DEPARTMENT OF BIOMEDICAL ENGINEERING
EE T44/ ELECTRICAL AND ELECTRONIC INSTRUMENTS

UNIT - 3

BRIDGES

- Bridge circuits are mainly used to measure unknown quantities in electronics such as resistance, capacitance, impedance and admittance.
- A bridge circuit consists of 4 arms with a DC source.
- The unknown component to be measured is place in one arm. The component in other arm is adjusted till the detector reads zero. At this condition the bridge is said to be balanced. Then the unknown value is found from the known value of the arm component.

Advantages of Bridge circuit

a. High measurement accuracy
b. The accuracy is independent of null detector's characteristics
c. The balance equation is independent of magnitude of input voltage
d. The interchange of source and detector does not affect the balance condition,
e. The bridge circuit can be used in control circuits

Measurement of Resistance

Resistance can be classified as follows

1. Low resistance – the order of less than 1 Ω
2. Medium resistance – range 1Ω to about 100K
3. High resistance – above 100K

Measurement of Low Resistance

The following methods are used for the measurement of low resistance

1. Ammeter-voltmeter method
2. Potentiometer method
3. Kelvin double bridge method

Measurement of Medium Resistance

1. Ammeter – voltmeter method

2. Substitution method
3. Wheat stone bridge
4. Carey –foster slide wire bridge method

Measurement of High Resistances

1. Direct deflection method
2. Loss of charge method
3. Mega ohm bridge
4. Megger

TYPES OF BRIDGES

1) DC Bridges

These bridges are mainly used for measurement of resistances

a) Wheatstone bridge

b) Kelvin Bridge

2) AC Bridges

These types of bridges are used to measure impedance consisting of capacitance and inductance.

a) Maxwell's Bridge (Inductance and Capacitance)

b) Hay's Bridge

c) Schering Bridge

d) Anderson Bridge

e) Wien Bridge

1. Ammeter-Voltmeter Method

Very common method used for the measurement of low resistance.

Current through the resistor (X) under test and the potential drop across it are simultaneously measured.

There are two ways in which the ammeter and voltmeter may be connected for measurement.

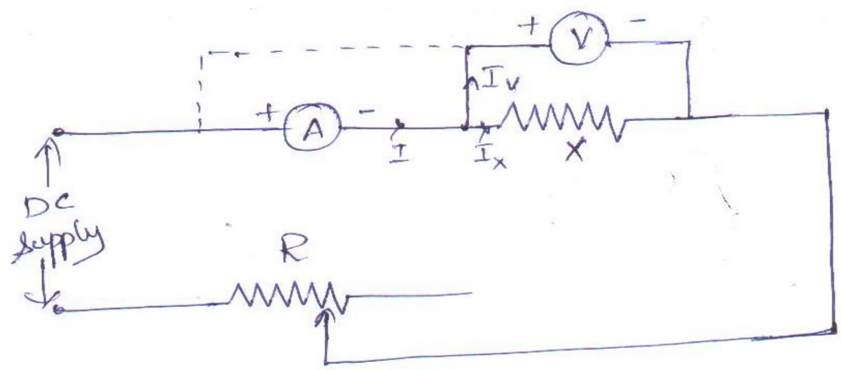


Fig., Ammeter-Voltmeter method

Case – 1

When the voltmeter is connected directly across the resistor,the ammeter measures current flowing through the unknown resistance X and the voltmeter.

Current through ammeter = current through unknown resistance(X) + current

through voltmeter

$I = I_x + I_V$

$I_x = I - I_v$

True value of unknown resistance

$X_{true} = V / I_x$

$X_{true} = V / I\text{-}I_v$

$X_{true} = V / I\text{-}(V/R_v)$

$X_{true} = V / I(1\text{-}V/IR_v)$

V –voltmeter reading

Rv - the resistance of voltmeter

I – the current indicated by the ammeter.

Case -2

When the ammeter is connected so that it indicates only the current flowing through the unknown resistance,the voltmeter measures voltage across the ammeter and unknown resistance X

$$V = IRa + IX$$

$$V = I(Ra+X)$$

$$X_{true} = V / I$$

Ra – the resistance of the ammeter.

Potentiometer Method

In This Method The Unknown resistance is compared with a standard resistance of the same order of magnitude.

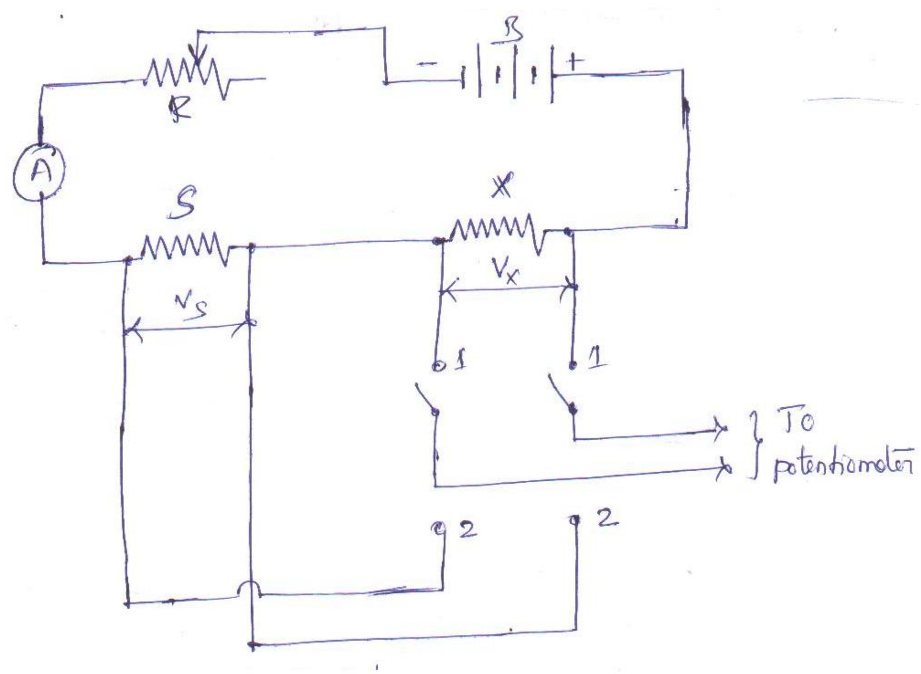


Fig., Potentiometer Method

Draw the circuit diagram of hays bridge and derive its expression for the measurement of high Q of the given coil.(MAY 19)

Explain the purpose of Hays Bridge. Draw the necessary phasor diagram.(sep 2020)

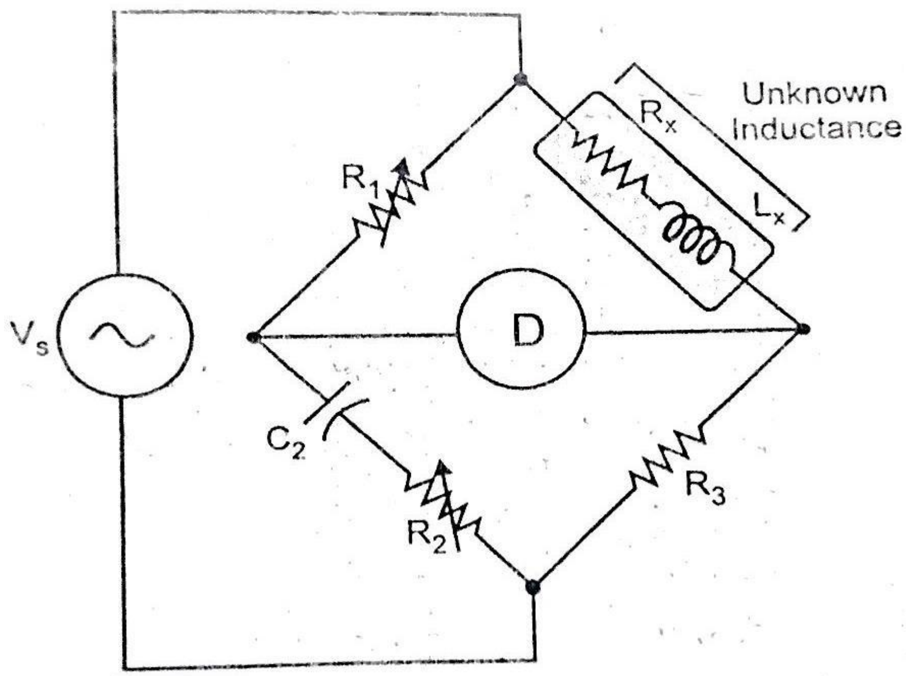
<u>Introduction on Hay's Bridge:</u>

- The hay bridge or opposite angle bridge is used for measurement of high Q inductors(Q>10).

➤ The hay bridge differs from the maxwell in that it has a standard capacitor in series with a variable resistor, as opposed to a parallel combination in the arm opposite to the unknown inductor.

➤ Since the two opposite arms contains opposite reactance type, they have opposite impedance angle(hence the name)

➤ Like the maxwell bridge it has the advantage of using a standard capacitance and containing a capacitive reactance (opposite impedance angle) as well as a standard capacitor to measure inductance.



For balance R1 and R2 are variable, while R3 and C2 are fixed value standard. The balance equation are given below

$$\left(R_2 - \frac{j}{\omega C_2}\right)(R_X + j\omega L_X) = R_1 R_3$$

$$R_2 R_X + jR_2 L_X - \frac{jR_X}{\omega C_2} + \frac{\omega L_X}{\omega C_2} = R_1 R_3$$

Equating the real and imaginary parts

$$\left(R_2 R_X + \frac{L_X}{C_2}\right) = R_1 R_3 -----------(1)$$

$$R_2 \omega L_X = \frac{R_X}{\omega C_2} --------------(2)$$

Solve the above eqns

$$R_X = \frac{\omega^2 C_2^2 R_1 R_2 R_3}{1 + \omega^2 R_2^2 C_2^2}$$

$$L_X = \frac{R_1 C_2 R_3}{1 + \omega^2 R_2^2 C_2^2}$$

The above expressions indicate that the balance condition is a function frequency.

$$\text{Q – factor of the coil} = \frac{\omega Lx}{Rx} = \frac{\frac{\omega R_1 C_2 R_3}{1+\omega^2 R_2^2 C_2^2}}{\frac{\omega^2 C_2^2 R_1 R_2 R_3}{1+\omega^2 R_2^2 C_2^2}}$$

$$Q = \frac{1}{\omega R2C2}$$

Advantages of Hay's Bridge:

i) It is best suitable for the measurement of inductance with high Q typically greater than 10.

ii) It gives very simple expression for Q factor in terms of elements in the bridge.

iii) It requires very low value resistor $_2$ to measure high Q inductance.

Disadvantage of Hay's Bridge:

It is only suitable for measurement of high Q inductance, Consider expression for unknown inductance.

$$= \frac{2\ \ 3\ \ 1}{1 + \ \underline{1}^{2}}$$

For high Q inductances, (1/ ^{2}) term can be neglected. But for low Q measurements, (1/ ^{2}) term is significant, hence cannot be neglected. Hence Hay's bridge is not suitable for the measurement of low Q inductances. In such cases, Maxwell's bridge is preferred.

Describe the working of series and shunt ohmmeter.

Ohmmeter

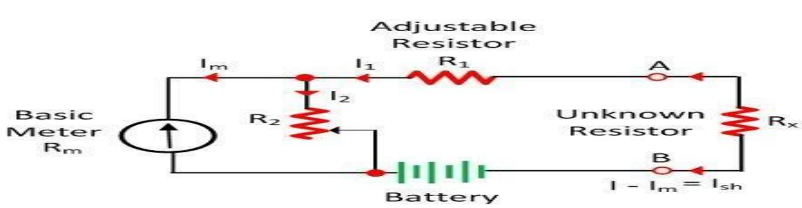
Definition: The meter which measures the resistance and the continuity of the electrical circuit and their components such type of meter is known as the ohmmeter. It measures the resistance in ohms. The micro-ohmmeter is used for measuring the low resistance and the mega ohmmeter measures the high resistance of the circuit. The ohmmeter is very convenient to use but less accurate.

Types of Ohmmeter

The ohmmeter gives the approximate value of resistance. It is very portable and hence used in the laboratory. It is of three types; they are the series ohmmeter, shunt ohmmeter and multi-range ohmmeter. The detail explanation of their types is given below.

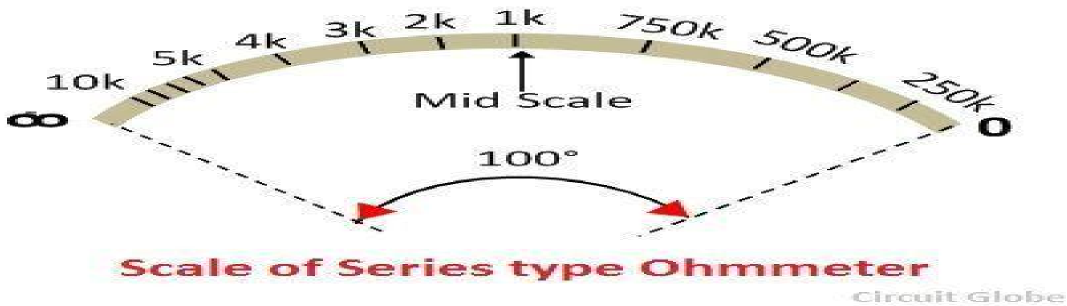
Series Ohmmeter

In series ohmmeter, the measuring resistance component or circuit is connected in series with the meter. The value of resistance is measured through the d'Arsonval movement connected in parallel with the shunt resistor R_2. The parallel resistance R_2 is connected in series with the resistance R_1 and the battery. The component whose resistance is used to be measured is connected in series with the terminal A and B.



Series Type Ohmmeter

When the value of unknown resistance is zero the large current flow through the meter. In this condition, the shunt resistance is adjusted until the meter indicates the full load current. For full load current, the pointer deflects towards zero 0 ohms.



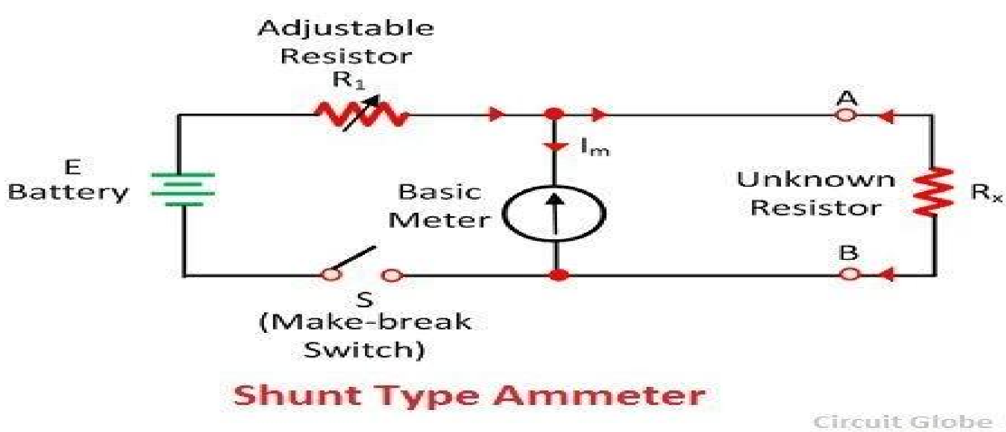
When the unknown resistance R_x is removed from the circuit the resistance of the circuit becomes infinite and no current flow through the circuit. The pointer of the meter deflects towards the ∞ (infinity). The meter shows the infinite resistance at zero current and the zero resistance when full range current flows through it.

When the unknown resistance is connected in series with the circuit and if their resistance is high, then the pointer of the meter deflects toward the left. And if the resistance is low, then pointer deflects toward the right.

Shunt Type Ohmmeter

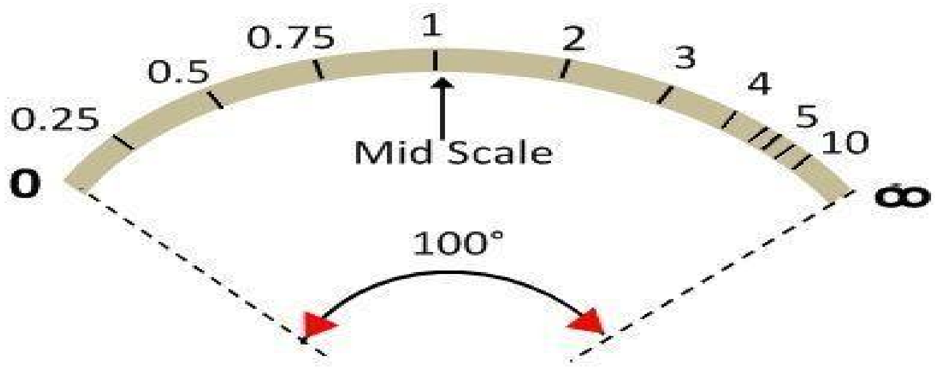
The meter in which the measuring resistance is connected in parallel with the battery is known as the shunt ohmmeter. It is mainly used for measuring the low-value resistance.

The circuit diagram of the shunt ohmmeter is shown in the figure below.



The battery (E), basic meter (R_m) and the adjustable resistance are the main components of the shunt ohmmeter. The unknown resistance is connected across terminal A and B.

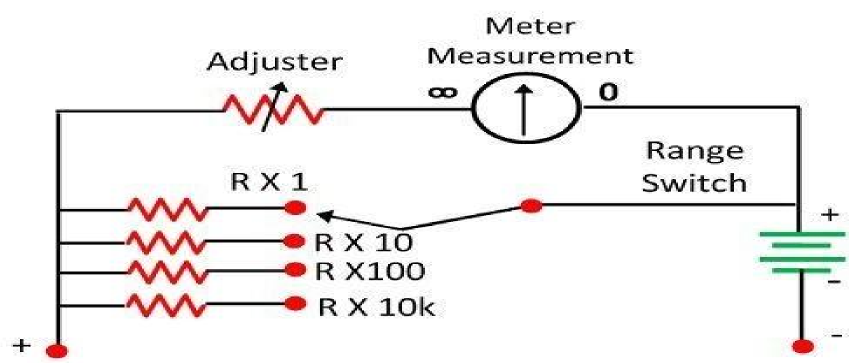
When the value of unknown resistance is zero the meter current becomes zero. And if the resistance becomes infinite (i.e., the terminal A and B are open) then the current passes through the battery and the pointer shows the full-scale deflection toward left. The shunt type ohmmeter has the zero mark (no current) on the left of the scale and the infinity mark on their right side.



Scale of Shunt Type Ohmmeter

Multi-Range Ohmmeter

The range of this type of ohmmeter is very high. The meter has adjuster which selects the range according to need.



Multi Range Ohmmeter

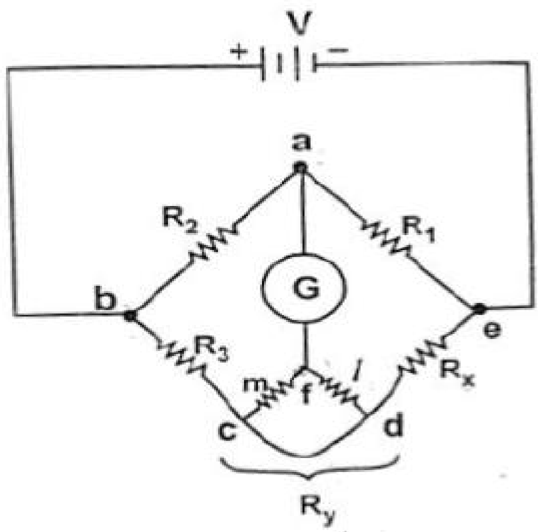
For example, consider we use the meter for measuring the resistance under 10 ohms. For this first, we have to set the range of 10 ohms. The resistance whose value is used to be measured is connected in parallel with the meter. The magnitude of the resistance is determined through the deflection of the pointer.

3. KELVIN DOUBLE BRIDGE (LOW RESISTANCE MEASUREMENT)

Principle:-

The principle of Kelvin double bridge is null deflection when all the arms are balance.

Diagram:



Construction:-

- The circuit diagram of kelvin's double bridge.
- This circuit consists of double bridge.
- Because it incorporates a second set of ratio arms.
- The second set of arms m and I connect the galvanometer to a point f at the appropriate potential between c and d and it eliminates the effect of the resistance Ry

The ratio of the resistance of arms m and I is the same as the ratio of R1 and R2 the galvanometer indication is zero when the potentials at a and f are equal.

$$V_{AB} = V_{BCF}$$

By Voltage division rule (Consider b, a, e and voltage source)

$$V_{ab} = \frac{R_2}{R_2+R_1} \times V \text{--(1)}$$

By simplifying the circuit (Consider C,d,f)

$$V = I\left[R_3 + R_X + \frac{(m+1)R_y}{(m+1)R_y}\right] \text{--(2)}$$

Substituting for V in equation 1, we get

$$V_{ab} = \frac{R_2}{R_2+R_1} \times I\left[R_3 + R_X + \frac{(m+1)R_y}{(m+1)R_y}\right] \text{------------------------(3)}$$

Similarly,

$$V_{bcf} = I\left[R_3 + \frac{m}{m+1}\left\{\frac{(m+1)R_y}{(m+1)R_y}\right\}\right] \text{--------------------------------(4)}$$

But

$$V_{ab} = V_{bcf}$$

$$\frac{R_2}{R_2+R_1} \times I\left[R_3 + R_X + \frac{(m+1)R_y}{(m+1)R_y}\right] = I\left[R_3 + \frac{m}{m+1}\left\{\frac{(m+1)R_y}{(m+1)R_y}\right\}\right]$$

$$R_3 + R_X + \frac{(m+1)R_y}{(m+1)+R_y} = \frac{R_1+R_2}{R_2}\left[R_3 + \frac{m}{m+1}\left\{\frac{(m+1)R_y}{(m+1)R_y}\right\}\right]$$

$$R_X + \frac{(m+1)R_y}{m+1+R_y} + R_3 = \frac{R_1R_3}{R_2} + R_3 + \frac{mR_1R_y}{R_2(m+1+R_y)} + \frac{mR_y}{m+1+R_y}$$

$$R_X = \frac{R_1R_3}{R_2} + \frac{mR_1R_y}{R_2(m+1+R_y)} + \frac{mR_y}{m+1+R_y} - \frac{(m+1)R_y}{m+1+R_y}$$

$$R_X = \frac{R_1R_3}{R_2} + \frac{mR_1R_y}{R_2(m+1+R_y)} + \frac{mR_y - R_y - mR_y}{m+1+R_y}$$

$$R_X = \frac{R_1R_3}{R_2} + \frac{mR_1R_y}{R_2(m+1+R_y)} - \frac{R_y}{m+1+R_y}$$

$$R_X = \frac{R_1R_3}{R_2} + \frac{mR_y}{R_2(m+1+R_y)}\left[\frac{R_1}{R_2} - \frac{1}{m}\right]$$

But

$$\frac{R_1}{R_2} = \frac{1}{m}$$

$$R_X = \frac{R_1R_3}{R_2}$$

The above equation is the usual equation for kelvin's bridge

- It indicates that the resistance of the connecting load Ry, has no effect, on the measurement, provided that the ratios of the resistance of the two sets of ratio arms are equal.
- The kelvin's bridge is used for measuring very low resistances from 1Ω to 0.00001Ω (accuracy)varying from ±0.05% to ±0.2% .

Measurement of Medium Resistance

1. Ammeter – voltmeter method
2. Substitution method
3. Wheat stone bridge
4. Carey –foster slide wire bridge method

1. **Substitution Method**

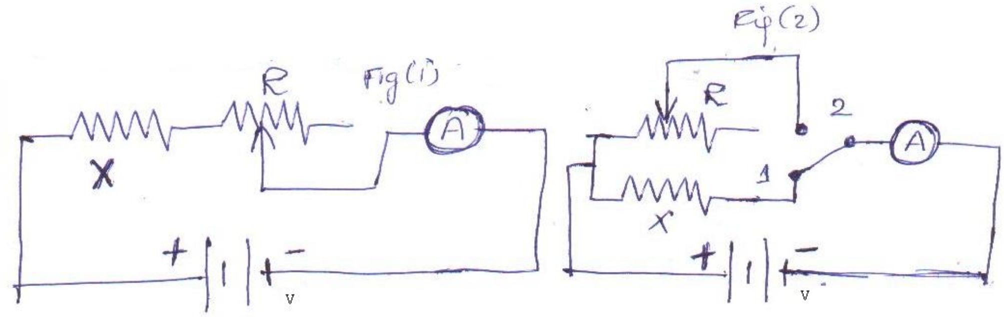


Fig., Substitution Method

Let R be the variable resistance which can be changed in small steps ,say of 0.1ohm.

Case:I

First resistance X is put in the circuit and the value of current noted.

Then resistance X is removed and it is substituted by a known variable resistance R which is varied so that the value of the current is same in both the cases,this value of R is equal to the unknown resistance.

Case:II

If R is fixed value,note the readings of the ammeter for the following cases.

1. For resistance X and R in series
2. When resistance X is removed

let the readings of the ammeter for these cases be I_1 and I_2

I_1= V / R+X: I_2 = V / R

$$I_1 = \frac{V}{R+X}$$

$$I_2 = \frac{V}{R}$$

$$\frac{I_2}{I_1} = \frac{\frac{V}{R}}{\frac{V}{R+X}} = \frac{R+X}{R} = 1 + \frac{X}{R}$$

$$1 + \frac{X}{R} = \frac{I_2}{I_1}$$

$$\frac{X}{R} = \frac{I_2}{I_1} - 1$$

$$X = R\left(\frac{I_2}{I_1} - 1\right)$$

In fig. ,the two way switch first makes contact with 1 and then with 2 and let these readings be I1 and I2

$$I_1 = \frac{V}{X}$$

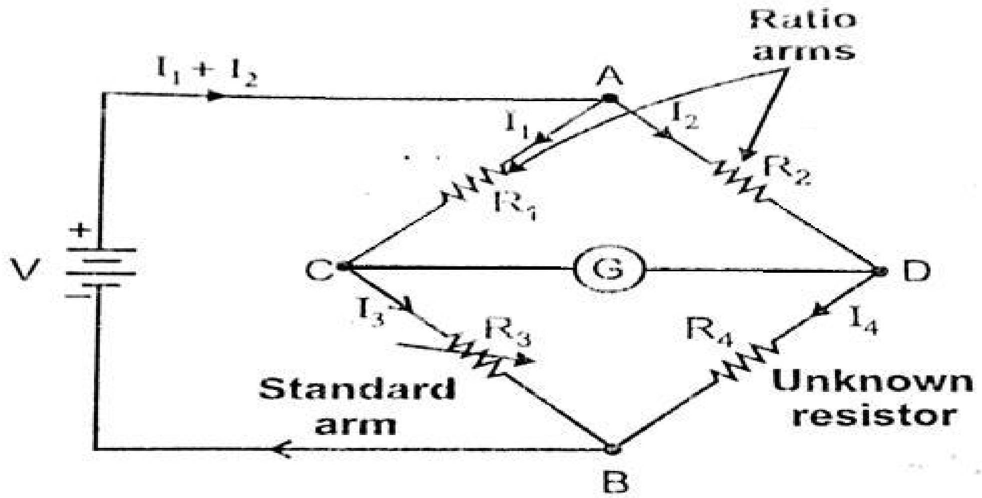
$$I_2 = \frac{V}{R}$$

$$\frac{I_2}{I_1} = \frac{\frac{V}{R}}{\frac{V}{X}} = \frac{X}{R}$$

$$X = R.\frac{I_2}{I_1}$$

2.WHEATSTONE BRIDGE (MEDIUM RESISTANCE MEASUREMENT)

- The **Wheatstone bridge** was originally developed by Charles Wheatstone to measure unknown resistance values and as a means of calibrating measuring instruments, voltmeters, ammeters, etc, by the use of a long resistive slide wire.
- The simplest form of brides is for the purpose of *measuring resistance* and is called the Wheatstone bridge.
- *This bridge is widely used for precision measurement of resistance from 1Ω to the low meg-ohm range.*
- It is most accurate method available for measuring resistance



- This bridge consists of four resistive arms, together with a DC source V and null detector.
- The null detector may be galvanometer (G) or other sensitive current meter.
- The current through the galvanometer depends on the potential difference between C and D .When the current through the galvanometer is zero, the circuit said to be balanced.
- The bridge is balanced when the potential difference across C and D is zero.

$$I_1R_1 = I_2R_2$$

If the galvanometer current is zero, the following condition should be satisfied

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

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

Substituting the value of I_1 and I_2

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

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

$$R_1R_2 + R_1R_4 = R_1R_2 + R_2R_3$$

$$R_1R_4 = R_2R_3$$

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

The resistor R_1 and R_2 arecalled ratio arms and resistor R_3 is called standard arm of the bridge.

Suggest a suitable technique for the measurement of high resistance and illustrate it in detail.(NOV 17)

Methods for Measurement of High **Resistance:**

The different .methods employed are :

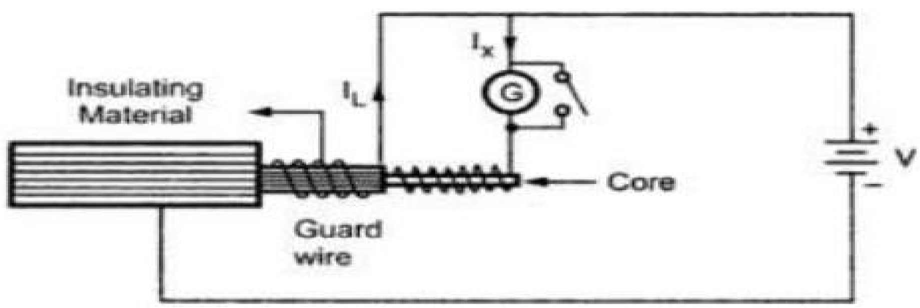
1.Direct deflection method.

2. Loss of charge method.

3.Megohm bridge.

4. Meggar

i) Direct Deflection Method In this method, a high resistance (more than 1000 Cl) and very sensitive moving coil galvanometer is connected in series with the resistances to be measured along with supply voltage as shown in the Figure 1.



The direct deflection method is used for very high resistances such as insulation resistances cables. A sensitive galvanometer is used in place of micro ammeter. The Figure shows this method making use of with and without Guard wire at the terminal A .

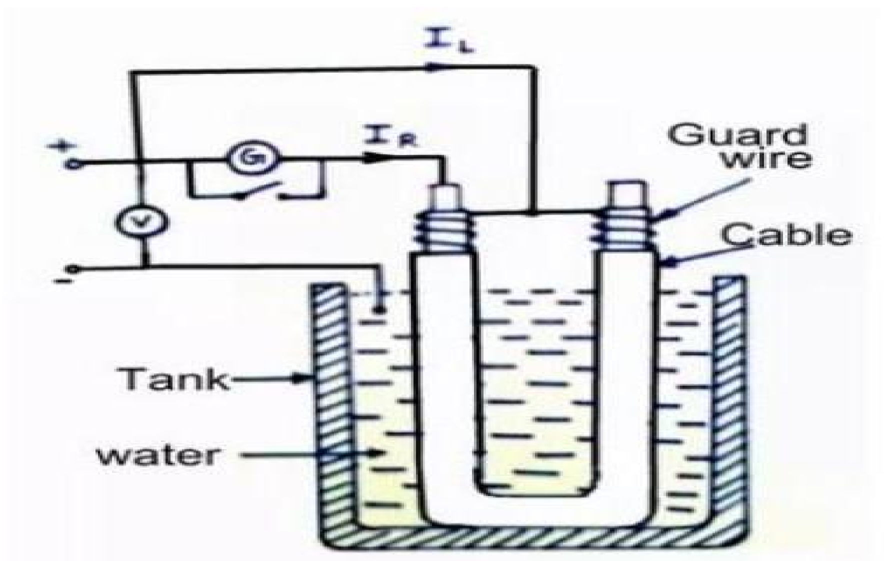
The Galvanometer G measures the current Ig between the conductor and the metal sheath. The leakage current IL is actually carried out by the guard wire which ultimately do not flow through the galvanometer and thereby eliminating the source of error. Cables without the metal sheaths can be tested in similar way but the cable is immersed in water tank first except its end where connections are made.

The cable should be immersed for at least 24 hours in slightly alkaline water at a room temperature (approx..20˚) which will provide return path for the current as in Figure 2. The readings obtained give the Volume resistance of the conductor.

