Transducers

Unit-5

Transducers

- **Intoduction:**
- Transducers are devices that are used to convert one form of energy into another form.
- They convert physical quantities such as pressure, force, temperature into quantities suitable for measuring.
- The transducer, which converts non-electrical form of energy into electrical form of energy, is known as electrical transducer.
- The output of electrical transducer is equivalent to the input, which has non-electrical energy.

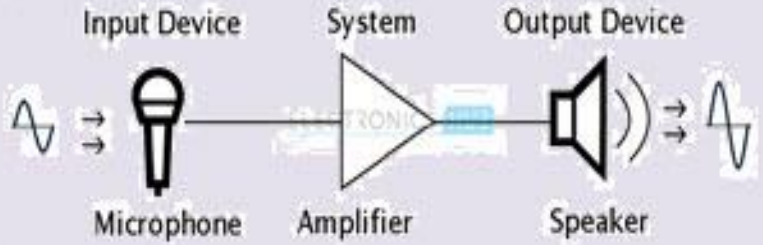
- Transducer is a device which responds to the physical conditions or chemical state of a substance and converts to an output signal.
- If the output is a mechanical signal then it is called as Mechanical Transducer
- If the output signal is electrical in nature then it is termed as Electrical transducer.
- The Electrical transducers are the devices that convert energy in the form of sound, light, heat, etc., into an equivalent electrical signal, or vice versa.

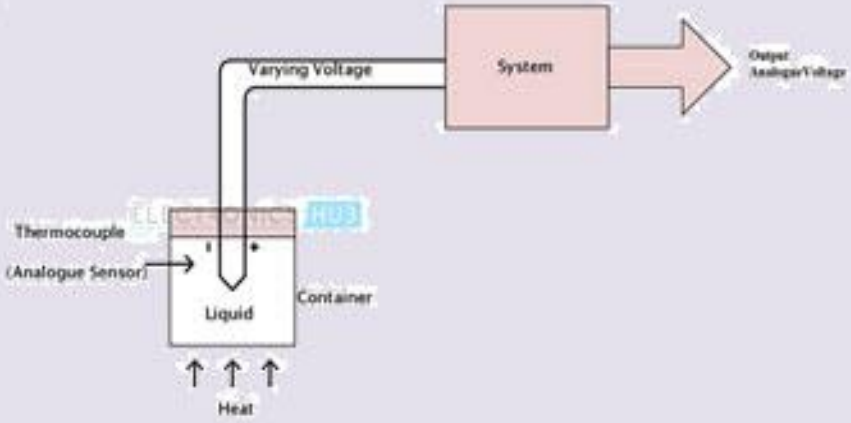
- The output electrical signal may be voltage, current, or frequency. Production of these electrical signals is based upon resistive, inductive, capacitive effects.

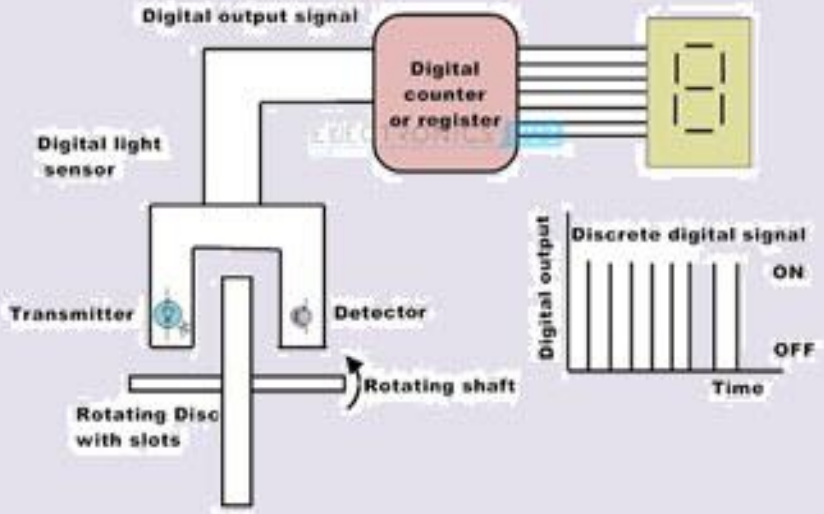
- Transducer is a device that can convert energy from one form to another.

- sensor is a device that can detect a physical quantity and convert the data into an electrical signal.

What are Sensors and Transducers?







- Based on the role of transducers, it can be classified into input and output type.

- An input transducer is used to measure and hence is known as instrument transducer.

- The power transducers are nothing but output transducers which provide output signals like force, torque etc when electrical signal is given as input.

- Based on operation it is classified as active and passive transducers.

