Sri Sai Vidya Vikas Shikshana Samithi ®
SAI VIDYA INSTITUTE OF TECHNOLOGY
Approved by AICTE, New Delhi, Affiliated to VTU, Recognized by Govt. of Karnataka.Accredited by NBA, New Delhi (CSE, ECE, ISE, MECH & CIVIL), NAAC – "A" Grade
DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING
RAJANUKUNTE, BENGALURU – 560 064, KARNATAKA
Phone: 080-28468191/96/97/98 * E-mail: hodece@saividya.ac.in * URL www.saividya.ac.in

Subject Name: Basic Electronics	Faculty: Tejashree S
Subject Code: BBEE103	Scheme: 2022

Syllabus:

Introduction to Transducers: Introduction, Resistive Transducers, Inductive Transducers, Capacitive Transducers, Thermal transducers, Optoelectronic transducer, and Piezoelectric transducers.

Communications: Introduction to communication, Communication System, Modulation.

Introduction:

A transducer is a device that converts a signal in one form of energy to another form of energy. It is a device or combination of elements, which responds to the physical condition or chemical state of a substance and converts it into an output signal.

Classification Based on Operation

Based on the operation, transducers are classified into active and passive transducers.

1. **Active Transducer**

It develops a voltage or current as the output signal from the physical parameter being measured. It does not require any external source of power for its operation. Examples: Thermocouple, piezoelectric transducer, photovoltaic cell, photoelectric cell, etc.

2. **Passive Transducer**

It requires an external source of power. It produces a change in the electrical parameters such as resistance, inductance or capacitance in response to the physical parameter being measured. Examples: Resistance strain gauge, thermistor, LVDT, resistance thermometer, etc.

Table 1 Comparison between active and passive transducers

Active Transducers	Passive Transducers
They do not require any external source of power for their operation	They require an external source of power for their operation
They are self-generating type of transducers.	They are not self-generating type of transducers
They produce electrical parameter such as voltage or current proportional to the physical parameter being measured	They produce a change in the electrical parameters such as resistance, inductance or capacitance in response to the physical parameter being measured
Examples: Thermocouple, piezoelectric transducer, photovoltaic cell, photoelectric cell, etc.	Examples: Resistance strain gauge, thermistor, LVDT, resistance thermometer, etc.

Table 1 gives the comparison between active and passive transducers.

Passive Electrical Transducers

- The transducers that are based on the variation of the parameters due to application of an external stimulus are called passive transducers.
- The passive elements in an electric circuit are resistor, inductor and capacitor.
- Passive electrical transducers can be further classified into:
  i) Resistive Transducers (where resistance is varied)
  ii) Inductive Transducers (where inductance is varied)
  iii) Capacitive Transducers (where capacitance is varied)

Resistive Transducers

- A resistance transducer produces a resistance variation in accordance with the physical quantity sensed.
- The resistance of a conductor is given by

$$R = \frac{\rho L}{A} \quad \text{..... (Aeqn ())}$$

where ρ = resistivity in Ωm
L = length of conductor in m
A = area of cross-section in m^2

- The electrical resistance transducer is designed on the basis of the methods of variation of any one of the quantities in (A), such as change in length, change in area of cross section and change in resistivity.
- The resistance change due to the change in length of the conductor is used in rotational displacement.
- The change in resistance of conductor or semiconductor due to the strain applied is the working principle of the strain gauge which is used to measure various physical quantities such as pressure, displacement and force.
- The change in resistivity of conductor due to the temperature variations causes change in resistance. This principle is used to measure temperature.

Advantages:

- Both ac and dc voltages and currents are suitable for the measurement of resistance change.

- The speed of response of the resistance transducer is high.
- They are available in various sizes with wide range of resistance value.
- High resolution in measurements can be achieved.

Potentiometric Transducer

- A potentiometric transducer is an electromechanical device containing a resistance element that is contacted by a movable slider.
- Motion of the slider results in a resistance change that may be linear, logarithmic, exponential, and so on, depending on the manner in which the resistance wire is wound.
- In some cases, deposited carbon, platinum film, and other techniques are used to provide the resistance element. The basic elements of the potentiometric transducer are given in Fig below.

