



R. C. Patel College of Engineering & Polytechnic, Shirpur



Department of Electrical Engineering

Name of Subject: - **Electrical & Electronic Measurement (EEM)**

Course Code: - **313334**

Scheme:- **EE-3K**

Semester:- **Third**

Unit No. 04- Transducer and Pressure Measurement

CO4 - Maintain required pressure for given application using pressure transducer.

| Unit | Title | COs | Learning hours | R Level | U Level | A Level | Total Marks |
|------|-------------------------------------|-----|----------------|---------|---------|---------|-------------|
| 4 | Transducer and Pressure Measurement | CO4 | 9 | 4 | 4 | 6 | 14 |

THEORY SYLLABUS CONTENT

Fundamentals of Measurement

- 4.1 Instrumentation System-Block diagram, function of each block.
- 4.2 Difference between sensors and transducer with examples.
- 4.3 Classification of transducer.
- 4.4 Electrical Transducers: a) Resistive transducers- Linear and Angular potentiometers, strain gauge, load cell. b) Capacitive transducer. c) Inductive transducer –LVDT, RVDT.
- 4.5 Working of piezoelectric transducer, classification, examples.
- 4.6 Pressure measurement: Pressure and its units, types - Absolute, Gauge, Atmospheric, Vacuum.
- 4.7 Classification of Pressure measuring devices.
- 4.8 Method of pressure measurement- Bourdon tube with LVDT as secondary transducer.

Subject Incharge

Mr. N. S. Borse

Unit-4

Transducer and Pressure Measurement.

* Instrumentation system:

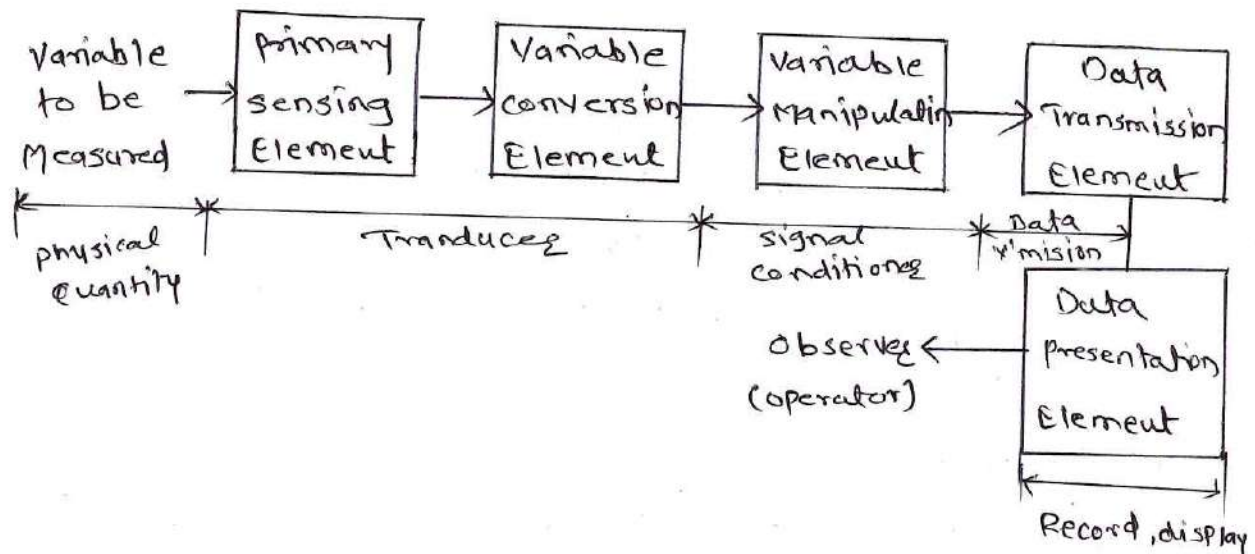


Fig: Block diagram of Instrumentation system.

The block diagram of Instrum^m system is shown in above fig. It consist of.

- i) primary sensing Element
- ii) Variable conversion Element
- iii) Variable manipulation Element
- iv) Data transmission Element
- v) Data presentation Element.

i) Primary Sensing Element -

- It is nothing but the sensor which sense physical quantity such as temp, pressure etc.
- The primary sensing element receive energy from measured medium and produce output.
- The output of sensing element is given to Variable Conversion element.

ii) Variable Conversion Element -

- It is a transducer, it convert input of primary sensing element into suitable form, which can be handle by another instrument.

iii) Variable Manipulation Element -

- It is nothing but a signal conditioner which modify the signal and make capable so that it can be handle by transmitter.

iv) Data transmission Element -

- It transmit data from one element to another element.
- By using data transmission element, the data is transmitted to the remote control room for display or recording purpose.

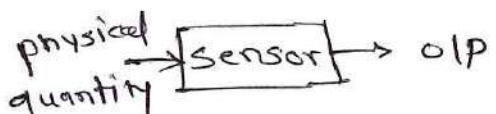
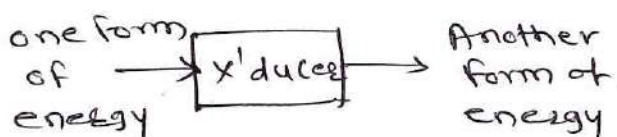
v) Data presentation Element -

- It perform translation function, such as simple indication of pointer moving over a scale.
- Indicator display the measured quantity.

* Transducer:

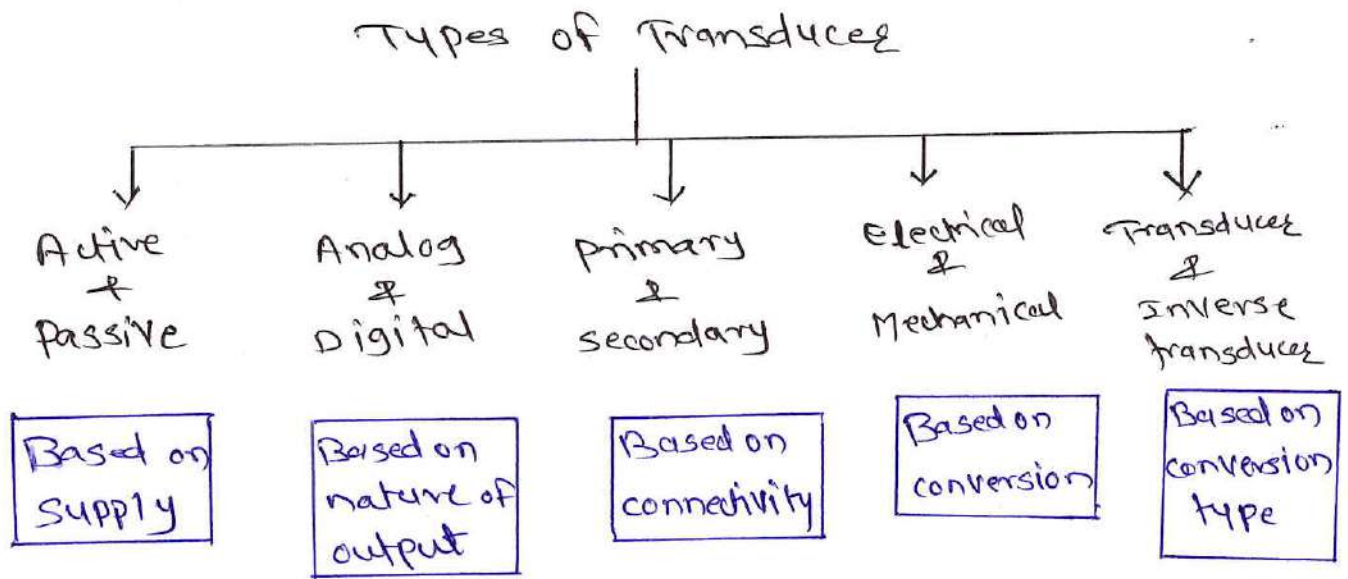
It is a device, which convert energy from one form to another. i.e. physical to physical, physical to electrical or electrical to physical.