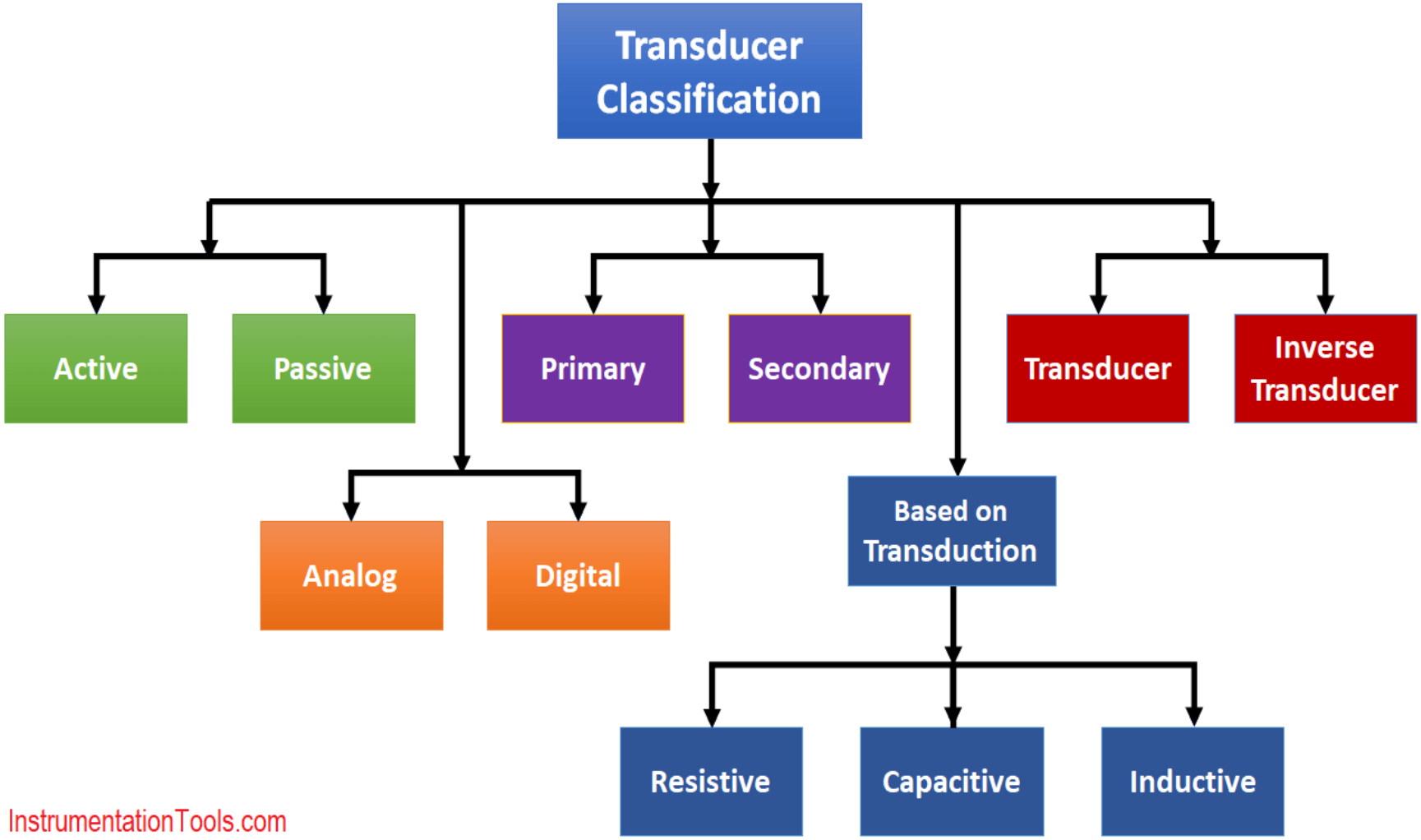
- When the physical quantity is measured active transducers produce voltage and current as output signals.

- But in case of passive transducer external energy is required to create electrical signals.

Need for transducers

1. Physical parameters like temperature need to measured and controlled in the industry.
2. To measure heart rate, blood pressure, to obtain EEG and ECG waveforms in the medical field.
3. Converting variations in sound into variations in voltage or current in communication system.
4. To measure and indicate the speed, to indicate the fuel level and so on in automobile industry.

Classification



Passive Transducers:

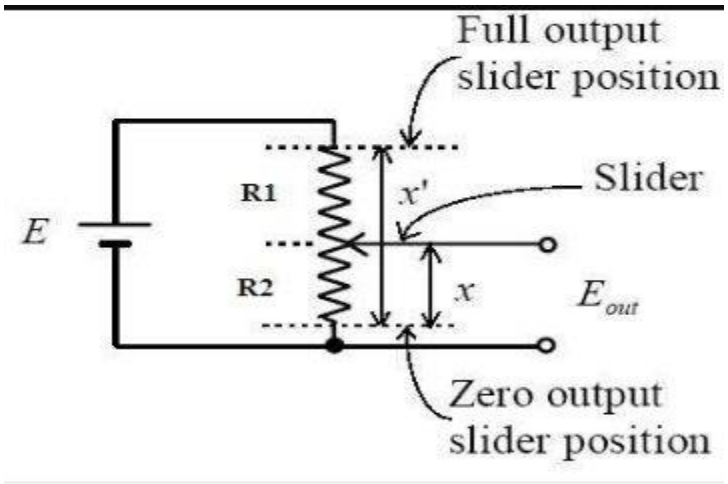
- It is also called as externally powered transducers. They derive the power required for energy conversion from an external power source.
- The passive transducers are further classified into Resistive type, Inductive type and capacitive type.
- I) Resistance: Thermistor, Photoconductive cell, Resistance strain gauge
- II) Inductance: LVDT- Linear Variable Differential Transformer
- III) Capacitance: Photoemissive cell, Hall effect based devices.

