MAR GREGORIOS COLLEGE OF ARTS & SCIENCE

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DEPARTMENT OF ELECTRONICS & COMMUNICATION SCIENCE

SUBJECT NAME: ELECTRICAL AND ELECTRONICS INSTRUMENTATION

SUBJET CODE: TAG5C

SEMESTER: V

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ELECTRICAL AND ELECTRONIC INSTRUMENTATION (SYLLABUS)

UNIT I

DC INDICATION INSTRUMENTS – PMMC Galvanometer (D' Arsonal Movement) – Principle, Constructionand Working – Conversion of Galvanometer into Ammeter, Voltmeter and Ohmmeter (Series and Shunt Types) – Multimeter – Loading Effect.

AC INDICATING INSTRUMENTS – Electrodynamometer – Principle, Construction and Working – Merits andDemerits – Rectifier Type Instruments – thermocouple Instruments (Contact & Non-contact types) – electrostatic Voltmeters – Principle, construction and Working – Watt-hour Meter.

UNIT II

DC BRIDGES – Wheatstone bridge – Determination of resistance – Kelvin Double Bridge – Determination ofresistance.

AC BRIDGES – Maxwell's Bridge – Determination of Self-Inductance – Wien's Bridge – Determination ofFrequency – Schering's Bridge – Determination of Capacitance.

UNIT III

OSCILLOSCOPES – Block Diagram – Deflection Sensitivity – electrostatic Deflection – Electrostatic Focusing –CRT Screen – Measurement of Waveform frequency, phase difference and Time Intervals – Sampling Oscilloscope – Storage Oscilloscopes (Introduction).

UNIT IV

INSTRUMENTATION AMPLIFIERS AND SIGNAL ANALYZER – Instrumentation amplifier – ElectronicVoltmeter – Electronic Multimeter – Digital Voltmeter – Ohm meter – Function Generation – Wave analyzer – Fundamentals of Spectrum Analyzer.

UNIT V

TRANSDUCERS AND DISPLAY DEVICES – Strain gauge, Linear voltage differential transformer(LVDT),Resistance Thermometer – Photoelectric Transducer – LED,LCD – Seven Segment Display.

Electrical and Electronic Instrumentation

UNIT I

PMMC Galvanometer

Construction:

- PMMC stands for 'Permanent magnet moving coil'. It is one of the simple and most used instruments.
- They are also known as D'alvanometer (A type of galvanometer based on D'Arsonval principles).
- A PMMC Equipment consists of two main parts; moving coil and a permanent magnet along with other parts.

1. **Magnet System**

   A big U-shaped or horse shoe magnet is used.

2. **Moving Coil**

   It is made up of copper coils wounded to a rectangular block in between the magnetic poles.

   The rectangular block is made up of Aluminum former pivoted to the jeweled bearing. This allows the coil to rotate freely.

   When current is passed through these coils; it receives a deflection in the field which is then used to determine the voltage / Current magnitude.

3. **Control**

   Two springs made of phosphorus bronze acts as a control system for the permanent magnet moving coil. These springs are mounted on the jewel bearing of PMMC; providing the essential controlling torque.

   They oppose the force of deflection; so the electromagnetic force of Moving Coil come in equilibrium with the spring tension.

   This helps in keeping the pointer at a fixed position after an initial deflection.

4. Scale and Pointer

The pointer connected to the moving coil moves over a marked scale. The pointer moves along with the coil deflection to show readings marked on the scale.

Working Principle of a PMMC Instrument:

- When a current caring conductor is placed in a magnetic field; it experiences a force perpendicular to the field and the current." (Fleming Left Hand Rule). This force tends to move the conductor.

- According to Fleming left-hand rule; if your left-hand thumb, fore finger, and middle finger are at 90 degrees to each other, then the magnetic field would be along with the fore finger, current across the middle while the force along with the thumb.
- The moving system is subjected to the following three torques:
  1. A deflecting or operating torque
  2. A controlling or restoring torque
  3. A damping torque
- DEFLECTING TORQUE

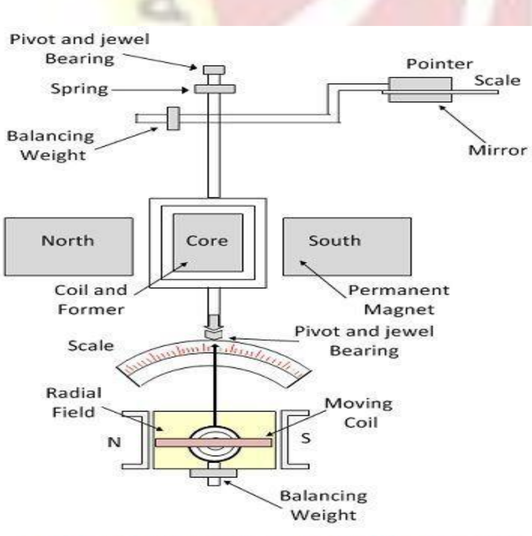
The deflecting torque is produced by electromagnetic induction effect of current or voltage and cause the moving system of the instrument to move from its zero position.

- CONTROLLING TORQUE

It increases with increase in deflection of moving system. Without controlling torque the pointer will swing at its maximum position & will not return to zero after removing the source. Controlling torque is produced either by spring or gravity control.

- DAMPING TORQUE

Due to inertia of the moving system, the pointer will not come to rest immediately but oscillate about its final deflected position. The damping torque is proportional to the speed of rotation of the moving system,



Permanent Magnet Moving Coil Instrument

Let a current I flow through the rectangular coil of n number of turns and a cross-sectional area A. When this coil is placed in a uniform radial magnetic field B, the coil experiences a torque τ.

Hence the torque acting on n turns of the coil is given by

τ = BIAN

Where B is the magnetic flux, I is the current in the coil, A is the area of the coil and N is the number of turns of coil

The magnetic torque thus produced causes the coil to rotate, and the phosphor bronze strip twists. In turn, the spring S attached to the coil produces a counter torque or restoring torque kθ which results in a steady angular deflection.

Damping Mechanism

Depending upon the degree of damping introduced in the moving system, the instrument may have any one of the following conditions:

1. Under damped condition: The response is oscillatory
2. Over damped condition: The response is sluggish and it rises very slowly from its zero position to final position.
3. Critically damped condition: When the response settles quickly without any Oscillation, the system is said to be critically damped.

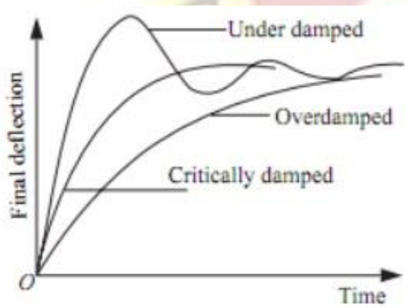


Fig. 12.3 *Dynamic response of a measuring instrument*

Sensitivity of Moving Coil Galvanometer:

The sensitivity of a moving coil galvanometer is given as the ratio of change in deflection of the galvanometer to the change in current in the coil.

$S = d\theta/dI$

The sensitivity of a galvanometer is higher if the instrument shows larger deflection for a small value of current.

Sensitivity is of two types, namely current sensitivity and voltage sensitivity.

Current Sensitivity

The deflection θ per unit current I is known as current sensitivity θ/I

$\theta/I = nAB/k$

Voltage Sensitivity

The deflection θ per unit voltage is known as Voltage sensitivity θ/V. Dividing both sides by V in the equation $\theta = (nAB / k)I$

$\theta/V = (nAB / V k)I = (nAB / k)(I/V) = (nAB / k)(1/R)$

R stands for the effective resistance in the circuit.

Factors Affecting Sensitivity of A Galvanometer

a) Number of turns in the coil

b) Area of the coil

c) Magnetic field strength B

d) The magnitude of couple per unit twist k/nAB

Figure of Merit of a Galvanometer

It is the ratio of the full-scale deflection current and the number of graduations on the scale of the instrument. It is also the reciprocal of the current sensitivity of a galvanometer.

Applications of Galvanometer

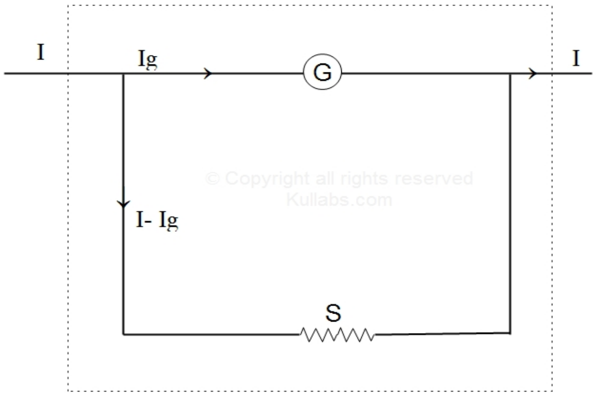
The moving coil galvanometer is a highly sensitive instrument due to which it can be used to detect the presence of current in any given circuit. If a galvanometer is a connected in a Wheatstone's bridge circuit, the pointer in the galvanometer shows null deflection, i.e no current flows through the device. The pointer deflects to the left or right depending on the direction of the current.

The galvanometer can be used to measure:

a) the value of current in the circuit by connecting it in parallel to low resistance.

b) The voltage by connecting it in series with high resistance.

Conversion of Galvanometer into DC Ammeter:



Ammeter

An Ammeter is an instrument use to measure the current passing through a Circuit. A Galvanometer can be converted to ammeter by connecting a low resistance called shunt in parallel to the Galvanometer. Since the shunt resistance is parallel with meter movement, the voltage drops across shunt and movement must be same and

Vshunt = Vmovement

IsRs = ImRm and Is = Im.Rm/Rs

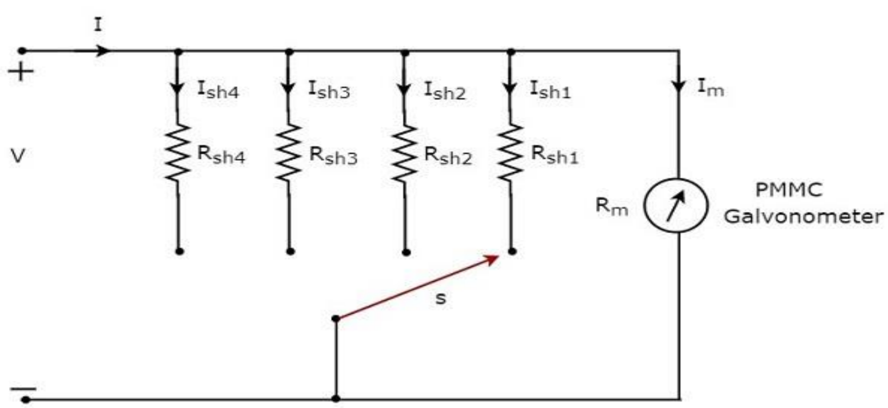
Since Is = I – Im , we can write

Rs = Im.Rm /I – Im

For each required value of full scale-meter current we can solve for the value of shunt resistance.

Multi range Ammeter:

If we want to use the DC ammeter for measuring the Direct Currents of **multiple ranges**, then we have to use multiple parallel resistors instead of single resistor and this entire combination of resistors is in parallel to the PMMC galvanometer.

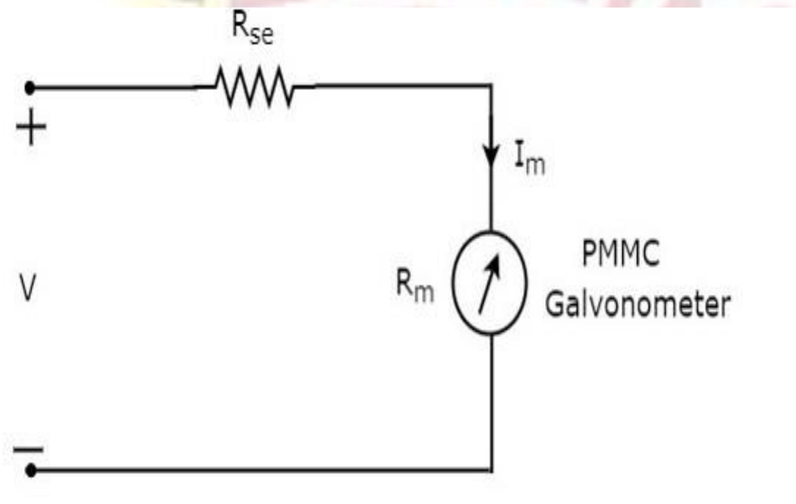


Precautions when using an ammeter in a circuit

- Never connect an ammeter across an source EMF . Because of low resistance it draws more current . Always connect an ammeter in series with the load
- Observe the correct polarity . Reverse Polarity causes the meter to deflect against the mechanical stop which damages the pointer
- When using a multi range meter first use the highest range, Then decreases the range according to the value.

DC Voltmeter:

DC voltmeter is a measuring instrument, which is used to measure the DC voltage across any two points of electric circuit. If we place a resistor in series with the Permanent Magnet Moving Coil (PMMC) galvanometer, then the entire combination together acts as **DC voltmeter**. The series resistance, which is used in DC voltmeter is also called series multiplier resistance or simply, multiplier. It basically limits the amount of current that flows through galvanometer in order to prevent the meter current from exceeding the full scale deflection value.



We have to place this DC voltmeter across the two points of an electric circuit, where the DC voltage is to be measured. Apply **KVL** around the loop of above circuit.

$$V - I_m R_{se} - I_m R_m = 0$$ (Equation 1)

$$\Rightarrow V - I_m R_m = I_m R_{se}$$

$$\Rightarrow R_{se} = \frac{V - I_m R_m}{I_m}$$

$$\Rightarrow R_{se} = \frac{V}{I_m} - R_m$$ (Equation 2)

Where,

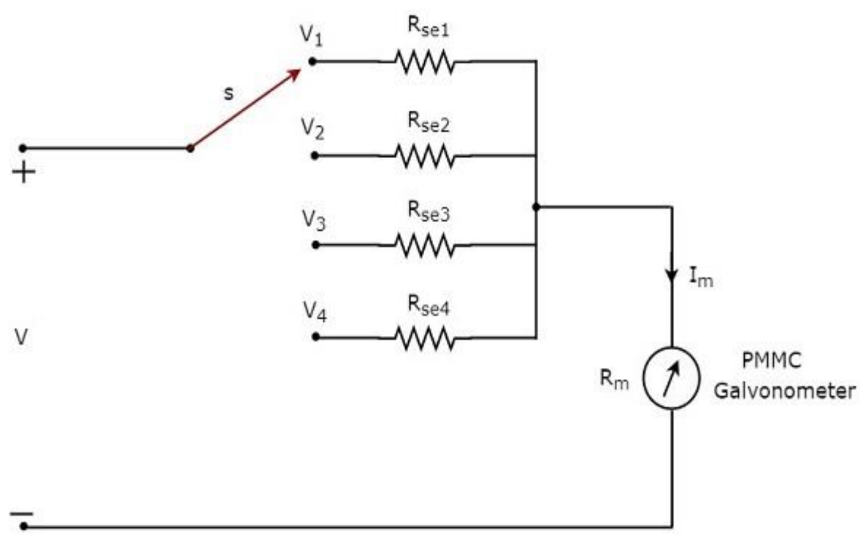
R_{se} is the series multiplier resistance

V is the full range DC voltage that is to be measured

I_m is the full scale deflection current

Multi Range DC Voltmeter:

If we want to use the DC voltmeter for measuring the DC voltages of **multiple ranges**, then we have to use multiple parallel multiplier resistors instead of single multiplier resistor and this entire combination of resistors is in series with the PMMC galvanometer.



We have to place this **multi range DC voltmeter** across the two points of an electric circuit, where the DC voltage of required range is to be measured. We can choose the desired range of voltages by connecting the switch s to the respective multiplier resistor.

