UNIT 7

1. What is transducer? Write the classifications of transducers?

Ans:

Transducer

A measuring device which measures and converts nonelectrical variable into electrical variable is known as transducer.

Transducers are classified into several types. However, these can be categorized into five types. They are,

1. Classification on the basis of transduction principle used.
2. Active and passive transducers
3. Analog and digital transducers
4. Primary and secondary transducers
5. Transducers and inverse transducers.

1. Classification on the Basis of Transduction Principle Used

This classification is done depending on the transduction principle i.e., how the input variable is being converted into capacitance, resistance and inductance values. (These are named as capacitive transducer, resistive transducer and inductive transducer respectively).

Examples of Capacitive Transducer	Applications
1. Dielectric gauge.	1.It is used to measure, (i) Thickness and (ii) Liquid level.
2. Capacitor Microphone.	2.It is used to measure, (i) Noise (ii) Speech and Music

Examples of Resistive Transducer	Applications
1. Resistance thermometer.	1. Used in the measurement or, (i) Temperature and (ii) Radiant heat.
2. Potentiometer device.	2. (i) Used in displacement measurement and (ii) Used in pressure measurement.

Examples of Inductive Transducer	Applications
1. Reluctance pick up.	1. It is used to measure, (i) Pressure (ii) Vibrations (iii) Position and (iv) Displacement.
2. Magnetostriction gauge.	2. It is used to measure, (i) Sound (ii) Force (iii) Pressure.

2. Active and Passive Transducers

Active Transducer

The transducer which does not requires any external excitation to provide their outputs are referred as active transducer.

Examples of Active Transducer	Applications
1. Photo voltaic cell.	1. (i) Used in light meters (ii) Used in solar cells.
2. Thermocouple.	2. Used to measure, (i) Temperature (ii) Radiation and (iii) Heat flow.

Passive Transducer

The transducer which requires an external excitation to provide their output is referred as passive transducer.

Examples of Passive Transducer	Applications
1. Capacitive transducers.	1. Used to measure liquid level, noise, thickness etc.
2. Resistive transducers.	2. Used to measure temperature, pressure, displacement etc.
3. Inductive transducers.	3.Used to measure pressure, vibration, position, displacement etc.

3. Analog and Digital Transducers

Analog Transducer

The transducer which produces their outputs in analog form or a form which is a continuous function of time is referred as analog transducer.

Examples of Analog Transducer	Applications
1.Strain gauge	1. Used to measure, (i) Displacement (ii) Force and (iii) Torque.
2. Thermistor	2.Used to measure, (i) Temperature and (ii) Flow.

Digital Transducer

The transducer which produces their outputs in digital form or a form of pulses is referred as digital transducers.

Examples of Digital Transducer	Applications
Turbine meter	Used in flow measurement.

4. Primary and Secondary Transducers

Primary Transducer

The transducer which sends the measurement and converts them into another variables (like displacement, strain etc.) and whose output forms the input of another transducer **is** called as primary transducer.

Examples of Primary Transducer	Applications
1. Bourdon tube 2. Strain gauge	1. Used in pressure 2. Used in measurements

Secondary Transducer

The transducer which converts the output of first transducer into an electrical output called secondary transducer.

Examples of Secondary Transducer	Applications
LVDT	Used to measure, (i) Displacement (ii) Force (iii) Pressure and (iv) Position

5. Transducers and Inverse Transducers

Transducers

A measuring device which measures and converts nonelectrical variable into electrical variable is known as transducer.

Example of Transducer	Applications
Thermocouple	Used to measure, (i) Temperature (ii) Radiation and (iii) Heat flow

Inverse Transducer

A measuring device which measures and converts an electrical variable into nonelectrical variable is known as inverse transducer.

Example of Inverse Transducers	Applications
Piezo-electric crystal	Used to measure, (i) Pressure (ii) Vibration and acceleration

2. What parameters should be considered in selecting a transducer?

Ans:

Parameters to be considered in the selection of a transducer for a particular application are.

