TRANSDUCERS

INTRODUCTION: A transduce is defined as a device that receives energy from one system and transmit it to another, often in a different form.

Broadly defined, the transcuder is a device capable of being actuated by an exergising input from one (or) more transmission media and in turn generating a related signal to one (or) more transmission systems. The energy transmitted by these systems may be electrical, mechanical (or) acoustical.

ELECTRICAL TRANSDUCER:

An electrical transducer is a sensing device by which the physical, mechanical (or) optical quantity to be measured is transformed directly by a suitable mechanism into an electrical voltage/current proportional to the input measurand.

Electrical transducers can be broadly classified into two major categories, i) Active ii) Passive.

i) ACTIVE TRANSDUCER:

An active transducer generates an electrical signal directly in response to the physical parameter and doesnot require an external power source for its operation. Active transducers are self-generating devices, which operate under energy conversion principle and generate an equivalent output signal.

ii) PASSIVE TRANSDUCER :

It operates under energy controlling principles, which makes it necessary to use an external electrical source with them. They depend upon the change in an electrical parameter (R, L and C).

Typical examples are strain guage and thermistors.

RESISTIVE TRANSDUCER :

Resistive transducers are those in which the resistance changes due to a change in some physical phenomenon. The change in the value of the resistance with a change in the length of conductor can be used to measure the displacement.

Strain guages work on principle that the resistance of a conductor (or) semi-conductor changes when strained. This can be used for measurement of force, displacement and pressure.

The resistivity of materials changes with changes in temperature. It can be used for measurement of temperature.

INDUCTIVE TRANSDUCER :

Inductive transducers may be either of self generating (or) the passive type. The self generating type utilises the basic electrical generator principle i.e., a motion between a conductor and magnetic field induces a voltage in the conductor. An inductive electromechanical transducer is a device that converts physical motion into a change in inductance. Transducers of the variable inductance type work upon one of the following principles.

1. Variation of self inductance.
2. Variation of mutual inductance.

These are mainly used for measurement of displacement. The displacement to be measured is arranged to cause variation in any of these three variables:

1. No. of turns.
2. Geometric configuration.
3. Permeability of magnetic material.

When a current i is passed through it, the flux is:

$$\phi = \frac{Ni}{R} \Rightarrow \frac{d\phi}{dt} = \frac{N}{R} \times \frac{di}{dt} - \frac{Ni}{R^2} \times \frac{dR}{dt}$$

If current varies rapidly,

$$\frac{d\phi}{dt} = \frac{N}{R} \times \frac{di}{dt}$$

But emf is given by: $e = N \times \frac{d\phi}{dt}$

$$\Rightarrow e = N \times \frac{N}{R} \times \frac{di}{dt} = \frac{N^2}{R} \times \frac{di}{dt}$$

Self- inductance is given by: $L = \frac{e}{di/dt} = \frac{N^2}{R}$.

The o/p from an inductive transducer can be in the form of either change in voltage (or) a change in inductance.

CAPACITIVE TRANSDUCER:

A linear change in capacitance with changes in the physical position of moving element may be used to provide an electrical indication of element's position.

The capacitance is given by: $C = KA/d$.

where, K = the dielectric constant

A = the total area of capacitor surfaces.

d = distance between two capacitive surfaces.

C = the resultant capacitance.

STRAIN GUAGE:

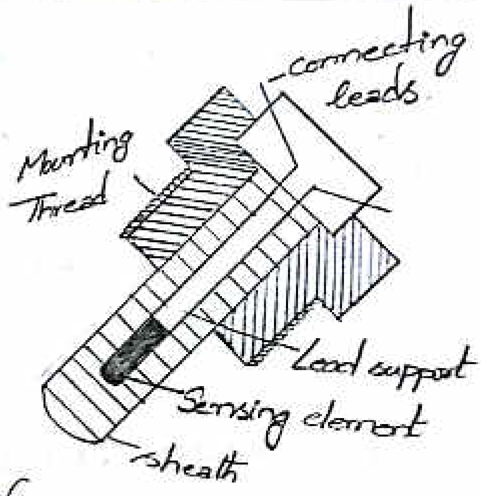
The strain guage is an example of a passive transducer that uses the variation in electrical resistance in wires to sense the strain produced by a force on the wires.

