

Unit - III❖ Transducer ❖

The Transducers are the device that is used for the conversion of energy from one form to another. In terms of instrumentation, more specifically we can say, transducers are the device that change non-electrical quantity into its electrical equivalent form.

Mostly, transducer finds its applications in measuring devices. The contents of transducers are:-

- (i.) Type.
- (ii.) Selection Parameters.
- (iii.) Advantage.
- (iv.) Key terms.

4) Types of Transducers :-

A transducer is the heart of instrumentation system and can be classified as :-

- (i.) Active and Passive Transducer.
- (ii.) Analog and Digital Transducer.
- (iii.) Primary and Secondary Transducer.
- (iv.) Transducer and its inverse transducer.

Examples of Transducers :-

NOTE :- Between source as a i/p and destination as a o/p , the middle path are known as channel.
In our electrical - sound signal , the electrical signal works as a channel and sound signal b/w i/p (speaker) and o/p (amplifier).

2nd example of Transducer :-

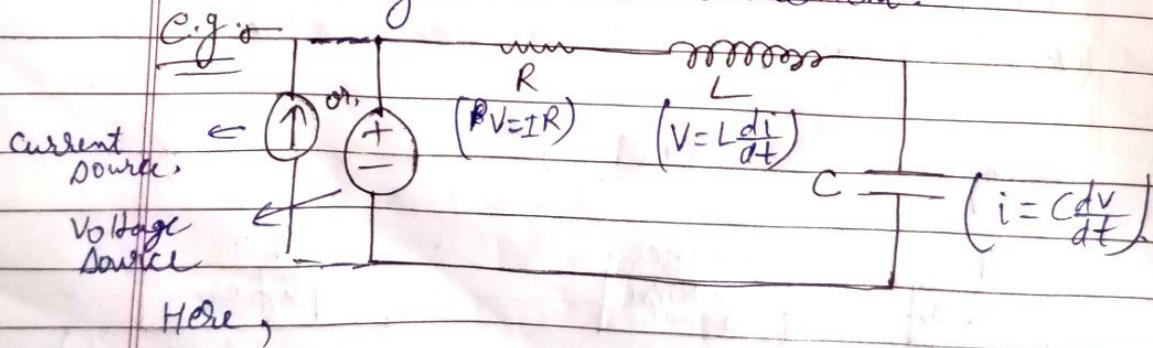
- Generator that converts mechanical energy into electrical energy.
- Motor that converts electrical energy into mechanical energy .

(i) Active & Passive Transducer :-

These two basically shows variations according to the energy conversion technique . The Active transducers are the device that does not make use of any external source to generate the output.

These actually generate the driving energy from the system under operation.

whereas , passive transducer is a device that require an external source of energy in order to drive the system under measurement.



Now,

Voltage & current source are active transducers,
and, R, L & C are passive transducers.

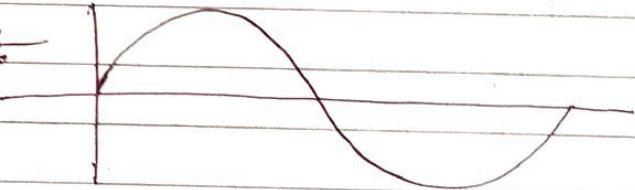
Ques:

(ii) Analog and Digital Transducers :-

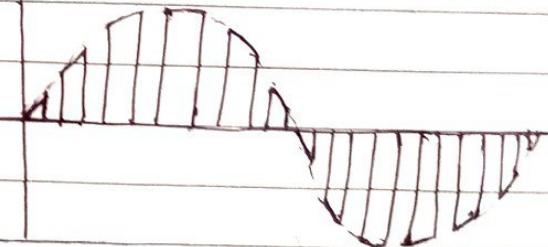
The analog transducer produces analog signal as a o/p at the time of energy conversion. This one is continuous function of time.

whereas, Digital transducer produces digitized signal at the o/p that is in the form of pulses.

