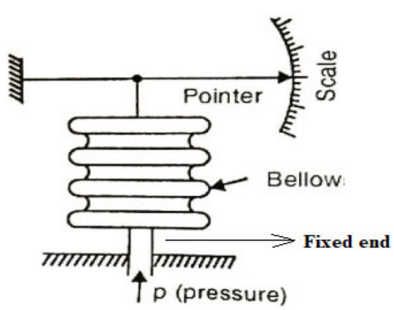
(iv) Mechanical and Electrical transducers

The output signal of the transducer may be Mechanical or Electrical. Based on this, the transducers are classified as Mechanical or Electrical transducers.

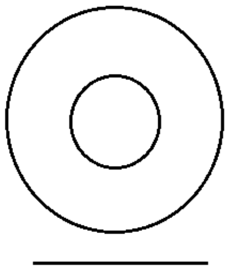
Mechanical transducer: the output is mechanical or non-electrical.
Example: Bourdon tube & bellows

Electrical transducer: the output is electrical.
Example: strain gauge, L.V.D.T, thermocouple, thermistor, RTD

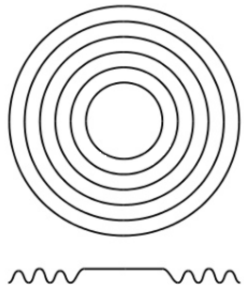
1.2 Mechanical transducer: Bellows, diaphragm, bourdon tube, bimetallic strip Bellows



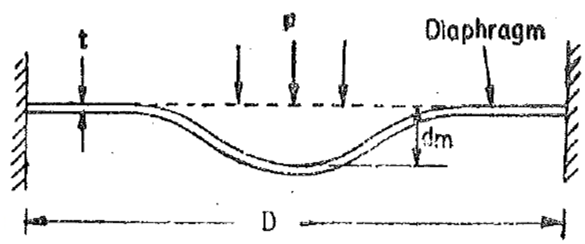
diaphragm



a) Flat type

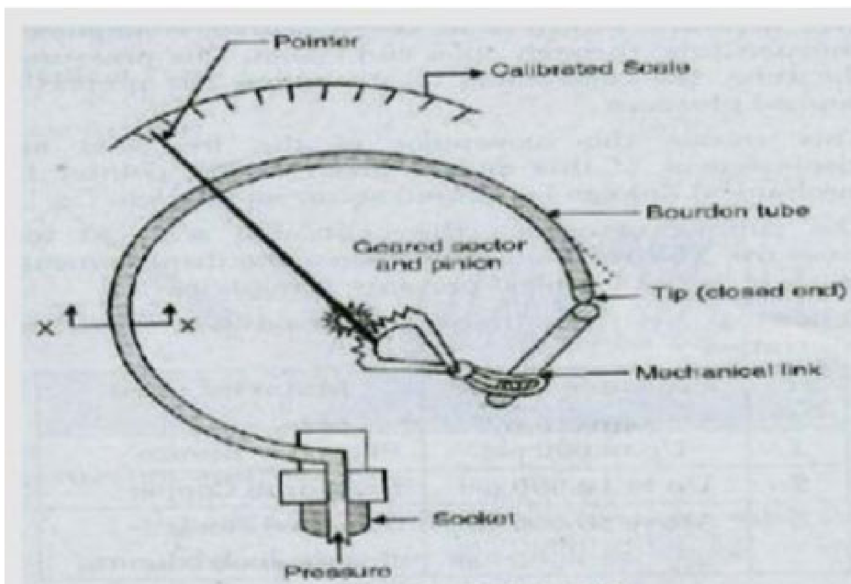


b) Corrugated type



Flat diaphragm.

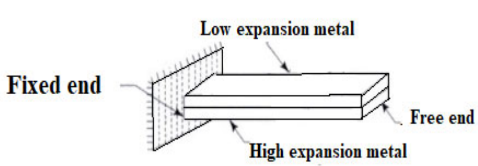
Bourdon tube



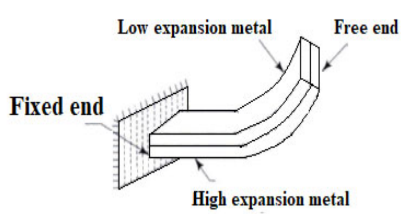
(a) C type bourdon tube

Fig: C-Type Bourdon Tube

Bimetallic strip



(before heating)



(after heating)

Bimetallic Strips

1.3 Electrical Transducer: resistive transducer- linear and Angular Potentiometers, Strain gauge-types, gauge factor.

Advantages of electrical transducers.

1) The electrical systems can be controlled with a very small level of power. i.e. The power requirement of transducers is very small
2) The electrical output can be easily used, transmitted and processed for the process of measurement.
3) The output can be indicated and recorded remotely from the sensing element.
4) Friction effect is minimized.
5) Electrical signals can be easily attenuated or amplified and can be brought up to the level suitable for various devices.
6) Due to IC technology, electrical & electronic systems are compact, having less weight
7) Reduce effect of mass inertia problems

Electrical Transducers:

Here, the output is electrical quantity. Based on the principle used to convert physical input to electrical output, electrical transducers are classified as resistive, capacitive, inductive, piezoelectric

Resistive transducers:

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

where R is the resistance (ohms),
L is the length of the conductor (m),
A is the cross-sectional area of the conductor (m2)
ρ is the specific resistance of the metal conductor (ohm-m).

The resistance of a metal conductor is directly proportional to the length of the conductor and inversely proportional to the cross-sectional area of the conductor.

The transducer whose resistance varies because of any physical phenomena which changes any of the above physical quantities 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.
Examples for resistive transducers are potentiometer, strain gauge, RTD and thermistor.

1. Linear and Angular potentiometers

·The **Linear and Angular potentiometers** are the examples of the resistive transducers used for measurement of displacement. Potentiometers convert change in mechanical position into change in resistance.

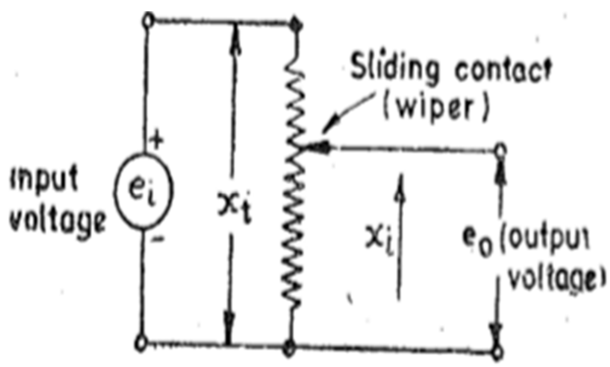
· Potentiometers consist of a resistance element provided with a sliding contact called wiper.