* Difference between sensor and transducer:

| Sensor | Transducer. |
|---|--|
| 1) It senses physical quantity and gives output. | 1) It convert one form of energy into another form |
| 2) It's main function is sensing. | 2) It's main function is energy conversion. |
| 3) Block diagram  | 3) Block diagram  |
| 4) All sensor are not transducer. | 4) All transducer are sensor. |
| 5) Ex. proximity sensor | 5) Ex. loudspeaker, microphone. |
| 6) Sensing Element | 6) sensor + conversion element. |

* Classification of Transducer:

The transducer may be classified according to their applications, requirement of power source nature of output signal and their connectivity.



* Active - convert physical quantity into electrical signal without applying external power supply, ex. Thermocouple.

* Passive - convert with the help of external power supply ex. Thermistor, potentiometer.

* Analog - convert i/p quantity into analog o/p ex. LVDT

* Digital - convert i/p signal to o/p in form of pulses or 0 and 1 form. ex. Pressure gauge.

* Primary - i/p signal directly sensed by transducer and convert into o/p signal ex. thermistor

* Secondary - It connected with primary transducer. ex Bourdon tube with LVDT.

* Electrical - convert physical quantity into electrical o/p ex. Thermistor, RTD

* Mechanical - convert physical quantity into another physical quantity ex. Bourdon tube, Bellows.

* Electrical Transducer:

1) Resistive Transducer - ($R = \frac{\rho l}{a}$)

- The operation of this transducer is based on variable resistance.
- These transducer convert pressure or displacement into equivalent electrical signal i.e. V/mg or cm
- potentiometer (POT) which convert displacement into voltage.
- They are classified as:
 - i) linear POT
 - ii) Angular POT
- Potentiometer provides variable resistance as rotational or translation movement is applied to the shaft of POT.

i) linear potentiometer:

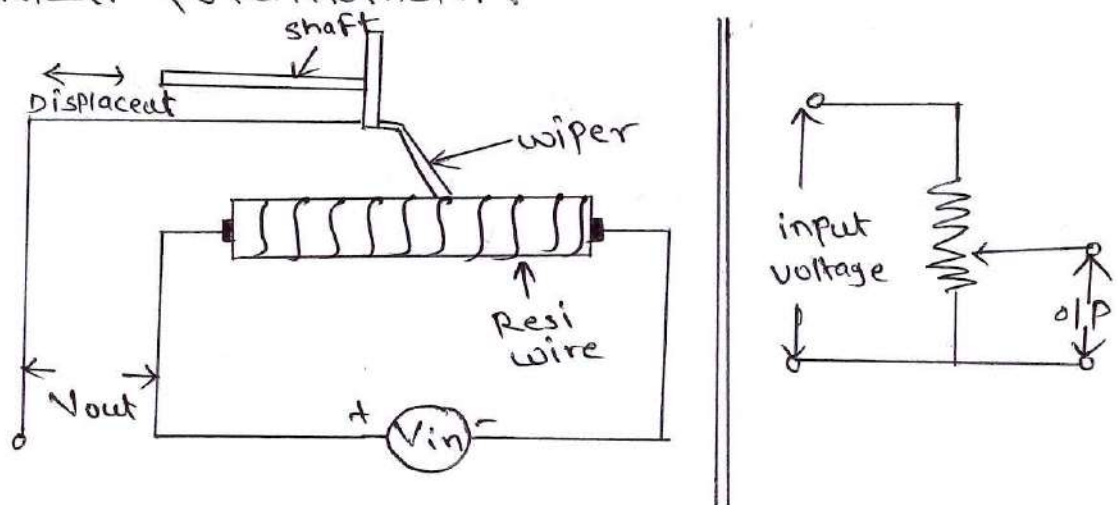


Fig: Linear or translation POT

- Above fig. shows, construction and circuit of linear POT, where applied motion to the POT is linear.
- As linear motion is applied to the shaft from left to right or vice versa, wiper also moves which change the resi. of POT & output voltage varied as POT act as voltage divider.

ii) Angular potentiometers:

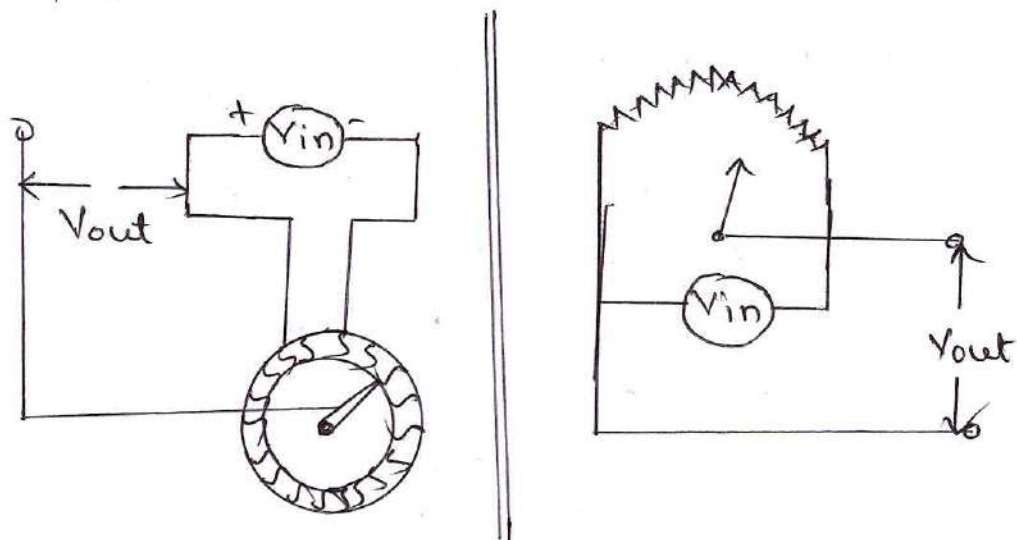


Fig: Construction & circuit of rotary pot

- Above Fig. shows, construction and circuit of angular / rotational pot, where applied motion to the pot is angular.
- As angular motion is applied to the wiper, angular displacement is converted into variable resistance. i.e. output is voltage.

