BBEE 103/203.

Module - 5.

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* Introduction to Transducers and Communication

A transducer is a device that converts a signal in one form of energy to another form of energy for measurement or for controlling.

Transducers basically classified according to:

* Quantity monitored

  Force, pressure, displacement, temperature humidity, liquid level, velocity etc.

* Mode of operation

  Resistive, inductive, capacitive, thermal optical etc.

* Classification of Transducers.

- Transducers.
  - Based on input/output
    - Sensors (input). Ex: LDR
    - Actuators (output) Ex: LED
  - Based on energy source.
    - Passive Ex: thermistor
    - Active Ex: piezo-electric.

* Based on input/output device, the transducers are classified into two types
Sensors and Actuators.

1) Sensors;

Sensors or also called as input transducers
Converts physical signal quantity into electrical energy.

Ex: 1) A microphone converts sound into electrical impulses.

2) A solar cell converts light into electricity

3) A thermocouple converts thermal energy into electrical energy.

2) Actuators;

Actuators are also called output transducers
They convert electrical energy into physical form of energy.

Ex: An electric motor is an actuator used for conversion of electrical energy into mechanical energy or motion.

Other examples: Loud speaker, Electric lamp, LED, electric heater etc.

* Based on operation or energy source.

1) Passive transducers

External Energy is required for their operation.

used to measure pressure, temperature, flow rate and liquid level.

Ex: strain gauge resistance, thermistor, LVDT, hall-effect sensor, photomultiplier etc.

2) Active Transducers.

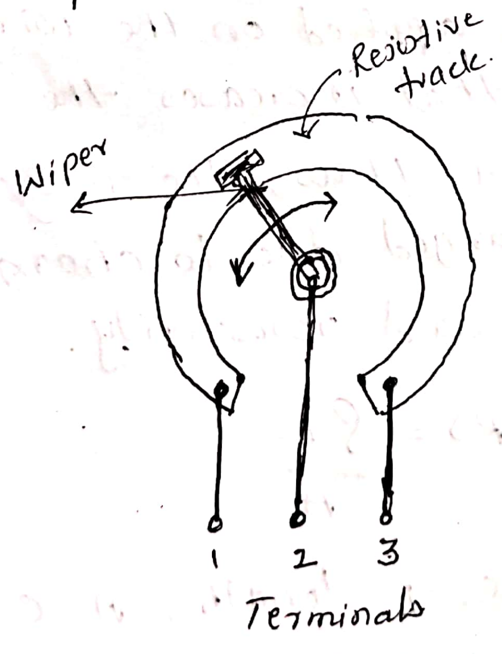
Active transducers develop the voltage and current as the output signal from the physical quantities being measured.

Ex: Thermocouple, piezo electric transducers, photo electric cell and photo voltaic cell.

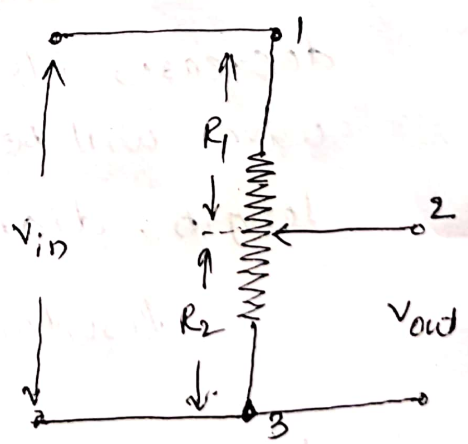
* Resistive Transducers.

* potentiometric Transducer.

A potentiometer is a resistive-type transducer that converts linear or angular displacement into electrical parameter, resistance.



Rotary (angular) potentiometer construction



Equivalent circuit

An input voltage source is applied across resistive track between points 1 and 3 of potentiometer. Thus a voltage divider circuit is formed. When the wiper comes across any displacement, the voltage across point 2 and 3 changes. (i,e V_{out}).

* Strain Gauges:

Strain is the amount of deformation experienced by the body in the direction of the force applied divided by the initial dimensions of the body.

Strain gauge is a sensor whose resistance will vary when any force is applied. A strain gauge converts force, pressure, tension, weight etc. in to a change in electrical resistance which is then measured.

* Strain gauge working principle

When a force is applied on the wire, there occurs a strain that increases the length and decreases its area. Thus, the resistance of the wire will be changed due to changes in its length, diameter and resistivity.

$$\text{Resistance } (R) = \frac{\rho L}{A}$$

Where R= Resistance, L= length, A= cross sectional area.
ρ= resistivity of the material.

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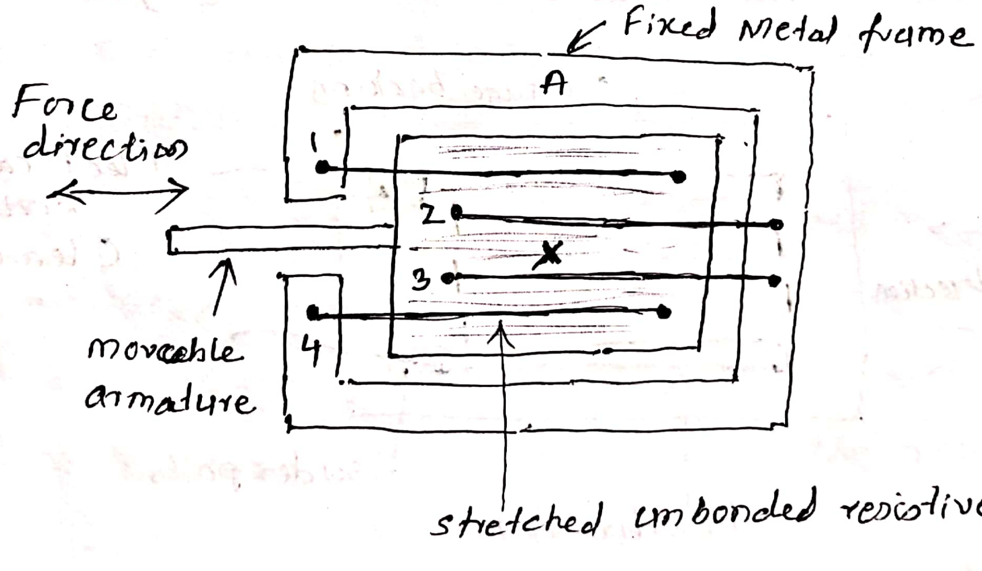
There are two types of wire strain gauge
1) Unbonded metal strain gauge
2) Bonded strain gauge

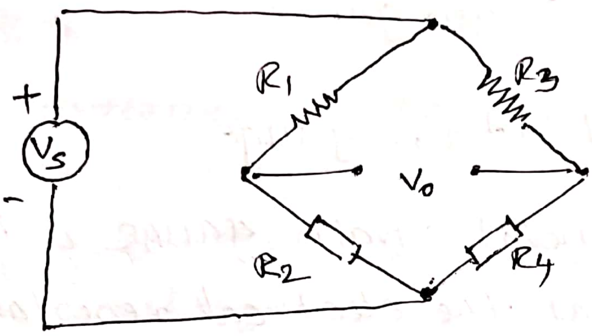
- Unbonded metal strain gauge.

The unbonded metal strain gauge is based upon the principle that the electrical resistance of a wire changes due to the change in the tension of the wire. This type of strain gauge consists of four nickel alloy wires which are tightly stretched between a fixed metallic frame A and movable platform X as shown in fig.



when the external force is applied to the movable frame X, increases the tension in two loops 1 & 4 This causes extension in the length of wires. While decreases the tension in other two loops 2 and 3. This cause shorten in the length of wires. If these wires are appropriately connected to the four arms of Wheatstone bridge, the change in

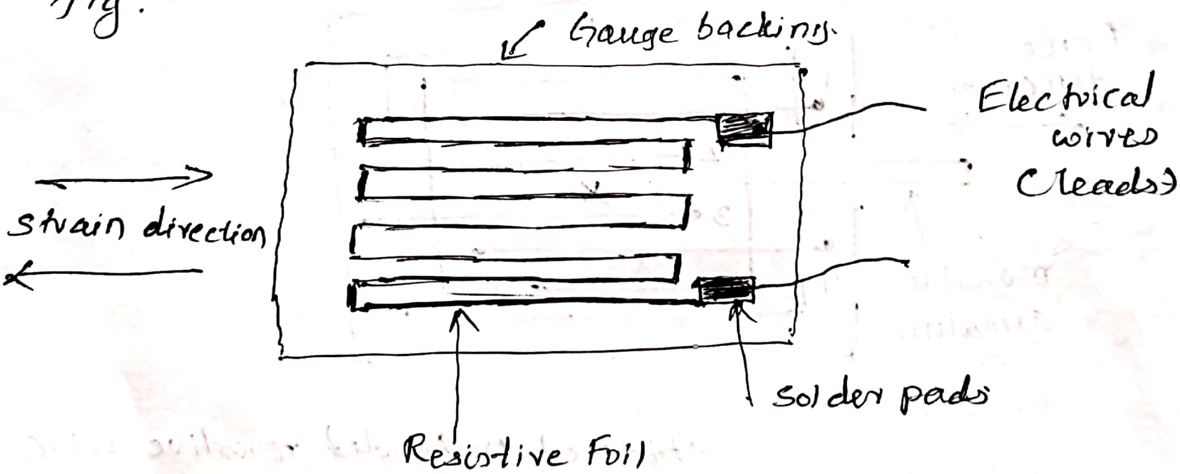
The resistance can be measured- proportionally change in the force can be measured as shown in fig.