Analog signal at o/p :-



Digital signal at o/p :-

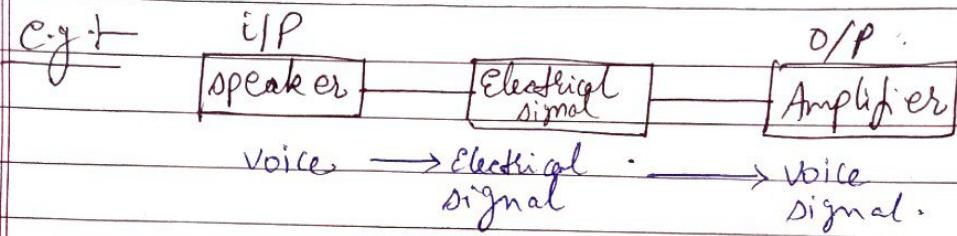


(iii) Primary and Secondary transducers :-

Primary transducer is one that does not require an individual i/p sensing unit. This means that applied i/p can be directly detected by transducers.

However, Secondary transducer requires an additional unit that can detect the applied i/p. The o/p of this detector is then fed to the transducers.

for energy conversion.



∴ speaker is primary transducer.
Amplifier is secondary transducer.

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Characteristics of Transducers :-

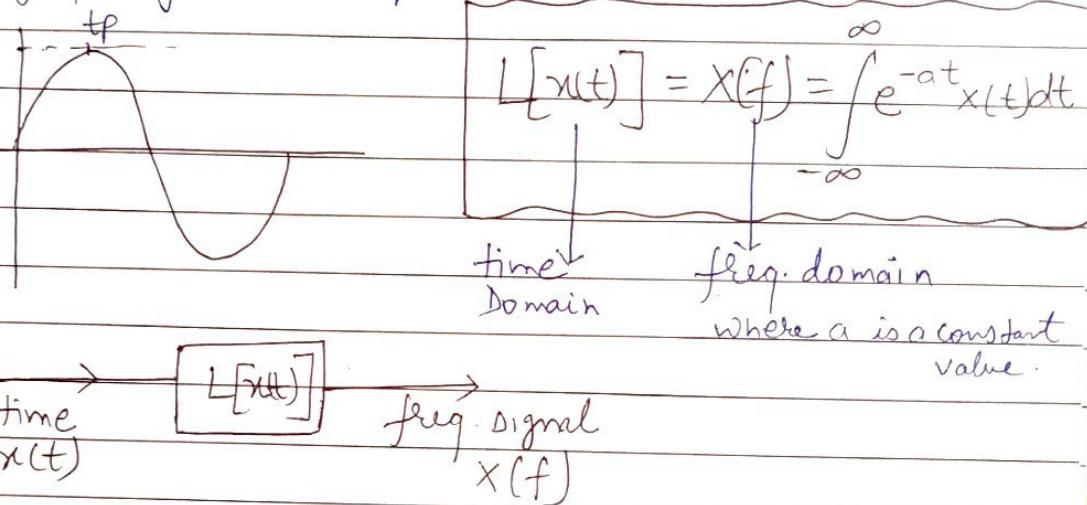
- 1) Ruggedness
- 2) Linearity
- 3) Repeatability
- 4) Accuracy
- 5) High stability & reliability.
- 6) Speed of response.
- 7) Sensitivity.
- 8) Small size.

Transducers Selection Factors :-

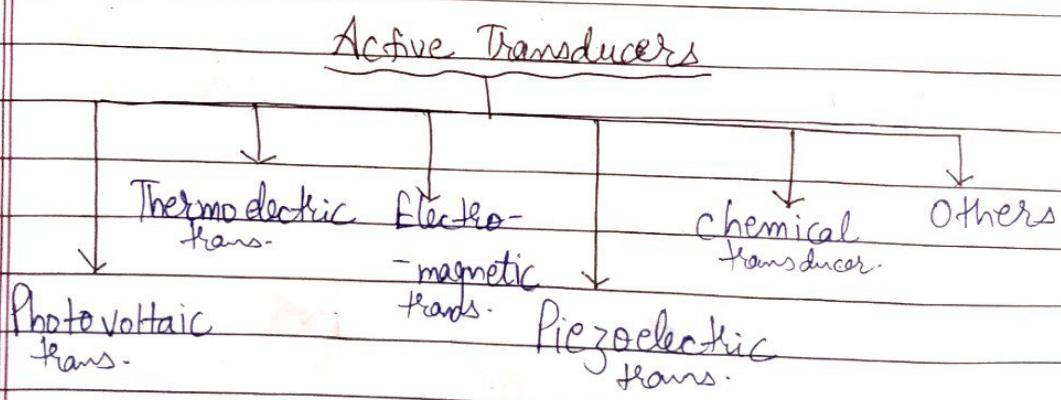
- 1) Operating principle :— The operating principle may be selective, resistive, capacitive, inductive, optoelectronic and piezo electric transducers, etc.
- 2) Sensitivity :— It is highly sensible device that produces detectable output. Ex:- ECG testing.
- 3) Operating range :— , BP, pulse oscillator.
It have good resolution over entire range.
- 4) Accuracy :— It is applicable for higher accuracy during entire range of device and can be used.