It is well known that stress and strain in a member (or) portion of any object under pressure is directly related to the modulus of elasticity.

Many detectors and transducers e.g., loadcells, torque meters, pressure gauges, temperature sensors etc., employ strain gauge as secondary transducers.

When a gauge is subjected to a +ve stress, its length increases while its area of cross-section decreases. Since the resistance of a conductor is directly proportional to its length and inversely proportional to its area of cross-section, the resistance of gauge increases with positive strain.

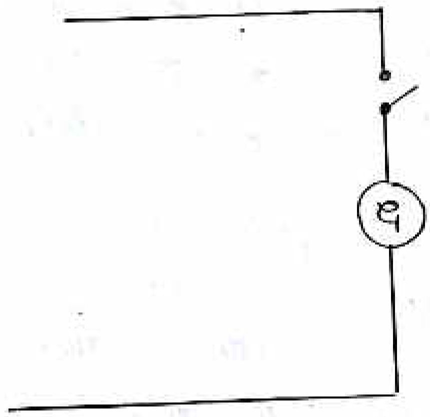
Resistance Thermometer:



The resistance of a conductor changes when its temperature is changed. It is used for measurement of temp.

Resistance thermometer is an instrument used to measure electrical resistance in terms of temperature i.e., it uses the change in electrical resistance of conductor to determine temperature.

To maintain the calibration of a resistance thermometer, it is necessary to consider its stability. The need for stability frequently limits the temperature range over which the sensing element may be used.



The changes in resistance caused by changes in temperature are detected by a Wheatstone bridge.

The sensing element R_S is made of a material having a high temperature co-efficient, and R_1, R_2 and R_5 are made of resistances that are practically constant under normal temperature changes.

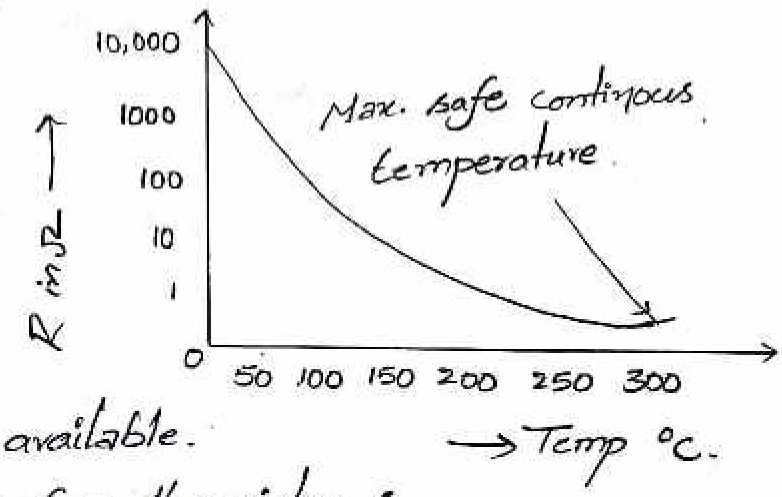
Therefore, $\frac{R_1}{R_2} = \frac{R_S}{R_5}$ the sensing element is away from indicator, & its leads have a resistance, say R_3, R_4.

$$\frac{R_1}{R_2} = \frac{R_3 + R_3 + R_4}{R_5}.$$

THERMISTOR : The electrical resistance of most materials changes with temperature. By selecting materials that are very temperature sensitive, devices that are useful in temperature control circuits and for temperature measurement can be made.

Thermistor [Thermally sensitive resistor] are non-metallic, made by sintering mixtures of metallic oxides such as manganese, nickel, cobalt, copper and uranium.

Thermistor has a negative temperature co-efficient i.e., resistance decreases as temperature increases. The resistance of thermistors at room temperature may decrease by 5% for each 1°C rise in temp. This high sensitivity to temperature changes makes the thermistor extremely useful for precision temperature measurements, control and compensation.