The insulation resistance of the cable is given by, In some cases, the deflection of the galvanometer is observed and its scale is afterwards calibrated by replacing the insulation by a standard high resistance (usually 1MΩ), the galvanometer shunt being varied, as required to give a deflection on the same order as before. In tests on cable the galvanometer should be short-circuited before applying the voltage. The short-circuiting connection is removed only after sufficient time is elapsed.

so that charging and absorption currents cases to flow. The galvanometer should be well shunted during the early stages of measurement, and it is normally desirable to influence a protective series resistance (of several mega ohm) in the galvanometer circuit. The value of this resistance should be subtracted from the observed resistance value in order to determine the true resistance

A high voltage battery of 500V emf is required and its emf should remain constant through out



the test.

ii) Loss of charge method

In loss of charge method unknown resistance is connected in parallel with capacitor and electrostatic voltmeter. The capacitor is initially charged to some suitable voltage by means of a battery of voltage V and then allowed to discharge through the resistance. The terminal voltage is observed during discharge and it is given by, V= v exp (-t/CR) V/v = exp (-t/CR) Or insulation resistance is given by, R= t/(C ln V/v)

= 0.4343 t / (C log V/v)

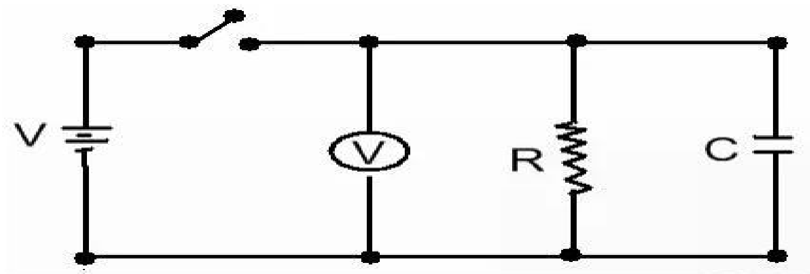
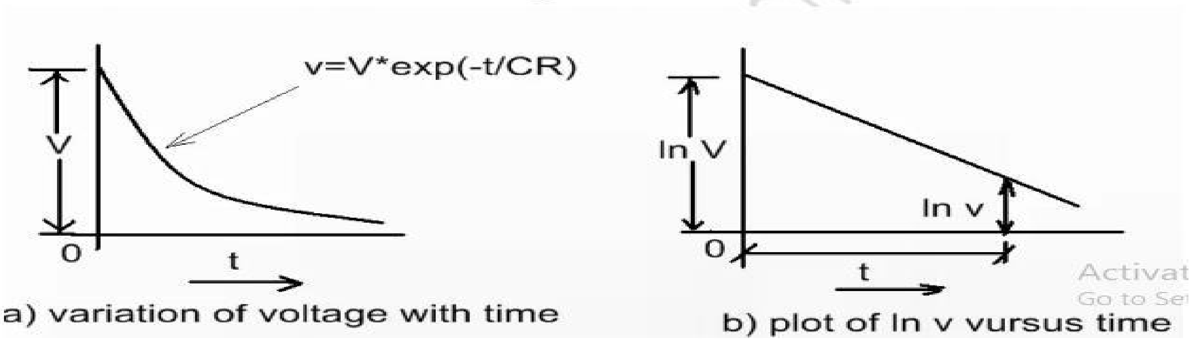


Figure.3



From above equation it follows that if V, v, C and t are known the value of R can be computed. If the resistance R is very large the time for an appreciable fall in voltage is very large and thus this process may become time consuming. Also the voltage-time curve will thus be very flat and unless great care is taken in measuring voltages at the beginning and at the end of time t, a serious error may be made in the ratio V/v causing

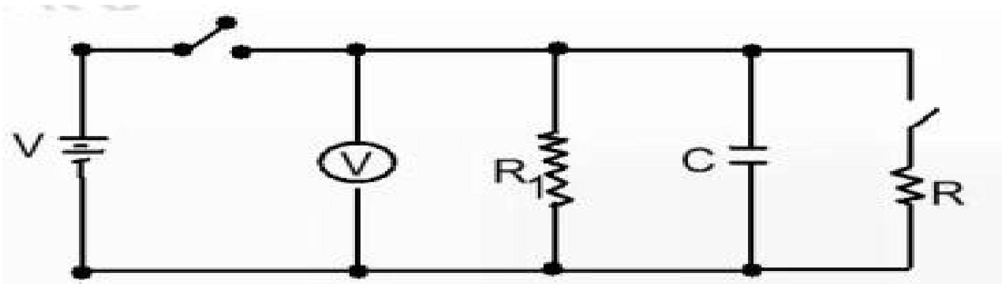
the considerable corresponding error in the measured value of R. more accurate results may be

obtained by change in the voltage V-v directly and calling this change as e, the expression for

$$R = \frac{0.4343\, t}{C\, log_{10} \frac{V}{V - e}}$$

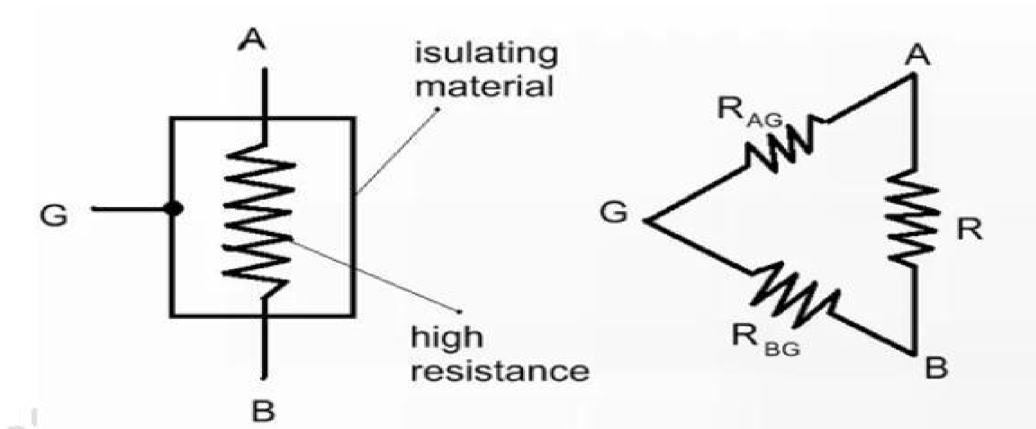
R becomes:

This change in voltage may be measured by a galvanometer. However, from the experimental point of view, it may be advisable to determine the time t from the discharge curve of the capacitor by plotting curve of log v against time t. this curve is linear as shown in second figure and thus determination of time t from this curve for the voltage to fall from V to v yields more accurate results. Loss of charge method is applicable to some high resistances, but it requires a capacitor of very high leakage resistance as high as resistance being measured. The method is very attractive if the resistance being measured is the leakage resistance of a capacitor as in this case auxiliary R and C units are not required. Actually in this method, the true value of resistance is not measured, since it is assumed that the value of resistance of electrostatic voltmeter and the leakage resistance of the capacitor have infinite value. But in practice corrections must be applied to take into consideration the above two resistances. Let R1 be the leakage resistance of the capacitor. Also R’ be the equivalent resistance of the parallel resistances R and R1.



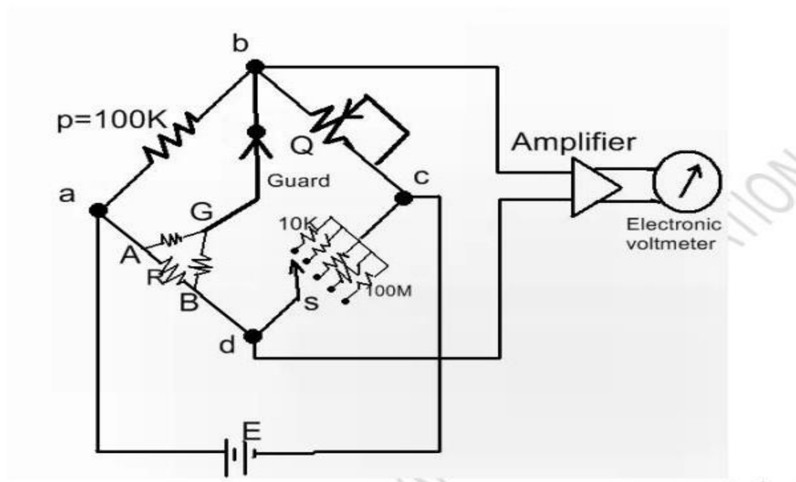
Loss of charge method

Then discharge equation of capacitor gives, $R' = 0.4343\ t / (C \log V/v)$ The test is then repeated with the unknown resistance R disconnected and the capacitor discharging through R1. The value of R1 obtained from this second test and substituted into the expression, $R' = (R\ R1) / (R+R1)$ In order to get value of R, The leakage resistance of the voltmeter, unless very high resistance should also be taken into consideration. iii) Megohm bridge Megohm Bridge is another important method for measurement of high resistances. It has one three terminal high resistance located in one arm of the bridge. Figure shows the very high resistance with terminals A and B, and a guard terminal, which is put on the insulation. So it forms a three terminal resistance.



Three terminal resistance

Let us consider take the hypothetical case of a 100 Mohm resistance and assume that this resistance is measured by an ordinary Wheatstone bridge. It is clear that Wheatstone will measure a resistance of 100*200/(100+200)=67Mohm instead of 100Mohm thus the error is



33 percent.

However if the same resistance is measured by a modified Wheatstone bridge as shown in fig b)with the guard connection G connected as indicated, the error in measurement will be redused and this modified Wheatstone bridge is called megohm bridge. The arrangement of above figure illustrated the operation of Megohm Bridge. Figure shows the circuit of the completely elf-contained Megohm Bridge which includes power supplies, bridge members, amplifiers, and indicating instrument. It has range from 0.1MΩ to 10^6MΩ. The accuracy is within 3% for the lower part of the range to possible 10% above 10000MΩ. Sensitivity of balancing against high resistance is obtained by using an adjustable high voltage supplies of 500V or 1000V and the use of a sensitive null indicating arrangement such as a high gain amplifier with an electronic voltmeter or a C.R.O. The dial on Q is calibrated 1-10-100-

1000MΩ, with main decade 1-10 occupying grater part of the dial space. Since unknown resistance R=PS/Q, the arm Q
is made, tapered, so that the dial calibration is approximately logarithmic in the main decade, 1-10. Arm S give five multipliers, 0.1,1,10,100 and 1000. iv) Megger

1) **Deflecting & Control coil** : Connected parallel to the generator, mounted at right angle to each other and maintain polarities in such a way to produced torque in opposite direction.

2) **Permanent Magnets**: Produce magnetic field to deflect pointer with North-South pole magnet.

3) **Pointer** : One end of the pointer connected with coil another end deflects on scale from infinity to zero.

4) **Scale :** A scale is provided in front-top of the megger from range 'zero' to 'infinity', enable us to read the value.

5) **D.C generator or Battery connection** : Testing voltage is produced by hand operated D.C generator for manual operated Megger. Battery / electronic voltage charger is provided for automatic type Megger for same purpose.

6) **Pressure coil resistance and Current coil resistance** : Protect instrument from any damage because of low external electrical resistance under test Working Principle of Megger • Voltage for testing produced by hand operated Megger by rotation of crank in case of hand operated type, a battery is used for electronic tester. • 500 Volt DC is sufficient for performing test on equipment range up to 440 Volts. • 1000V to 5000V is used for testing for high voltage electrical systems. • Deflecting coil or current coil connected in series and allows flowing the electric current taken by the circuit being tested. • The control coil also known as pressure coil is connected across the circuit. Current limiting resistor (CCR & PCR) connected in series with control & deflecting coil to protect damage in case of very low resistance in external circuit. • In hand operated megger electromagnetic induction effect is used to produce the test voltage i.e. armature arranges to move in permanent magnetic field or vice versa. • Where as in electronic type megger battery are used to produce the testing voltage. • As the voltage increases in external circuit the deflection of pointer increases and deflection of pointer decreases with a increases of current. • Hence, resultant torque is directly proportional to voltage & inversely proportional to current. • When electrical circuit being tested is open, torque due to voltage coil will be maximum & pointer shows 'infinity'

means no shorting throughout the circuit and has maximum resistance within the circuit under test. • If there is short circuit pointer shows ‘zero’, which means ‘NO’ resistance within circuit being tested. Work philosophy based on ohm-meter or ratio-meter. The deflection torque is produced with megger tester due to the magnetic field produced by voltage & current, similarly like ‘Ohm's Law’ Torque of the megger varies in ration with V/I, (Ohm's Law :- V=IR or R=V/I). Electrical resistance to be measured is connected across the generator & in series with deflecting coil. Produced torque shall be in opposite direction if current supplied to the coil.

High resistance = No current :- No current shall flow through deflecting coil, if resistance is very high i.e. infinity position of pointer

1. Small resistance = High current :- If circuit measures small resistance allows a high electric current to pass through deflecting coil, i.e. produced torque make the pointer to set at ‘ZERO’.
2. Intermediate resistance = varied current: - If measured resistance is intermediate, produced torque align or set the pointer between the range of ‘ZERO to INIFINITY’

7. Write in detail about the following :(NOV 17)

(a) Hays Bridge.

Briefly explain the working of Schering bridge.(NOV18)

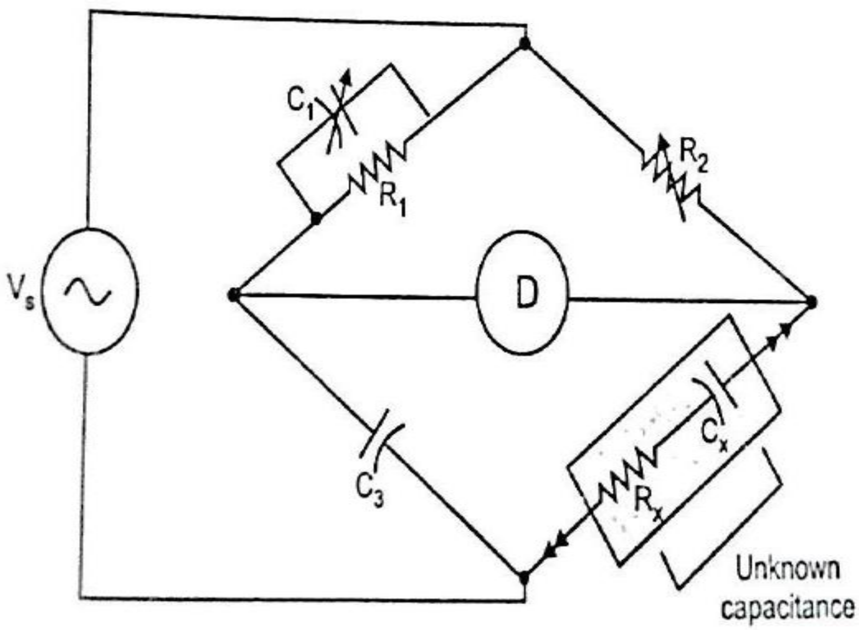
Explain the method of measuring capacitance using bridge circuit. give the phasor diagram.(sep 2020)

Draw the circuit diagram of Schering bridge and derive its expression for the measurement of dielectric losses.(NOV 19) (sep 2020)

SCHERING CAPACITANCE BRIDGE

A Schering Bridge is a bridge circuit used for measuring an unknown electrical capacitance and its dissipation factor. The dissipation factor of a capacitor is the ratio of its resistance to its capacitive reactance.

The Schering Bridge is basically a four-arm alternating-current (AC) bridge circuit whose measurement depends on balancing the loads on its arms. Figure 1 below shows a diagram of the Schering Bridge.



In the Schering Bridge above, the resistance values of resistors R1 and R2 are known, while the resistance value of resistor Rx is unknown.

- The capacitance values of C1 and C3 are also known, while the capacitance of Cx is the value being measured.
- To measure Rx and Cx, the values of C3 and R1 are fixed, while the values of R2 and C1 are adjusted until the current through the ammeter between points A and B becomes zero. This happens when the voltages at points A and B are equal, in which case the bridge is said to be 'balanced'.

When the bridge is balanced,

$$Z_X = Z_2 Z_3 Y_1$$

$$R_X - \frac{J}{\omega C_X} = R_2\left(\frac{-J}{\omega C_3}\right)\left(\frac{1}{R_1} + J\omega C_1\right)$$

$$R_X - \frac{J}{\omega C_X} = \left(\frac{R_2 C_1}{C_3}\right) - \left(\frac{J R_2}{\omega C_3 R_1}\right)$$

$$R_X = \frac{R_2 C_1}{C_3}$$

$$C_X = \frac{R_1}{R_2} C_3$$

Power factor can be measured by

$$PF = \frac{R_X}{C_X} = \omega C_X R_X$$

Dissipation factor of a RC circuit is given by

$$D = \frac{R_X}{C_X} = \omega C_X R_X$$

Advantages:

1. The balance equation is independent of frequency
2. It is used for measuring the insulating properties of electrical cables and equipment.

Uses of Schering Bridge:

The Schering Bridge can be used to define the quality of the capacitor by obtaining following information:

(i) Power factor,

(ii) Dissipation Factor

Thus if the resistance $_1$ is fixed, then the dial of capacitor $_1$can be directly calibrated to give dissipation factor D i.e. quality of $_1$the capacitor. As the term w is Present in the equation, the calibration of dial holds good for only one Particular frequency. The different frequency can be used but a correction should be made to multiply the $_1$ dial reading b the ratio of the two frequencies.

Similarly if the resistance ratio is maintained at fixed value, the dial of 3 can be graduated in terms of direct readings of .

Commercial Schering Bridge measures the capacitors from 100 PF – 1 F, with + 2% accuracy.

The bridge is widely used for testing small capacitors at low voltages with very high precision.

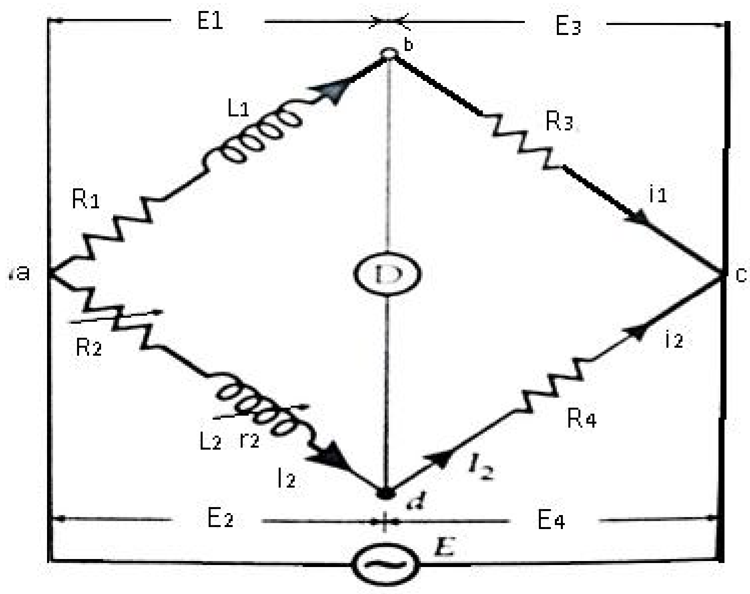
Explain how self-inductance can be measured in terms of a standard capacitor using an AC bridge.(MAY 17)

Maxwell's Bridge:

Maxwell's bridge can be used to measure inductance by comparison either with a variable standard self- inductance or with a standard variable capacitance. These two measurements can be done by using the Maxwell's Bridge in two different forms.

MAXWELLS INDUCTANCE BRIDGE:

- Here the bridge circuit measures an inductance by comparison with a variable standard self-inductance.



L1 – Unknown inductance of resistance R1

L2 – variable inductance of fixed resistance R2

R2 – Variable resistance connected in series with inductor L2

R3, R4 – Known non-inductive resistor

$$Z_1 \times Z_4 = Z_3 Z_2$$

$$(R_1 + j\omega L_1) \times R_4 = R_3 \times (R_1 + j\omega L_2)$$

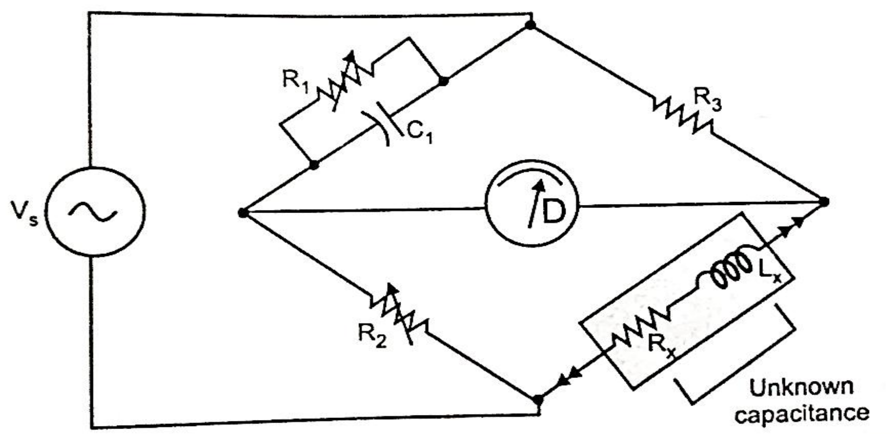
$$L_1 = \frac{R_3}{R_4} L_2$$

$$R_1 = \frac{R_3}{R_4}(R_2 + r_2)$$

PHASOR DIAGRAM

MAXWELL INDUCTANCE CAPACITANCE BRIDGE:

- ***The Maxwell Bridge or Maxerllwien bridge is used to measure unknown inductance in terms of calibrated resistance and capacitance***.
- Calibration-grade inductors are more difficult to manufacture than capacitors of similar precision, and so the ***use of a simple "symmetrical" inductance bridge is not always practical.***
- Because the phase shifts of inductors and capacitors are exactly opposite each other, capacitive impedance can balance out inductive impedance if they are located in opposite legs of a bridge, as they are here.
- Magnetic fields can be difficult to shield, and even a small amount of coupling between coils in a bridge can introduce substantial errors in certain conditions. With no second inductor to react with in the Maxwell Bridge, this problem is eliminated.



$$Z_1 Z_x = Z_2 Z_3$$

$$Z_x = Z_2 Z_3 Y_1 \text{ ----------- } (1)$$

$$Z_1, Z_2, Z_3 = impeadance\ of\ arm\ 1,2,3\ respectively$$

$$Y_1 = Admittance\ of\ arm\ 1$$

$$Z_2 = R_2$$

$$Z_3 = R_3$$

$$Y_1 = \frac{1}{R_1} + j\omega C_1$$

Sub the value of Z2, Z3 and Y1 in eqn (1)

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

Equating the real and imaginary parts

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

therefore, $$L_x = R_2 R_3 C_1$$

The resistors are expressed in ohms, the inductances in henry and capacitance in farads.

The quality factor of the coil is given by,

$$Q = \frac{\omega Lx}{Rx}$$

$$= \frac{wR2\ R3\ C1}{\left(\frac{R2R3}{R1}\right)}$$

$$Q = \omega R1C1$$

PHASOR DIAGRAM

Advantages:

a) The two balance equations are obtained is independent if we choose R1 and C1as variable elements

b) The frequency does not appear in any of the two equations.

c) The scale of the resistance can be calibrated to read the inductance directly.

d) The scale of R1 can be calibrated to read the Q value directly.

Disadvantages:

a) It cannot be used for the measurement of high Q values. It use is limited to the measurement of low Q values from 1 to 10.

b) There is an interaction between the resistance and reactance balances. Getting the balance adjustment is little difficult.

c) It is unsuited for the coils with low Q values, less than one, because of balance convergence problem.

d) The bridge balance equations are independent of frequency. But practically, the properties of coil under the test vary with frequency which can cause error.

Limitations of Maxwell Bridge:

The limitations of the Maxwell Bridge are:

- It cannot be used for the measurement of high Q values. Its use is limited to the measurement of low Q values from 1 to 10. This can be proved from phase angle balance condition which says that sum of the angles of one pair of opposite arms must be equal.

$$_1 + _4 = _2 \; _3$$

But $_2$ and $_3$ are zero, as the corresponding impedances are pure resistance. For high Q values, the angle Q is almost 90. Hence $_1$ must be -90. But $_1$gets decided by parallel combination of $_1$ and $_1$.

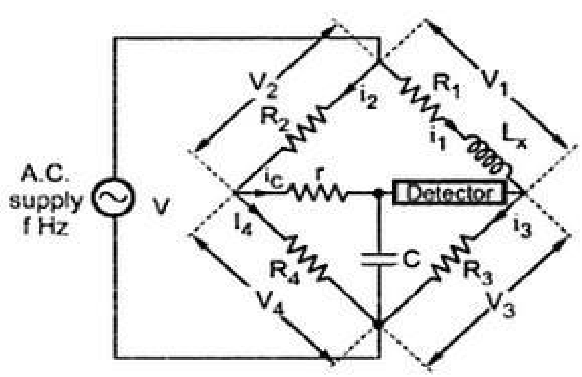
To get $_1$as almost -90, the value of $_1$should be very high. Practically such high resistance is not possible. Hence high Q values cannot be measured.

- There is an interaction between the resistance and reactance balances. Getting the balance adjustment is little difficult.
- It is unsuited for the coils with low Q values, less than one, because of balance Commercial Maxwell bridge measures the inductance from 1 – 1000 H, with + 2% error.

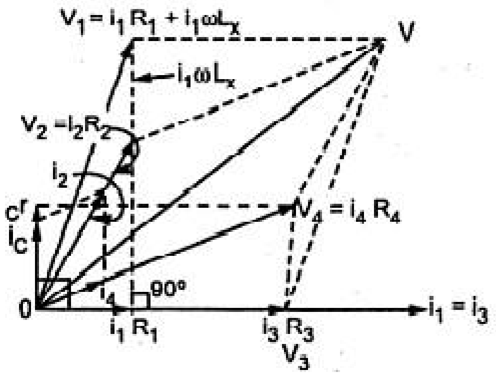
8. Explain with the neat diagram the working of Andersons Bridge. Also discuss the advantage and disadvantage with Maxwell Bridge.(NOV 16)

It is another important AC bridge used for the measurement of self-inductance in terms of standard capacitor. Actually this bridge is nothing bur modified Maxwell's bridge in which also the value of self-inductance is obtained by comparing it with a standard capacitor. This bridge is basically used for the precise measurement of inductance over a wide range of value.

Circuit Diagram:



Phasor Diagram:



The expression for unknown inductance and its resistance of Anderson's Bridge is,

$$[\ {}_{2} + {}_{4} + {}_{2}\ {}_{4}]$$

Advantages:

- ✓ Can be used for accurate measurement of capacitance in terms of inductance.
- ✓ Fixed capacitor can be used in Anderson Bridge, while in other bridges variable capacitors are used.
- ✓ The bridge is easy to balance from convergence point of view compared to Maxwell's bridge in case of low values of Q.

Disadvantages:

- ✓ More complicated than other bridges.
- ✓ Uses more number of components.
- ✓ Balance equations are complicated to derive.
- ✓ Cannot be easily shielded due to additional junction point, to avoid the effects of stray capacitance.

Describe the functions of earth resistance measurement technique with a suitable diagram.(NOV 19)

Methods of Earth Resistance Testing

Introduction:

The measurement of ground / Earth resistance for an earth electrode is very important for not only for human safety but also for preventing damages of equipment, industrial plants and to reduce system downtime.

It also provides protection against natural phenomenon such as lightning stock by providing path to the lightning current to the ground.

Ground resistance is the measurement of the resistance between conducting connection and earth Soil.

Earth Resistance should be Low as possible to provide low resistance path to leakage current to the earth.

Ground resistance depends on grounding electrode selection, soil resistivity, soil contact, and other factors

Difference between Ground Resistance and Ground Resistivity

Ground / Earth Resistance:

Ground Resistance is the resistance (Which oppose of current flow) of an installed earthing electrode system.

It is the resistance between a buried electrode and the surrounding soil. It is measured in

Ground Resistance is measured with a four-point, three-point or clamp on tester.

Ground / Earth Resistivity:

Ground resistivity is a measurement of how much the soil resists the flow of electricity. Ground resistivity is the electrical properties of the soil for conducting current.

It indicates how good the soil /Earth conducts electric currents. For the lower the resistivity, the lower the earth electrode resistance at that location.

Ground resistivity is theoretical resistance of a cylinder of earth Piece having a cross-section area of 1 Sq. meter.

Ground resistivity (ρ)is measured in **Ohm centimeters.**

Ground resistivity has nothing to deal with any installed electrical structure, but is a pure measurement of the electrical conductivity of the soil itself.

Ground resistivity is measured with a four-point tester.

Ground resistivity varies significantly according to the region, season and the type of soil because it depends on the level of humidity and the temperature (frost or drought increase it).

Purpose of Measurement of Earth Resistivity:

Earth resistivity measurements have a Main three purpose.

Earth resistivity data is used to use survey for Surface of Land to identifying locations, depth to bedrock and other geological phenomena.

Earth resistivity data is used for protective anticorrosion treatment of underground pipelines, because Earth resistivity is direct related on the degree of corrosion of underground pipelines. Lower in resistivity increase in corrosion of Underground Pipes.

Earth resistivity directly affects the design of an Earthing system. When we design an Earthing system, it is advisable to locate the area of lowest soil resistivity to achieve the most economical grounding installation. If the lower the soil resistivity value, the lower the grounding electrode resistance.

Earth Resistivity depends on:

There are various that affect the ground resistance of a ground system

Diameter of Ground Rod:

Increasing the diameter of the ground electrode has very little effect in lowering the resistance.

Doubling diameter of ground rod reduces resistance only **10%.**

Using larger diameter ground rods is mainly a strength issue. In rocky conditions, a larger diameter ground rod might be advantageous.

Depth of Ground Rod:

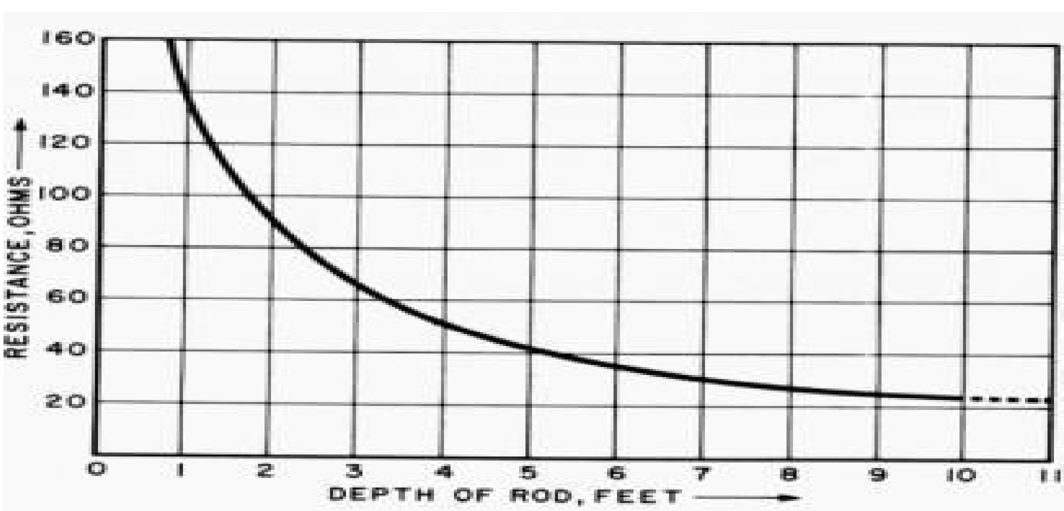
As per NEC code minimum ground electrode length of 2.5 meters (8.0 feet) to be in contact with the soil.

Doubling depth of Rod theoretically reduces resistance **40%.**

Earthing Spike (electrodes) deeper is a very effective way to lower Earthing resistance. Actual reduction of resistance depends on soil resistivity encountered in multi-layered soils. The resistance decreases rapidly as the length of the electrode increases and less rapidly as the diameter increases.

Spacing of Ground Rod:

Earth resistance decrease when distance between adjustments earthing Rod is twice the length of the rod in Ground (in good soil).



Probe Spacing		
Probe distance (m)	Soil resistance, Re (Ω)	Soil resistivity, ρρ (Ω m)
0.3	14.75	27.79
0.6	7.93	29.88
0.9	6.37	36.00
1.2	4.36	32.86
1.5	4.31	40.60

No of Ground Rods:

Using multiple ground electrodes provides another way to lower ground resistance. More than one electrode is driven into the ground and connected in parallel to lower the resistance.

The spacing of additional rods must be at least equal to the depth of the driven rod.

Two well-spaced rods driven into the earth provide parallel paths and act as two resistances in parallel. However the rule for two resistances in parallel does not apply exactly so the resultant resistance is not one-half the individual rod resistances.

The reduction in Earth resistance for equal resistance rods is 40 % for 2 rods

60 % for 3 rods

66 % for 4 rods

Material & Surface Condition of Ground Rod:

Grounding electrodes are usually made of a very conductive metal (stainless steel, copper or copper clad) with adequate cross sections so that the overall resistance is negligible.

The resistance between the electrode and the surrounding earth is eligible if the electrode is not free of paint, grease, or other coating, and not firmly packed with earth.

If the electrode is free from paint or grease, and the earth is packed firmly, contact resistance is negligible.

Rust on an iron electrode has little or no effect .But if an iron pipe has rusted through, the part below the break is not effective as a part of the earth electrode

(1) Moisture

Low-resistivity soils are highly influenced by the presence of moisture. The amount of moisture and salt content of soil affects its resistivity.

Actually, pure water has an infinitely high resistivity. Naturally occurring salts in the earth, dissolved in water, lower the resistivity. Only a small amount of salt can reduce earth resistivity quite a bit.

(2) Temperature

Increase in temperature will decrease resistivity

Increase in temperature markedly decreases the resistivity of water.

When water in the soil freezes, the resistivity jumps appreciably; ice has a high resistivity. The resistivity continues to increase a temperatures go below freezing.

(3) Soil type

Some soils such as sandy soils have high resistivity that conventional ground. Frozen and very dry soils are good insulators and have high resistivity.

In low resistivity soils, the corrosion rate is often greater than in high resistivity soils

The resistivity is much lower below the subsoil water level than above it. In frozen soil, as in a surface layer in winter, it is particularly high.

(4) Choosing Proper Instrument:

Use a dedicated ground tester for measuring earth resistance.

Do not use a generalized ohmmeter, multi meter or Megger for that.

1. **Explain the working of Q meter with a necessary circuit diagram and analyze how it measures the Q of a coil.(MAY 19)**

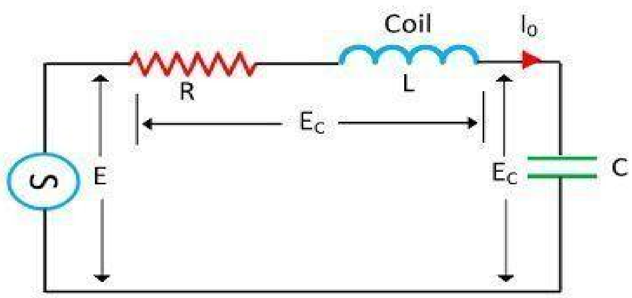
   Definition: The instrument which measures the storage factor or quality factor of the electrical circuit at radio frequencies, such type of device is known as the Q-meter. The quality factor is one of the parameters of the oscillatory system, which shows the relation between the storage and dissipated energy.

   The Q meter measures the quality factor of the circuit which shows the total energy dissipated by it. It also explains the properties of the coil and capacitor. The Q meter uses in a laboratory for testing the radio frequency of the coils.

Working Principle of Q meter

The Q meter works on series resonant. The resonance is the condition exists in the circuit when their inductance and capacitance reactance are of equal magnitude. They induce energy which is oscillating between the electric and magnetic field of the capacitor and inductor respectively.

The Q-meter is based on the characteristic of the resistance, inductance and capacitance of the resonant series circuit. The figure below shows a coil of resistance, inductance and capacitance connected in series with the circuit.