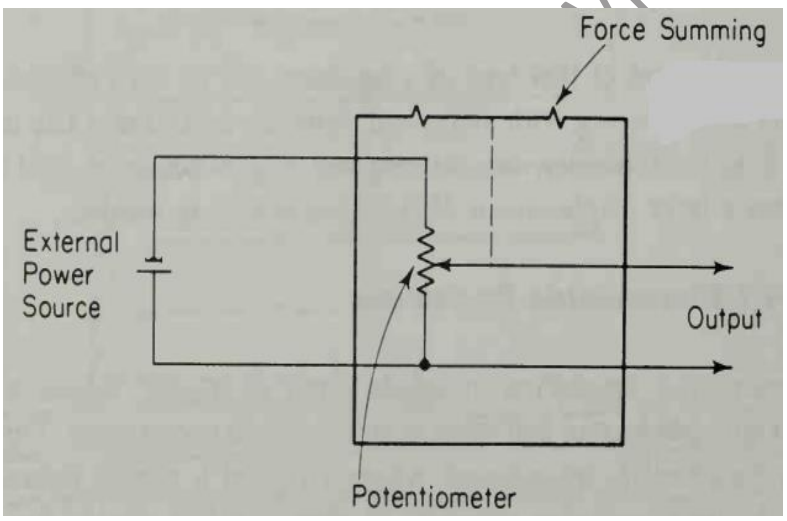


Fig: Principle of the potentiometric transducer.

- A voltage source is applied across the resistive element in a potentiometer. Thus a voltage divider circuit is formed.
- When the wiper come across any displacement, it slides across a fixed resistive element. The output voltage (Vout) is measured as shown in the figure above.
- The output voltage is proportional to the distance travelled by the wiper.

Advantages of Potentiometer

1. They are cheap.
2. It is easy to use and useful in many applications where requirements are not severe.

3. It gives sufficient output that does not require further amplification.
4. Potentiometer efficiency is high.
5. They are useful for the measurement of large displacement.
6. The resolution is infinite in cermet and metal film potentiometers.

Disadvantages of Potentiometer

1. The major disadvantage is that it requires a large force to move their sliding contacts i.e. wiper. There is wear and tear due to movement of the wiper. It reduces the life of this transducer.
2. Also, there is limited bandwidth.
3. There is inertial loading.

Applications of Potentiometer

It is used in many applications such as

1. Linear displacement measurement
2. Liquid level measurements using floats
3. Rotary displacement measurement
4. Brightness control
5. Volume control

Inductive Transducers

The self-inductance of a coil or mutual inductance of pair of coil is altered in value due to a variation in the value of the quantity under measurement.

Applications:

- Displacement measurements
- Thickness measurements

Linear Variable Differential Transformer (LVDT)

The LVDT is a variable inductance displacement transducer in which the inductance is varied according to the displacement.

Construction:

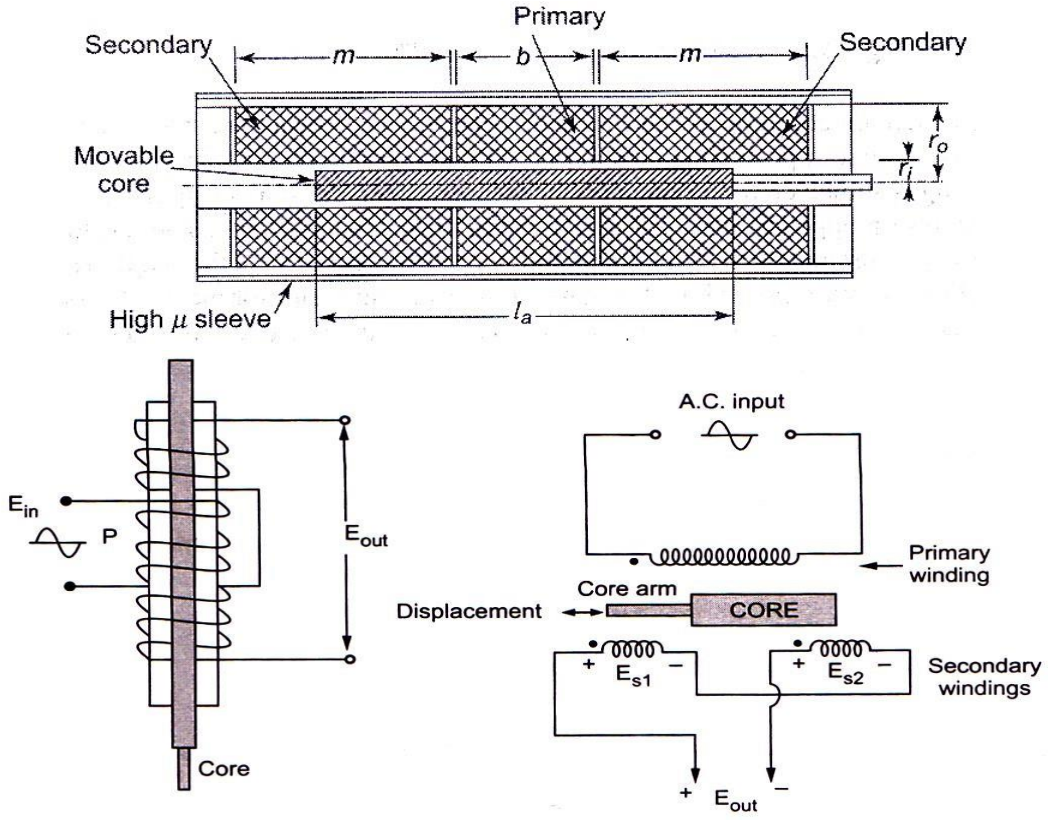


Fig. Linear variable differential transformer

It consists of a primary coil, uniformly wound over a range of the transducer and two identical secondary coils symmetrically wound on either side of the primary as shown in Fig. 5. The iron core is free to move inside the coil in either direction from the centre.

Principle of Operation:

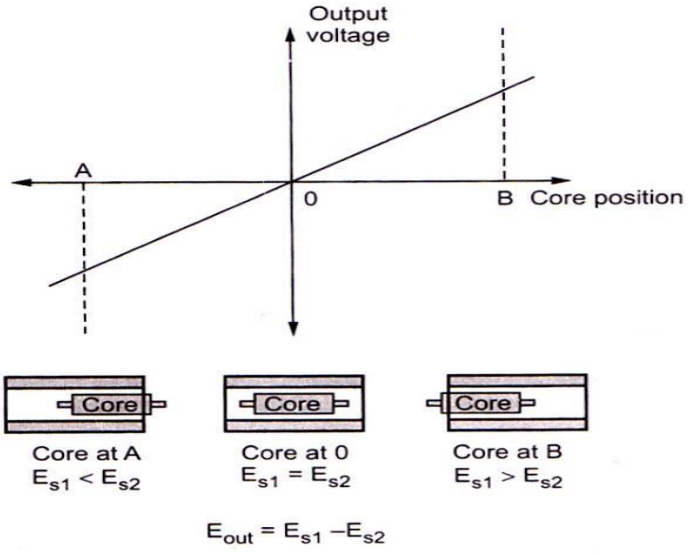


Fig: Operation of LVDT

- The LVDT is based on mutual inductance with variable coupling between the primary and the two secondary coils.
- As shown in Fig. 6, when the iron core is at the centre, the secondary emfs are equal to each other. i.e. $E_{s1} = E_{s2}$. The secondary coils are connected in series, but in phase opposition so that net voltage is zero.
- If the core is moved in any direction, it results in an output voltage that is proportional to displacement.
- When the core is moved to the right (Position A), more flux links the right-hand coil than the left -hand coil. i.e. $E_{s1} < E_{s2}$. Therefore, E_{out} is negative.
- When the core is moved to the left (Position B), more flux links the left-hand coil than the right-hand coil. i.e. $E_{s1} > E_{s2}$. Therefore, E_{out} is positive.