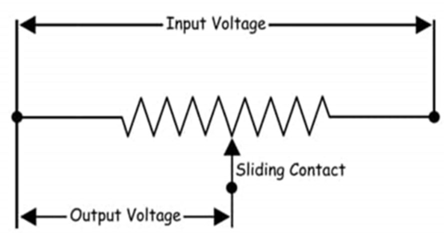
·The motion of the siding contact can be translational (**Linear**) or rotary (**Angular**).

·Potentiometers work on the basis of change in the value of resistance with the change in the length of the resistance element or the conductor.

·The linear resistive elements are straight and angular resistive elements are circular.

·The resistance element needs AC or DC external supply. So, a potentiometer is a **passive** device.





Linear potentiometer

· The sliding contacts are placed on the resistive element. The movement of the slider changes the value of the resistance of the transducer.

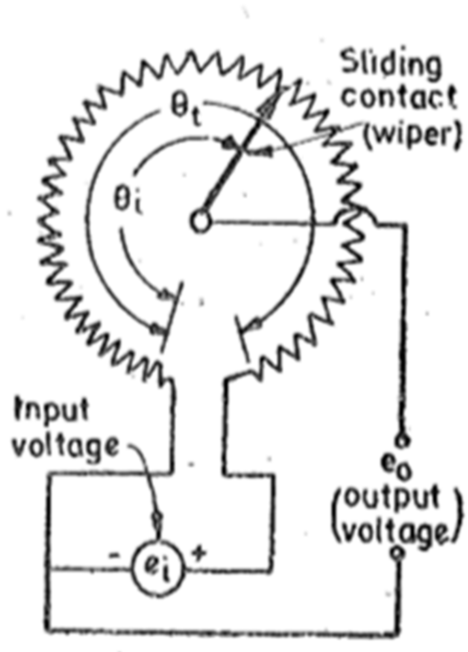
· X_t is the total length of the resistance element,

X_i is the length of the resistance element where wiper is kept (or, it is the displacement of the wiper from its 0 position).

Total resistance is R_t

·Output voltage $e_0 = e_i \frac{x_i}{x_t}$

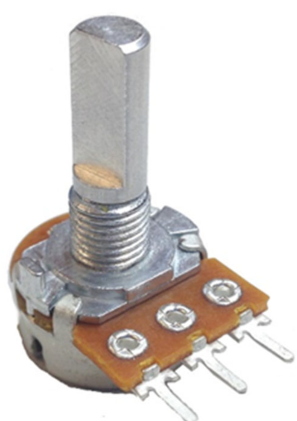
Angular potentiometer:

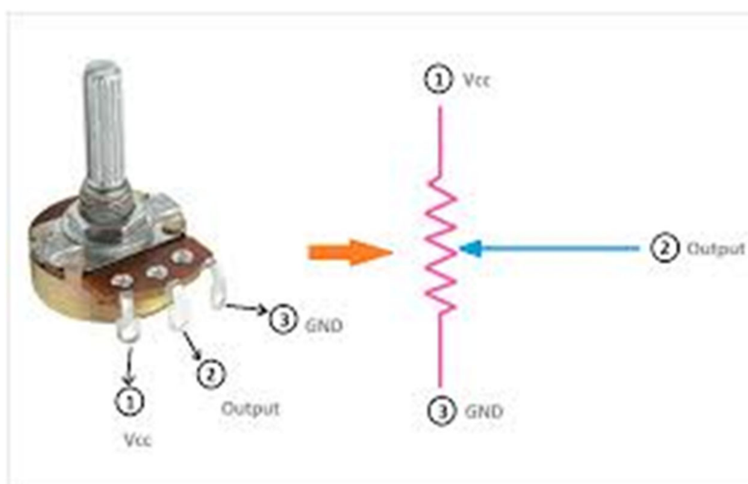


Θ is the angular displacement.

·Output voltage of Angular potentiometer $e_0 = e_i \frac{\theta_i}{\theta_t}$

Potentiometer:

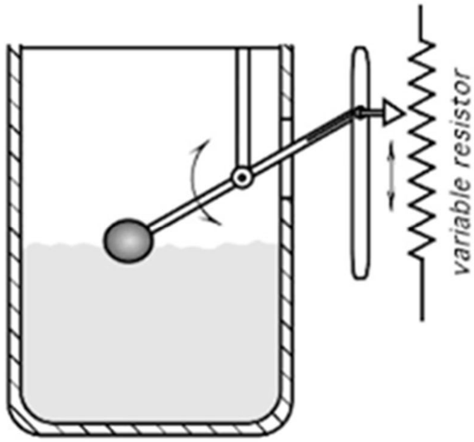


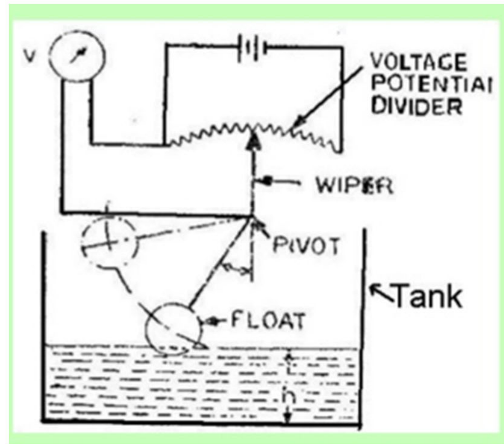


Applications of potentiometer:

I. Measurement of displacement,

ii. Measurement of level and pressure as secondary transducer





Advantages of resistive potentiometer:

i. Inexpensive
ii. Simple to operate
iii. Useful for measurement of large amplitude of displacement

Disadvantages of resistive potentiometer:

i. Linear potentiometer requires large force to move their sliding contact (wipers)
ii. The sliding contact can be contaminated, become misaligned, generate noise and can wear out; so, the life of the transducer is limited.

STRAIN GAUGE, TYPES, GAUGE FACTOR

Strain:

It is defined as the ratio of change in length to original length
OR
The ratio of change in dimension to the original dimension is called strain
OR
The effect of applied force is referred to as Stress, and the resulting deformation is the Strain.
i.e the deformation due to the effect of applied force is called Strain.