Resonant RLC Series Circuit

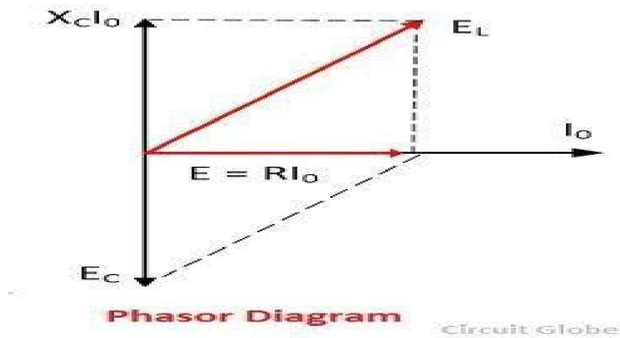
At resonant frequency f_0, $X_C = X_L$ The value of capacitance reactance is $X_C = \frac{1}{2}\pi f_0 C = \frac{1}{\omega_0 C}$ At inductive reactance, $X_L = \frac{1}{2}\pi f_0 L = \frac{1}{\omega_0 L}$

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

At the resonant frequency,

and current at resonance becomes $$I_0 = \frac{E}{R}$$

The phasor diagram of the resonance is shown in the



The voltage across the capacitor is expressed as $E_C = I_0 X_C = I_0 X_L = I_0 \omega_0 L$

Input voltage $E = I_0 r$

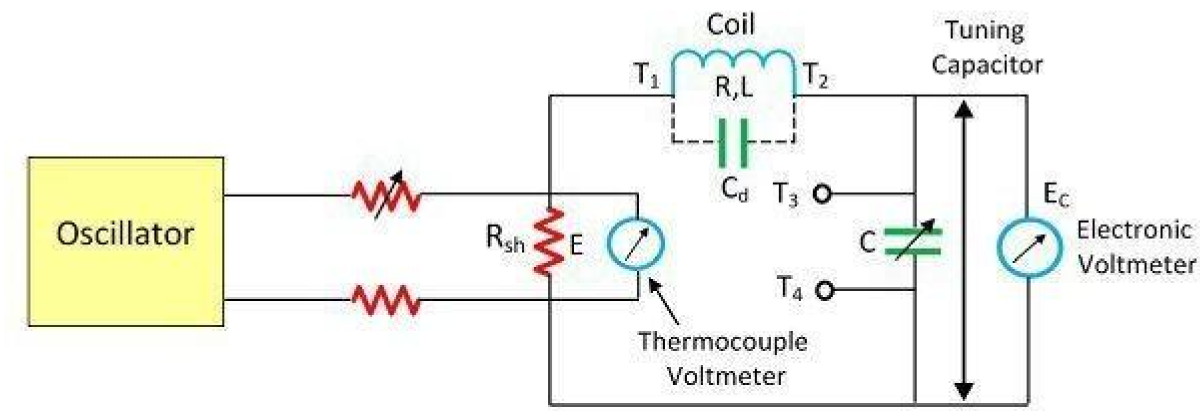
$$\frac{E_C}{E} = \frac{I_0 \omega_0 L}{I_0 R} = \frac{\omega_0 L}{R} = Q \quad E_0 = QE$$

The above equation shows that the input voltage E is Q times the voltage appears across the capacitor. The voltmeter is calibrated for finding the value of Q factor.

Applications of the Q-meter

The following are the applications of the Q-meter.

1. Measurement of Q – The circuit used for measurement of Q is shown in the figure.



Circuit of Q meter

The oscillator and tuning capacitor adjust to the desired frequency for obtaining the maximum value of E_0. Under this condition, the value of the quality factor is expressed as

$$Q_{max} = \frac{\omega_0 L}{R}$$

$$Q_{max} = \frac{\omega_0 L}{R}$$

$$Q_{true} = Q_{meas}\left(1 + \frac{R_{sh}}{R}\right)$$

True value is given as

The value of the quality factor is obtained by the voltmeter which is connected across the capacitor. The measured value is the Q factor of the whole circuit and not only of the coil. Thus, errors occur in the reading because of the shunt resistance and distributed capacitance.

$$Q_{true} = Q_{meas}\left(1 + \frac{C_d}{C}\right)$$

The above equations show that the measured value of the Q is smaller than the true value.

Measurement of Inductance – The inductance is measured by the equation shown

$$L = {}^{1}\!/_{4\pi^2 f_0^2 C}$$

below.

The value of f_0 & C is required for calculating the value of inductance.

Measurement of Effective resistance – The equation computes the value of effective resistance

$$R = \frac{\omega_0 L}{Q_{true}}$$

3. **Measurement of Self-Capacitance –** The self-capacitance is determined by measuring the two capacitance at different frequencies. The capacitor is adjusted to the high value, and the circuit is resonated by adjusting the oscillator frequency. The resonance of the circuit is

$$f_1 = \frac{1}{2\pi\sqrt{L(C_1 + C_d)}}$$

determined by the Q meter.

$$f_2 = \frac{1}{2\pi\sqrt{L(C_2 + C_d)}}$$

$$f_2 = 2f_1$$

$$\frac{1}{2\pi\sqrt{L(C_2 + C_d)}} = 2 \times \frac{1}{2\pi\sqrt{L(C_1 + C_d)}}$$

Thus,

or distributed capacitance

$$C_d = \frac{C_1 - 4C_2}{3}$$

5. **Measurement of Bandwidth – T**he equation below calculates the bandwidth

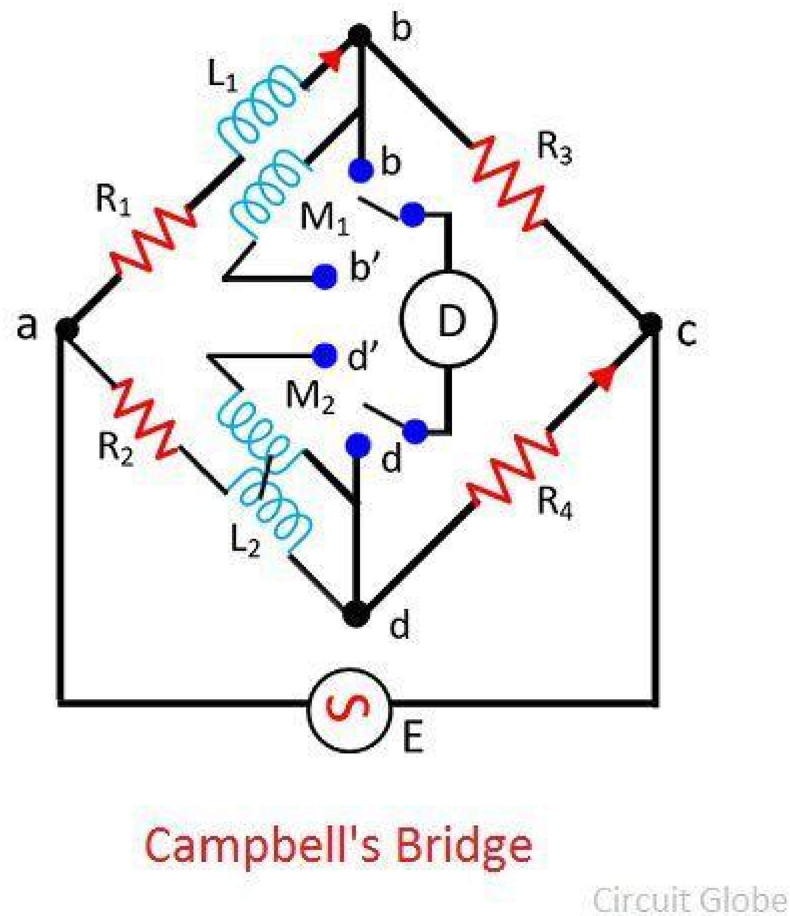
$$Q_{max} = \frac{\omega_0 L}{R}$$

6. **Measurement of Capacitance –** The capacitance is determined by connecting the dummy coil across the terminal T_1 and T_2. Let the capacitor under test is connected across the terminal T_3 and T_4. The circuit is again resonated by varying the value of tuning capacitor C_2. The value of testing capacitance is determined by subtracting the C_1 and C_2.

Campbell bridge to measure mutual inductance

Definition: The bridge which measures the unknown mutual inductance regarding mutual inductance such type of bridge is known as the Campbell bridge. The mutual inductance is the phenomenon in which the variation of current in one coil induces the current in the nearer coil. The bridge also used for measuring the frequency by adjusting the mutual inductance until the null point is not obtained.

7. Consider the figure below shows the mutual inductance.



8.

Let, M_1 – unknown mutual inductance
L_1 – self-inductance of secondary of mutual inductance M_1
M_2 – variable standard mutual inductance
L_2 – self-inductance of secondary of mutual inductance M_2
R_1, R_2, R_3, R_4 – non-inductive resistance
The two steps are required for obtaining the balanced position of the bridge.
1. The detector is connected between points 'b' and, 'd'. The circuit behaves like a simple self-inductance commercial bridge. The condition requires for obtaining the balanced position of a bridge

$$\frac{L_1}{L_2} = \frac{R_1}{R_2} = \frac{R_3}{R_4}$$

is
The bridge is in balanced condition by adjustment the R_3 or R_4 and R_1 and R_2.
2. The detector is connected between the b' and d'. Along with the step-1 adjustment if the mutual inductance M_2 is varied, then the balance point is obtained.

$$\frac{M_1}{M_2} = \frac{R_3}{R_4} \quad M_1 = \frac{M_2 R_3}{R_4}$$

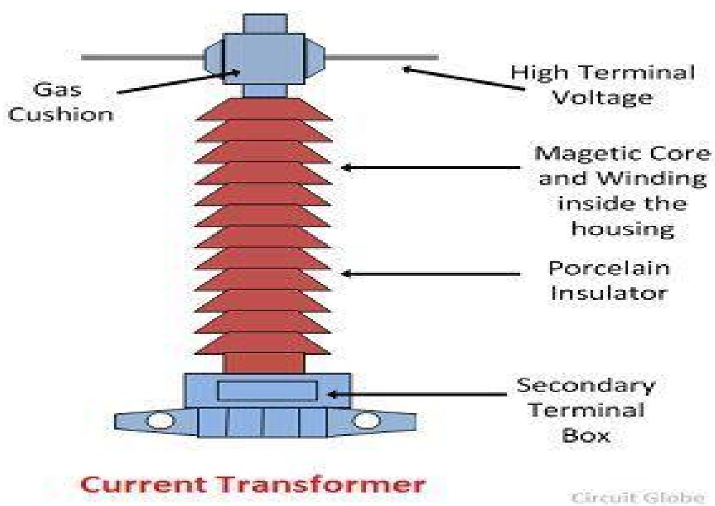
DEPARTMENT OF BIOMEDICAL ENGINEERING
EE T44/ ELECTRICAL AND ELECTRONIC INSTRUMENTS
UNIT II

1 .Explain in detail the working of a current transformer.(SEP 2020)
With necessary phasor diagram deduce expression for actual ratio and phase angle of a CT.(MAY 19)(NIOV 19)(MAY 17)(MAY 16)(MAY 15)

Current Transformer (CT)

Definition: A current transformer is a device that is used for the transformation of current from a higher value into a proportionate current to a lower value. It transforms the high voltage current into the low voltage current due to which the heavy current flows through the transmission lines is safely monitored by the ammeter.

The current transformer is used with the AC instrument, meters or control apparatus where the current to be measured is of such magnitude that the meter or instrument coil cannot conveniently be made of sufficient current carrying capacity. The current transformer is shown in the figure below.



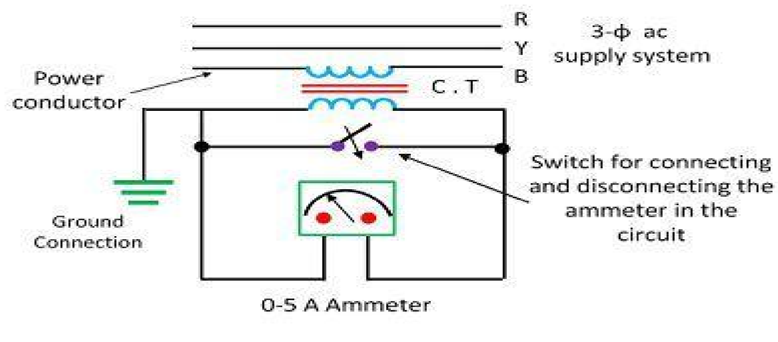
Current Transformer

The primary and secondary current of the current transformers are proportional to each other. The current transformer is used for measuring the high voltage current because of the difficulty of inadequate insulation in the meter itself. The current transformer is used in meters for measuring the current up to 100 amperes.

Construction of Current Transformers

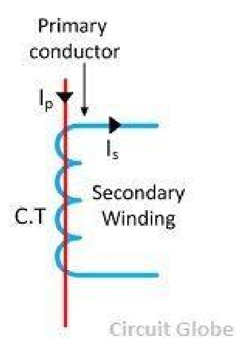
The core of the current transformer is built up with lamination of silicon steel. For getting a high degree of accuracy the Permalloy or Mumetal is used for the making cores. The primary windings of the current transformers carry the current which is to be measured, and it is connected to the main circuit. The secondary windings of the transformer carry the current proportional to the current to be measured, and it is connected to the current windings of the meters or the instruments.

The primary and the secondary windings are insulated from the cores and each other. The primary winding is a single turn winding (also called a bar primary) and carries the full load current. The secondary winding of the transformers has a large number of turns.



Current Transformer

The ratio of the primary current and the secondary current is known as a **current transformer ratio** of the circuit. The current ratio of the transformer is usually high. The secondary current ratings are of the order of 5A, 1A and 0.1A. The current primary ratings vary from 10A to 3000A or more. The symbolic representation of the current transformer is shown in the figure below.



The working principle of the current transformer is slightly different from the power transformer. In a current transformer, the load's impedance or burden on the secondary has slightly differed from the power transformers. Thus, the current transformer operates on secondary circuit conditions.

Burden on a Load

The burden of a current transformer is the value of the load connected across the secondary transformer. It is expressed as the output in volt-amperes (VA). The rated burden is the value of the burden on the nameplate of the CT. The rated burden is the product of the voltage and current on the secondary when the CT supplies the instrument or relay with its maximum rated value of current.

Effect of Open Secondary Windings of a CT

Under normal operating conditions the secondary winding of a CT is connected to its burden, and it is always closed. When the current flows through the primary windings, it always flows through secondary windings and amperes turns of each winding are subsequently equal and opposite.

The secondary turns will be 1% and 2% less than the primary turns and the difference being used in the magnetizing core. Thus, if the secondary winding is opened and the current flows through the primary windings, then there will be no demagnetizing flux due to the secondary current.

Due to the absence of the counter ampere turns of the secondary, the unopposed primary MMF will set up an abnormally high flux in the core. This flux will produce core loss with subsequent heating, and a high voltage will be induced across the secondary terminal.

This voltage caused the breakdown of the insulation and also the loss of accuracy in the future may occur because the excessive MMF leaves the residual magnetism in the core. Thus, the secondary of the CT may never be open when the primary is carrying the current.

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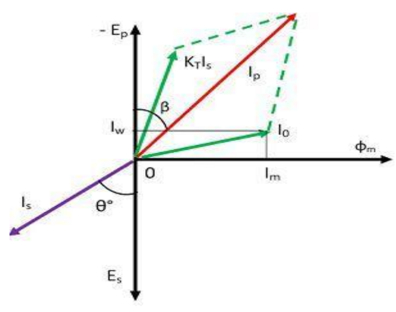


Phasor Diagram of Current Transformer

where, I_s – secondary current

E_s – secondary induced voltage

I_p -primary current

E_p – primary induced voltage

K_t – turn ratio, number of secondary turn/number of primary turn

I_0 – excitation current

I_m – magnetising current

I_w – working component

Φ_s – main flux

The secondary current lags behinds the secondary induced voltage by an angle θº. The secondary current relocates to the primary side by reversing the secondary current and multiply by the turn ratio. The current flows through the primary is the sum of the exciting current I_0 and the product of the turn ratio and secondary current $K_t I_s$.

Ratio and Phase Angle Errors of CT

The current transformer has two errors – ratio error and a phase angle error.

Current Ratio Errors – The current transformer is mainly due to the energy component of excitation current and is given as

$$Ratio\ Error = \frac{K_t I_s - I_p}{I_p}$$

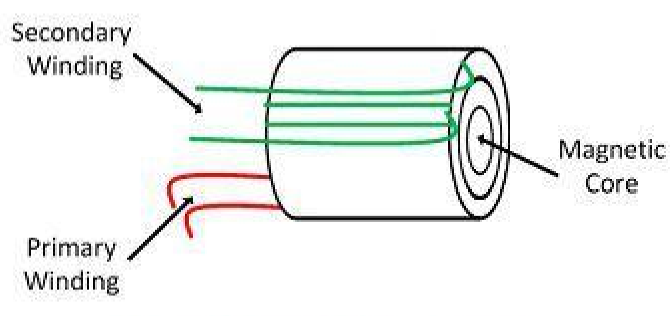
Where I_p is the primary current. K_t is the turn ratio and is the secondary current.

Phase Angle Error – In an ideal current transformer the vector angle between the primary and reversed secondary current is zero. But in an actual current transformer, there is a phase difference between the primary and the secondary current because the primary current has also supplied the component of exciting current. Thus, the difference between the two phases is termed as a phase angle error.

Types of current Transformer

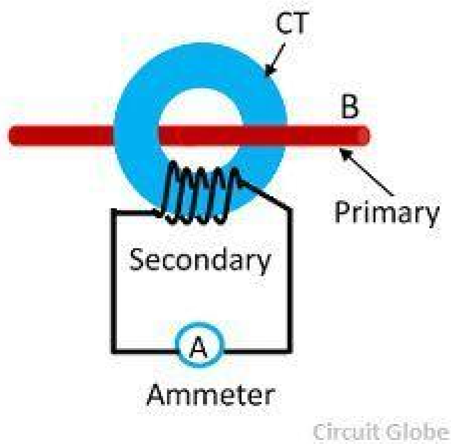
The current transformer is mainly classified into three types, i.e., wound current transformer, toroidal current transformer and bar-type transformers.

1. Wound Transformer – In this transformer the primary winding is composed inside the transformer. The primary winding had a single turn and connected in series with the conductor that measured the current. The wound transformer is mainly used for measuring the current from 1amps to 100 amps.



Wound Current Transformer

2. Bar-type Current Transformer – The bar type transformer has only secondary windings. The conductor on which the transformer is mounted will act as primary windings of the current transformers.



3.Toroidal Current Transformer – This transformer does not contain primary windings. The line through which the current flow in the network is attached through a hole or a window of the transformers. The major advantage of this transformer is that the transformer has a symmetrical shape due to which it has a low leakage flux, thus less electromagnetic interference.

2. Draw the circuit diagram of a Crompton`s potentiometer and explain its working.(SEP 2020)(MAY 16)

Standardization of Potentiometer

Standardization of a potentiometer is a process of adjusting the working current supplied by the supply battery such that the voltage drop across a portion of sliding wire matches with the Standard reference source.

The practical set up for standardising a d.c. potentiometer is as shown in the Fig. 5.4.

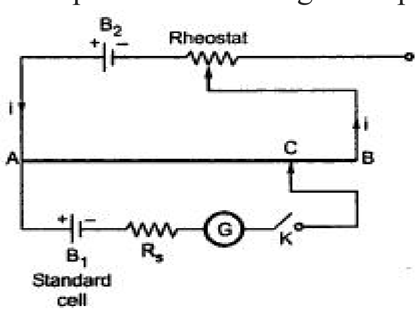


Fig. 5.4 Practical set up for d.c. potentiometer standardisation

A battery of sufficient capacity i.e. B_2 is connected in series with a rheostat R_h, which regulates the working or Standard current flowing through the slide wire. A Standard cell of e.m.f usually a weston Standard cell of e.m.f. 1.0186 volts is connected to galvanometer and a switch K through a series resistance R. By properly adjusting RH full sensitivity of the galvanometer can be obtained.

A slide wire with total length of 200 cm and resistance of 200 *ii* is connected which is indicated by points A and B.

During standardisation process, switch K is closed and the sliding contact is placed at the mark of 101.86 cm along the slide wire as indicated by point C in the Fig. 5.4.

Thus we can observe some deflection in the galvanometer. Now by adjusting the value of rheostat R_h we can get null deflection in the galvanometer.

Under the condition of null deflection, the voltage drop along 101.86 cm portion of the slide wire equals the emf, of standard weston cell This is nothing but the standardisation of a potentiometer and once the potentiometer is standardised, the rheostat is not disturbed.In other words, the working or standard current is kept constant After standardising a potentiometer, it İs used as direct reading potentiometer as the voltage along the slide wire at any point is proportional to the length of the slide wire where the point is obtained by moving sliding contact along the wire to get null deflection in the galvanometer for any battery whose e.m.f. is to be measured.

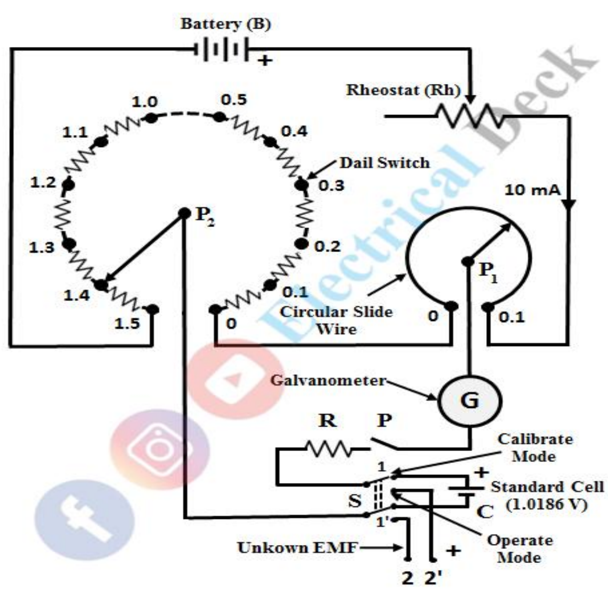
DC Crompton's Potentiometer - Construction, Operation & Applications

A potentiometer is a device used for measuring the emf of a cell or potential difference between two points in a circuit. It works on the principle of comparison i.e., comparing the unknown voltage with the known voltage and makes use of balanced condition.

DC Crompton's Potentiometer :

DC Crompton's potentiometer is the laboratory-type potentiometer that is used to measure unknown emf effectively with a great degree of precision.

DC Crompton's potentiometer works on the principle of a slide wire potentiometer. In other words, the DC Crompton potentiometer is a modified version of a slide-wire potentiometer. It basically consists of a small slide wire which is circular in shape and a dial switch with calibrated resistors, as shown in the figure below.



In the figure shown,

- B = Battery
- Rh = Rheostat
- G = Galvanometer
- R = Protective resistance which is of order of 10 KΩ
- S = Double throw switch
- C = Standard cell

In DC Crompton's potentiometer, the dial switch is divided into fifteen steps with each step having a resistance of 10Ω. Hence, the total resistance of dial switch is equal to 150Ω (15 X 10 = 150). The slide wire is in the form of a circular wire and has a resistance of 10Ω, with a single turn. A double-throw switch is provided for standardization and for measuring the unknown emf, one after the other.

A protective resistance is connected in series with the galvanometer in order to protect the galvanometer and is shorted when the galvanometer reaches the balanced condition. As the working current provided by the battery is 10 mA, the voltage drop across each step is 0.1 V and hence it has a total range of 1.5 V (1.5 x 10 = 15 V). If circular slide wire has 200 divisions, then each division in slide wire has a resolution of 0.0005 V (0.1/200 = 0.0005). Hence, it is possible to measure the readings up to 0.0001 V with great precision and accuracy by taking readings up to 1/5th division in the scale.

First, the potentiometer is to be standardized to the standard cell voltage (1.0186 V) by keeping the dial switch at 1.0 V and slide wire at 0.0186. After making these adjustments, switch S is operated in calibrate mode and key k is closed and the rheostat is adjusted in such a way that, the galvanometer shows null deflection. With this, the potentiometer is standardized to the voltage of standard cell which is connected between the terminals 1 and 1'.

Now, the switch is thrown into the operating mode for measuring the unknown emf connected between terminals 2 and 2'. The value of unknown emf can be measured directly from the dial switch and circular slide wire, after balancing the galvanometer to show null deflection. In this way, an unknown emf can be measured with great precision using DC Crompton's potentiometer.

Standardization of DC Crompton's Potentiometer :

DC Crompton potentiometer is a laboratory-type potentiometer, with high precision. Here, the long slide wire is replaced with extension coils having the resistance same as that of the slide wire. Standardization is defined as the process of adjusting the working current of the potentiometer such that the voltage drop across the section of slide wire is equal to the standard reference voltage. The following are the steps involved in the standardization of DC Crompton's potentiometer.

- Settings are made such that, the sum of the voltage across the dial resistors and the slide wire is equal to the standard cell voltage.
- The switch is closed to calibrate the positions and the rheostat is set for null deflection. The galvanometer key is tapped and the resistance is kept in the circuit to protect the galvanometer.
- As soon as zero deflection is obtained, the protective resistance is replaced by a short-circuit, and then final settings are done for null deflection using a rheostat.

Applications of DC Crompton's Potentiometer :

- Measurement of resistance.
- Measurement of power.
- Calibration of wattmeter.
- Calibration of voltmeter.
- Calibration of ammeter.

Disadvantages of a pots

Potentiometers, or pots, are adjustable resistors having a contact that moves across a resistive element. Some have a rotary action, and others are linear. This motion involves friction between internal parts, and leads to wear and noise. While designers use pots as inexpensive, easy-to-use electronic controls, wear and inertia limit their usefulness as sensors in mechanical systems. Over decades, potentiometer materials have improved, but these fundamental problems still exist.

Wear

Most potentiometers last only a few thousand rotations before the materials wear out. Although this may sound like a lot, and may mean years of service in some applications, it takes special designs to stand up to daily, demanding use. And it means they can’t be used for machine sensing where rapid cycling would wear them out in a matter of minutes.

Noise

The action of the wiper moving across the element creates a noise called "fader scratch." In new pots, this noise is inaudible, but it can get worse with age. Dust and wear increase the bumpiness of the action and make the noise noticeable. Small cracks can appear in the element, and these make noise as the wiper moves over them.

In addition to these mechanically caused noises, carbon elements, in particular, are prone to producing electrical noise. This noise is heard as a soft, steady hiss that can degrade sound recordings. The resistive materials have improved over the years, so newer pots are quieter than their ancestors.

Inertia

The friction between the potentiometer's wiper and resistive element creates a drag or inertia that the pot must overcome before it turns. Although this drag is not large, it prevents the pot from being used as a rotary sensor in more sensitive applications.

Limited Power

Out of necessity, most potentiometers can dissipate only a few watts of power at most. To handle more power, they would have to be larger and more expensive. Engineers work around this problem by putting the potentiometer in low-power parts of circuits. They control small currents, which, in turn, control transistors and other components with greater power ratings.

Advantages of Potentiometer

- **Potentiometer** works on zero deflection method so possibility of error is very small.
- The standardization of **potentiometer** can be done directly with a standard cell.
- This is highly sensitive so can be used to measure small emf's.
-

Disadvantages of Potentiometer

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

3.Analyze the operation of Drysdale type potentiometer and specify its merits and demerits.(NOV 19)(MAY 17)

Drysdale A.C. Potentiometer

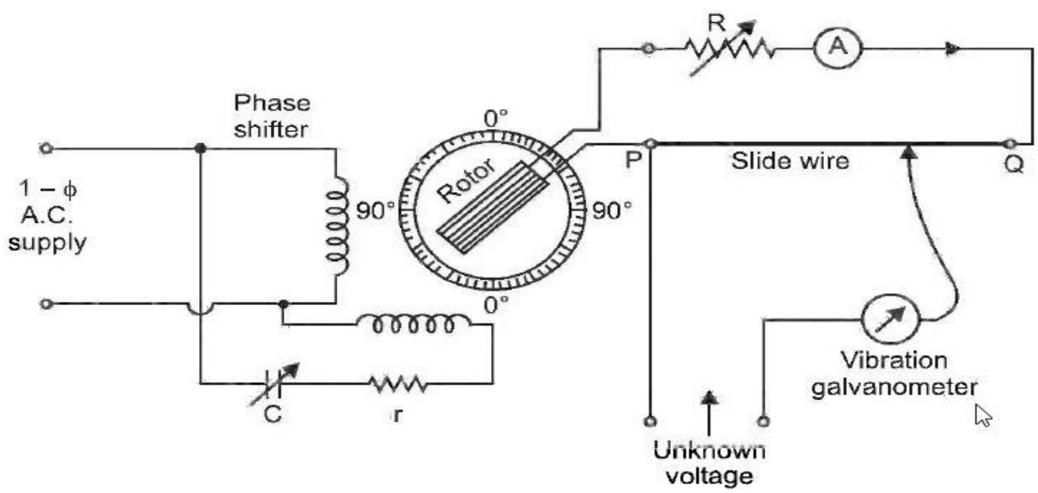
This potentiometer was developed by C. V. Drysdale for a.c. measurements. In this potentiometer, the unknown a.c. voltage is measured in the polar form V∠θ i.e., in magnitude and relative phase. For this reason, it is called polar potentiometer.

Construction. Fig. (a) shows the basic construction of Drysdale a.c. potentiometer. The slidewire PQ is supplied from a phase-shifting circuit so arranged that the magnitude of a.c. voltage supplied by it remains constant but its phase can be changed from 0^0 to 360°. The phase-shifting circuit consists of

(i) two-phase stator winding and

(ii) a movable single-phase rotor winding.

The stator is supplied from a single-phase supply which is converted into 2-phase supply by using a phase-splitting device consisting of capacitor C and resistance r as shown. The two-phase winding produces a rotating magnetic field which induces a secondary e.m.f. in the rotor winding. The e.m.f. induced in the rotor winding is of constant magnitude but its phase can be changed by rotating the rotor to any desired position. The rotor moves over a graduated circular scale marked in degrees to indicate the phase of the rotor e.m.f. relative to the stator



Working. The working of Drysdale a.c. potentiometer is as under:

First, the a.c. potentiometer is standardised i.e., it is made direct reading. For this purpose, the slide-wire circuit is connected to d.c. supply and the standard current is obtained as usual by using a standard cell. This standard current makes the potentiometer direct reading and is measured by a dynamometer ammeter which is included in the battery supply circuit of the potentiometer.This ammeter remains connected for a. c. operation also because the r.m.s. value of cun-ent in theslide-wire must be maintained at the same value (i.e., standard current) as was required on direct current. Since dynamometer ammeter reads correctly on both direct and alternating current, the potentiometer remains direct reading with an a.c. supply.

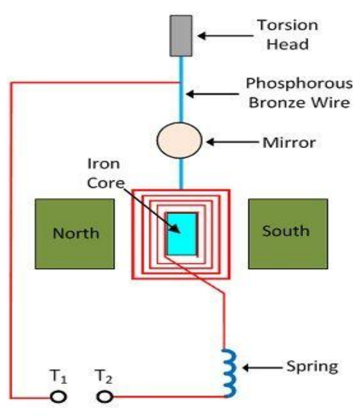
Once the a.c. potentiometer is standardised, the d.c. supply is removed and the slide-wire is connected to the rotor winding of the phase-shifting circuit. The r.m.s. value of alternating current in the slide-wire is made (through the adjustment of rheostat R) the same as on the d.c. supply. Now, the unknown a.c. voltage is applied to the slide-wire through the vibration galvanometer (detector). Balance is obtained by varying the position of slide-wire contact and position of the phase-shifting rotor. When the vibration galvanometer reads zero, it means that balance is achieved. Now, slidewire reading gives the magnitude r 'of the unknown a.c. voltage and the rotor position its phase angle θ. Therefore, the unknown a.c. voltage is represented as V∠θ.

4.Prove that in a ballistics galvanometer the charge is proportional to first swing of the moving coil.(nov 18)

Definition: The galvanometer which is used for estimating the quantity of charge flow through it is called the ballistic galvanometer. The working principle of the ballistic galvanometer is very simple. It depends on the deflection of the coil which is directly proportional to the charge passes through it. The galvanometer measures the majority of the charge passes through it in spite of current.

Construction of Ballistic Galvanometer

The ballistic galvanometer consists coil of copper wire which is wound on the non-conducting frame of the galvanometer. The phosphorous bronze suspends the coil between the north and south poles of a magnet. For increasing the magnetic flux the iron core places within the coil. The lower portion of the coil connects with the spring. This spring provides the restoring torque to the coil.



Ballistic Galvanometer

When the charge passes through the galvanometer, their coil starts moving and gets an impulse. The impulse of the coil is proportional to the charges passes through it. The actual reading of the galvanometer achieves by using the coil having a high moment of inertia. The moment of inertia means the body oppose the angular movement. If the coil has a high moment of inertia, then their oscillations are large. Thus, accurate reading is obtained.

Theory of Ballistic Galvanometer

Consider the rectangular coil having N number of turns placed in a uniform magnetic field. Let **l** be the length and **b** be the breadth of the coil. The area of the coil is given as

$$A = l \times b \ldots..equ(1)$$

When the current passes through the coil, the torque acts on it. The given expression determines the magnitude of the torque.

$$\tau = NiBA \ldots\ldots equ(2)$$

Let the current flow through the coil for very short duration says dt and it is expressed as

$$\tau dt = NiBAdt \ldots\ldots equ(3)$$

If the current passing through the coil for t seconds, the expression becomes

$$\int_0^t \tau dt = NBA \int_0^t idt = NBAq \ldots\ldots equ(4)$$

The q be the total charge passes through the coil. The moment of inertia of the coil is given by l, and the angular velocity through ω. The expression gives the angular momentum of the coil

$$Angular\ momentum = l\omega \ldots\ldots.equ(5)$$

The angular momentum of the coil is equal to the force acting on the coil. Thus from equation (4) and (5), we get.

$$l\omega = NBAq \ldots\ldots equ(6)$$

The Kinetic Energy (K) deflects the coil through an angle θ, and this deflection is restored through the spring.

$$\text{Restoring torque} = \frac{1}{2} c\theta^2$$

$$\text{Kinetic energy K} = \frac{1}{2} l\omega^2$$

The resorting torque of the coil is equal to their deflection.

$$\frac{1}{2} c\theta^2 = \frac{1}{2} l\omega^2$$

Thus,

$$c\theta^2 = l\omega^2 \ldots\ldots\ldots.equ(7)$$

$$T = 2\pi\sqrt{l/c}$$

$$T^2 = \frac{4\pi^2 l}{c}$$

$$\frac{T^2}{4\pi^2} = \frac{l}{c}$$

The periodic oscillation of the coil is given as $$\frac{cT^2}{4\pi^2} = l$$

By multiplying the equation (7) from the above equation we get $$\frac{c^2T^2\theta^2}{4\pi^2} = l^2\omega^2$$

$$\frac{ct\theta}{2\pi} = l\omega \dots \dots \dots equ(8)$$

On substituting the value of equation (6) in the equation (8) we get

$$\frac{ct\theta}{2\pi} = NBAq$$

$$q = \frac{ct\theta}{NBA2\pi} \dots \dots \dots equ(9)$$

$$q = \frac{ct}{2\pi BNA} \times (\theta)$$

$$Let, k = \frac{ct}{2\pi BNA}$$

$$q = k\theta$$

The K is the constant of the ballistic galvanometer.
Calibration of Galvanometer

The calibration of the galvanometer is the process of determining its constant value by the help of the practical experiments. The following are the methods used for determining the constant of the ballistic galvanometer.