in all electric vehicles, medical accessories.

- 5) Error :- The transducer maintain its as expected i/p - o/p relationship; that is described by the transf. funcⁿ which avoid all type of error.
- 6) Transient and frequency response :- The transducer required the time domain specification like rise time, peak time, settling time and also we can convert into frequency domain response.



*.) Classification of Active transducers :-

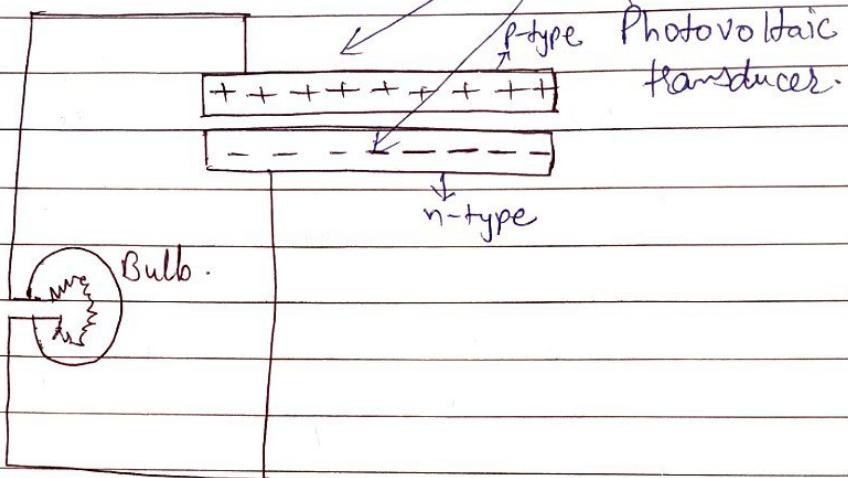


1) Photo voltaic Transducer

In this, the transduction measured is converted to voltage generated when the

junction between dissimilar material is
seen illuminated as shown in fig :-

It will convert
optical energy.
light energy into
electrical energy.

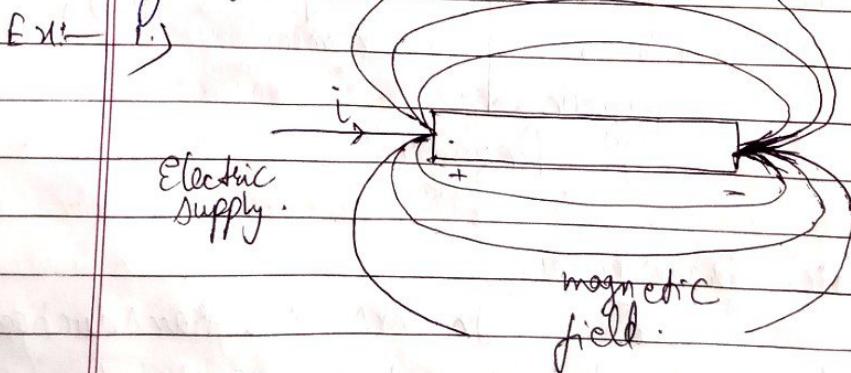


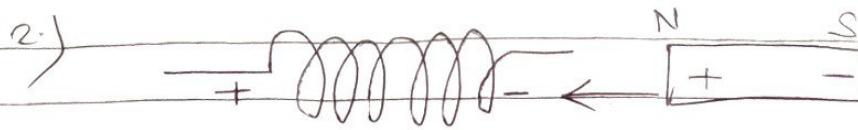
2) Thermoelectric transducer

In this device, the thermal energy convert into electrical energy. Ex:- Thermometer, immersion rod.