It is the relative change in shape or size of an object due to externally applied force.
$strain = extension\ (change\ in\ length)/original\ length$

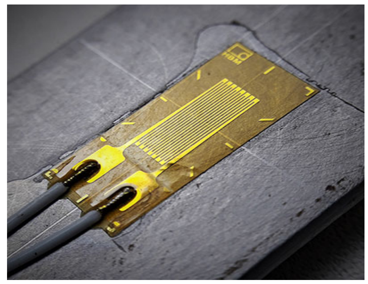
$$\varepsilon = \Delta L / L$$

Stress:

It is defined as the force experienced per unit area

Strain Gauge:

It is a resistive transducer whose resistance varies with applied force; it converts force, pressure, tension, weight, etc., into a change in electrical resistance which can then be measured.
Strain gauge is a passive transducer



Working principle of strain gauge.

If a metal conductor is stretched or compressed, the resistance changes as both length and diameter change. There is a change in the value of resistivity of the conductor also, when it is strained and this property is called Piezo resistive effect. Strain gauges work on the principle of "Piezo resistive effect".
Therefore strain gauges are also known as Piezo resistive gauges.

When a strain gauge is subjected to positive strain (tensile force) its length increases and area of cross section decreases. As resistance R is directly proportional to its length L and inversely proportional to the area of cross section A, the resistance of the conductor increases with positive strain. But this change is greater than that due to change in dimensions.
As $\mathbf{R = \rho \frac{L}{A}}$
Where ρ = resistivity of the conductor,
The extra change in dimensions is due to change in resistivity of the conductor when strained.
This property is a piezo resistive effect.
Application: Strain gauges can be used as the secondary electrical transducer along with a suitable primary mechanical transducer for converting the basic quantity under measurement into electrical output.
Thus, strain gauges can be used to measure force, displacement and weight.

Gauge Factor: It is defined as the ratio of per unit change in resistance to per unit change in length.
Gauge factor of a strain gauge is called strain sensitivity factor.

$$GF = \frac{\frac{\Delta R}{R}}{\frac{\Delta L}{L}}$$

OR

The measurement of the sensitivity of a material to strain is called as Gauge factor (GF)

Types of strain gauges:

1. Unbonded metal wire strain gauges
2. Bonded metal wire strain gauges
3. Bonded metal foil strain gauges
4. Semiconductor strain gauges
5. Vacuum deposited metal film strain gauges
6. diffused metal strain gauges
7. Sputter deposited thin metal strain gauge

.

Bonded metal strain gauge.

Construction and working:

1. These gauges may be of metallic, semiconductor material or in the form of grid of fine resistance wire of about 0.025mm or less than it in diameter in different shapes such as linear, helical or metal foil etc.

2. Materials used in construction of strain gages are

1) Gauge wire material

It is basic sensing element Ex Nichrome, Constantan, Nickel, platinum, Manganin, soft iron etc.

2) Base (Carrier) material

It is used to support the wire Ex Paper or Teflon or Bakelite is commonly used. For limited operation material like Epoxy, fiber glass is used. It is used to support the wire.

3) Adhesives

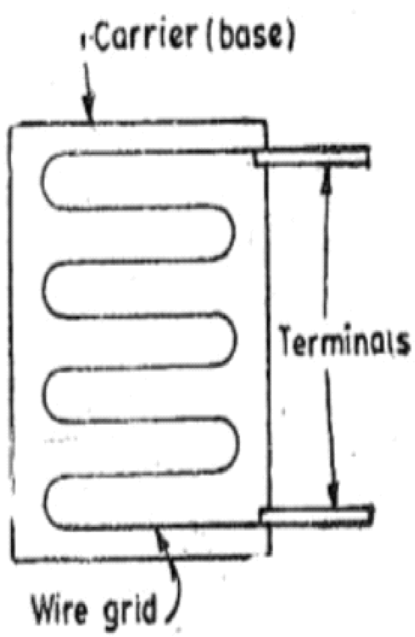
The carrier is bonded with an adhesive material to the structure. It is used to stick the gauge wire to the base. It is bonding material to stick the gauge wire to the base. Ex- Epoxy cement, Bakelite cement, ethyl cellulose cement, nitrocellulose cement. This permit good transfer of strain from carrier to wires.

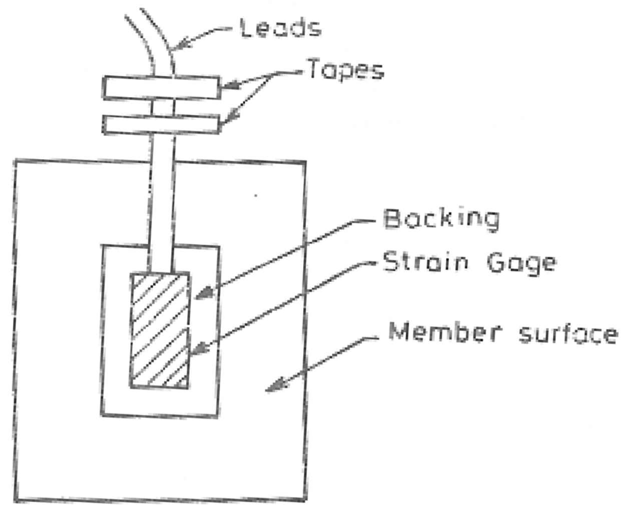
3.The grid of wire is fixed with carrier (base) with an adhesive material as listed

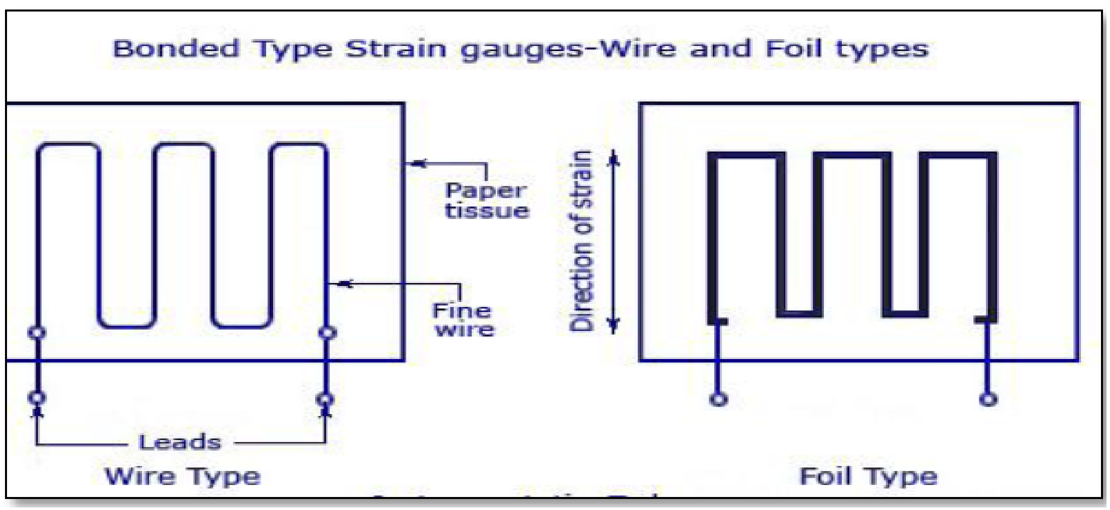
4.The grid wire is covered with protective layer of thin sheet to avoid any mechanical damage.