This type of strain gauge is used to measure acceleration, pressure and force.

* Bonded strain gauge.

These gauges are directly bonded (pasted) on the surface of the structure under study. as show in fig.



when any external force is applied to an object, deformation occurs in the shape of the object. The deformation observed in the shape can be both compressive and tensile. This is called strain. This strain is measured by a strain gauge setup using wheatstone bridge.

we know that

$$R = \frac{\rho l}{A}$$

As a result of strain, two physical parameters are of particular interest-

1. change in gauge resistance
2. The change in length.

- gauge Factor (GF)

it is the ratio of change in resistance to changes in length.

$$GF = \frac{\Delta R / R}{\Delta l / L}, \quad GF = 1 + 2\mu$$

where $\mu = \frac{\Delta d / d}{\Delta l / l}$, poisson ratio

$$\text{strain}, \ \sigma = \frac{\Delta L}{L}$$

R → Resistance
L → length

$$GF(K) = \frac{\Delta R / R}{\sigma}$$

$$R = \frac{\rho L}{A} = \rho \frac{L}{\pi r^2} \qquad r = d/2$$

$$R = \rho \frac{L}{\pi d^2 / 4}$$

$$R_s = \rho \frac{L + \Delta L}{\frac{\pi}{4} (d - \Delta d)^2}$$

Bonded strain gauge is used in various applications. some of them include the measurement of pressure, temperature, acceleration, force. It is also used to test vehicles, dams, bridges etc.

Ex: A strain gauge with 40 cm wire length and a $25\mu m$ diameter has a resistance of 250Ω and gauge factor of 2.5. Calculate the change in the length and change in the diameter when the resistance change is measured as 0.5Ω. Assume the complete length of the wire is strained positively.

Soln: Given; $GF = 2.5$, $\Delta R = 0.5\Omega$ $L = 40cm = 0.4\,m$
$d = 25\mu m$, $R = 250\Omega$.

$$GF = \frac{\frac{\Delta R}{R}}{\frac{\Delta l}{l}} \Rightarrow \frac{\Delta l}{l} = \frac{\Delta R}{R} \times GF = \frac{0.5}{250} \times 2.5$$
$$= 8 \times 10^{-4}$$

$\therefore$ Change in length, $\Delta l = L \times 8 \times 10^{-4} = 0.4\,m \times 8 \times 10^{-4}$
$= 0.32\,mm.$

$$\mu = \frac{GF - 1}{2} = \frac{2.5 - 1}{2} = 0.75$$

$$\mu = \frac{\frac{\Delta d}{d}}{\frac{\Delta l}{l}} \Rightarrow \frac{\Delta d}{d} = \mu \times \frac{\Delta l}{l} = 0.75 \times 8 \times 10^{-4}$$
$$= 0.6 \times 10^{-3}$$

$\therefore$ change in diameter, $\Delta d = 0.6 \times 10^{-3} \times d.$
$= 0.6 \times 10^{-3} \times 25 \times 10^{-6}$
$= 15 \times 10^{-9}$
$= 0.015\,\mu m.$

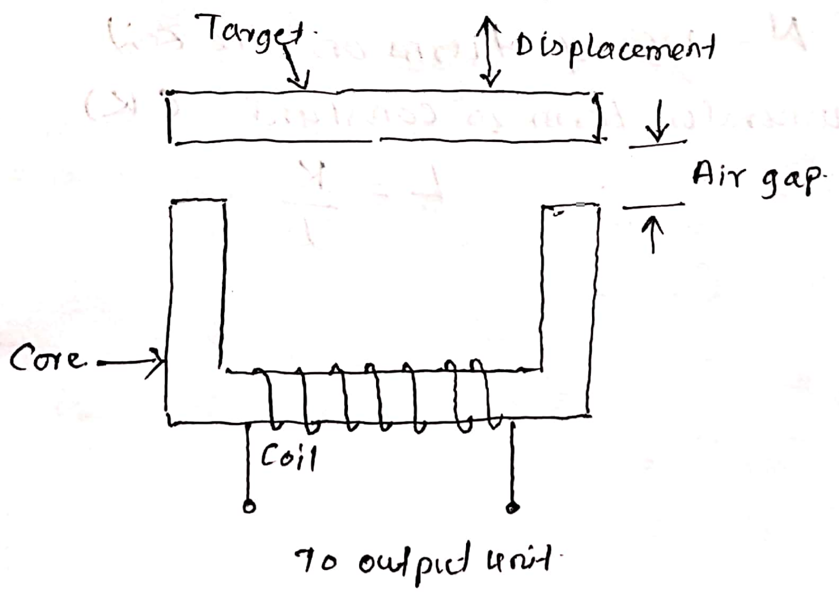
* Inductive Transducers

Variable Reluctance Transducer.

This transducer is used for the measurements of acceleration, sensing force, displacement and velocities.

principle: when the displacement to be measured is applied, the air gap changes, causing a change in reluctance, which in turn causes change in inductance.

Working: The device consists of a coil that is wounded on a core made up of ferromagnetic material as shown in fig.



Displacement to be meausered is given to the core through the target that makes it an upward and downward movement. Care must be taken in such a way that target does not touch the core of the coil. and a smaller air gap is made between them. When the target moves closer to the coil due to displacement, the air gap becomes less causing the reluctance of the magnetic field to reduce and thus coil inductance to increase. The value of inductactance keeps on varying according to the variation in target movement.

Magnetic path reluctance is given by.

$$R_m = L / \mu_0 A$$

L = air gap length, μ_0 = permeability of free space.
A = Air gap cross sectional area.

Inductance L is inversely proportional to reluctance R_m.

$$L = \frac{N^2}{R_m} = \frac{N^2 \mu_0 A}{L}$$

N = no. of turns on the coil
Numerator term is constant, (K)

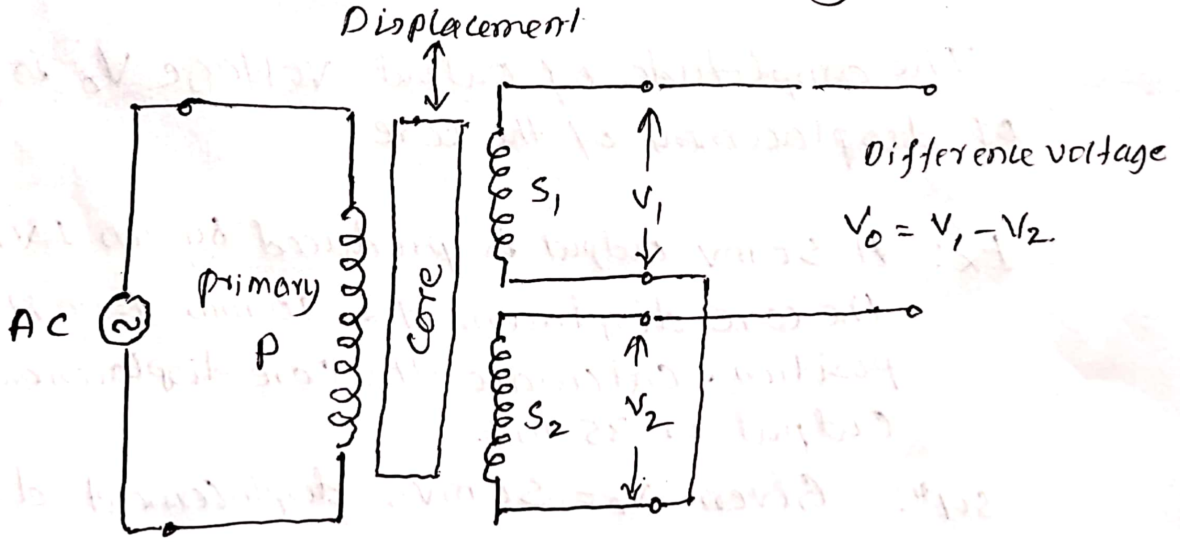
$$\therefore L = \frac{K}{l}$$

* Linear Variable Differential Transducer (LVDT)

LVDT is an electromechanical sensor used to convert mechanical motion or vibration in to variable electrical current.