3) Electromagnetic transducer

In this transducer, the electrical energy convert into magnetic energy. Ex:- Electrical wire supply the current i that will produce magnetic field.



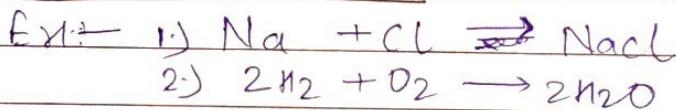


4.) Piezo electric transducer

In this transducer, the measurand is converted into charge in electric electrostatic charge or voltage V generated by crystal when mechanically it is stretched stressed. Here, pressure is converted into electrical energy.

Ex:- Electrical weighing machine utilized by medicinally different mally.

5.) Chemical transducer

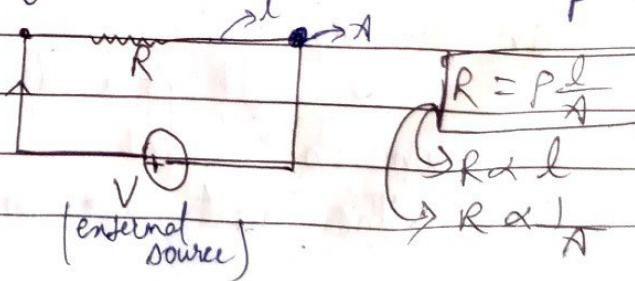


In this transducer, the adding of two composition of matter convert into another form of matters.

★) Classification of Passive transducer :-

1.) Resistive Transducers

In this case of transducer, firstly we will supply an external source after checking the value of resistance, it will change the coil length, area and its resistivity also vice versa same process happened.



148.) If the resistivity of the coil is $5 \Omega\text{-cm}$, length (l) is 25cm , area (A) is 5cm^2 . Find out the resistance of the coil.

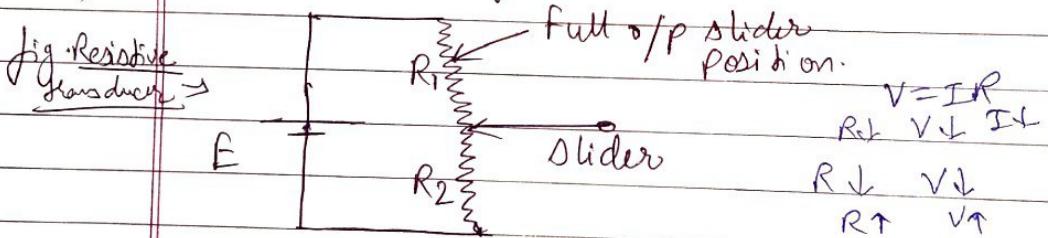
Sol¹² $R = \rho \frac{l}{A} = \frac{5 \times 25}{5} = 25 \Omega$

*.) There are four types of Resistive transducers:-

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

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*.) The example of resistive transducer ←

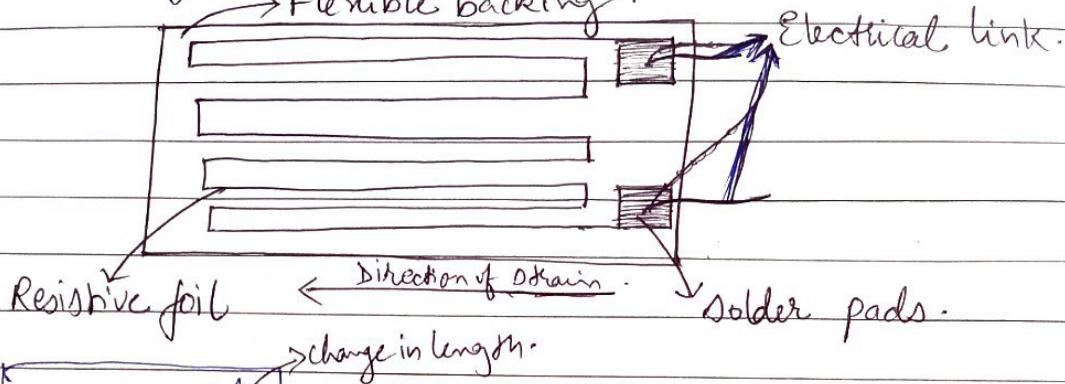


Here the circuit of sliding resistive transducer is shown in the figure above where the sliding contact are placed on the resistive element. The slider moves horizontally that changes the value of resistive element of the transducer which is measured by the voltage source 'E'.