I) Resistive transducer:

- A passive transducer is said to be a resistive transducer, when it produces the variation in resistance value.
- R=ρ*l/A

Where,

- ρ is the resistivity of conductor.
- l is the length of conductor.
- A is the cross sectional area of the conductor.
- The resistance value depends on the three parameters ρ, l & A.

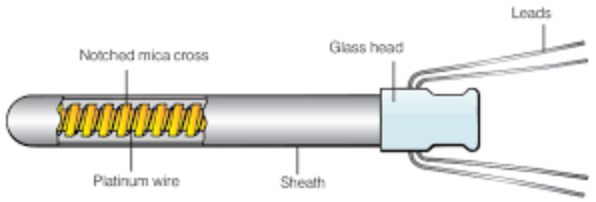


- When the resistive element is subjected to pressure, force or torque, changes in the dimensions occur.
- Which will in turn change the conductive properties of the material.
- They can be used to measure displacement, force and pressure.

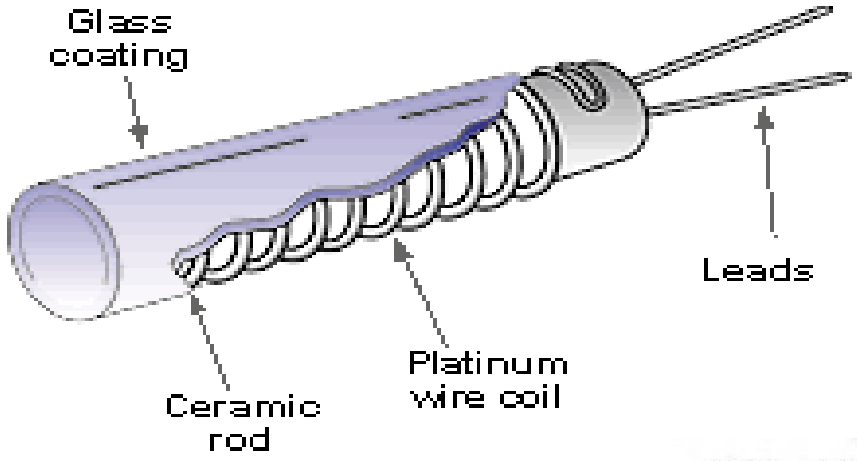
1) Resistance thermometer

- The change in temperature is measured in terms of the change in resistance.
- The resistive element is usually made from metal, metal alloy or semiconductor.
- The only difference is that the resistivity decreases in semiconductor and insulator materials where as in metals it increases as the temperature increases.
- In metals there is change in resistance due to change in length also.

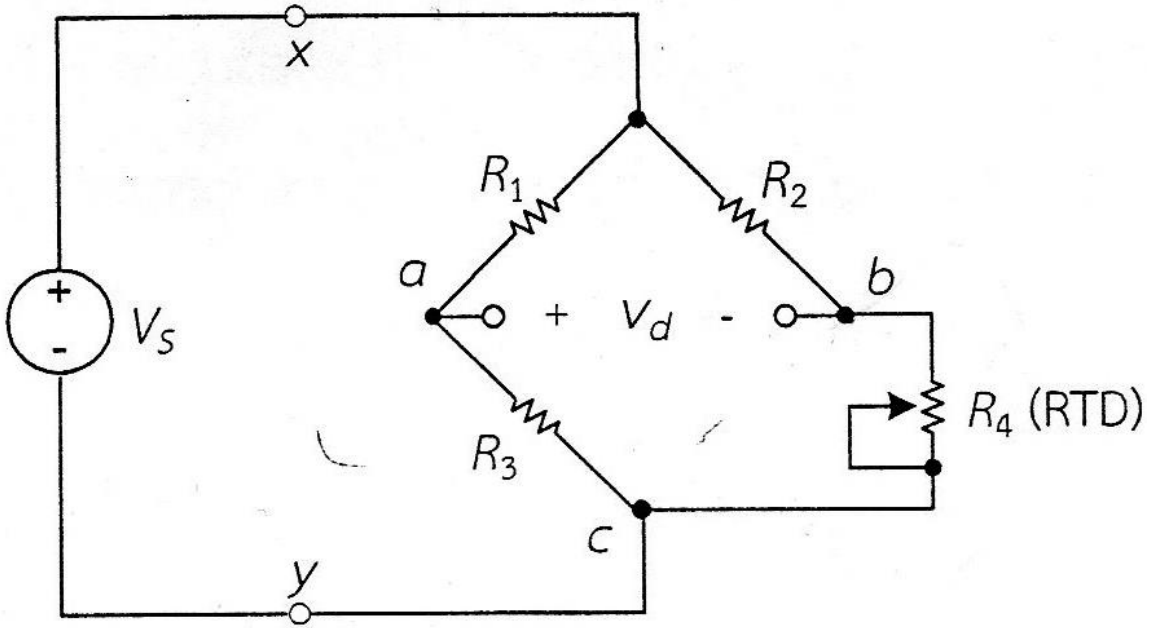
- $R_T = R_o (1 + \alpha t)$
- R_o = resistance at 0 degree C.
- T= temperature in degree C.
- α = temperature co-efficient in degree C.
- $\alpha = \Delta R / (\Delta T * R_o)$
- Where ΔT = change in temperature.
- ΔR = change in resistance.