1. **Operating Principle**

   Basically the transducers are selected based on their operating principle. Examples of operating principles used by the transducers are resistive, capacitive, piezoelectric, inductive, up to electronic principle etc.

2. **Operating Range**

   This factor is considered so that the transducer should be able to function within the specified range with good resolution. Every transducer should be provided with some rating within which there will be breakdown in its function.

3. **Accuracy**

   It is one of the most desired characteristic of any transducer. If the transducer doesn't needs frequent calibration, it must have high degree of accuracy and repeatability. Because errors may occur due to the sensitivity of the transducer to other stimulations.

4. **Sensitivity**

   It is also a desired characteristic of a transducer. Every transducer should be sufficiently sensitive to provide some output that can be sufficient and detectable.

5. **Stability and Reliability**

   The transducer should have high degree of stability during its function and also storage life. It should also have a high degree of reliability.

6. **Usage and Ruggedness**

The ruggedness, size and weight of a transducer should be chosen depending on the application in which it is used.

7. **Transient Response and Frequency Response**
   The transducer should have required time domain specifications such as, settling time, rise time, peak over shoot and small dynamic error etc.

8. **Loading Effects**

   The transducers should undergo minimum loading effect so that if can provide accurate measurement. The parameters of a transducer are that, which characterize the loading effect is its input and output impedances.lt is considered in order to get minimum loading effects (Which can be neglected). For minimum loading effect the transducer should have low output impedance and high input impedance.

9. **Electrical Parameters**

   The type and length of cable required, signal to noise ratio in case the transducer is used with amplifiers and frequency response limitations should also be considered.

10. Ability to be insensitive to unwanted signals (or the ability to be sensitive to desired signals).
11. Environmental compatibility.
12. Static Characteristics

    The selected transducer should have low hysteresis, high linearity and high resolution.

3. What is the difference between photoemmissive, photoconductive and photovoltaic transducers?

Ans:

Photo emissive Transducer	Photoconductive transducer	Photovoltaic transducer

1. When cathode of photo emissive cell is subjected to radiations, it emits electrons. These electrons increase the current of the cell. Hence, this cell provides the measure of light intensity in terms of current.	When a photoconductive semi-conductor element is subjected to radiations, its resistance changes (i.e., if decreases). Due to this, the flow of current through the cell increases.	When radiations fall on a photovoltaic cell, it generates a voltage whose value is proportional to the intensity of radiation incident on the cell. Thus, it converts electromagnetic energy into electrical energy.
2. It is a, passive transducer.	This cell is a passive transducer.	It is an active transducer.
3. They have a moderate luminous sensitivity of 10-100 uA/lm and 40-150 uA/lm. A very high sensitivity of 20 A/lm can also be achieved by photomultiplier tube.	They are highly sensitive with small change in light intensity they exhibit high change in their resistance.	They possess sensitivity of 1 mA/lm.
4. The response time of these cells ' is less than that of photoconductive cells.	These cells possess a short response time of 10-100 ps.	These cells have very short response time of 1-50 ps.
5. The spectral response of these cells range from visible to infrared region up to 220° nm.	These cells do not respond to radiations having wavelength less than 300 nm. Their spectral response extend from thermal radiation through visible, IR, UV up to X-rays and y-rays.	The spectral response of these cells range from 200 nm - 2000 nm These cells are sensitive to, a-rays, (3-rays, y-rays and X-rays.
6. Photo emissive cells possess good amount of stability.	The characteristics of photoconductive cells are affected by temperature.	Photovoltaic cells are also stable but, they are seriously affected by temperature. An increase in temperature leads to a rapid decrease in output voltage of these cells, usually few mV/°C.

7. They are used to measure luminous flux or luminous intensity.	These cells are widely used in measurement of radiant heat, quantitative spectroscopic measurements and pyrometry.	They are used for energy conversion purpose.