* Capacitive Transducer: ($C = \frac{\epsilon A}{d}$)

1) Capacitive transducer operates on equation of capacitor. i.e.

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

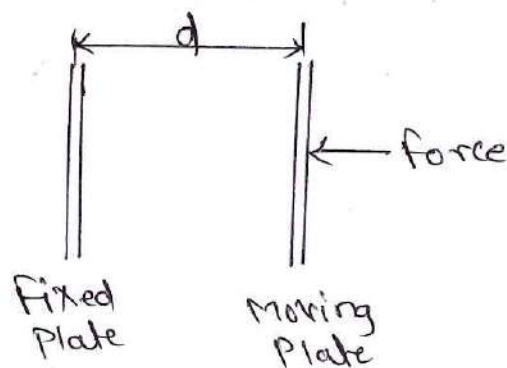
where, C = Capacitance

ϵ = dielectric const

A = Area of plate

d = dist betⁿ plate

- 2) As the distance between plates varies, the value of capacitor also changes.
- 3) The principle of change of capacitance with change in distance between two plates is used for measurement of press, force, displacement.



- 4) Above fig. shows, two plate capacitor, ~~out~~ ^{out} of which one is fixed and other is movable. The parameter which is to be measured (e.g. press, force etc) is applied to the movable plate.
- 5) As the distance between plate change (d) capacitance also changes.
i.e. $C \propto \frac{1}{d}$
- 6) As distance increases, capacitance decreases and vice versa.

Advantages:

- 1) Good frequency response
- 2) Fast response
- 3) It can be used for maximum angular displacement upto 180° .

Disadvantages:

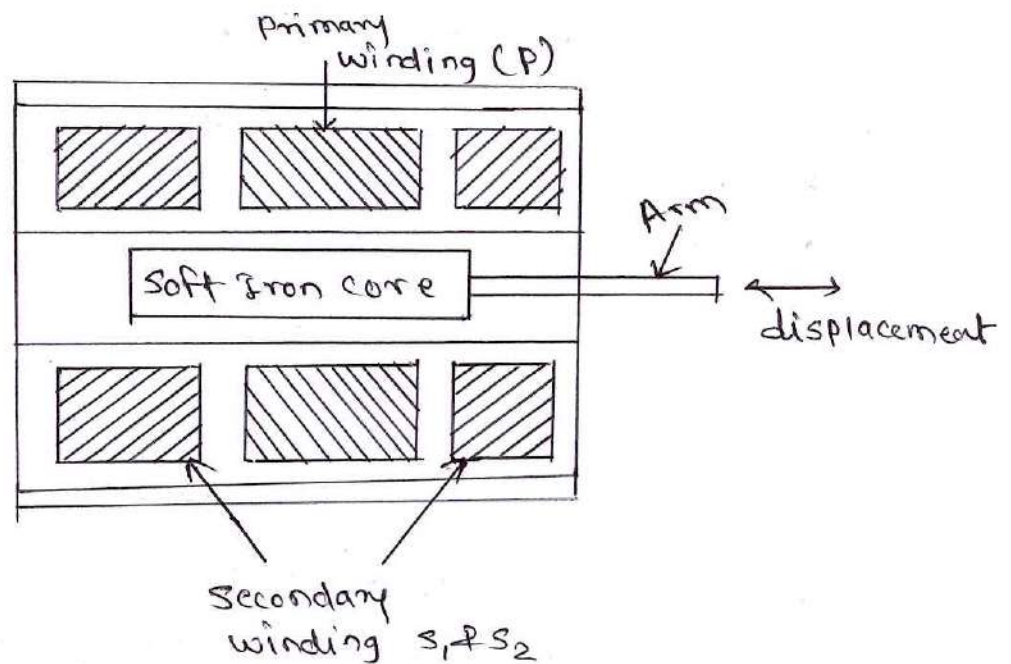
- 1) Sensitivity is not constant.
- 2) For angular displacement measurement, frame must be earthed.
- 3) It is affected by dirt.
- 4) Bridge circuit is required for measurement.

* Inductive Transducer:

- These transducer are worked on the variable reluctance theory and variable permeability principle.
- LVDT & RVDT are the examples of inductive transducer.

i) LVDT (Linear Variable Differential xducer)

- It is a passive transducer, which operates on inductive principle.
- It is used to convert linear motion into voltage i.e. electrical signal.



- Above fig. shows construction of LVDT. It consist of one primary (P) which supplied with AC input and two secondary winding (S_1 & S_2).
- The secondary winding have equal number of turns and are connected in series with each other with phase difference at 180° .
- A movable soft iron core is placed inside core.
- The displacement which is to be measured is applied to the arm attached with core.

- The output vltg of LVDT is difference betⁿ two voltages i.e. $V_0 = V_{s1} - V_{s2}$

Working:

case I - (when there is no displacement)

- when there is no displacement attached to the core i.e. core is at normal position, the flux linking with both the sec. wdg are equal and opposite.

$$V_0 = V_{s1} - V_{s2} = 0$$

- Hence the o/p vltg (V_0) at null position is zero.

case II - (when there is positive displacement)

- when there is positive displacement applied to the core, i.e. core is moved to left of null position, more flux links with winding S_1 than winding S_2 .

- Hence emf induced with winding S_1 is greater than winding S_2 ($V_{s1} > V_{s2}$)

$$V_0 = V_{s1} - V_{s2}$$

- Hence the output voltage $V_0 = V_{s1} - V_{s2}$ and the output vltg is in phase with the input primary voltage.

case III - (when there is negative displacement)

- when there is negative displacement applied to the core i.e. core moved to right of null position, more flux links with winding S_2

- Hence emf induced with winding S_2 is greater than winding S_1 ($V_{s2} > V_{s1}$)

$$V_0 = V_{s2} - V_{s1}$$

- output vltg is 180° out of phase with input primary voltage.

Advantages:

- 1) High range of measurement of displacement
- 2) High sensitivity
- 3) Low Hysteresis
- 4) low power consumption
- 5) Frictionless construction & electrical isolation is available.

