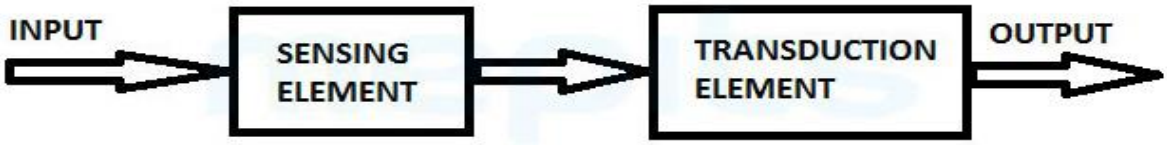
UNIT-3
Transducers and Ultrasonics

1. **Define the term transducer.**

A transducer is a device which converts energy from one form to another form



The input quantity in most of the instrumentation systems is non-electrical. These input quantities areultimately converted into an electrical signal because an electrical signal can easily be amplified. The non-electrical quantities are converted in to electrical signals by devices called Transducers. Thus any device which converts non-electrical quantities (mechanical, chemical, optical,thermal, etc.) into an electrical signal is called a transducer.

Any transducer basically consists of two elements, namely

Sensing Element: It is the part of the transducer which senses or responds to a physical quantity or a change in a physical quantity.

Transduction Element: It is that part of the transducer which transforms the response of the sensingelement into an electrical signal.

2. **Classify different electrical/electronic transducers on the basis of principle of operation and applications.**

(a) Based on their operating principle:

1. Resistive type
2. Capacitive type
3. Inductive type
4. Piezo electric type
5. Thermo couple type

(b) Based on their applications:

1. Temperature transducer
2. Pressure transducer
3. Displacement transducer
4. Liquid level transducer
5. Flow transducer
6. Force transducer
7. Acceleration transducer

3. **List different Resistive, Inductive and Capacitive transducers**

(i) Resistive transducers:

(a) Resistance strain gauge
(b) Resistance thermometer
(c) Resistance hygrometer
(d) hotwire re meter
(e) Thermistor

(ii) Inductive transducers:

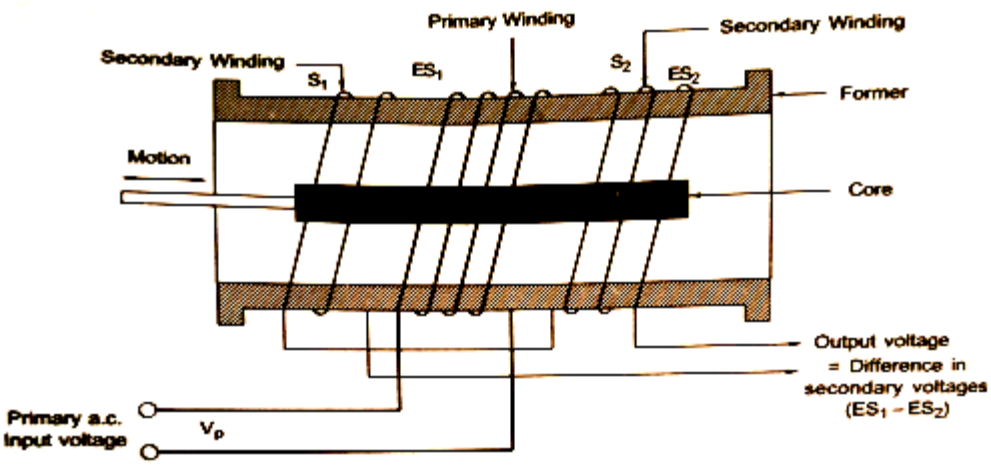
(a) Differentialtransformer
(b) Magnetic circuitbreaker
(c) Eddy currentgauge

(iii) Capacitive transducers:

(a) Dielectric gauge.
(b) Variable capacitance pressure gauge.
(c) Capacitor microphone.