d.) Strain Gauge :-

It is a device used to measure strain on an object invented by Albert E. Simons in 1938. The most common type of strain of

an insulated flexible backing which support a metallic foil pattern.

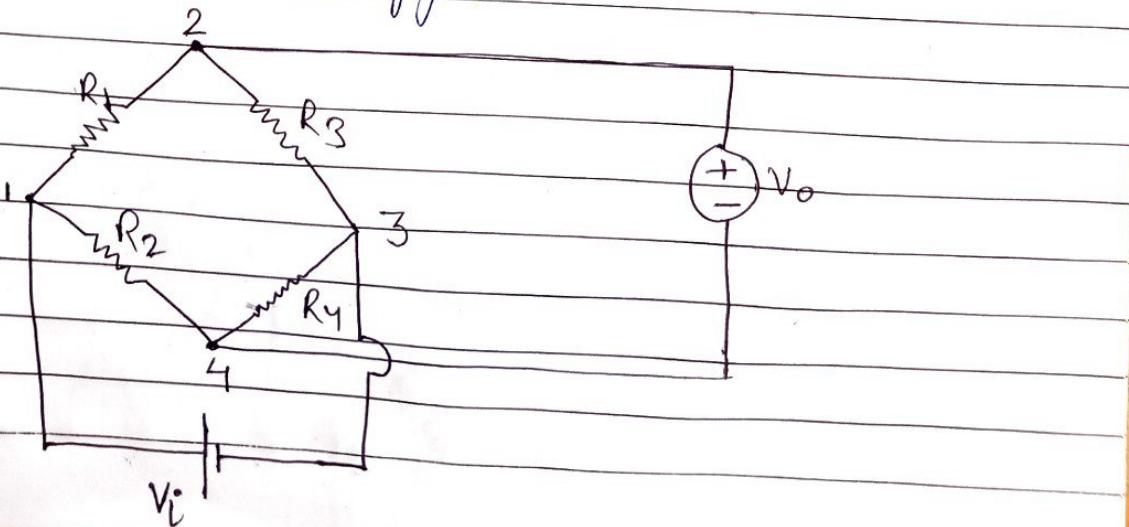


$\text{Strain} = \frac{\Delta l}{l}$ \rightarrow The strain gauge is a passive resistive transducer which converts mechanical elongation and compression into resistance change.

The strain gauge are of different type :-

- a) Wire Gauge
- b) Bonded gauge
- c) Unbonded gauge
- d) foil type

d) Unbonded strain gauge :- An unbonded meter strain gauge that consist of wire in an insulating medium such as air, the wire made up of copper, nickel, chromium that is shown in the fig.



In this case, unbounded strain gauge, the i/p is unbounded b/w terminal 1 & 3 & given supply V_i whereas unbounded o/p at terminal 2 & 4 will get the o/p voltage V_o .

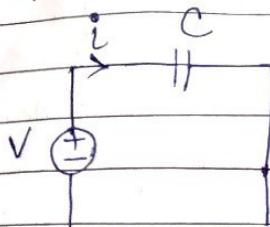
Assignment -3

- 1.) Write down short notes on i) foil type bounded strain gauge.
- 2.) (ii) Semiconductor Gauge.
(iii) Resistance Thermometer.

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→ Capacitive Transducer :-



$$\cancel{V = \frac{1}{2} \frac{dC}{dt}}$$

$$i = C \frac{dv}{dt}$$

In a network/circuit, current through capacitor i is equal to

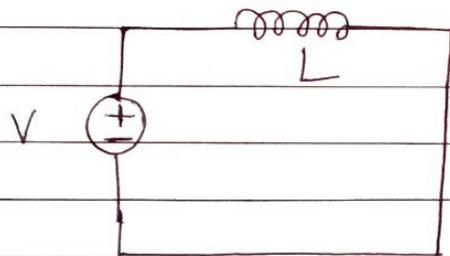
$$i = C \frac{dv}{dt}$$
 that is

the rate of change of voltage w.r.t time. such type of voltage can be utilized for the charging of capacitor C .