Precautions when using an Voltmeter in a Circuit:

- Connect an Voltmeter across a source or load.
- Observe the correct polarity . Reverse Polarity causes the meter to deflect against the mechanical stop which damages the pointer.
- When using a multi range meter first use the highest range, Then decreases the range according to the value.
- Be aware of Loading Effect.

Loading Effect:

- A low resistance voltmeter may give correct reading when measuring voltage in low resistance circuit. But the Voltmeter produces unreliable reading when connected in high resistance circuit.
- This is because, as the resistance of voltmeter is less when compared to the circuit resistance, this will act as a shunt path for the current and therefore the voltage drop across the resistor where we want to measure the voltage will be less.
- Because of this the reading of voltmeter will not be the actual voltage.
- This is called Loading Effect.

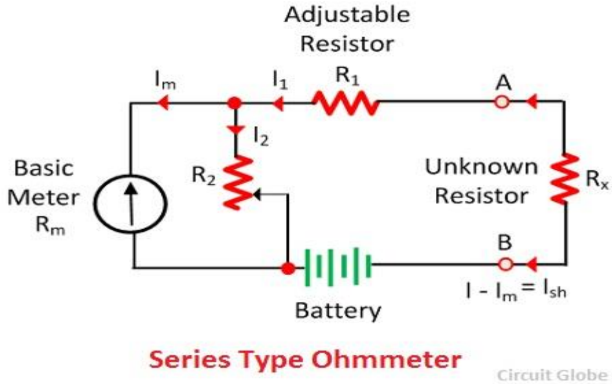
Series Type Ohmmeter:

The OHMMETER is an instrument which measures resistance of a quantity.There are two types of Ohmmeter. They are

1. Series type
2. Shunt type

Series type ohmmeter:

- The circuit consists of PMMC instrument connected in series with a resistance and a battery connected to a pair of terminals to which the unknown resistance has to be connected.



- The current through the movement depends on magnitude of unknown resistor and the meter indication is proportional to the value of the unknown.

R1= current limiting resistance

R2=Zero adjustment resistor

E= Internal Battery

Rm = Internal resistance of d'Arsonal movement

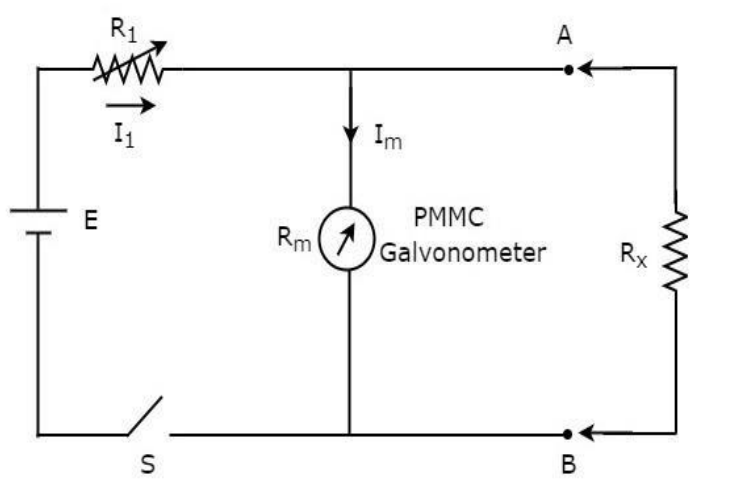
Rx = Unknown resistor

When Rx = 0 i.e.when terminals A and B shorted maximum current flows in the circuit.Shunt resistance R2 is adjusted until the movement indicates full scale deflection current (Ifsd). The full scale position is marked as 0Ω on the scale.When Rx=∞ then terminals A and B are open and current in the circuit drops to zero.

For different values of Rx, the meter shows different deflections. Series ohmmeter is useful for measuring **high values of resistances.**

Shunt Ohmmeter:

If the resistor's value is unknown and to be measured by placing it in parallel (shunt) with the ohmmeter, then that ohmmeter is called shunt ohmmeter.



If Rx=0Ω, then the terminals A & B will be short circuited with each other. Due to this, the entire current, I1I1 flows through the terminals A & B. In this case, no current flows through PMMC galvanometer. Hence, the **null deflection** of the PMMC galvanometer can be represented as 0Ω.

If Rx=∞Ω, then the terminals A & B will be open circuited with each other. So, no current flows through the terminals A & B. In this case, the entire current, I_1 flows through PMMC galvanometer. If required vary (adjust) the value of resistor, R1 until the PMMC galvanometer shows full scale deflection current. Hence, this **full scale deflection** current of the PMMC galvanometer can be represented as ∞Ω.

In this way, by considering different values of Rx, the meter shows different deflections. Shunt ohmmeter is useful for measuring **low values of resistances**.

Calibration of DC instruments

- The calibration is the process of checking the accuracy of the result by comparing it with the standard value.
- In other words, calibration checks the correctness of the instrument by comparing it with the reference standard.
- It helps us in determining the error occur in the reading and adjusts the voltages for getting the ideal reading.

Calibration of Voltmeter

- The circuit consists of a DC source, a rheostat, Resistance, voltmeter under test and Standard meter.
- The voltage across the dropping resistor R is accurately measured with a standard meter.

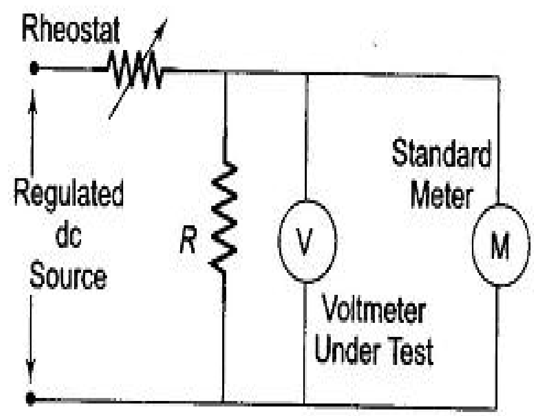


Fig. 4.32 Calibration of Voltmeter

- The meter to be calibrated is connected across the same two points and should indicate the same voltage.
- A rheostat is connected to the circuit to control the amount of current so that several points on the voltmeter scale can be calibrated.
- This method gives an accuracy of ± 0.01%.

Calibration of DC Ammeter

- Connect the two terminals of the ammeter across the resistor.
- Connect the two terminals of ammeter in series with the resistor.

- Switch on voltage supply and set to 1v.
- Calculate the expected value of current using Ohms law.
- Compare this with the measured value shown on the ammeter.

If the values are different adjust the calibration knob to match the reading.

Calibration of Ohmmeter

- The Ohmmeter is generally considered to be an instrument of moderate accuracy and low precision.
- A rough calibration may be done by measuring a standard resistance and noting the reading of Ohmmeter.
- Doing this for several points on the ohmmeter scale the meter can be calibrated.

AC Indicating Instruments

Electrodynamometer

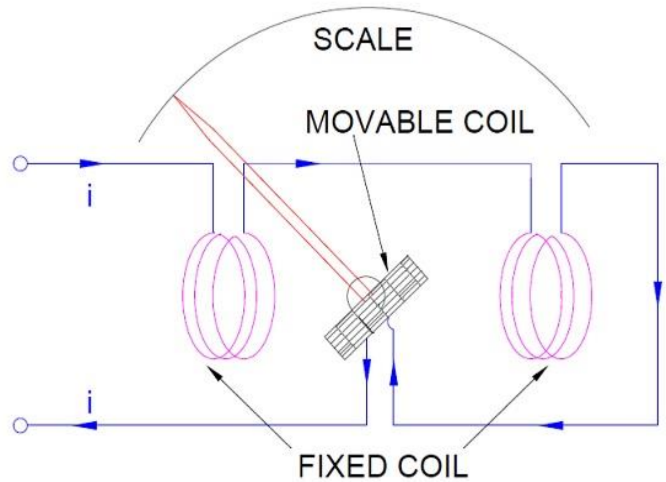
- Electrodynamic type instrument is used for the measurement of AC and DC quantities unlike PMMC instrument which can only be used for the measurement of DC quantity.

Construction of Electrodynamic Type Instrument

- The instrument consists of Two Fixed Coil, a Moving Coil, Control Spring, Damping Device and Magnetic Shielding arrangement. Fixed Coil: Fixed coil which is divided into two equal halves provides uniform magnetic field in which the movable coil rotates. The two coil halves are connected in series with the movable coil and are fed by current under measurement.
- **Moving Coil :** The movable coil carries a pointer which is balanced by counter weights. Its rotation is controlled by springs.
- **Damping:** Air friction damping is employed in electrodynamic type instrument. To provide air friction damping, a pair of aluminium vane is attached to the spindle at the bottom. These vanes move in a sector shaped chamber.
- **Shielding:** The complete assembly is surrounded by laminated shield to protect the instrument from stray magnetic fields which may affect its operation. The operation of Instrument may be understood by the expression for Torque,

  T=BxAxIxN

- The torque is directly proportional to coil constants (A and N), the strength of the magnetic field in which the coil moves (B) and the current(I) through the coil. The flux density depends on the current through the fixed coil and is proportional to the deflecting current.



Advantages:

- These instruments are free from hysteresis losses and eddy current losses.
- They have a precision grade accuracy.
- These instruments can be used on both A.C and D.C. They are also used as a transfer instruments.
- Electrodynamometer voltmeters are very useful where accurate RMS values of voltage, irrespective of waveforms, are required.

Disadvantages:

- They have a non-uniform scale.
- These instruments have a low sensitivity due to a low torque to weight ratio.
- They are more expensive than either the PMMC or the M.I type instruments.
- These instruments are sensitive to overloads and mechanical impacts. Therefore, they must be handled with great care.
- The operating current of these instruments is large due to the fact that they have a weak magnetic field.

Rectifier Type Instrument

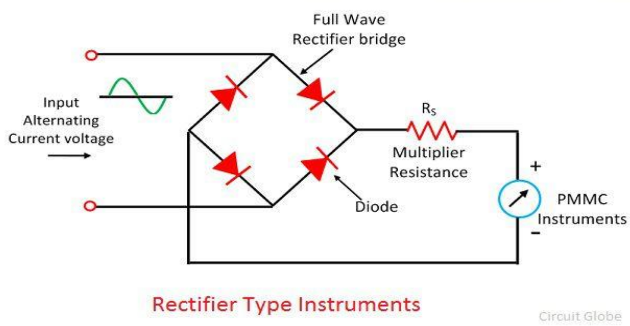
Definition:

- The instrument which uses the rectifying element for measuring the voltage and current is known as the rectifying instruments.The rectifying element converts the alternating current to the direct current which indicates by the DC responsive meter.

  The PMMC uses this as an indicating instrument.The sensitivity of the rectifying instruments is high as compared to the moving coil and the Electrodynamometer instrument. Thereby, it uses for measuring the current and voltage.

Circuit Diagram:

The device uses the four diodes which act as a rectifying element.The multiplier resistance R_s uses for limiting the value of current so that their value does not extend more than the rating of the PMMC instrument. The rectifier element is used for the conversion of the AC to DC so that the unidirectional current flows through the PMMC instrument. The rectifying instrument does not have any voltage drops in the forward direction and no current flows in the reverse direction.



The AC voltage is applied to the circuit. The rectifying element converts the AC voltage into unidirectional DC voltage. Thus, the rectified output voltage obtains through the rectify instrument. The PMMC instrument deflects through the average value of current which depends on the average voltage of the apparatus.

Advantages of Rectifying Instrument:

- The frequency range of the instruments increases from 20HZ to high-frequency range.
- The current operating range for such type of instrument is much lower for voltmeter as compared to the other AC instrument.
- The instrument has uniform scales for the large range.
- The accuracy of the instrument is ±5 percent when it is in normal operating condition.

Applications of Rectifying Instrument:

- The instrument uses for measuring the voltage whose range lies between 50 –250 V.
- It use as a milliammeter or micro-ammeter.
- The rectifying instrument is used in the communication circuit for measurement.

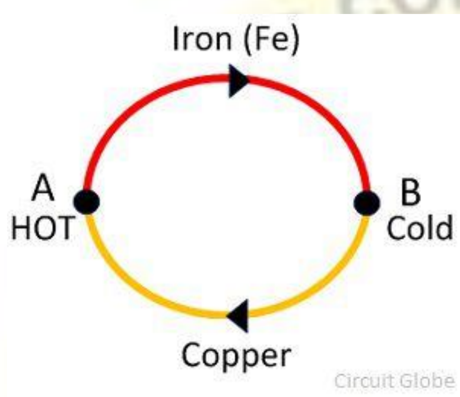
Thermocouple

Definition:

The thermocouple is a temperature measuring device. It is used to measure the temperature at one particular point. In other words, it is a type of sensor used for measuring the temperature in the form of an electric current or the EMF.

Working Principle of Thermocouple:

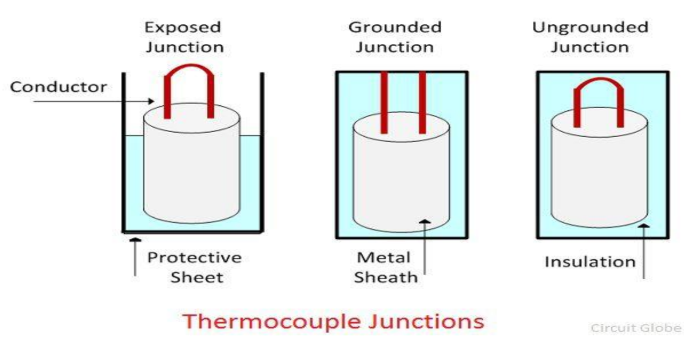
- The working principle of the thermocouple depends on the three effects.
- See back Effect – The See back effect occurs between two different metals. When the heat provides to any one of the metal, the electrons start flowing from hot metal to cold metal. Thus, direct current induces in the circuit.
- It is a phenomenon in which the temperature difference between the two different metals induces the potential differences between them. The See beck effect produces small voltages for per Kelvin of temperature.



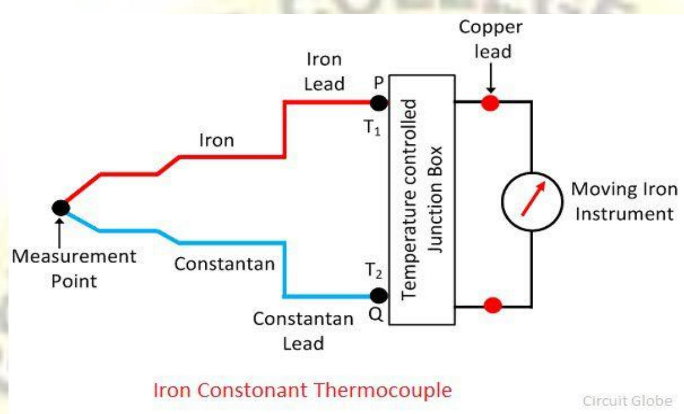
- Peltier Effect – The Peltier effect is the inverse of the Seebeck effect. The Peltier effect state that the temperature difference can be created between any two different conductors by applying the potential difference between them.
- Thompson Effect – The Thompson effect state that when two dissimilar metals join together and if they create two junctions then the voltage induces the entire length of the conductor because of the temperature gradient. The temperature gradient is a physical term which shows the direction and rate of change of temperature at a particular location.

Construction of Thermocouple

The thermocouple consists two dissimilar metals. These metals are welded together at the junction point. This junction considers as the measuring point. The junction point categorises into three types.



- Ungrounded Junction – In ungrounded junction, the conductors are entirely isolated from the protective sheath. It is used for high-pressure application works. The major advantage of using such type of junction is that it reduces the effect of the stray magnetic field.
- Grounded Junction – In such type of junction the metals and protective sheath are welded together. The grounded junction use for measuring the temperature in the corrosive environment. This junction provides resistance to the noise.
- Exposed Junction – Such type of junction uses in the places where fast response requires. The exposed junction is used for measuring the temperature of the gas.
- The material used for making the thermocouple depends on the measuring range of temperature.