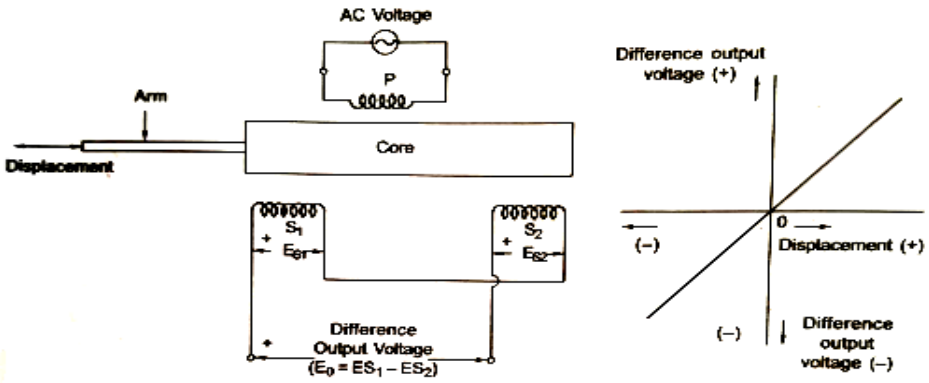
4. **Explain the construction and working principle of LVDT.**

Linear Variable Differential Transformer (LVDT): The Linear Variable Differential Transformer (LVDT) is an induction type displacement transducer. It measures force in terms of the displacement of the ferromagnetic core of a transformer.



Construction:

- The basic construction of a LVDT is shown in Fig. It consists of one primary windingP and two secondary windings S1 and S2.
- The two secondary windings S1 and S2 have equal number of turns and are placed on either side ofthe primary winding as shown in the figure. The secondary windings are connected in series opposition so that the emfs induced in the coils oppose each other.
- A movable soft iron core is placed along the axis of the cylindrical former.



Operation: An a.c. voltage of frequency 50 Hz or 400 Hz is applied to the primary as shown in Fig.This results in voltages E_{s1} and E_{s2} across the two secondary windings S_1 and S_2 respectively. The two voltages E_{s1} and E_{s2} are combined in series to yield the

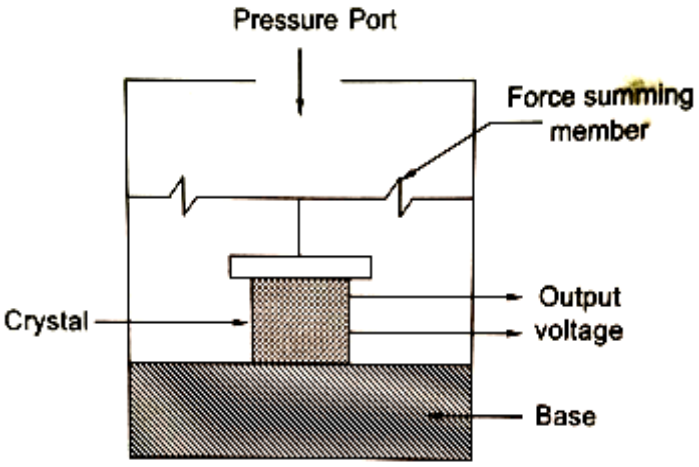
difference output voltage (E_{s1}- E_{s2}) as shown in Fig.

- With the core in the center, or reference position, the induced emfs in the secondaries are equal, andsince they oppose each other, the output voltage will be '0' volts.
- When an externally applied force moves the core to the left hand position, more magnetic flux linksthe left-hand coil than the right-hand coil.
- The induced e.m.f of the left-hand coil is therefore larger than the induced e.m.f of the right-hand coil.
- The magnitude of the output voltage is then equal to the difference between the two secondaryvoltages, and it is in phase with the voltage of the left-hand coil.
- Similarly, when the core is forced to move the right, more flux links the right-hand coil than the left-hand coil and the resulting output voltage is now in phase with the e.m.f of the right-hand coil, while its magnitude again equals the difference between the two induced emfs. Fig. shows the LVDT, output voltage as a function of the core position.

5. State the concept of piezo-electric effect

Certain Asymmetrical crystalline materials such as Quartz, Rochelle salt, Lithium sulphate, etc. produce an emf when they are placed under stress.If an electric stress is applied in the direction of an x-axis, a mechanical strain is produced in the direction of the y-axis which is perpendicular to the relevant x-axis. This potential (e.m.f) is produced by the displacement of charges. The effect is reversible i.e. if a varying potential is applied to the proper axis of the crystal it will change the dimensions of the crystal there by deforming it. This effect is known as "Piezoelectric effect".

6. Explain the construction and working of Piezo-electric transducer



Piezoelectric transducer is an active transducer which utilizes the piezoelectric effect. These transducers are used in measurement of force, pressure and acceleration.

