Unit-3: Transducers

A device that converts energy ~~to form~~ one form to another is called a transducer.

eg: mike which converts voice signals into electrical form.

classification of transducers -

→ Based on technology - 1) mechanical Transducers
2) Thermal "
3) chemical "
4) optical "
5) Acoustical "
6) magnetic "

→ Based on measured type - 1) pressure transducer
2) displacement "
3) tempreature "
4) flow "

→ Based on output - ① Analog
② digital

→ Based on location of transducer - 1) Internal sensors
2) External sensors.

→ Based on energy - 1) Active transducers.
2) Passive "

Resistive transducer - The transducer whose resistance varies because of the environmental effects such type of transdu-cers is known as resistive transducer.

The change in the 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 difficu-
-lt. The resistive transducer converts the physical quantities into variable resistance which is easily measured by the meters.

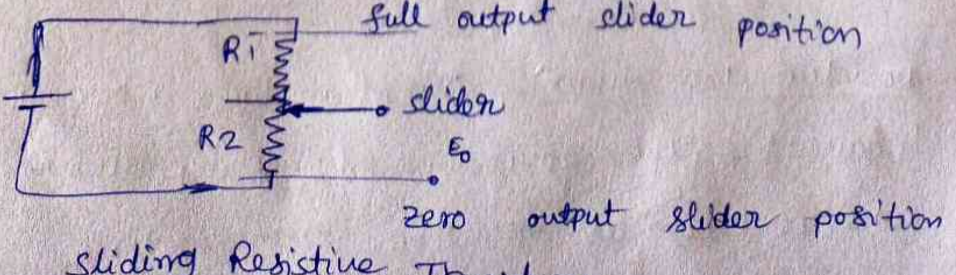
→ The process of variation in resistance is widely used in the industrial applications.

→ The resistive transducer can work both as the primary as well as the secondary transducer.

→ The primary transducer changes the physical quantities into a mechanical signal, and the secondary transducer directly transforms it into an electrical signal.

Ex:_ The circuit of the sliding resistive transducer is shown in the fig 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 soure 'V'



Sliding Resistive Transducer

- The displacement of the slider is converted into an electrical signal.

Advantages of Resistive Transducer

- Both AC and DC current & voltage is appropriate for the measurement of variable resistance.
- the resistive transducer gives the fast response
- 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 that the resistance of the element is directly proportional to the length of the conductor and inversely proportional to the area of the conductor.

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

here R = resistance in (ohms)

ρ = specific resistance or resistivity of the conductor. (ohm - meter)

L = length of the conductor - (meter)

A = area of conductor - (meter^2)

Applications of Resistive transducer -

The following are the 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 guage - The resistance of their semiconductor material changes when the strain occurs on it.

- This property of metals is used for the measurement of 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 ~~temperature~~ thermistor material varies with temperature.

- The thermistor has the negative temperature coefficient.
- The NTC means the temperature is inversely proportional to resistance.
- There are n.o. ways because of which the resistance of the metal changes with the changes in the physical phenomenon. And this physical property of conductors is used for measuring the physical quantity of material.

Capacitive transducer:-

The capacitive transducer is used for measuring displacement, Pressure & other physical quantities.

- It is a Passive transducer that means it requires external power for operation.
- It works on the Principle of variable capacitences
- The capacitence of a capacitive transducer changes because of many reasons like overlaping of plates, change in distance b/w the plates and dielectric constant
- The capacitive transducer contains 2 parallel metal plates these plates are seperated by the dielectric medium which is either air, material, Gas & liquid
- In normal capacitors the distance b/w plates is fixed but in capacitive transducer the distance b/w them is varied.

- The capacitive transducer uses the electrical quantity of capacitance for converting the mechanical movement to electrical form.
- 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 both the contacting and non-contacting modes.

principle of operation -

The equations below express the capacitance b/n the plates of a capacitor.

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

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

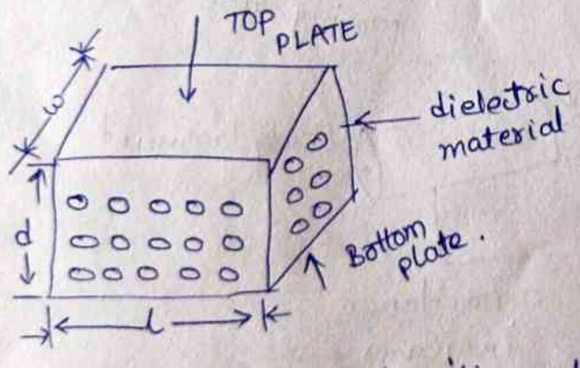
here A = area of the plate (m^2)

d = distance b/n two plates (m)

ϵ_0 = permittivity of free space.