Working of Thermocouple:

The circuit consists two dissimilar metals. These metals are joined together in such a manner that they are creating two junctions. The metals are bounded to the junction through welding.Let the P and Q are the two junctions of the thermocouples. The T_1 and T_2 are the temperatures at the junctions. As the temperature of the junctions is different from each other, the EMF generates in the circuit.If the temperature at the junction becomes equal, the equal and opposite EMF generates in the circuit, and the zero current flows through it.

If the temperatures of the junction become unequal, the potential difference induces in the circuit.The magnitude of the EMF induces in the circuit depends on the types of material used for making the thermocouple.The total current flowing through the circuit is measured through the measuring devices.

The EMF induced in the thermocouple circuit is given by the equation

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

Where $\Delta\theta$ – temperature difference between the hot thermocouple junction and the reference thermocouple junction. a, b – constants.

Measurement of Thermocouple Output:

- **Multimeter** – It is a simpler method of measuring the output EMF of the thermocouple. **The multimeter is connected to the cold junctions of the thermocouple**. The deflection of the multimeter pointer is equal to the current flowing through the meter.
- **Potentiometer** – The output of the thermocouple can also be measured with the help of the DC potentiometer.

Advantages of Thermocouple:

The following are the advantages of the thermocouples.

- The thermocouple is cheaper than the other temperature measuring devices.
- The thermocouple has the fast response time.
- It has a wide temperature range.

Disadvantages of the Thermocouple:

- The thermocouple has low accuracy.
- The recalibration of the thermocouple is difficult.
- Nickel-alloy, platinum/rhodium alloy, Tungsten/rhenium-alloy, chromel-gold, iron-alloy are the name of the alloys used for making the thermocouple.

Applications:

- These are used as the temperature sensors in thermostats in offices, homes, offices & businesses.
- These are used in industries for monitoring temperatures of metals in iron, aluminum, and metal.
- These are used in the food industry for cryogenic and Low-temperature applications. Thermocouples are used as a heat pump for performing thermoelectric cooling.
- These are used to test temperature in the chemical plants, petroleum plants.
- These are used in gas machines for detecting the pilot flame.

Electrostatic Voltmeter

Definition:

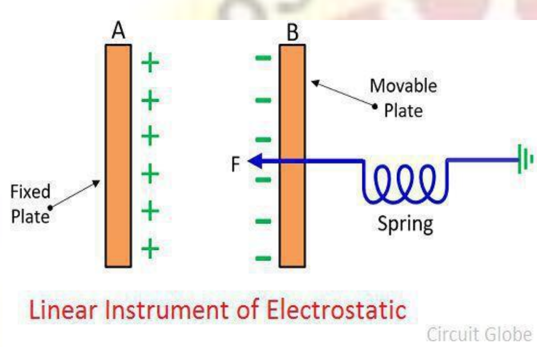
The instrument working depends on the principle of attraction or repulsion of electrodes that carry electrical charges such type of instrument is known as the electrostatic instrument. In other words, the instrument which uses the static electric field for producing the deflecting torque is known as the electrostatic instrument. The electrostatic instrument is used for measuring the high and low voltage and also the power of the given circuit.

Principle:

The electrostatic instrument works on the principle of mechanical interaction of the electrodes that consists the opposite electrical charge. The quantity which is measured by the electrostatic instrument is converted into either AC or DC voltage.

There are two ways of constructions of electrostatic instruments;

- In the electrostatic instrument, the charge is stored between the plates. The electrostatic instrument consists the charges of two opposite polarity and force of attraction occurs between these two plates. Because of the force of attraction, the movable plates move towards the fixed plates and store the maximum electrostatic energy.
- In this type of instruments, there are forces of attraction or repulsion that occurs between the rotary plate.



- When the voltage is applied to the plate, then the force of attraction induces between them.The plate tries to moves towards A until the force becomes maximum. The C is the capacitance (in farad) between the plate. The expression gives the total energy stores between the plates.

Let us assume there exists some force F between the two plates at equilibrium when electrostatic force becomes equal to spring force. At this point, the electrostatic energy stored in the plates is

$$\frac{1}{2}CV^2$$

If we increase the applied voltage by an amount dV, due to this the plate B moves towards the plate A by a distance dx. The work done against the spring force due to displacement of the plate B be F.dx. The applied voltage is related to current as

$$i = C\frac{dV}{dt} + V\frac{dC}{dt}$$

The input energy can be calculated as

$$Vidt = V^2dC + CVdV$$

By neglecting the higher order terms that appears in the expression. Now applying the principle of energy conservation we have input energy to the system = increase in the stored energy of the system + mechanical work done by the system. From this we can write,

$$V^2dC + CVdV = \frac{1}{2}V^2dC + CVdV + Fdx$$

From the above equation the force can be calculated as

$$F = \frac{1}{2}V^2\frac{dC}{dx} \cdots\cdots\cdots(1)$$

Advantages of Electrostatic Instrument:

- Both the AC and DC voltage can be measured by using the electrostatic instrument.
- The electrostatic type instrument consumes very less power.
- The high value of voltage can be measured by using the instrument.
- In the rotary type electrostatic instrument, in spite of linear displacement, the angular displacement occurs between the fixed and the moving plates.
- The instrument has less Waveform and frequency error.
- No error occurs because of the stray magnetic field.
- The instrument is designed for large voltage.

Disadvantages of Electrostatic type instrument:

- The non-uniform scale is used in the instrument.
- The force of very small magnitude involves in the instrument.
- The instrument is quite costly as compared to the other instrument.
- The size of the instrument is also very large.

Watthour Meter

- Watthour meter is widely used for commercial measurement of Electrical Energy.

Construction:

The current coil is connected in series with the line and voltage coil is connected across/parallel with the line.Both the coils are wounded on a metal frame which provides two magnetic circuits.Two magnets connected opposite to each other in the rim of the disk.A light Aluminium disk is suspended in the air gap of the current coil field which causes the eddy current to flow through the disk.A shaft is connected to the Aluminium disk which helps in free movement of disk.It is connected by a gear arrangement to the clock mechanism in front of the meter.

Working:

The reaction of eddy currents and field of the voltage coil creates a torque on the disk which makes it rotate.The developed torque is proportional to the field strength of the voltage coil and eddy current in the coil which in turn the function of field strength of the current coil.The number of rotations of the disk is proportional to the energy consumed by the load in a certain interval of time.The energy consumed in measured in kilowatt hours.Damping is provided by the magnets.

When the disk rotates the magnets induce eddy currents in them.The Eddy current react with the magnetic field which creates damping of the disk.Calibration of Watthour meter is done under full rated load and 10% of rated load.At full load the magnets are adjusted till the meter shows the correct reading.At light load the voltage component is verified.These two methods of calibration provides correct readings for all other load.Measurement of energy in three phase meter is done with polyphase watthour meters.

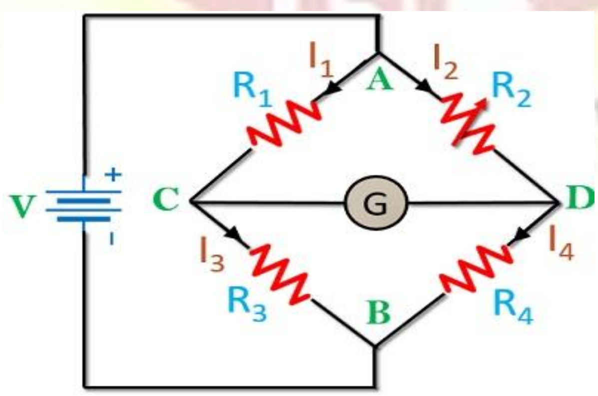
Each phase has its own magnetic circuit and disk and all the disks are mounted on a common shaft.The developed torque on each disk is added. Total number of revolutions is directly proportional to the three phase energy consumed.

UNIT II

DC Bridges

Wheatstone bridge

Wheatstone bridge is a type of dc bridge that is used for the measurement of unknown resistance.The circuit consists of four resistances R_1, R_2, R_3 and R_4. R_2 is the variable resistance and R_4 is the unknown resistance.



Wheatstone bridge circuit

The two opposite corners of the bridge is connected to a source of electric current, such as battery, while the galvanometer is connected across the other two opposite corners. The current through the galvanometer depends on the potential difference between the two point C and D. To find the value of unknown resistor we have to first balance the bridge circuit. The bridge is balanced when there is no current flow through the galvanometer. The potential difference across the galvanometer is zero.The variable resistor is adjusted until the galvanometer reads zero. In order to determine the bridge balance equation,

$$I_1 R_1 = I_2 R_2$$

Where

$$I_1 = I_3 = \frac{V}{R_1 + R_3}$$

$$I_2 = I_4 = \frac{V}{R_2 + R_4}$$

Substituting the values of I1 and I2 in the bridge balance equation we get

$$\frac{V\ X\ R_1}{R_1 + R_3} = \frac{V\ X\ R_2}{R_2 + R_4}$$

$$R_1 X\ (R_2 + R_4) = R_2 X\ (R_1 + R_3)$$

$$R_1 R_2 + R_1 R_4 = R_2 R_1 + R_2 R_3$$

Thus, on cancelling like terms from both the sides, we will have,

$$R_4 = \frac{R_2 R_3}{R_1}$$

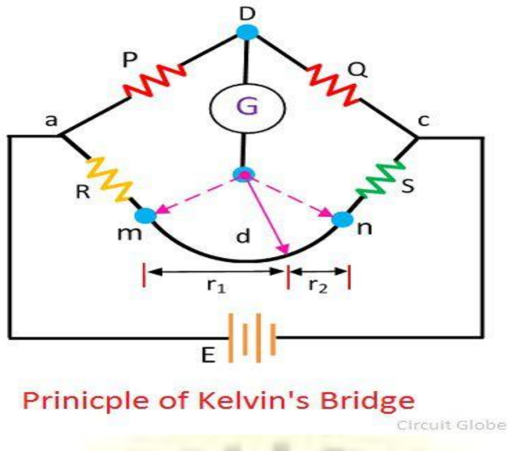
Hence, we can determine the value of unknown resistance in balanced condition using known resistances.

Kelvin Bridge

The Kelvin bridge is the modification of Wheatstone bridge. It measures the low resistance values with more accuracy. Ry is the rresistance of the connecting lead from R3 to Rx. Points m and n shows the two possible connections for galvanometer. The ratio of resistance between n and p and between m and p, namely, Rnp and Rmp respectively, will be given by

$$\frac{R_{np}}{R_{mp}} = \frac{R_1}{R_2}$$

$$\frac{R_{np} + R_{mp}}{R_{mp}} = \frac{R_1 + R_2}{R_2}$$



Therefore, $R_{mp} = \frac{R_2 R_y}{R_1 + R_2}$ (2)

Similarly, $R_{np} = \frac{R_1 R_y}{R_1 + R_2}$ (3)

- Now, the balance condition for the bridge becomes,

$$(R_x + R_{np})R_2 = R_1(R_3 + R_{mp})$$

$$R_x + R_{np} = \frac{R_1}{R_2}(R_3 + R_{mp})$$

- Then substituting the values of R_{np} and R_{mp} from equations (2) and (3) into the above equation, we get

$$R_x + \frac{R_1 R_y}{R_1 + R_2} = \frac{R_1}{R_2}\left(R_3 + \frac{R_2 R_y}{R_1 + R_2}\right)$$

$$R_x + \frac{R_1 R_y}{R_1 + R_2} = \frac{R_1 R_3}{R_2} + \frac{R_1 R_y}{R_1 + R_2}$$

$$R_x = \frac{R_1 R_3}{R_2} \qquad (4)$$

- Equation (4) above is called the balance equation and it shows that the effect of resistance of the connecting lead from m to n has been removed by connecting the galvanometer to the intermediate position p.

Kelvin Double Bridge

Kelvin double bridge contains one more set of ratio arms. The second set of arms, a and b, connect the galvanometer to a point c at the appropriate potential between m and n connection, i.e. Ry. The ratio of the resistances of arms a and b is the same as the ratio of R1 and R2. The galvanometer indication is zero when the potentials at k and c are equal.

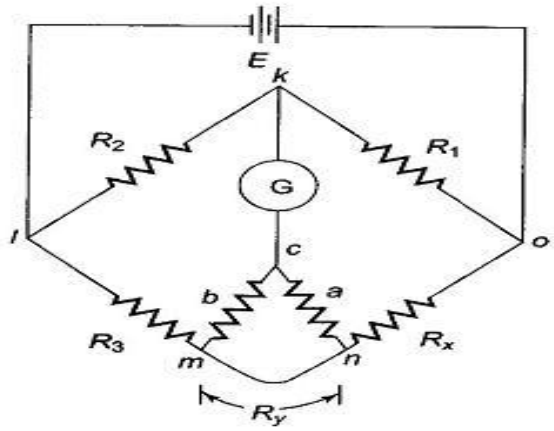


Fig. 11.11 Kelvin's Double Bridge

$$E_{lk} = E_{lmc}$$

$$E_{lk} = \frac{R_2}{R_1 + R_2} \times E \qquad (11.9)$$

$$E = I\left(R_3 + R_x + \frac{(a+b)R_y}{a+b+R_y}\right)$$

Substituting for E in Eq.(11.9)

$$E_{lk} = \frac{R_2}{R_1 + R_2} \times I\left(R_3 + R_x + \frac{(a+b)R_y}{a+b+R_y}\right) \qquad (11.10)$$

$$E_{lmc} = I\left(R_3 + \frac{b}{a+b}\left[\frac{(a+b)R_y}{a+b+R_y}\right]\right) \qquad (11.11)$$

$$E_{lk} = E_{lmc}$$

i.e. $$\frac{IR_2}{R_1 + R_2}\left(R_3 + R_x + \frac{(a+b)R_y}{a+b+R_y}\right) = I\left[R_3 + \frac{b}{a+b}\left\{\frac{(a+b)R_y}{a+b+R_y}\right\}\right]$$

$\therefore$ $$R_3 + R_x + \frac{(a+b)R_y}{a+b+R_y} = \frac{R_1 + R_2}{R_2}\left(R_3 + \frac{bR_y}{a+b+R_y}\right)$$

$\therefore$ $$R_3 + R_x + \frac{(a+b)R_y}{a+b+R_y} = \left(\frac{R_1}{R_2} + 1\right)\left(R_3 + \frac{bR_y}{a+b+R_y}\right)$$

$$R_x + \frac{(a+b)R_y}{a+b+R_y} + R_3 = \frac{R_1 R_3}{R_2} + R_3 + \frac{b R_1 R_y}{R_2 (a+b+R_y)} + \frac{b R_y}{a+b+R_y}$$

$$R_x = \frac{R_1 R_3}{R_2} + \frac{b R_1 R_y}{R_2 (a+b+R_y)} + \frac{b R_y}{a+b+R_y} - \frac{(a+b)R_y}{a+b+R_y}$$

$$R_x = \frac{R_1 R_3}{R_2} + \frac{b R_1 R_y}{R_2 (a+b+R_y)} + \frac{b R_y - aR_y - bR_y}{a+b+R_y}$$

$$R_x = \frac{R_1 R_3}{R_2} + \frac{b R_1 R_y}{R_2 (a+b+R_y)} - \frac{aR_y}{a+b+R_y}$$

$$R_x = \frac{R_1 R_3}{R_2} + \frac{b R_y}{(a+b+R_y)}\left(\frac{R_1}{R_2} - \frac{a}{b}\right)$$

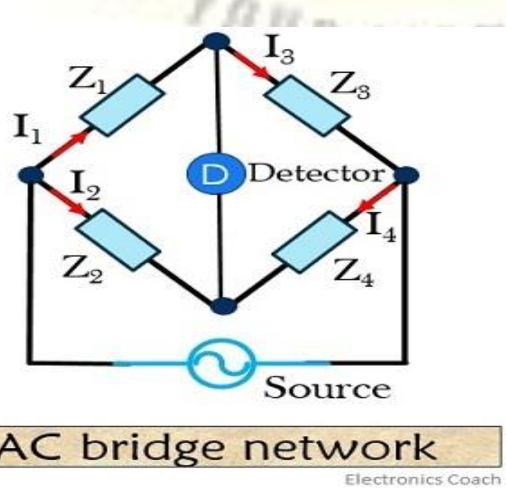
But $\frac{R_1}{R_2} = \frac{a}{b}$

Therefore, $R_x = \frac{R_1 R_3}{R_2}$

This is the usual equation for Kelvins Bridge theory. It indicates that the resistance of the connecting lead has no effect on the measurement, provided that the ratios of the resistances of the two sets of ratio arms are equal. The range of a resistance covered is 1 — 0.00001 Ω (10 μohm) with an accuracy of ± 0.05% to ± 0.2%.