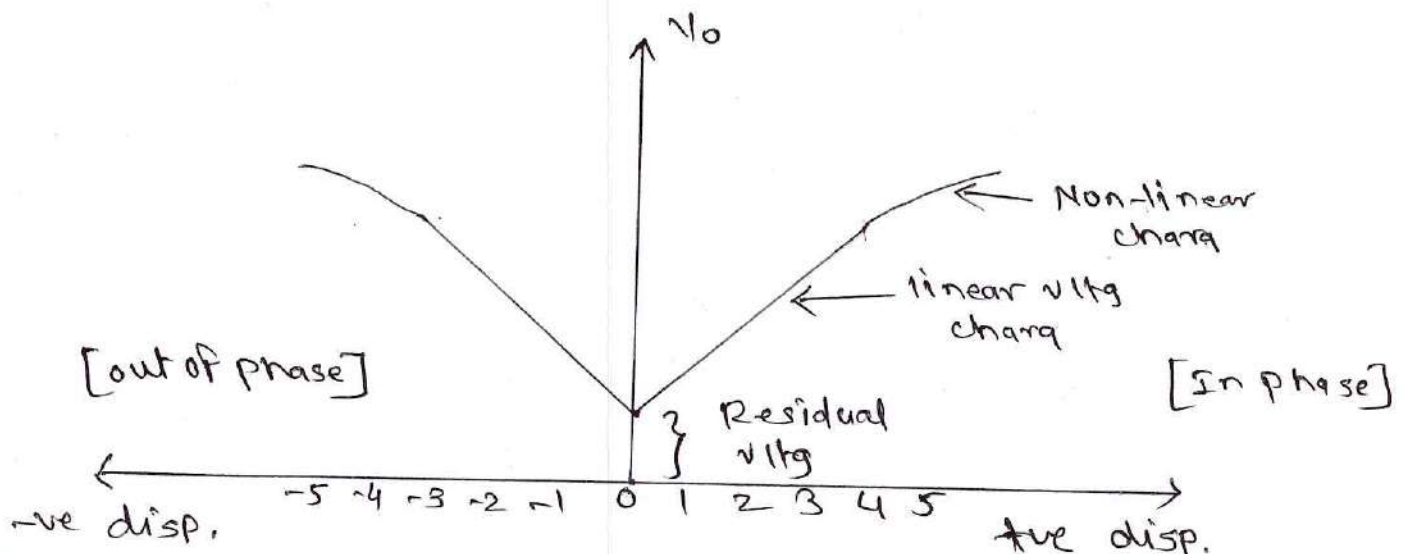
Disadvantages:

- 1) Residual voltage problem
- 2) Relatively large displacement are required for different output.
- 3) affected by vibrations.
- 4) affected by temperature.
- 5) sensitive to magnetic field.

Applications:

- 1) LVDT is used to measure linear displacement
- 2) useful in force, pressure and weight measurement as a secondary measurement.
- 3) work as a secondary transducer.

characteristics of LVDT



ii) RVDT: (Rotary Variable differential transducer)

- RVDT is an inductive transducer, which converts the angular displacement into an electrical signal.

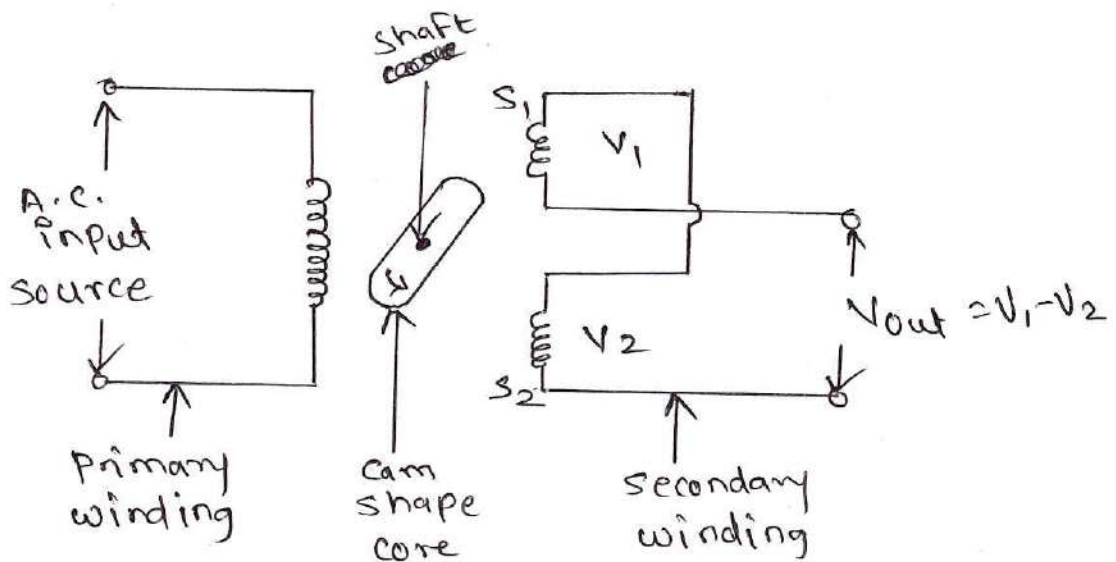


Fig: Circuit diagram of RVDT

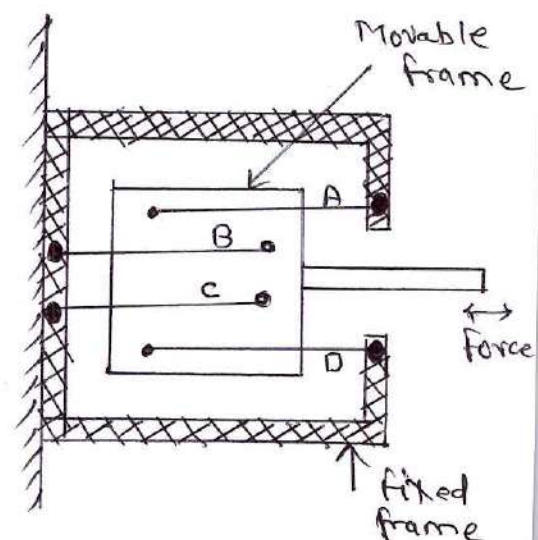
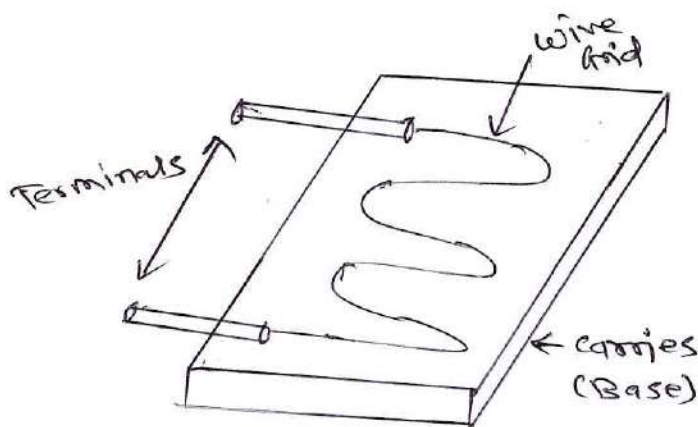
- Above fig. shows the circuit diagram of RVDT, which is similar to LVDT, except for the cam-shaped core and it is rotated between the windings with the help of a shaft.
- If there is no angular displacement of the core, i.e. null position, the output voltages of the secondary windings S_1 and S_2 are equal and opposite. Hence, the output voltage is zero.
- If the core rotates in the anticlockwise direction, it produces more voltage in winding S_1 than S_2 , hence the output is $V_o = V_{s1} - V_{s2}$.
- If the core rotates in the clockwise direction, it produces more voltage in winding S_2 than S_1 , hence the output is $V_o = V_{s2} - V_{s1}$.
- Thus, by using RVDT, we can determine angular displacement and its direction.