<u>Principle</u>: The working principle of LVDT is based on mutual induction. When an AC excitation of 5-15V at a freq. of 50-400Hz is applied to the primary windings, a magnetic field is produced. This magnetic field induces a mutual current in the secondary windings, S_1 and S_2. Hence the net output voltage is the difference between the induced voltages in the secondary windings.

An LVDT consists of two elements, a moving core and a fixed coil assembly as shown in fig.



i) a moving core → made of ferro-magnetic material

ii) a fixed coil assembly → A hollow tube surrounded by one primary winding in the centre and two secondary windings S_1 and S_2 equal, but they are opposite to each other.

Working: Case 1): when the core is in the centre.

Due to equal magnetic flux linked, equal voltages are induced in S_1 and S_2, so that $V_1 = V_2$, which results in net output is equal to zero

i.e $V_0 = (V_1 - V_2) = 0V$.

Case 2); when the core move towards S_1 more magnetic flux is linked with S_1 than S_2 as a result, more EMF is induced in S_1. Hence $V_1 > V_2$, then V_0 increases.

Case 3) when the core move towards S_2 more magnetic flux is linked with S_2 than S_1 as a result, more EMF is induced in S_2

Hence $V_2 > V_1$, then V_0 decreases.

The amplitude of output voltage V_0 is a function of displacement of the core.

Ex: A 50mv output is produced by an LVDT when the core displacement is 10 mm from its zero position. Calculate the core displacement when the output is 35 mv.

Sol^n: Given $V_0 = 50mv$, displacement $d = 10mm$

New $V_0 = 35mv$.

Sensitivity $S = \frac{V_0}{d} = \frac{50mv}{10mm} = 5mv/mm$

Core displacement, $d = \frac{V_0}{S} = \frac{35mv}{5mv/mm} = 7mm$. ← Ans.

* Capacitive Transducers.

Capacitance transducers are passive transducers that work on the principle of change of Capacitance C. A capacitor consists of two parallel plates of area A, placed at a distance 'd' from each other with any material (insulator) between them. The dielectric constant ε is unique for different medium.

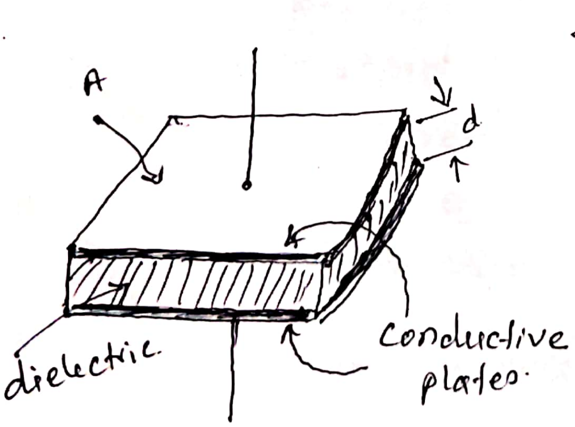
$$C = \frac{\varepsilon_r \varepsilon_0 A}{d}.$$

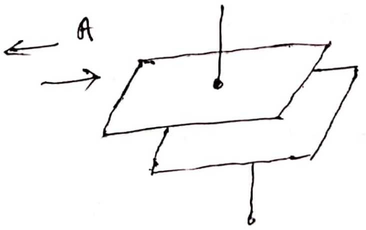
Where ε_r is the relative permittivity of the dielectric medium, ε_0 is permittivity of air or free space (8.85×10^{-12} F/m). A is cross sectional area of plates, d is the distance between the two parallel plates.

Capacitance transducer can be used for displacement measurements.

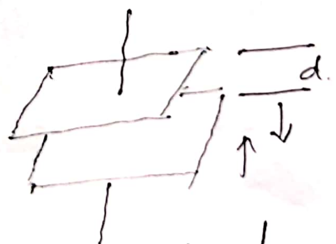
The capacitance of the capacitor can be changed by three parameters

1) Change in overlapping area, A.
2) change in the distance between the capacitor plates, d.
3) change in dielectric constant, ε.

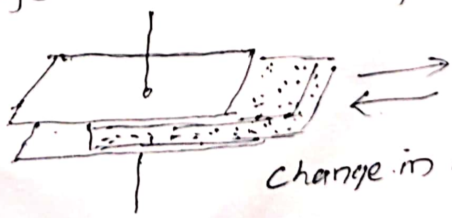




change in A



change in d.



change in dielectric. ε.

Ex: A parallel plate capacitor transducer has a plate area $A = l \times l0 = 40mm \times 40mm$ and plate spacing $d = 0.5mm$. Calculate device capacitance and displacement that causes the capacitance to change by 5pF. Also determine the transducer sensitivity.

Soln: $A = 40 \times 40\ mm^2$, $d = 0.5mm$, $\Delta C = 5pF$

$\varepsilon_0 = 8.84 \times 10^{-12}$, $\varepsilon_r = 1$

displacement $\Delta d = ?$, sensitivity $= ?$

$$C = \frac{\varepsilon_r \varepsilon_0 A}{d} = \frac{8.84 \times 10^{-12} \times 1 \times 40 \times 40 \times 10^{-6}}{0.5 \times 10^{-3}}$$

$$= 28.3pF.$$

$$C - \Delta C = \frac{\varepsilon_r \varepsilon_0 A}{d + \Delta d} \quad \text{or}$$

$$d + \Delta d = \frac{\varepsilon_r \varepsilon_0 A}{C - \Delta C} = \frac{8.84 \times 10^{-12} \times 1 \times 40 \times 40 \times 10^{-6}}{(28.3 - 5) \times 10^{-12}}$$

$$= 0.607\ mm.$$

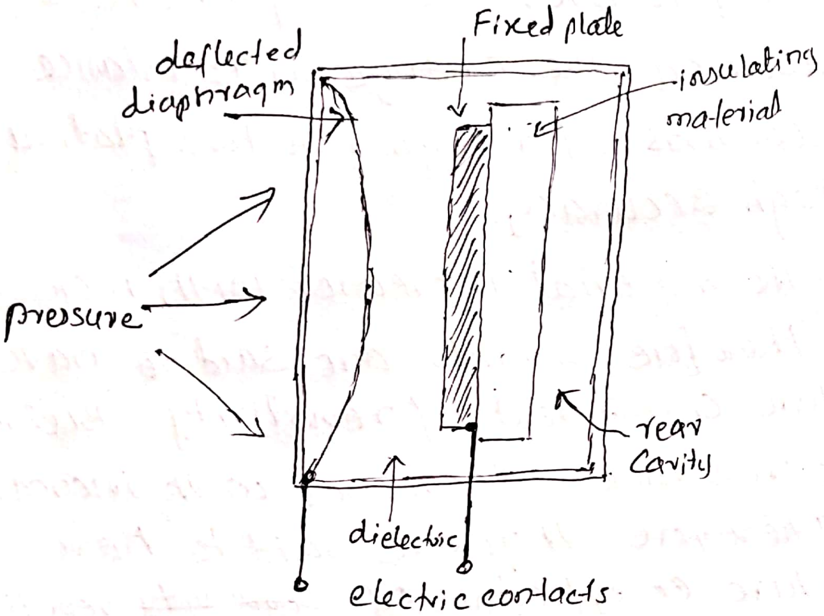
$$\Delta d = d + \Delta d - d$$

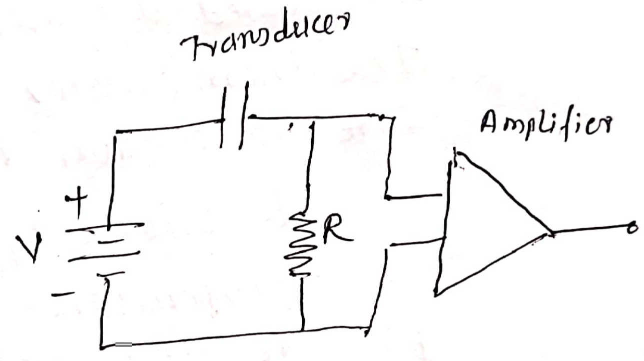
$$= 0.607mm - 0.5m = 0.107\ mm.$$

$$\text{Sensitivity} = \frac{\Delta C}{\Delta d} = \frac{5pF}{0.107\ mm} = 46.7\ pF/mm.$$

* Capacitive pressure Transducer.

Capacitive transducer has a fixed plate and a metal coated movable diaphragm with dielectric enclosed in an air-tight container as shown in fig.





Capacitance detector ckt.