4. Explain working of semiconductor strain gauge and what are its specific advantages?

Ans:

A typical semiconductor strain gauge is formed by the semiconductor technology i.e., the semiconducting wafers or filaments of length varying from 2 mm to 10 mm and thickness of 0.05 mm are bonded on suitable insulating substrates (for example Teflon). The gold leads are usually employed for making electrical contacts. The electrodes are formed by vapour deposition. The assembly is placed in a protective box as shown in the figure below.

elements used by the gauge are the materials such as

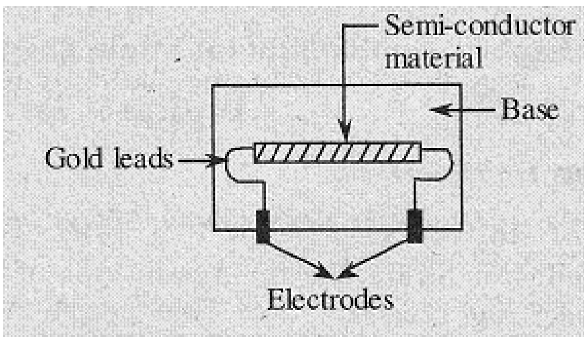

fig 4.1 Semiconductor Strain gauge

The strain sensitive semiconductor strain semiconductor silicon and germanium. When the strain is applied to the semiconductor element a large of change in resistance occur which can be measured with the help of a wheatstone bridge. The strain can be measured with high degree of accuracy due to relatively high change in resistance. A temperature compensated semiconductor strain gauge can be used to measure small strains of the order of 10^{-6} i.e., micro-strain. This type of gauge will have a gauge factor of 130 ± 10% for a semiconductor material of dimension 1 x 0.5 x 0.005 inch having the resistance of 350 Ω.

Advantages of Semiconductor Strain Gauge

1. The gauge factor of semiconductor strain gauge is very high, about ±130.
2. They are useful in measurement of very small strains of the order of 0.01 micro-strains due to their high gauge factor.
3. Semiconductor strain gauge exhibits very low hysteresis i.e., less than 0.05%.
4. The semiconductor strain gauge has much higher output, but it is as stable as a metallic strain gauge.
5. It possesses a high frequency response of 10^{12} Hz.
6. It has a large fatigue life i.e., 10 x 10^6 operations can be performed.
7. They can be manufactured in very small sizes, their lengths ranging from 0.7 to 7.0 mm.

5. What is temperature coefficient of resistor? Explain in detail?

Ans:

The resistance thermometers (RTD) and thermistors employ the principle of change in electrical resistance with change in temperature. If the temperature changes, the resistance also changes due to changes in both length and sensitivity. Therefore materials used for resistance thermometers have temperature coefficient of resistivity much larger than the coefficient of thermal expansion. Thus, the temperature coefficient of resistance 'a' is given by

$$\alpha = \frac{1}{\Delta T} \times \frac{\Delta \rho}{\rho_0} \Rightarrow \frac{1}{\Delta T} \times \frac{\Delta R}{R_0}$$

Where,

ΔT = Change in temperature, °C

$\Delta\rho/\rho_0$ = Fractional change in resistivity

$\Delta R/R_0$ = Fractional change in resistance.

ρ_0 = Resistivity at 0 °C

R_0 = Resistance at 0 °C.

The change in resistance with temperature can be given by the following relationship.

$$R=R_0(1+\alpha_1 T+\alpha_2 T^2+\text{------------------}+\alpha_n T^n+\text{--------})$$

Platinum, nickel, copper and tungsten are the commonly used resistance materials. These metals provide a definite resistance value at each temperature within its range. Curves indicate that the resistance of platinum and copper increases almost linearly with increasing temperature, while the characteristic of nickel is nonlinear. Tungsten has relatively high resistivity, but its use is limited for high temperature applications.