After getting fully charged, the capacitor will be used as a battery source during discharge mode.

→ The energy of capacitance during charging mode is $\left[\frac{1}{2} CV^2 \right]$.

→ Inductive Transducer → From the given $C K t$, voltage across inductor, $V = L \frac{di}{dt}$



$$V = L \frac{di}{dt}$$

Here, one form of energy Voltage can be convert into current. Now the rate of change of current w.r.t time multiplied by inductor, their value generate what amount of voltage that can be charged or utilized to the inductor.

→ Its energy level of inductor is $\left[\frac{1}{2} LI^2 \right]$.

Ex. of Inductive Transducer is Transformer.

★) L V D T (Linear Variable Differential Transformer) / Transducers

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Also called as "Linear Variable displacement Transformer", or simply, "LVDT". It is a type of electrical transformer that is used for measuring linear displacement in position, for this purpose it is called as linear variable. A counter part, if this device is used for measuring rotatory displacement that is called as rotatory / rotary variable differential transformer (RVDT).

1.)

2.) (ii)

(iii)

LVDT is a linear position displacement transducer.

They have virtually infinite cycle life time when properly used. As ac operated LVDT not contain any electronics and can be designed to operate at ~~over~~ ^{over} temperature upto 650°C (1200°F)

It is widely used in power turbine, hydraulics, aircraft, satellite, nuclear reactor and many others. The frequency usually used in the range of 1 - 10 kHz

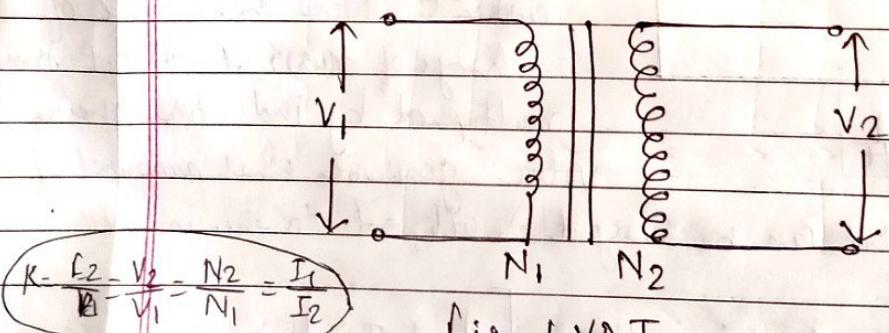
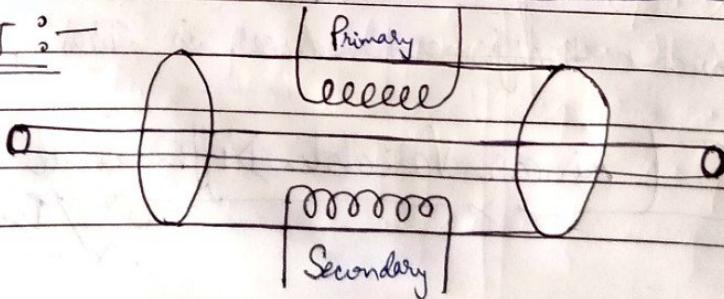
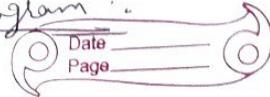


Fig. LVDT.