AC Bridges

AC bridges are used for the measurement of **electrical quantities** such as inductance, capacitance etc.An AC bridge consists of 4 nodes with **4 arms**, a **source** excitation and a balanced **detector**. Each of the 4 arms of the bridge consists of impedance.



AC bridge network

- The conditions for the balance of bridge require that there should be no current through the detector.This requires that the potential difference between points b and d should be zero.This will be the case when the voltage drop from a to b equals to voltage drop from a to d, both in magnitude and phase.

$$E_1 = E_2$$
$$I_1 Z_1 = I_2 Z_2$$

Also at balance,

$$I_1 = I_3 = \frac{E}{Z_1 + Z_3}$$
$$I_2 = I_4 = \frac{E}{Z_2 + Z_4}$$

On Substitutions we get,

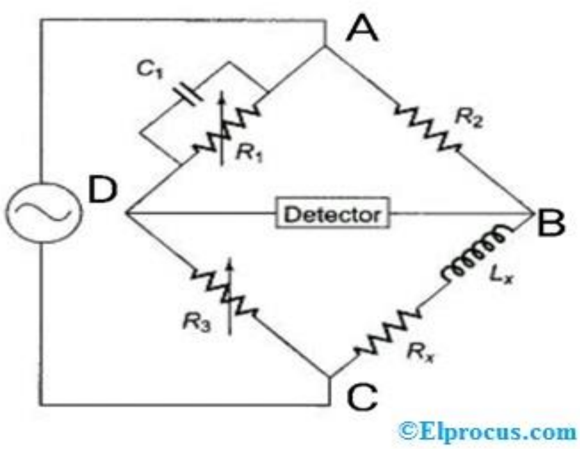
Z1 Z4 = Z2 Z3

When using admittances instead of impedances

Y1 Y4 = Y2 Y3

MAXWELL BRIDGE

The Maxwell bridge is used to measure an unknown inductance in terms of a known capacitance. Maxwell’s bridge is an AC bridge having four arms in which wo arms of the bridge consist of a single resistor, one arm consists of a series combination of resistor and inductor & the other arm consists of a parallel combination of resistor and capacitor.



The balance condition of the bridge can be given by

$Z_1 Z_X = Z_2 Z_3$

$Z_X = Z_2 Z_3 Y_1$

where $Y_1 = 1/Z_1$ = admittance

$$Y_1 = \frac{1}{Z_1} = \frac{1}{R_1} + \frac{j}{X_1} = \frac{1}{R_1} + j\omega C_1 \qquad (2)$$

$$Z_2 = R_2 ; \quad Z_3 = R_3 \qquad (3)$$

$$Z_x = R_x + jX_L = R_x + j\omega L_x \qquad (4)$$

$$R_x + j\omega L_X = R_2 R_3 \left(\frac{1}{R_1} + j\omega C_1\right)$$

$$R_x + j\omega L_X = \left(\frac{R_2 R_3}{R_1} + j\omega C_1 R_1 R_2\right)$$

- Equating the real parts of the above equation we get

$$R_x = \frac{R_2 R_3}{R_1}$$

- Equating the imaginary parts we get

$$L_x = R_2 R_3 C_1$$

Limitation of the Maxwell Bridge:

It is not suitable for the determination of the self-inductance of coils having quality factor Q > 10 or Q < 1. It is suitable for the coils having Q values in the range 1<Q.

Schering Bridge

Schering bridge is used to measure the value of capacitance. One arm consists of a single resistor, one arm consists of a series combination of resistor and capacitor, one arm consists of a single capacitor & the other arm consists of a parallel combination of resistor and capacitor.

Let, Z1, Z2,Z3 and Z4 are the impedances of arms DA, AB, CD and BC respectively.

The **values of these imepedances** will be

$$Z_x = Z_2 Z_3 Y_1 \qquad (1)$$

- The impedances of the arms are given by

$$\frac{1}{Z_1} = Y_1 = \frac{1}{R_1} + \frac{j}{X_{C1}} = \frac{1}{R_1} + j\omega C_1 \; ; \qquad Z_2 = R_2 \; ; \qquad (2)$$

$$Z_3 = -jX_{C3} = \frac{-j}{\omega C_3} ; \qquad Z_x = R_x - jX_{Cx} = R_x - \frac{j}{\omega C_X} \qquad (3)$$

- Substituting the values from equations (2) and (3) into equation (1), we get

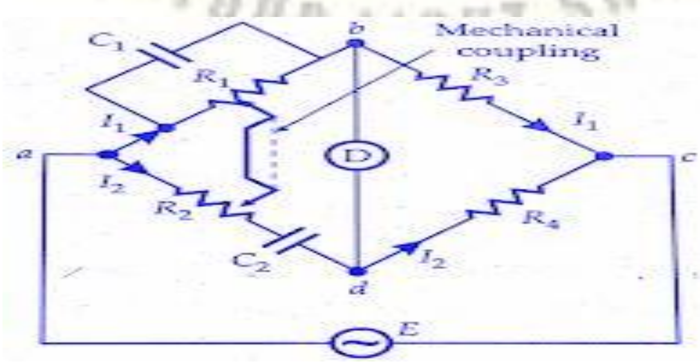
$$R_x - \frac{j}{\omega C_X} = R_2 \left(\frac{-j}{\omega C_X}\right)\left(\frac{1}{R_1} + j\omega C_1\right)$$

$$R_x - \frac{j}{\omega C_X} = \frac{R_2 C_1}{C_3} - \frac{jR_2}{\omega C_3 R_1}$$

- Then equating the real and imaginary parts in the above equation, we get

$$R_x = R_2 C_1 / C_3 \qquad \text{and} \qquad C_x = C_3 R_1 / R_2 \qquad (4)$$

WIEN BRIDGE



A Wien bridge is generally used to measure the frequency of the source. It is also extensively used in other applications like, harmonic distortion analyser, in audio and HF oscillators as the frequency determining element, etc.The Wien bridge consists of a series RC combination in one arm and a parallel RC combination in the adjoining arm.

The balance condition for the bridge is given by

$$Z_2 Z_3 = Z_1 Z_4$$

$$Z_2 = Z_1 Z_4 (1/Z_3) = Z_1 Z_4 Y_3$$

The impedances of the arms are given by the following equations

$$Z_1 = R_1 - jX_{C1} = R_1 - \frac{j}{\omega C_1} \quad ; \quad Z_2 = R_2 ; \qquad (2)$$

$$1/Z_3 = Y_3 = \frac{1}{R_3} + \frac{j}{X_{C3}} = \frac{1}{R_3} + j\omega C_3 \quad ; \quad Z_4 = R_4 \qquad (3)$$

- Substituting the values from equations (2) and (3) into equation (1), we get

$$R_2 = \left(R_1 - \frac{j}{\omega C_1}\right) R_4 \left(\frac{1}{R_3} + j\omega C_3\right)$$

$$R_2 = \frac{R_1 R_4}{R_3} + j\omega C_3 R_1 R_4 - \frac{jR_4}{\omega C_1 R_3} + \frac{R_4 C_3}{C_1} \qquad (4)$$

- Equating the real parts we get,

$$R_2 = \frac{R_1R_4}{R_3} + \frac{R_4C_3}{C_1}$$

- Dividing by R_4 on both the sides we get

$$\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1} \qquad (5)$$

- Now equating the imaginary parts we get,

$$j\omega C_3R_1R_4 = \frac{jR_4}{\omega C_1R_3} \qquad 5)$$

$$\omega^2 = \frac{1}{C_1C_3R_1R_3} \qquad \text{where } \omega = 2\pi f$$

$$f = \frac{1}{2\pi\sqrt{C_1C_3R_1R_3}} \qquad (7)$$

- If $R_1 = R_3 = R$ and $C_1 = C_3 = C$, then we get $R_2 = 2R_4$ and

$$f = \frac{1}{2\pi RC} \qquad (8)$$

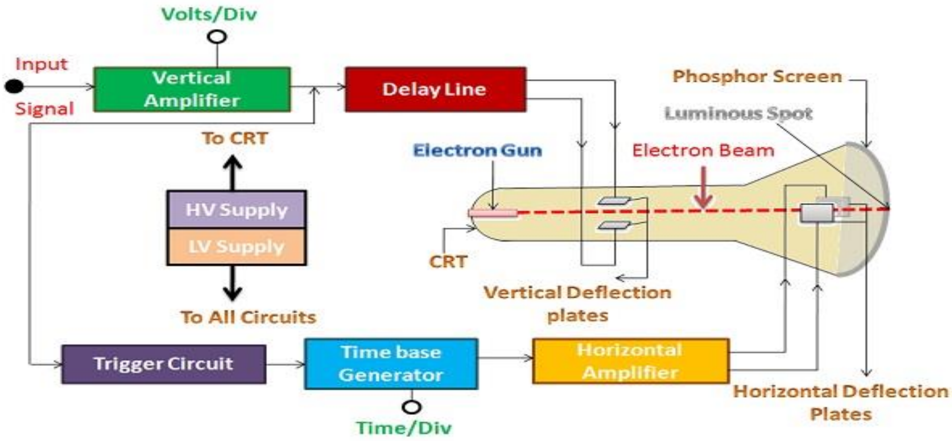
- Using the above equation, we can determine the frequency of the source. Also the bridge can be calibrated directly in terms of frequency.

UNIT III

Oscilloscope

Block Diagram of Oscilloscope

The cathode ray oscilloscope is the instrument which reproduces the waveform of any electrical quantity. The waveform is displayed in such a way that the amplitude of the signal is represented along Y-axis and the variation in the time is represented along X-axis.



Block Diagram of a general purpose CRO

Cathode Ray Tube

The cathode ray tube consists of an electron gun, vertical deflection plates, horizontal deflection plates, phosphor screen and electrode. The electron gun generates the beam of an electron when the voltage is applied to it. The voltage applied for accelerating the beam of electron is very high.The beam of an electron when generated by the electron gun is passed from vertical deflection plate and horizontal deflection plate and it creates the pattern on the phosphor screen. When the light ray strikes the phosphor screen, a bright spot or luminous spot is created.

Vertical Amplifier

The vertical amplifier receives the input signal and then amplifies it so that the signal of high intensity is supplied to the vertical deflection plate.If a low-intensity signal strikes the vertical deflection plate the vertical amplifier helps in effective reproduction of signal on the screen.

Horizontal Amplifier

The horizontal deflection plates deflect the beam along the horizontal direction. This is helpful to create the waveform along with the time domain.The horizontal amplifier helps to create the bright spots at the desired location on the phosphor screen.

Delay line Circuit

When the signal from the vertical amplifier is fed to the vertical deflection plates, then some part of the amplified signal is supplied to the time base generator. This trigger pulse generated from the time-based generator is amplified with the help of the horizontal amplifier.This is fed to horizontal deflection plates.This process requires approximately **100ns**. Thus a delay signal is generated by the vertical amplifier too in order to maintain synchronization.

Trigger Circuit

The trigger pulse is generated by the time base generator to provide synchronization of the signals obtained from the horizontal and vertical amplifier.

Working of Cathode Ray Oscilloscope

The electron gun generates the beam of electrons which consists of several electrons moving towards phosphor screen. The control grids are also used in **CRT (Cathode Ray Tube)** to control the intensity of electrons.The accelerating anodes are used to increase the velocity of electrons so that they strike the phosphor screen with high speed and thus forms a bright spot. The beam creates the luminous spot at the different points on the screen with the help of deflection plates which deflects the electron beam through various angles.

Position Control: The position control knob in the oscilloscope is used for controlling the position of the bright spot from left to right and top to bottom.

Brightness Control: The brightness of the beam is directly dependant on the intensity of the electrons. The control grids are responsible for the intensity of the electron in the electron beam.

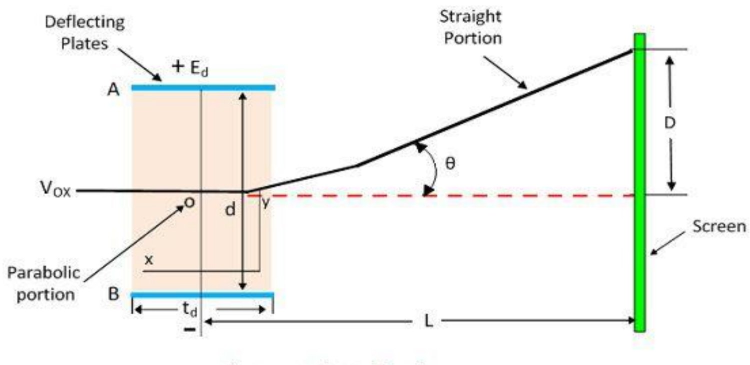
Focus Control: The focus control can be attained by adjusting the voltage applied to the middle anode of the cathode ray tube. The middle anode and the other two anodes around it form the **electrostatic lens.**

Applications of Oscilloscope

- An oscilloscope is used for voltage measurement, current measurement, measurement of other physical quantities after conversion to electrical form.
- Cathode ray oscilloscope is also used in the laboratory to study the output waveforms of various signals.
- It can also be used to measure their phase and frequency.

Electrostatic deflection:

Electrostatic deflection is the method of aligning the path of charged particles by applying the electric field between the deflecting plates. The deflection sensitivity of a CRO is defined as the vertical deflection of the beam on the screen per unit deflecting voltage. It is also defined as the deflection produced per volt of deflecting voltage. Therefore, the unit of deflection sensitivity of the CRO is – meter per volt ($m \cdot V^{-1}$). The cathode ray tube uses deflecting plates for modifying the path of electrons. The electrons after exiting through the electron gun pass through deflecting plates. The CRT uses vertical and horizontal plates for focusing the electron beam.



Electrostatic Deflection

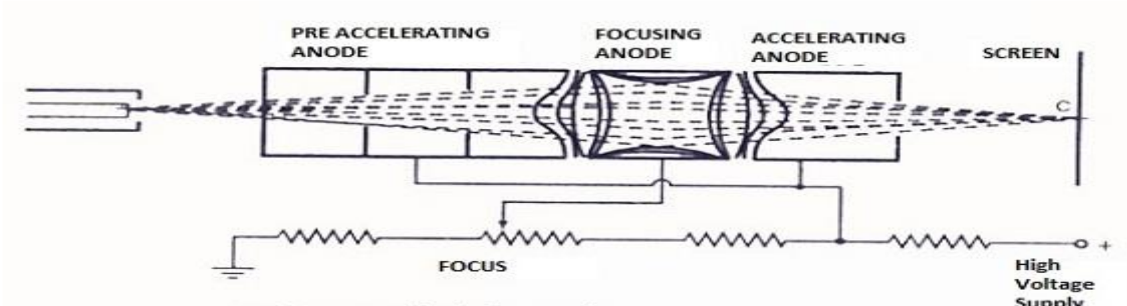
In the figure A and B are the two parallel plates between which the potential difference is applied. These deflection plates produce the uniform electrostatic field in the Y direction.The electron enters between the plates experienced the force only in the Y direction, and the electron will move only in that direction. There is no force either in X direction or the Z direction.When the electron moves from the accelerating cathode to anode, they lose their potential energy. The formula gives the potential energy of the electron.The electrons gain the kinetic energy. And their energy is given by the equation

$$K.E = \frac{1}{2}mv_{ox}^2$$

Equating the potential and kinetic energy we get the velocity of the electron when it enters in the deflecting plates.