Advantages

1. Wide range of displacement
2. Frictionless operation as there is no physical contact
3. Ruggedness
4. Insensitive to temperature change
5. High sensitivity
6. Linearity of output

Disadvantages

1. Sensitive to stray magnetic fields
2. Large displacements are necessary for differential output

Applications

1. LVDT is used to measure displacement ranging from millimeters to centimeters.
2. As secondary transducer, it can also be used to measure force, weight, pressure, etc. Force or pressure is first converted into a displacement using a primary transducer. This displacement is applied to an LVDT that acts as a secondary transducer.

Capacitive Transducer:

- The capacitance of a parallel-plate capacitor is given by

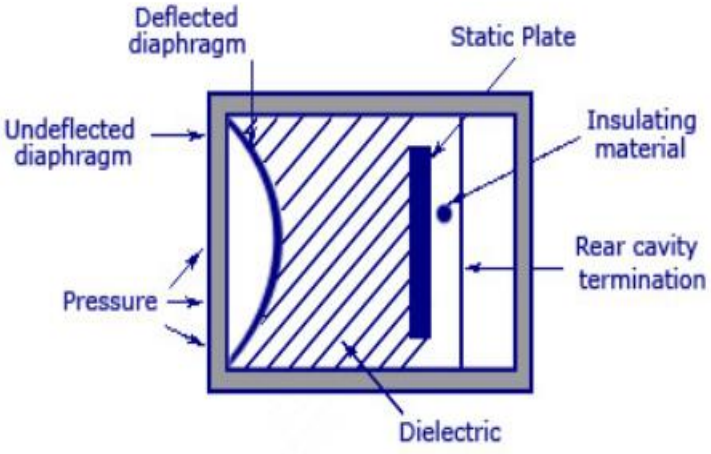
$$C = \frac{kA\in o}{d} \qquad \text{(farads)}$$

where A = the area of each plate, in m^2

d = the plate spacing, in m $€_0$ = 9.85 X 10^{12} in F/m

k = dielectric constant

- From the equation it is clear that the value of capacitance C and the distance between the parallel plates are inversely proportional to each other.
- An increase of distance between the parallel plates will decrease the capacitance value correspondingly. The same theory is used in a capacitive transducer.
- This transducer is used to convert the value of displacement or change in pressure in terms of frequency.
- As shown in the figure below, a capacitive transducer has a static plate and a deflected flexible diaphragm with a dielectric in between.
- When a force is exerted to the outer side of the diaphragm the distance between the diaphragm and the static plate changes. This produces a capacitance which is measured using an alternating current bridge or a tank circuit.



- A tank circuit is more preferred because it produces a change in frequency according to the change in capacitance. This value of frequency will be corresponding to the displacement or force given to the input.

Advantages

- It produces an accurate frequency response to both static and dynamic measurements.

Disadvantages

- An increase or decrease in temperature to a high level will change the accuracy of the device.
- As the lead is lengthy it can cause errors or distortion in signals.

Applications:

- Linear and Angular displacement.
- To find humidity level, pressure variations.

Thermal transducers:

- Resistance Temperature Detectors (RTDs) are another sort of thermal (temperature) transducer.
- Resistance of a conductor changes when its temperature changes. The resistive element is usually made of a solid material, a metal, a metallic alloy or semiconductor compound.
- The resistivity of the metal increases with temperature, but in semiconductor and insulator gradually decreases. It is also called as "Resistive Temperature Detector(RTD)".
- Wire-wound elements employ considerable length of wires, and it is free to expand. The length also increases with increase in temperature. Hence, as temperature changes, the change in resistance will be due to changes in both lengths and resistivity.
- The temperature co-efficient of resistance is given by:

$$\propto = \frac{1}{\Delta T} \frac{\Delta R}{Ro} \quad \ldots\ldots\ldots (1)$$

Where, ΔT = change in temperature

$\Delta R/_{Ro}$ = fractional change in resistance.