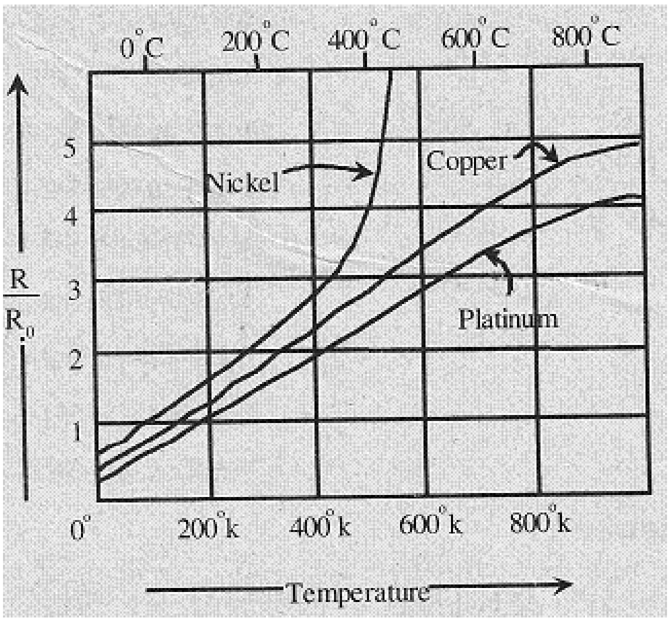

fig 5.1 Characteristics of Materials

Gold and Silver are rarely used owing to their extremely low resistivity. Electrolytic copper which has highly consistent temperature coefficient of resistance i.e., higher than platinum. Due to their low relativity, their application is limited to low range industrial purposes. Phosphor bronze alloys are found suitable for low temperature measurements. Generally Nickel is chosen for resistance temperature measurements which has high temperature coefficient, less expensive than platinum and good reliability. According to their intended application the resistance material is selected.

6. Explain Piezo-electric effect?

Ans:

When some pressure or stress is applied to the surface of the piezo-electric crystal, the dimensions of the crystal change and an electric charge voltage will be developed across certain surfaces of the piezo-electric crystal. Conversely, when an electric charge voltage or potential is applied to the crystal, the crystal get deformed and hence, the dimensions of it will change. This effect is referred as piezo-electric effect.

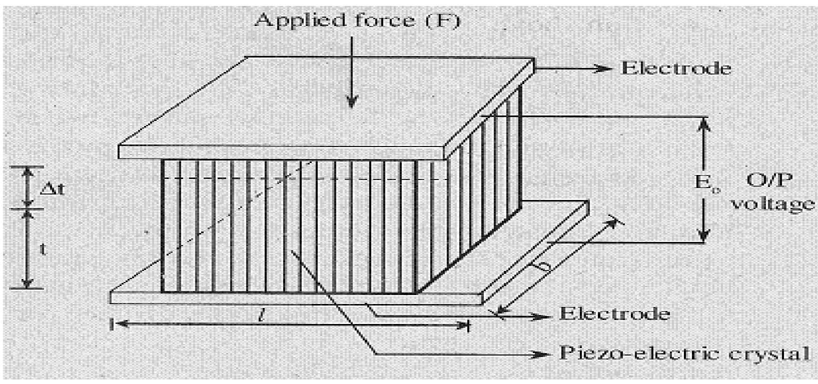

fig 6.1 Piezo-electric Crystal

All the piezo-electric transducers work on the principle of piezo-electric effect. The piezo-electric materials or the materials used in the construction of piezoelectric crystal are quartz, rochelle salt, dipotassium titrate, lithium sulphate, barium titanate, potassium dihydrogen phosphate, ammonium dihydrogen phosphate etc. A piezoelectric crystal subjected to force is illustrated in figure 6.1.