5. The specific shape of the grid permits a uniform distribution of applied stress or strain. The carrier is bonded.

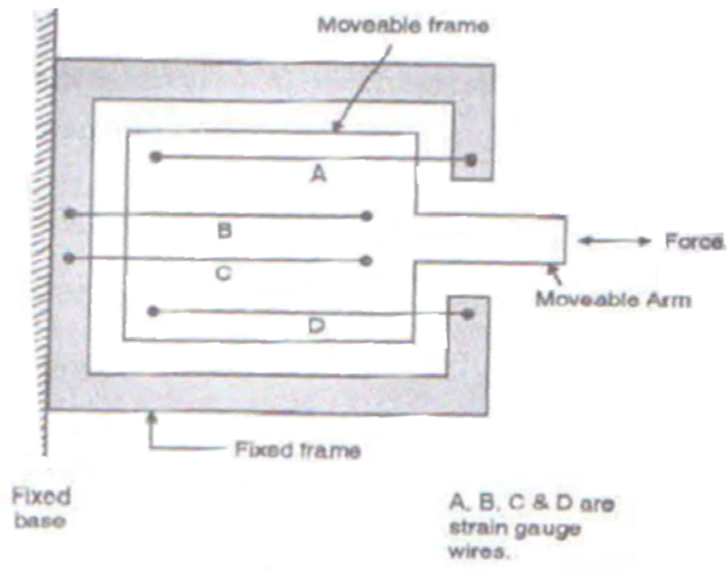
6. As the strain or stress is applied to gage, the resistance of gage will change which is available across the gauge leads.


Carrier (base)
Terminals
Wire grid

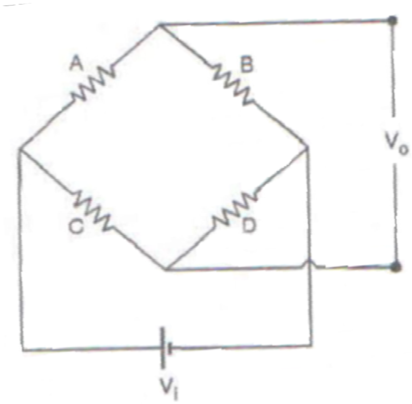

Leads
Tapes
Backing
Strain Gage
Member surface


Bonded Type Strain gauges-Wire and Foil types
Paper tissue
Fine wire
Direction of strain
Leads
Wire Type
Foil Type

18. The working of strain gauge using Wheatstone configuration.



(a) Unbounded strain gauge



(b) Wheat stone bridge arrangement

Working:

- Four strain gauges are connected as four arms in Wheatstone's bridge.
- Two strain gauges will be under tension and two under compression.
- When mechanical deformation is applied, the strain gauges will get compressed or expanded and the bridge becomes unbalanced. Thus, the electrical output is obtained.

1.4 CAPACITIVE TRANSDUCER

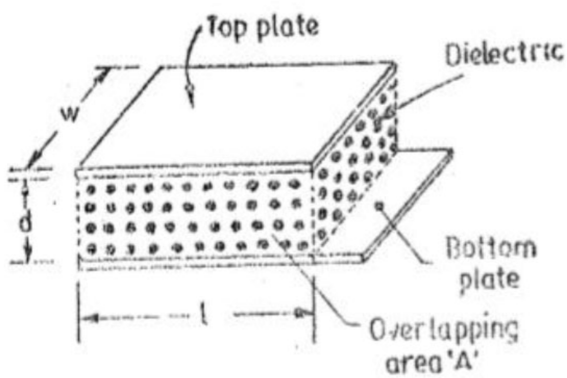
The principle of operation of capacitive transducer is based on the equation for capacitance of a parallel plate capacitor

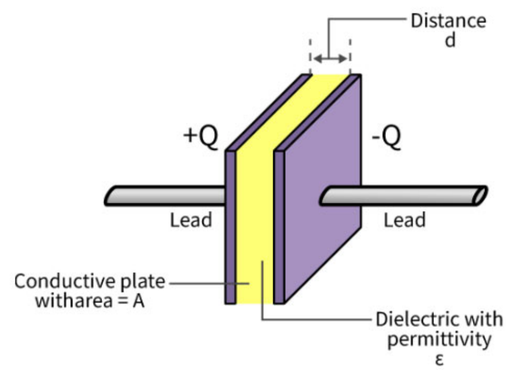
$$C = \varepsilon \frac{A}{D}$$

C = Capacitance
A = Overlapping area between the parallel plates, m^2
D = Distance between the parallel plates ,m

ε = Dielectric constant

Capacitance is directly proportional to the overlapping area between the parallel plates and inversely proportional to the distance between the parallel plates.
Schematic diagram of parallel plate capacitor:



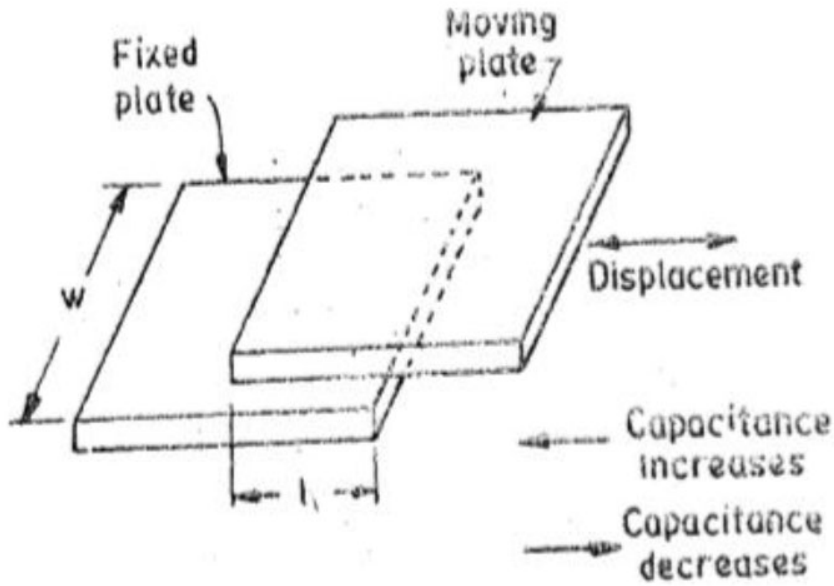


The capacitance transducer works on the principle of change of capacitance which may be caused by