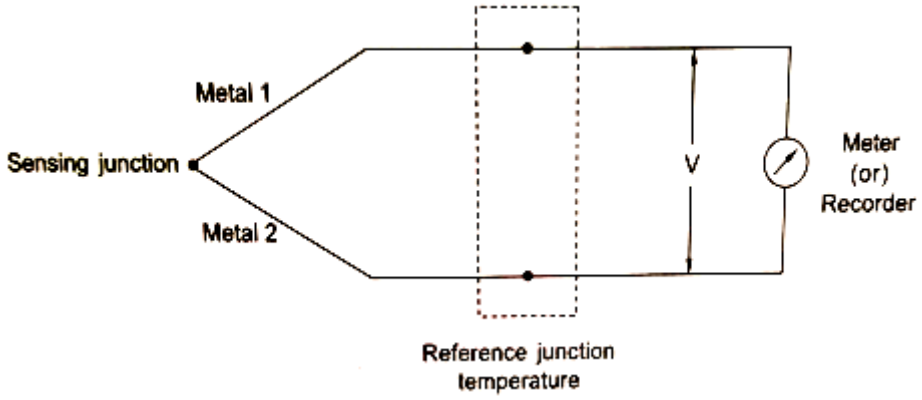
Fig. shows a piezoelectric transducer. A crystal is placed between a solid base and the force summing member. The mechanical elements that are used to convert the applied force into a displacement are called force summing devices. An externally applied force, entering the transducer through its pressure port, applies pressure to the top of the crystal.

This produces an emf across the crystal which is directly proportional to the magnitude of the applied pressure. However, if applied pressure is decreased, even then potential difference is developed with opposite polarity.

7. Explain the construction and working of Thermocouple transducer.

Thermocouple comes under the category of active transducer. It works on the principle of seebeck effect or thermoelectric effect.

Seebeck effect: When two dissimilar metals were in contact, a voltage was generated where the voltage was a function of (i) temperature difference (ii) the type of wire material used.



Construction and working: A thermocouple consists of a pair of dissimilar metal wires joined together at one end, called the sensing junction (hot junction) and terminated at the other end called the reference junction (cold junction). The most common pairs of thermocouple materials are Iron-constantan, copper- constantan, Nickel-chromium, nickel-aluminium, etc. The thermo couple junctions are made by
welding or soldering without any flux. The thermo junctions are usually enclosed in protective sheaths to protect against contamination. Fig. shows the basic thermo couple unit.

The reference junction of the thermocouple is maintained at a known constant temperature called the reference temperature. But the sensing junction is left free as it should sense the temperature to be measured. When the sensing junction and the reference junction are at different temperatures, a potential difference gets produced which causes a current in the circuit. The meter current is proportional to the temperature difference between the sensing junction and the reference junction. Thermocouples are used to measure a wide range of temperature from -270°C to +2700°C.

The e.m.f produced in a thermocouple circuit is given by,

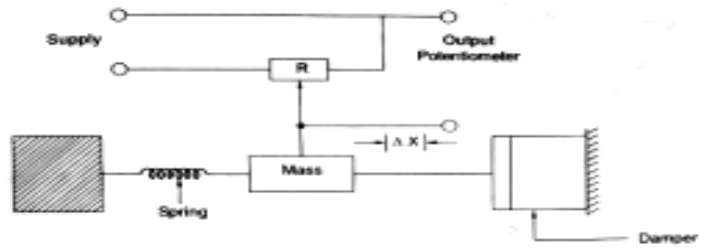
$$V = a\,(\Delta\theta) + b\,(\Delta\theta)^2$$

Where $\Delta\theta$ = difference in temperature between the sensing junction and reference junction of the thermocouple; °C.

a, b = constants of the thermocouple material.

8. Explain the working principle of Accelerometer.

Accelerometer: Accelerometers, which are generally used for measurement of acceleration. It consistsof a suspended spring mass damper system such that the mass is free to move in one direction only. Movement of the mass may be sensed by some form of position transducer such as potentiometer as shown in Fig.