The diaphram is used as one plate of the capacitor. The pressure is applied to the outerside of the diaphragm, the distance between the diaphragm and the fixed plate changes. This produces a capacitance which is measured using AC bridge circuit.

Capacitor charge equation is $Q = CV$.

Here, C varies with varying pressure.

The varying current in the circuit causes varying voltage drop across R, which can be amplified and further processed.

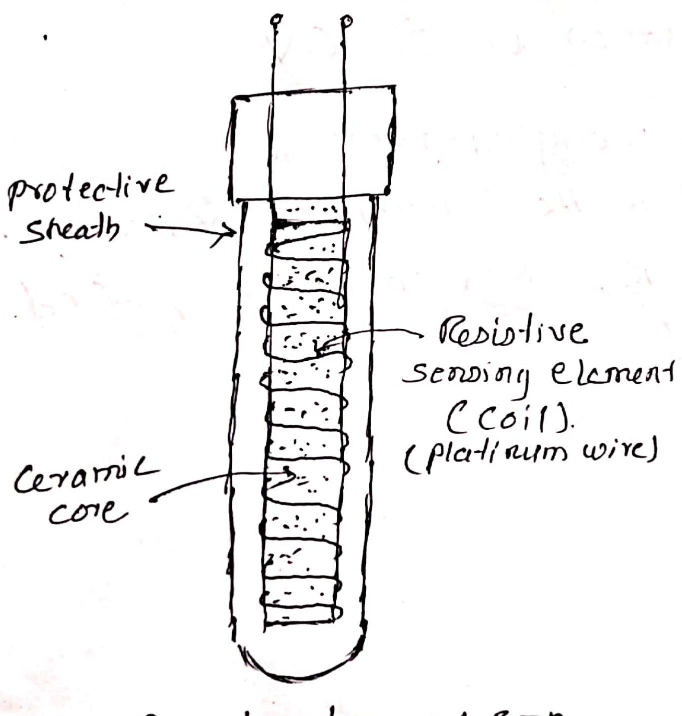
* Thermal Transducers.

* Resistance thermometer. (RTD - Resistance Temperature Detector)

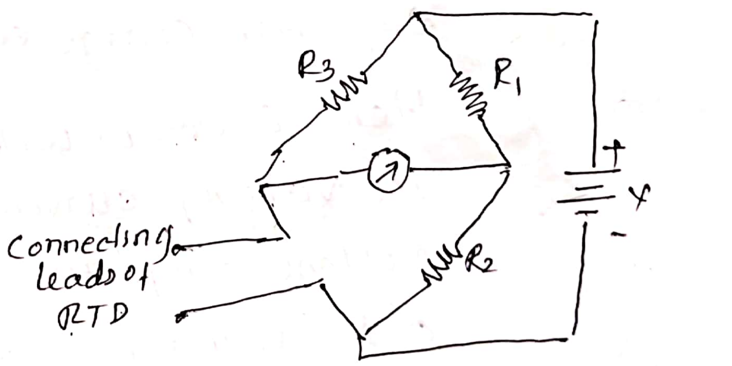
Thermometer is a device that is used in the measurement of temperature. The temperature is measured by measuring the change in resistance. The thermometer consists of a high resistive platinum wire to attain high accuracy.

Resistance of the material increases with increase in temperature. Therefore, metals are said to have positive temperature co-efficient of resistivity, But in semiconductors the resistance decreases with increase in temperature. Therefore, they are said to have negative temperature co-efficient of ~~sensivity~~ resistivity

with rising temperature, an RTD's resistance rises. An electrical circuit is constructed to measure a change in the resistance of RTD, which is proportional to change in temperature.



Construction of RTD



Wheatstone Bridge arrangement

When the RTD is brought in contact with the substance (say, liquid) whose temperature is to be measured, the resistance of the platinum wire changes with the change in temperature. The two leads of the thermometer are connected with wheatstone bridge for measurement of change in resistance and so the temperature is measured.

$$\Delta R = R_0 [1 + \alpha \Delta T]$$

$$\text{where } \alpha = \frac{\Delta R / R_0}{\Delta T}$$

$$\Delta T = \frac{1}{\alpha} \left[\frac{R_2}{R_1} - 1 \right] \qquad \begin{aligned} R_1 &= R_0 \\ R_2 &= \Delta R \end{aligned}$$

RTD is used in automotive to measure the temperature of engine oil, in food processing etc.

Ex: The resistance of a coil of nickel wire is $25\,\Omega$ at $20^\circ C$. This rises to $37\,\Omega$ when the coil has been submerged in a liquid for some time. Calculate the temperature of the liquid. assume $\alpha = 0.006$ for nickel.

Soln: $R_0 = 25\,\Omega$, $\alpha = 0.006$ $\Delta R = 37\,\Omega$ $T_1 = 20^\circ C$.

new temperature, $T_2 = ?$

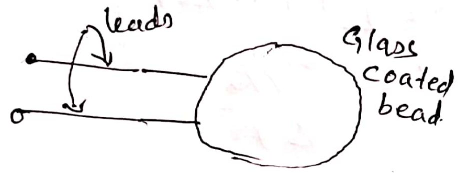
$$\Delta T = \frac{1}{\alpha} \left[\frac{R_2}{R_1} - 1 \right] = \frac{1}{0.006} \left[\frac{37}{25} - 1 \right]$$

$$= 80^\circ C$$

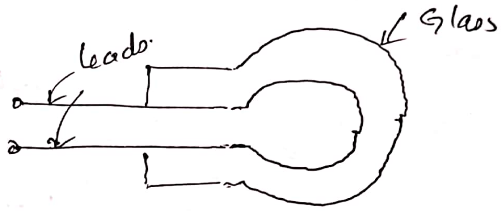
$$\begin{aligned} \text{New temperature, } T_2 &= T_1 + \Delta T \\ &= 20^\circ C + 80^\circ C \\ &= 100^\circ C. \end{aligned}$$

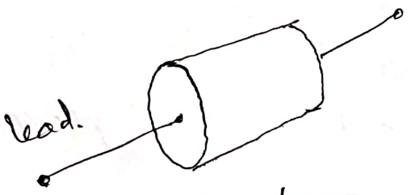
* Thermistors.

Thermistor is a thermally sensitive resistor, hence is termed as thermal resistor. Thermistors are negative temperature co-efficient resistivity. That means, their resistance decrease as their temp. increases. Various common types of thermistors are bead, probe, disc & rod types.

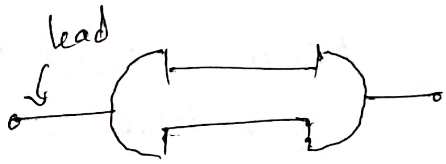


Bead type.



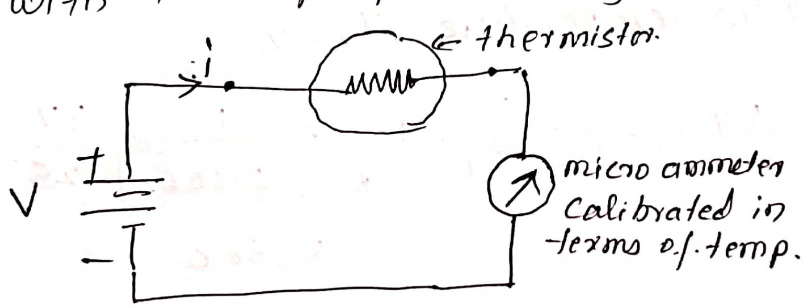


Disc type.



Rod type.

working principle: when the temperature changes, the resistance of the thermistor changes. Temperature is measured by connecting the thermistor in series with a battery V. and calibrated micro ammeter. The calibrat micro ammeter is used to read the temperature direc with the help of a battery V. as shown in fig.



$$R_T = R_0 e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)}$$

R_T = Resistance at any given temp. T

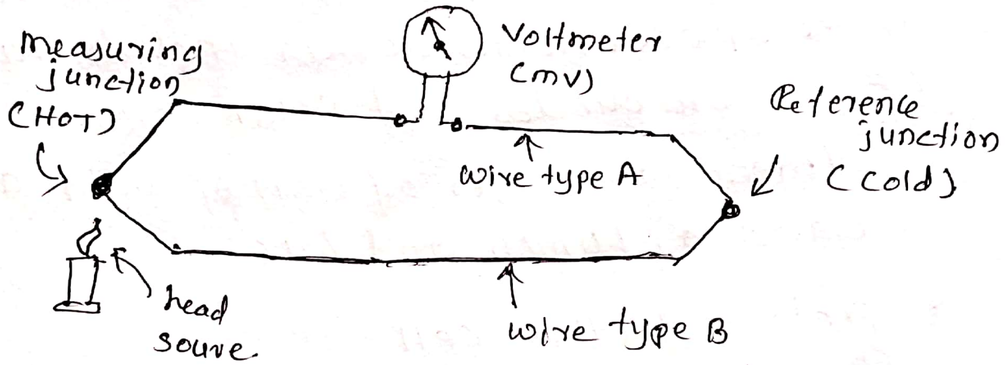
R_0 = resistance at ref. temp. T_0 (Kelvin)

T_0 = Temp at 273 Kelvin

β = material const. at 273 kelvin.