ϵ_r = relative permittivity

ϵ = permittivity of medium



parallel plate capacitive transducer.

→ The change in capacitance occurs because of the physical 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 circuit. The o/p impedance of transducer is given as

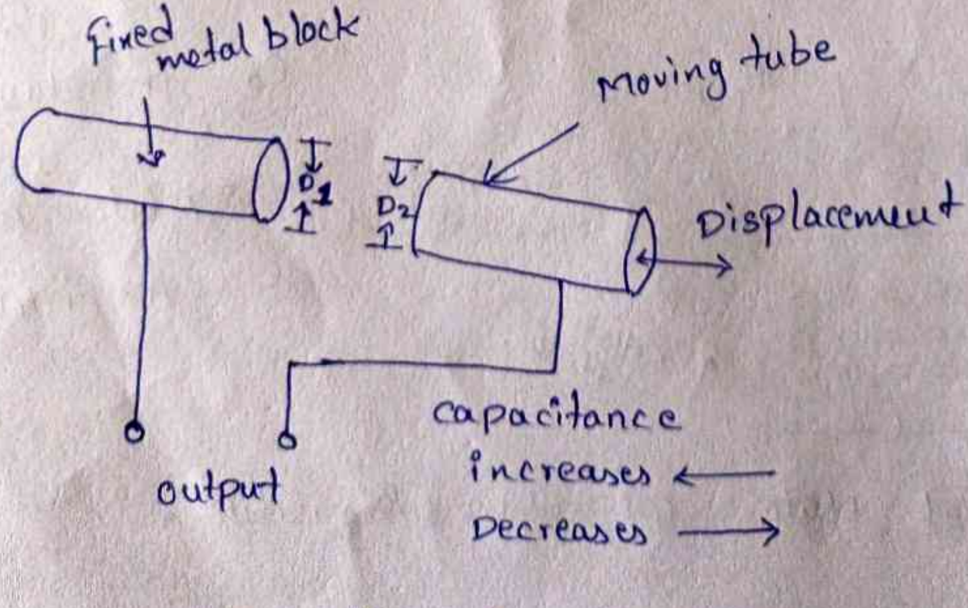
$$X_c = \frac{1}{2\pi f C}$$

$C \rightarrow$ capacitance
$f \rightarrow$ freq of excitation in Hz.

- It's maily used for measurement of linear displacement it uses the following '3' effects.
  1. variation in 'C' because of the ~~of~~ overlapping of capacitive plates.
  2. Variation in 'C' because of change in 'd' b/n the plates
  3. variation in 'C' because of change in 'ε' dielectric constant.

Methods used for measuring displacement :-

1. A transducer using the change in the area of plates.



Capacitive transducer

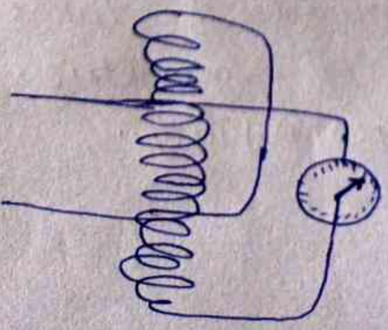
- The capacitive transducer for measuring the displacements ranging from 1mm to several cms.
- The area of the capacitive transducer changes linearly with the capacitence and displacement.
- The capacitence of the parallel plates is given as

$$C = \varepsilon A/d = \varepsilon x w/d \ F$$

where x - The length of overlapping part of plates
w - width of overlapping " " "

- sensitivity of displacement $S = \frac{\partial C}{\partial x} = \frac{\varepsilon w}{d} \ F/m$

- Inductive Transducer - (LVDT) Inductive transducers work on the principle of inductance change due to any appreciable change in the quantity to be measured.
- for example. LVDT, a kind of inductive transducer, measures displacement in terms of voltage in terms of voltage difference b/n their secondary voltages. are nothing but the result of induction due to flux change in the secondary coil with the displacement of iron bar.
- Hence LVDT is discussed here briefly to explain the principle of inductive transducer.



an example of an Inductive Transducer (LVDT)

- working of Inductive transducer can be done by changing the flux with the help of measured and this changing flux obviously changes the inductance and this inductance change can be calibrated in terms of measurement.