Ro = Resistance at ^{0} C

- The resistance R_T at any other temperature T ^{o}C is given by

$$R_T = Ro\ (1 + \alpha T) \ldots\ldots\ldots\ldots (2)$$

Construction of RTD:

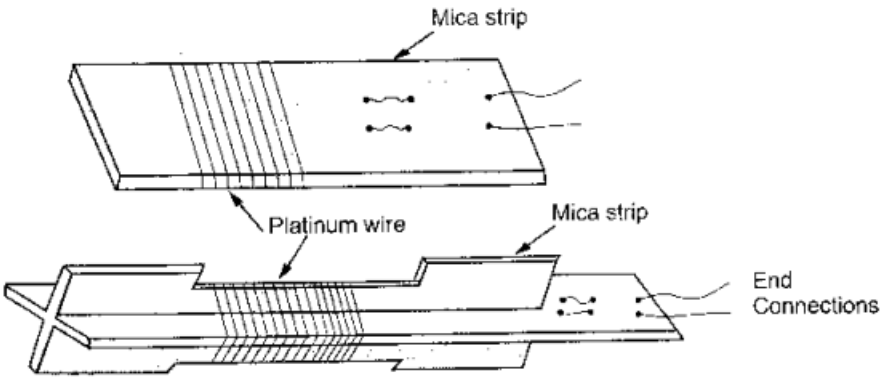


Fig: Resistance thermometer

- An RTD or resistance temperature detector is made by wounding the resistive material around a mica base.
- The element is protected by a stainless steel case or sheath. There is an insulator between the element and the outer sheath.
- The element is designed in a helical shape to reduce the effects due to tension on it. As we know that the resistance of a wire depends on the temperature as well as the length of the wire.
- Due to thermal expansion, the wire length increase with temperature which also affects the resistance of the elements.
- It causes an error in the reading because we want the only temperature to change the resistance and not the physical strain on the wire. Therefore, the element is designed in a helical shape.
- The outer protective sheath is made of Inconel, an alloy made of nickel, iron and chromium. It has excellent corrosion resistive properties to protect the inner element from harsh environments.
- It is an excellent heat conductor that quickly reaches the surrounding temperature and passes it to the element.

Advantages

- High accuracy
- Does not require temperature compensation.
- Excellent stability
- Good sensitivity.

Disadvantages

- High Cost.
- Large sixe compared to thermocouples.
- Affected by shock vibration.

Optoelectronic transducer:

- Optoelectronic transducer is a device which convert light beam into an electrical signal.
- By proper interruption of the light signal due to motion input, the electrical signal produced can be related to the input.
- Operate on principle that when light strikes special combination of materials then following may result.
    1. Electrons may flow
    2. A voltage may be generated
    3. A resistance change may take place.
- Types are
    - Photo-emissive
    - Photo-conductive
    - Photo-voltaic

Photo-emissive

- Light beam strikes a photo-emissive cathode, which releases electrons.
- Electrons are attracted towards the anode producing a current I in the circuit.
- Current I depend upon intensity of radiation and anode cathode voltage.

Photo-conductive

- It uses semiconductor material whose resistance changes in accordance with the radiant energy received.
- Resistivity of selenium, cadmium sulphaide, lead sulfide and thalmium sulphide is decreased when irradiated.
- Used for detecting ships & aircrafts by the radiations given out by their exhausts and for telephony by modulated infrared lights.

Photo-voltaic

- A sensitive element is semiconductor (not metal) generates voltage in

proportion to the light or any radiant energy incident on it.

- In 'selenium cell' due to light, a negative charge will build up on gold electrode and positive charge on bottom electrode.
- Used in fields 1. Automatic control system 2. Television circuits 3. Sound motion picture & reproducing equipment.

Piezoelectric transducers:

They convert mechanical energy into electrical energy and are based on the direct piezoelectric effect observed in certain non-metallic and insulating dielectric compounds.

Principle of Operation

- Electrical charge is developed on the surface of the crystals, when they are under mechanical strain due to application of stress. This is called ***piezoelectric effect***.
- Piezoelectric transducers are having high mechanical rigidity so it is used to measure force, pressure, acceleration, torque, strain and amplitude of vibration.
- The basic piezoelectric phenomenon is the effect of force applied in longitudinal and transverse directions.
- The three modes of operation are:
  - Thickness expander mode
  - Length expander mode
  - Volume expander mode.