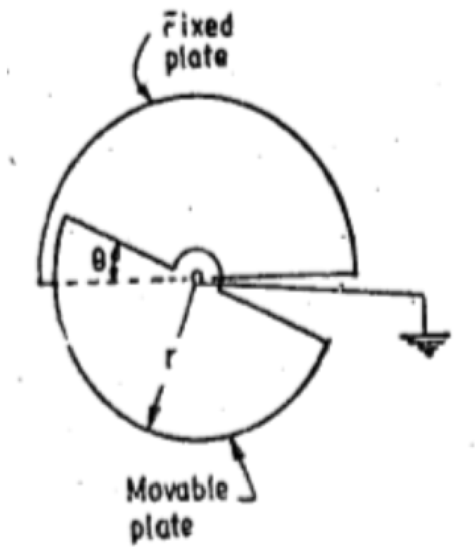
1. The change in overlapping area between the parallel plates
2. Change in the distance between the parallel plates
3. Change in the dielectric constant

These changes are caused by physical variables like displacement, force or pressure. Change in capacitance due to change in dielectric Constant is used in the measurement of liquid level or gas level.

i The capacitive transducer with change in overlapping area:
The capacitive transducer working with the principle of change of capacitance with change in overlapping area between the parallel plates is used for the measurement of displacement. Capacitance is directly proportional to the overlapping area between the parallel plates. Therefore, the capacitance increases with increase in the overlapping area between the parallel plates.
The capacitive transducer for the measurement of linear displacement with change in overlapping area is shown in the figure below:



The capacitive transducer for the measurement of angular displacement with change in overlapping area is shown in the figure below:

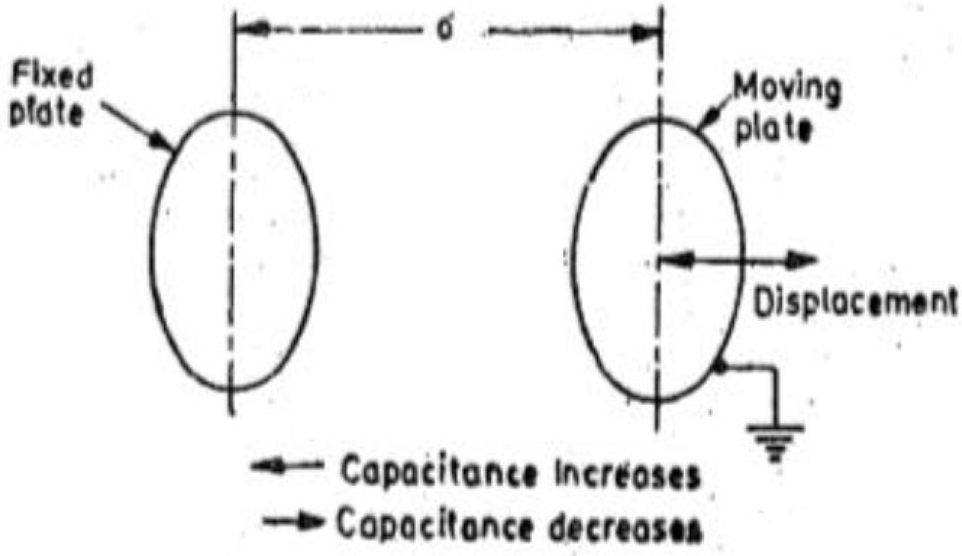


One plate is fixed and the other is movable. The angular displacement to be measured is applied to movable plate. The angular displacement changes the effective area between the plates. This changes the capacitance. When two plates completely overlap each other, the capacitance is maximum.

ii)iThe capacitive transducer with change in the distance between the parallel plates:

The capacitive transducer working with the principle of change of capacitance with change in distance between the parallel plates is used for the measurement of displacement. Capacitance is inversely proportional to the distance between the parallel plates. Therefore, the capacitance decreases with increase in the distance between the parallel plates.

One plate is fixed and the other is movable. The displacement to be measured is applied to
movable plate. This changes the distance between the plates. Thus, the capacitance is changed inversely. It is used for measurement of small displacement since the response is not linear.



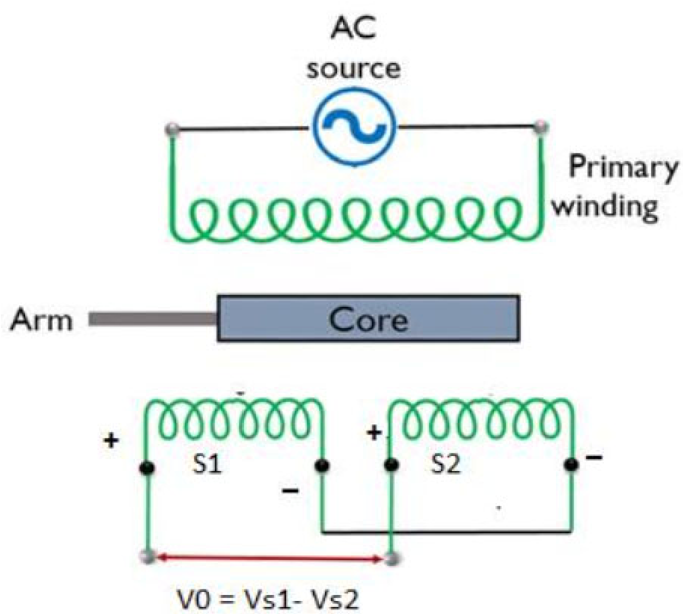
Advantages of capacitive transducer:
• Require very small forces to operate them and hence are very useful in small systems
• They are extremely sensitive
• They have good frequency response
• They have very high input impedance therefore loading effects are minimum
• Good resolution
• Less power is required to operate as less forces required
Disadvantages of capacitive transducer:
• The metallic parts of the capacitive transducer must be insulated from each other
• The output impedance is high as value of capacitance is small
• The capacitance may be changed due to the presence of dust particles
• They are temperature sensitive
• The instrumentation circuitry with these transducers is very complex
Applications of capacitive transducer:
I Capacitive transducer is used for the measurement of linear and angular displacement.
i Capacitive transducer is used for the measurement of liquid level, force, pressure, weight, volume & humidity in gases

