Lecture
on
Measurement of Non-Electrical Quantities
Transducer

Transducer is defined as a device which convert energy or information from one form to another. Transducer may be mechanical, electrical, magnetic, optical, chemical, thermal or combination of two or more of these.
Electrical Transducers

Most quantities to be measured are non-electrical such as temperature, pressure, displacement, humidity, fluid flow, speed, pH, etc., but these quantities cannot be measured directly. Hence such quantities are required to be sensed and changed into some other form of quantities. Therefore, for measurement of non-electrical quantities these are to be converted into electrical quantities (because these are easily measurable). This conversion is done by device called Electrical Transducer
Classification of transducers

1. Based on principle of transduction
2. Active & passive
3. Analog & digital
4. Inverse transducer
Based on principle used

- Thermo electric
- Magneto resistive
- Electro kinetic
- Optical
Passive transducer

Device which need external power for transduction from auxiliary power source

Eg: resistive, inductive, capacitive
Without power they will not work
Active transducer

• No extra power required.
• Self generating
• Draw power from input applied
• Eg. Piezo electric x’tal used for acceleration measurement
Resistive Transducer

In this transducer, the resistance of the output terminal of the transducer gets varied according to the measurand. Some resistive transducers are:-

- Potentiometer
- Strain gauge
- Resistance Thermometer
RESISTIVITE POTENTIOMETERS

A resistance element provided with a movable contact. This is very simple and cheap form of transducer and is widely used. It convert linear or rotational displacement into a voltage.

The contact motion can be

- Linear
- rotation
- combination of the two such as helical
**Strain Gauges**

It is a device which is used for measuring mechanical surface strain and one of the most extensively used electrical transducer. It can detect and convert force or small mechanical displacement into electrical signal. Many other quantities such as torque, pressure, weight and tension etc, which involve the effect of force or displacement can be measured with string gauge.

Gauge Factor (G) = Change in resistance per unit strain.

Strain Gauge can be of four types:-
1. Wire strain gauge
2. Foil strain gauge
3. Thin film strain gauge
4. Semiconductor strain gauge
INDUCTIVE TRANSDUCERS

Inductive transducers are those in which SELF INDUCTANCE of a coil or the MUTUAL INDUCTANCE of a pair of coil is altered due to variation in the measurand. Change in inductance $\Delta L$ is measured.

The **self inductance** of a coil refers to the flux linkage within the coil due to current in the same coil.

**Mutual inductance** refers to the flux linkages in a coil due to current in adjacent coil.
A capacitor is an electrical component which essentially consists of two plates separated by an insulator.

The property of a capacitor to store an electric charge when its plates are at different potential is referred to as capacitance.
Capacitance $C = \frac{Q}{V}$

If the capacitance is large, more charge is needed to establish a given voltage difference. The capacitance between two parallel metallic plates of area

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

($\varepsilon_0 = 8.85 \times 10^{-12} \frac{F}{m}$)
Linear Variable Differential Transformer (LVDT)
• There is one primary winding connected to an ac source (50 Hz – 20 kHz), excitation 3 – 15 \( V_{\text{rms}} \).

• Core is made of high permeability soft iron or nickel iron.

• Two secondary windings are connected in series opposition.
Geometric centre of coil arrangement is called the NULL position. The output voltage at the null position is ideally zero.

However it is small but nonzero (null voltage).

Why?

1. Harmonics in the excitation voltage and stray capacitance coupling between the primary and the secondary

2. Manufacturing defects.
Advantages

1. Wide range of displacement from µm to cm.
2. Frictionless and electrical isolation.
3. High output.
4. High sensitivity [sensitivity is expressed in mV (output voltage)/ mm (input core displacement)].
Disadvantages

1. Sensitive to stray magnetic fields.
2. Affected by vibrations.
3. Dynamic response is limited mechanically by the mass of core and electrically by frequency of excitation voltage.
Pressure Measurement

The measurement of force or pressure can be done by converting the applied force or pressure into displacement by elastic element (such as diaphragm, capsule, bellows or bourdon tube) which act as primary transducer. This displacement, which is function of pressure is measured by transducer which act as secondary transducer (these may be potentiometer, strain gauge, LVDT, piezoelectric, etc.).
Thermo-couple

The thermocouple is one of the most commonly used method for measuring the process temperature. The operation is based on seebeck effect.

Thermo-couple consists of two dissimilar metals joined together as shown. It forms two junctions 1 and 2 in which one junction is hot and other is cold. Due to this difference in temperature, an e.m.f. is generated and electric current flow in circuit.
Flow Measurement

• Electromagnetic Flow meter:
  This is suitable for measurement of slurries, sludge and any electrical conducting liquid.
Electromagnetic flow meter consist of insulated electrodes pair buried in opposite sides of non conducting pipe placed in magnetic field of electromagnet.

The voltage induced across electrodes is $E=Blv$ volts
Liquid Level Measurement

- Gamma Ray Method

The liquid level can be measured with ultrasonic method and by using float also.
PIEZOELECTRIC AND HALL EFFECT TRANSDUCERS
Piezoelectricity

Phenomenon of generating an electric charge in a material when subjecting it to a mechanical stress (direct effect).

and

Generating a mechanical strain in response to an applied electric field (converse effect).

Piezoelectric materials are *Anisotropic* – Electrical and mechanical properties differ along different directions.
There are two families of constants: ‘g’ constants and ‘d’ constants. In the constants the first subscript refers to the direction of electrical effect and the second to that of the mechanical effect according to the axis systems.
Commercially available Hall generators made of:

- Bulk Indium Arsenide (InAs)
- Thin Film InAs
- Gallium Arsenide (GaAs)
- Indium Antimonide (InSb).
Summary
Thank you