Thermistors are non-linear devices over a temp range, although now units with better than 0.2% linearity over the 0-100°C temp range are available.

The typical sensitivity of a thermistor is approximately 3 mV/°C at 200°C.

Thermistor has a very non-linear resistance temp. relation. The resistance R of a thermistor at a temp. T can be given by:

$R = \alpha \cdot e^{\beta/T}$.

where, α & β are constants depending upon the material and manufacturing technique is used.

Now, resistance for temperatures T_1 and T_0

$\beta\left(\frac{1}{T_1} - \frac{1}{T_0}\right)$.

R_0.

$$R_1 = R_0 \cdot e^{\beta\left(\frac{1}{T_1} - \frac{1}{T_0}\right)}$$

where, R_1 & R_0 are resistances in Ω at absolute temp. T_1 and T_0.

β = Thermistor constant.

T = Reference temp (or) 25°C.

Temp co-eff, $\alpha = \frac{dR_1/R}{dT} = \frac{-\beta}{T^2}$

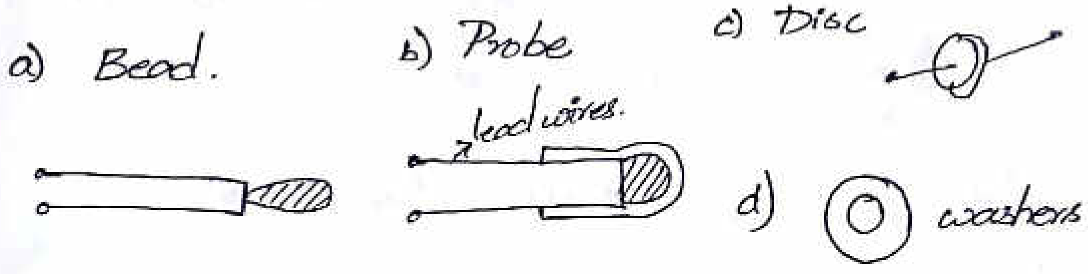
$\beta = 4000$ °c.

$T = 25°C = 298$ k

$$\alpha = \frac{4000}{(298)^2} = -0.045 \ \Omega/\Omega/°c.$$

MATERIALS USED:

Modern thermistors are manufactures from the oxides of metals like nickel, cobalt, copper, iron, zinc etc. Their oxides and their sulphides and silicates are milled, mixed in appropriate proportional, pressed into desired shape with appropriate binders.



SALIENT FEATURES:

1. High resistance temp. coeff characteristics results in inherent high sensitivity and high level of o/p.

2. It eliminates the need of extremely sensitive read out devices

3. Because of large change of resistance per degree of temp variations in thermistor, they can provide good accuracy and resolution when used for measurement of temp.

4. Thermistor are compact, rigid and inexpensive.

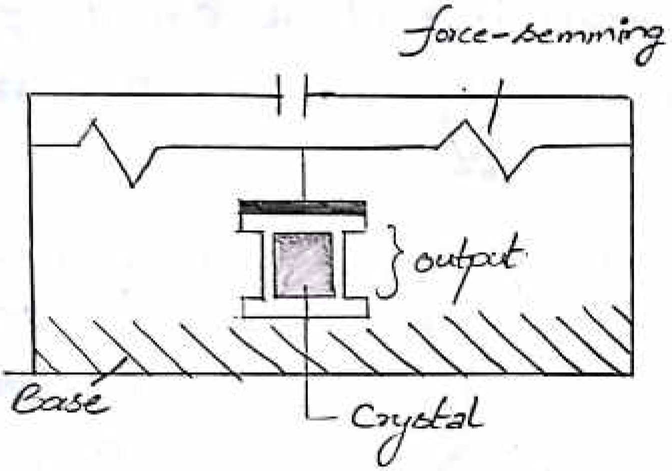
LIMITATIONS:

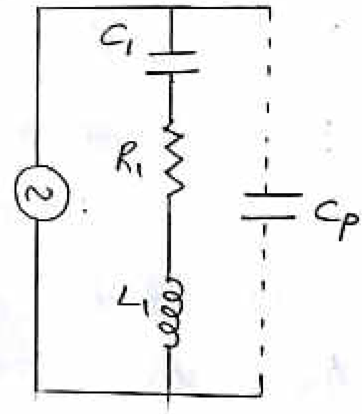
1. The high degree of non-linearity in the resistance-temp function usually limits the range of read-out in instrumentation.