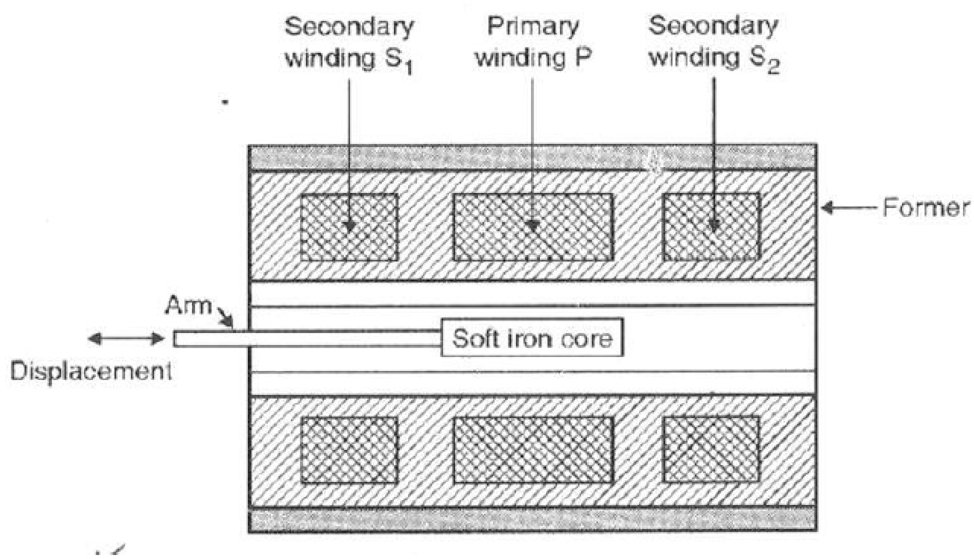
1.5 INDUCTIVE TRANSDUCER- LVDT, RVDT,Magnetostrictive

Inductive transducer
It works on the principle of variable inductance. The inductance is varied according to the displacement. Examples of inductive transducers are LVDT and RVDT

LVDT-Linear Variable Differential Transformer

LVDT is a type of inductive transducer which is used to measure linear displacement. It converts displacement into voltage.





It works on the principle of variable inductance. The inductance is varied according to the displacement.

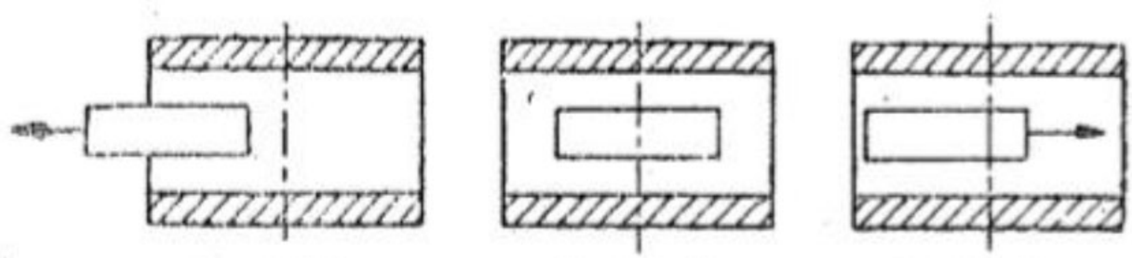
Construction of LVDT:

1) A differential transducer consists of a one primary winding and two secondary winding S1 and S2 wound on a cylindrical former. S1 and S2 have equal number of turns and are connected in series opposition
2) The two secondary winding are placed identically on either side of the primary winding.
3) A movable soft iron core is placed inside the former and it is placed in between the primary and secondary windings. Displacement to be measured is applied to the arm attached to the soft iron core.
4) An AC input voltage is applied across the primary winding. When the core moves, it

varies the coupling between primary and two secondary windings.

5) When a displacement is applied to the movable core, the flux linking with both the secondary winding changes and produces output voltage which is proportional to the displacement applied.
6) An AC source is applied across the primary winding and core varies the coupling between it and two secondary windings.
7) When a displacement is applied to the movable core, the flux linking with both the secondary winding changes and produces output voltage which is proportional to the displacement applied.
   The output voltage is Vo = (VS1 -VS2)
   where VS1 is voltage induced in S1 and VS2 is voltage induced in S2.

Working:



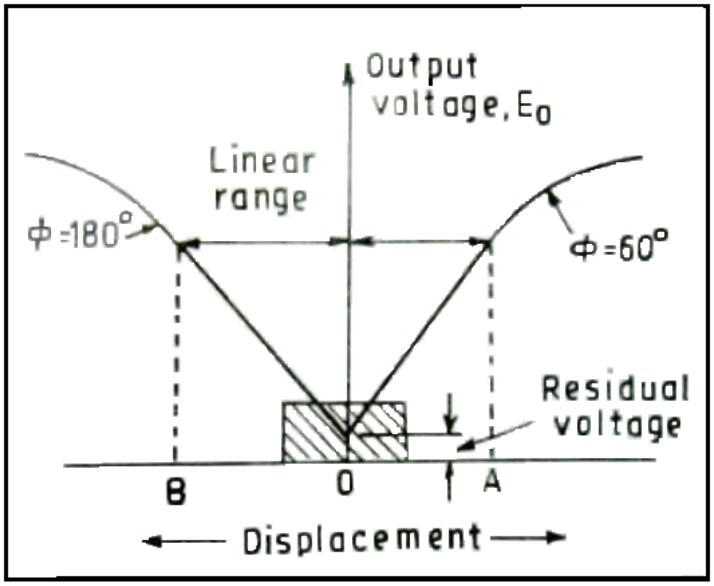
Case I: When there is no displacement. (Core is at NULL (normal) position)
When no displacement is applied to the core, the core is at normal position. The flux linking with both the secondary windings is equal. Equal e.m.f. is induced in both secondary windings or VS1=VS2
So, Vo = VS1 -VS2 = 0
The output voltage Vo at null position is zero.
Case II: When the core moves to the left due to some displacement or the core is at A:
When the core is moved to the left of the null position due to some displacement applied, more flux links with winding S1 than winding S2
Hence e.m.f. induced in S_1 is greater than the e.m.f. in S_2, that is $V_{S1}>V_{S2}$
The output voltage $V_o = V_{S1}-V_{S2}$ and is in phase with the input primary voltage.
Case III: When the core moves to the right due to some displacement or the core is at B:
When the core is moved to the right of the null position due to applied displacement, more flux links with winding S_2 than winding S_1. So e.m.f. induced with winding S_2 is greater than S_1. that is $V_{S2}>V_{S1}$

Hence the output voltage $V_o= V_{S1}-V_{S2}$ and is 180^0 out of phase with the input primary voltage. In this way any physical displacement of the core causes the voltage of one secondary winding to increase while simultaneously reducing the voltage in the other winding. By noting which output voltage is increasing or decreasing, the direction of motion can be determined.