Electrostatic Focusing:

Electrostatic lens consists of three anodes, with the middle anode at a lower potential than the other two electrodes.The pre-accelerating electrode or anode, the focusing anode and the accelerating anode are shown along with the grid structure and the supply voltages.The pre-accelerating anode A_1 and the accelerating anode A_2 are connected in common to a high positive potential. The focusing anode is connected to a lower + ve potential.As the focusing anode is negative with respect to the two accelerating anodes A_1A_2, the electric field lines are non-uniformly placed.A potentiometer is connected along with the potential divider network to supply varying voltage to the electrodes. This is called the focus control. This control is made available on the front panel of the CRO as a user control. Varying this voltage changes the focal length of the electron lens. Therefore the beam of electrons can be accurately focused on the screen by proper adjustment of the voltage on the focusing anode.



Focusing system of cathode ray tube

The electron beam enters the pre-accelerating anode through the centrally located holes. The beam then enters the electric field between the focusing anode and the accelerating anode. The high voltage anode accelerates the beam to the center of the screen.

CRT Screens

The inside of the large end of a CRT is coated with a fluorescent material that gives off light when struck by electrons. The material used to convert the electrons' energy into visible light is PHOSPHOR. Many different types of phosphor materials are used to provide different colored displays and displays that have different lengths of **PERSISTENCE** (duration of display). The phosphor absorbs kinetic energy of the bombarding electrons and reemits energy in the visual spectrum. The property of crystalline material to emit light when stimulated by radiation is called fluoroscence.

The property of phosphor to continue light emission even after the source of energy is cut off is called as phosphorescence. The amount of time during which the phosphorescence occurs is called persistence or luminance of the material.

Phosphor Type	Trace Color Under Excitation	Trace Color Afterglow	Persistence	Application
P1	green	green	medium	General purpose CRO
P2	yellow-green	yellow-green	medium-short	Observation of low- and medium-speed nonrecurrent phenomena
P4	white	yellow	medium	Television picture tube
P7	white	yellow-green	long	Observation of low-speed recurrent or medium-speed nonrecurrent phe-nomena
P11	blue	blue	medium-short	Photographic applications
P31	green	green	medium-short	Observation of low- or medium-speed nonrecurrent phenomena

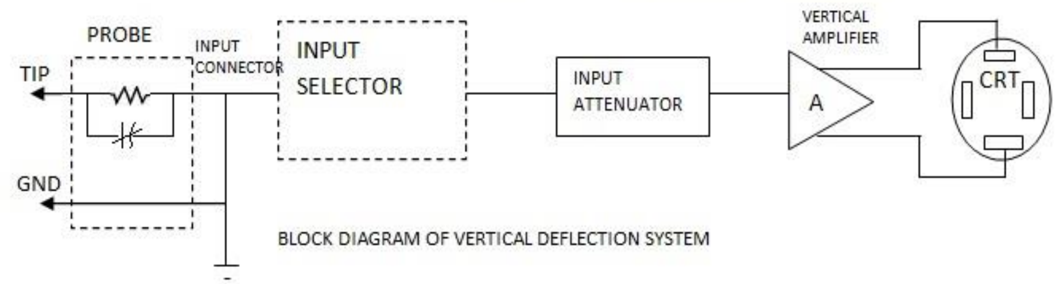
The intensity of light emitted from the CRT screen depends on

1. Screen material (coating)
2. Beam current
3. Velocity of electrons

Several screen materials are available and a proper selection of type of phosphor must be made on the basis of application of CRO.

Vertical Deflection System

The vertical deflection system is used to amplify and reproduce the input signal. The amplifier must amplify the input signal within the limits of its bandwidth, without effecting the amplitude, frequency and phase.



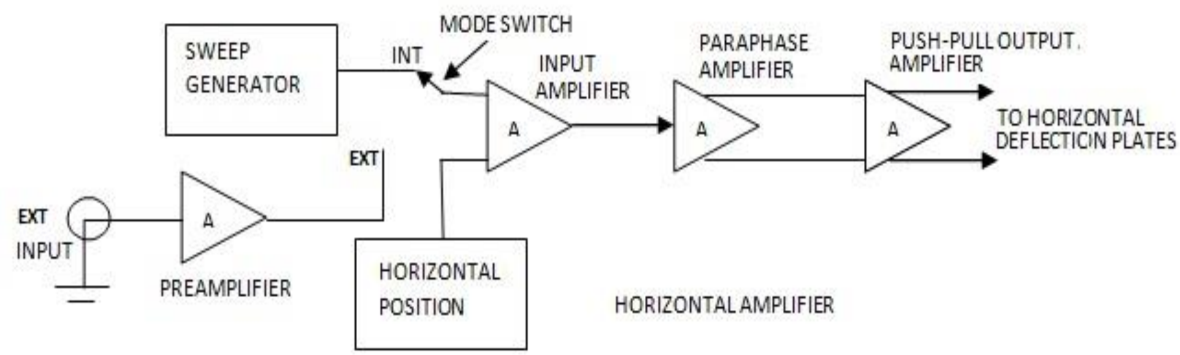
The Probe

The input to the CRO is given through the probe. An external adjustment is given in the outside panel. There are different types of probes available.

Input Selector

The input selector is nothing but a single pole three way switch. It's pole is connected to the input terminals of the vertical amplifier. The three connections are AC,DC and ground.

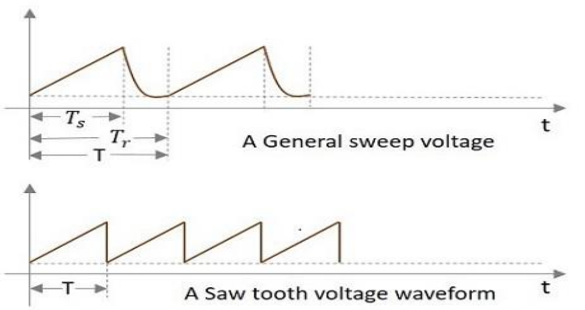
Horizontal Deflection System



Sweep generator or time base generator:

For an oscilloscope to display the waveform the voltage has to fall in its amplitudes at time periods.This voltage which is of the saw tooth waveform is applied to the horizontal deflecting plates to sweep the beam horizontally. Hence the name- sweep voltage or time base voltage.

A sweep generator is used to produce this sweep voltage. The sweep voltage will be employing an R.C. charging circuit. The capacitor after acquiring a predetermined value of charge will be discharged using a voltage operated switch.



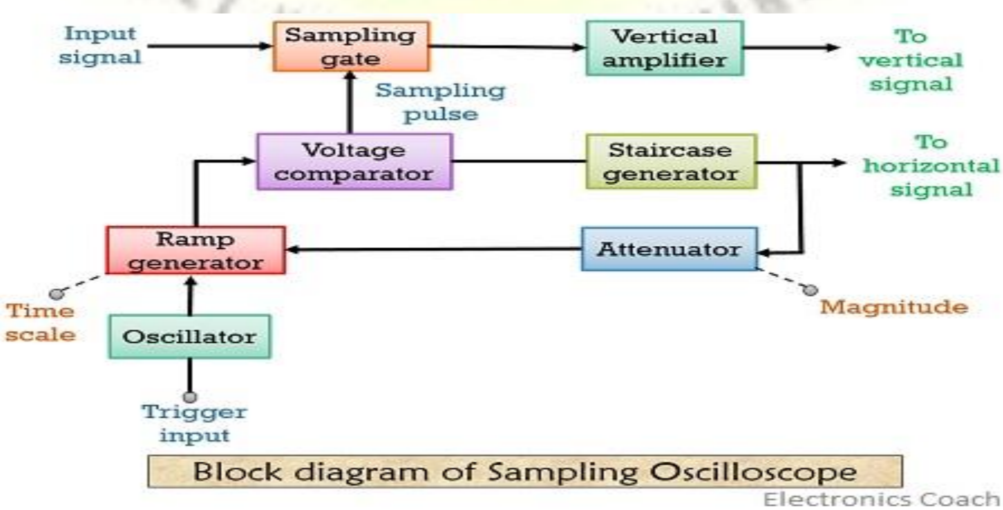
The linearly increasing portion of the voltage is called 'ramp' voltage. The time taken by the voltage to fall to the initial value from the maximum, T_r is called the retrace period.

Horizontal Amplifier

The horizontal amplifier consists of an input signal amplifier which is a single ended amplifier. The output of the input signal amplifier is given to a paraphase amplifier which drives the push pull output amplifier. The push pull output amplifier presents the positive and negative going ramp voltages of the required amplitude to the two deflecting plates.

Sampling Oscilloscope

Sampling Oscilloscope is an instrument that is used to **generate waveform by collecting various samples** of an electrical signal. It is basically an advancement of digital oscilloscope having additional features for special purposes.Itis used toanalyze fast electrical signals.In a consecutive waveform from various portions of the waveforms, different samples are taken.In order to create a waveform around 1000 points are to be needed.The input signal is fed into the sampling gate.

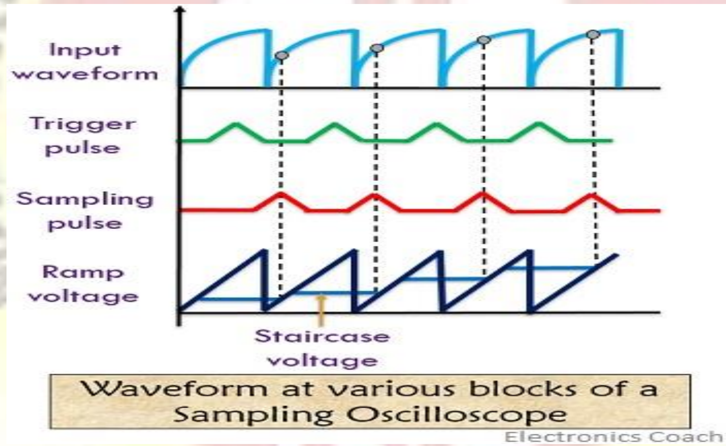


Block diagram of Sampling Oscilloscope

When the sampling pulse is provided to the sampling gate, it gets open in order to sample the input waveform. The input signal is fed into the sampling gate. When the sampling pulse is provided to the sampling gate, it gets open in order to sample the input waveform. The sampling is to be done in synchronization with the frequency of the applied input signal.

The vertical amplifier in the circuit delays the input signal and after amplification, the signal is given to the vertical plates.When the sampling cycle begins, the oscillator gets activated by the trigger pulses. Due to which, linear ramp output voltage is produced.

The signal generated from the ramp generator is then fed to the voltage comparator unit.The ramp signal gets compared with the staircase signal, generated by the staircase generator.During comparison when the amplitude of the two signals is equal, it advances the staircase by one step, thus generating a sampling pulse.This again opens the sampling gate and the cycle is repeated in a similar manner.The size of the steps generated by the staircase generator determines the resolution of the image at the output.When the size of the steps is smaller, the number of samples will be larger. Thus, the image resolution will be higher.



Waveform at various blocks of a Sampling Oscilloscope

Advantages of sampling oscilloscope

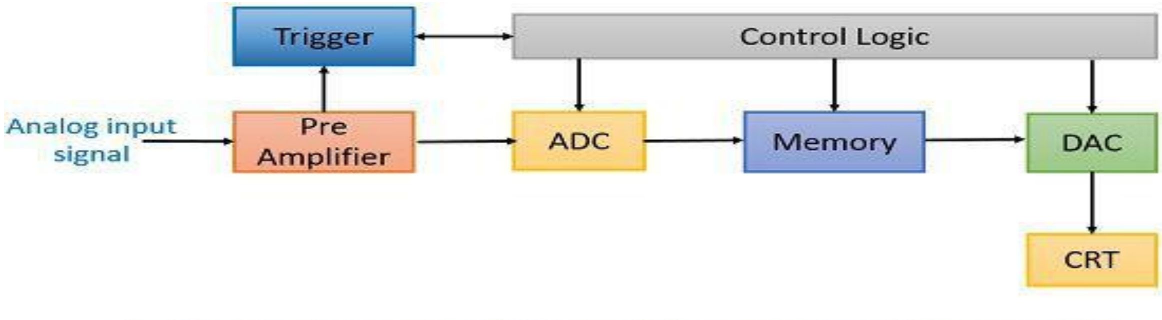
- It can measure high-speed electrical signals.
- By using sampling techniques, the input signal can be instantly transformed into a signal in a low-frequency domain. Further circuitry produces a highly efficient display.
- It has the ability to react and store information in the form of rapid bits.

Disadvantage of sampling oscilloscope

- Sampling oscilloscope allows the measurement to be done on signals having repetitive waveforms

Digital Storage Oscilloscope

Digital Storage Oscilloscope is an instrument that analyses the signal digitally and stores the data in the electronic digital memory.It digitizes the input signal in order to have subsequent digital signals. The input is stored in digital memory in the form of 0 and 1. This stored digitized signal is then viewed on the CRT screen after the signal reconstruction in analog form.



Block diagram of Digital Storage Oscilloscope

The CRT in the circuit displays the data stored in the electronic digital memory. the signal is reconstructed in analog form in order to be displayed on the screen of CRT. The analog input signal is fed into the pre-amplifier unit. This unit amplifies the input so as to raise the level of the amplitude of the signal.This signal is then fed to an analog to digital converter (ADC) and the trigger detector. As the voltage crosses the **threshold value**, the device starts recording on the application of the signal sent by the trigger unit.

The output of the pre-amplifier is sampled by the ADC at regular intervals. The **digital outpu**t provided by the ADC is **stored in memory** at consecutive locations. The recording of signal continues until the memory is full.The **DAC** employed in the circuit **produces analog signal** to be displayed in CRT.The **size of the memory** unit determines the **number of samples stored** in it. One can alter the length of recording by changing the sampling frequency of ADC.

Advantages

- They possess infinite storage time.
- It can be easily operated.

Applications

- It is used in audio and video recording.
- It is used in radio broadcasting for signal testing.
- In circuit debugging, it is used for testing of the voltage of the signal.
- In case of digital storage oscilloscope, the replacement of internal equipment is more **economical**. This is so because it employs CRT which is cheaper than analog storage oscilloscope.

UNIT IV

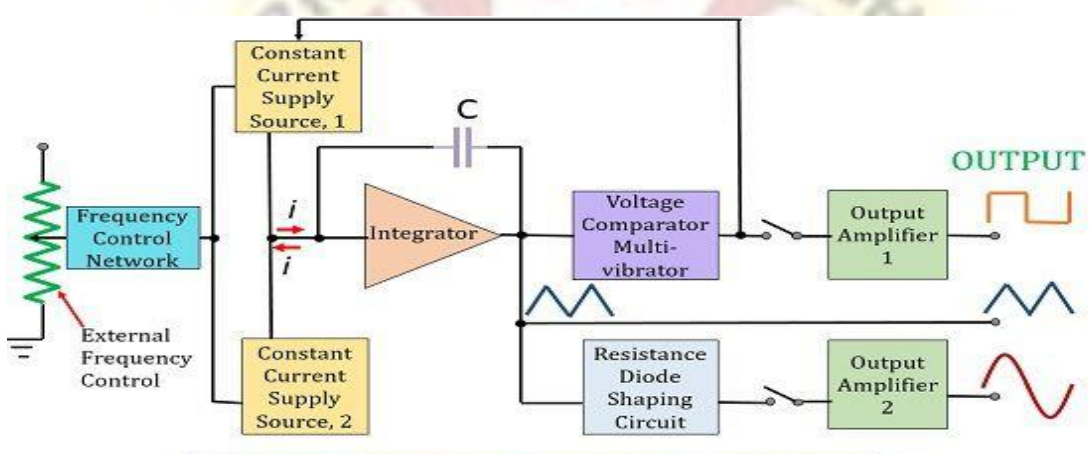
Function Generator

Function Generator is basically a signal generator that produces different types of waveforms at the output. It has the ability to produce waveforms such as sine wave, square wave, a triangular wave, saw tooth wave etc. An adjustable frequency range is provided by the function generator which is in the range of some Hz to several 100 KHz.