Wire resistance thermometer construction



RTD with wheat stone bridge



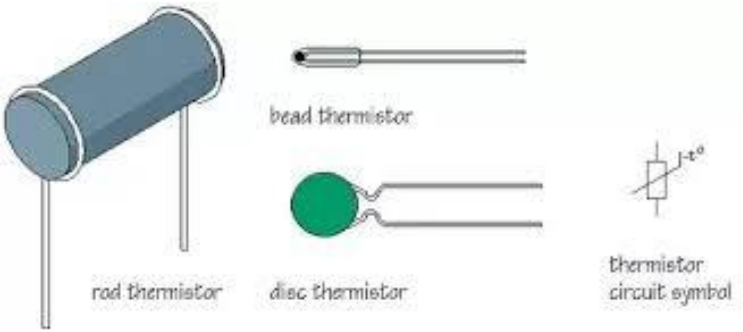
- Wire resistance thermometer consists of fine wire wrapped around a ceramic, mica or glass bar.
- Since the element is very fragile and hence it is enclosed in protective glass, porcelain, quartz or nickel.
- Thermometer is built using platinum, copper etc
- Temperature measurement is carried on by placing resistance thermometer as one of the arm in wheat stone bridge.
- Whenever resistance of RTD changes due to change in temperature the bridge is imbalanced generating difference voltage V_d.

- **Advantages:**
- Accurate temperature sensor
- Provides excellent stability and precision
- High linear temperature-resistance characteristics
- Faster response

- **Disadvantage:**
- Bigger in size
- Higher cost
- Possibility of self heating

2) Thermistor

- Thermistor is a temperature sensing device made from semiconductor material that acts like an electrical resistor but is temperature sensitive.
- Thermistors can be used to produce an analogue output voltage with changes in temperature and hence is referred to as transducer.



- It is a two terminal device whose resistance decreases with increase in temperature i.e. negative temperature coefficient.

- $R = R_o e^{-\alpha t}$
- R_o =maximum resistance corresponding to minimum temperature
- α =a constant dependent on the thermistor type
- It is made up of oxides of metals such as manganese, nickel etc.

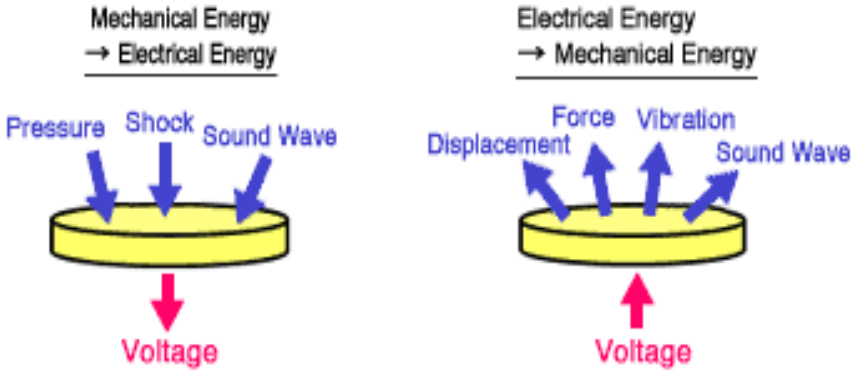
- **Advantages:**
- Small size
- Fast response
- Good sensitivity
- **Disadvantages:**
- The temp-resistance characteristics is non-linear
- Not suitable for wide range of temperature measurement.
- **Applications:** measurement of temperature, flow and pressure, liquid level, voltage and power.

Active Transducers:

- **Active Transducers:**
- It is also known as self-generating type transducers.
- They develop their own voltage or current as the output signal.
- The energy required for production of this output signal is obtained from the physical phenomenon being measured.
- Examples: Thermocouple, Piezoelectric transducers, Photovoltaic cell, Moving coil generator, Photoelectric cell.

I) Piezoelectric transducers

- The ability of materials to produce charges when subjected to mechanical stress is called piezoelectric effect.
- The EMF develops because of this displacement of the charges.
- The effect is changeable, i.e. if the varying potential applies to a piezoelectric transducer, it will change the dimension of the material or deform it. This effect is known as the piezoelectric effect.



- The piezo-electric effect is direction sensitive (Fig.)