7. Compare RTD with thermistor.

Ans:

RTD	Thermistor
1. RTD is made up of metals.	Thermistor is made up of semiconductor materials
2. Metals have Positive Temperature Coefficient (PTC) of resistance. Hence, the resistance of RTD increases with an increase in temperature and decreases with a decrease in temperature.	Semiconductor materials have Negative Temperature Coefficient (NTC) of resistance. Hence, the resistance of a thermistor decreases with an increase in temperature and increases with a decrease in temperature.
3. The resistance temperature characteristics of RTD's are linear.	The resistance temperature characteristics of thermistor are highly nonlinear.
4. It is less sensitive to temperature compared to thermistor.	It has large temperature coefficient of resistance i.e. It is highly sensitive to temperature.
5. But, it has-a wide operating temperature range i.e., - 200 to + 650°C.	It has low operating temperature range compared to RTD i.e., -100 to + 300°C.
6. RTD's are relatively larger in size.	Thermistors are small in size.
7. They are costlier.	They are available at low costs.
8. They have low self resistance.	They have high self resistance. Thus, they require shielding cables to minimize interference problems.

9. RTD's provide high degree of accuracy and long term stability.	Thermistors also provide an accuracy of ± 0.01°C.
10. They are used in laboratory and industrial applications.	They are widely used for dynamic temperature measurement.

8. Explain briefly about poissons ratio?

Ans:

Poisson's Ratio

Poisson's ratio is defined as the ratio of lateral strain to axial strain.

(or)

It can also be stated as the ratio of unit strain in lateral (transverse) direction to the unit strain in axial direction. It is denoted by the symbol μ.

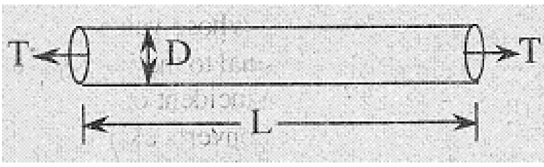

fig 8.1 Steel Bar Subjected to Tensile Load

μ =Lateral Strain/Axial Strain

Derivation of Poisson's Ratio

Consider, a steel bar of length (L), and diameter D, as shown in the below figure.

When this steel bar is not subjected to any load, its dimensions (L and D) remain the same. When a tensile load is applied to the bar, the bar habits a change in its dimensions. The tensile load act-the bar, increases the length of the bar in axial direction. Due to the increase in length, the diameter of *e* bar decreases and thus the cross sectional area of the bar changes i.e., the bar exhibits a change in its dimensions in lateral or transverse direction. Thus due to load, the bar experiences strain in axial direction as well as in lateral direction.

Axial strain, Σ_a =Change in length/original length =ΔL/L

Lateral strain, Σ_l = Change in diameter/original diameter = $-\Delta D/D$

9. Write short notes on resistive transducer?
Ans:

Resistance of an electrical conductor is given by,

$$R=\rho l/A$$

Where ,

R = Resistance in 'Ω'

P = Resistivity of the conductor (Ω - cm)

l = Length of the conductor in cm.

A = Cross-sectional area of the metal conductor in cm^2

It is clear from the equation (1) that, the electrical resistance can be varied by varying,

(i) Length

(ii) Cross-sectional area and

(iii) Resistivity or combination of these.

Principle

A change in resistance of a circuit due to the displacement of an object is the measure of displacement of that object Method of changing the resistance and the resulting devices are summarized in the following table.

Method of changing resistance	Resulting device	Use
1. Length - Resistance can be changed varying the length of the conductor, (linear and rotary).	Resistance potentiometers or sliding contact devices displacements	Used for the measurement of linear and angular.
2. Dimensions - When a metal conductor is subjected to mechanical strain, change in dimensions of the conductor occurs, that changes the	Electrical resistance strain gauges.	Used for the measurement of mechanical strain.

resistance of the conductor. 3. Resistivity - When a metal conductor is subjected to a change in temperature and change in resistivity occurs which changes resistance of the conductor.	Thermistor and RTD.	Used for the temperature measurement.

10. Draw the different forms of metal foil strain gauges and explain their principles of operation?

Ans:

Metal Foil Strain Gauges

In this type of strain gauges a metal foil is used to sense the applied strain. The materials used for its construction are nickel, nichrome, platinum, isoelastic (nickel + chromium + molybdenum), constantan (nickel + copper). The gauge factor and characteristics of foil strain gauges are similar to the wire strain gauges.