5. TESTING OF SPECIMENS IN THE FORM OF RODS OR BARS

It is obviously much easier to prepare a specimen in the form of a rod or bar than to prepare a ring specimen. However, if test methods described for ring specimens are employed to bar specimens, some difficulties and inaccuracies arise in testing. Bar specimens suffer from the disadvantage of "self-demagnetization". When a bar is magnetized electromagnetically, poles are produced at the ends, and these poles produce, inside the rod, a magnetizing force from the north pole to the south which is in opposition to the applied magnetizing force, thus rendering the true value of H acting on the bar a somewhat uncertain quantity. For accurate results, therefore, if the methods of measurement using a ballistic galvanometer are used, this demagnetizing effect must be corrected for, or, since the effect is least when the ratio of diameter to length of the rod is small, the dimensions of the specimen should be chosen so that the effect is negligible.

The demagnetizing force due to this "end effect" is given by the expression where, $B f$ is the ferric induction, i.e. the flux density due to the magnetization of the iron piece itself, and F is a constant which depends upon the relative dimension of the rod. For an ellipsoid or very long rod, the value of the coefficient F can be calculated from the expression where,

a = minor axis of the ellipsoid

b = major axis of the ellipsoid

To obtain the true value of the magnetizing force H acting on the bar specimen, $H d$ must be subtracted from the value of H calculated from the ampere-turns per meter length of the magnetizing winding. It has been seen that the length-to-diameter ratio of the specimen must be of the order of 25 or more for to have a negligible influence upon the value of H .

On account of this demagnetizing effect, the value of H is often measured by means of search coils wound on thin strips of glass and placed with the glass lying flat on the bar specimen. The flux density in the air at the surface of the specimen (which is same as H in the specimen) is measured by this means instead of relying upon calculated values and corrections.

PERMEAMETERS

There are various forms of "permeameters" that have been devised to avoid difficulties incurred to test straight specimens. Permeameters provide controllable field conditions to test bar specimens. They consist generally of a fixed steel frame to which straight samples can be fitted, but differ widely in the arrangement of magnetizing and pick-up or search coils and in the means of guarding against leakage fluxes and mmf drops at the joints. All permeameters use return paths of large cross-section area in order to make the reluctance of the paths negligible. Most of the permeameters incorporate modifications of the bar and yoke arrangements first described by Hopkinson. The following discussion shall be limited only on a few of many forms of permeameters.

Hopkinson Permeameter (Bar-and-Yoke Method)

This method is used for the testing of bar specimens and the demagnetizing effect is largely eliminated by the use of heavy-section yokes. A search coil is wound around the bar specimen at its centre, and the bar is then clamped between the two halves of a massive iron yoke, whose reluctance is small compared with that of the specimen, as shown in Figure 14 . The magnetizing winding is fixed inside the yoke, as shown, the specimen fitting inside it.

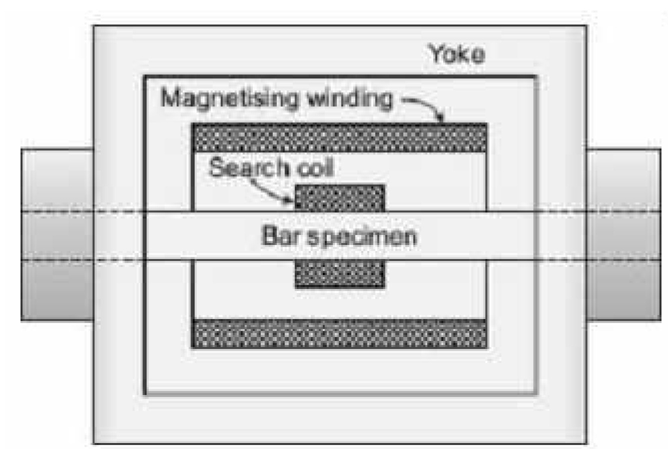


FIG. 14 *Bar and yoke method*

Let, N = number of turns of the magnetizing winding

I = current in the magnetizing winding

l = length of specimen between two halves of the yoke

A = cross-section of the specimen

$\mu_s = \mu_{sr} \mu_0$ = permeability of the specimen when the magnetizing current is *I*, μ_{sr} being the relative permeability of the specimen

R_y = reluctance of the yoke

R_j = reluctance of the two joints between bar specimen and yoke

Φ = flux in the magnetic circuit

Then, Reluctance of the specimen, $R_s = l/\mu_s A$ So, flux Φ = mmf/reluctance of magnetic circuit

Flux density in the specimen, Magnetizing force, Let, *m* = Reluctance of yoke and joints/Reluctance of the specimen The value of *m* is made small by keeping the reluctance of the yoke and the joints to a small value. This can be achieved by carefully fitting the specimen into the yoke so that air gap between the bar and yoke is negligible and making the yoke of large cross-section.

So if *m* is small, which means that the actual value of *H* in the specimen differs from the value calculated from the magnetizing ampere-turns and length of specimen by the amount *mNI/l.* The flux density may be measured by a ballistic galvanometer in the usual way.

6.Discuss about the construction of potential transformer along with its phasor diagram and characteristics.(NOV 17)

Definition – The potential transformer may be defined as an instrument transformer used for the transformation of voltage from a higher value to the lower value. This transformer step down the voltage to a safe limit value which can be easily measured by the ordinary low voltage instrument like a voltmeter, wattmeter and watt-hour meters, etc.

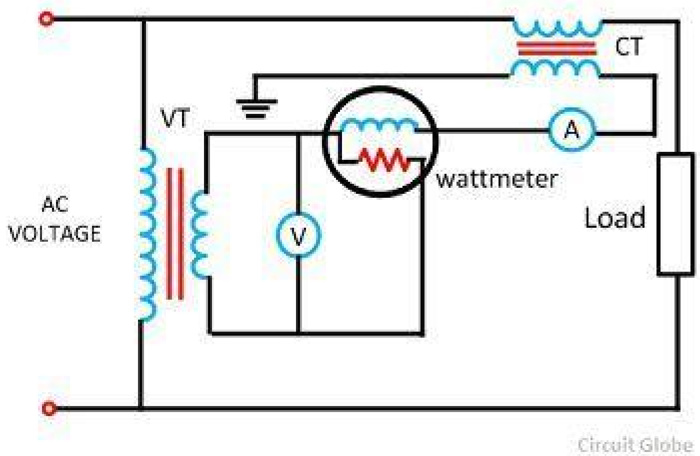
Construction of Potential Transformer

The potential transformer is made with high-quality core operating at low flux density so that the magnetising current is small. The terminal of the transformer should be designed so that the variation of the voltage ratio with load is minimum and the phase shift between the input and output voltage is also minimum.

The primary winding has a large number of turns, and the secondary winding has a much small number of turns. For reducing the leakage reactance, the co-axial winding is used in the potential transformer. The insulation cost is also reduced by dividing the primary winding into the sections which reduced the insulation between the layers.

Connection of Potential Transformer

The potential transformer is connected in parallel with the circuit. The primary windings of the potential transformer are directly connected to the power circuit whose voltage is to be measured. The secondary terminals of the potential transformer are connected to the measuring instrument like the voltmeter, wattmeter, etc.The secondary windings of the potential transformer are magnetically coupled through the magnetic circuit of the primary windings

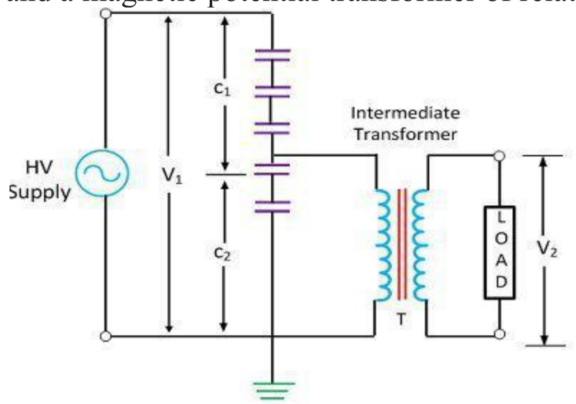


The primary terminal of the transformer is rated for 400V to several thousand volts, and the secondary terminal is always rated for 400V. The ratio of the primary voltage to the secondary voltage is termed as transformation ratio or turn ratio.

Types of Potential Transformer

The potential transformer is mainly classified into two types, i.e., the conventional wound types (electromagnetic types) and the capacitor voltage potential transformers.

Conventional wound type transformer is very expensive because of the requirement of the insulations.Capacitor potential transformer is a combination of capacitor potential divider and a magnetic potential transformer of relatively small ratio.



Capacitor Potential Transformer Circuit Diagram

The circuit diagram of the capacitor potential transformer is shown in the figure below. The stack of high voltage capacitor from the potential divider, the capacitors of two sections become C_1 and C_2, and the Z is the burden.

The voltage applied to the primary of the intermediate transformer is usually of the order 10kV. Both the potential divider and the intermediate transformer have the ratio and insulation requirement which are suitable for economical construction.

The intermediate transformer must be of very small ratio error, and phase angle gives the satisfactory performance of the complete unit. The secondary terminal voltage is given by the formula shown below.

$$V_2 = V_1 \times \frac{C_1}{C_1 + C_2}$$

Ratio and Phase Angle Errors of Potential Transformer

In an ideal potential transformer, the primary and the secondary voltage is exactly proportional to the primary voltage and exactly in phase opposition. But this cannot be achieved practically due to the primary and secondary voltage drops. Thus, both the primary and secondary voltage is introduced in the system.

Voltage Ratio Error – The voltage ratio error is expressed in regarding measured voltage, and it is given by the formula as shown below.

$$Ratio\ Error = \frac{K_t I_s - I_p}{I_p}$$

Where K_n is the nominal ratio, i.e., the ratio of the rated primary voltage and the rated secondary voltage.

Phase Angle Error – The phase angle error is the error between the secondary terminal voltage which is exactly in phase opposition with the primary terminal voltage.

The increases in the number of instruments in the relay connected to the secondary of the potential transformer will increase the errors in the potential transformers.

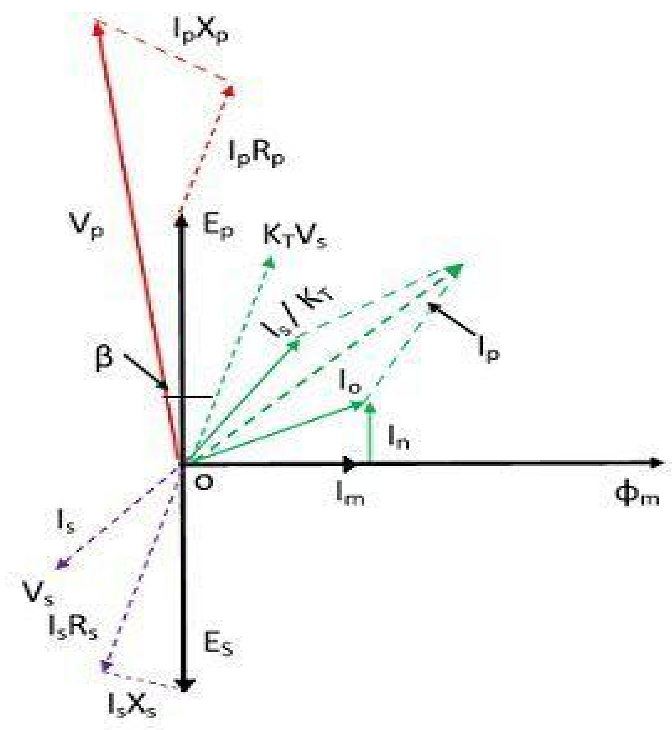
Burden of a Potential Transformer

The burden is the total external volt-amp load on the secondary at rated secondary voltage. The rated burden of a PT is a VA burden which must not be exceeded if the transformer is to operate with its rated accuracy. The rated burden is indicated on the nameplate.

The limiting or maximum burden is the greatest VA load at which the potential transformer will operate continuously without overheating its windings beyond the permissible limits. This burden is several times greater than the rated burden.

Phasor Diagram of a Potential Transformer

The phasor diagram of the potential transformer is shown in the figure below.



Phasor Diagram of Potential Transformer

Where, I_s – secondary current
E_s – secondary induced emf
V_s – secondary terminal voltage
R_s – secondary winding resistance
X_s – secondary winding reactance
I_p – Primary current
E_p – primarily induced emf
V_p – primary terminal voltage
R_p – primary winding resistance
X_p – primary winding reactance
K_t – turn ratio
I_o – excitation current
I_m – magnetising component of I_o
I_w – core loss component of I_o
Φ_m – main flux
B- phase angle error

The main flux is taken as a reference. In instrument transformer, the primary current is the vector sum of the excitation current I_o and the current equal to the reversal secondary current I_s multiplied by the ratio of $1/k_t$. The V_p is the voltage applied to the primary terminal of the potential transformer.

The voltage drops due to resistance and reactance of primary winding due to primary current is given by I_pX_p and I_pR_p. When the voltage drop subtracts from the primary voltage of the potential transformer, the primarily induced emf will appear across the terminals.

This primary emf of the transformer will transform into secondary winding by mutual induction and converted into secondary induced emf E_s. This emf will drop by the secondary winding resistance and reactance, and the resultant voltage will appear across the secondary terminal voltage, and it is denoted by V_s.

Applications of Potential Transformer

1. It is used for a metering purpose.
2. For the protection of the feeders.
3. For protecting the impedance of the generators.
4. For synchronising the generators and feeders.

The potential transformers are used in the protecting relaying scheme because the potential coils of the protective device are not directly connected to the system in case of the high voltage. Therefore, it is necessary to step down the voltage and also to insulate the protective equipment from the primary circuit.

8. Discuss about the advantages and disadvantage of resistance type potentiometers.

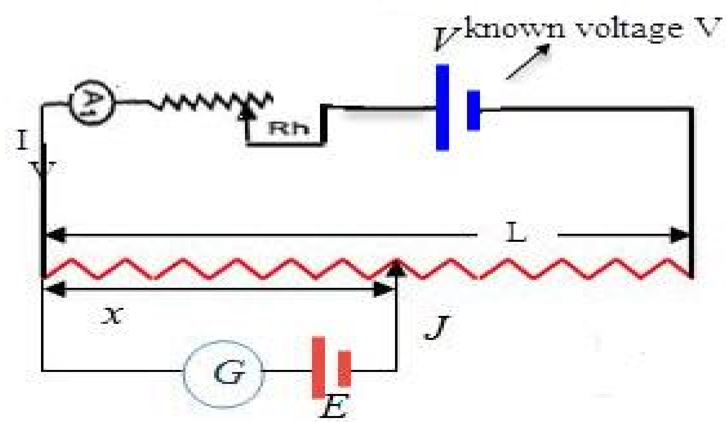
A potentiometer is a passive electronic component. Potentiometers work by varying the position of a sliding contact across a uniform resistance. In a potentiometer, the entire input voltage is applied across the whole length of the resistor, and the output voltage is the voltage drop between the fixed and sliding contact as shown below.

A potentiometer has the two terminals of the input source fixed to the end of the resistor.

To adjust the output voltage the sliding contact gets moved along the resistor on the output side.

This is different to a rheostat, where here one end is fixed and the sliding terminal is connected to the circuit,

This is a very basic instrument used for comparing the emf of two cells and for calibrating ammeter, voltmeter, and watt-meter. The basic **working principle of a potentiometer** is quite simple. Suppose we have connected two batteries in parallel through a galvanometer. The negative battery terminals are connected together and positive battery terminals are also connected together through a galvanometer as shown in the figure below.



Here, if the electric potential of both battery cells is exactly the same, there is no circulating current in the circuit and hence the galvanometer shows null deflection. The **working principle of potentiometer** depends upon this phenomenon.

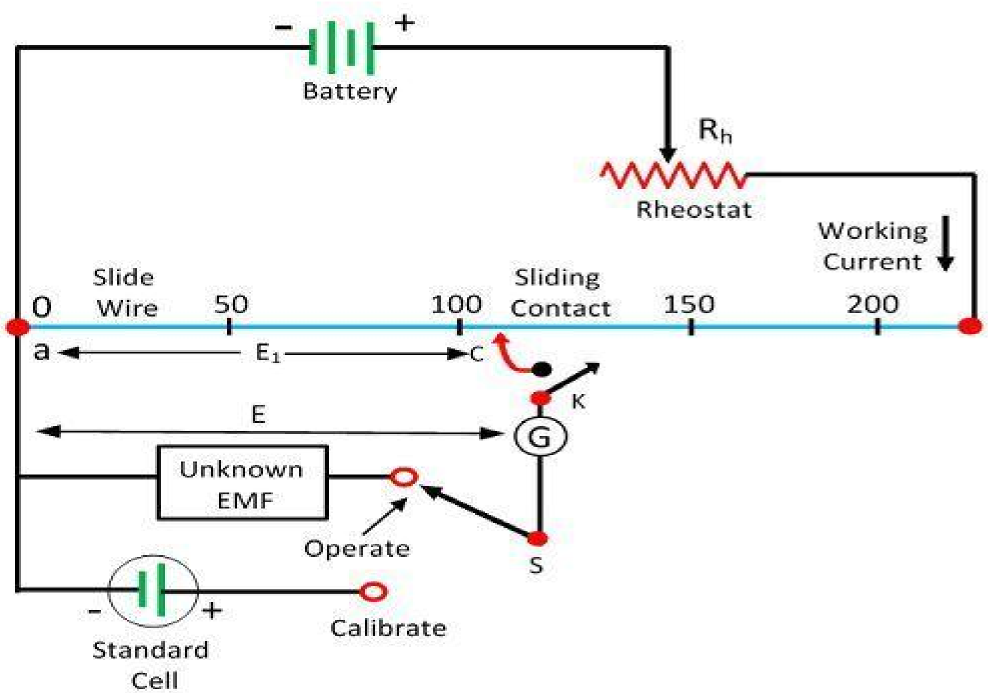
Now let's think about another circuit, where a battery is connected across a resistor via a switch and a rheostat as shown in the figure below.

The resistor has the uniform electrical resistance per unit length throughout its length. Hence, the voltage drop per unit length of the resistor is equal throughout its length. Suppose, by adjusting the rheostat we get v volt voltage drop appearing per unit length of the resistor.

Now, the positive terminal of a standard cell is connected to point A on the resistor and the negative terminal of the same is connected with a galvanometer. The other end of the galvanometer is in contact with the resistor via a sliding contact as shown in the figure above. By adjusting this sliding end, a point like B is found where there is no current through the galvanometer, hence no deflection in the galvanometer.

That means, emf of the standard cell is just balanced by the voltage appearing in the resistor across points A and B. Now if the distance between points A and B is L, then we can write emf of standard cell E = Lv volt.

This is how a potentiometer measures the voltage between two points (here between A and B) without taking any current component from the circuit. This is the specialty of a potentiometer, it can measure voltage most accurately.



Circuit Diagram of a Basic Slide Wire Potentiometer

Potentiometer Types

There are two main types of potentiometers:

Rotary potentiometer

Linear potentiometer

Although the basic constructional features of these potentiometers vary, the working principle of both of these types of potentiometers is the same.

Note that these are types of DC potentiometers – the types of AC potentiometers are slightly different.

Rotary potentiometer

The rotary type potentiometers are used mainly for obtaining adjustable supply voltage to a part of electronic circuits and electrical circuits. The volume controller of a radio transistor is a popular example of a rotary potentiometer where the rotary knob of the potentiometer controls the supply to the amplifier.

This type of potentiometer has two terminal contacts between which a uniform resistance is placed in a semi-circular pattern. The device also has a middle terminal which is connected to the resistance through a sliding contact attached with a rotary knob. By rotating the knob one can move the sliding contact on the semi-circular resistance. The voltage is taken between a resistance end contact and the sliding contact. The potentiometer is also named as the POT in short. POT is also used in substation battery chargers to adjust the charging voltage of a battery. There are many more uses of rotary type potentiometer where smooth voltage control is required.

Linear Potentiometers

The linear potentiometer is basically the same but the only difference is that here instead of rotary movement the sliding contact gets moved on the resistor linearly. Here two ends of a straight resistor are connected across the source voltage. A sliding contact can be slide on the resistor through a track attached along with the resistor. The terminal connected to the sliding is connected to one end of the output circuit and one of the terminals of the resistor is connected to the other end of the output circuit.

This type of potentiometer is mainly used to measure the voltage across a branch of a circuit, for measuring the internal resistance of a battery cell, for comparing a battery cell with a standard cell and in our daily life, it is commonly used in the equalizer of music and sound mixing systems.

9.DETERMINATION OF B-H CURVES

Two methods

1. Method of Reversals
2. Step – by Step Method

Method of Reversals

To determine the B-H curve, the known dimension of ring shaped specimen is used.

A layer of thin tape is put on the ring and a search coil insulated by paraffin wax is wound over a tape. Another layer of tape is put over the search coil and the magnetizing winding is uniformly wound over this tape

Procedure

The specimen is demagnetized and then the magnetizing current I is set to its lowest value.

Ballistic Galvanometer key K is closed and reversing switch S is operated about twenty times backward and forward. It is done to bring the specimen into a reproducible cyclic magnetic state.

Now key K is opened, By reversing the switch S, the value of flux corresponding to the value of H is measured and the throw of galvanometer is noted. The value of flux density corresponding to this H can also be calculated by dividing the flux by the area of the specimen.

The above procedure is repeated for various value of H up to the maximum test point.

Step By Step Method

The special feature of this method of determination of B-H curve is that there is no reversal of magnetizing current.

The Direct current is supplied to the magnetizing coil through a potential divider having a number of tapping. The tappings are so arranged that the value of magnetizing current I and so magnetizing force H is increased up to the desired maximum value, in a number of suitable steps.

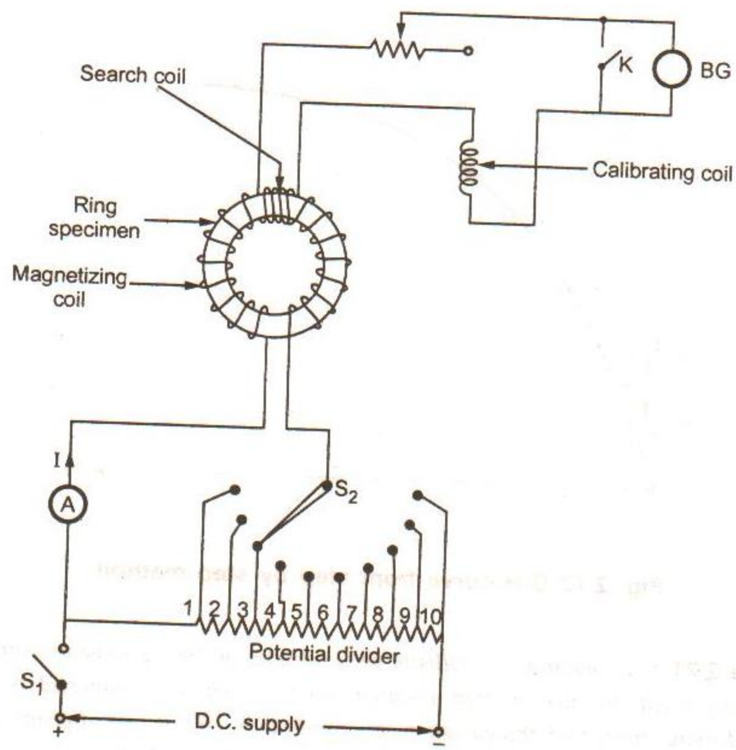


Fig., Step by step method

Procedure

The tappings switch S2 is set on tapping 1 and switch S1 is closed. The throw of galvanometer corresponding to the increase in flux density in the specimen from zero to some value B1 is observed .The value of B1 can be calculated from the throw of the galvanometer. The value of the corresponding magnetizing force H1 may be calculated from the value of current flowing in the magnetizing winding at tapping1.

The magnetizing force is then increased suddenly to H2 by suddenly changing the position of switch S2 from tapping1 to tapping 2 and the corresponding increase in flux density is determined from the galvanometer throw observed. The flux density B2 corresponding to magnetizing force H2 will be equal to B1 plus increase in flux density B determined from the galvanometer throw.

The process is repeated for other values of H to the maximum point and complete B-H curve is obtained.

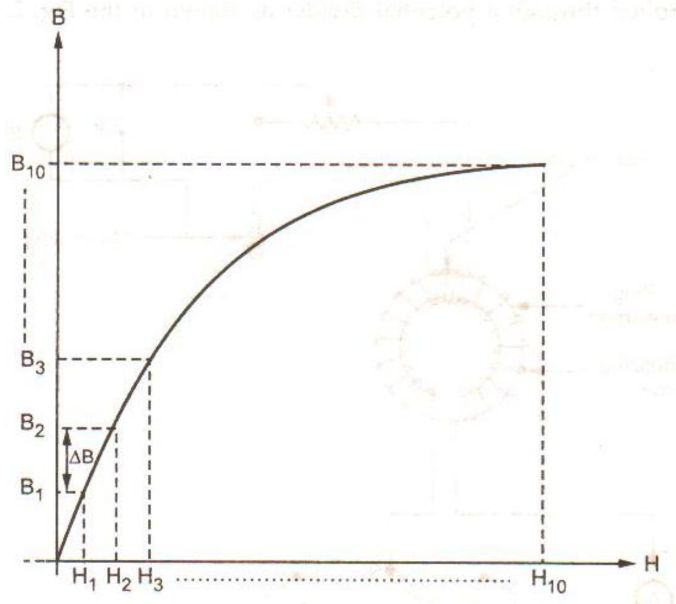


Fig., B-H Curve From Step by Step Method

DETERMINATION OF HYSTERESIS LOOP

There are two methods

1. Method of Reversal
2. Step –by-step method

Method of Reversal

R1,R2 and R3 are the variable resistance for adjusting the resistance in the B.G and magnetizing coil circuits .R4 is a variable shunting resistance, which can be connected across the magnetizing coil by means of switch S2 thus reducing the magnetizing current from its maximum value down to any desired value depending upon the value of R4.

The value of magnetizing force Hmax required to produce flux density Bmax to be used during the test is obtained from the B-H curve of the specimen.

The resistances R2 and R3 are adjusted to give such a current in a magnetic coil that magnetizing force Hmax is produced with S2 is off position. The resistance in the galvanometer circuit R1 is adjusted to obtain suitable deflection in B.G on reversing the maximum magnetizing current I. The shunting resistance R4 is adjusted to give required reduction in magnetizing current when connected across magnetizing winding.

The reversing switch RS2 is placed on contacts 1.1' and B.G is connected to the circuit by opening short-circuiting key K.The value of B_{max} is determined corresponding to H_{max} from the deflection of galvanometer observed on reversing switch RS2 and point A on the hysteresis loop is obtained.

The switch S2 is then thrown from off position to contact b in order to connect resistance R4 across the magnetizing winding and reduce the magnetizing force to Hk. The corresponding reduction in flux density δB is obtained from the galvanometer throw and thus point K is obtained on the loop.

The galvanometer is then short circuited by closing key K and reversing switch RS2 is reversed to contact 2, 2'.Switch S2 is moved to the off position and reversing switch S2 is moved back to contacts 1.1'.This procedure passes the specimen through the cycle of magnetization and back to the point A

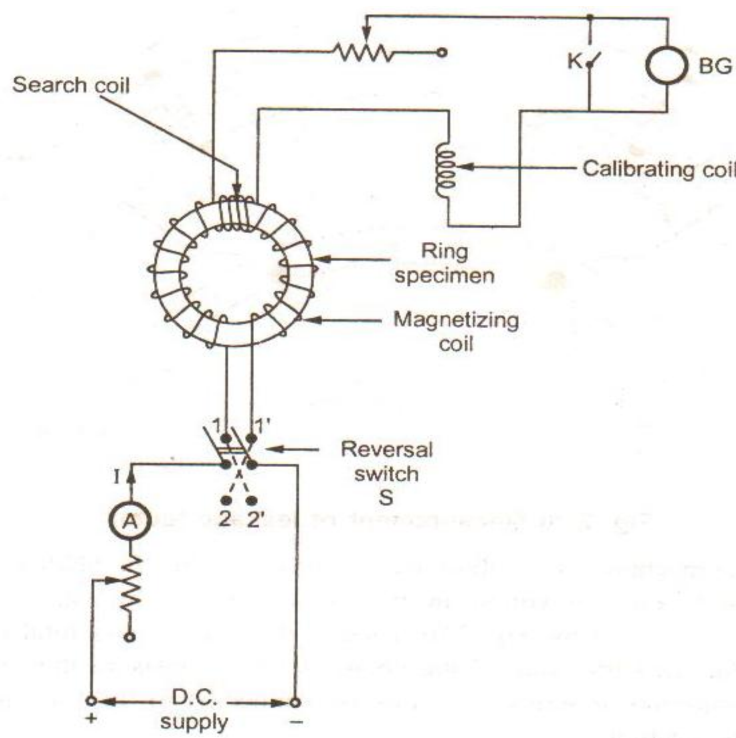


Fig..Method of reversal

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The specimen is now ready for the next step in the test. The part AC of the loop is obtained by adjusting the shunting resistance R4 to give different reduced values of H and determining corresponding reduction in B.

In order to obtain part CDE of the loop, galvanometer is short circuited, switch S2 is put in the off position, and reversing switch RS2 moved back again to contacts 1, 1'.Now place switch S2 on contact a, open the key K and rapidly reverse RS2 to contacts 2, 2'.This causes the magnetizing force to change from +Hmax to –HL from the throw of galvanometer change in flux density δB can be obtained.

The magnetizing of the specimen is brought back to point A by reversing Switch RS2 on to contacts 1.1' with key K closed. By continuing this procedure, other parts on part of CDE of the hysteresis loop are obtained .Thus part ACDE of the loop can be traced.

The part EFGA of the loop may be obtained by drawing in the reverse of the part ACDE as the two halves are identical.

10. LOSS MEASUREMENT USING WATTMETER

The methods of measuring iron losses are classified as,

1. Wattmeter Method
2. Bridge Method
3. Potentiometer Method
4. Oscillographic Method

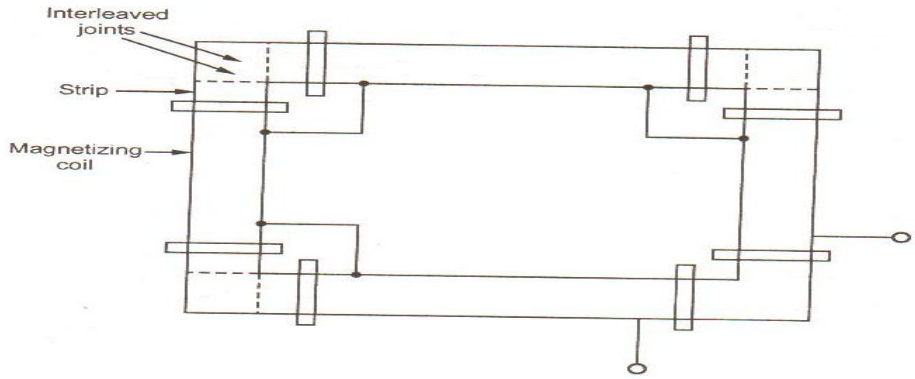
1 Wattmeter Method

This is most commonly used and simple method of measuring iron loss in a strip steel material. The material is arranged in a form of closed magnetic circuit, in a shape of a Square. The square carries the magnetizing and the search coils.

There are two types of magnetic square

1. Epstein Square
2. Lioyed-Fisher Square

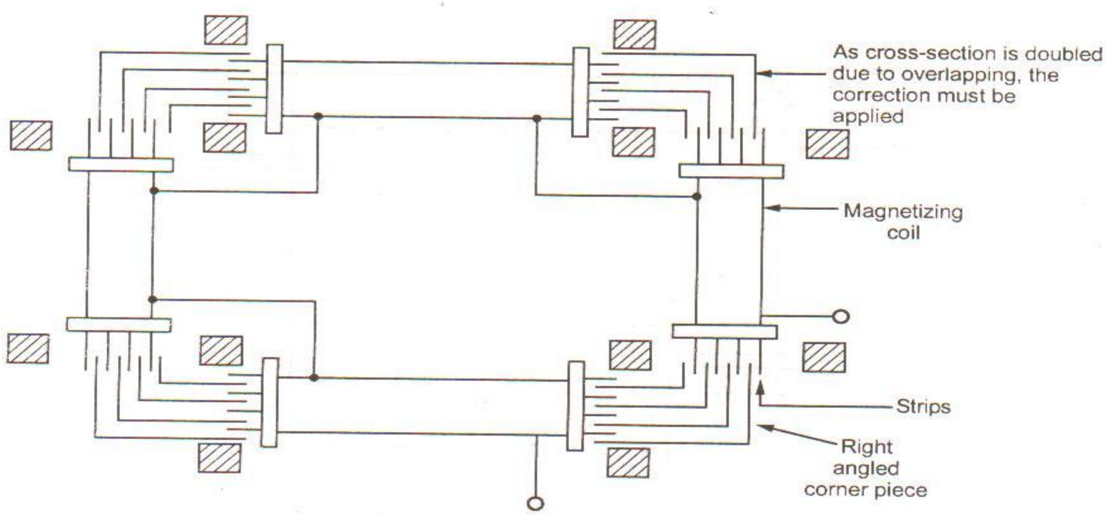
Epstein Square



It consists of four stacks of strips which are bound taped. All the stips are in the plane of the square. The strips are insulated from each other. The corner joints are interleaved. The strips are inserted into four magnetizing coils and strips are projected beyond the coils.