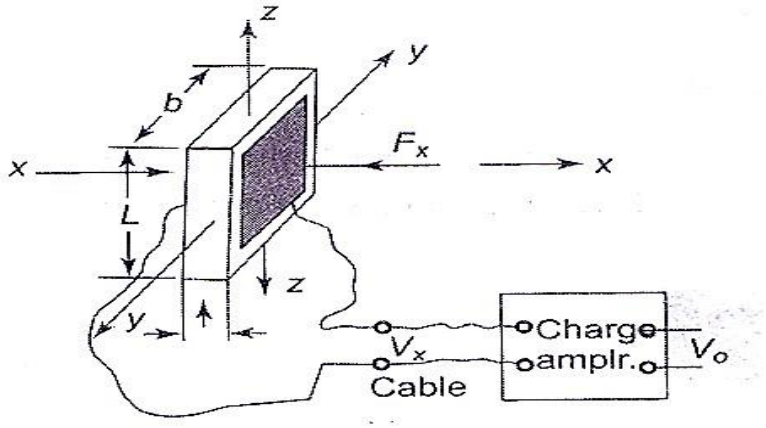


Fig. Piezoelectric transducer

- These modes are based on the direction of force applied which is to be measured.
- The materials exhibiting piezoelectric effect are quartz, Rochelle salt, tourmaline, Ammonium Dihydrogen Phosphate (ADP), Lithium Sulphate (LS), Di Potassium Tartrate (DKT), etc. Fig. 8 shows a piezoelectric crystal used as a transducer.
- The net piezoelectric effect is represented by the vector of electric Polarization $\overline{P} = \bar{P}xx + \bar{P}yy + \bar{P}zz$

  Where,

  $\bar{P}xx$, $\bar{P}yy$, $\bar{P}zz$ refer to the effect on the face perpendicular to each axis due to the application of stress.

Advantages

1. Smaller in size
2. High natural frequency
3. Linearity
4. High sensitivity
5. Wide measuring angle
6. Polar sensitivity
7. High mechanical rigidity

Applications

Piezoelectric transducers are used to measure force, pressure, acceleration, torque, strain.

INTRODUCTION TO COMMUNICATION:

Communication is a process of transferring information meaningfully (voice, text, picture etc) from one point to another. In electronics, communication refers to sending, receiving information.

Elements of a Communication System:

Figure shows the generic block diagram of a communication system. Any communication system will have five blocks, including the information source and destination blocks.

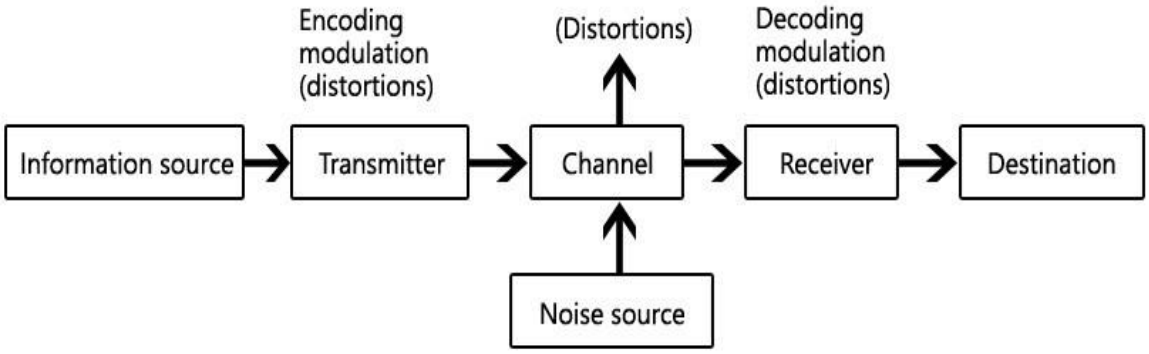


Fig: Basic block diagram of communication system

Information source

- Information source gives the message to be transmitted. EX: Text, voice, video etc.

Transmitter

- The message is converted into electrical form and then transmitted.
- Before transmitting, the electrical signals is modulated. So that it becomes easy to transmit for a longer distance.

Channel

- Channel is a medium through which the electrical signal is transmitted from one place to another.
- There are two types of channels
  1. Wired channel or line communication.
     Ex: Co-axial cable, OFC, pair of conducting wire.
  2. Wireless channel or radio communication
     Ex: Free space.