* Strain Gauge:

- strain - It is defined as the change in dimension due to applied load divided by initial dimension. When load is applied, the dimension can change axially and laterally.
- Strain is the ratio of change in a length of material to the original length of material.

Strain Gauge -

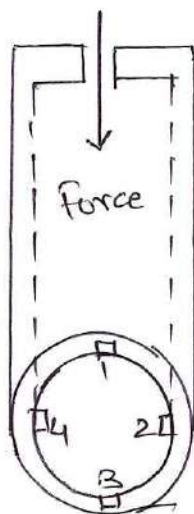
- It is nothing but a metal conductor, when metal conductor stress or compressed then resistance change with length and diameter of conductor change.
- strain gauge is a passive transducer which uses the variation in the resistance of conductor wire, the measure strain produced by pressure or stress in the wire.
- If the wire is stress or compress, resistance change due to change in a dimension of wire.
- strain gauge are mainly classified as
 - 1) Bonded strain gauge
 - 2) Unbonded strain gauge.



compressed - B & C
stressed - A & D

* Load cell:

- Load cell is a transducer which convert force into an electrical signal.
- The force applied causes deformation of strain gauge. strain gauge produces electrical output.
- when force/pressure is applied, the surface of strain gauge are stretched or compressed changing their resistance. The electrical output can be obtained.

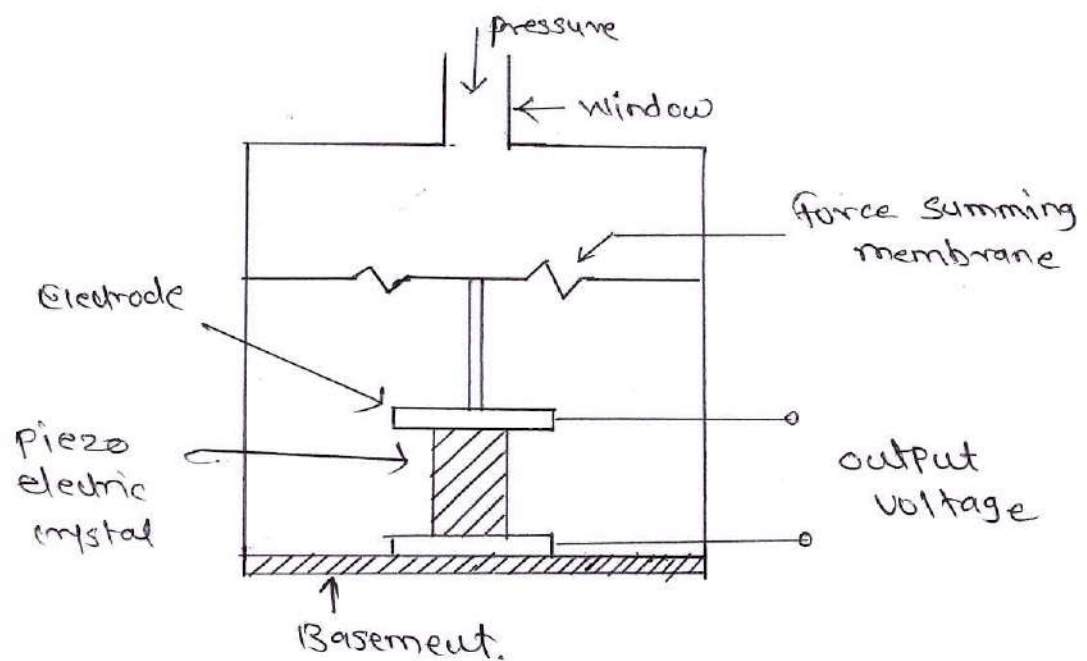


Strain Gauge
1, 2, 3, 4,

- when force applied, out of these four strain gauges two gauges are stressed and other two gauges are compressed.
- Due to this stressed & compression, strain gauge change their resistance value.
- These strain gauges can be connected in wheatstone bridge. as resistance value changes bridge become unbalance, and gives a measure of force/pressure.

* Piezoelectric Transducer:

- Piezoelectric transducer is an active device, whose operation based on piezoelectric effect.
- piezoelectric effect state that, "when a pressure or force is applied to the crystalline material like quartz crystal or crystalline substance then an EMF is generated across the material".



- above fig shows arrangement to measure the pressure or force with the help of piezoelectric transducer, where piezoelectric crystal is placed between the basement and force summing membrane.
- Metal electrodes are connected to the plates of crystal. one plate of crystal is connected to the force summing membrane, this membrane collect the pressure or force coming from ilp window
- The output is collected from the output terminal
- In this way physical quantity (force, pressure, vibration etc) is converted into electrical quantity (emf).

- Piezoelectric transducers can be classified as

- 1) Compression type - crystal is subjected to compressive force.
- 2) Tension type - crystal is subjected to tensile force.
- 3) Bending type - crystal is bent to produce an electrical output.

* Advantages :

- 1) Piezoelectric transducers are self-generating as they need no external power source.
- 2) They have high stability.
- 3) They provide high output which is independent of temperature, mechanical vibration.
- 4) They have good frequency response.
- 5) They have small size & rigid construction.

* Disadvantages :

- 1) They require protection from moisture.
- 2) The open-circuit voltage is affected by temperature variation.
- 3) Piezoelectric crystals are water-soluble.