- Hence Inductive transducers use any one of the following principles of workings.
  1) change of self Inductance
  2) change of mutual inductance
  3) production of eddy current.

→ change of self Inductance of Inductive Transducer -

$$L = \frac{N^2}{R}$$

- we know very well that self inductance of the coil is given by

where N = no. of turns
R = reluctance of the magnetic circuit

also we know that $R = \frac{l}{\mu A}$

$$L = \frac{N^2 \mu A}{l}$$

where μ = effective permeability of the medium

$$L = N^2 \mu G.$$

here $G = A/l$ ⇒ Geometric form factor.
A = area of cross-section of the coil.
l = length of the coil.

So we can vary self Inductance by
→ change the number of turns 'N'
→ changing the 'G' - geometric configuration.
→ changing permeability.

→ Change of mutual Inductance of Inductive Transducer –

These transducers work on the principle of change of mutual inductance by using multiple coils.

Here we use two coils for the sake of understanding.

– The self-inductance of each coil is L_1 and L_2.

then mutual inductance b/n these two coils is given by

$$M = K\sqrt{L_1 L_2}$$

– thus mutual inductance can be changed by varying self inductance or by varying coefficient of coupling k.

– Thus for the measurement of displacement, we fix one coil and make the other movable which moves with the source whose displacement is to be measured.

⇒ production of Eddy current of Inductive Transducer –

when a conducting plate is placed near a coil carrying alternating current, a circulating current is induced in the plate called "Eddy current".

– This principle is useful for the Inductive transducers.

⇒ when a coil is placed near to coil carrying alternating current, a circulating current is induced in it which in turn produces its own flux, which try to reduce the flux of the current carrying coil and hence the inductance of the coil changes.

– Nearer the plate to the coil, higher will be the eddy current. higher will be the reduction of inductance of the current carrying coil. and vice versa.

– Thus the movement of plate can be calibrated in terms of inductance change to measure displacement.

Applications - Inductive transducers find application in proximity sensors, which are used for position measurement. dynamic motion measurement, touch pads etc.

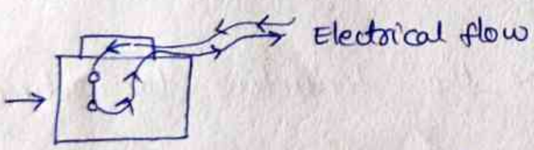
→ used in detection of type of metal.
→ finding missing parts.
→ counting the number of objects.

Touch-screen sensors -

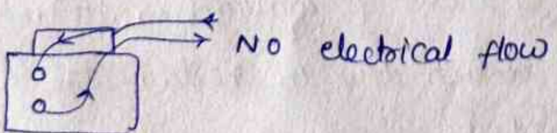
- Touch sensor technology is slowly replacing the mechanical objects like mouse and keyboards, buttons and switches.
- They are more convenient and more reliable to use without moving parts.

principle of working -

- Touch sensors are also called tactile sensors and are sensitive to touch, force or pressure. They are one of the simplest and useful sensors. Its working is similar to that of a simple switch.



Touch sensor pressed



Touch sensor released

- when there is contact with the surface of the touch sensor, the circuit is closed inside the sensor and there is a flow of current.
- when the contact is released, the circuit is opened and no current flows.

Capacitive Touch Sensor -

- These are widely used in most of the portable devices like mobiles, mp3 players, laptops etc.
- In several home appliances, automotive, industrial applications also these are used.
- The reasons for the usage of these sensors is
  - durability
  - robustness
  - actractive design
  - cost.
- unlike mechanical switches, they donot have moving parts.
- These sensors are robust as there are no openings for humidity and dust to enter.
- The principle of capacitive Touch screen sensors is

A simple capacitor can be made with two conductor plates seperated by an insulator.

The metal plates can be considered as conductors.

- The capacitance 'C' = $\varepsilon_0 \varepsilon_r A/d$

where ε_0 is permittivity of free space

ε_r is releative permittivity or di-electric constant.

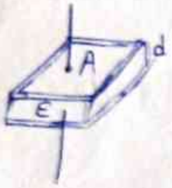
A is area of the plates and

d is the distance between them.