From the above Fig. the mass supported by a spring and a damper is connected to the housing frame. The frame is rigidly attached to the machine or system whose acceleration characteristics are to be determined. When an acceleration is imparted by the system to the housing frame, the mass would move relative to the frame, and this relative displacement is sensed by an electrical transducer. The transducer used may be of the potentiometric type, variable inductance type, variable capacitance type, bonded straingauge type etc.

9. Define the term Ultrasonics

Ultrasonics is the term used in acoustics to denote frequencies which are beyond the range of human hearing. Thus ultrasonic waves are sound waves of frequencies above about 20,000 c/s.

By using modern methods of generation, it has become possible to produce ultrasonic vibrations up to frequencies of about 5×10^5 C/S. Ultrasonic vibrations are produced by exciting a transducer by either mechanical or electrical energy.

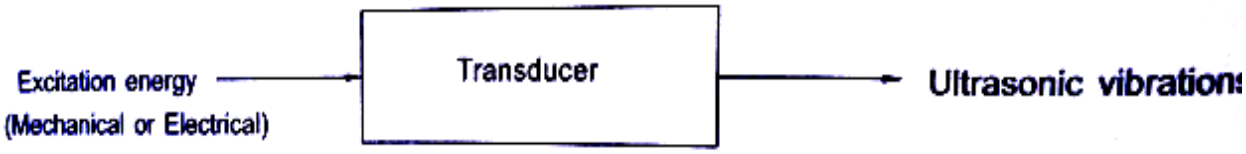
Depending on the type of transducer used, the excitation can be of two types.

(i) Mechanical

(ii) Electrical

(a) Magnetostriction generator and the

(b) Piezoelectric generator.



The first type is called mechanical generation of ultrasonics while the second type is known as the electrical generation of ultrasonics. Electrical methods of ultrasonic generation are universally preferred

over the mechanical methods because of their convenience, compactness, and ease of handling.

In the electrical methods of ultrasonic generation, generally an oscillator circuit is used to drive the transducer for producing the ultrasonics.

10. List the applications of ultrasonics

Applications of ultrasonic waves:

1. Communication.
2. Testing of materials.
3. Separation of mixtures.

4. Cutting and machining of hard materials.
5. Physical, chemical and biological effects are used.
6. Medical electronics for scanning.
7. Soldering and welding.

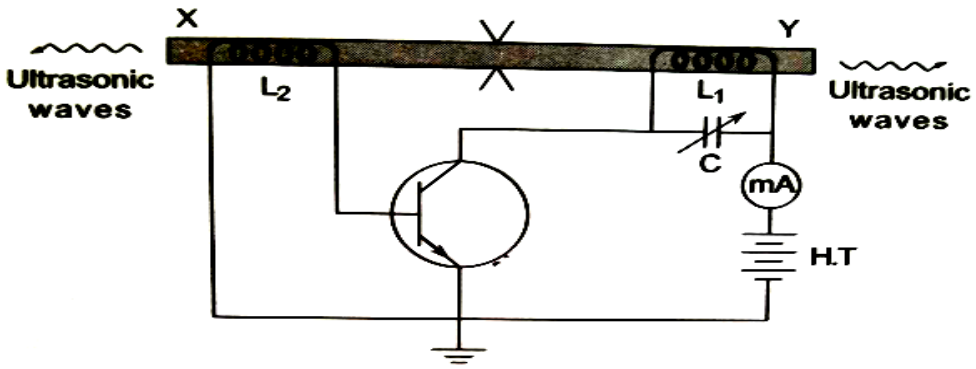
11. **What is Magnetostriction effect.**

Whenever a Ferro Magnetic material, (Iron (or) Nickel)is placed across an alternating source causes the magnetic material to get change in its dimensionseither length wise (or) breadth wise. This effect is called Magnetostriction effect.

The change in dimensions mainly depends upon the following factors,

1. Strength of alternating source
2. Type of magnetic material

12. **Explain the construction and working of Magnetostriction ultrasonic generator.**



Construction of Magnetostriction Oscillator

It has XY is arod of ferromagnetic materials like iron or nickel and is clamped in the middle as shown inFig.

1. The alternating magnetic field is generated by electronic oscillator.
2. The coil L_1 wound on the right hand portion of the rod along with a variable capacitor C.
3. This forms the resonant circuit of the collector tuned oscillator. The frequency of oscillator iscontrolled by the variable capacitor.
4. The coil L_2 wound on the left hand portion of the rod is connected to the base circuit. The coil L_2acts as feed-back loop.