Lioyed-Fisher Square

In this square, the strips are built up into four stacks. Each stack consists of two types of strips, one cut in the direction of rolling and other cut perpendicular to the direction of rolling. The stacks are inserted inside four magnetizing coils having large cross-sectional ares.All these coils are connected in series to form a primary winding.



Below each magnetizing coil, there are two similar single layer coils are placed. These are secondary coils. The four coils are connected in series and such two groups exist. Thus two separate secondary windings exist.

The strips are projected beyond the coil and arranged in such a way that each is perpendicular to the plane of the square. The right angled corner pieces are used at the corners to form the corner joints. The corner pieces and strips are overlapped due to which the cross-section of the iron is doubled at the corners. Hence a correction is required to be applied for the measured value of iron loss.

The correction is required for this value of flux density as S2 encloses the flux in air gap between specimen and the coil, in addition to the flux in the specimen.

$$B_m = B'_m - \mu_o H_m \, [A_c / A_s - 1]$$

B_m = Maximum flux density required

A_c = Cross section of coil in m^2

A_s = Cross section and specimen in m^2

Measurement setup of wattmeter Method

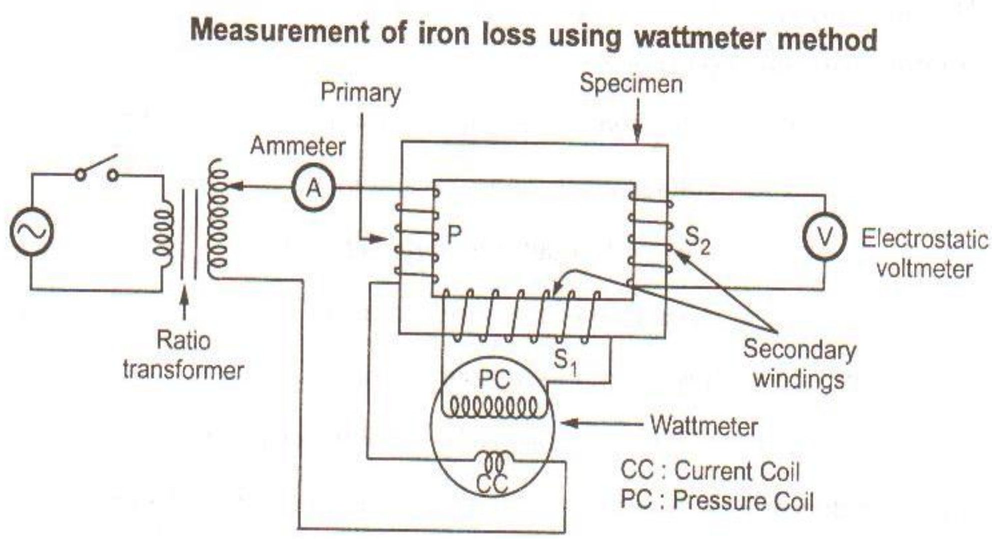


Fig shows the connection diagram for the measurement of total iron loss by a wattmeter method. The weight and cross section of the test specimen is determined before the test.

The four magnetizing coil connected in series together form a primary winding. It is connected to the transformer secondary through the current coil (CC) of the wattmeter, for the alternating supply. The pressure coil (PC) is connected to one of the secondary windings. The other secondary winding is connected to the very high impedance electrostatic voltmeter. The supply frequency is adjusted to the required value. The wattmeter is a low power factor device having power factor of about 0.2.

Theory

The supply voltage is adjusted using the tappings on the secondary of the ratio transformer, till the required maximum flux density (Bm) is reached in the specimen. The voltage induced in the secondary S2 is measured on voltmeter while the wattmeter reading is observed.

The voltage measured by voltmeter is given by,

$$E = 4K_f(B'_m A_s)fN_2$$

$\Phi_m = B'_m A_s$

K_f =Form Factor= 1.11 for sinusoidal flux

B'_m = Apparent value of maximum flux density in Wb / m2

A_s = Cross sectional area of specimen in m2

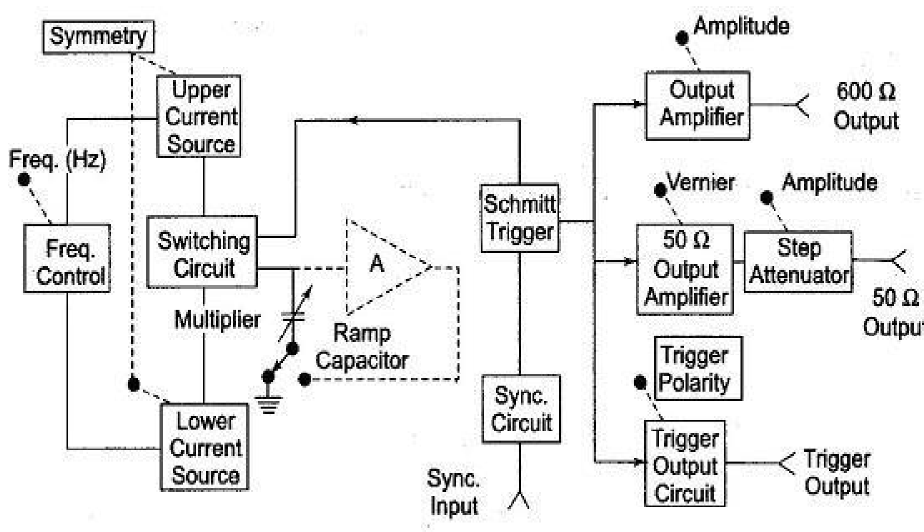
N_2 = Number of turns in the winding S2

f = Frequency in Hz

$B'_m = E / 4K_f A_s f N_2$

UNIT –IV

1. Draw the block diagram of pulse wave generator and explain.(SEP2020)



Pulse- and square-wave generators are generally used with an oscilloscope for measurement Purposes.

The generated waveforms are displayed on the oscilloscope screen; they provide sufficient information about the system under test.

The major difference between both of these generators lies in their duty cycle which can be defined as the ratio of the width of the pulse and the time period or pulse repetition time it takes. Mathematically, it can be given as:

Duty cycle = Width of the pulse/Time period of the pulse

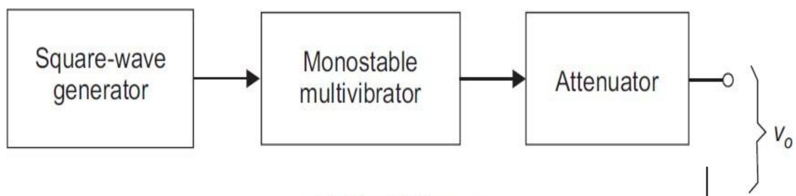
It can also be defined as the ratio of the average value of the generated pulse over one cycle and the peak value.

It is to be noted here that the average as well as peak value of a pulse are inversely related to its time duration.

Thus, the duty cycle can also be expressed as:

Duty cycle = Average value of the pulse/ Peak value of the pulse

It must be noted here that the duty cycle of a square wave is a square-wave generator produces a waveform in which there are equal time periods for both on and off portions (that is, equal positive and negative half cycles). Irrespective of the operating frequency, the duty cycle of a square wave always remains 0.5 or 50% as depicted in Figure

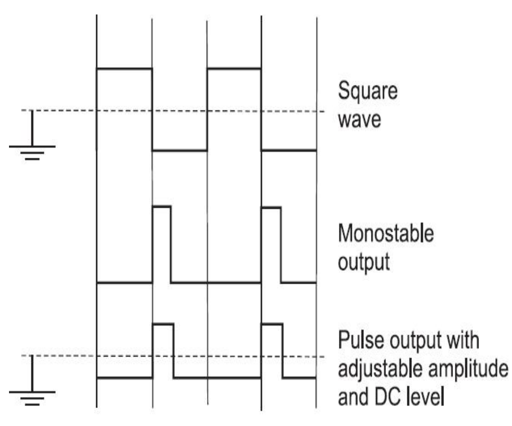


(a) Block Diagram

A pulse-wave generator basically consists of a square-wave generator, a monostable multivibrator, and an output attenuator stage.

With the N corresponding output waveforms at each stage.

It can be seen from the figure that the negative-going edge of the output of the square-wave generator triggers the monostable multivibrator, which in turn produces a pulse waveform of constant width. The frequency of this waveform is determined by the square-wave frequency. In addition, the amplitude of this pulse waveform can be adjusted by the output attenuator. Furthermore, the output attenuator can also adjust the DC level of the pulse.



What is wave analyzer? How it analyzes the harmonics?Explain.(SEP2020)

An electronic instrument that analyzes the signal or wave by measuring the amplitude of the frequency components or harmonics is called a Wave Analyzer. It is also known as signal analyzer or carrier frequency voltmeters or frequency-selective voltmeters, or selective level voltmeters. This instrument uses a set of filters for tuning and voltmeters to analyze the signal in the frequency domain. The wave analyzers are available in the RF range (low) and 50 MHz below range and also runs through AF range with high-frequency resolution.

Block Diagram

The wave analyzer block diagram is shown below. It contains a primary detector, full-wave rectifier, and PMMC galvanometer.

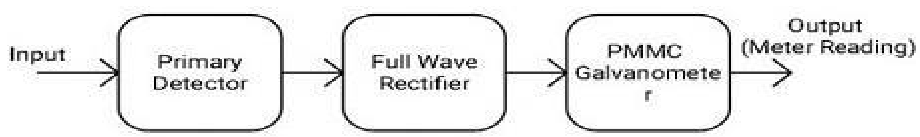
Primary Detector: It is made up of an LC circuit. By adjusting the values of 'L' (inductor) and 'C', the particular frequency component of the signal is allowed to measure.

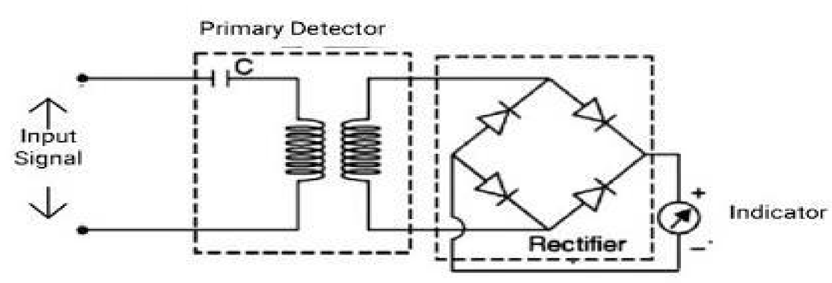
Full-wave Rectifier: The input AC signal is converted into the DC signal and the average value of the signal is obtained

PMMC Galvanometer: It is used to indicate the value of the signal i.e, the output of the full-wave rectifier.

Types of Wave Analyzer

There are two types of wave analyzers used to analyze the frequency components in the signal.





Wave Analyzer

Basic Wave Analyzer

The basic wave analyzer circuit diagram is shown below. The basic wave analyzer works as a frequency selective voltmeter because it is tuned to a particular frequency component and rejects all other components of the signal, which is to be analyzed. The CRO or a voltmeter is used as an indicator to measure the amplitude. A switch is used to connect the set of tuned filters with the indicator.

Principle and Working

The basic wave analyzer works on the principle of the frequency-selective voltmeter. It should be tuned to any one frequency component of the signal and all other components are rejected. The particular selected frequency component of the wave/signal is calibrated in the form of amplitude and its value indicated by a voltmeter or CRO.

From the circuit, the LC circuit is used as a primary detector to adjust the resonance to measure the desired frequency component of the harmonics of the signal. The average DC value of the input signal is obtained by the full-wave rectifier. The output of the full-wave rectifier is calibrated in the form of peak value and it is indicated by a DC voltmeter.

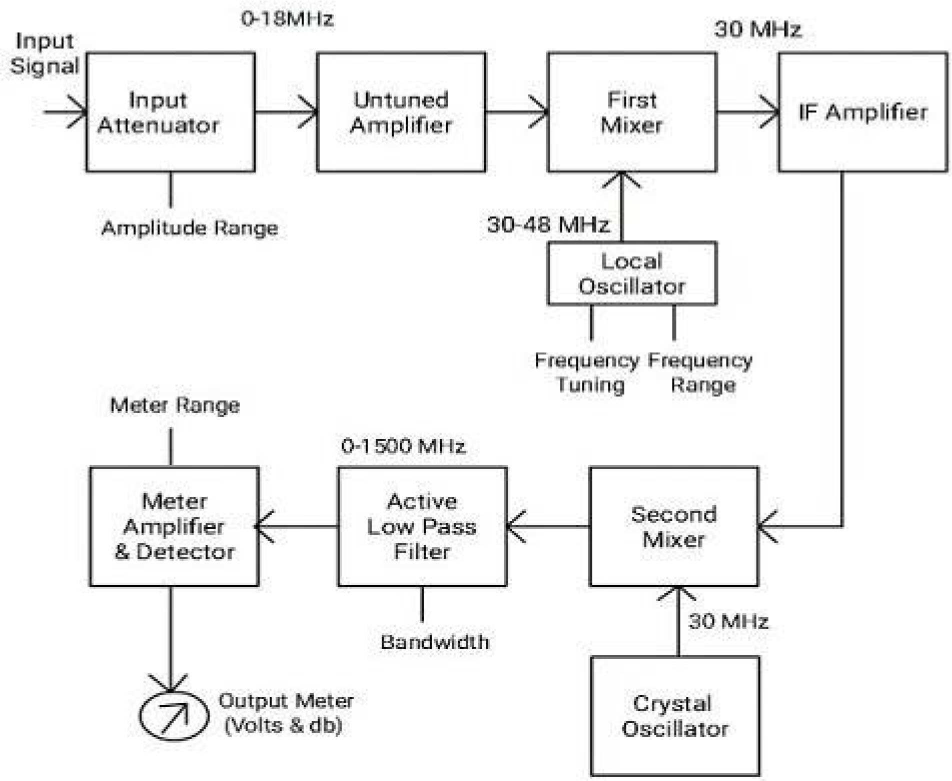
Based upon Frequency Ranges

Based on the frequency ranges, the wave analyzers are divided into two types.

Heterodyne Wave Analyzer

The electronic instrument that analyzes the periodic signal in the RF range and above MHz ranges, is called heterodyne wave analyzer. It is also known as a superheterodyne wave analyzer. Its working principle is heterodyne (mix) of high IF (intermediate frequency range) with the input signal, which is to be analyzed. The frequency components of the signal are fed to the passband IF amplifier due to the tuning of the local oscillator. The IF amplifier is rectified and applied to the meter circuit to display the output.

The block diagram of the heterodyne wave analyzer is shown below.



Heterodyne Wave analyzer

- The input RF signal that is to be analyzed is given to an input attenuator to attenuate the amplitude of the signal. The output signal will be in the range of 0-18 MHz.
- The output of the input attenuator is fed to the untuned amplifier to amplify the RF signal and its output is fed to the first mixer.
- The signal of the first mixer is heterodyned with the signal from the local oscillator in the frequency range of 30-48MHz. The output of the first mixer will be in the 30MHz frequency range i.e., IF signal.
  The IF amplifier amplifies the IF signal obtained from the first mixer.
- This amplified IF signal of 30MHz is heterodyned (mixed) with the Crystal oscillator signal frequency 30MHz in the second mixer. As the frequencies of the signals are the same, the output frequency of the second mixer is 0 Hz.

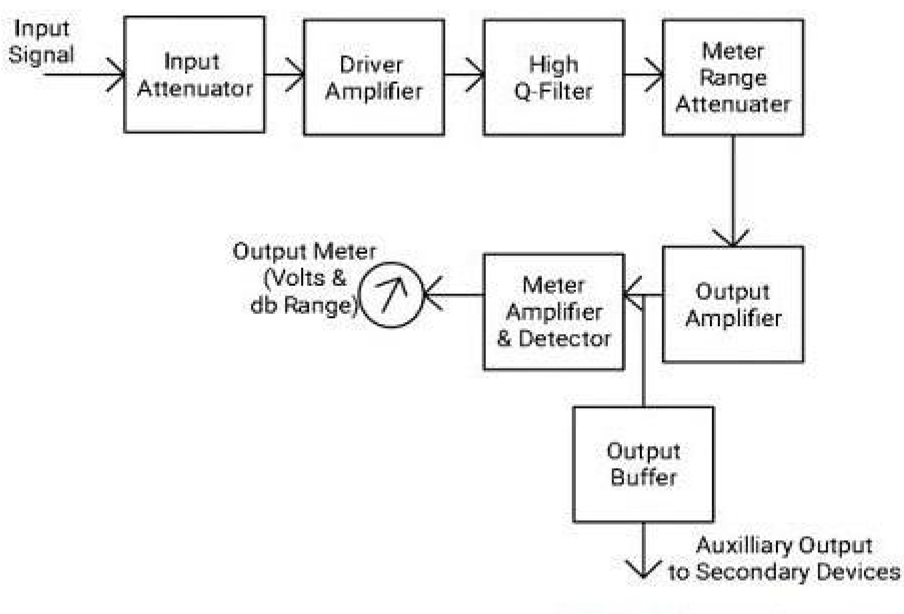
- This output signal with 0 Hz is applied to an active low pass filter which has a frequency range of 0-1500MHz.

The output of the active LPF is fed to the meter circuit to display the reading of the selected RF signal in the range of volts or decibels.

Frequency Selective Wave Analyzer

Principle: The frequency selective wave analyzer is one of the types of wave analyzer works on the principle of the frequency-selective voltmeter. It is operated to measure the frequency in the audio range of 20 Hz – 20 kHz. It uses a narrow-pass band filter and it is tuned to the desired frequency components to measure. The block diagram of the frequency selective wave analyzer is shown below. The frequency distortion is very low and bandwidth is also low nearly 1% of the selected frequency.

The AF input signal that is to be analyzed is given to an input attenuator. The signal contains maximum amplitude and it is attenuated by the input attenuator. It works as a range multiplier because a high range of amplitude of the signal is measured.



Frequency Selective Wave Analyzer

The output of the input attenuator is amplified by the driver amplifier and its output is fed to the high-Q filter section.

The high Q-filter section selected the particular frequency component and rejects the remaining unwanted frequencies of the signal. It contains two RC sections, two amplifier filters, connected in cascade. By varying the value of the capacitor, the frequency range can be changed. By varying the value of the resistor, the desired frequency can be changed within the desired range.

The output of the High Q-filter is fed to the meter range attenuator to select the AF input signal. The AF input signal is attenuated by a meter range attenuator. The output of the meter range attenuator is amplified by the output amplifier. The output buffer drives the AF signal to the output devices such as counters, recorders, etc. The meter circuits display the reading output of the AF signal in the range of volts and decibels.

Applications of Wave Analyzer

- Measures the harmonic distortion of the signal.
- Desired frequency components of the signal can be selected to analyze the signal Used in harmonics analyzation whose signal is to be analyzed.
- Measuring the amplitude of the selected frequency component in the signal. Used to analyze the DC component in the periodic signal
- Used to reduce sound and vibration produced by the electrical machines in the industries. Used to measure the amplitude of the signal along with noise and interfering signals.
- Used as a harmonic distortion analyzer Used as an automatic frequency controller. Used in electrical measurements

2. Depict the function block diagram of harmonic distortion analyzer and find the equation to deduce the THD.(NOV 17)

Types of THD meter

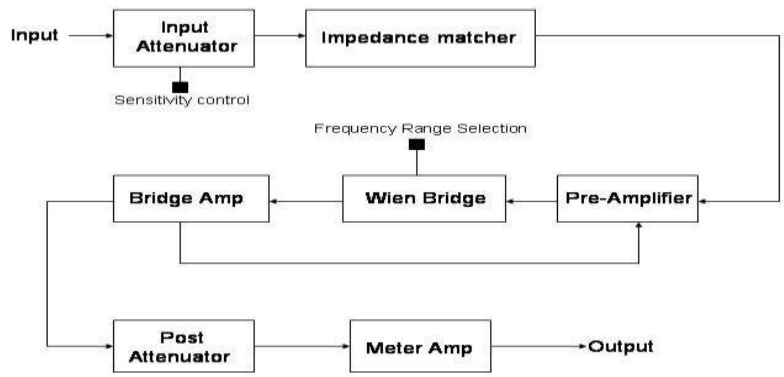
There are several types of distortion analyzers

Fundamental suppression

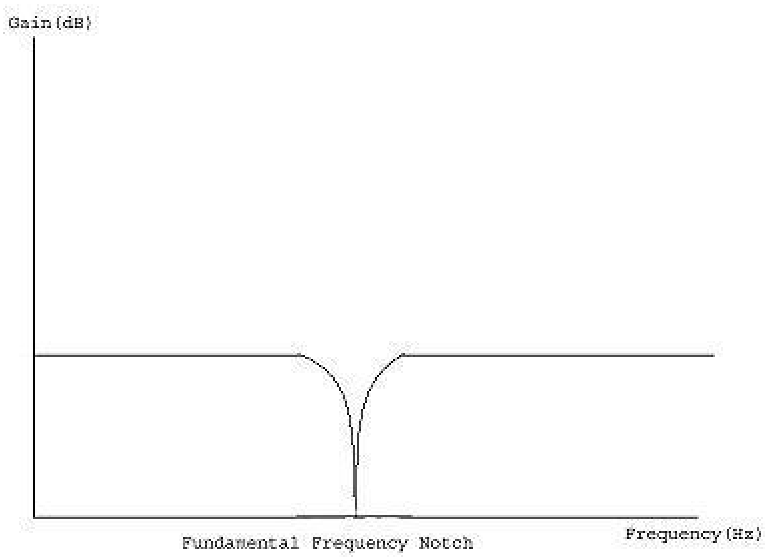
Heterodyne type

Tuned circuit

Spectrum analyzer



Principles of operation



The frequency response of a Fundamental Suppression Analyzer

A fundamental suppression analyzer consists of three main sections: input section with impedance matcher, a notch filter and amplifier section, and an output metering circuit. Negative feedback from the bridge amplifier to the pre-amp section may be applied to enable the rejection circuit to work more accurately.

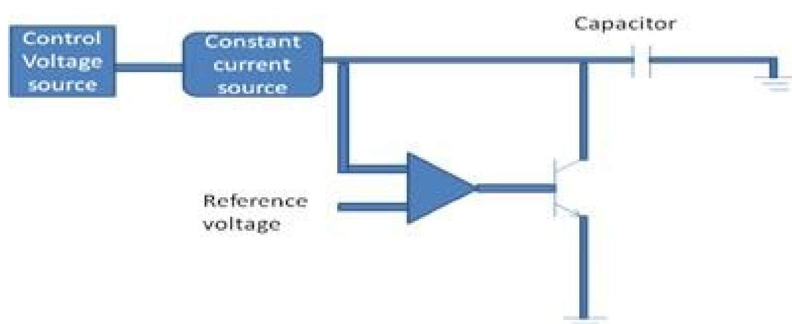
Working of a typical unit

The input is impedance-matched with the rejection circuit with the help of an attenuator and an impedance matcher. This signal is then pre-amplified to a desired level. The following section consists of a Wien bridge notch filter tuned to reject the fundamental frequency and balanced for minimum output by adjusting the bridge controls. The output, which is the remaining signal after the fundamental has been suppressed, is amplified to a measurable level. A feedback loop from the bridge amplifier output to the pre-amp input helps to eliminate any remaining contribution from the fundamental frequency. The output from these blocks is measured, typically using an instrumentation amplifier driving an analog or digital meter. The voltage at the meter is due to the harmonic distortion products plus noise.

5.Modify the functioning of LM566 to work as a function generator and justify the modification by its working.

A voltage-controlled oscillator is an oscillator with an output signal whose output can be varied over a range, which is controlled by the input DC voltage. It is an oscillator whose output frequency is directly related to the voltage at its input. The oscillation frequency varies from few hertz to hundreds of GHz. By varying the input DC voltage, the output frequency of the signal produced is adjusted.

Basic Working principle of Sawtooth waveform generator VCO



Types of Voltage Controlled Oscillators

Harmonic Oscillators: The output is a signal with a sinusoidal waveform. Examples are crystal oscillators and tank oscillators

Relaxation Oscillators: The output is a signal with a sawtooth or triangular waveform and provides a wide range of operational frequencies. The output frequency depends on the time of charging and discharging of the capacitor.

For a Voltage controlled oscillator generating a sawtooth waveform, the main component is the capacitor who's charging and discharging decides the formation of the output waveform. The input is given in form a voltage that can be controlled. This voltage is converted to a current signal and is applied to the capacitor. As the current passes through the capacitor, it starts charging and a voltage starts building across it. As the capacitor charges and the voltage across it increase gradually, the voltage is compared with a reference voltage using a comparator.

When the capacitor voltage exceeds the reference voltage, the comparator generates a high logic output that triggers the transistor, and the capacitor is connected to the ground and starts discharging. Thus the output waveform generated is the representation of the charging and discharging of the capacitor and the frequency is controlled by the input dc voltage.

Applications of VCO

Electronic jamming equipment.

Function generator.

Production of electronic music, for the production of different types of noise.

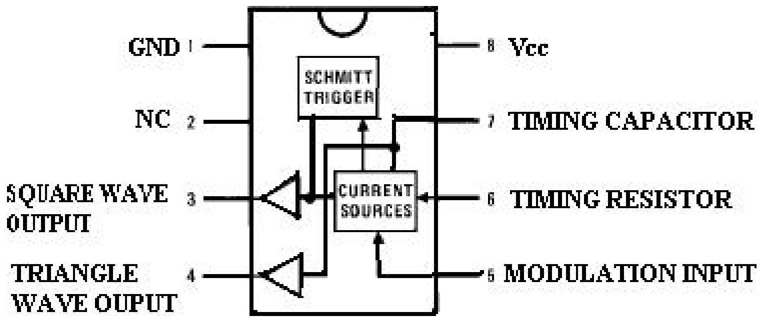
Phase-locked loop.

Frequency synthesizers, used in communication circuits.

A Practical VCO – LM566

A practical example of a voltage-controlled oscillator (VCO) is the LM566. The LM566 is a general-purpose VCO that may be used to generate square wave and triangular waveforms as a function input voltage.

The LM566 is specified for operation over 0˚C to 70˚C temperature range. The frequency of which is a linear function of a controlling voltage. The frequency is also controlled by an external resistor and capacitor, whose values control the free-running frequency.



Pin Description:

Pin 1: Ground (GND)

Pin 2: No connection (NC)

Pin 3: Square wave output

Pin 4: Triangular wave output

Pin 5: Modulation input

Pin 6: Timing resistor

Pin 7: Timing capacitor

Pin 8: Vcc

Features:

The maximum operating voltage is 10V to 24V

High-temperature stability

Operating temperature is 0˚C to 70˚C

The frequency can be controlled using current, voltage, resistor or capacitor

Power dissipation is 300mV

Excellent power supply rejection

Applications:

Function generator

Tone generator

FM modulation

Frequency shift keying

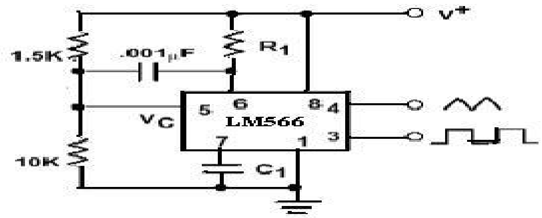
Clock generator

Working of LM566:

The figure shows that the LM566 IC contains current sources to charge and discharge an external capacitor at a rate set by an external resistor R1 and the modulating dc input voltage V.

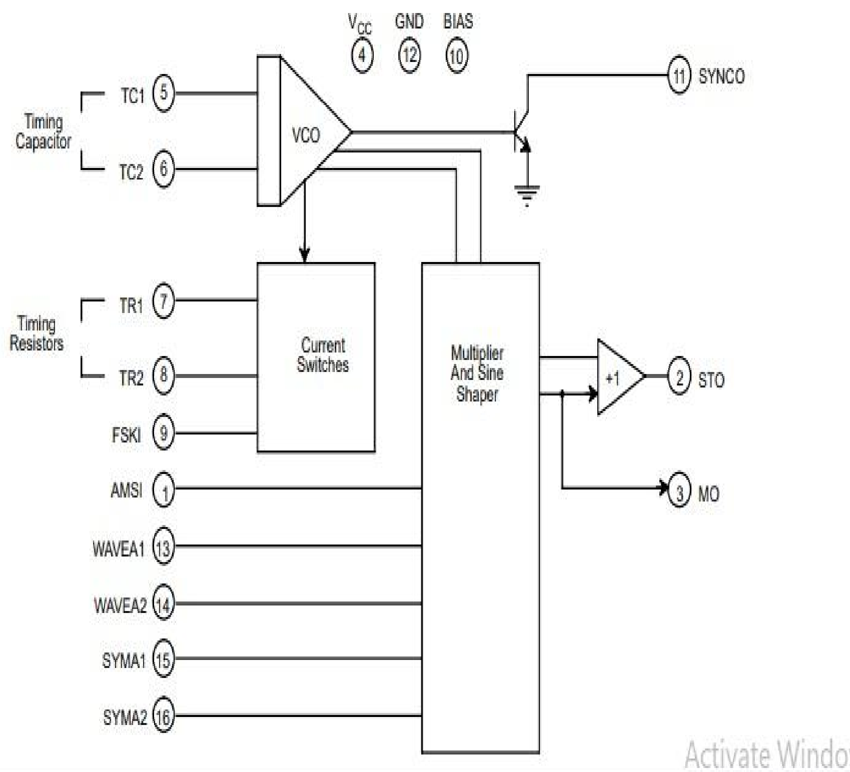
A 0.001µF capacitor is connected to pin 5 and pin 6. A Schmitt trigger circuit is used to switch the current sources between charging and discharging the capacitor and the triangular voltage produced across the capacitor and square wave from the Schmitt trigger are provided as outputs through buffer amplifiers. Both the output waveforms are buffered so that the output impedance of each is 50 f2. The typical magnitude of the triangular wave and the square wave is 2.4Vpeak to peak and 5.4Vpeak to the peak. The free-running or center-operating frequency, f0 is

$$f_O = \frac{2\ (V^+ - V_C)}{R_1 C_1 V^+}$$



5. Illustrate the working of monolithic function generator using XR2206 and give the merits and demerits.

The XR-2206 is a monolithic function generator integrated circuit capable of producing high quality sine, square, triangle, ramp, and pulse waveforms of high-stability and accuracy. The output waveforms can be both amplitude and frequency modulated by an external voltage. Frequency of operation can be selected externally over a range of 0.01Hz to more than 1MHz.



Frequency-Shift Keying The XR-2206 can be operated with two separate timing resistors, R1 and R2, connected to the timing Pin 7 and 8, respectively, as shown in Figure 13. Depending on the polarity of the logic signal at Pin 9, either one or the other of these timing resistors is activated. If Pin 9 is open-circuited or connected to a bias voltage 2V, only R1 is activated. Similarly, if the voltage level at Pin 9 is 1V, only R2 is activated. Thus, the output frequency can be keyed between two levels. f1 and f2, as: f1 = 1/R1C and f2 = 1/R2C For split-supply operation, the keying voltage at Pin 9 is referenced to V- . Output DC Level Control The dc level at the output (Pin 2) is approximately the same as the dc bias at Pin 3. In Figure 11, Figure 12 and Figure 13, Pin 3 is biased midway between V+ and ground, to give an output dc level of V+/2.

APPLICATIONS INFORMATION Sine Wave Generation Without External Adjustment Figure 11 shows the circuit connection for generating a sinusoidal output from the XR-2206. The potentiometer, R1 at Pin 7, provides the desired frequency tuning. The maximum output swing is greater than V+/2, and the typical distortion (THD) is < 2.5%. If lower sine wave distortion is desired, additional adjustments can be provided as described in the following section. The circuit of Figure 11 can be converted to split-supply operation, simply by replacing all ground connections with V- . For split-supply operation, R3 can be directly connected to ground.

With External Adjustment: The harmonic content of sinusoidal output can be reduced to -0.5% by additional adjustments as shown in Figure 12. The potentiometer, RA, adjusts the sine-shaping resistor, and RB provides the fine adjustment for the waveform symmetry. The adjustment procedure is as follows: 1. Set RB at midpoint and adjust RA for minimum distortion. 2. With RA set as above, adjust RB to further reduce distortion. Triangle Wave Generation The circuits of Figure 11 and Figure 12 can be converted to triangle wave generation, by simply open-circuiting Pin 13 and 14 (i.e., S1 open). Amplitude of the triangle is approximately twice the sine wave output. FSK Generation Figure 13 shows the circuit connection for sinusoidal FSK signal operation. Mark and space frequencies can be independently adjusted by the choice of timing resistors, R1 and R2; the output is phase-continuous during transitions. The keying signal is applied to Pin 9. The circuit can be converted to split-supply operation by simply replacing ground with V- . Pulse and Ramp Generation Figure 14 shows the circuit for pulse and ramp waveform generation. In this mode of operation, the FSK keying terminal (Pin 9) is shorted to the square-wave output (Pin 11), and the circuit automatically frequency-shift keys itself between two separate frequencies during the positive-going and negative-going output waveforms. The pulse width and duty cycle can be adjusted from 1% to 99% by the choice of R1 and R2. The values of R1 and R2 should be in the range of 1k to 2M

PRINCIPLES OF OPERATION Description of Controls Frequency of Operation: The frequency of oscillation, fo, is determined by the external timing capacitor, C, across Pin

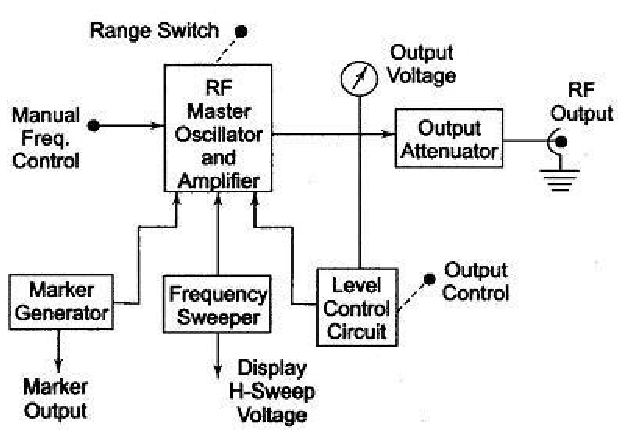
5 and 6, and by the timing resistor, R, connected to either Pin 7 or 8. The frequency is given as: f0 1 RC Hz and can be adjusted by varying either R or C. The recommended values of R, for a given frequency range, as shown in Figure 5. Temperature stability is optimum for 4k < R < 200k. Recommended values of C are from 1000pF to 100F. Frequency Sweep and Modulation: Frequency of oscillation is proportional to the total timing current, IT, drawn from Pin 7 or 8: f 320IT (mA) C(F) Hz Timing terminals (Pin 7 or 8) are low-impedance points, and are internally biased at +3V, with respect to Pin 12. Frequency varies linearly with IT, over a wide range of current values, from 1A to 3mA. The frequency can be controlled by applying a control voltage, VC, to the activated timing pin as shown in Figure 10. The frequency of oscillation is related to VC as: f 1 RC1 R RC 1 – VC 3Hz where VC is in volts. The voltage-to-frequency conversion gain, K, is given as: K fVC – 0.32 RCC HzV.