Noise

- Noise is an unwanted signal that gets added to the message signal during transmission over the channel.
- Noise signal is random in nature. Its effect is greatest when message signal is weak.
- Noise may be natural or man-made.

Receiver

- The original message signal is extracted from the modulated signal at the receiver. Most of the receiver are of super heterodyne receiver.
- The output of the receiver can be fed to the loud speaker or radio display or video display and TV picture tube etc.

Block diagram of typical radio transmitter:

- The objective of the transmitter block is to collect the incoming message signal and modify it in a suitable fashion (if needed), such that, it can be transmitted via channel to the receiving point.
- Channel is a physical medium which connects the transmitter block with the receiver block.
- For instance, if you are talking to your friend sitting in the next room via intercom service then the speech signal collected from your handset need not go through the sequence of steps needed when your friend is far off and you are reaching him/her over the mobile phone.
- This is because, in the first case the channel is a simple copper wire connecting your handset with your friend's hand set, whereas in the second case it is the free atmosphere.

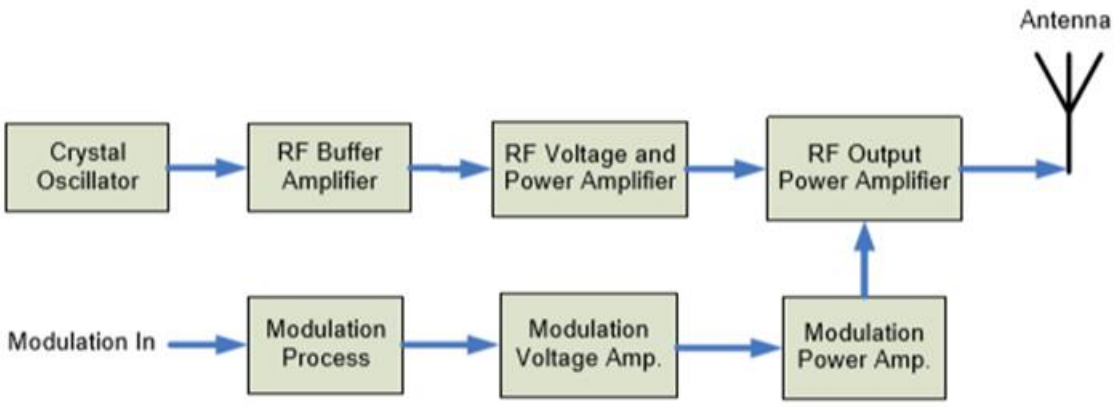


Fig: Block diagram of typical radio transmitter

- The block diagram of typical radio transmitter is shown in Fig. This transmitter block involves several operations like amplification, generation of high-frequency carrier signal, modulation and then radiation of the modulated signal.
- The amplification process essentially involves amplifying the signal amplitude values and also adding required power levels. The high-frequency signal is essential for carrying out an important operation called modulation.
- The carrier signal is characterized by the three parameters amplitude, frequency and phase. The modulation process involves varying one of these three parameters in accordance with the variation of the message signal.
- The modulated signal from the modulator is transmitted or radiated into the atmosphereusing an antenna as the transducer. Which converts the signal energy in guided wave form to free space electromagnetic waves and vice versa.

Block diagram of super heterodyne receiver:

- The receiver block receives the incoming modified version of the message signal fromthe channel and processes it to recreate the original form of the message signal.
- There are a great variety of receivers in communication systems, depending on the processing required to recreate the original message signal. Most of the receivers do conform broadly to the super heterodyne type, as does the simple broadcast receiver whose block diagram is shown in Fig.