The difference of the two voltages due to the series opposition connection appears across the

output terminals of the transducer and gives a measure of the physical position of the core and hence the displacement.
The output voltage of LVDT is a linear function of core displacement within a limited range of motion (5 mm from null position)

Graph of L V D T between displacement and output voltage:



Residual voltage:

Ideally the output voltage at the null position should be equal to zero but in actual practice there exists a small voltage at null position . this voltage is called residual voltage.
Residual output is due to presence of harmonics in the input supply, harmonics produced in the output voltage due to iron core, temperature effect and stray magnetic field.

This finite residual voltage is generally less than 1% of the max. o/p voltage in the linear range.

Advantages of LVDT :-

Very basic transducer which is always useful in the field of instrumentation, Infinite resolution is present in LVDT

- High output
- Simple design
- High sensitivity
- Very good linearity
- Ruggedness
- Provides Less friction
- Low hysteresis
- LVDT gives Low power consumption

Disadvantages of LVDT:-

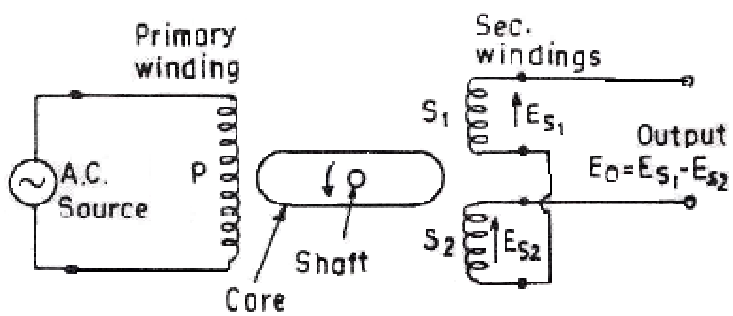
- It has large primary voltage which produces distortion in output.
- Temperature affects the performance.

- Sensitive to stray magnetic field.
- . Large displacements are required for differential output
- It has residual voltage
- Not suitable for dynamic displacement measurement
- Dynamic response is limited mechanically by the mass of the core and electrically by the frequency of applied voltage
- Large displacements are required for differential output

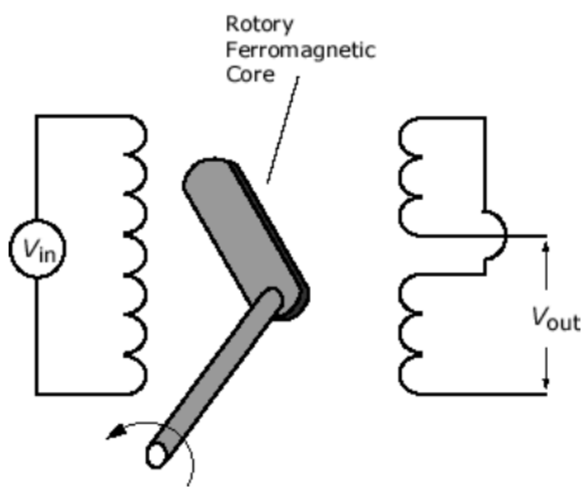
Application of LVDT:

1) L.V.D.T as a primary transducer can be used for displacement measurement ranging from fraction of a mm to a few cm
2) Acting a secondary transducer, used to measure force, weight and pressure.

Inductive Transducer - RVDT (Rotary Variable Differential Transformer)



Rotary variable differential transformer (RVDT)



RVDT is used to measure angular displacement. Construction of RVDT is similar to LVDT except that the core is cam shaped and it is rotated between the windings with the help of a shaft. Linear output is possible for only +/- 40 degree. Thus angular displacement can be measured. It has sensitivity of 10 to 20 mv per degree.

The operation of RVDT is similar to that of an LVDT.

At the null position of the core, output voltage of secondary winding S1 and S2 are equal and in opposite thus net output is zero.

Any rotary motion from null position will result in differential voltage output. The greater this angular or rotary displacement, greater will be differential output hence response of transducer is linear.

Clockwise rotation produces an increasing voltage of secondary voltage of one phase while counter clockwise rotation produces an increasing voltage of opposite phase hence the amount of angular displacement and its direction may be ascertained from the magnitude and phase of output voltage of transducer.

Inductive Transducer Magnetostrictive

Magnetostriction can be explained as the corresponding change in length per unit length produced as a result of magnetization. The material should be magnetostrictive in nature. This phenomenon is known as Magnetostrictive Effect.

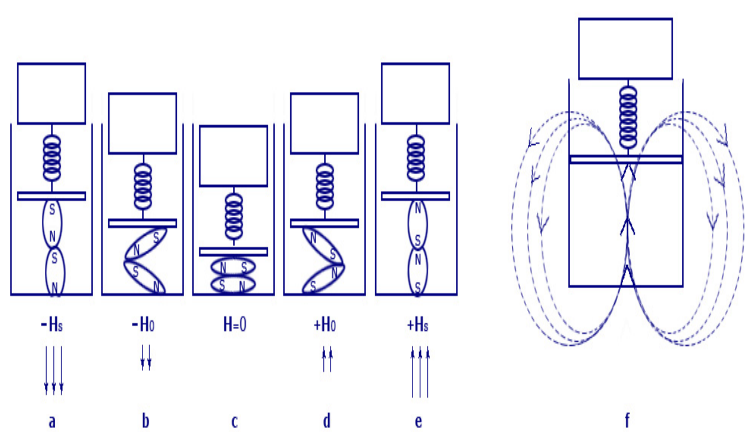
This process is highly applicable as a transducer as the magnetostriction property of a material does not degrade with time.

Magnetostriction Transducers

A magnetostriction transducer is a device that is used to convert mechanical energy into magnetic energy and vice versa. Such a device can be used as a sensor and also for actuation

Working

The figure below describes the exact working of a Magnetostrictive transducer. The different figures explain the amount of strain produced from null magnetization to full magnetization. The device is divided into discrete mechanical and magnetic attributes that are coupled in their effect on the magnetostrictive core strain and magnetic induction.