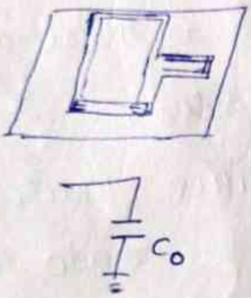
'C' is directly proportional to 'A' and inversely proportional to 'd'.

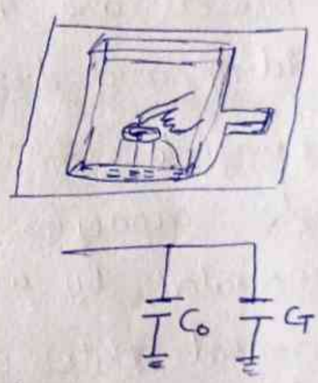
- In these sensors, the electrode represents one of the plates of the capacitor.

- The second plate is represented by two objects
  ① is the environment of the sensor electrode which forms parasitic capacitor C_0.
  ② is the conductive object like human finger which forms touch capacitor C_T.
- The sensor electrode is connected to a measurement circuit and the capacitance is measured periodically.
- The o/p capacitance will increase if a conductive object touches or approaches the sensor electrode.
- The measurement circuit will detect the change in the capacitance and converts it into a trigger signal.



$$c = \frac{\varepsilon A}{d}$$





- If the area of the sensor electrode is bigger and the thickness of the cover material is less, the touch capacitance C_T is also large.
- As a result the capacitance difference b/n touch pad and untouched sensor pad is also large.

⇒ The size of the sensor electrode and covering material will influence the sensitivity of the sensor.

→ The measurement of capacitance is used in many applica-tions like determining distance, pressure, acceleration etc.

⇒ There are two types of capacitive touch sensors,
  → ① surface capacitive sensing
  ② projected capacitive sensing

- In surface capacitive sensors, an insulator is applied with a conductive coating on one side of its surface. on top of this conductive coating, a thin layer of insulator is applied.
  current is applied to all the corners of the conductive coating.

- In projected capacitive sensors, the whole surface is not charged, but an X-Y grid of conductive material is placed b/n two insulating materials. The grid is often made of copper or gold on a PCB or Indium Tin oxide on glass.
  An IC is used to charge and monitor the grid.

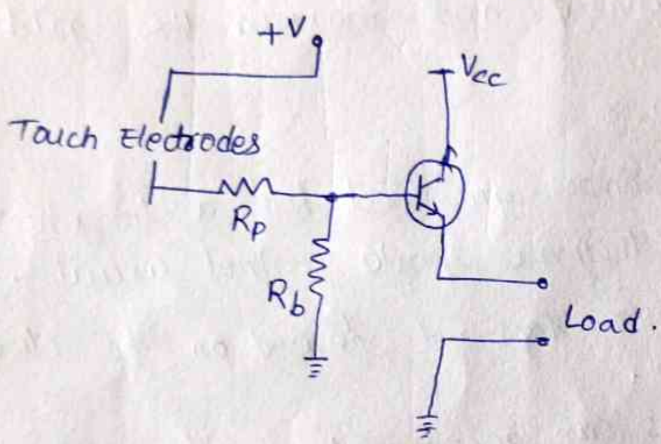
- Resistive Touch sensor -

Resistive touch sensors are used for a longer time than capacitive solutions as they are simple control circuits.

- A resistive touch sensor does not depend on the electrical property of capacitance.
  Hence resistive sensors can accomodate non-conducting materials like stylus and glove wrapped finger.
- In contrast to capacitive touch sensors which measure the capacitance, resistance touch sensors sense the pressure on the surface.

- A resistive touch sensor consists of two conductive layers seperated by small spacer dots.
- The bottom layer is made of either glass or film, and the top layer is made of film.
- The conductive material is coated with metallic film generally Indium Tin oxide and is transparent in nature.
- A voltage is applied across the surface of the conductor