* Thermocouple Thermometers.

Thermocouple consists of a junction of two dissimilar wires, selected in such a way that a small emf (mv) is generated at the junction. This is termed as Seebeck effect. Emf produced is directly proportional to the heating effect of the material. examples of dissimilar metals — copper and constantan.



The arrangement shown in fig. requires reference junction (cold) and compensated cables for accurate measurement. The equation for the thermocouple junction voltage is

$$V = \alpha \Delta T$$

α = metal constant, ΔT → is diff. between the junction temp.

* Opto electronic Transducers.

Light is a type of radiation that moves through space. Radiation of light consists of particles or packets of energy called photons. Light is only part of the electromagnetic spectrum that is visible.

Optoelectronic transducers are devices that convert light in to electrical signal and vice.versa. majority of the optoelectronic devices include laser, optical fiber, LED, photo diodes and solar cells.

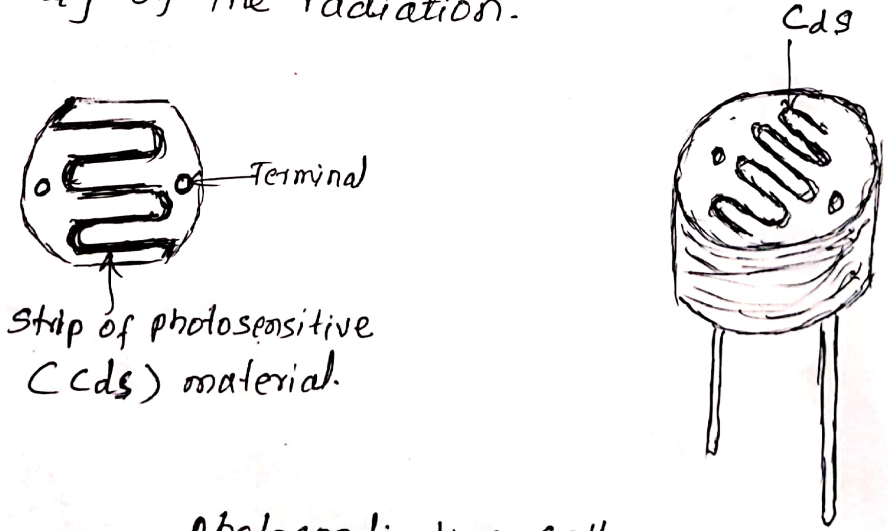
Three main types of unit of light are as follows. Candela, Lumen and Lux.

* photoconductive cell.

A photoconductive cell is a light-sensitive semiconducting device whose electrical conductivity varies with the amount of light falling on it.

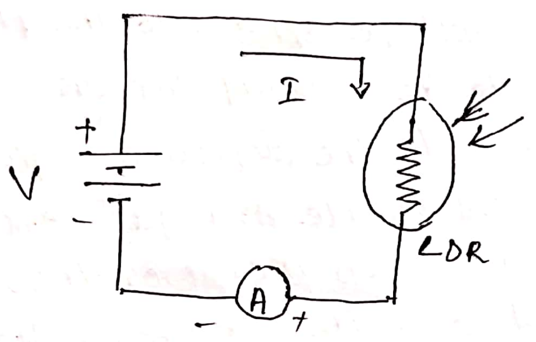
This is often referred to as an LDR (light-dependent resistor).

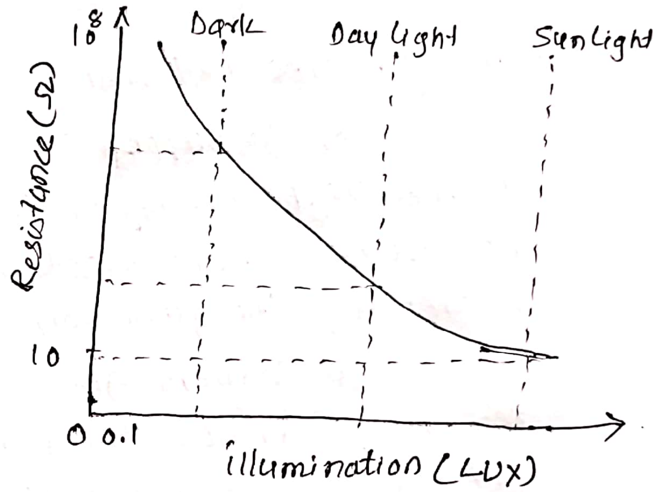
photoconductive cell is working based on the principle of photoconductive effect. The photoconductive effect is a process in which the conductivity of a semiconductor material changes according to the wavelength and intensity of the radiation.



photoconductive cell
(LDR)

The resistance value in an LDR is inversely proportional to the intensity of the light falling on it. That is the material has high resistance in the absence of light, and the resistance drops when the material is illuminated.
Cadmium Sulfide (CdS) and cadmium selenide (CdSe) are the material that are normally used in photoconductive cell manufacture.





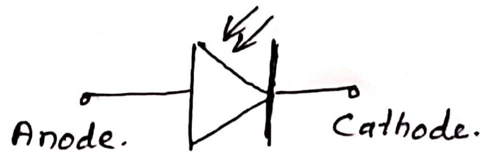
Advantages: Low Cost, available in many shapes & sizes, Low power operation, High sensitivity.

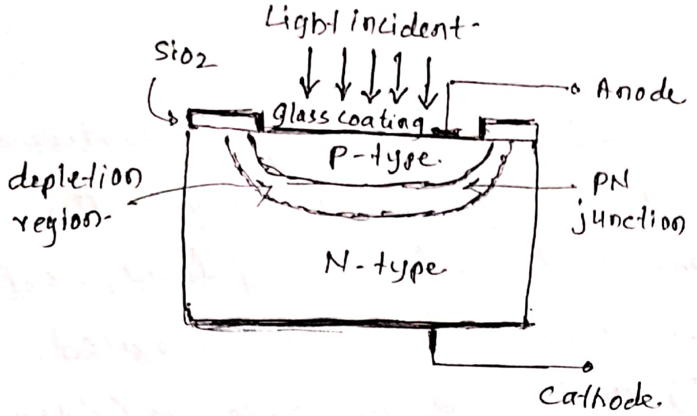
Applications: used in automatic street lightings, Cameras alarm clocks, burglar ckts, to count objects etc.

* Photo Diodes.

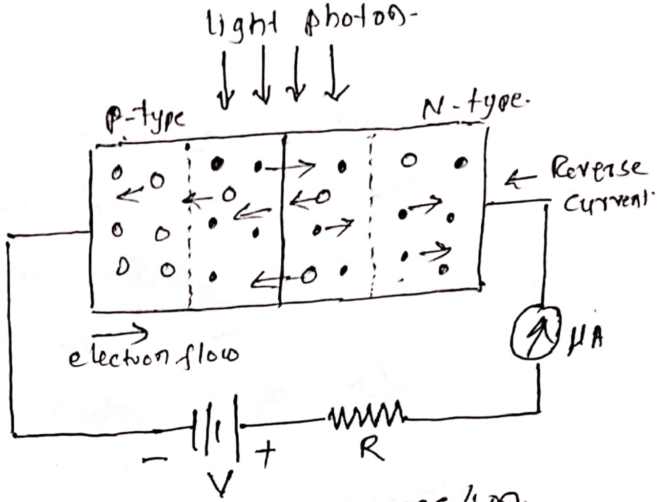
A photodiode is a PN junction semiconductor device that consumes light energy to generate electric current. It is also sometimes referred as photo-detector, photo-sensor, or light detector. photo diodes are specially designed to generate more number of charge carriers in depletion region by operating in the reverse bias condition.

The symbol of photo diode.





Construction of photodiode.



Circuit connection.