It provides adjustment of wave shape, frequency, magnitude and offset but requires a load connected before adjustment.A frequency control network used here whose frequency is controlled by the variation in the magnitude of current. The current sources 1 and 2 drive the integrator.A constant current is supplied to the integrator by current supply source 1. Due to this, the voltage of the integrator rises linearly with respect to time. This linear rise is according to the output signal voltage equation:

$$V_{out} = \frac{-1}{C} \int_0^t i \, dt$$

Any increase or decrease in the current will resultantly increase or decrease the slope of the voltage at the output and thus controls the frequency.



Block Diagram Of Function Generator

The **Voltage Comparator Multi-vibrator present here cause variation in the state** of the integrator output voltage at a previously determined maximum level. Due to this change of state, the current supply from source 1 cuts off and switches to supply source 2.

A reverse current is supplied to the integrator by current source 2. This reverse current cause drops in the output of integrator linearly with time.When the output attains a predetermined level, the comparator again changes its state and switches to current supply source 1.

Thus we will have a triangular wave at the output of the integrator whose frequency depends on current by the supply sources.A square wave signal is obtained at the output of the comparator.

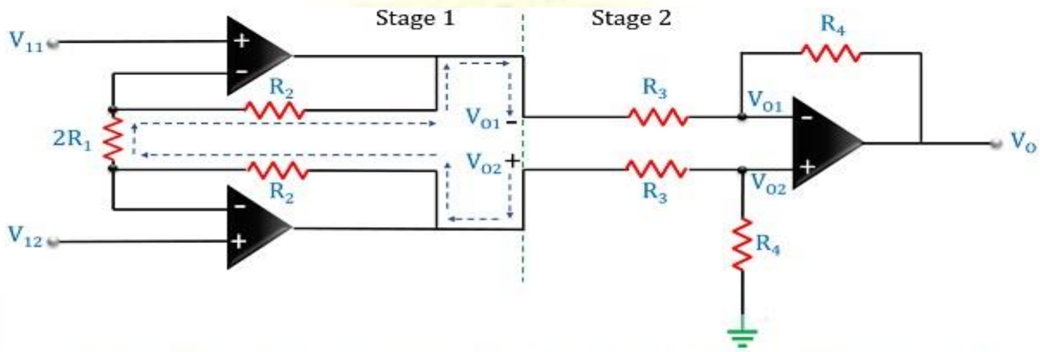
The resistance diode network employed in the circuit changes the slope of that triangular wave and the resultant wave is Sine wave.

Instrumentation Amplifier

A special type of amplifier that is used to **amplify signals of extremely low-level** is known as Instrumentation Amplifier. It is basically a differential amplifier that performs amplification of difference of input signal.It has high CMMR, offers high input impedance and consumes less power. **CMMR** stands for common mode rejection ratio, it is the ability to reject unwanted signals.

Need of Instrumentation Amplifier

In order to generate quality products, accurate measurement of a physical quantity such as temperature, pressure and humidity is the requirement of industrial and control system.Transducers are the device that is used to measure a physical quantity.Transducer basically transforms the physical quantity into its electrical form. These electrical signals are then used to operate the other units of the system. The transducer generates low-level signals. Thus, it is necessary to perform the amplification of such signals.



Three op-amp circuit of an Instrumentation Amplifier

A 3 op-amp circuit of instrumentation amplifier gives high input impedance in order to have a proper signal measurement from the transducer.The first stage is nothing but a voltage follower and the second stage is a difference amplifier.The voltage follower unit consists of 2 buffer amplifier, having high input impedance.At the input of the first stage the current flowing can be represented as:

$$I = \frac{V_{12} - V_{11}}{2R_1}$$

Let, $V_{12} - V_{11} = V_{id}$

Applying KVL at the first stage,

$$\mathbf{IR_2 + I(2R_1) + IR_2 = V_{O2} - V_{O1}}$$

$$\mathbf{2IR_2 + 2IR_1 = V_{O2} - V_{O1}}$$

Substituting the value of I in the above equation,

$$\frac{2V_{id}}{2R_1} R_2 + \frac{2V_{id}}{2R_1} R_1 = V_{O2} - V_{O1}$$

On simplifying we get,

$$\frac{V_{id}}{R_1} R_2 + \frac{V_{id}}{R_1} R_1 = V_{O2} - V_{O1}$$

$$V_{id}(\frac{R_2}{R_1} + 1) = V_{O2} - V_{O1}$$

The output V_O can be written as

$$V_O = (V_{O2} - V_{O1})\frac{R_3}{R_4}$$

Substituting the value of $V_{O2} - V_{O1}$ in the above equation, we get

$$V_O = V_{id}(\frac{R_2}{R_1} + 1)\frac{R_3}{R_4}$$

This is the equation for the overall output voltage of an instrumentation amplifier.

Advantages of Instrumentation amplifier

- It provides high CMMR.
- Instrumentation amplifier has high input and low output impedance.
- It consumes less power.

Disadvantages of Instrumentation amplifier

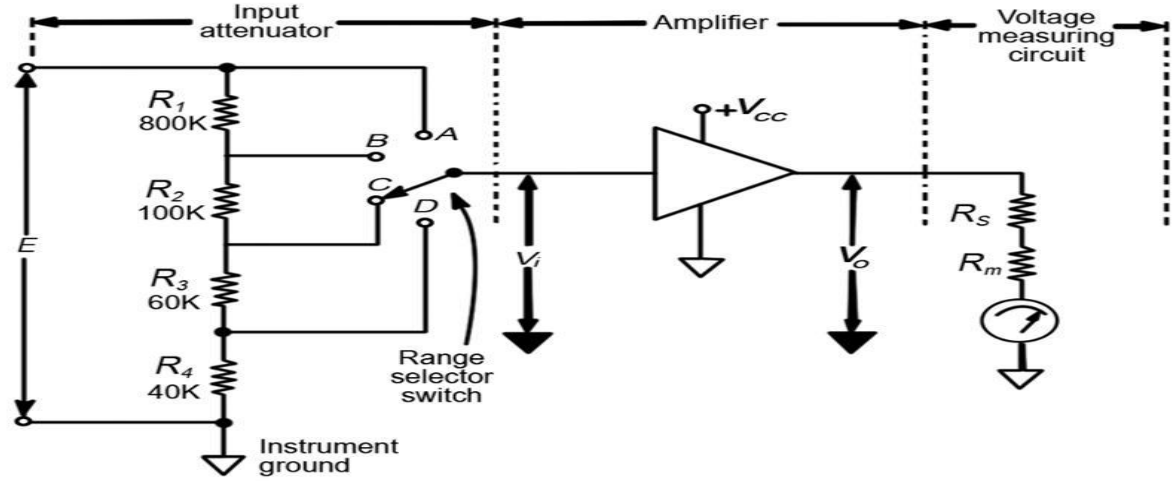
- The device performs amplification of low-level signals that has to be transmitted over long distance. But sometimes originally transmitted signal gets highly distorted due to noise effect because of long distance.

Applications of Instrumentation Amplifier

- An instrumentation amplifier can be used both as a temperature controller as well as a temperature indicator. Such amplifiers are used to show variation in the output with the corresponding variation in the temperature.
- It is widely used in amplifying the bio-signals.

Electronic Voltmeter

An analog electronic voltmeter uses an electronic amplifier to improve the performance of an electromechanical voltmeter. For example, an electronic voltmeter has a much higher input resistance than an electromechanical instrument, so voltmeter loading effect is considerably reduced. Voltage levels that are normally too small for measuring on an electromechanical instrument can be amplified to measurable levels in an electronic instrument.



This circuit is made up of three stages: an input attenuator, an electronic amplifier, and an electromechanical voltmeter stage.

Attenuator

The input attenuator is simply a voltage divider that divides (or attenuates) high input voltages to measurable levels.The amplifier has a very high input resistance.It also has a low output resistance to supply the current required by the electromechanical voltmeter stage.The attenuator switch is the voltmeter range-selection switch which is used to select the particular range.

Amplifier

The amplifier has voltage gain (or amplification) of 1, which means that a 1 V input produces a 1 V output.It acts as a buffer between the attenuator and voltage-measuring stages; thus, it is termed a buffer amplifier.

Electromechanical Voltmeter Stage

The electromechanical voltage-measuring stage is designed to give meter FSD for an amplifier output of 1 V. Because the amplifier has a gain of 1, its output voltage (V_0) is equal to the input (V_i) from the attenuator.

Advantages

- It consumes very low power
- Its accuracy level is high.
- Compact and portable in shape and size.
- It has low level of signal detection.
- Also it has high sensitivity.
- It offers very high input impedance.
- Loading effect is quite low.

Electronic Multimeter

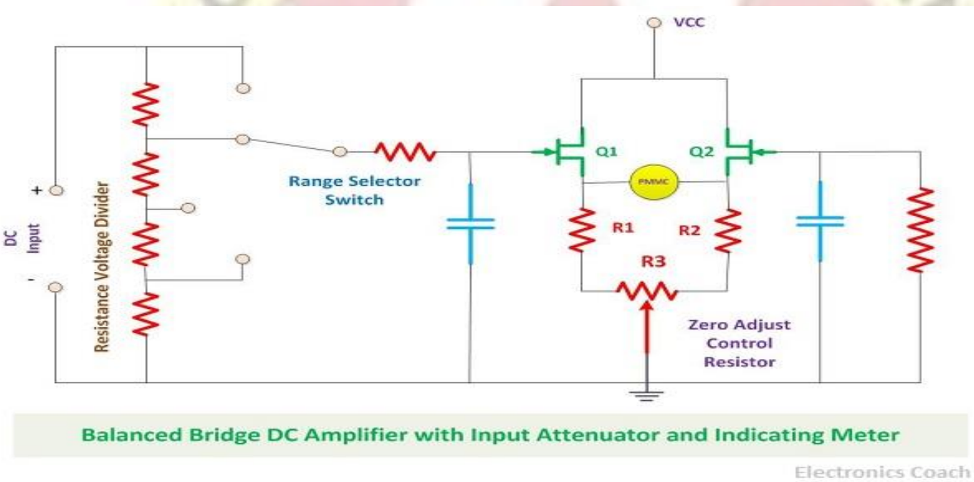
The **Electronic Multimeter** is a device which is used for the measurement of various electrical and electronic quantities such as current, voltage, resistance etc.

Construction

The multimeter basically consists of a **bridge DC amplifier, rectifier, PMMC meter, function switch, internal battery** and an **attenuator.** The function of the attenuator is to select a particular range of voltage values.The rectifier is used for the conversion of AC voltage into DC voltage. An inbuilt power supply is connected for the functioning of the device.

The Bridge DC amplifier is nothing but two Field effect transistor connected opposite to each other with three resistors forming a bridge-like structure. The two resistors are for balancing the bridge, and the third resistor is a zero adjust control resistor.

Working



Balanced Bridge DC Amplifier with Input Attenuator and Indicating Meter

Input voltage is given to the gate terminal of the **FET,** and this gate voltage is responsible for the increase in the source voltage of the FET. The **PMMC meter** is connected between the two FET.

In the ideal condition, no current should flow from PMMC meter so thus it must show zero deflection, but in the practical implementation, the PMMC meter shows some deflection. This is undesirable in steady state. Thus a **zero adjusts control resistor** is used for adjusting the value of current to zero.

The first step is to set the knob of the multimeter for the values or quantity which is to be measured.The second step is to set the range of multimeter.The resistance can be measured by multimeter easily by connecting the two probes of the multimeter with two ends of a resistor.The unknown resistor the resistance of which is to be measured is connected to the function switch and the battery.The battery of 1.5 V is connected to the circuit when the resistor is connected and the voltage across the resistor is measured by the circuit.As the value of resistance increases the value of the voltage drop across it increases, and thus the PMMC meter shows the deflection accordingly. In this way, the value of resistance is measured.

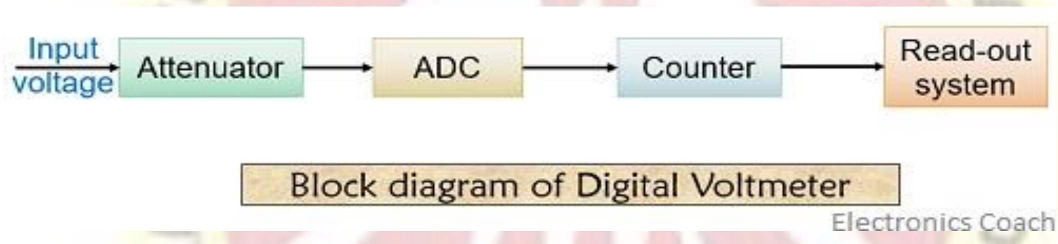
Advantages

- The input impedance is high.
- The frequency range is high.
- The construction is rugged.
- The circuit is simple.
- It is less suffered from electric noise.
- The cost is less

Digital Voltmeter (DVM)

Digital Voltmeter is a **voltage sensitive device**. It **measures AC** or **DC voltage** and **displays** the value directly in **numeric form** instead of pointer deflection. **DVM** is an acronym for **Digital Voltmeter. This** provides greater accuracy.The input range of DVM may vary from **±1 V** to **1000 V**. Precision DVM offers **input resistance** of **1 GΩ** or high for a voltage range of less than **20 V**.

Block diagram of Digital Voltmeter



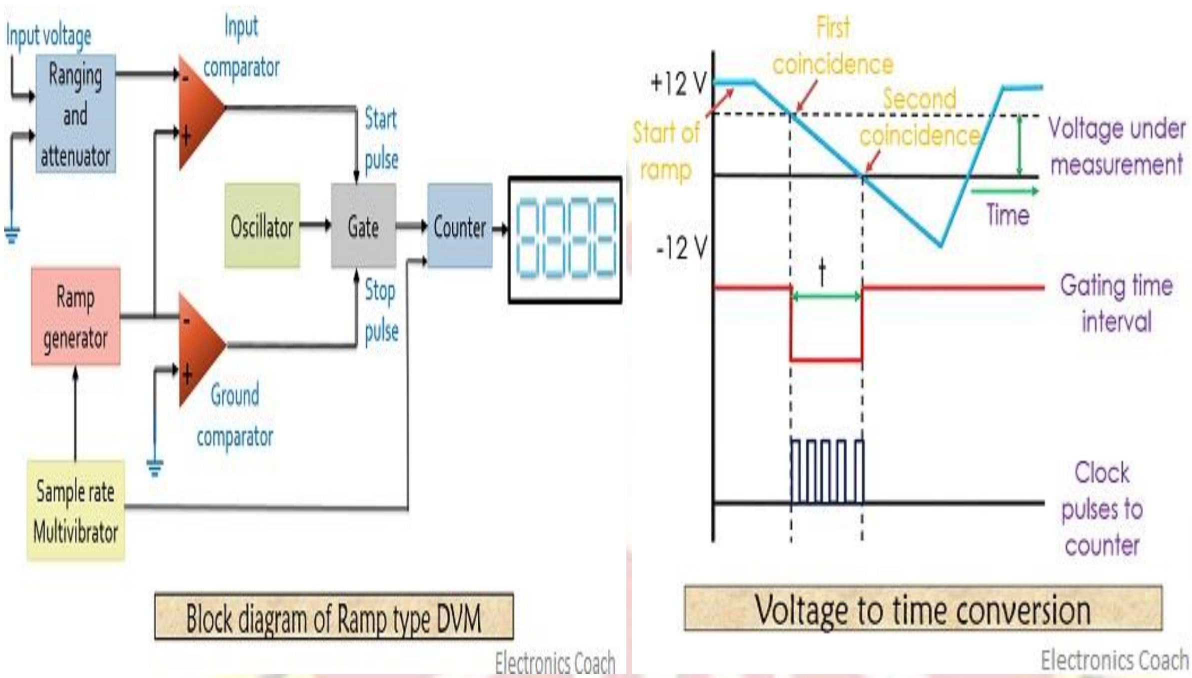
A counter section is usually a **decade counter**. The **read-out system** is used to display the **digital voltage** of the input signal. The attenuator section consists of a series resistance that attenuates the input signal.An attenuator placed here minimizes the excess voltage that can damage the other components of the device. It is basically a **predefined resistive network** that performs attenuation for circuit protection.The ADC connected in the circuit converts analog signal into digital one in order to provide the digital output. A digital signal is the one having **2 levels** i.e., **0** and **1**. This will provide us a sequence of digital pulses. These digital pulses are then fed to the Decade counter unit. A decade counter counts in decimal values. These decade counters have the ability to count from **0-9** i.e., **10 counts**. Hence the three will count up to 1000.**IC 7447** converts the BCD value into **7 segment display**.