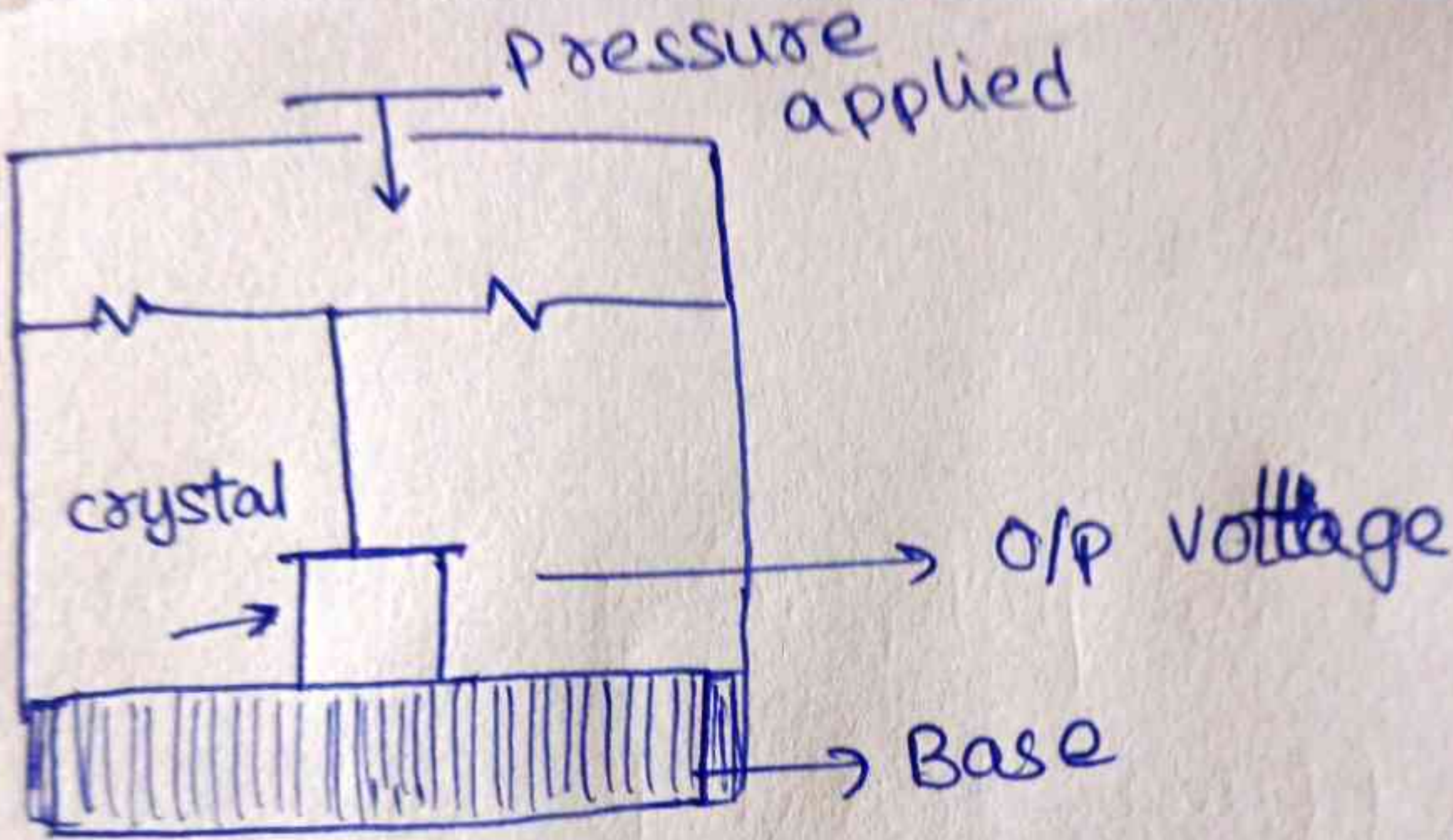
- when any probe like a finger, stylus pen, pen etc is used to apply pressure on the top film of the sensor, it activates the sensor.
- when ample pressure is applied, the top film flexes inwards and makes contact with bottom film.
- This results in the voltage drop and the point of contact creates a voltage divider network in the x-y direction
- This voltage and the changes in the voltage are detected by a controller and calculate the position of the touch where the pressure is applied based on the x-y co-ordinates of the touch.



piezo-Electric Transducer - used to measure change in accelera-tion, pressure, strain, temperature or force by converting this energy into an electric charge.

It works with the help of piezo electric effect.

- The electric voltage produced by the piezo electric transducer can be easily measured by the voltage measuring instruments
- Since this voltage will be a function of the force or pressure applied to it, we can infer what the force/pressure was by the voltage reading.
- In this way, the physical quantities like mechanical stress or force can be directly measured by piezo electric transducers.



piezo electric Transducer.