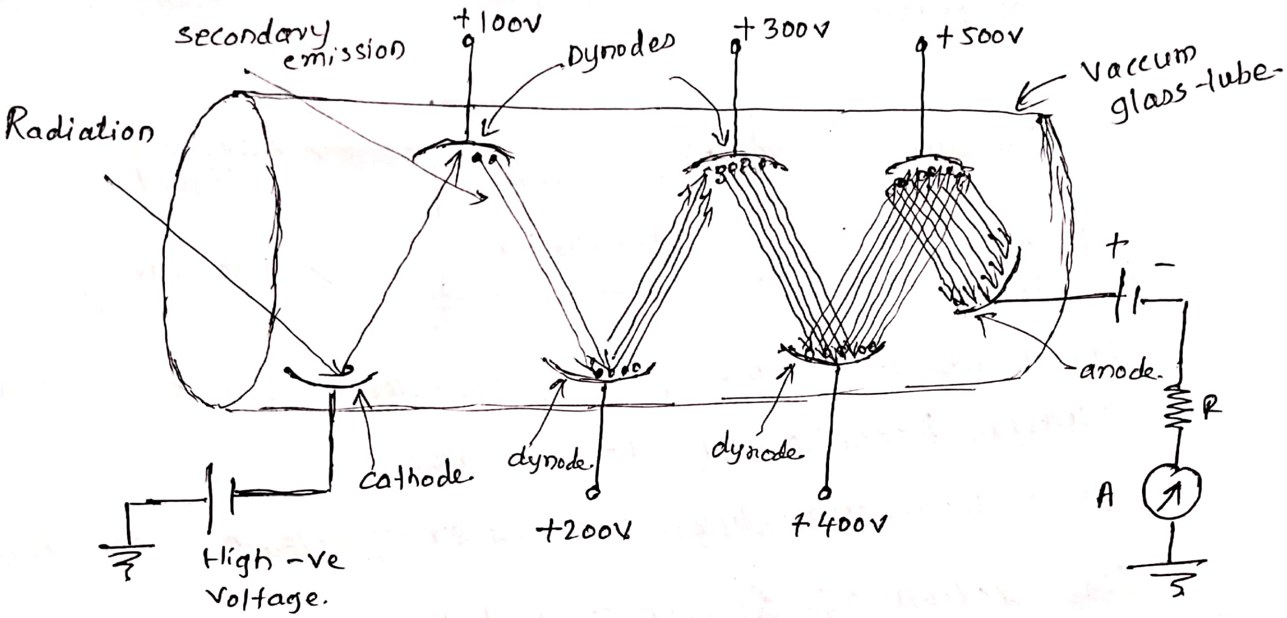
Working: The external reverse voltage applied to the PN diode that causes to ~~supply~~ energy to the minority carriers. When an external light energy is supplied to the depletion region of photodiode, more electrons will create and gain energy. Increasing the junction illumination increases the number of charge carriers generated, and thus increases the level of reverse current. From the circuit, it is observed that the photodiode converts light energy into electrical energy.

Advantages: low resistance, Better frequency response, Linear, Less Noisy, The speed of operation is very high.

Applications: Light detector
Demodulators
Encoders.
Optical communication system.
High speed counting & switching circuits
Light operated switches.

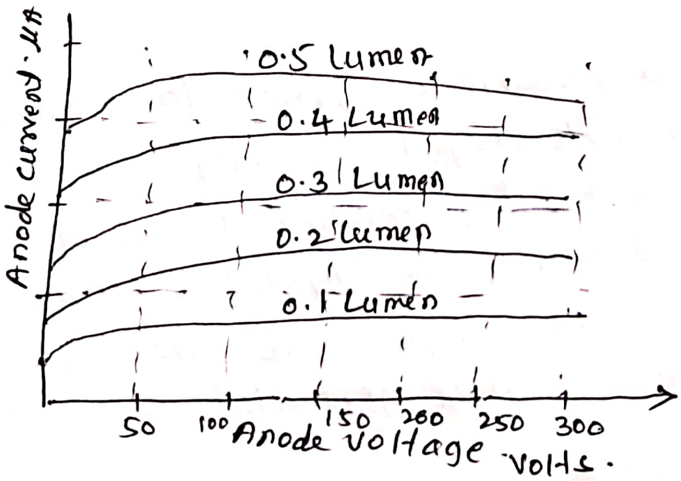
* Photo multiplier Tube.

Photomultiplier tube consists of a photocathode and series of dynodes in an evacuated glass chamber as shown in fig.



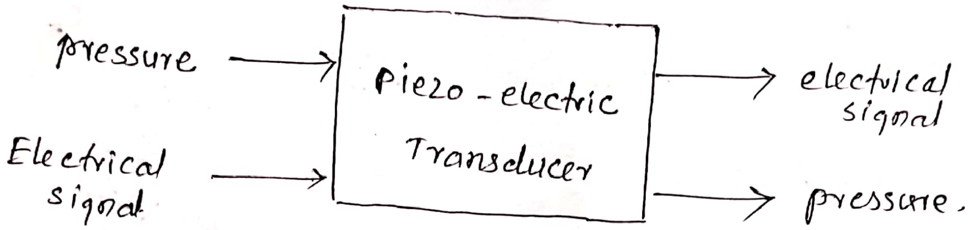
working principle: photons that strikes the photo-emissive cathode emits electrons due to the photoelectric effect. These electrons are accelerated towards a series of additional electrodes called dynodes. Additional electrons are generated at each dynodes is called secondary emission. This cascading effect creates enormous electrons depending on the number of dynodes and the accelerating voltage. This amplified signal is finally collected at the anode. The current is converted to a voltage measurement which is proportional to the intensity of the light emitted, where it can be measured.

V-I characteristics



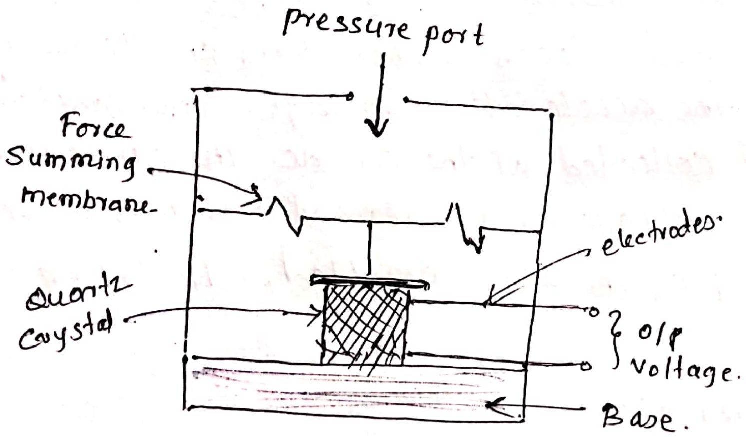
* Piezoelectric Transducers.

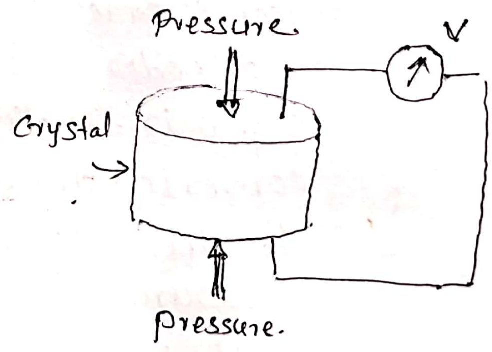
It is a type of transducer which converts mechanical energy (stress, sound, pressure, etc) in to electrical energy and vice-versa.



- The materials exhibiting the piezo-electric phenomenon are Quartz, Rochelle salt, Tourmaline.
- Piezoelectric transducers are smaller in size, high sensitivity
- Construction of Quartz crystal piezo-electric transducer.

Piezo-electric transducer mainly consists of quartz crystal. It is placed in between the solid base and force summing membrane. Metal electrodes are connected to the faces of crystal to measure output as shown in fig.





When a pressure is applied to a quartz crystal, it deforms (changes in its shape) elastically and resulting in the generation of an electrical potential across it. This electric voltage generated across the crystal is directly proportional to the amount of applied pressure. The applied pressure can be measured in terms of voltage generated across the crystal.

BBEE103/203

Module-5

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Communication Systems:

* Introduction

Communication is the basic process of exchanging information. word communication essentially refers to the transmission of information from one point to other.

In its basic electrical sense, the term communication refers to the sending, receiving and processing of information by electric means.

As such, it has started with wire telegraphy, developing with telephony some decades later and radio at the begining of 20th century. The use of satellites and fiber optics has made communication even more widespread, with an increasing emphasis on computer and other data communications.

* Elements of Communication systems

The communication system exists to communicate a message. A basic block diagram of communication system is as shown in fig.