Magnetostrictive Transducers www.InstrumentationToday.com

Magnetostrictive Transducers

First, considering the case where no magnetic field is applied to the material. This is shown in fig.c. Thus, the change in length will also be null along with the magnetic induction produced. The amount of the magnetic field (H) is increased to its saturation limits (±Hsat). This causes an increase in the axial strain to "esat". Also, there will be an increase in the value of the magnetization to the value +Bsat (fig.e) or decreases to –Bsat (fig.a). The maximum strain saturation and magnetic induction is obtained at the point when the value of Hs is at its maximum. At this point, even if we try to increase the value of field, it will not bring any change in the value of magnetization or field to the device. Thus, when the field value hits saturation, the values of strain and magnetic induction will increase moving from the centre figure outward.

The value of Hs is kept fixed. At the same time, if we increase the amount of force on the magnetostrictive material, the compressive stress in the material will increase on to the opposite side along with a reduction in the values of axial strain and axial magnetization.

In fig.c, there are no flux lines present due to null magnetization. Fig.b and fig.d has magnetic flux lines in a much lesser magnitude, but according to the alignment of the magnetic domains in the magnetostrictive driver. Fig.a also has flux lines in the same design, but its flow will be in the opposite direction. Fig.f shows the flux lines according to the applied field Hs and the placing of the magnetic domains. These flux fields produced are measured using the principle of Hall Effect or by calculating the voltage produced in a conductor kept in right angle to the flux produced. This value will be proportional to the input strain or force.

Applications

In the case where magnetic energy is converted to mechanical energy it can be used for producing force in the case of actuators and can be used for detecting magnetic field in the case of sensors.

- If mechanical energy is converted to magnetic energy it can be used for detecting force or motion.
- it is used in making devices like high force linear motors, positioners for adaptive optics, active vibration or noise control systems, medical and industrial ultrasonic, pumps, and so on. Ultrasonic magnetostrictive transducers have also been developed for making surgical tools, underwater sonar, and chemical and material processing.

1.6 PIEZOELECTRIC TRANSDUCER

A piezoelectric material is one in which an electric potential appears across certain surfaces of crystal if the dimensions of the crystal are changed by the application of a mechanical force. This potential is produced by the displacement of charges. This effect is reversible i.e. if a varying potential is applied to the proper axis of the crystal it will change the dimension of the crystal and deforms it. This effect is called piezo electric effect.

Or,

When a pressure or force or vibration is applied to crystalline material like quartz crystal or crystalline substances, then an e.m.f. is generated across the material or vice versa. This effect is called piezo electric effect.

The piezoelectric transducer is made of piezo electric element. It is used for converting mechanical movement into electric signals. The piezoelectric element can be considered as a

capacitor. Therefore, the mechanical deformation generates charges and this charge appears as a voltage across the electrodes.

The voltage is given by

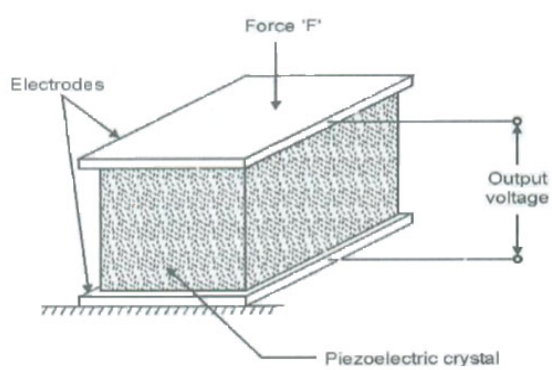
V= Q/C

Where, V= e.m.f. across electrode

Q= charges

C= capacitance

Piezo electric element:



Piezoelectric crystal

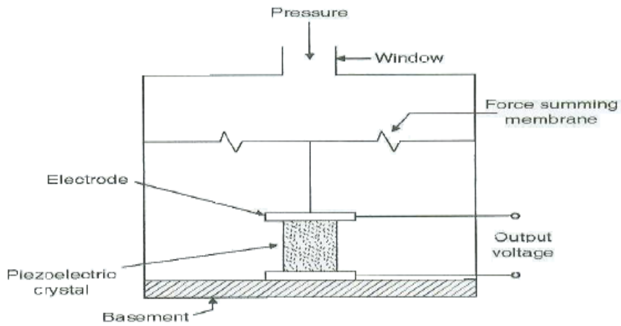
Piezoelectric Materials:

1) Natural crystal: Quartz crystal, Rochelle salt
2) Synthetic crystals: Barium Titanate, Lithium sulphate

Applications of piezoelectric transducer:

1. Piezoelectric transducers are used in high frequency accelerometer.
2. Piezoelectric materials are used in industrial cleansing apparatus.
3. It is used in under water detection system i.e. SONAR.
4. These are used in measurement of surface roughness in accelerometers and vibration picks ups.

5. It is used in ultrasonic flow meters, non-destructive test (NDT) equipment's
6. Piezoelectric materials are used in ultrasonic transducers.



Pressure measurement using piezoelectric transducer

1.7 SELECTION CRITERIA OF TRANSDUCER

. The following points should be considered while selecting a transducer for a particular application. These are the transducer specifications which give the information of how well and how quick the transducer converts the measuring quantity into electrical signal.

1. Operating range
2. Operating principle
3. Sensitivity
4. Accuracy
5. Frequency response and resonant frequency
6. Errors
7. Environmental compatibility
8. Usage and ruggedness.
9. Electrical aspect.
10. Stability and Reliability
11. Loading effect
12. Static characteristics
13. Electrical output of transducer (Current/voltage level)
14. Type of mounting required for transducer.
15. Cost and availability.

Explanation:

1. Operating range: i.e. maximum and minimum values of parameters to be measured. The range of the transducer should be appropriate for measurement to get a good resolution.
2. Operating principle: The transducers are selected on the basis of operating principle; it may be resistive, inductive, capacitive, optical etc.
3. Sensitivity: The transducer must sensitive to small variation in input to produce the output. A transducer must have high sensitivity to detect small variation in input to produce the output.

4. Accuracy: The accuracy should be as high as possible or as per the measurement.

5. Frequency response and resonant frequency: It should operate constant in given band width
6. Errors: The error produced by the transducer should be as low as possible.
7. Environmental compatibility: The transducer should maintain input and output characteristics for the selected environmental condition.
8. Usage and ruggedness.: it should be rugged in construction
9. Stability and Reliability: Transducers should produce stable and accurate output in any environmental condition.
10. Loading effect: The transducer's input impedance should be high and output impedance should be low to avoid loading effect.