* Pressure: It is defined as the amount of force applied to a surface or distributed over it and is measured as force per unit area.

$$\text{Pressure} = \frac{\text{Force (in Newton)}}{\text{Area (in sq. meter)}}$$

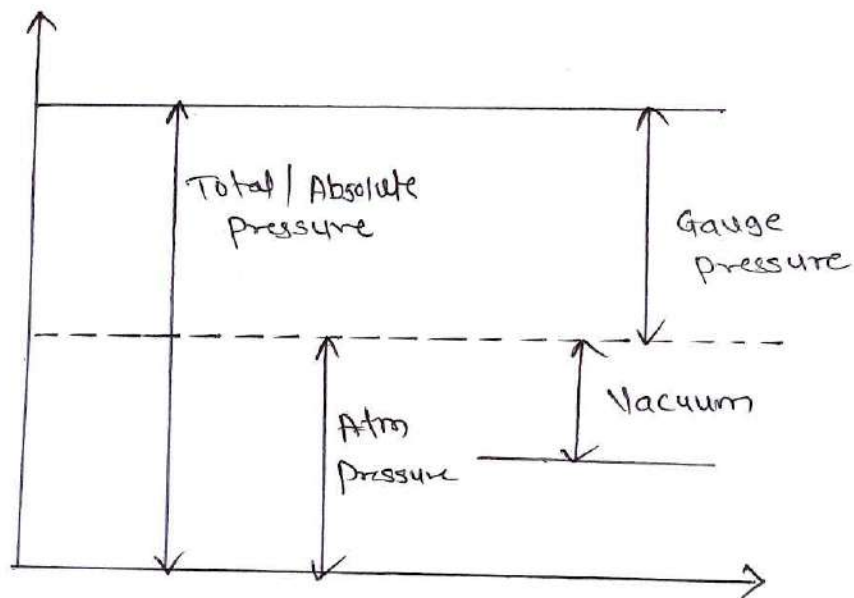
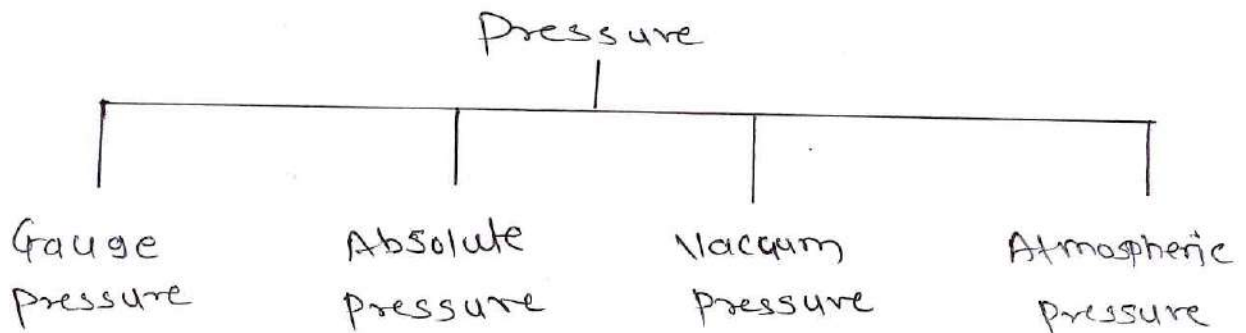
- The SI unit for pressure is Newton per square meter (N/m^2)
- Sometimes, press can be measured in terms of liquid columns, where

$$\text{Atm Press} = 760 \text{ mm of Hg.}$$

- Pressure also measured in pounds per square inch (psi) unit, where

$$\text{Atm Press} = 14.696 \text{ Psi}$$

* Types of pressure:



1) Gauge pressure:- It is defined as the difference between absolute pressure & atmospheric pressure.

$$\text{Gauge pressure} = P_{\text{abs}} - P_{\text{atm}}$$

- unit of gauge pressure is pounds per square inch (psi) gauge & it is represented by psig.

2) Absolute pressure:- It is defined as actual total pressure including atmospheric pressure acting on surface.

$$P_{\text{abs}} = P_{\text{atm}} + P_{\text{gauge}}$$

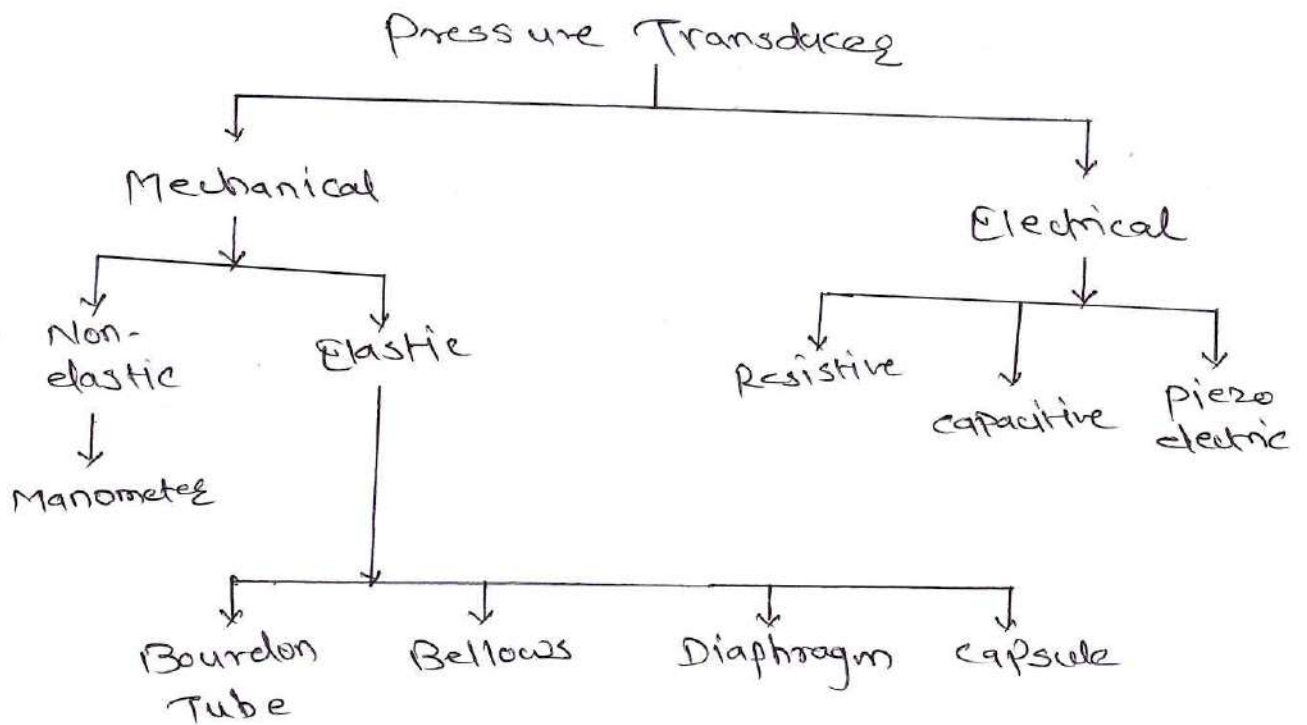
- unit of absolute pressure is pounds per square inch & represented by psia.