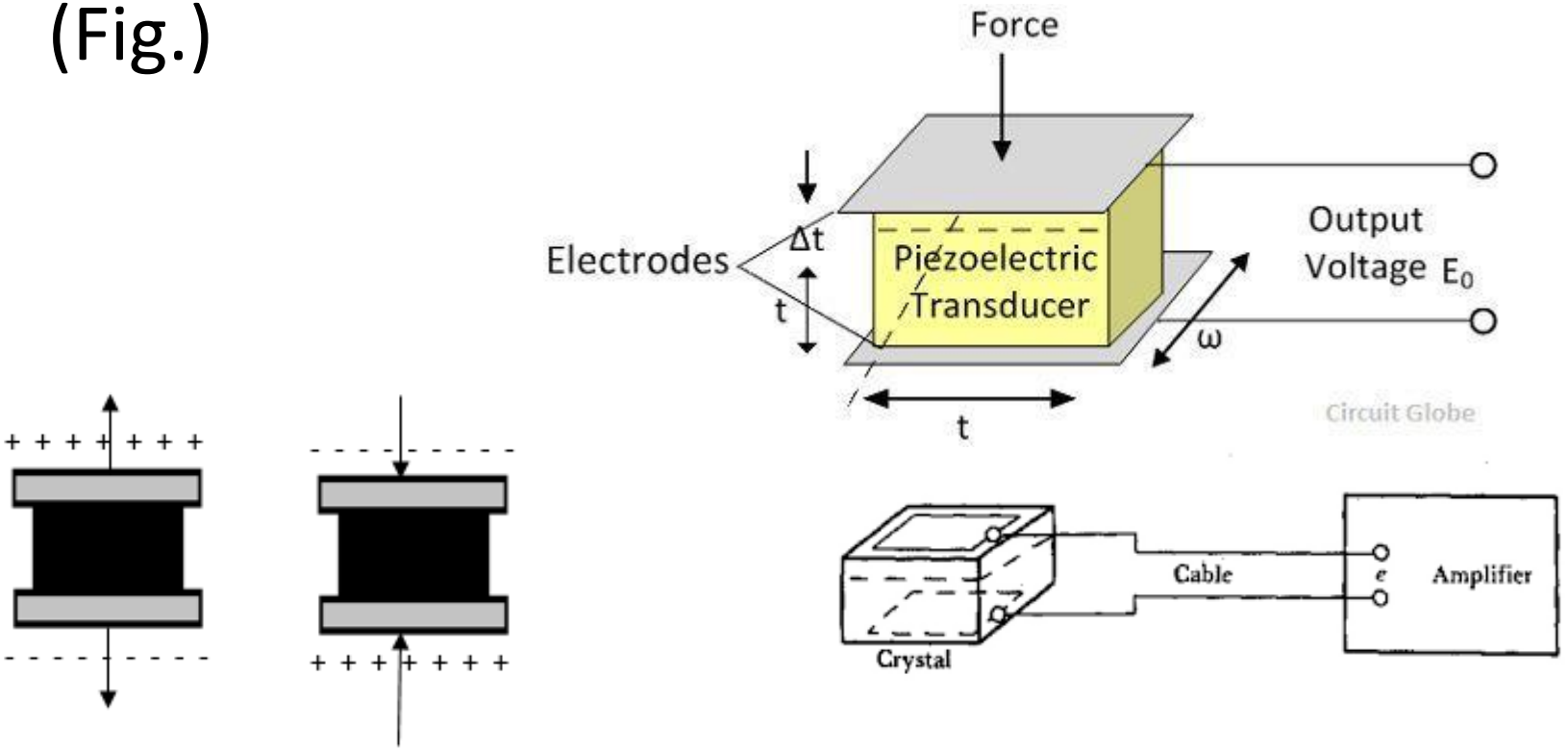


Fig (a): direction sensitivity of Piezo-electric material (b): Piezoelectric Transducer

$E_o = Q/C$

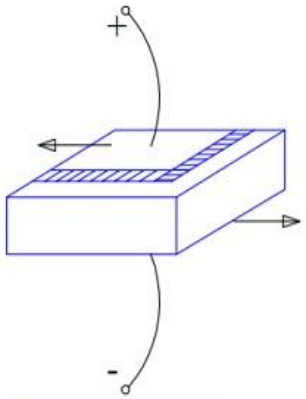
V= O/p Voltage

Q=Charge of an element

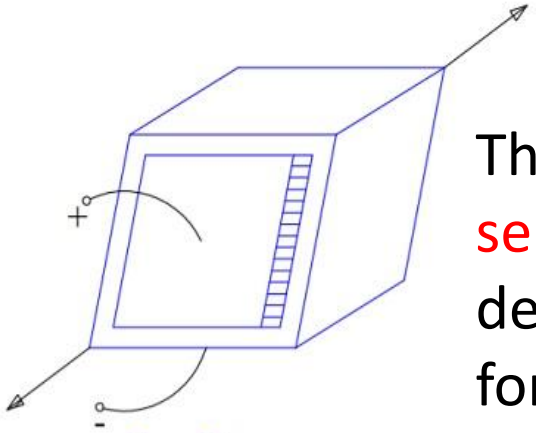
C= Capacitance of an element

- The Quartz is the examples of the natural piezoelectric crystals,
- The Rochelle salts, ammonium dehydration, phosphate, lithium sulphate, dipotassium tartrate are the examples of the man-made crystals.
- These materials operate in four different modes: (i) thickness expander mode (ii) length expander mode (iii) thickness shear mode (iv) face shear mode
- When the mechanical deformation occurs in the crystals, it generates charges. And this charge develops the voltages across the electrodes.

