Unit 3
Potentiometers

A potentiometer is an instrument designed to measure an unknown voltage by comparing it with a known voltage. The known voltage may be supplied by a standard cell or any known voltage. At null condition, no current flows, so no power consumed. So the measurement is independent of source resistance.

It can also measure current by measuring voltage drop across a standard resistor.

It is used extensively for calibration of voltmeters & ammeters.

Measurements using comparison methods are capable of a high degree of accuracy because the result obtained does not depend upon the actual deflection of a pointer, as is the case in deflection methods, but only upon the accuracy with which the voltage of the reference source is known.

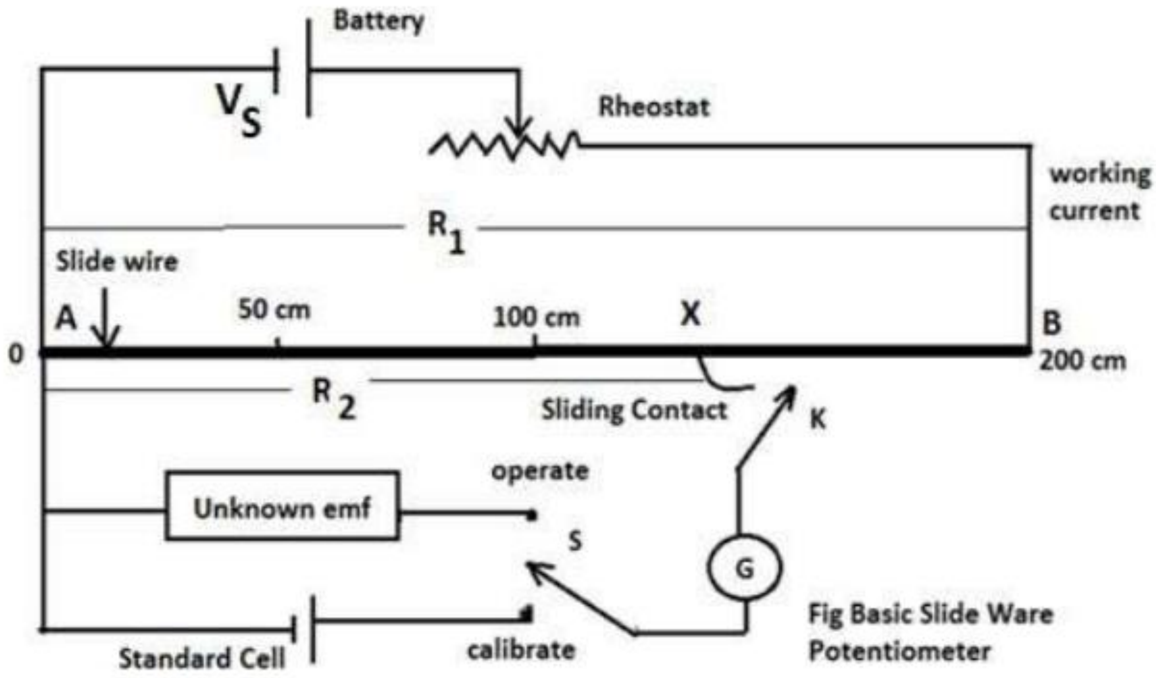


Fig Basic Slide Ware Potentiometer

Procedure to Calibrate Volt-meter

1. In this circuit, the ends of a uniform resistance wire R1 are connected to a regulated DC supply VS for use as a voltage divider.
2. A standard electrochemical cell is used whose emf is known (e.g. 1.0183 volts)