Working:

When High Tension (H.T) battery is switched on, the collector circuit oscillates with a frequency,

$$f = 1/2\pi\sqrt{L_1C}$$

This alternating current flowing through the coil L_1 produces an alternating magnetic field along the length of the rod. The result is that the rod starts vibrating due to magnetostrictive effect.

The capacitor C is adjusted so that the frequency of the oscillatory circuits equal to natural

Frequency of the rod and thus resonance takes place. Now the rod vibrates longitudinally with maximum amplitude and generates ultrasonic waves of

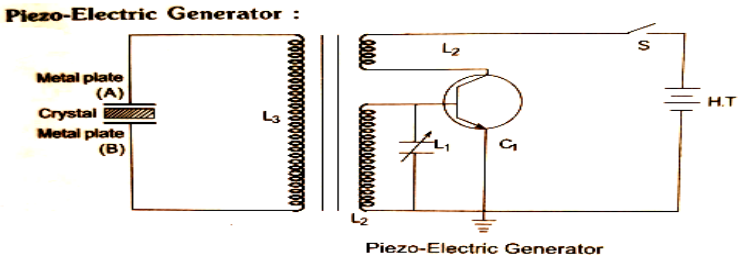
high frequency from its ends.

13. **Explain the construction and working of piezoelectric ultrasonic generator.**

Piezo-Electric Effect : If mechanical pressure is applied to one pair of opposite faces of certain crystals like quartz causes an equal and opposite electrical charges appears across its other faces. This effect is called as Piezo-Electric effect.

The below fig**.** shows the construction diagram two metals of Piezo-electric plates A and generator B. It consists a quartz crystal which is placed between,

1. The plates are connected to the primary (L_3) of a transformer which is inductively coupled to the electronics oscillator.
2. The electronic oscillator circuit is a base tuned oscillator cirucit.
3. The coils L_1 and L_2 of oscillator circuit are taken from the secondary of a transformer.
4. The collector coilL_2 is inductively coupled to base coil L_1.
5. The coil L_1 and variable capacitor C_1 form the tank circuit of the oscillator.
6. When H.T. battery is switched on, the oscillator produces high frequency alternating voltages with a frequency .
7. Due to the transformer action, an oscillatory e.m.f. is induced in the coil L_3.



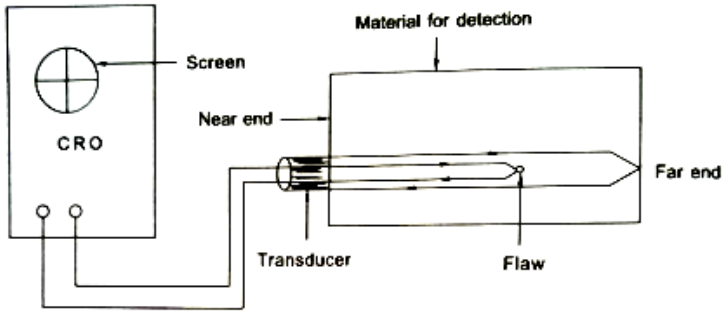
Piezo-Electric Generator

14. **Explain the construction and working of pulsed-echo ultrasonic flaw detector.**

Flaw Detection:

In various Engineering applications, strength of the component plays an important role. The strength of a material gets greatly reduced if there are defects in the material. These defects may be as large as cracks or as tiny as cavities produced during the process of Casting, Slag inclusions, Porosity or Stratifications. The ultrasonic testing is Cheap, Convenient and sufficiently reliable. Hence the ultrasonic testingmethod is widely used in many Engineering applications.

Pulsed-Echo Ultrasonic Flaw Detector



Pulsed-Echo Ultrasonic Flaw Detector

1.This is the equipment most widely used and is basically a pulsed flaw detector operating of the principle of reflected signal indication.
2.The ultrasonic pulse uses high frequencies of 0.8 to 2.5 M Hz for inspection of steel, alluminium and brass articles but uses lower frequencies for inspection of cast iron, plastic goods, porcelain, concrete, timber etc.
3. Small a single probe or transducer is used. This transducer first acts as a transmitter.
4.Generally, sending out a pulse of high frequency ultrasonic waves into the article to the inspected and then acts as a receiver to receive the ultrasonic echo pulses reflected from the flaw and from the far end of the material.
5.The received ultrasonic echo pulses are transformed by the transducer into corresponding electric echo pulses of the same frequency as the sound waves.
6.These are then amplified and displayed in the form of a series of pips and pulses on the screen of a CR tube.
7.The first pulse corresponds to the transmitted pulse. This is followed by pulse corresponding to the flaws and lastly comes the pulse from the far end of the materials.
8. Thus the process of the inspection is very simple. The equipment can be used for detection of flaws as deep as 10 metres from the front surface.