Types of Digital Voltmeter

1. Ramp type DVM
2. Dual Slope Integrating DVM
3. Successive approximation DVM

Ramp type DVM

In a ramp type DVM, the operation basically depends on the measurement of time. The time which a ramp voltage takes to change from the level of the input voltage to that of 0 voltage or vice versa. An electronic time interval counter is used to measure the time interval and the count is displayed in digits as voltmeter output.A negative going ramp voltage is compared with the unknown voltage.



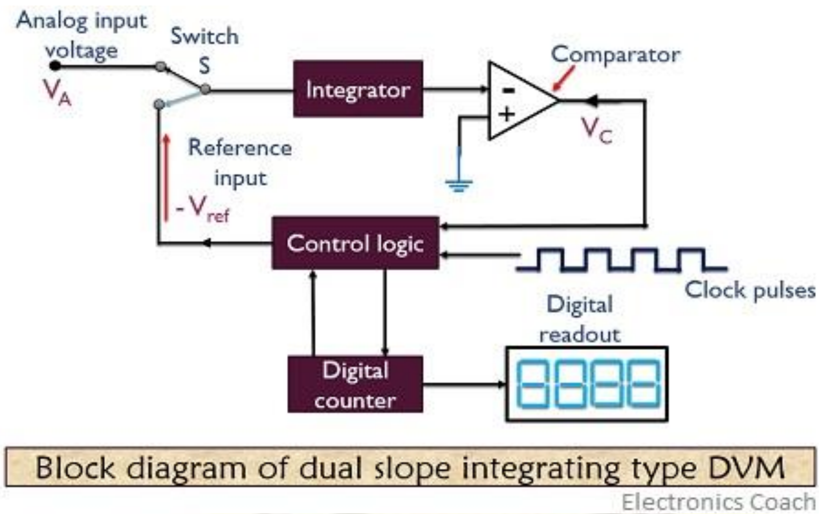
Block diagram of Ramp type DVM

Voltage to time conversion

An input comparator connected in the circuit generates a pulse when ramp voltage becomes equal to the voltage under measurement.When the ramp voltage falls to reach 0 value, the ground comparator circuit generates stop pulse. This stop pulse closes the gate. The **gate opening time duration** is **proportional** to the value of **input voltage**. The sample rate Multivibrator is used to find the rate by which the measurement cycle begins.

Dual slope integrating type DVM

The **control logic** resets the counter and enables the clock signal generator in order to send the clock pulses to the counter, when it is received the start commanding signal.For a fixed time interval, the analog input is applied to the integrator via switch S.The output of the **integrator** is connected to one of the two inputs of the comparator and the other input of comparator is connected to ground.



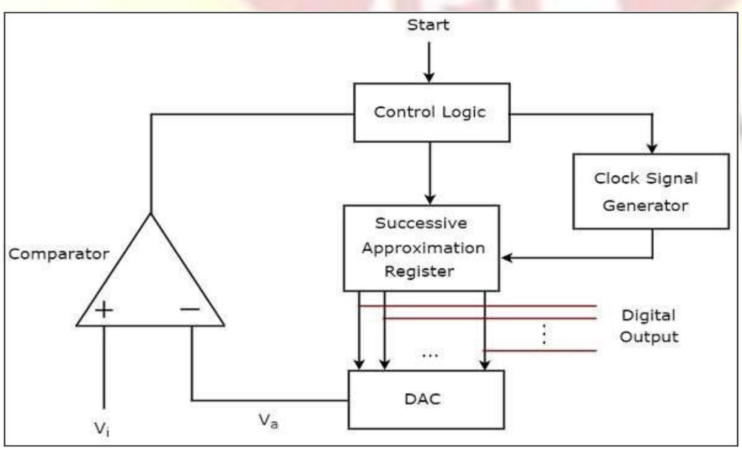
Block diagram of dual slope integrating type DVM

Comparator compares the output of the integrator with zero volts (ground) and produces an output, which is applied to the control logic.The level of the input voltage is raised in the comparator to some desired positive value.At the end of a fixed time interval, the rate of increase in voltage will be proportional to the input voltage.Initially the count is set at 0 and the **switch** gets **shifted to reference voltage**. The **counter** gets incremented by one for every clock pulse and its value will be in binary (digital) format. It produces an overflow signal to the control logic, when it is incremented after reaching the maximum count value. At this instant, all the bits of counter will be having zeros only.

The output of integrator will start decreasing and drops until it reaches below the comparator reference voltage. At this time **control logic** will receive a signal in order to **stop** the count.

The control logic disables the clock signal generator and retains (holds) the counter value. The **counter value** is proportional to the external analog input voltage and it is displayed at the Digital read-out.

Successive Approximation DVM



In this type, the ADC makes use of **successive approximation converter**. Thus it is named as so. These are capable of 1000 readings per second. The successive approximation ADC mainly consists of 5 blocks– Clock signal generator, Successive Approximation Register (SAR), DAC, comparator and Control logic.The **control logic** resets all the bits of SAR and enables the clock signal generator in order to send the clock pulses to SAR, when it received the start commanding signal.The binary (digital) data present in **SAR** will be updated for every clock pulse based on the output of comparator. The output of SAR is applied as an input of DAC.

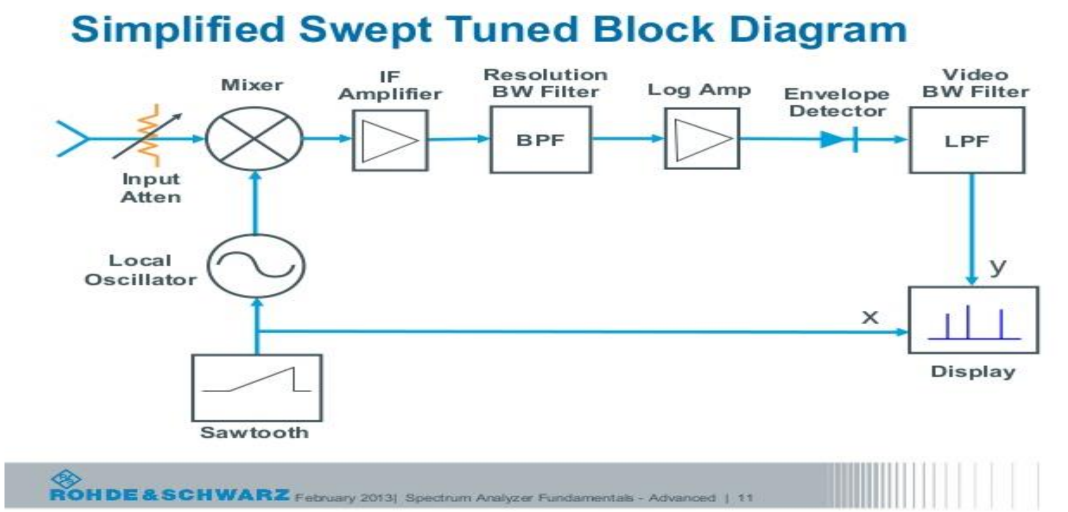
DAC converts the received digital input, which is the output of SAR, into an analog output. The comparator compares this analog value Va with the external analog input value Vi.The **output of a comparator** will be '1' as long as Vi is greater than Va. Similarly, the output of comparator will be '0', when Vi is less than or equal to Va.

SPECTRUM ANALYZER

Spectrum analyzers usually display raw, unprocessed signal information such as voltage, power, period, wave shape, sidebands, and frequency. They can provide you with a clear and precise window into the frequency spectrum. A signal could have several different characteristics. For example, in communications, in order to send information such as your voice or data, it must be modulated onto a higher frequency carrier. Using frequency domain the signal is analyzed in a spectrum analyzer.

The spectrum analyzer is to the frequency domain as the oscilloscope is to the time domain. (It is important to note that spectrum analyzers can also be used in the fixed-tune mode (zero span) to provide time-domain measurement capability much like that of an oscilloscope.)It is used to measure the frequency, power, harmonic content, modulation, spurs, and noise. Also we can measure total harmonic distortion, occupied bandwidth, signal stability, output power, intermodulation distortion, power bandwidth, carrier-to-noise ratio, and a host of other measurements, using just a spectrum analyzer. A mixer is a three-port device that converts a signal from one frequency to another.

The IF filter is a bandpass filter which is used as "window" for detecting signals. It's bandwidth is also called the resolution bandwidth (RBW) of the analyzer and can be changed via the front panel of the analyzer. The video filter is a low-pass filter that is located after the envelope detector and before the ADC. This filter determines the bandwidth of the video amplifier, and is used to average or smooth the trace seen on the screen.



The spectrum analyzer displays signal-plus-noise so that the closer a signal is to the noise level.The RF input attenuator is used to adjust the level of the signal before it is given to the first mixer. The IF gain is used to adjust the vertical position of signals on the display without affecting the signal level at the input mixer.The signal to be analyzed is connected to the input of the analyzer. This signal is then combined with the LO through the mixer to convert it to an IF. These signals are then sent to the IF filter, whose output is detected, indicating the presence of a signal at the analyzer's tuned frequency.

The output voltage of the detector drives the vertical axis (amplitude) of the LCD display. The sweep generator provides synchronization between the horizontal axis (frequency) and tuning of the LO. The resulting display shows amplitude versus frequency of the spectral components of each incoming signal.

UNIT V

Resistance Thermometer

Definition:

Resistance thermometer is a device that is used to determine temperature by the variation in the resistance of a conductor. It is commonly known as Resistance Temperature Detector (RTD) and is an accurate temperature sensor. RTD is not used for dynamic temperature measurement.

Working Principle of Resistance Thermometer

The resistance of the conductor is dependent on the variation in temperature. When the temperature of the metal is increased, there is an increase in the vibrational amplitude of the atomic nuclei of the material. This increases the probability of collision of free electrons with that of the bounded ions. Thus, the interruption in the motion of the electron causes resistance to increase. Hence, causing temperature to increase.Resistance temperature detector is typically made up of nickel, platinum, copper or tungsten. Platinum is used as a primary element in accurate temperature sensors.

In a metal, the change in resistance with respect to temperature is given by the following relationship:

$\mathbf{R_t = R_o (1 + \alpha t + \beta t^2 + \Upsilon t^3 \text{———})}$

α, β, ϒ etc are constants.

Basic equation for Resistance Thermometer

As we know,

$$\mathbf{R_t = R_o (1 + \alpha t + \beta t^2 + \Upsilon t^3 \text{———})}$$

R_t from the above equation can be approximated as:

$\mathbf{R_t = R_o (1 + \alpha t + \beta t^2)}$

When the element is pure platinum,

$\alpha = 3.94 \times 10^{-3} /^oC$

$\beta = -5.8 \times 10^{-7} /(^oC)^2$

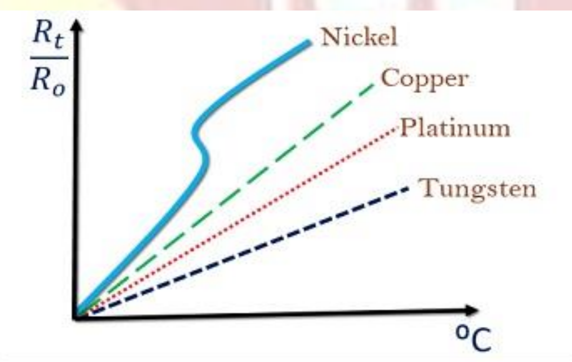
The above equation can be rewritten as:

$\mathbf{R_t = R_o (1 + C\, t_{pt})}$

C = mean resistance temperature coefficient between 0 ºC and 100 ºC.

Characteristics of materials used in Resistance Thermometer

As gold and silver are less resistive materials thus these are hardly used in RTD construction. Tungsten has high resistivity but it is restrained for high-temperature applications.



Resistance temperature characteristic of various materials

Advantages of Resistance Thermometer

- It provides highly accurate results.
- RTD provides a vast operating range.

- Due to its high accuracy, RTD is used in all such applications where precise results are needed.

Disadvantages of Resistance Thermometer

- The sensitivity of platinum RTD is very less for the minor variation in temperature.
- RTD possess slower response time.

Piezo-electric Transducers

- **Definition**: Piezo-electric transducers are the devices that change **electrical charges**, generated by the application of mechanical force into **electrical potential**.
- The voltage generated by piezoelectric transducers is the **effect of the displacement of charges**. The voltage is given as:

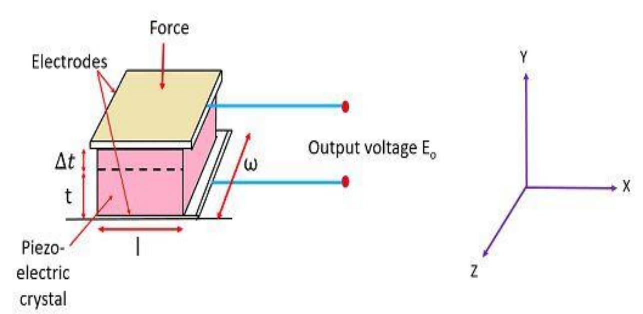
$$E = \frac{Q}{C}$$

Piezo-electric Effect

Piezo-electric transducers are based on the principle of **the piezoelectric effect**. The word piezo means **stress or force**. The higher the force, higher will be the voltage at the output. The electric potential can be easily measured by voltage measuring devices.

Piezo-electric materials possess the property of piezoelectricity. The potential appears across the surface of a crystal of piezo-electric material if the dimensions of crystals are changed.The elements that possess piezo-electric qualities are called **electro-resistive element.**

Some commonly used piezo-electric materials include Rochelle salts, ammonium dihydrogen phosphate, quartz, lithium sulphate etc. **Quartz** crystal shows unique property by generating the electrical voltage on applying mechanical stress to it.A piezo-electric transducer changes **mechanical motion** into **electrical signals** because mechanical motion generates charges and this charge appears as a voltage. This effect is direction sensitive.



Piezoelectric crystal used for force measurement

Axis of the crystal

Electronics Coach

The magnitude and polarity of charges generated at the surface of crystal are proportional to the magnitude and direction of the force applied.