Discuss the operation of sweep frequency generator with neat block diagram.(NOV 16)(MAY 16)

Block Diagram of Sweep Generator:

Block Diagram of Sweep Generator – It provides a sinusoidal output voltage whose frequency varies smoothly and continuously over an entire frequency band, usually at an audio rate. The process of frequency modulation may be accomplished electronically or mechanically.

It is done electronically by using the modulating voltage to vary the reactance of the oscillator tank circuit component, and mechanically by means of a motor driven capacitor, as provided for in a modern laboratory type signal generator. Figure 8.10 shows a basic block diagram of a sweep generator.



The frequency sweeper provides a variable modulating voltage which causes the capacitance of the master oscillator to vary. A representative sweep rate could be of the order of 20 sweeps/second. A manual control allows independent adjustment of the oscillator resonant frequency.

The frequency sweeper provides a varying sweep voltage for synchronisation to drive the horizontal deflection plates of the CRO. Thus the amplitude of the response of a test device will be locked and displayed on the screen.

To identify a frequency interval, a marker generator provides half sinusoidal waveforms at any frequency within the sweep range. The marker voltage can be added to the sweep voltage of the CRO during alternate cycles of the sweep voltage, and appears superimposed on the response curve.

The automatic level control circuit is a closed loop feedback system which monitors the RF level at some point in the measurement system. This circuit holds the power delivered to the load or test circuit constant and independent of frequency and impedance changes. A constant power level prevents any source mismatch and also provides a constant readout calibration with frequency.

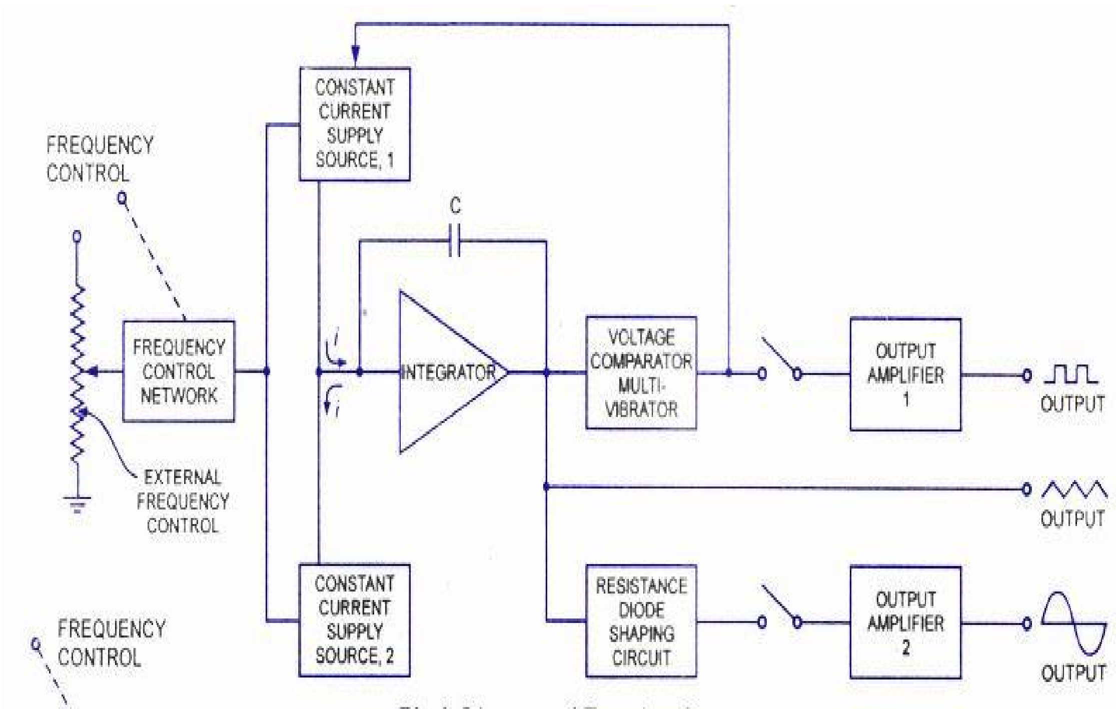
6. Explain the working principle of function generator with a neat block diagram and appropriate waveforms.(NOV 16)(MAY 16)

A function generator is a signal source that has the capability of producing different types of waveforms as its output signal. The most common output waveforms are sine- waves, triangular waves, square waves, and saw tooth waves. The frequencies of such waveforms may be adjusted from a fraction of a hertz to several hundred kHz.

Actually, the function generators are very versatile instruments as they are capable of producing a wide variety of waveforms and frequencies. In fact, each of the waveforms they generate is particularly suitable for a different group of applications. The uses of sinusoidal outputs and square-wave outputs have already been described in the earlier Arts. The triangular-wave and sawtooth wave outputs of function generators are commonly used for those applications which need a signal that increases (or reduces) at a specific linear rate. They are also used in driving sweep oscillators in oscilloscopes and the X-axis of X-Y recorders.

simultaneously (from different output terminals, of course). This can be a useful feature when two generated signals are required for a particular application. For instance, by providing a square wave for linearity measurements in an audio-system, a simultaneous sawtooth output may be used to drive the horizontal deflection amplifier of an oscilloscope, providing a visual display of the measurement result. For another example, a triangular-wave and a sine-wave of equal frequencies can be produced simultaneously. If the **zero crossings** of both the waves are made to occur at the same time, a linearly varying waveform is available which can be started at the point of zero phase of a sine-wave.

Another important feature of some function generators is their capability of phase-locking to an external signal source. One function generator may be used to phase lock a second function generator, and the two output signals can be displaced in phase by an adjustable amount. In addition, one function generator may be phase locked to a harmonic of the sine-wave of another function generator. By adjustment of the phase and the amplitude of the harmonics, almost any waveform may be produced by the summation of the fundamental frequency generated by one function generator and the harmonic generated by the other function generator. The function generator can also be phase locked to an accurate frequency standard, and all its output waveforms will have the same frequency, stability, and accuracy as the standard.



Block Diagram of Function Generator

The block diagram of a function generator is given in the figure. In this instrument, the frequency is controlled by varying the magnitude of the current that drives the integrator. This instrument provides different types of waveforms (such as sinusoidal, triangular and square waves) as its output signal with a frequency range of 0.01 Hz to 100 kHz.

The frequency controlled voltage regulates two current supply sources. Current supply source 1 supplies a constant current to the integrator whose output voltage rises linearly with time. An increase or decrease in the current increases or reduces the slope of the output voltage and thus controls the frequency.

The voltage comparator multivibrator changes state at a predetermined maximum level, of the integrator output voltage. This change cuts-off the current supply from supply source 1 and switches to the supply source 2. The current supply source 2 supplies a reverse current to the integrator so that its output drops linearly with time. When the output attains a predetermined level, the voltage comparator again changes state and switches on to the current supply source. The output of the integrator is a triangular wave whose frequency depends on the current supplied by the constant current supply sources. The comparator output provides a square wave of the same frequency as output. The resistance diode network changes the slope of the triangular wave as its amplitude changes and produces a sinusoidal wave with less than 1% distortion.

Depict the function block diagram of spectrum analyzer and mention its merits, demerits and applications.(MAY 16)

13.3 SPECTRUM ANALYZER

The spectrum analyzer is an instrument which is used to analyze the distribution of energy over a frequency spectrum of a given electrical signal. It provides information about the bandwidth, spurious signal generation, and effects of various modulation techniques. This information is useful in design and testing of radio frequency (that is, RF) and pulse circuitry. The spectrum analyzers are of two types—*high-frequency* and *low-frequency spectrum analyzers*. The spectrum analysis of high-frequency spectrum analyzers can be of further two sub-types namely, *audio frequency analysis* (also known as AF analysis) and *radio frequency analysis* (also known as RF analysis). The RF spectrum covers a majority of fields like communication, radar, industrial instrumentation, and navigation and thus its frequency range is from 10 MHz to 40 GHz. The spectrum analyzer gives a graphical representation of amplitude of signal as a function of its frequency in the RF spectrum range.

13.3.1 High-frequency Spectrum Analyzer

The basic swept-tuned radio-frequency spectrum analyzer is shown in Figure 13.4 which consists of a sawtooth generator, voltage-tuned local oscillator, mixer, intermediate frequency (IF) amplifier, and detector and video amplifier. The sawtooth generator produces a ramp voltage and feeds it to the frequency control element of the voltage tuned local oscillator. The horizontal plates of CRO is also applied with same sawtooth voltage. The mixer input is provided with the RF signal to be tested. The local oscillator sweeps at a recurring linear rate in its frequency band to beat with the input signal so that the intermediate frequency is generated. The RF input signal generates the IF component only when it is present in the

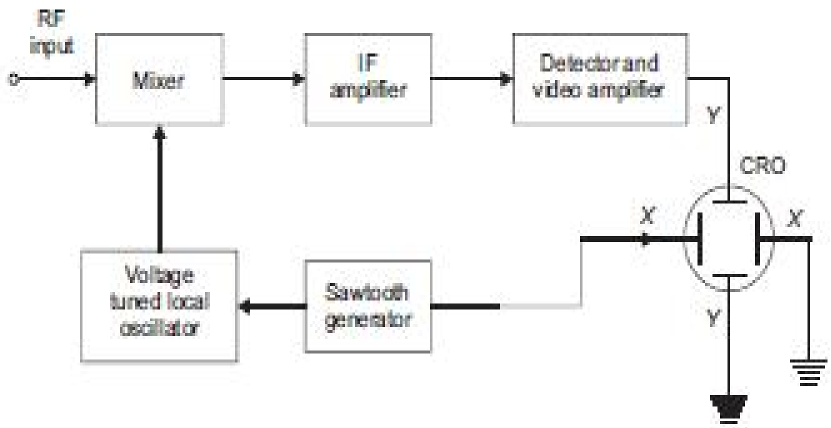
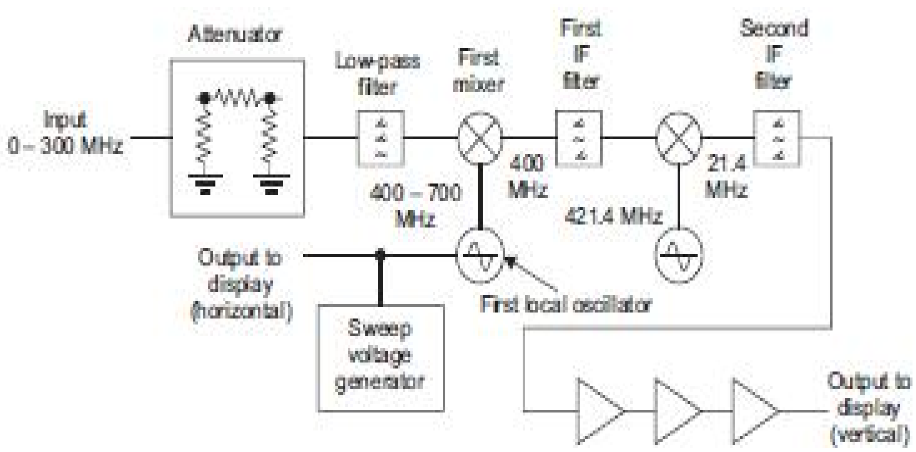


Fig. 13.4 Block Diagram of Swept Radio Frequency Spectrum Analyzer

band. The IF signal is then amplified, detected, and applied to the vertical deflection plates of the CRO thereby producing an amplitude versus frequency display on the screen.

The general purpose spectrum analyzer is shown in Figure 13.5. It works on the principle of superheterodyne receiver with the frequency range of 10 kHz to 300 MHz. It generates an IF signal higher than the highest input frequency, that is, 400 MHz in our case. The low-pass filter removes the input image, that is, a band of frequencies from 800 to 1100 MHz and also attenuates the signal at the first IF of 400 MHz. This spectrum analyzer has a selectivity of 1 kHz when set at the narrowest band. However, this selectivity cannot be achieved at 400 MHz. Therefore, the first IF of 400 MHz is heterodyned to a relatively lower frequency while the second IF in our case is at 21.4 MHz. Here, the crystal filters are used to achieve the desired selectivity. The image components in the second oscillator must be removed in the same manner. The second local oscillator is at 421.4 MHz, that is, 21.4 MHz above the first IF which sets the image frequency at 442.8 MHz to be removed by the first IF filter. The first local oscillator frequency is swept by the varactor diodes and the frequency spectrum which has been swept is called **dispersion** of the spectrum analyzer. It is the band



of frequency that can be displayed on the screen. The spectrum analyzer basically sweeps the narrow frequency ranges where there is a possibility that the frequency instabilities of the first local oscillator may destroy the display of the analyzer.

The frequency instabilities that occur in the instrument are of two types, namely, *long-term instability* and *phase noise*.

- **Long-term instability:** This instability arises due to drift of the first local oscillator frequency and appears as the movement of the spectrum across spectrum analyzer screen. This instability can be compensated by bringing back the spectrum analyzer to centre the display. If the frequency drift is too fast, the display cannot be centred by the operator.
- **Phase noise:** The noise voltages in the tuned circuit or those picked up by the varactor circuit cause rapid variation in frequency resulting in phase noise. The tuning range of first local oscillator is of several hundred megahertz or microvolts of noise on the varactor tuning voltage which may cause significant frequency modulation. The frequency modulation cannot be corrected due to phase noise, therefore, some electronic means must be applied to the first local oscillator.

13.3.2 Low-frequency Spectrum Analyzer

The low-frequency spectrum analyzer (also termed as LF spectrum analyzer) is another type of spectrum analyzer with the frequency range from 7–30 Hz. Figure 13.6 shows an LF spectrum analyzer which consists of an amplifier to which input signal is applied. This amplifier has an overall gain of 200 depending on the magnitude of the input signal along with the number of stages. Then the signal is fed to the band pass filter (also known as **BPF**) whose centre frequency can be varied at a rate by the ramp and applied to the *X*-plates of a CRO. The BPF gives a full-wave rectified output which is filtered to give an absolute value of the amplitude of the frequency component present at that moment.

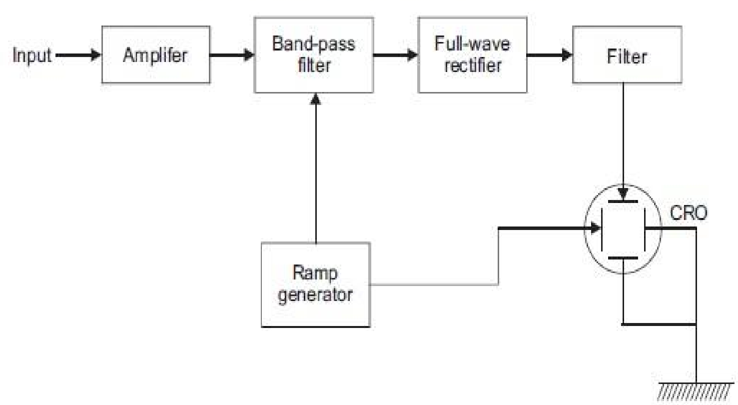


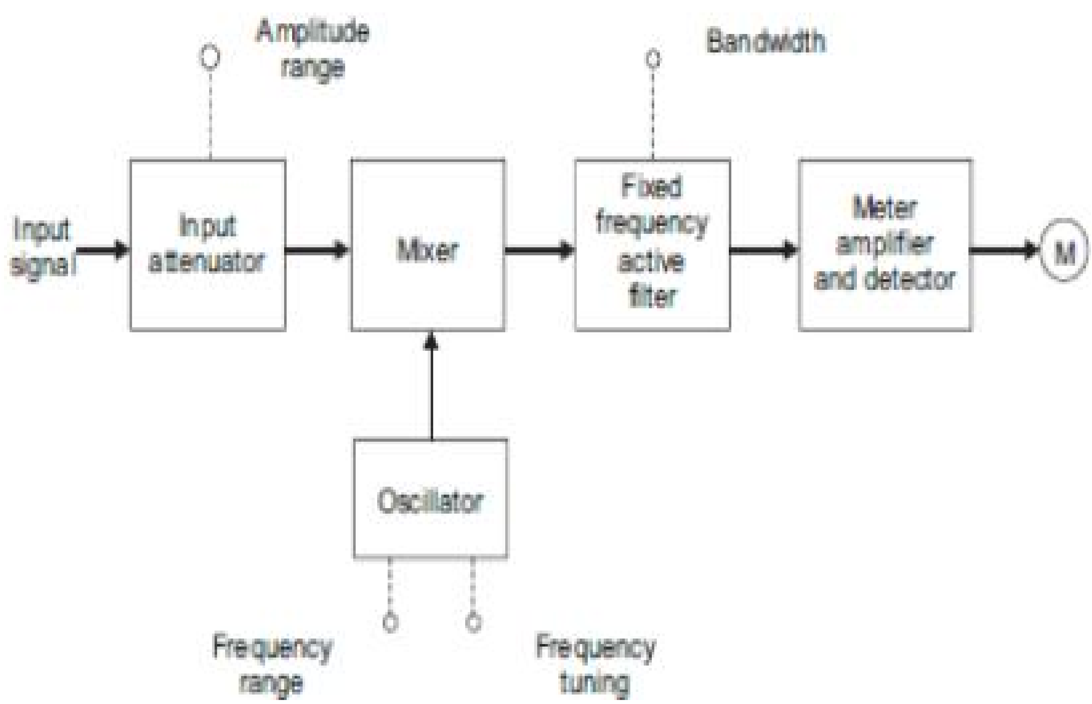
Fig. 13.6 Block Diagram of LF Spectrum Analyzer

It is to be noted here that low-frequency signals are difficult to mix so RF spectrum analyzers are not used for them. Also, unlike RF spectrum analyzers, LF spectrum analyzers do not use local oscillators.

7. With schematic block diagram explain the working of a heterodyne wave analyzer.(MAY 17)

13.5.2 Heterodyne Harmonic Analyzer or Wavemeter

The heterodyne harmonic analyzer, also known as **wavemeter** is used to overcome the limitations of the tuned-circuit harmonic analyzer by using a highly selective fixed-frequency filter. Figure 13.11 shows functional sections of this analyzer in which the variable frequency oscillator output is heterodyned with each harmonic of the input signal efficiently. The frequency of the filter is made equal to the sum or the difference of the frequency of the signal output from the mixer. Highly selective quartz-crystal type filters are used as each harmonic frequency is converted to constant frequency. At the output, the metering circuit receives a constant frequency signal corresponding to the particular harmonic being measured. The meter is calibrated in terms of voltage. The instruments that provide direct reading are known as **frequency-selective voltmeters**. They are of heterodyne type instruments. In these instruments, the input signal frequency is read by a calibrated dial. Only the difference frequency is passed by a low-pass filter in the input circuit while rejects the sum of the mixed



frequencies. This voltage is compared with the input signal and read by a voltmeter calibrated in dBm and volts. The range of such instruments lies between −90 dBm and +32 dBm.

Advantages

The advantages of this analyzer are as follows.

- The mixer is generally a balanced modulator, so eliminating the original frequency of the harmonic is easier through it.
- The harmonic distortion generated by the balanced modulator is low as compared to different types of mixers.
- Quartz crystal filters or inverse feedback filters are used as they give excellent selectivity.

Explain about fundamental – suppression harmonic distortion analyzer.(MAY 17)(MAY 16)

13.5 HARMONIC DISTORTION ANALYZER

When a sinusoidal signal is applied as an input to an electronic device, such as an amplifier, ideally the output should also be a sinusoidal wave. However, due to the inherent non-linear characteristics of the device, it is not an exact replica of the input signal. Thus, we may conclude that non-linearities of different circuit elements produce harmonics in the output wave. Hence, this distortion is known as **harmonic distortion** (abbreviated as HD).

The total harmonic distortion (abbreviated as THD) can be expressed in terms of the harmonic content of the wave as harmonics get produced in the input sine wave and these harmonics are the multiples of the fundamental frequency of the input signal. Mathematically, total harmonic distortion, denoted as D, is given as:

$$D = \sqrt{D_2^2 + D_3^2 + D_4^2 + \dots}$$

where D_n ($n = 2, 3, 4\dots$) is the distortion of the nth harmonic .

Here, each harmonic distortion can be obtained by the ratio of the amplitude of the harmonic to that of the fundamental frequency, represented as:

$$D_2 = \frac{H_2}{H_1},\quad D_3 = \frac{H_3}{H_1},\quad D_4 = \frac{H_4}{H_1}$$

where H_n is the amplitude of the nth harmonic.

There are different methods by which harmonic distortion can be measured, namely, *tuned-circuit harmonic analyzer*, *heterodyne harmonic analyzer* or *wavemeter*, and *fundamental-suppression harmonic distortion analyzer*.

13.5.1 Tuned-circuit Harmonic Analyzer

In tuned-circuit harmonic analyzer, a circuit formed by the series combination of an inductor L and a capacitor C, that is, *series-resonant circuit* is tuned to a specific harmonic frequency. The input of the amplifier is then transformer-coupled to this harmonic component. The amplifier output is rectified and applied to a meter circuit. Once the reading is obtained on the meter, the resonant circuit returns to the next harmonic frequency for the next reading. Figure 13.10 shows the block diagram of a tuned circuit harmonic analyzer.

It is to be noted here that the compensation for the variation in the AC resistance of the series-resonant circuit as well as for the variation in the amplifier gain over the frequency range of the instrument is provided by the parallel-resonant circuit made of inductor L_1, resistance R_1, and capacitor C_1.

Disadvantages

This analyzer has many disadvantages as follows.

- For the analyzer to work at low frequencies, the values required for L and C would be very large. Therefore, the physical size of these components would be impractical.
- It is difficult to separate and distinguish the harmonics of the signal frequency as they are very close in frequency.

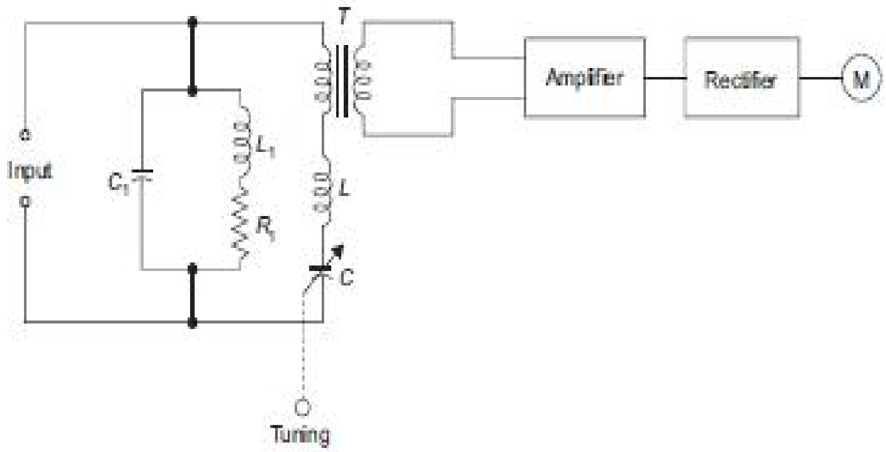
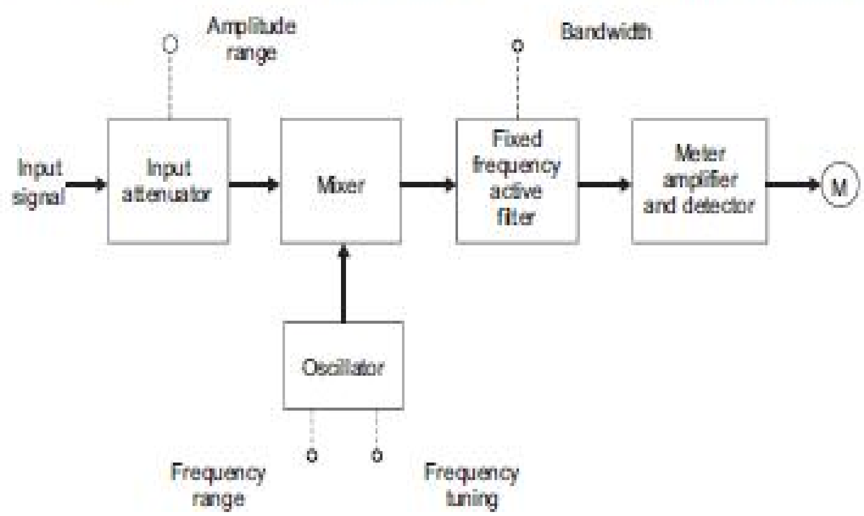


Fig. 13.10 Tuned-circuit Harmonic Analyzer

13.5.2 Heterodyne Harmonic Analyzer or Wavemeter

The heterodyne harmonic analyzer, also known as **wavemeter** is used to overcome the limitations of the tuned-circuit harmonic analyzer by using a highly selective fixed-frequency filter. Figure 13.11 shows functional sections of this analyzer in which the variable frequency oscillator output is heterodyned with each harmonic of the input signal efficiently. The frequency of the filter is made equal to the sum or the difference of the frequency of the signal output from the mixer. Highly selective quartz-crystal type filters are used as each harmonic frequency is converted to constant frequency. At the output, the metering circuit receives a constant frequency signal corresponding to the particular harmonic being measured. The meter is calibrated in terms of voltage. The instruments that provide direct reading are known as **frequency-selective voltmeters**. They are of heterodyne type instruments. In these instruments, the input signal frequency is read by a calibrated dial. Only the difference frequency is passed by a low-pass filter in the input circuit while rejects the sum of the mixed



frequencies. This voltage is compared with the input signal and read by a voltmeter calibrated in dBm and volts. The range of such instruments lies between −90 dBm and +32 dBm.

Advantages

The advantages of this analyzer are as follows.

- The mixer is generally a balanced modulator, so eliminating the original frequency of the harmonic is easier through it.
- The harmonic distortion generated by the balanced modulator is low as compared to different types of mixers.
- Quartz crystal filters or inverse feedback filters are used as they give excellent selectivity.

8. With suitable diagram discuss the working audio frequency generator.

12.5 AUDIO FREQUENCY SIGNAL GENERATOR

The audio frequency (AF) signal generators are meant to produce an output signal in the audio frequency range, that is, between 20 Hz to 20 kHz. The main components of an AF signal generator are *sinusoidal oscillator*, *sine-to-square wave converter*, and *attenuator circuit*. Either the sine or the square wave output can be obtained at the output of the generator. The block diagram of an AF signal generator is depicted in Figure 12.13.

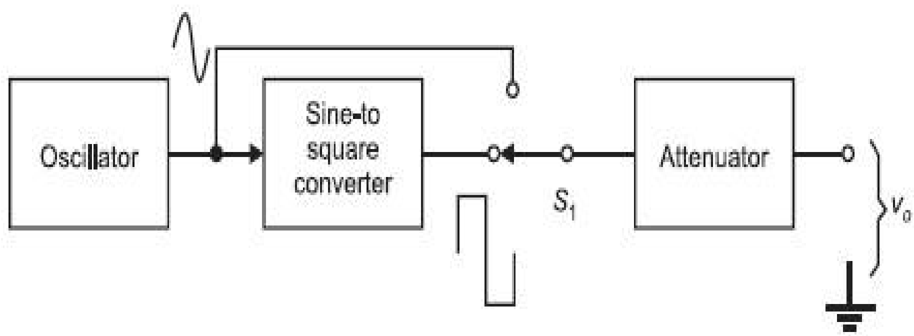


Fig. 12.13 Block Diagram of an AF Signal Generator

12.5.1 Oscillator Circuit

The sinusoidal oscillator is basically an RC network with amplification and feedback features and which produces a low frequency signal at its output as well as offers a controlled phase shift of the signal. A Wien bridge oscillator can be used for this purpose since it generates a clean sine-wave signal with low distortion, good amplitude, and frequency stability. Figure 12.14 illustrates the configuration of a Wien bridge oscillator circuit.

DEPARTMENT OF BIOMEDICAL ENGINEERING
EE T44/ ELECTRICAL AND ELECTRONIC INSTRUMENTS

UNIT –IV

1. **With a neat sketch explain about the CRT.(SEP 2020)**

Definition: The CRT is a **display screen** which produces images in the form of the **video signal.** It is a type of vacuum tube which displays images when the electron beam through **electron guns** are **strik**es on the **phosphorescent surface**. In other Words, the CRT **generates** the beams, **accelerates** it at high velocity and **deflec**t it for creating the images on the **phosphorous screen** so that the beam becomes **visible.**

Working of CRT

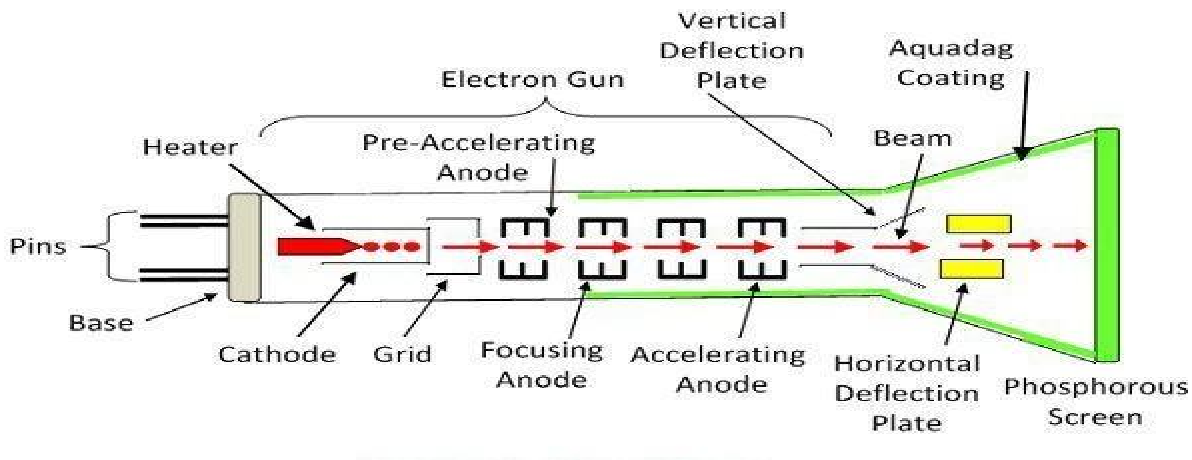
The working of CRT depends on the movement of electrons beams. The electron guns generate sharply focused electrons which are accelerated at high voltage. This high-velocity electron beam when strikes on the fluorescent screen creates luminous spot

After exiting from the electron gun, the beam passes through the pairs of electrostatic deflection plate. These plates deflected the beams when the voltage applied across it. The one pair of plate moves the beam upward and the second pair of plate moves the beam from one side to another. The horizontal and vertical movement of the electron are independent of each other, and hence the electron beam positioned anywhere on the screen.

The working parts of a CRT are enclosed in a vacuum glass envelope so that the emitted electron can easily move freely from one end of the tube to the other.

Construction of CRT

The Electrons Gun Assembly, Deflection Plate Assembly, Fluorescent Screen, Glass Envelope, Base are the important parts of the CRT. The electron gun emits the electron beam, and through deflecting plates, it is strikes on the phosphorous screen. The detail explanation of their parts is explained below.



Cathode Ray Tube

Electrons Gun Assembly

The electron gun is the source of the electron beams. The electron gun has a heater, cathode, grid, pre-accelerating anode, focusing anode and accelerating anode. The electrons are emitted from the highly emitted cathode. The cathode is cylindrical in shape, and at the end of it, the layer of strontium and barium oxide is deposited which emit the high emission of electrons at the end of the tube.

The electron passes through the electron in the small grid. This control grid is made up of nickel material with a centrally located hole which is coaxial with the CRT axis. The electron which is emitted from the electron gun and passes through the control grid have high positive potential which is applied across the pre-accelerating and accelerating anodes.

The beam is focused by focusing anode. The accelerating and focusing electrodes are cylindrical in shape which has a small opening in the centre of each electrode. After exiting the focusing anode, the beams passes through the vertical and horizontal deflecting plates.

The pre-accelerating and accelerating anode are connected to the positive high voltage of about 1500V and the focusing anode are connected to the lower voltage of about 500V.There are two methods of focusing the electron beam. They are the Electrostatic Focussing Beam and the Electromagnetic Focusing.

Electrostatic Deflection Plates

The deflection plate produces the uniform electrostatic field only in the one direction. The electron beam entering into the deflection plates will accelerate only in the one direction, and hence electrons will not move in the other directions.

Screen For CRT

The front of the CRT is called the face plate. The face plate of the CRT is made up of entirely fibre optics which has special characteristics. The internal surface of the faceplate is coated with the phosphor. The phosphorous converts the electrical energy into light energy. The energy level of the phosphorous crystal raises when the electron beams strike on it. This phenomenon is called cathodoluminescence.

The light which is emitted through phosphorous excitation is called fluorescence. When the electron beam stop, the phosphorous crystal regain their original position and release a quantum of light energy which is called phosphorescence or persistence.

Aquadag

The Aquadag is the aqueous solution of graphite which is connected to the secondary of the anode. The Aquadag collects the secondary emitted electrons which are necessary for keeping the CRT screen in the state of electrical equilibrium.