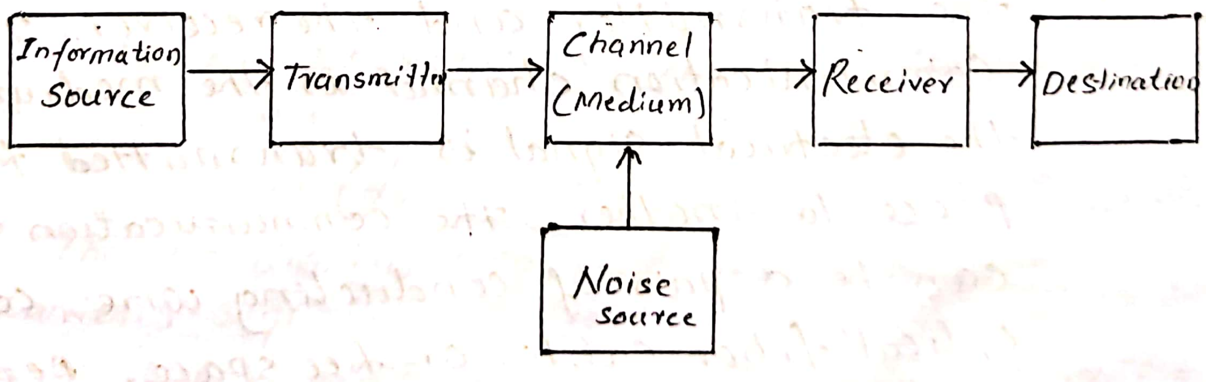


Fig. Basic block diagram.

Communication systems are used to transfer information from a generation point to the place where it is needed / processed.

The basic Elements (components) of communication systems are Transmitter, a communication channel and a receiver. Noise is inherently present in the channel. It gets added to the information being communicated.

- Information source

The communication systems communicate messages. The message comes from the information source. It may contain human voice, picture, code, data, music and their combination

- Transmitter

The transmitter is a collection of electronic circuits designed to convert the information in to a signal suitable for transmission over a given communication medium. This operation is called modulation. In a transmitter the information signal modulates the carrier signal

- Communication channel

It provides the physical connection between the transmitter and the receiver. The communication channel is the medium by which the electrical signal is transmitted from one place to another. The communication medium can be a pair of conducting wire, co-axial cable optical fiber cable or free space. Depending on the types of communication medium, the communication system can be classified as

→ Wire communication or Line communication.
→ Wireless communication or Radio communication

Channels are generally of two types
Point-to-point channels
Broadcast channels.

- Noise

Noise is random, undesirable electric energy that enters the communication system via the medium and interferes with the transmitted message. Noise can be either natural or man made

- Receiver

A receiver is a collection of electronic circuits designed to convert the signal back to the original information. This process is known as demodulation. It consists of circuits like RF amplifier, mixer, oscillator, demodulator and so on.

* Frequency Bandwidth

Bandwidth is defined as range of frequency occupied by a signal. more specifically, it is the difference between the upper and lower frequency limits of the signal. If the upper frequency is f_2 and lower frequency is f_1, then the bandwidth is given as

$$BW = (f_2 - f_1)\ Hz.$$

The bandwidth required for transmission of various signals is different for each signal. It basically depends on the bandwidth occupied by the information or modulating signal.

Following table gives the commonly used frequency ranges and its application.

Frequency range	Application
- Extremely low frequencies 30 Hz - 300 Hz	power Transmission
- Voice Frequencies 300 Hz - 3 kHz	Audio, submarine Comm, Navigation
- Very low frequencies 3 kHz - 30 kHz	Submarine communication, Navigation
- Low frequencies 30 kHz - 300 kHz	Navigation, submarine communication
- Medium frequencies 300 kHz - 3 MHz	Am broadcast
- High frequencies 3 MHz - 30 MHz	Short-wave broadcast
- Very high frequencies 30 MHz - 300 MHz	TV and FM broadcast
- Ultra high frequencies 300 MHz - 3 GHz	Communication satellites, cellular phones, personal communication systems
- Super high frequencies 3 GHz - 30 GHz	Radar

* Modulation.

Modulation is a process in which some characteristics (Amplitude, frequency or phase) of a high frequency sine wave (carrier wave) is varied in accordance with the instantaneous value (i.e amplitude) of the message signal.

Modulation techniques are classified according which parameter or characteristics of the carrier is changed.

1) Amplitude Modulation (Am)

In amplitude modulation, the amplitude of the carrier is varied according to the message signal keeping its fequency and phase constant.

2) Frequency modulation (FM).

In fequency modulation, the fequency of the carrier is varied according to the amplitude of message signal keeping amplitude and phase of the carrier constant.

3) Phase modulation (PM)

In phase modulation, the phase of the carrier is varied according to the message signal.

- Need for modulation.

The advantages of using modulation technique are given below

1) Reduces the hight of antenna

Hight of antenna required = $\frac{\lambda}{4}$ meters where $\lambda = \frac{c}{f}$

where C is velocity of light & f is frequency of the signal to be transmitted

for $f = 15$ KHz

Hight of the antenna required $= \frac{\lambda}{4} = \frac{c}{f \times 4}$

$$= \frac{3\times10^8}{15\times10^3 \times 4} = 5000 \text{ meters}$$

for $f = 1$ MHz

Hight of the antenna $= \frac{c}{f\times4} = \frac{3\times10^8}{1\times10^6\times4} = 75$ meters

$\therefore$ modulation can decrease hight of antenna

2) Avoids mixing of signals

All sound signals are concentrated within the range from 20 Hz to 20 kHz. The transmission of message signals (base band signals) from various sources causes the mixing of signals and then it is difficult to seperate at the receiver end. Therefore modulating different signal sources by different carrier frequencies avoids mixing of signals.

3) Increase the range of communication

At low frequencies radiation is poor and signal gets highly attenuated. Therefore base band signals cannot be transmitted directly over long distance. modulation effectively increases the frequency of the signal to be radiated and thus increases the distance over which the signals can be transmitted faithfully.

4) Allows multiplexing of signals

The modulation permits multiplexing to be used. multiplexing means transmission of two or more signals simultaneously over the same channel.

5) Allows adjustment in the bandwidth.

Bandwidth of the modulated signal may be made smaller or larger than the original signal.

6) Improves the quality of reception.

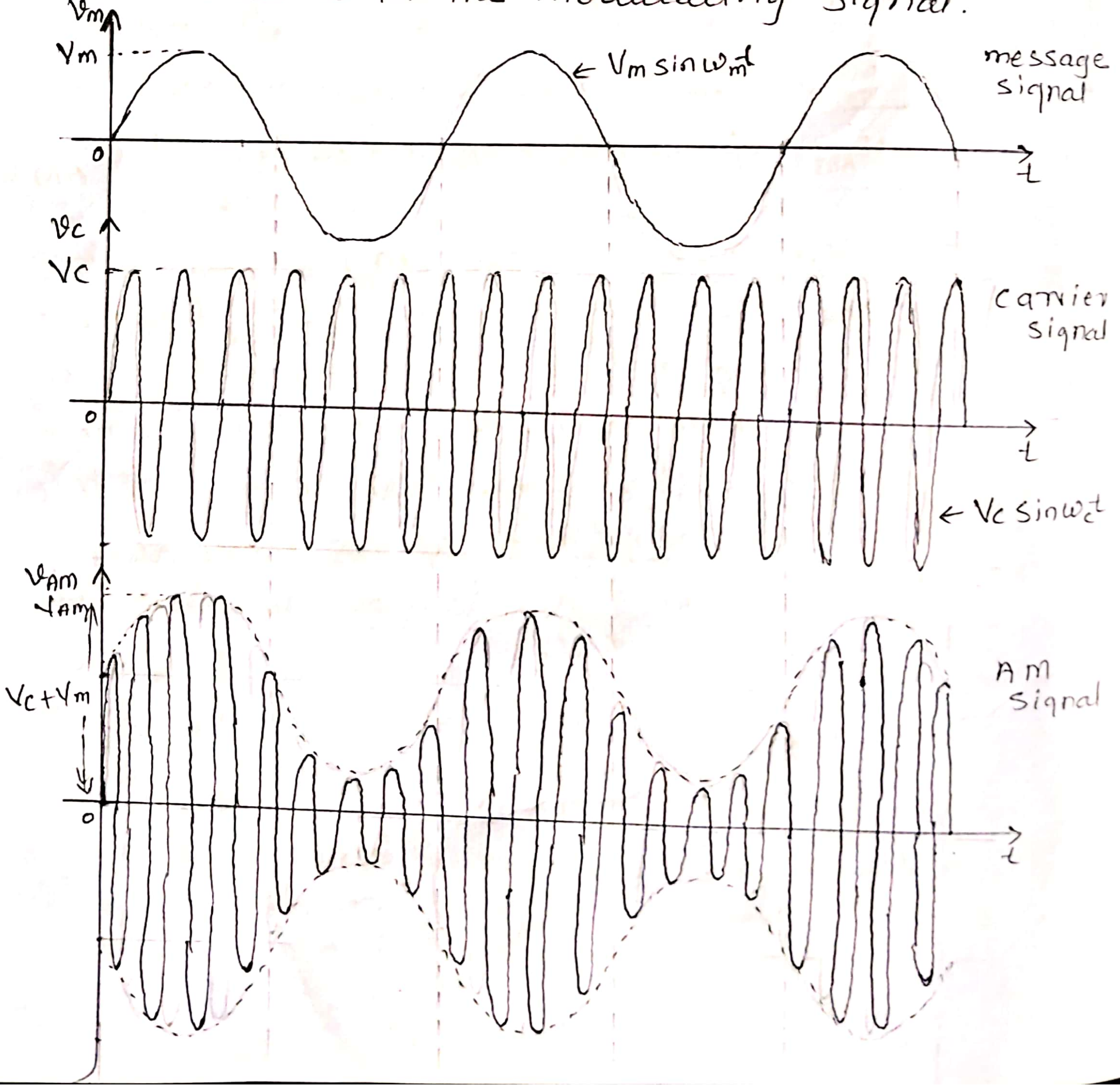
modulation technique reduces the effect of noise. Reduction in noise improves the quality of reception.