2. wide range of temp, these are less stable.

PIEZO ELECTRICAL TRANSDUCER :

– A symmetrical crystalline materials such as Quartz, Rochelle salt and Barium titanate produce an emf when they are placed under stress. This property is used in piezo electric transducers, where a crystal is placed between as solid base and the force – summing member.





The basic expression for o/p voltage E is given by :

$$E = \frac{Q}{C_p}$$ where, C_p = shunt capacitance.
Q = generated charge.

This transducer is inherently a dynamic responding sensor and doesnot readily measure static conditions.

For a piezo electric element under pressure, part of energy is converted to an electric potential that appears on opposite faces of element, analogous to a charge on plates of capacitor.

$$\text{Coupling co-efficient, } k = \frac{\text{mechanical energy converted to electrical energy}}{\text{applied mechanical energy}}$$

SENSISTORS :

Sensistor is a resistor whose resistance changes with temperature.

The resistance increases exponentially with temperature, that is the temperature co-efficient is positive.

Sensistors are used in electronic circuits for compensation of temperature influence (or) as sensors of temperature for other circuits.

Sensistors are made by using very heavily doped semiconductors so that their operation is similar to PTC type thermistors. However, very heavily doped semi conductors behaves more like a metal, and the resistance change is more gradual than it is the case for other PTC thermistors.

Thermistors are of two opposite fundemental types:

→ With NTC thermistors, resistance decreases as temp rises. An NTC is commonly used as a temp sensor (or) in series with a circuit as an inrush current limitor

→ With PTC thermistors, resistance increases as temp rises. PTC are commonly installed in series with a circuit, and used to protect against over current conditions, as resettable fuses.

Measurement Requirements:

The measurement requirements for a transducer as follows:

Range: The range is set of values a transducer is designed to measure. The min and max. values of transducer's range are called the endpoints. Some can be adjusted to cover a different range by attenuating the measurand.

Input Threshold: It is the smallest dectable value of the measured quantity starting near the zero value of the variable. For an input to be discerned, it must be possible to assign a unique number to the input. The selection of a transducer requires that it respond in a discernible manner to the threshold.

Dynamic Behaviour:

The dynamic behaviour of a transducer specifies how the transducers can respond to a changing input. No transducer could follow an instruction instantaneous change. The dynamic performance is usually specified as a freq response (or) response time depending on the type of transducer. The response time is the time required to reach a specified percentage of the final value for a given change of input.

ACCURACY AND RESOLUTION :

Accuracy is the difference between the measured and accepted value. Its requirements for a particular measurement can be greatly affect the total cost of the measurement system.

In addition, certain transducers such as strain gauges and pressure transducers. have a fatigue life that can change the accuracy, depending on duration and cyclic behaviour of measurand. In some cases, the accuracy isn't as important as ability to detect small change, as when quantities are being compared.

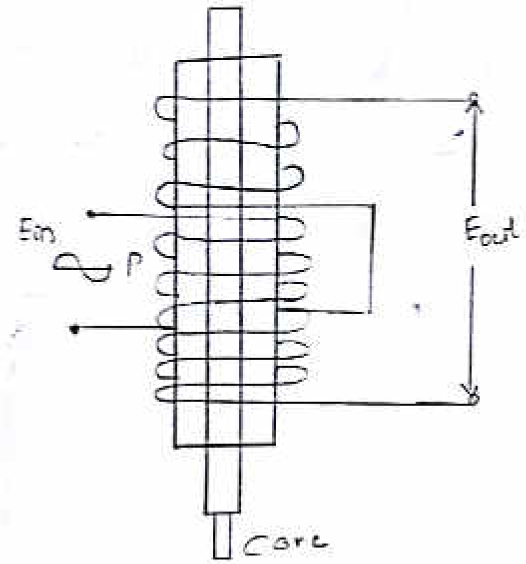
REPEATABILITY AND HYSTERESIS ERRORS :