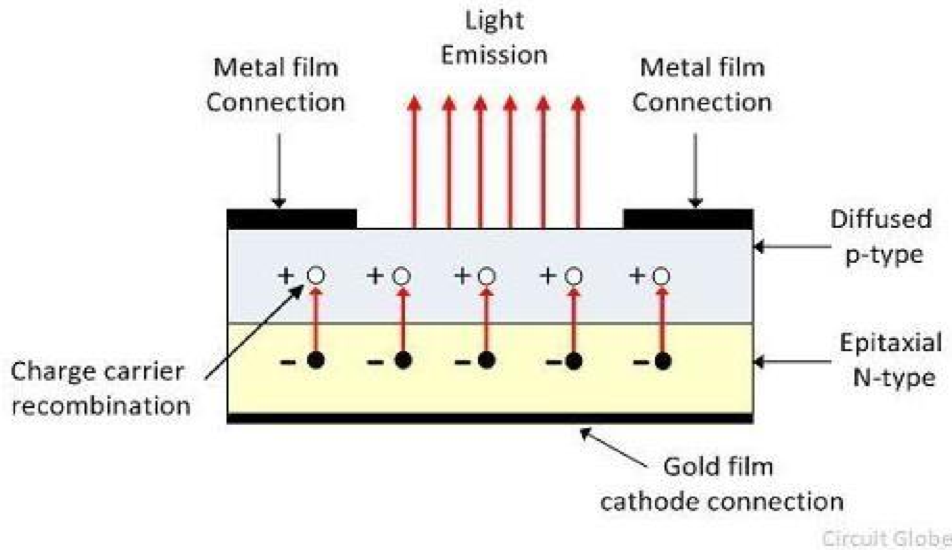
2. **Explain the theory and working of an LED and describe their advantages.(SEP 20)**

Definition: The LED is a PN-junction diode which emits light when an electric current passes through it in the forward direction. In the LED, the recombination of charge carrier takes place. The electron from the N-side and the hole from the P-side are combined and gives the energy in the form of heat and light. The LED is made of semiconductor material which is colourless, and the light is radiated through the junction of the diode.

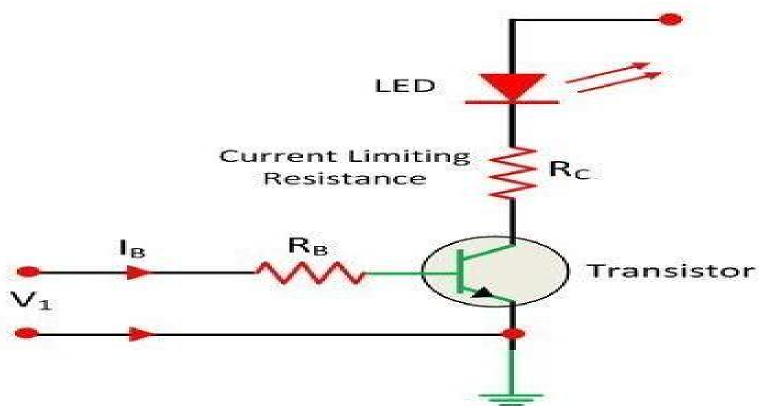
The LEDs are extensively used in segmental and dot matrix displays of numeric and alphanumeric character. The several LEDs are used for making the single line segment while for making the decimal point single LED is used.

Construction of LED

The recombination of the charge carrier occurs in the P-type material, and hence P-material is the surface of the LED. For the maximum emission of light, the anode is deposited at the edge of the P-type material. The cathode is made of gold film, and it is usually placed at the bottom of the N-region. This gold layer of cathode helps in reflecting the light to the surface.



The gallium arsenide phosphide is used for the manufacturing of LED which emits red or yellow light for emission. The LED are also available in green, yellow amber and red in colour.

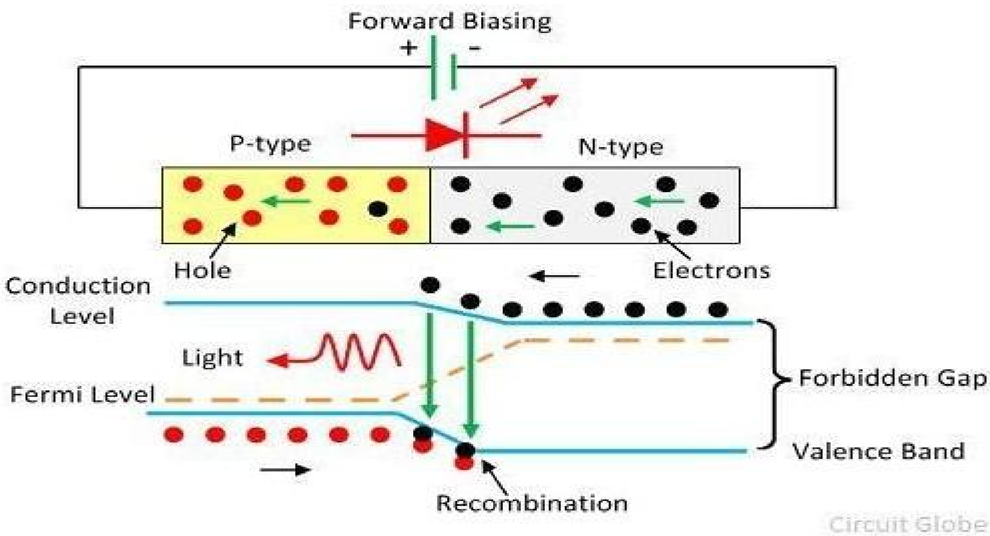


LED controlled by a Transistor switch

The simple transistor can be used for off/on of a LED as shown in the figure above. The base current IB conducts the transistor, and the transistor conducts heavily. The resistance RC limits the current of the LED.

Working of LED

The working of the LED depends on the quantum theory. The quantum theory states that when the energy of electrons decreases from the higher level to lower level, it emits energy in the form of photons. The energy of the photons is equal to the gap between the higher and lower level.



The LED is connected in the forward biased, which allows the current to flows in the forward direction. The flow of current is because of the movement of electrons in the opposite direction. The recombination shows that the electrons move from the conduction band to valence band and they emits electromagnetic energy in the form of photons. The energy of photons is equal to the gap between the valence and the conduction band.

Advantages of LED in electronic displays

The followings are the major advantages of the LED in an electronics displays.

1. The LED are smaller in sizes, and they can be stacked together to form numeric and alphanumeric display in the high-density matrix.
2. The intensity of the light output of the LED depends on the current flows through it. The intensity of their light can be controlled smoothly.
3. The LED are available which emits light in the different colours like red, yellow, green and amber.
4. The on and off time or switching time of the LED is less than of 1 nanoseconds. Because of this, the LED are used for the dynamic operation.
5. The LEDs are very economical and giving the high degree of reliability because they are manufactured with the same technology as that of the transistor.

6. The LED are operated over a wide range of temperature say 0° – 70°. Also, it is very durable and can withstand shock and variation.
7. The LED have a high efficiency, but they require moderate power for operation. Typically, the voltage of 1.2V and the current of 20mA is required for full brightness. Therefore, it is used in a place where less power are available.

Disadvantages of LED

The LED consumes more power as compared to LCD, and their cost is high. Also, it is not used for making the large display.

3. Draw the functional diagram of general purpose CRO and explain the function of each block.(Dec 19)(May 16)

Cathode Ray Oscilloscope (CRO)

Definition: The cathode ray oscilloscope (CRO) is a type of electrical instrument which is used for showing the measurement and analysis of waveforms and others electronic and electrical phenomenon. It is a very fast X-Y plotter shows the input signal versus another signal or versus time. The CROs are used to analyse the waveforms, transient, phenomena, and other time-varying quantities from a very low-frequency range to the radio frequencies.

The CRO is mainly operated on voltages. Thus, the other physical quantity like current, strain, acceleration, pressure, are converted into the voltage with the help of the transducer and thus represent on a CRO. It is also used for knowing the waveforms, transient phenomenon, and other time-varying quantity from a very low-frequency range to the radio frequencies.

The CRO has Stylus (i.e., a luminous spot) which move over the display area in response to an input voltage. This luminous spot is produced by a beam of electrons striking on a fluorescent screen. The normal form of the CRO uses a horizontal input voltage which is an internally generated ramp voltage called “time base”.

The horizontal voltage moves the luminous spot periodically in a horizontal direction from left to right over the display area or screen. The vertical voltage is the voltage under investigation. The vertical voltage moves the luminous spot up and down on the screen. When the input voltage moves very fast on the screen, the display on the screen appears stationary. Thus, CRO provides a means of the visualising time-varying voltage.

Construction of Cathode Ray Oscilloscope

The main parts of the cathode ray oscilloscope are as follows.

Cathode Ray Tube

Electronic Gun Assembly

1. Deflecting Plate
2. Fluorescent Screen For CRT
3. Glass Envelop

Their parts are explained below in details.

1. Cathode Ray Tube

The cathode ray tube is the vacuum tube which converts the electrical signal into the visual signal. The cathode ray tube mainly consists the electron gun and the electrostatic deflection plates (vertical and horizontal).The electron gun produces a focused beam of the electron which is accelerated to high frequency.

The vertical deflection plate moves the beams up and down and the horizontal beam moved the electrons beams left to right. These movements are independent to each other and hence the beam may be positioned anywhere on the screen.

2. Electronic Gun Assembly

The electron gun emits the electrons and forms them into a beam. The electron gun mainly consists a heater, cathode, a grid, a pre-accelerating anode, a focusing anode and an accelerating anode. For gaining the high emission of electrons at the moderate temperature, the layers of barium and strontium is deposited on the end of the cathode.

After the emission of an electron from the cathode grid, it passes through the control grid. The control grid is usually a nickel cylinder with a centrally located co-axial with the CRT axis. It controls the intensity of the emitted electron from the cathode.

The electron while passing through the control grid is accelerated by a high positive potential which is applied to the pre-accelerating or accelerating nodes.

The electron beam is focused on focusing electrodes and then passes through the vertical and horizontal deflection plates and then goes on to the fluorescent lamp. The pre-accelerating and accelerating anode are connected to 1500v, and the focusing electrode is connected to 500 v. There are two methods of focusing on the electron beam. These methods are

- Electrostatic focusing
- Electromagnetic focusing.

The CRO uses an electrostatic focusing tube.

3. Deflecting Plate

The electron beam after leaving the electron gun passes through the two pairs of the deflecting plate. The pair of plate producing the vertical deflection is called a vertical deflecting plate or Y plates, and the pair of the plate which is used for horizontal deflection is called horizontal deflection plate or X plates.

4. Fluorescent Screen for CRT

The front of the CRT is called the face plate. It is flat for screen sized up to about 100mm×100mm. The screen of the CRT is slightly curved for larger displays. The face plate is formed by pressing the molten glass into a mould and then annealing it.

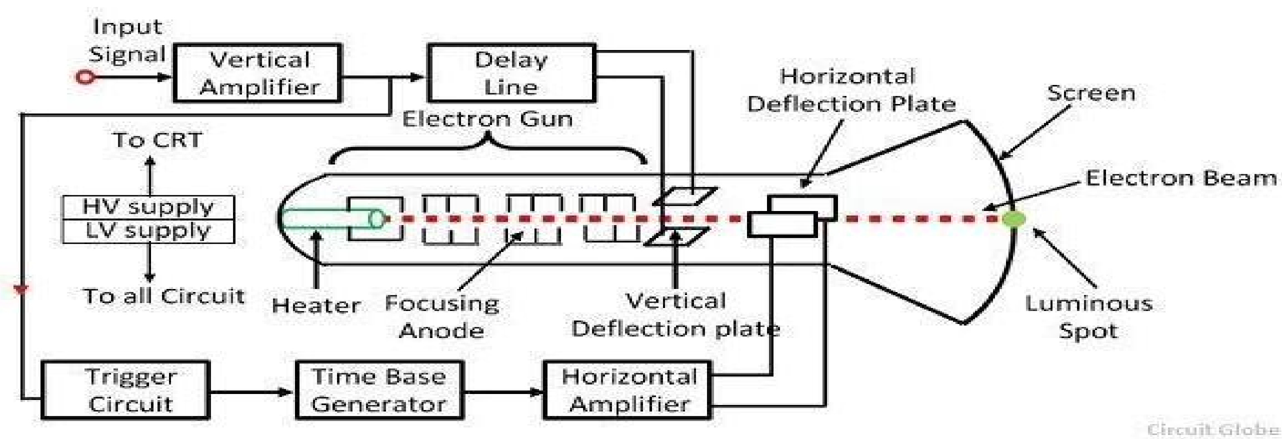
The inside surface of the faceplate is coated with phosphor crystal. The phosphor converts electrical energy into light energy. When an electronics beam strike phosphor crystal, it raises their energy level and hence light is emitted during phosphorous crystallisation. This phenomenon is called fluorescence.

5. Glass Envelope

It is a highly evacuated conical shape structure. The inner surface of the CRT between the neck and the screen is coated with the aquadag. The aquadag is a conducting material and act as a high-voltage electrode. The coating surface is electrically connected to the accelerating anode and hence help the electron to be the focus.

Working of Cathode Ray Oscilloscope

When the electron is injected through the electron gun, it passes through the control grid. The control grid controls the intensity of electron in the vacuum tube. If the control grid has high negative potential, then it allows only a few electrons to pass through it. Thus, the dim spot is produced on the lightning screen. If the negative potential on the control grid is low, then the bright spot is produced. Hence the intensity of light depends on the negative potential of the control grid.



After moving the control grid the electron beam passing through the focusing and accelerating anodes. The accelerating anodes are at a high positive potential and hence they converge the beam at a point on the screen.

After moving from the accelerating anode, the beam comes under the effect of the deflecting plates. When the deflecting plate is at zero potential, the beam produces a spot at the centre.If the voltage is applied to the vertical deflecting plate, the electron beam focuses at the upward and when the voltage is applied horizontally the spot of light will be deflected horizontally.

4. **Explain the working of magnetic tape recorders with necessary diagrams.(DEC19)**

The magnetic tape is passes over a reproducing head, thereby resulting in an output voltage proportional to the magnetic flux in the tape, across the coil of the reproducing head. Thus the magnetic pattern in the tape is detected and converted back into original electrical signal.

Magnetic Tape Recorder Working Principle:

The major advantage of using a Magnetic Tape Recorder Working Principle is that once the data is recorded, it can be replayed an almost indefinite number of times.

The recording period may vary from a few minutes to several days. Speed translation of the data captured can be provided, i.e. fast data can be slowed down and slow data speeded up by using different record and reproduce speeds.

The recorders described earlier have a poor high frequency response. Magnetic tape recorder, on the other hand, have a good response to high frequency, i.e. they can be used to record high frequency signals. Hence, magnetic tape recorders are widely used in instrumentation systems.

Basic Components of Magnetic Tape Recorder:

A magnetic tape recorder consists of the following basic components.

1. **Recording Head**
2. **Magnetic Head**
3. **Reproducing Head**
4. **Tape transport mechanism**
5. **Conditioning devices**

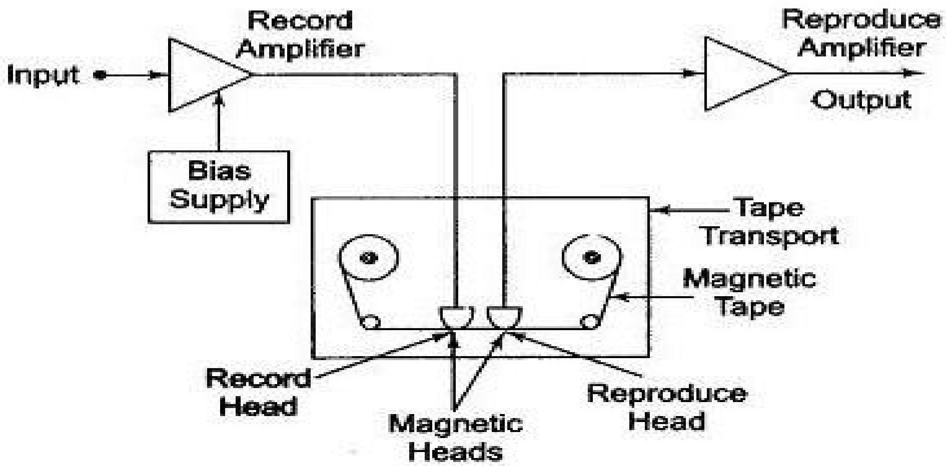


Fig. 12.10(a) Elementary Magnetic Tape Recorder

The Magnetic Tape Recorder Working Principle is made of a thin sheet of tough, dimensionally stable plastic, one side of which is coated with a magnetic material.

Some form of finely powdered iron oxide is usually cemented on the plastic tape with a suitable binder. As the tape is transferred from one reel, it passes across a magnetising head that impresses a residual magnetic pattern upon it in response to an amplified input signal.

The methods employed in recording data on to the magnetic tape include direct recording, frequency modulation (FM) and pulse code modulation (PCM).

Modulation of the current in the recording head by the signal to be recorded linearly modulates the magnetic flux in the recording gap. As the tape moves under the recording head, the magnetic particles retain a state of permanent magnetisation proportional to the flux in the gap. The input signal is thus converted to a spatial variation of the magnetisation of the particles on the tape. The reproduce head detects these changes as changes in the reluctance of its magnetic circuit which induce a voltage in its winding. This voltage is proportional to the rate of change of flux. The reproduce head amplifier integrates the signal to provide a flat frequency characteristics.

Since the reproduce head generates a signal which is proportional to the rate of change of flux, the direct recording method cannot be used down to dc. The lower limit is around 100 Hz and the upper limit for direct recording, around 2 MHz. The upper frequency limit occurs when the induced variation in magnetisation varies over a distance smaller than the gap in the reproduce head.

The signal on an exposed tape can be retrieved and played out at any time by pulling the tape across the magnetic head, in which a voltage is induced.

It is possible to magnetise the tape longitudinally or along either of the other two main axis, but longitudinal magnetisation is the best choice.

Figure 12.10(b) shows simply how the tape is magnetised. If a magnetic field is applied to any one of the iron oxide particles in a tape and removed, a residual flux remains. The relationship between the residual flux and the recording field is determined by the previous state of magnetisation and by the magnetisation curves of the particular magnetic recording medium.

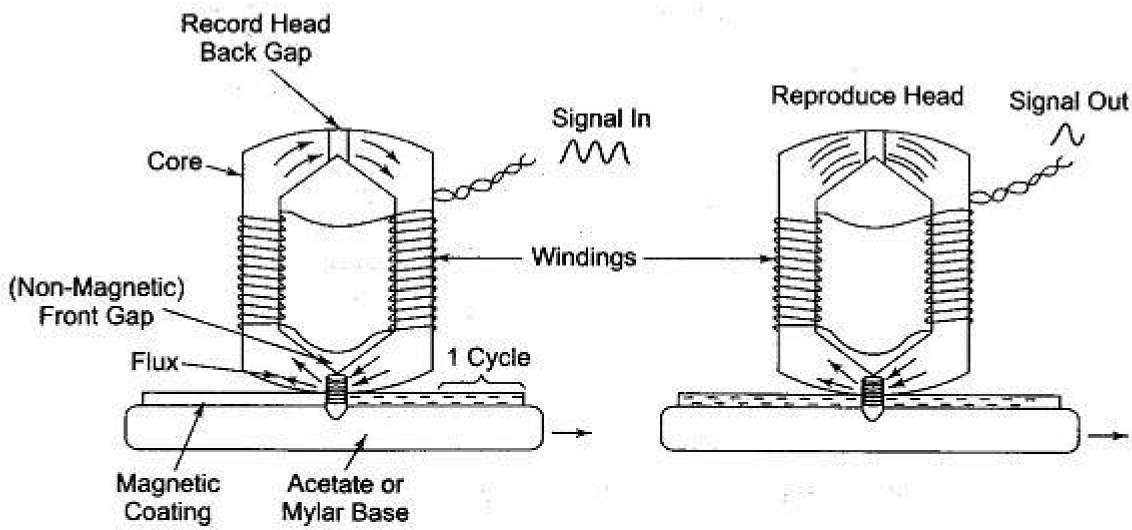
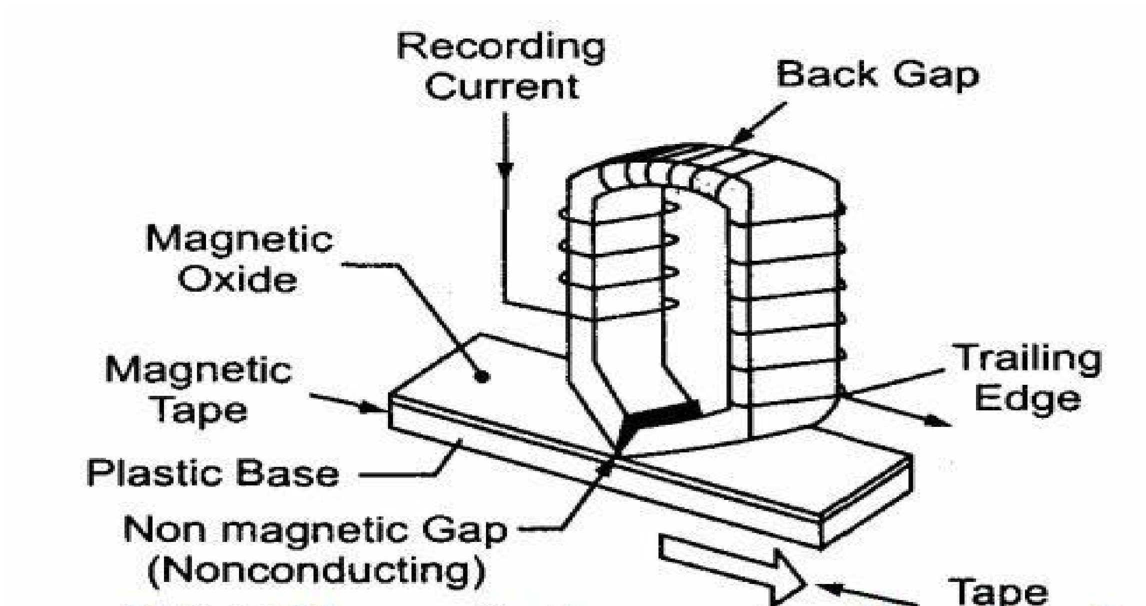


Fig. 12.10(b) Magnetisation of Tape

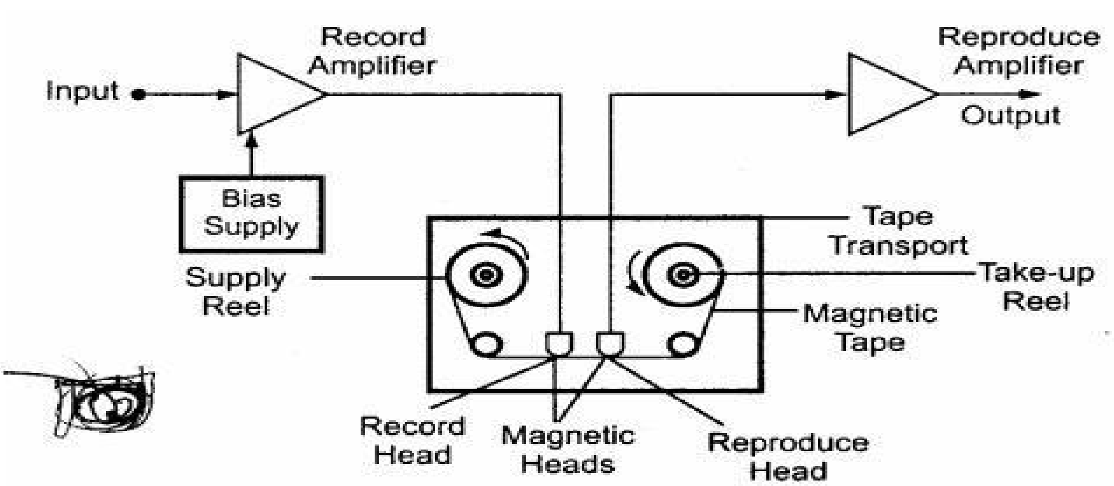
A simple magnetic particle on the tape might have the B H curve shown in Fig. 12.10(c) where H is the magnetising force and B the flux density in the particle.

Consider the material with no flux at all, i.e. the condition at point 0. Now if the current in the coil of the recording head [Fig. 12.10(b)] is increased from 0 in a direction that gives positive values of H, the flux density increases along the path 0 — 1— 2, until the material is eventually saturated. If the operating point is brought from 0 only as far as 1, and H is brought back to 0, B follows a minor hysteresis loop back to point 6. A greater value of coil current would leave a higher residual flux, and a lower current a lower residual; a very simple recording process results.

However, the linearity between residual flux and recording current is very poor. Hence to obtain linearity in direct recording, FM is used. In all systems, the signal is reproduced by passing the magnetised tape over a magnetic head similar to the recording head. The magnetisation of the particles on the tape induces a varying flux in the reproducing head and a voltage is induced in the coil, proportional to the rate of change of flux.



(Fig) Magnetic tape recording head



(Fig) Basic tape transport mechanism

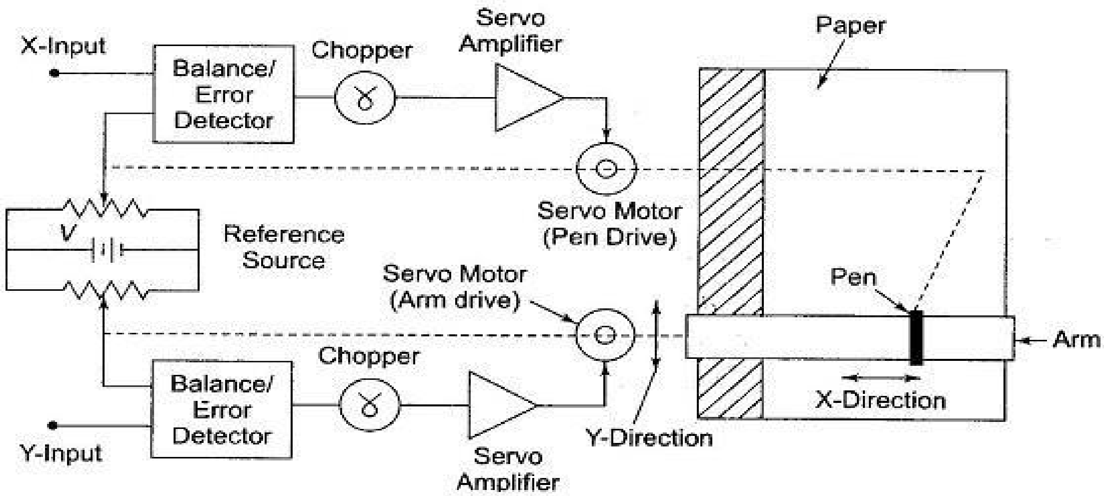


Fig. 12.9 Basic X–Y Recorder

5. **Describe the working of X-Y plotters with its suitable diagram and its applications(MAY 19) (NOV 18)(NOV 16)**

XY Recorder Working:

XY Recorder Working – In most research fields, it is often convenient to plot the instantaneous relationship between two variables [Y = f(x)], rather than to plot each variable separately as a function of time.

In such cases, the X—Y recorder is used, in which one variable is plotted against another variable. In an analog X—Y recorder, the writing head is deflected in either the x-direction or the y-direction on a fixed graph chart paper. The graph paper used is generally squared shaped, and is held fixed by electrostatic attraction or by vacuum.

The writing head is controlled by a servo feedback system or by a self balancing potentiometer. The writing head consist of one or two pens, depending on the application. In practice, one emf is plotted as a function of another emf in an X—Y recorder.

In some cases, the X—Y recorder is also used to plot one physical quantity (displacement, force, strain, pressure, etc.) as a function of another physical quantity, by using an appropriate transducer, which produces an output (EMF) proportional to the physical quantity.

The motion of the recording pen in both the axis is driven by servo-system, with reference to a stationary chart paper. The movement in x and y directions is obtained through a sliding pen and moving arm arrangement.

A typical block diagram of an XY Recorder Working is illustrated in Fig.

Referring to Fig. each of the input signals is attenuated in the range of 0-5 mV, so that it can work in the dynamic range of the recorder. The balancing circuit then compares the attenuated signal to a fixed internal reference voltage. The output of the balancing circuit is a dc error signal produced by the difference between the attenuated signal and the reference voltage. This dc error signal is then converted into an ac signal with the help of a chopper circuit. This ac signal is not sufficient to drive the pen/arm drive motor, hence, it is amplified by an ac amplifier. This amplified signal (error signal) is then applied to actuate the servo motor so that the pen/arm mechanism moves in an appropriate direction in order to reduce the error, thereby bringing the system to balance. Hence as the input signal being recorded varies, the pen/arm tries to hold the system in balance, producing a record on the paper.

The action described above takes place in both the axes simultaneously. Hence a record of one physical quantity with respect to another is obtained.

Some X—Y recorders provides x and y input ranges which are continuously variable between 0.25 mV/cm and 10 V/cm, with an accuracy of ± 0.1% of the full scale. Zero offset adjustments are also provided.

The dynamic performance of X—Y recorders is specified by their slewing rate and acceleration. A very high speed X—Y recorder, capable of recording a signal up to 10 Hz at an amplitude of 2 cm peak to peak, would have a slewing rate of 97 cm/s and a peak acceleration of 7620 cm/s.

An XY Recorder Working may have a sensitivity of 10 µV/mm, a slewing speed of 1.5 ms and a frequency response of about 6 Hz for both the axis. The chart size is about 250 x 180 mm. The accuracy of X—Y recorder is about ± 0.3%.

Applications of X—Y Recorders

These recorders are used to measure the following.

1. Speed-torque characteristics of motors.
2. Regulation curves of power supply.
3. Plotting characteristics of active devices such as vacuum tubes, transistors, zener diode, rectifier diodes, etc.
4. Plotting stress-strain curves, hysteresis curves, etc.
5. Electrical characteristics of materials, such as resistance versus temperature.

Digital X—Y Plotters

The rapid increase in the development in digital electronics has led to the replacement of analog X—Y recorders by digital X—Y plotters. The latter provide increased measurement and graphics capabilities. Digital X—Y plotters use an open loop stepping motor drive, in place of the servo motor drive used in analog X—Y recorders.

Digital measurement plotting systems provide the following features:

1. Simultaneous sampling and storage of a number of nput channels.

2. A variety of trigger modes, including the ability to display pre-triger data.
3. Multi-pen plotting of the data.
4. Annotation of the record with date, time and set up conditions.
5. An ability to draw grids and axis.

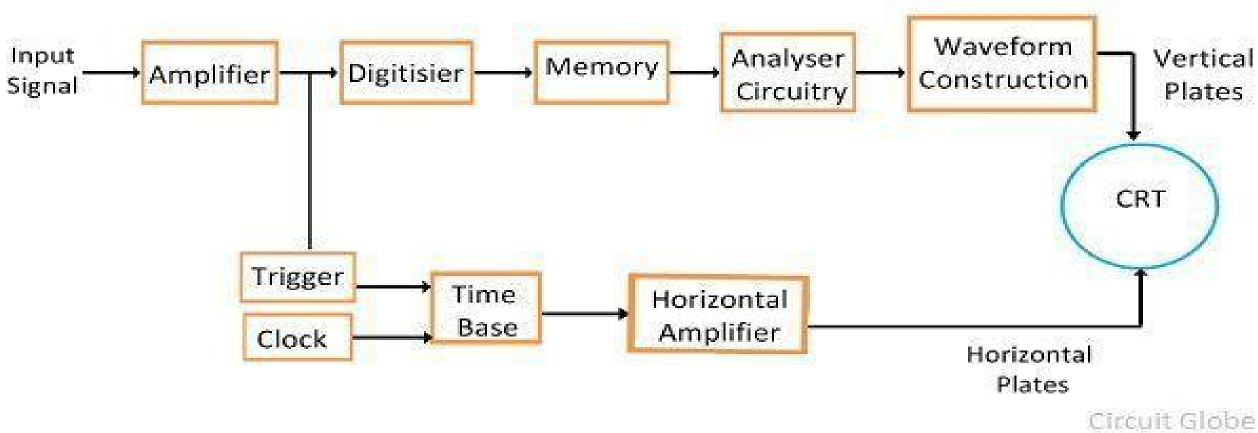
6. With a neat sketch, explain the working principle of digital CRO. Compare the same with analog oscilloscope.(MAY 19) .(NOV17) .(NOV 18)(MAY 15)

Digital Storage Oscilloscope

Definition: The digital storage oscilloscope is defined as the oscilloscope which stores and analysis the signal digitally, i.e. in the form of 1 or 0 preferably storing them as analogue signals. The digital oscilloscope takes an input signal, store them and then display it on the screen. The digital oscilloscope has advanced features of storage, triggering and measurement. Also, it displays the signal visually as well as numerically.

Working Principle of Digital Storage Oscilloscope

The digital oscilloscope digitises and stores the input signal. This can be done by the use of **CRT** (Cathode ray tube) and **digital memory**. The block diagram of the basic digital oscilloscope is shown in the figure below. The digitisation can be done by taking the sample input signals at periodic waveforms.



The maximum frequency of the signal which is measured by the digital oscilloscope depends on the two factors. Theses factors are the

1. Sampling rate
2. Nature of converter.

Sampling Rate – For safe analysis of input signal the sampling theory is used. The sampling theory states that the sampling rate of the signal must be twice as fast as the highest frequency of the input signal. The sampling rate means analogue to digital converter has a high fast conversion rate.

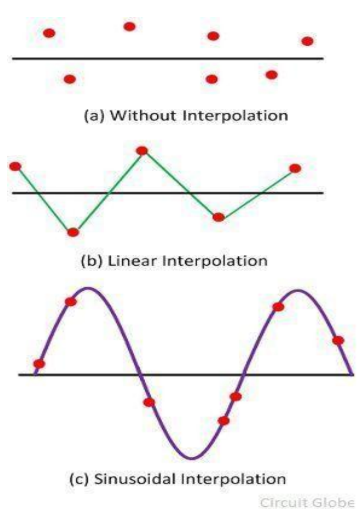
Converter – The converter uses the expensive flash whose resolution decreases with the increases of a sampling rate. Because of the sampling rate, the bandwidth and resolution of the oscilloscope are limited.

The need of the analogue to digital signal converters can also be overcome by using the shift register. The input signal is sampled and stored in the shift register. From the shift register, the signal is slowly read out and stored in the digital form. This method reduces the cost of the converter and operates up to 100 mega sample per second.

The only disadvantage of the digital oscilloscope is that it does not accept the data during digitization, so it had a blind spot at that time.

Waveform Reconstruction

For visualizing the final wave, the oscilloscopes use the technique of inter-polarization. The inter-polarization is the process of creating the new data points with the help of known variable data points. Linear interpolation and sinusoidal interpolation are the two processes of connecting the points together.



In interpolation, the lines are used for connecting the dot together. Linear interpolation is also used for creating the pulsed or square waveform. For sine waveform, the sinusoidal interpolation is utilized in the oscilloscope.