Fig. RVDT :-

Note: Refer A.K.Sawhney book
for LVDT & RVDT diagram

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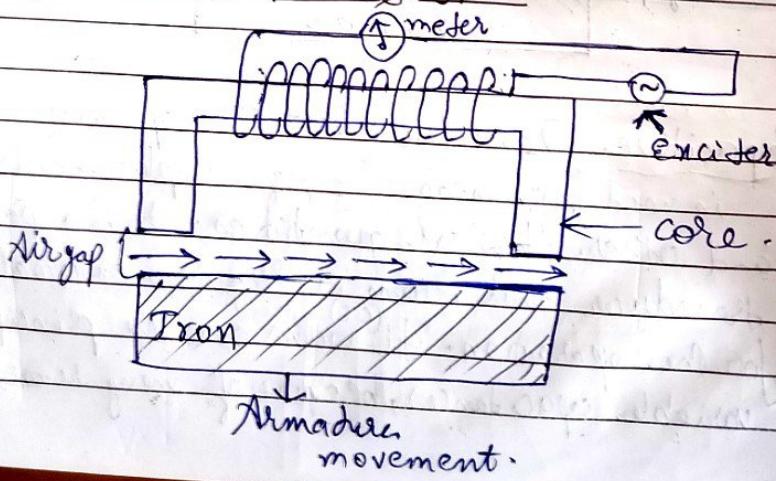
A) Inductive Transducer :— A transducer that works on the principle of electromagnetic conduction or transduction mechanism is called as Inductive Transducer. A self-inductance or mutual inductance is varied to measure required physical quantities like displacement (rotary or linear), force, pressure, velocity as well as, torque, accⁿ, etc. These physical quantities are noted as measurands. Linear Variable Differential Transformer or linear vari. diff. Transducer (LVDT). By using LVDT, displacement is measured in terms of voltage that is induced in the coil winding by moving core of the dirⁿ.

b) Types of Inductive Transducers

It may be passive type or self generating type transducers. The tachometer is the example of a self generating inductive transducer. In the structural form, the indu. transducer are again two types—

- 1.) Single Coil Inductance Type Transducer.
- 2.) Mutual Two coil Inductance Type Transducer.

1.) Single Coil Inductance type



When the armature of the Ckt is moved, the air gap b/w magnetic materials and permeability of the flux produced in the Ckt changes. This results in a change of the inductance of the Ckt.

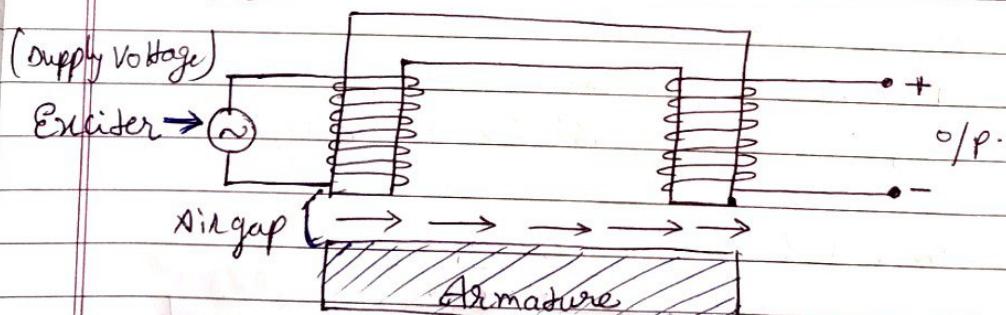
NOTE :— Studied in about Lap winding & wave winding from A. K. Dahney book.

2.) Two Coil Mutual Inductance Transducers :—

The magnetic core can be moved inside the hollow material, which has a coil wound around it. The hollow magnetic material where the opp is proportional to the ip and can be calibrated in terms of measurand.

The air gap decides the changes in the magnetic field of the coils and the flux linkage.