15. **Explain the operation of resistance strain gauge.**

Resistance Strain Gauge: Strain gauge is a passive transducer which converts a mechanical displacement into change of resistance of the strain wire.

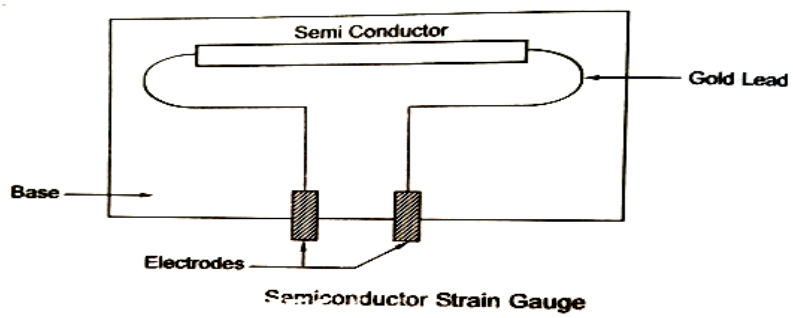
Types of Strain Gauges

1. Semiconductor gauges.
2. Wire Gauges

a. Unbounded b .Bonded c Foil type

Working principle: A strain gauge works on the principle of piezoresistive effect. The piezo-resistive effect is the change in the value of the resistance due to a change in the resistivity of the material due to a change in length of material. Strain gauges use this phenomenon to measure strain by the change in resistance of a metal.

Gauge factor: Gauge factor is defined as the ratio of per unit change in resistance to per unit change in length. It is a measure of the sensitivity of the gauge.



Semiconductor Strain Gauge

Applications of Strain Gauges:

1. For the measurement of strain and stress in experimental stress analysis.
2. Investigate strain in many structural materials over a wide range of environmental condition

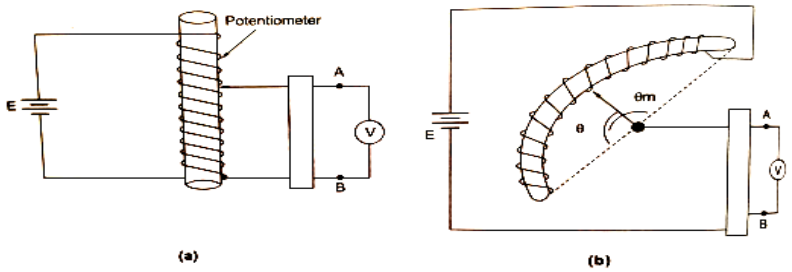
3. For the measurement of temperature.
4. For the measurement of pressure.
5. For the measurement of acceleration.
6. In medical field of investigation.

16. **Explain the operation of Potentiometric transducer.**

Potentiometric (or) Resistive Transducer:

1. A potentiometric (or) resistive transducer is aelectromechanical device which converts a linear (or) rotational displacement in to an e.m.f.

2.It consists of a resistance element provided with sliding facility. This sliding contact is known as "wiper" its motion being either translatory (or) rotational according to the design and are as shown in Fig.



Potentiometric (or) Resistive Transducers

3. From the above fig. the translational resistive potentiometers are straight devices where as rotational resistivepotentiometers are circular in shape and are used for measuring angular displacement.

4.The resistance element of a potentiometer is excited either with d.c. or with a.c. voltage.

5.Motion of the slider or wiper results in a resistance change that may be linear, non linear.

6.where the motion of an object changes the effective resistance and the output voltage V between terminals A and B.

7. The output voltage, V appearing across terminals A and B is directly proportional to the displacement of the moving object.

Applications of Potentiometric (or) Resistive Transducer:

i) These transducers are mainly used to calculate the temperature in several applications.

ii) Measuring displacement various applications