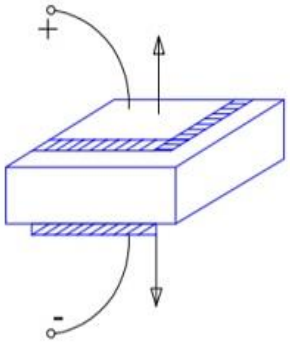
Four different modes



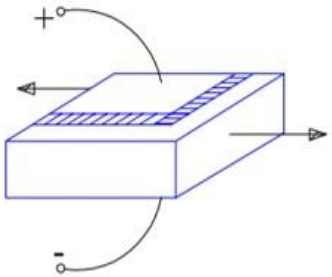
Thickness Shear



Face Shear



Thickness Expansion



Transverse Expansion

The Piezoelectric crystal is direction sensitive. The polarity of the voltage depends on the direction of the force which is either tensile or compressive.

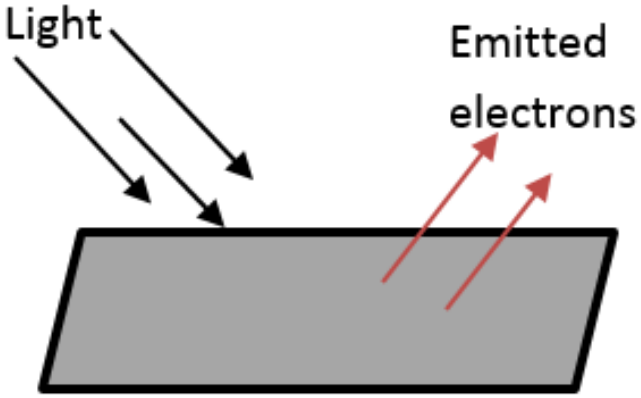
The magnitude and the polarity of the charges depend on the magnitude and the direction of the applied force.

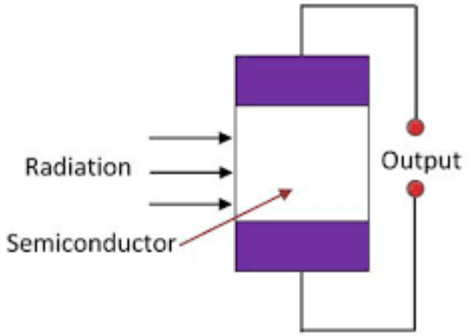
The whole setup of parallel plates and piezoelectric material between them forms a capacitor structure.

- **Advantages:**
- 1) High frequency response 2) High transient response
- 3) High output 4) The piezoelectric transducers are small in size and have rugged construction
- **Disadvantages:**
- 1) High impedance: The piezoelectric crystals offer high impedance hence they have to be connected to the amplifier and the auxiliary circuit.
- These external circuits have the potential to cause errors in measurement.
- To reduce these errors amplifiers high input impedance and long
- cables should be used.
- 2) Forming into shape: It is very difficult to give the desired shape to the crystals with sufficient strength.
- **Applications:**
- Used to measure force, pressure, acceleration, torque, strain etc