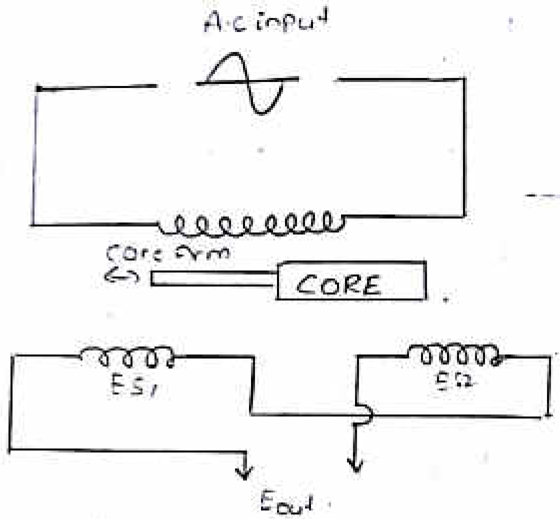
It is the max. difference between consecutive measurements of same quantity when the measured point is approached each time from same direction for full-range traverses. It is usually expressed as a percentage difference of the full scale output.

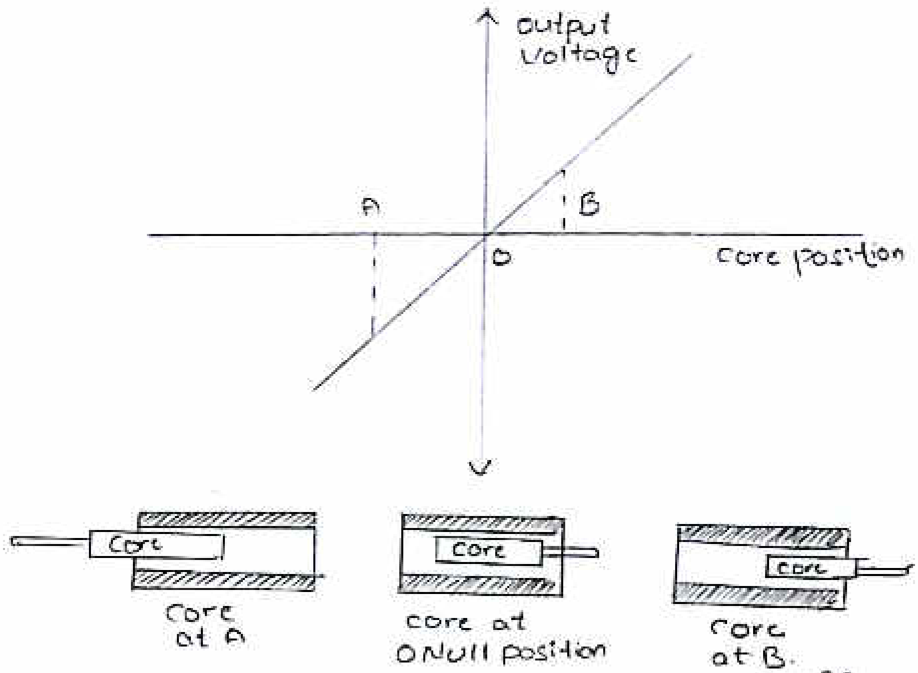
Hysteresis error is max difference between consecutive measurements for the same quantity when the measured point is approached each time from a different direction for full-range traverses.

7.

Linear Variable Differential Transformer (LVDT).







Output voltage of LVDT at different core positions

When an externally applied force moves the core to the left-hand position, more magnetic flux links the left-hand coil than the right hand coil. The emf induced in the left hand coil, is therefore larger than the induced emf of the right hand. The magnitude of the output voltage is then equal to the difference between the two secondary voltages and it is in phase with the voltage of left-hand coil.