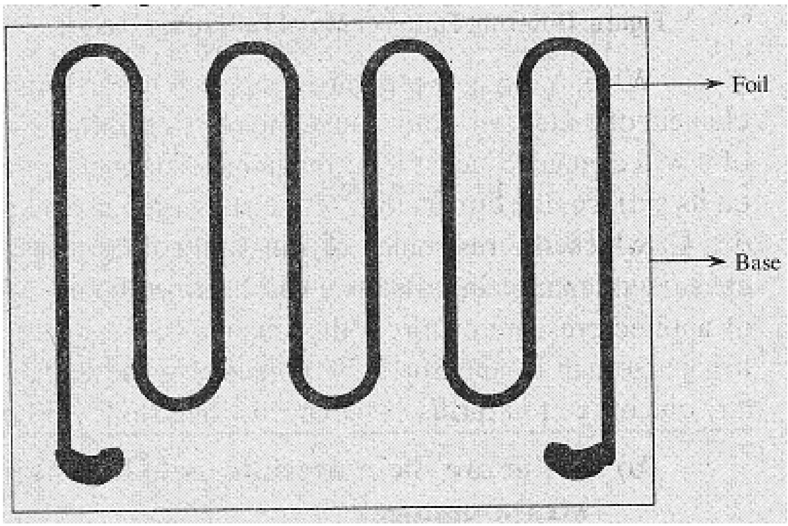

fig 10.1 Foil type Strain Gauge

The metal foil gauges can be easily etched on a flexible insulating carrier film. In the construction of etched foil strain gauge first a layer of strain sensitive material is bonded to a thin sheet of backelite or paper. The part of some masking material and then to this unit an etching solution is applied. Therefore, the unmasked part of the metal will be removed thereby leaving the required grid structure. By this method of construction, the etched foil strain gauges are made in thinner sizes.

Different forms of metal foil strain gauges are shown below.

When a force or pressure is applied to the sensing element of metal foil strain gauge the physical dimensions of it will change. Since, the strain gauge element is pasted on its surface, the dimensions of the strain gauge changes due to which the resistance of the gauge changes. The measure of change in resistance will become the measure of applied pressure or force (this

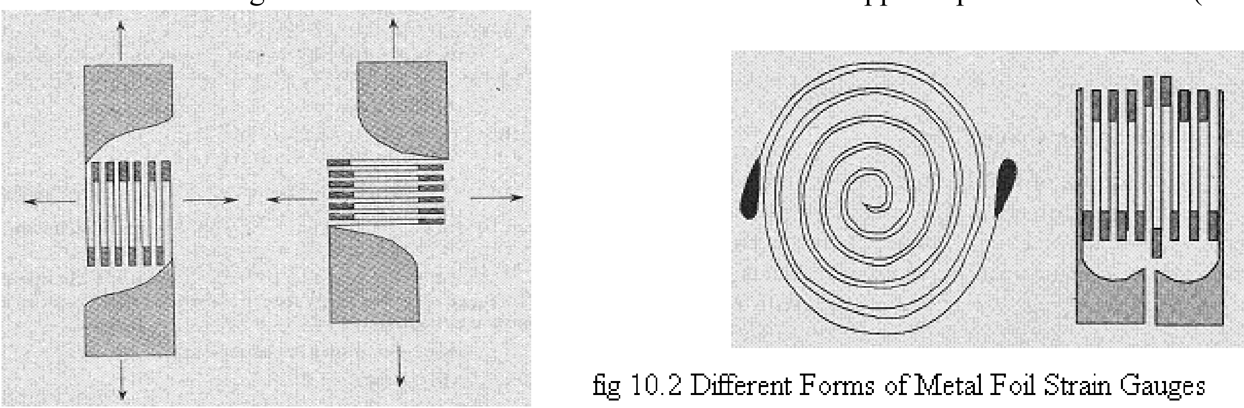

fig 10.2 Different Forms of Metal Foil Strain Gauges

change in resistance of the gauge can be measured by connecting the gauge in any one of the four arms of balanced Wheatstone bridge).