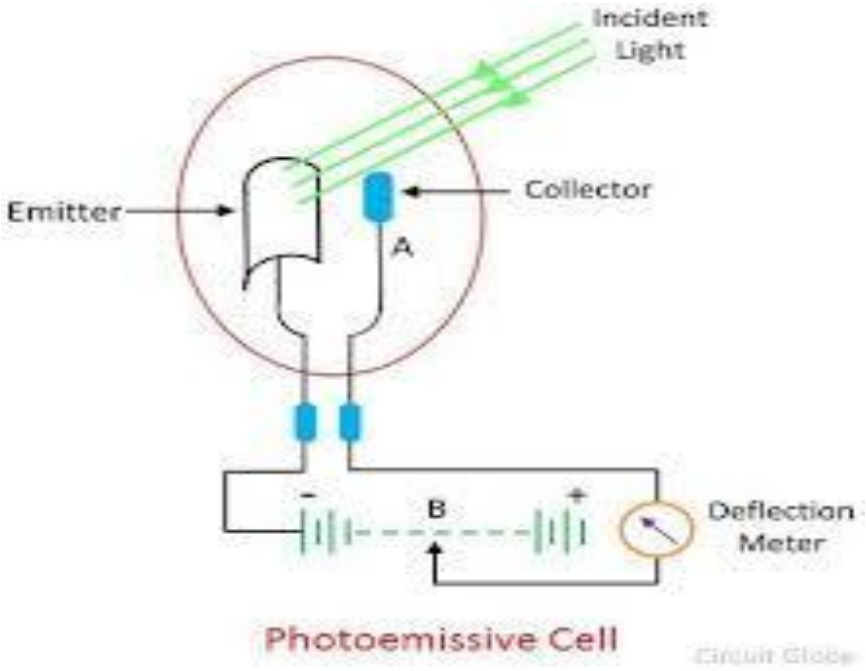
II) Photoelectric transducer

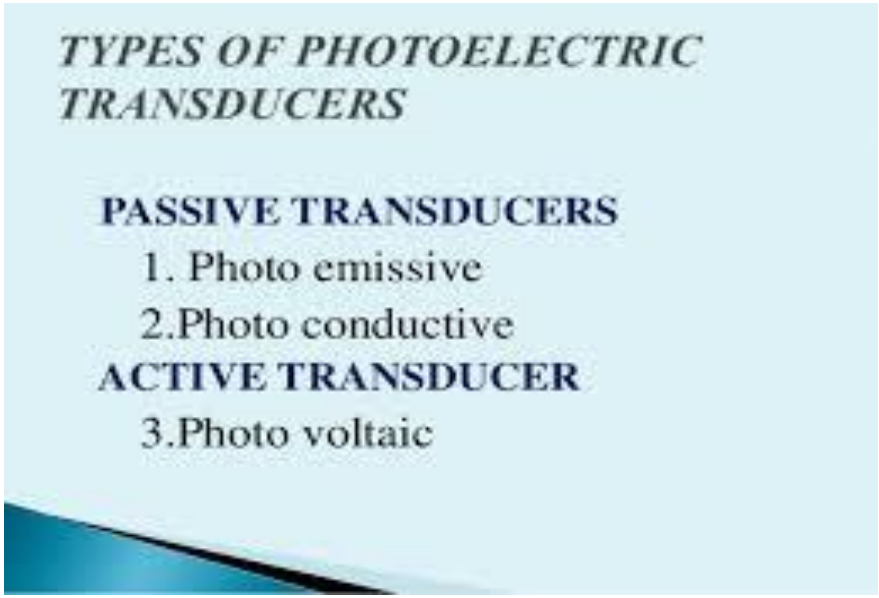
- Low-work function materials like cesium emit electrons when light falls on it. This property of materials is called as photo electricity.
- When the light falls on such materials photons interact with the electrons on the surface of such materials.
- Converts quantum energy into kinetic energy.
- Acceleration of electrons in the flow of current.