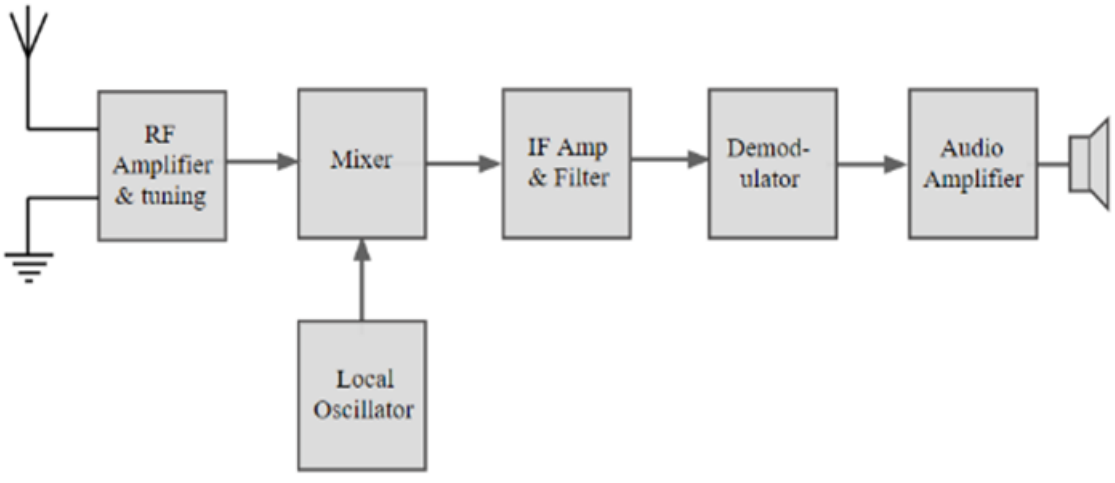


Fig: Block diagram of AM super heterodyne receiver.

- The super heterodyne receiver includes processing steps like reception, Amplification, mixing, demodulation and recreation of message signal.
- Among the different processing steps, demodulation is the most important one which converts the message signal available in the modified form to the original electrical version of the message. Thus demodulation is essentially an inverse operation of modulation.
- RF amplifier selects the desired radio wave and enhances the strength of the wave to the desired level.
- Mixer and local oscillator combines RF amplifier and local oscillator frequencies and produces an intermediate frequency (IF). IF is the difference between oscillator frequency and radio frequency.
- The Audio signals are extracted from the demodulation circuit and it is amplified by AF amplifier.

MODULATION

Modulation is the process of changing the parameters of the carrier signal, in accordance with the instantaneous values of the modulating signal. Types of modulation are AM, FM and PM.

1. **Amplitude modulation (AM):**

   AM is defined as the modulation technique in which the instantaneous amplitude of the carrier signal is varied in accordance with the instantaneous amplitude of the analog modulating signal to be transmitted.

2. **Frequency Modulation (FM):**

   A modulating signal may vary the frequency of the carrier keeping the amplitude and phase constant. This type of modulation is called Frequency modulation. Broadly speaking, the frequency modulation is the process of changing the frequency of the carrier voltage in accordance with the instantaneous value of the modulating voltage.

3. **Phase modulation:**

   Phase modulation is the process in which the instantaneous phase of the carrier signal is varied in accordance with the instantaneous amplitude of the modulating signal.

Need of modulation:

- Increases operating range of communication.
- Reduces size of transmitting & receiving antennas.
- Avoids mixing of signals.
- Improves quality of reception.
- Allows adjustments in the bandwidth.
- Extremely difficult to radiate low frequency signals through earth's atmosphere in form of electromagnetic energy.

Noise:

Noise is an unwanted signal which interferes with the original message signal and corrupts the parameters of the message signal. This alteration in the communication process, leads to the message getting altered. It is most likely to be entered at the channel or the receiver.

Effects of Noise:

- Noise is an inconvenient feature which affects the system performance. Following are the effects of noise.
  - Noise limits the operating range of the systems.
  - Sensitivity is the minimum amount of input signal necessary to obtain the specified quality output. Noise affects the sensitivity of a receiver system, which eventually affects the output.
- Noise indirectly places a limit on the weakest signal that can be amplified by an amplifier. The oscillator in the mixer circuit may limit its frequency because of noise. A system's operation depends on the operation of its circuits. Noise limits the smallest signal that a receiver is capable of processing.
  - Noise affects the sensitivity of receivers
  - The noise might distract the receiver, causing them not to hear the sender's message properly. Or it might distract the sender, making it difficult for them to communicate the message effectively.