* Amplitude Modulation (AM).

In amplitude modulation, the amplitude of the carrier signal is varied by the modulating signal. Here information signal is the modulating signal and high frequency signal which is being modulated is the carrier signal.

Amplitude modulation is defined as system of modulation in which the instantaneous value of the carrier amplitude changes in accordance with the amplitude of the modulating signal.

Fig. shows a single frequency sine wave modulating a high frequency carrier signal. We can see that frequency of the carrier signal remains constant during modulation process but its amplitude varies in accordance with the modulating signal.



- Equation of AM signal

Instantaneous value of modulating signal is given by

$$v_m = V_m \sin\omega_m t$$

Instantaneous value of carrier signal is given by

$$v_c = V_c \sin\omega_c t$$

Using above given mathematical expression for modulating and carrier signals, we can create new mathematical expression for the complete modulated wave (AM signal), as given below

$$V_{AM} = V_c + v_m$$

$$= V_c + V_m \sin\omega_m t \qquad \because v_m = V_m \sin\omega_m t$$

$\therefore$ The instantaneous, value of the amplitude modulated (AM) wave can be given as

$$v_{AM} = V_{AM} \sin\omega_c t$$

$$\boxed{v_{AM} = [V_c + V_m \sin\omega_m t] \sin\omega_c t} \leftarrow \text{AM wave.}$$

- Modulation Index (m)

The relationship between the amplitudes of the modulating and carrier signals is important and is expressed in terms of their ratio, commonly known as modulation index (m). The m is the ratio of maximum amplitude of the modulating signal voltage (V_m) to the maximum amplitude of the carrier signal (V_c).

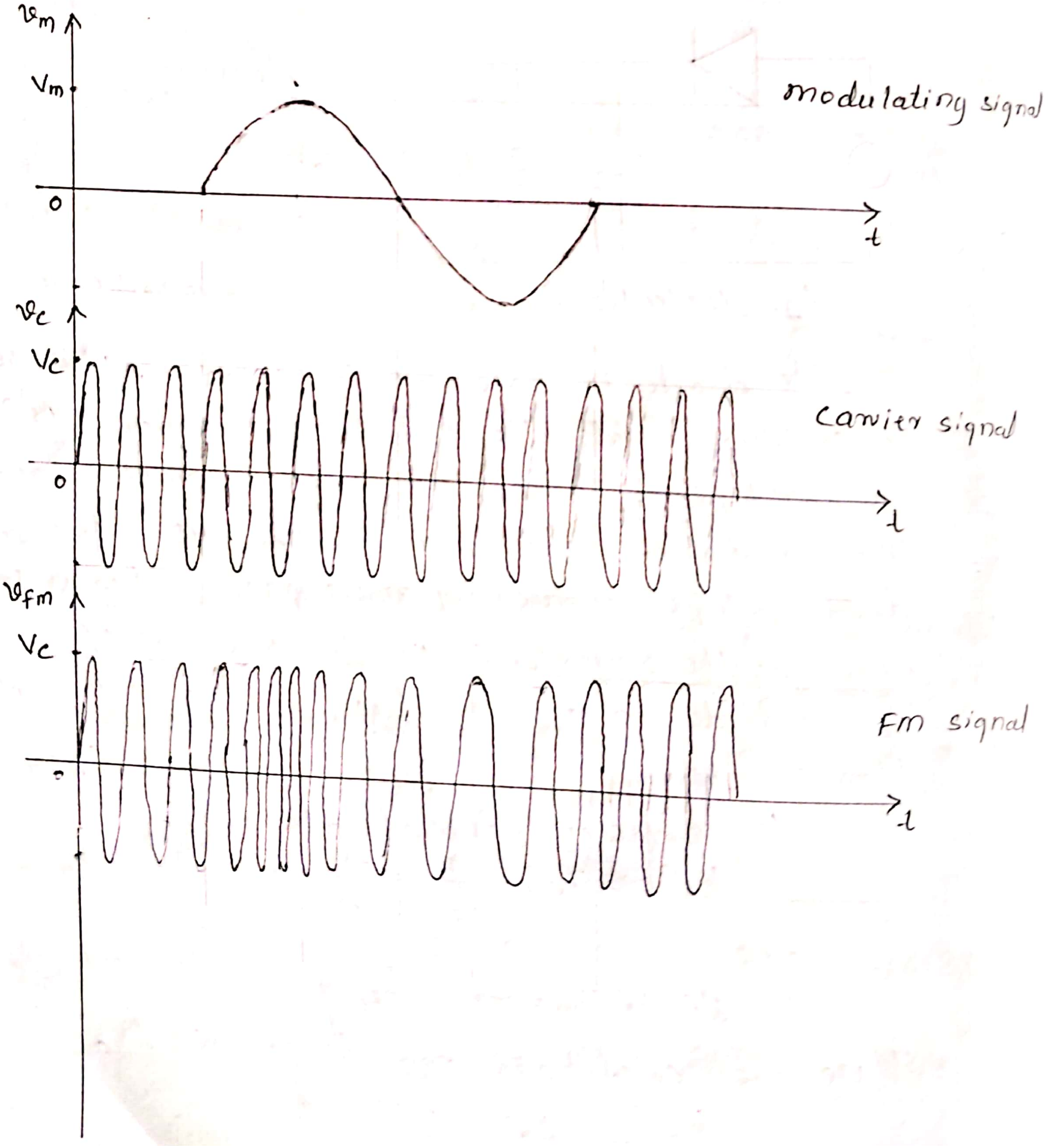
$$\boxed{m = \frac{V_m}{V_c}}$$

The modulation index is a number lying between 0 and 1 and it is very often expressed as a percentage and called percentage modulation.

* Frequency Modulation.

Frequency modulation is defined as system of modulation in which the frequency of the carrier signal is varied in accordence with the amplitude of the modulating signal, while the amplitude of the carrier is held constant.

In this modulation all information is represented by the changes in the carrier frequency. The fig. shows the FM signal.



As modulation is applied, the carrier frequency will increase and decrease in accordance with positive and negative alterations in modulating signal.

The FM wave is at its highest frequency when the modulating signal is at its maximum positive peak and lowest frequency when the modulating signal is at its maximum negative peak.

Expression for FM signal is given as

$$v_{Fm} = V_c \sin(\omega_c t + m_f \sin \omega_m t)$$

where m_f is modulation index for FM defined as

$$m_f = \frac{\delta}{f_m}$$ where δ is the maximum freq. deviati.

$$\delta = k V_m f_c$$

K is proportionality const,

V_m = maxm. amplitude of modulating signal.

V_c = " carrier signal.

- Bandwidth of FM

$$BW = 2(\delta + f_m)$$

* **Phase modulation**

In phase modulation, the phase angle of the carrier signal is varied according to the modulating signal.

The PM signal can be expressed as.

$$v(t) = A \sin(\omega_c t + k_p V_m(t))$$

Where $A = V_c$ = maxm amplitude of carrier signal.
k_p = const. for phase modulation.

FM and PM are generally known as angle modulation.

* Comparison between Am and Fm.

S.No.	Characteristics.	AM.	FM.
1	Channel Bandwidth	Am has smaller Bandwidth. i.e $2f_m$.	Fm has larger bandwidth because it produces a large number of sidebands.
2	operating carrier frequency	Am comparatively utilizes lower Carrier frequency	Fm utilizes higher carrier frequency (above 30 mHz).
3	Transmission efficiency	Am has less transmission efficiency	Fm has better transmission efficiency.
4	Noise performance	Am has poor noise performance.	Fm has better noise performance.
5	Area of reception	Am covers more distance than Fm.	Fm is limited to distance (line-of-sight).
6	Transmitted power	depend on modulation Index. m.	Fm does not dependent on modulation Index, m.
7	Equipment	Simple and cheaper.	complex and expensive.