Fig →

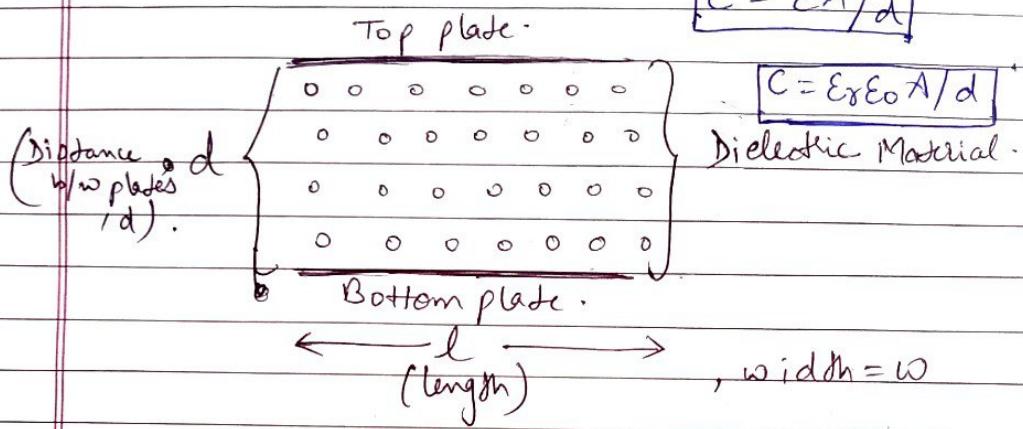


*) Capacitive Transducers :— The capacitive transducer is used for measuring of displacement, pressure and other physical quantities. It is a passive transducer that means it requires external power for the operation. It works on the principle of variable capacitances, because of many reasons like

Overlapping of plates, and dielectric constant.

In the principle of operating the C.T eqn that express the capacitance b/w the plates of the capacitor :-

$$C = \epsilon A/d$$



, width = w

where, A = overlapping area of plates in cm^2

d = the distance b/w two plates in mm

ϵ = permittivity of the medium

ϵ_0 = permittivity of free space.

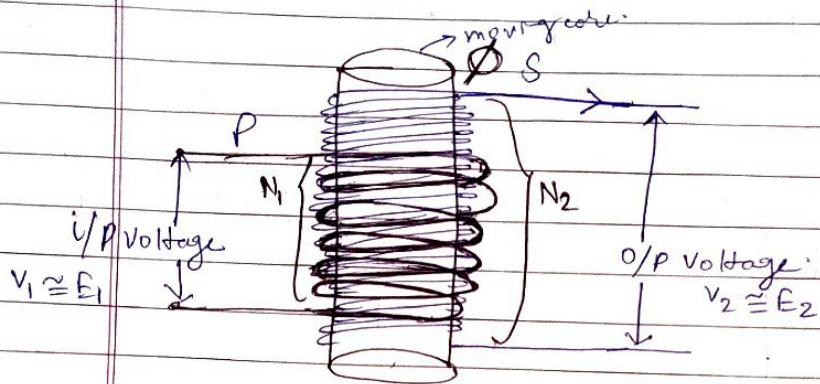
ϵ_r = Relative permittivity.

→ The changes of capacitance occurs becoz of physical variable like displacement, force, pressure. Therefore, capacitive transducer also changes by the variation in dielectric constant either liquid or gas.

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★.) L V D T :- The L V D T stands for Linear Variable Differential Transformer. It is the most widely used in inductive transducer, that converts the linear motion into electrical signal. The o/p across secondary of the transformer is the differential thus it

is called as LVDT. It is very accurate inductive transducer as compared to the other inductive transducer.



$$\frac{V_2}{V_1} = \frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K \quad \text{Voltage transformation ratio (VTR).}$$

The transformer consists of Primary winding, secondary winding on a cylindrical hollow iron core. Both primary and secondary depends on N_1 & N_2 (no. of turns).

The primary winding is connected to an a.c source which produces flux in the air gap and voltage are induced in secondary winding.

The iron core is generally of high permeability which helps in reducing harmonics and high sensitivity of LVDT. The LVDT is placed inside a stainless steel because it will provide electrostatic and electromagnetic shielding.

A.) Photo electric Cell :- The photo electric cell also called as electric eye, photo cell, phototube, electron tube with photo sensitive cathode that emits the electrons.

When illuminated b/w anode for collecting the emitted electrons. Various cathode materials are sensitive to specific species ⁱⁿ region such as ultraviolet, infrared or visible light. The voltage b/w anode & cathode causes no current in darkness becoz no electrons are emitted. These tubes are used in control systems where a beam of light open a Ckt like relay. These tubes are also used in photometry and in spectroscopy.

Ques:

The photo-

Voltaic transducer or cell that converts the light energy into electrical energy through the photo voltaic effect.

Sunlight

It is an effect

^{active} Transducer also known as solar cell. The o/p electrical energy not produced is proportional to the intensity of light.

Anti reflective
Coating.

S/C
materials