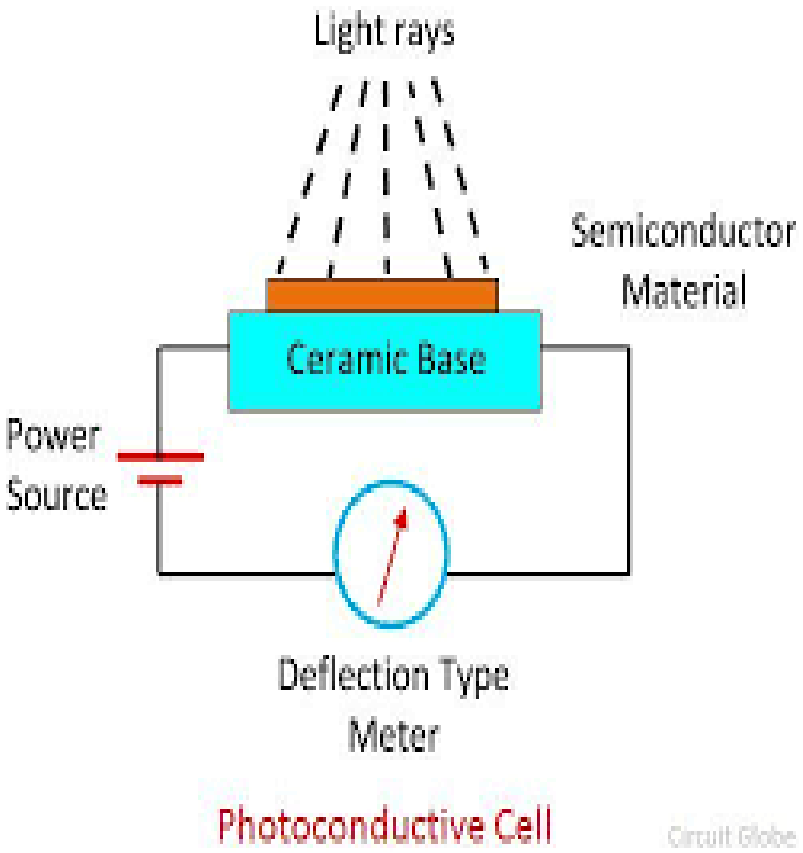


Photoelectric Transducer



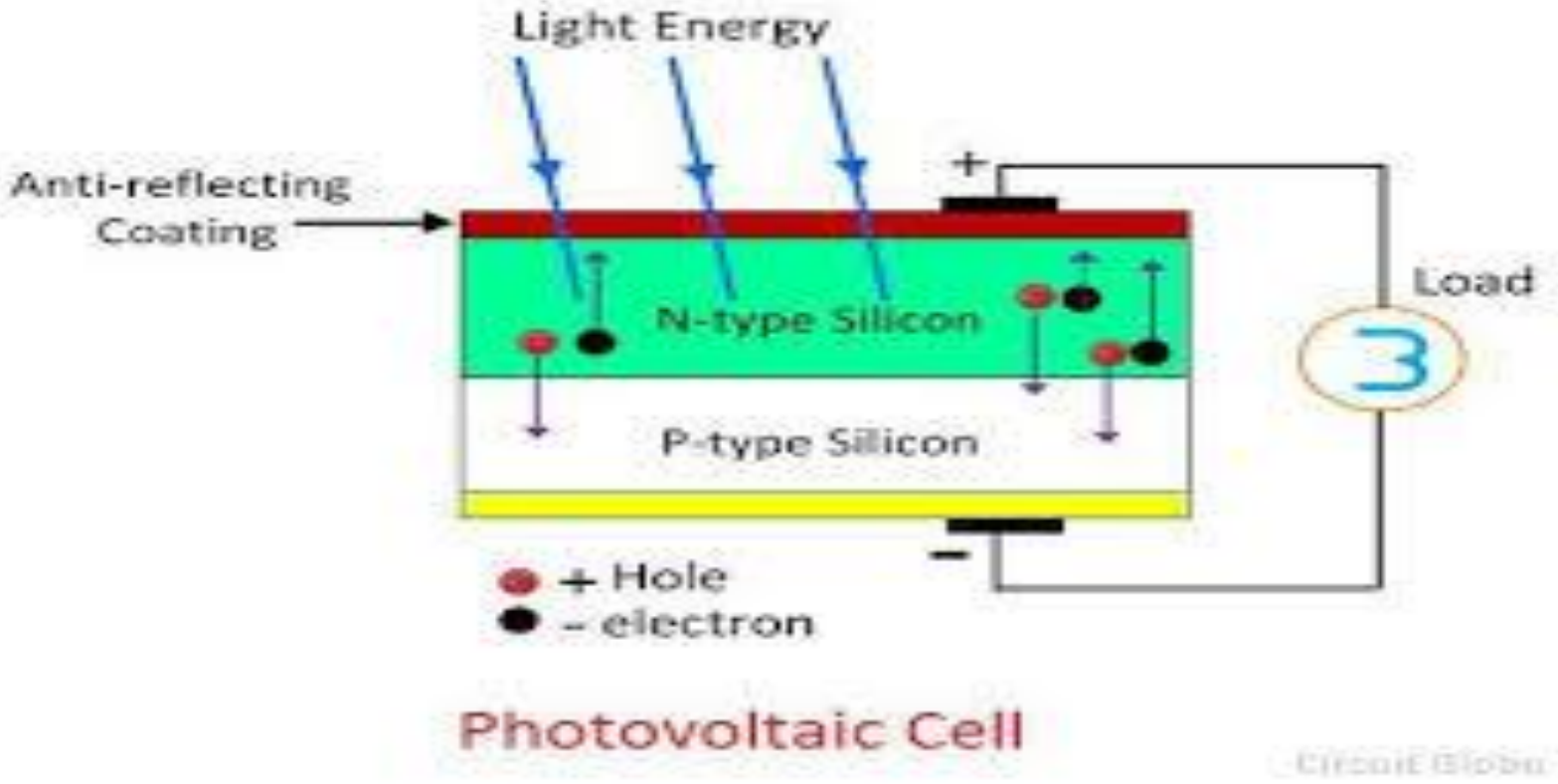


- **Photo-emissive Cell**: It consists of semi cylindrical cathode coated with photo-emissive material and anode is made from thick metallic wire, both of these enclosed in glass tube.
- When the light is made to fall on the emissive material electrons are emitted.
- If positive voltage is applied the anode draws all these electrons.
- The current generated is proportional to the light incident on the material.



- **Photoconductive Cell**: The photoconductive cell converts the light energy into an electric current.
- It uses the semiconductor material like cadmium selenide, Ge, Se, as a photo sensing element.
- When the beam of light falls on the semiconductor material, their conductivity increases and the material works like a closed switch.
- The current starts flowing into the material and deflects the pointer of the meter.

- **Photo-voltaic cell**: It generates potential when light falls on it.
- Photodiode and Phototransistor work in both photo-voltaic and photo-emissive modes



- **Applications:**

- Power stations for generating electrical power
- Solar vehicle
- Space craft
- Rural electrification etc…

References:
1) Basic electronics (Book), U B Mahadevaswamy
2) Basic electronics (Book), D P Kothari, I J Nagrath
3) Tutorials Point, https://www.tutorialspoint.com/electronic_measuring_instruments/electronic_measuring_instruments_transducers.html