7. **Explain the working principle and construction 7 segment LED display driver with neat sketch.(NOV17)**

The emission of these photons occurs when the diode junction is forward biased by an external voltage allowing current to flow across its junction, and in Electronics we call this process electroluminescence.

The actual colour of the visible light emitted by an LED, ranging from blue to red to orange, is decided by the spectral wavelength of the emitted light which itself is dependent upon the mixture of the various impurities added to the semiconductor materials used to produce it.

7-segment Display

Light emitting diodes have many advantages over traditional bulbs and lamps, with the main ones being their small size, long life, various colours, cheapness and are readily available, as well as being easy to interface with various other electronic components and digital circuits.

But the main advantage of light emitting diodes is that because of their small die size, several of them can be connected together within one small and compact package producing what is generally called a **7-segment Display**.

The 7-segment display, also written as "seven segment display", consists of seven LEDs (hence its name) arranged in a rectangular fashion as shown. Each of the seven LEDs is called a segment because when illuminated the segment forms part of a numerical digit (both Decimal and Hex) to be displayed. An additional 8th LED is sometimes used within the same package thus allowing the indication of a decimal point, (DP) when two or more 7-segment displays are connected together to display numbers greater than ten.

Each one of the seven LEDs in the display is given a positional segment with one of its connection pins being brought straight out of the rectangular plastic package. These individually LED pins are labelled from a through to g representing each individual LED. The other LED pins are connected together and wired to form a common pin.

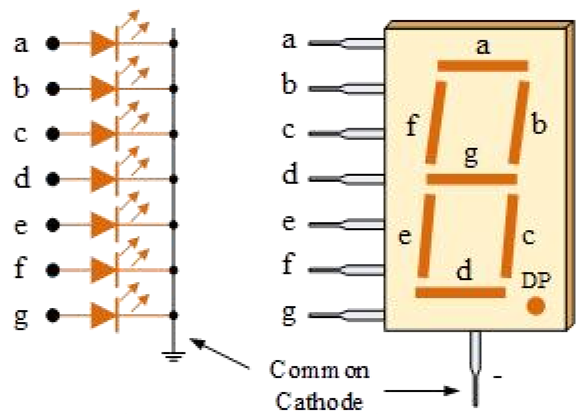
So by forward biasing the appropriate pins of the LED segments in a particular order, some segments will be light and others will be dark allowing the desired character pattern of the number to be generated on the display. This then allows us to display each of the ten decimal digits 0 through to 9 on the same 7-segment display.

The displays common pin is generally used to identify which type of 7-segment display it is. As each LED has two connecting pins, one called the "Anode" and the other called the "Cathode", there are therefore two types of LED 7-segment display called: **Common Cathode** (CC) and **Common Anode** (CA).

The difference between the two displays, as their name suggests, is that the common cathode has all the cathodes of the 7-segments connected directly together and the common anode has all the anodes of the 7-segments connected together and is illuminated as follows.

1. The Common Cathode (CC) – In the common cathode display, all the cathode connections of the LED segments are joined together to logic "0" or ground. The individual segments are illuminated by application of a "HIGH", or logic "1" signal via a current limiting resistor to forward bias the individual Anode terminals (a-g).

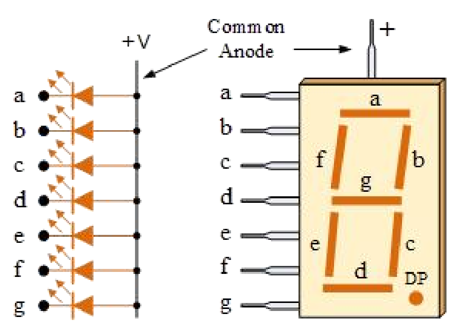
Common Cathode 7-segment Display



8.

The Common Anode (CA) – In the common anode display, all the anode connections of the LED segments are joined together to logic "1". The individual segments are illuminated by applying a ground, logic "0" or "LOW" signal via a suitable current limiting resistor to the Cathode of the particular segment (a-g).

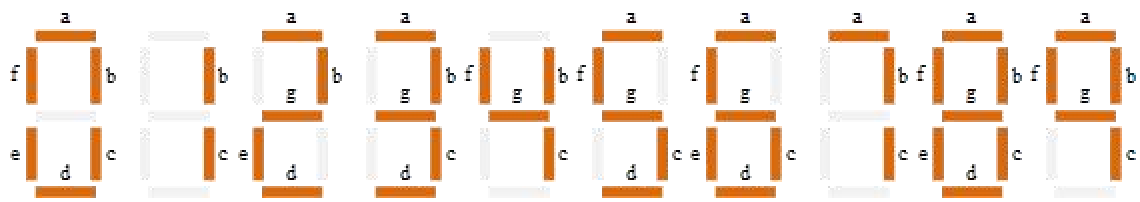
Common Anode 7-segment Display



In general, common anode displays are more popular as many logic circuits can sink more current than they can source. Also note that a common cathode display is not a direct replacement in a circuit for a common anode display and vice versa, as it is the same as connecting the LEDs in reverse, and hence light emission will not take place.

Depending upon the decimal digit to be displayed, the particular set of LEDs is forward biased. For instance, to display the numerical digit 0, we will need to light up six of the LED segments corresponding to a, b, c, d, e and f. Thus the various digits from 0 through 9 can be displayed using a 7-segment display as shown.

7-Segment Display Segments for all Numbers.



Then for a 7-segment display, we can produce a truth table giving the individual segments that need to be illuminated in order to produce the required decimal digit from 0 through 9 as shown below.

7-segment Display Truth Table

Decimal Digit	Individual Segments Illuminated						
	a	b	c	d	e	f	g
0	×	×	×	×	×	×	
1		×	×				
2	×	×		×	×		×

3	×	×	×	×			×
4		×	×			×	×
5	×		×	×		×	×
6	×		×	×	×	×	×
7	×	×	×				
8	×	×	×	×	×	×	×
9	×	×	×			×	×

Driving a 7-segment Display

Although a 7-segment display can be thought of as a single display, it is still seven individual LEDs within a single package and as such these LEDs need protection from over current. LEDs produce light only when it is forward biased with the amount of light emitted being proportional to the forward current.

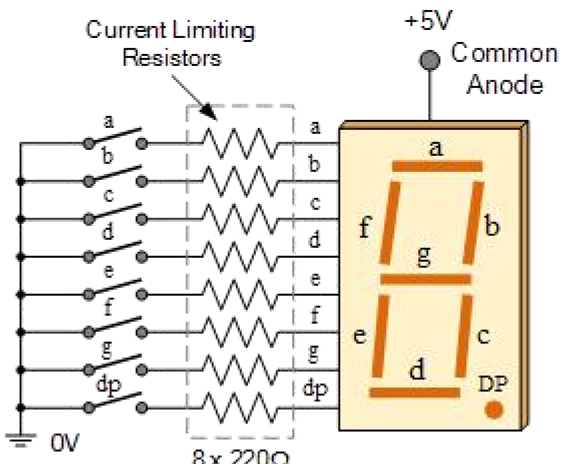
This means then that an LEDs light intensity increases in an approximately linear manner with an increasing current. So this forward current must be controlled and limited to a safe value by an external resistor to prevent damage to the LED segments.

The forward voltage drop across a red LED segment is very low at about 2-to-2.2 volts, (blue and white LEDs can be as high as 3.6 volts) so to illuminate correctly, the LED segments should be connected to a voltage source in excess of this forward voltage value with a series resistance used to limit the forward current to a desirable value.

Typically for a standard red coloured 7-segment display, each LED segment can draw about 15 mA to illuminated correctly, so on a 5 volt digital logic circuit, the value of the current limiting resistor would be about 200Ω (5v – 2v)/15mA, or 220Ω to the nearest higher preferred value.

So to understand how the segments of the display are connected to a 220Ω current limiting resistor consider the circuit below.

Driving a 7-segment Display

9. 

In this example, the segments of a common anode display are illuminated using the switches. If switch a is closed, current will flow through the "a" segment of the LED to the current limiting resistor connected to pin a and to 0 volts, making the circuit. Then only segment a will be illuminated. So a LOW condition (switch to ground) is required to activate the LED segments on this common anode display.

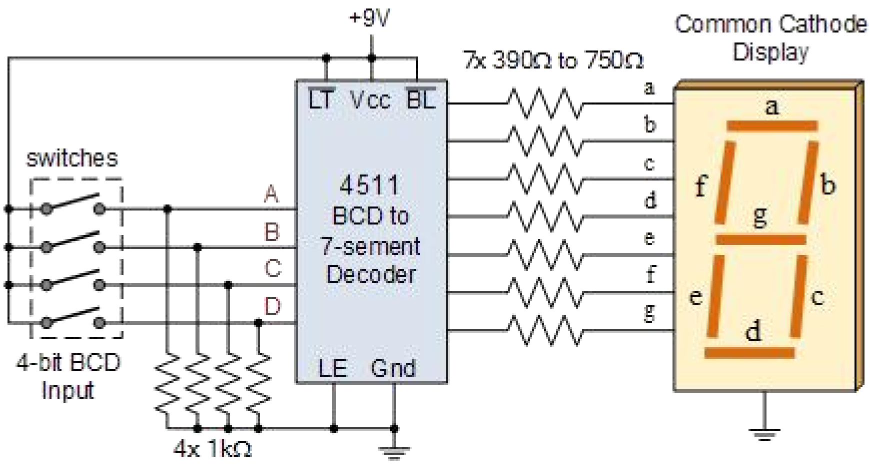
But suppose we want the decimal number "4" to illuminate on the display. Then switches b, c, f and g would be closed to light the corresponding LED segments. Likewise for a decimal number "7", switches a, b, c would be closed. But illuminating 7-segment displays using individual switches is not very practical.

7-segment Displays are usually driven by a special type of integrated circuit (IC) commonly known as a 7-segment decoder/driver, such as the CMOS 4511. This 7-segment display driver which is known as a Binary Coded Decimal or BCD to 7-segment display decoder and driver, is able to illuminate both common anode or common cathode displays. But there are many other single and dual display drivers available such as the very popular TTL 7447.

This BCD-to-7 segment decoder/driver takes a four-bit BCD input labelled A, B, C and D for the digits of the binary weighting of 1, 2, 4 and 8 respectively, has seven outputs that will pass current through the appropriate segments to display the decimal digit of the numeric LED display.

The digital outputs of the CD4511 are different from the usual CMOS outputs because they can provide up to 25mA of current each to drive the LED segments directly allowing different coloured LED displays to be used and driven.

Driving a 7-segment Display using a 4511



In this simple circuit, each LED segment of the common cathode display has its own anode terminal connected directly to the 4511 driver with its cathodes connected to ground. The current from each output passes through a 1kΩ resistor that limits it to a safe amount. The binary input to the 4511 is via the four switches. Then we can see that using a BCD to 7-segment display driver such as the CMOS 4511, we can control the LED display using just four switches (instead of the previous 8) or a 4-bit binary signal allowing up to 16 different combinations.

Most digital equipment use **7-segment Displays** for converting digital signals into a form that can be displayed and understood by the user. This information is often numerical data in the form of numbers, characters and symbols. Common anode and common cathode seven-segment displays produce the required number by illuminating the individual segments in various combinations.

LED based 7-segment displays are very popular amongst Electronics hobbyists as they are easy to use and easy to understand. In most practical applications, 7-segment displays are driven by a suitable decoder/driver IC such as the CMOS 4511 or TTL 7447 from a 4-bit BCD input. Today, LED based 7-segment displays have been largely replaced by liquid crystal displays (LCDs) which consume less current.

10. Derive an expression for deflection D in CRO which is the deflection of the electron beam.(MAY 17)

Electrostatic Deflection in CRT

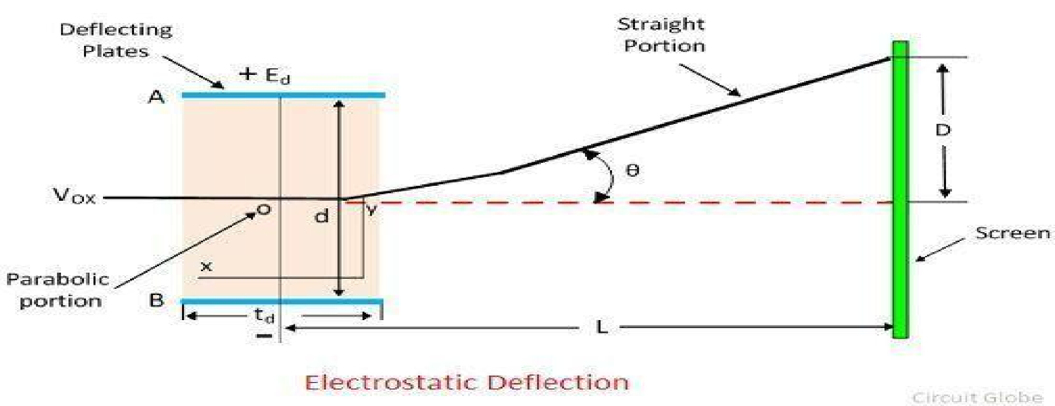
Definition: Electrostatic deflection is the method of aligning the path of charged particles by applying the electric field between the deflecting plates. The word electrostatic means the strength and the direction of the field changes concerning time. So that, the particles will move only in one direction.

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 focussing the electron beam.

The vertical plate produces an electrical field in the horizontal plane and causes horizontal deflection. The other pair is mounted horizontally and generates an electric field in the vertical plane and causes vertical deflection. These plates allow the beam to pass through the deflecting plates without striking them.

Electrostatic Deflection Arrangement

The general arrangement of the electrostatic deflection is shown in the figure below. The 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. Hence, no acceleration of electrons occurs in that direction.

E_0 = Voltage of pre-accelerating anode in volt.
e = charge of an electron in coulomb.

m = mass of electron in Kg.
V_{OX} = velocity of the electron when entering into the deflecting plates in meter per second.
E_d = potential between deflecting plates in Volts.
d = distance between deflecting plate in the meter.
L_d = length of deflecting plate in meters.
L = Distance between screen and the mid of the deflecting plates.
D = deflection of the electron beam on the screen in the Y 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.

$$P.E = eE_a$$

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.

$$v_{ox} = \left[\frac{2eE_a}{m}\right]^{1/2}$$

The velocity of the electron in X direction remains same throughout the deflection plate because no force was acting in the X direction.

$$\varepsilon_y = \frac{E_d}{d}$$

The equation gives the electric field intensity in the Y direction

$$F_y = e\varepsilon_y = \frac{eE_d}{d}$$

The force acting on the electron in the Y direction. The term ay shows the acceleration of electrons in the y direction.

$$F_y = ma_y$$

$$a_y = \frac{e\varepsilon_Y}{m}$$

The initial velocity of the electron enters into the deflection plate is equal to zero, and the equation gives the displacement of an electron in the Y direction at any time t

$$y = \frac{1}{2}a_y t^2 = \frac{1}{2}\frac{e\varepsilon_y}{m}t^2$$

The velocity in the Y direction is constant, and the displacement in the Y direction is given as

$$x = v_{ox}t$$

$$t = \frac{x}{v_{ox}}$$

Substituting the value of t in the displacement equation y gives

$$y = \frac{1}{2}\frac{e\varepsilon_y}{m}\left[\frac{x}{v_{ox}}\right]^2$$

The above equation represents parabola.The slope at any point is given as

$$\frac{dy}{dx} = \frac{e\varepsilon_y}{mv_{ox}^2}$$

By substituting the x = l_d, we get the value of tanθ.

$$tan\theta = \frac{1}{2}\frac{e\varepsilon_y}{mv_{ox}^2}l_d = \frac{eE_d l_d}{mdv_{ox}^2}$$

After passing through the deflection plate, the electrons move into the straight line.This straight line is the tangent to the parabola at x = l_d and intersect the X-axis at point O'.The equation gives the location of the point

$$x = \frac{y}{tan\theta} = \frac{\frac{1}{2}\frac{e\varepsilon_y}{m}\cdot\frac{{l_d}^2}{{v^2}_{ox}}}{\frac{e\varepsilon_y l_d}{mdv_{ox}^2}} = \frac{l_d}{2}$$

The deflection D on the screen is expressed as

$$D = Ltan\theta = \frac{LeE_d l_d}{mdv_{ox}^2}$$

By substituting the value of $v^2{}_{ox}$ in the above equation we get

$$D = \frac{LeE_d l_d}{md}\cdot\frac{m}{2eE_a} = \frac{LE_d l_d}{2dE_a}$$

From the above equation, we can conclude that the deflection of the electron is directly proportional to the deflecting voltage

Explain with a suitable example principle, operation and operation of data loggers.(MAY 17)

Data Logger Operation:

Data Logger Operation – For proper understanding of a Data Logger Operation, it is essential to understand the difference between analog and digital signals. For example, measurement of temperature by a milli voltmeter, whose needle shows a reading directly proportional to the emf generated by the thermocouple, is an analog signal.

However, digital equipment presents a digital output in terms of pulses and involves an electronic pulse counting equipment which counts the number of pulses. The pulses are generated such that each pulse corresponds to the smallest value of the parameter being measured.

These digital signals are precise at all times. Consider the example of temperature. In the case of analog measurements even the accuracy of the potentiometric method is limited by the precision with which the resistance can be subdivided. In the digital method, the electrical signal obtained from the thermocouple is subdivided by an electronic decade circuit and thus the thermocouple voltage can be measured to many places of decimal.

An analog device is capable of measuring with an error of ± 0.5% to ±1%,whereas a digital device can be obtained with an error of any ± 0.01%. An analog instrument responds to a change in input levels in times of the order of 0.25 to 1 s while a digital instrument gives accurate readings in a few hundredth's of a second, and often many times faster.

One advantage of a digital instrument is that its reading can be recorded by suitable printer.

The Data Logger Operation senses only digital signals and hence analog signals, if any, have to be converted to digital signals. The digital technique is employed because it measures very small (or large) signals accurately and fast.

The recording device may be a printed log or a punched paper tape. The printed output can be either line by line on a paper strip or on a type written page.

Time words are printed at the start of each sequence. Time is recorded in hours, minutes and seconds. Data Logger Operation consists of the channel identity number, followed by polarity indication (+ or —), the measured value (4 or 6 digits) and units of measurement. Sometimes the range may also be indicated.

Basic parts of a Data Logger Operation

1. Input scanner
2. Signal conditioner
3. A/D converter
4. Recording equipment

5. **Programmer**
The block diagram of a Data Logger Operation involving all these parts is shown in Fig.

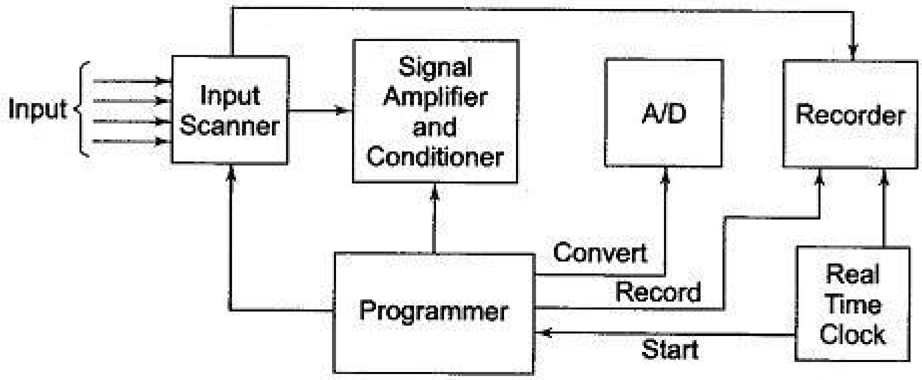


Fig. 17.24 Block Diagram of a Data Logger

The input scanner is an automatic sequence switch which selects each signal in turn. Low level signals, if any, are multiplied to bring them up to a level of 5 V. If the signals are not linearly proportional to the measured parameter, these signals are linearised by the signal conditioner.

The analog signals are then converted to digital signals suitable for driving the recording equipment (printer or punched paper tape).

The programmer (serialiser) is used to control the sequence operation of the various items of the logger. It tells the scanner when to step to a new channel, and receives information from the scanner, converter and recorder. The real time clock is incorporated to automatic the system. The clock commands the programmer to sequence one set of measurements at the intervals selected by the user.

Input Signals

The input signals fed to the input scanner of the Data Logger Operation can be of the following types.

1. **High level signals from pressure transducers**
2. **Low level signals from thermocouples**
3. **ac signals**
4. **Pneumatic signals from pneumatic transducers**
5. **On/off signals from switches, relays, etc.**
6. **Pulse train from tachometer**
7. **Digital quantities**

The last three signals (5, 6 and 7) are of the digital type and are handled by one set of input scanners and the remaining signals are of the analog type and are handled by a different set of input scanner.

Low level dc signals are first amplified and then conditioned by the law network and finally fed to the A/D converter.

High level signals are fed straight to law network and converter.

The ac and pneumatic signals are first converted to electrical dc signals, conditioned and then converted.

In this manner, all types of signals are converted to a form, suitable for handling by the data logger.

The purpose of the conditioner is to provide a linear law for signals from various transducer which do not have linear characteristics.

Filters are used for noise and ripple suppression at the interface of the output of the transducers and the input of the signal conditioner, since these signals carried by the cables are of very low magnitude. Digital signals are then fed to the digital interface, whereas analog signals are first amplified, linearised and then brought to the analog interface. They are then converted into digital form and finally fed to the digital interface.

Input Scanners

Because the scanner select each input signal in turn, the Data Logger Operation requires only one signal amplifier and conditioner, one A/D converter and a single recorder.

Modern scanners have input scanners which can scan at the rate of 150 inputs/s, but the rate of scanning has to be matched with the rate of change of input data, and the time required by the recorder and the output devices to print one output.

Sometimes it is desirable to scan certain parameters at a faster rate and some others at a longer intervals. For such mixed scan rates, the scanning equipment is designed for an interlaced scan operation, in which it is possible to log some parameters at 30 — 60 minutes interval, some every 5 minutes, and others every few seconds.

A scanner, in effect, is a multiway switch which is operated by a scanner drive unit for selecting the circuits. As the switch contacts have to continuously (24 hours/day) deal with low level signals at very, high frequencies, the following requirements (desired characteristics) must be considered in the design of the contacts and their operations.

Low closed resistance

High open circuit resistance

Low contact potential

Negligible interaction between switch energising signal and input signals

Short operating times

Negligible contact bounce

Long operation life

Although it may not be possible to achieve all these characteristics in one switch, the arrangement selected must satisfy the maximum possible conditions. The various switching elements available commercially are as follows.

Rotary selector switch
Electromagnetic operated relays
Dry Reed type
Mercury wetted reed type
Solid state switches
Scanner Drive
The most common arrangement for selecting individual input one after another, is to use a matrix, as shown in Fig.

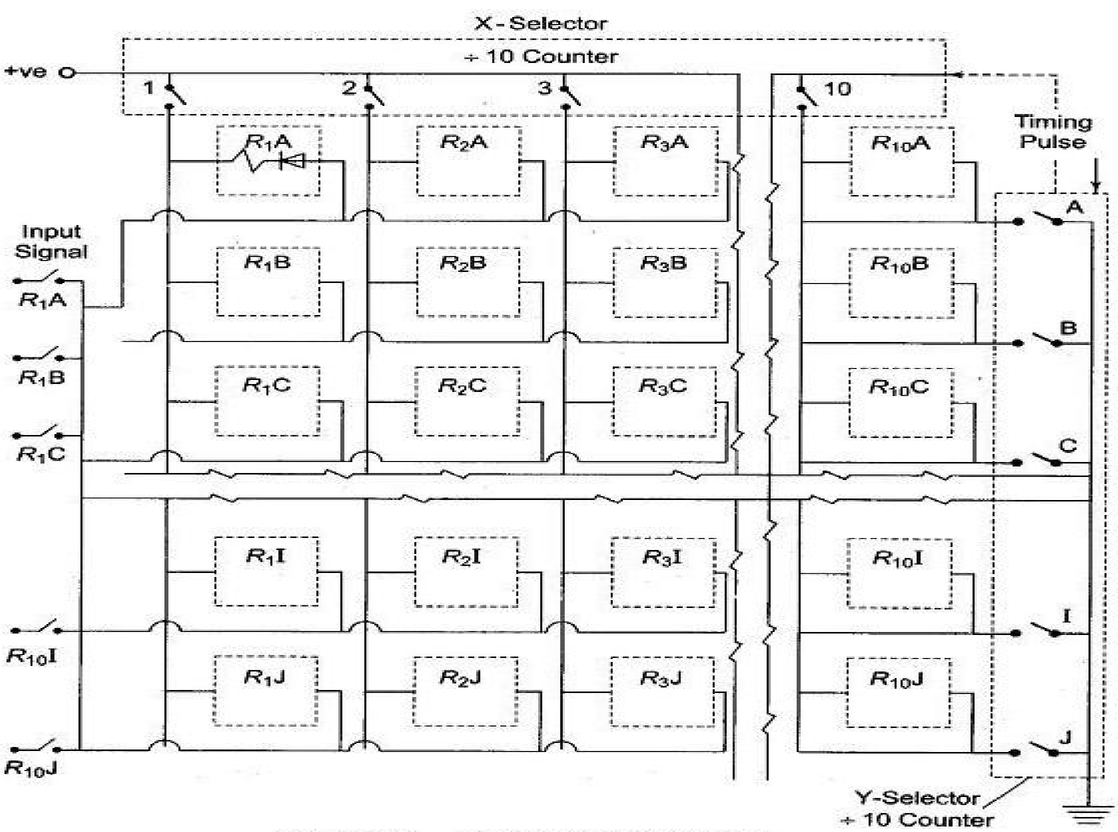


Fig. 17.25 Selector Switch (Matrix)

The matrix is formed by using two energising lines, X and Y, corresponding to horizontal and vertical respectively, each having 10 contacts. Hence a 10 x 10 matrix is formed, giving 100 input channels per scanner unit or module. The only relay at the intersection of the energised X and Y lines is operated. The timing pulse thus consists of two signals, one for the X line and the other for the Y line. Each relay has a diode in series with its coil, to prevent other relays being energised via other paths.

The energising signals, i.e. the timing pulses are normally developed using counter circuits, which start off selecting one of the X lines, and then all the Y lines in sequence. After this cycle is completed, the next X line is selected and again all the Y lines are selected in turn. In this way each input is scheduled in turn. Generally, transistor switches are used to select the input relay.

As the measuring transducers and sensing elements are located at distances of about 300 — 400 m away from the scanner, the electrical interference, i.e. the electrical voltage induced in the signal lines can swamp an actual signal voltage.

The most common method to eliminate or reduce the effect of common mode noise is to use an amplifier with a floating input.

Although the effect of noise is practically eliminated as the low level signals, these signals have to be amplified further to a suitable level to drive the A/D converter. Hence the signal amplifier should have the following characteristics.

Precise and stable dc gain

High signal to noise ratio

Good linearity

High input impedance

High CMRR

Low output impedance

Low dc drift

Wide band width

Fast recovery time

(Signal) Input Conditioning

Since Data Logger Operation give their readout in the units of measurements concerned, there are two requirements:

Scaling linear transducers

Correcting the curvature of a non-linear transducer, such as a thermocouple

Linear inputs can be dealt with in two ways.

The simplest is to provide individual resistance attenuation on each input in order to reduce the transducer output level, where the scale factor is an integral power of ten. For example, if a particular transducer has a full scale of 10 mV for a pressure of 500 kg/cm2, we can reduce the value to one half by the use of an attenuator, such that 500 kg/cm2 may be represented by 5 mV. If the system is to have a resolution of 1 kg/cm2, the A/D converter must have a resolution of 10 pV. This technique is limited only by the sensitivity of the A/D converter

The second method is to change the sensitivity of the A/D converter. But since each input may require a different scale factor, this is not convenient as an input attenuation technique.

The signal can be linearised at any one of the following three places.

In the analog stage before conversion

In the conversion process

Digitally after conversion

The first method is not suited to low level voltages, as it requires some form of amplification. The signal conditioner may be placed between the scanner and the converter. But, each type of transducer requires individual linearising circuits.

The third method requires a storage capability and a computer processing technique. The most satisfactory is the second method, whereby linearisation is built into the conversion process.

A/D Converters

These have been discussed already.

Recorders

The output from the Data Logger Operation can be printed on any of the following.

Typewriter

Strip printer and/or digitally recorded on punched tape or magnetic tape for further analysis in a digital computer.

The typewriter provides a conventional log sheet with tabulated results, and prints in two colours.

The signals obtained from the A/D converters are applied to the electro- magnetic operated levers of a typewriter. Plus, Minus, characters which can be printed one at a time, decimal point shift, line shift, type colour and spacing are controlled by the EM solenoids which are energised from the programmer unit. Punched paper tape or magnetic tape is used when the recorded data is to be further analysed or where the rate of data acquisition is too great for a printer.

11. Discuss the working principle of LCD with diagrams. (NOV16)(MAY 15)

Liquid Crystal Diode (LCD)

Definition: The LCD is defined as the **diode** that uses **small cells** and the **ionised gases** for the **production of images**. The LCD works on the **modulating property of light.** The light modulation is t**he technique of sending and receiving the signal** through the **light**. The **liquid crystal consumes** a small amount of energy because they are the **reflector and the transmitter of light.** It is normally used for **seven segmental display.**

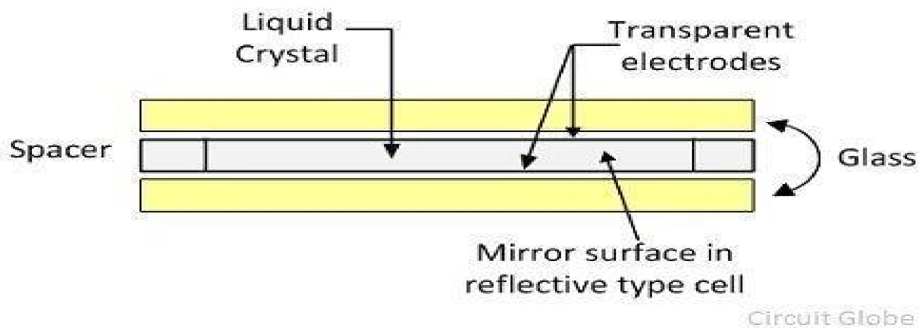
Construction of LCD

The liquid crystals are the organic compound which is in liquid form and shows the property of optical crystals. The layer of liquid crystals is deposited on the inner surface of glass electrodes for the scattering of light. The liquid crystal cell is of two types; they are Transmittive Type and the Reflective Type.

Transmittive Type – In transmitter cell both the glass sheets are transparent so that the light is scattered in the forward direction when the cell becomes active.

Reflective Type – The reflective type cell consists the reflecting surface of the glass sheet on one end. The light incident on the front surface of the cell is scattered by the activated cell.

Both the reflective and transmittive type cells appear brights, even under small ambient light conditions.

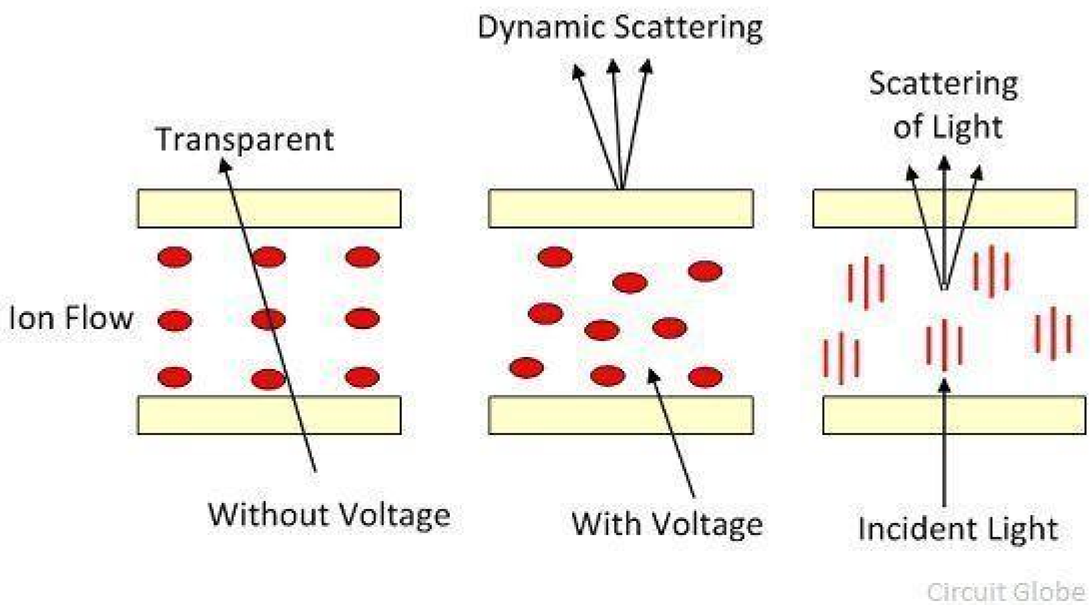


Working Principle of LCD

The working principle of the LCD is of two types. They are the dynamic scattering type and the field effects type. Their details explanation is shown below.

Dynamic Scattering

When the potential carrier flows through the light, the molecular alignment of the liquid crystal disrupts, and they produce disturbances. The liquid becomes transparent when they are not active. But when they are active their molecules turbulence causes scattered of light in all directions, and their cell appears bright. This type of scattering is known as the dynamic scattering. The construction of the dynamic scattering of the liquid crystal cell is shown in the figure



Field Effect Type

The construction of liquid crystals is similar to that of the dynamic scattering types the only difference is that in field effect type LCD the two thin polarising optical fibres are placed inside the each glass sheet. The liquid crystals used in field effect LCDs are of different scattering types that operated in the dynamic scattering cell.

The field affects type LCD uses the nematic material which twisted the unenergised light passing through the cell. The nematic type material means the liquid crystals in which the molecules are arranged in parallel but not in a well-defined plane. The light after passing through the nematic material passing through the optical filters and appears bright. When the cell has energised no twisting of light occurs, and the cell appears dull.

Advantages of LCD

The following are the advantages of LCD.

1. 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.
2. The cost of the LCD is low.

Disadvantages of LCD

The following are the disadvantages of LCD.

1. 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.
2. The LCD requires the large area.
3. The direct current reduces the lifespan of LCD. Therefore, the LCD uses with AC supply, having the frequency less than 500Hz.