3) Vacuum pressure:- It is defined as pressure below zero, (i.e. perfect vacuum) or negative pressure. It is also called as differential pressure.

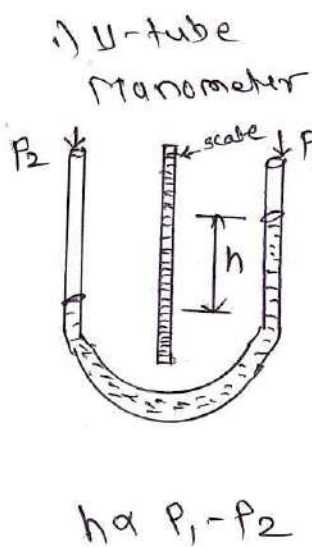
$$P_{\text{vacuum}} = \text{press below zero or -ve press.}$$

4) Atmospheric pressure:- It is defined as pressure exerted by the air surrounding to the earth. Having unit ~~psi~~ Pounds / sq. inch.

* classification of pressure measuring transducers:



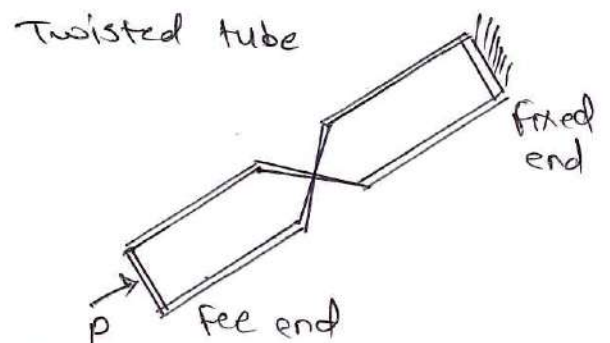
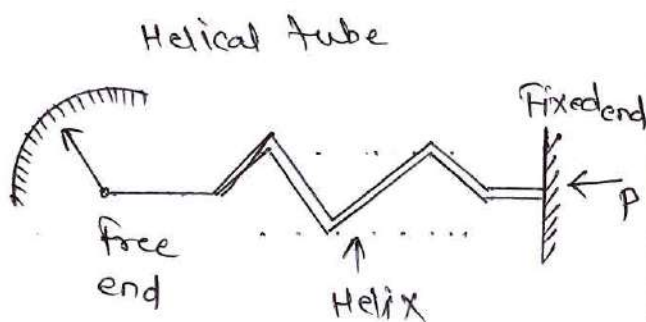
* Manometers: Manometer are again classified as



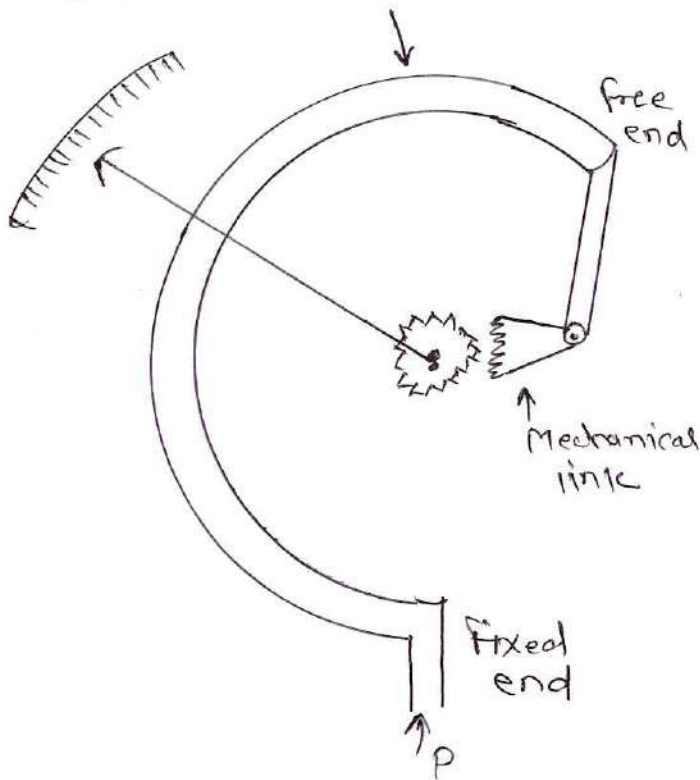
2) Inclined tube Manometer

3) Well type Manometer

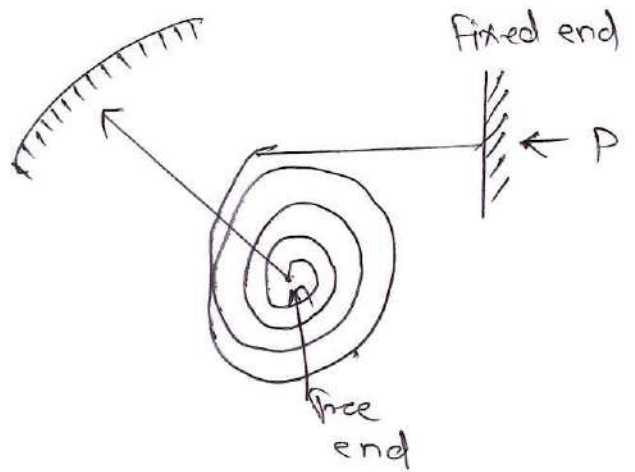
* Bourdon tube: Bourdon tube again classified as



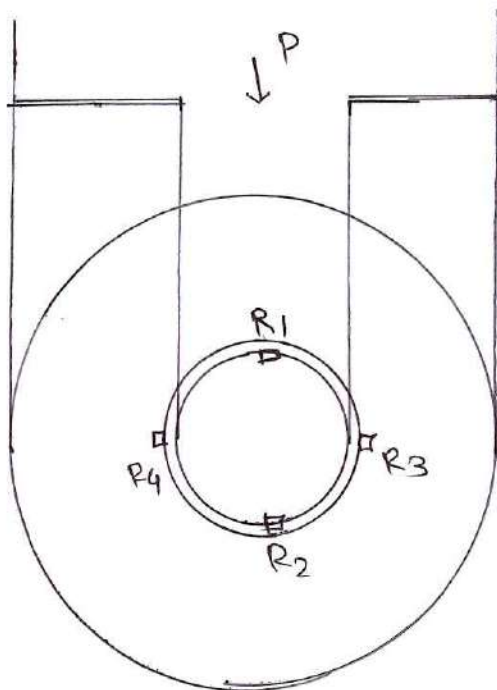
C-type Bourdon tube



Spiral tube



* Diaphragm:



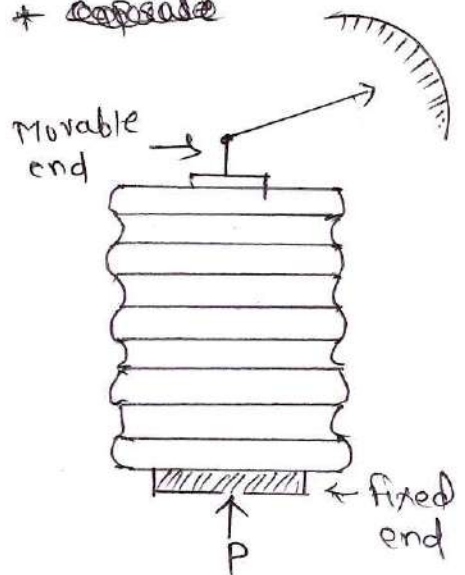
strain gauge - R_1, R_2, R_3, R_4

R_1 & R_2 - compressed

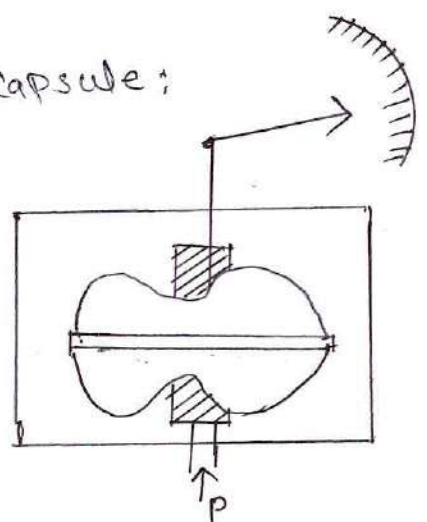
R_3 & R_4 - Tension

* Bellows:

* ~~capsule~~

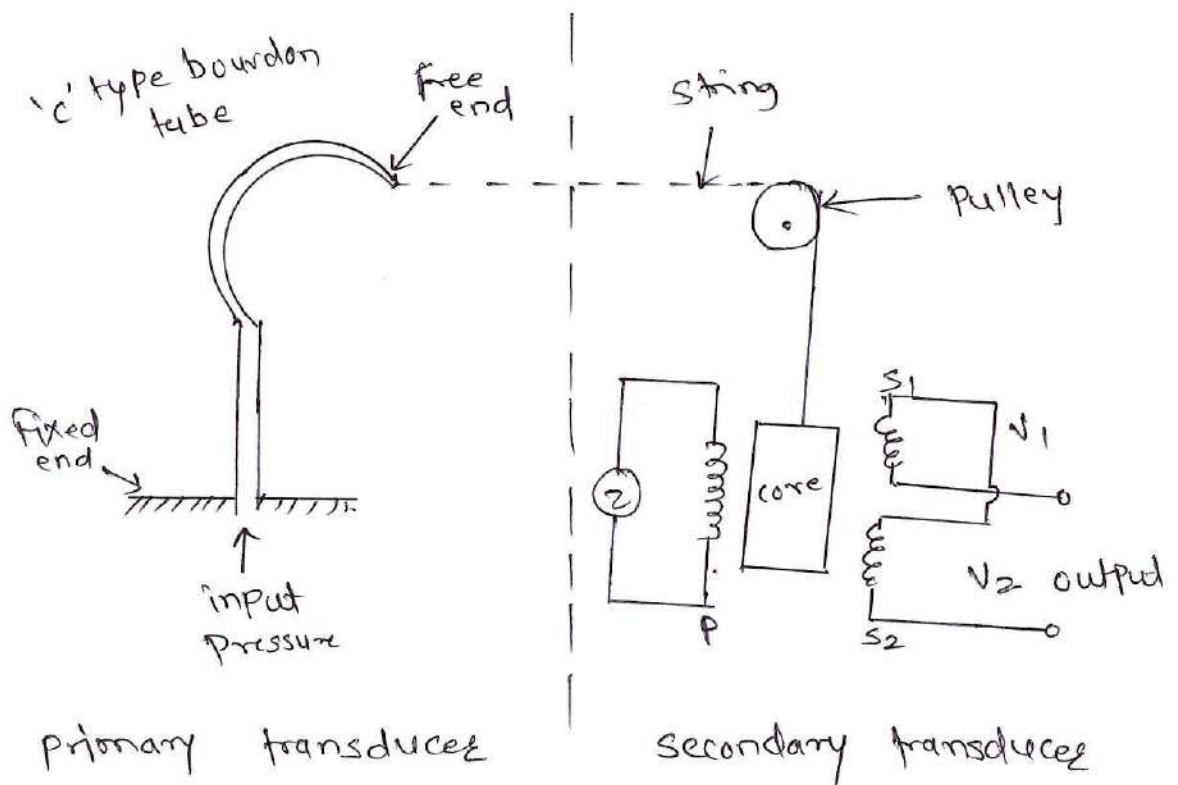


* Capsule:



* Bourdon tube with LVDT:

- Bourdon tube with LVDT is the example of secondary transducer. Bourdon tube is the primary and LVDT is the secondary transducer.



- primary transducer are detectors which sense a physical quantity.
- The input pressure is directly connected to the Bourdon tube hence act as primary transducer, which convert primary pressure into displacement at free end.
- This displacement is again given to the other transducer to get electrical output.
- This displacement is convert into proportional electrical quantity (voltage).

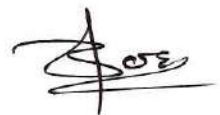
- Thus there are two stages of transduction, first pressure is converted into displacement by bourdon tube then the displacement is converted into voltage by LVDT.
- Here LVDT called as secondary transducer.

Question Bank

Unit-4

- 1) Define transducer with one example.
W-25
- 2) Compare between LVDT and RVDT
W-25
- 3) Describe the operation of piezoelectric transducer in brief
W-25 / S-26
- 4) Describe the working of bourdon tube with LVDT as a secondary transducer with neat sketch.
W-25/W-24/S-26
- 5) Elaborate any two difference between sensor and transducer with examples.
W-25/W-24
- 6) Define transducer, give its two example and sensor
S-25/S-26
- 7) Draw constructional diagram of LVDT; state its working principle for displacement measurement.
S-25/S-26
- 8) Write any three applications of capacitive and inductive transducer
S-25
- 9) Define instrumentation system. Draw its block diagram and explain function of each block.
W-24/S-26

- 10) Define transducer, give classification of transducers on different factors with one example each.
- 11) Compare Active - passive, Primary - secondary transducers.
- 12) Define pressure and give different types of pressure.
- 13) Draw & explain working of C-type Bourdon tube.
- 14) Explain U-tube manometer for pressure measurement.
- 15) Explain the method for measurement of linear displacement.



Mr. N. S. Borse
Subject Teacher