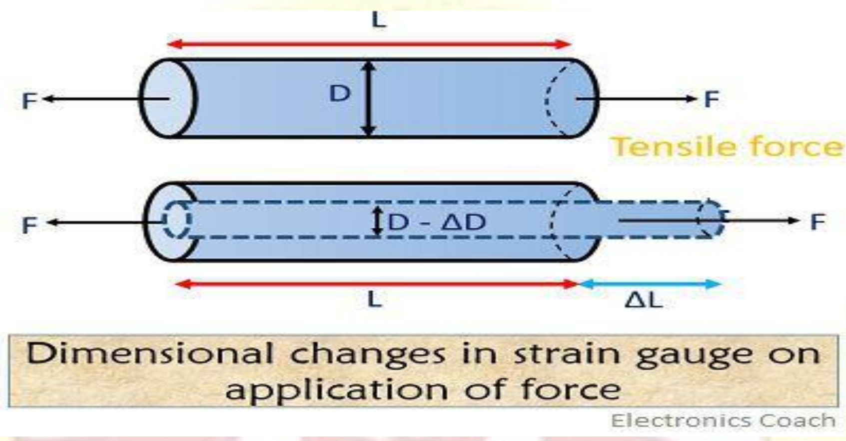
Charge, *Q = d X F coulomb*

d = charge sensitivity of the crystal; C/N

F = applied force, N

Strain Gauge

Strain gauge is a device which is when subjected to some **force results change in resistance** of the material. The change in resistance is measured in terms of either **load** or **displacement**. It basically measures strain on the application of stress. Strain gauge directly is used for the measurement of load and indirectly it is used for the measurement of displacement.



Strain gauges are employed as secondary transducers in many detectors and transducers. Such as load cells, torque meters, temperature sensors, accelerometer etc.

Theory of Strain Gauge

Let us take a wire having **length 'L'** and **cross-section area 'A'** The resistance of the wire will change if the wire is stretched or compressed. This is due to dimensional change and the property of material called the piezo-resistive effect. **Piezo-resistive effect** states that **change in dimensions** of the conductor resultantly **changes** its **resistance**. Resistance strain gauges are also known as **piezo-resistive gauges**.

The resistance is given by

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

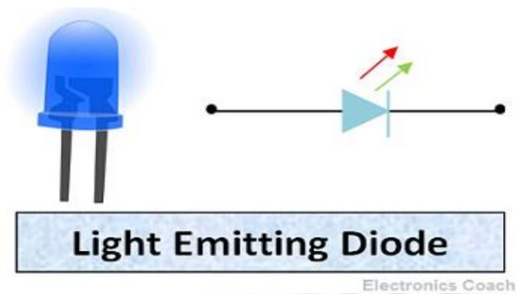
ρ = resistivity of the material,

L = length of material,

A = cross-sectional area of material

LED

LED (Light Emitting Diode) is an **optoelectronic device** which works on the principle of electro-luminance. **Electro-luminance** is the property of the material to convert electrical energy into light energy and later it radiates this light energy. In the same way, the semiconductor in LED emits light under the influence of electric field. The symbol of LED is formed by merging the symbol of P-N Junction diode and outward arrows. These outward arrows symbolise the light radiated by the Light emitting diode.



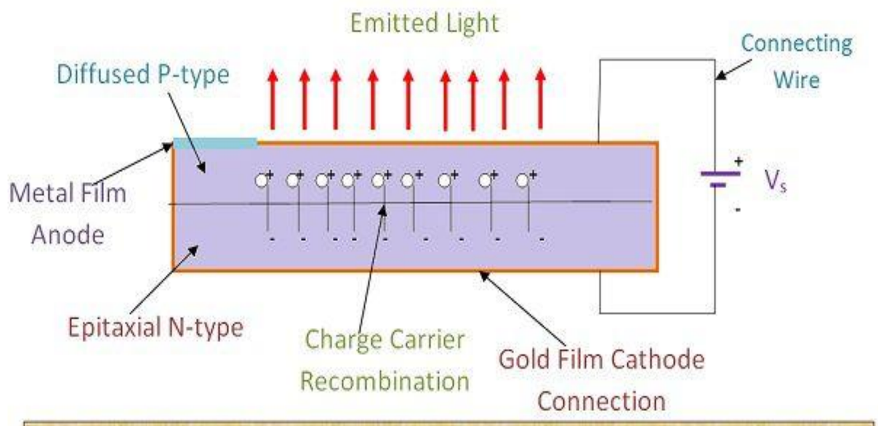
Construction of LED

The semiconductor material used in LED is **Gallium Arsenide (GaAs)**, **Gallium Phosphide (GaP)** or **Gallium Arsenide Phosphide (GaAsP).** The colour of radiated light changes with the change in material.

MATERIALS IN CONSTRUCTION	COLOUR	FORWARD VOLTAGE (IN VOLTS)
GaP	Green/Red	2.2
GaAsP	Yellow	2.2
GaAsP	Red	1.8
GaN	White	4.1
GaN	Blue	5.0
AlInGaP	Amber	2.1

Internal Architecture of LED

The semiconductor layer of **P-type** is placed above **N-type** because the charge carrier recombination occurs in p-type.



Cross-Sectional View of Diffused LED

The P-type layer is formed from diffusion of semiconductor material. The epitaxial layer is grown on N-type substrate.The metal film is used on the P-type layer to provide anode connection to the diode. Gold-film layer is coated on N-type to provide cathode connection.

Working of LED

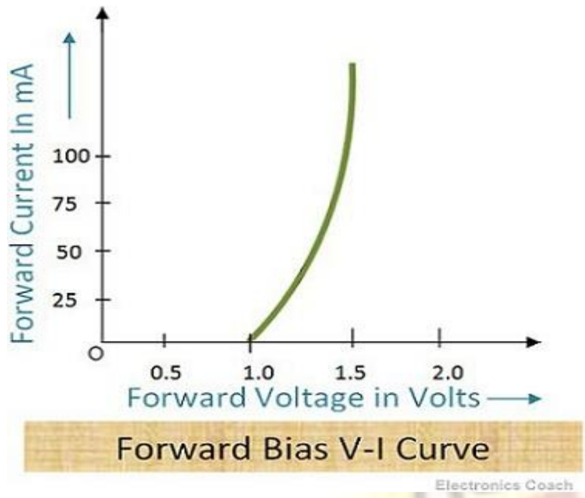
The electrons are majority carriers in N-type and holes are majority carriers in P-type. The electrons of N-type are in the conduction band and holes of P-type are in the valence band. The energy level of the Conduction band is higher than the energy level of the Valence band. Thus, if electrons tend to recombine with holes they have to lose some part of the energy to fall in lower energy band.

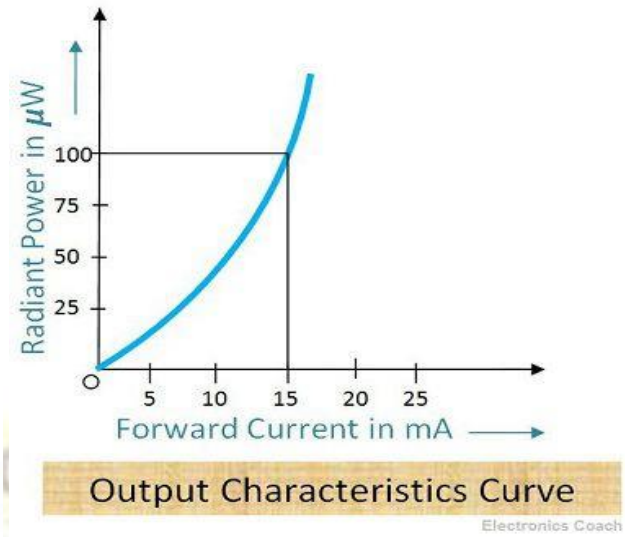
The electrons can lose their energy either in the form of heat or light. The electrons in Silicon and Germanium lose their energy in the form of heat. Thus, they are not used for LEDs as we want semiconductor in which electrons lose their energy in the form of light.Semiconductor compounds such as Gallium Phosphide (Gap), Gallium Arsenide (GaAs), Gallium Arsenide Phosphide (GaAsP) etc. emit light when electrons-holes recombine. The electrons in these compounds lose their energy by **emission of photons.**

LED is operated in forward **biased** mode only. It cannot be operated in reverse biased condition as it will get damage i.e.it cannot with stand reverse voltage.

Volt-Ampere Characteristics of LED

The characteristics curve of the LED shows that the forward bias of **1 V** is sufficient to increase the current exponentially.





Advantages of LED

- **Temperature Range**: It can be operated over a wide range of temperature ranging from 0^0C -70^0C
- **Switching Time:** The Switching time of LEDs is in order of 1ns. Thus, they are useful in dynamic operations where a large number of arrays are used.
- **Low Power Consumption:** They consume less power and they can be used even if the dc power supplied is low.
- **Better Controlling:** The radiant power of LEDs is the function of the current flowing in it. Thus, the light intensity of LED can be controlled easily.
- **Economical and Reliable:** LEDs are cheap and they possess a high degree of reliability.
- **Small Size and Portability:** They are small in size and can be stacked together for the formation of alphanumeric displays.
- **Higher Efficiency:** The efficiency of LEDs to convert power to light energy is 10-50 times greater than that of the tungsten lamp. The response time of LED is 0.1?S while in the case of tungsten lamp it is in tens or hundreds of milliseconds.

Disadvantages of LED

- **Overvoltage or Overcurrent:** The LEDs may get damaged when the current is increased beyond a certain limit.
- **Overheating due to radiant power:** It gets overheated with an excessive increase in radiant power. This may lead to damage of LED.

Applications of LED

- **Indicator in AC circuit:** It can be used as an indicator in AC circuit, but the internal resistance of LED is quite small. Thus, a resistor in series is connected with LED so that the over current can flow through the resistor and can protect LED from getting damaged.

- **Display Panel Indicator:** LEDs are used for displaying information processed by electronics circuits.
- **Digital Watches, Calculators & Multimeters:** The LEDs which emit visible light are used in digital watches and Calculators for indication purpose.
- **Remote Control Systems & Burglar alarm Systems:** Those LEDs which emit invisible infrared light such as GaAs LEDs are used in such applications.
- It is also used in optical fibre communication system.

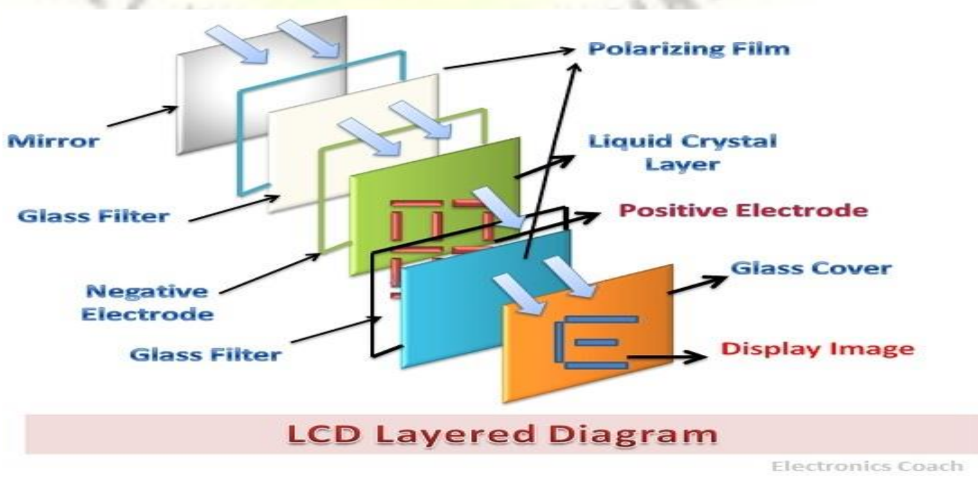
LCD

Difference between LED and LCD

- The main difference **LED and LCD** is that the LED works on the principle of **electroluminescence** i.e. it generates light due to recombination of electron and holes while LCD do not generate light of its own but control the light energy and modify it in such a way that some area of the display screen appears bright while some areas appear dark.
- LED and LCD both are the types of the display device but the brightness level of LED is more than that of LCD. The **power requirement** is also one of the main factors which differentiate LED and LCD.
- The LCD can be fabricated or designed in any particular **size** according to the specific application.
- We will discuss some more significant differences between LED and LCD with the help of comparison chart.

PARAMETERS	LED	LCD
Operation	The LEDs generates light due to recombination of charge carriers.	The LCD modifies the external light by passing it through the liquid crystals fed between polarizers.
Viewing Angle	The viewing angle of LED is about 150 degree.	The viewing angle of LCD is less than that of 100 degree.
Temperature Range	The temperature range of operation in case of LED lies between -400 degree Celsius to 850 degree celsius.	The temperature range of operation in case of LCD lies in the range of -200 degree Celsius to 600 degree Celsius.
Brightness Level	The brightness level of LED is high and thus LEDs provide good quality display.	The brightness level of LCD is lower than that of LEDs and thus the quality of LCD display is lower than that of LED.
Power Requirement	The power requirement of LED is in the range of 10-250 mW.	The power requirement of LCDs is less than that of LEDs, it is about 10-20 µW.
Operating Voltage	The operating voltage of LED lies between 1.5 V to 5 V DC.	The operating Voltage of LCD is in the range of 3 to 20 V ac.
Lifetime	The lifetime of LEDs is about 100,000 hours.	The lifetime of LCDs are less in comparison to LEDs i.e. about 50,000 hours.
Response Time	50- 500 ns	50-200 ms
Cost	Costly	LCDs are cheaper as compares to LEDs
Weight	Light as compared to LED	Heavy

LCD is an acronym for **Liquid crystal display**; the liquid crystal is used for the construction of LCD.The liquid crystal can be considered as the fourth state of the matter. This is because the liquid crystal has the property of solid as well as liquid. The crystal structure is responsible for the solid characteristics of liquid while the ability of the liquid crystal to flow imparts it the property of the liquid.



Construction

The LCD consists of a light source which supplies light from external source to the liquid crystal.The liquid crystals are filled between the polarizing films. These polarizers are applied voltage from the external electric field. The voltage applied through external electric field modifies the liquid crystal in such a way that the light is absorbed by the rear polarizer and this light creates dark and bright spots on the screen.

The liquid crystal is fed between the front polarizer and rear polarizer, when the voltage is not applied from the external electric field then the light ray rotate at the right angle and is reflected back to the external source. To prevent this polarizer are coated with conducting material and the electric field is applied to it.The electric field of 1000 V/m^2 is applied to the liquid crystals, for each 10 µm thick layer of the nematic crystal the applied electric field is 10 V.

Working

The main principle behind liquid crystal molecules is that when an electric current is applied to them, they tend to untwist. This causes a change in the light angle passing through them. This causes a change in the angle of the top polarizing filter with respect to it. Little light is allowed to pass through that particular area of LCD. Thus that area becomes darker comparing to others.

For making an LCD screen, a reflective mirror has to be setup in the back. An electrode plane made of indium-tin oxide is kept on top and a glass with a polarizing film is also added on the bottom side.

The entire area of the LCD has to be covered by a common electrode and above it should be the liquid crystal substance. Next comes another piece of glass with an electrode in the shape of the rectangle on the bottom and, on top, another polarizing film.When there is no current, the light passes through the front of the LCD it will be reflected by the mirror and bounced back.

As the electrode is connected to a temporary battery the current from it will cause the liquid crystals between the common-plane electrode and the electrode shaped like a rectangle to untwist. Thus the light is blocked from passing through. Thus that particular rectangular area appears blank.

Advantages of LCD

- The following are the advantages of LCD.
- The power consumption of LCD is low. The seven segmental display of LCD requires about 140µW which is the major advantages over LED which uses approximately 40mW per numeral.
- The cost of the LCD is low.

Disadvantages of LCD

- The following are the disadvantages of LCD.
- The LCD is a slow device because their turning on and off times are quite large. The turn-on time of the LCD is millisecond while there turn off time is ten milliseconds.
- The LCD requires the large area.
- The direct current reduces the lifespan of LCD. Therefore, the LCD uses with AC supply, having the frequency less than 500Hz.

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