CALIBRATION/STANDARDISATION OF POTENTIOMETER

3. Switch 'S' is placed at calibrate position
4. Sliding position k is positioned at a point corresponding to standard cell voltage (1.0183 volts)
5. The potentiometer is first calibrated by positioning the wiper (arrow) at the spot on the R1 wire that corresponds to the voltage of a standard cell

so that $\frac{R_2}{R_1} = \frac{\text{Cell Voltage}}{V_S}$

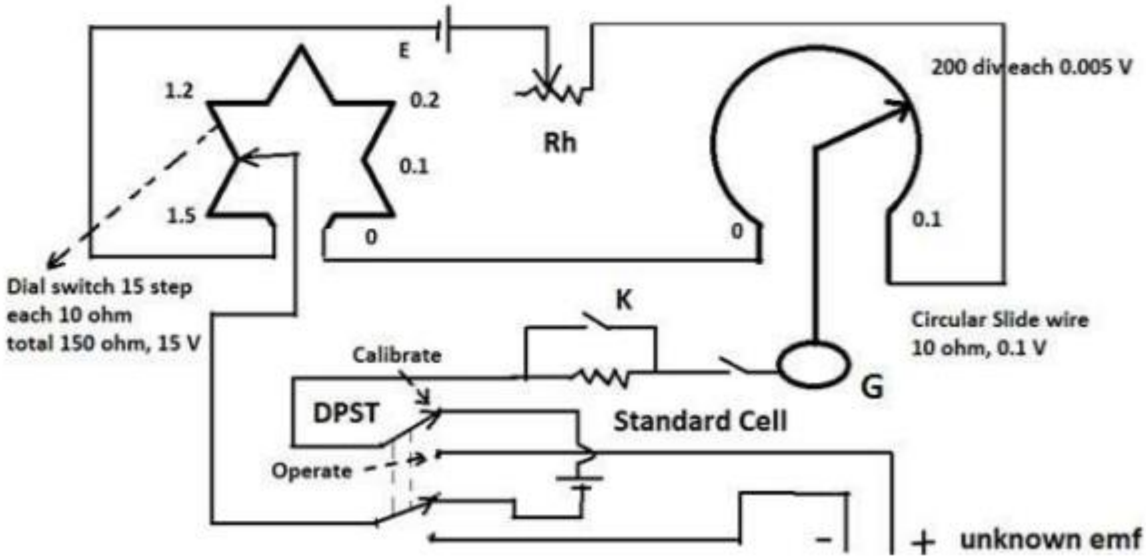
Cell Voltage=$\frac{R_2}{R_1}V_S$ =Working current * AX

6. The supply voltage VS is then adjusted until the galvanometer shows zero, indicating the voltage on R2 is equal to the standard cell voltage.
7. As resistance of wire is uniform & proportional to length, working current i.e. volts/cm is measured.

MEASUREMENT OF UNKNOWN VOLTAGE SOURCE

8. Now Rheostat will not be varied.
9. Now switch ‘S’ is placed at operate position
10. An unknown DC voltage, in series with the galvanometer, is then connected to the sliding wiper, across a variable-length section R3 of the resistance wire. The wiper is moved until no current flows into or out of the source of unknown voltage, as indicated by the galvanometer in series with the unknown voltage. The voltage across the selected R3 section of wire is then equal to the unknown voltage. The final step is to calculate the unknown voltage from the fraction of the length of the resistance wire that was connected to the unknown voltage.
11. If the length of the R1 resistance wire is AB, where A is the (-) end and B is the (+) end, and the movable wiper is at point Y at a distance AY on the R3 portion of the resistance wire when the galvanometer gives a zero reading for an unknown voltage, the distance AY is measured or read from a pre-printed scale next to the resistance wire. The unknown voltage can then be calculated as V_U= working cur * AY

CROMPTON-LABORATORY D.C. POTENTIOMATER:-



CONSTRUCTION:-

Modern Lab Potentiometers use calibrated dial resistors and a small circular wire of one or more turns (instead of previously used long slide wire), thus reducing the size of instrument. In the figure, there is one dial resistor with 15 steps, each having a precision resistor of 10 Ω. Total 150 Ω & 1.5 volt.

Slide-Wire:- is of single turn having resistance of 10 Ω & 0.1 Volt. The working current is 10 mA.

So each step of dial-resistor correspond to $10*10*10^{-3}$ =0.1 volt

The slide wire is provided with 200 scale divisions with a total voltage range of 0.1 volt.

So each division=0.1/200=0.005 volt

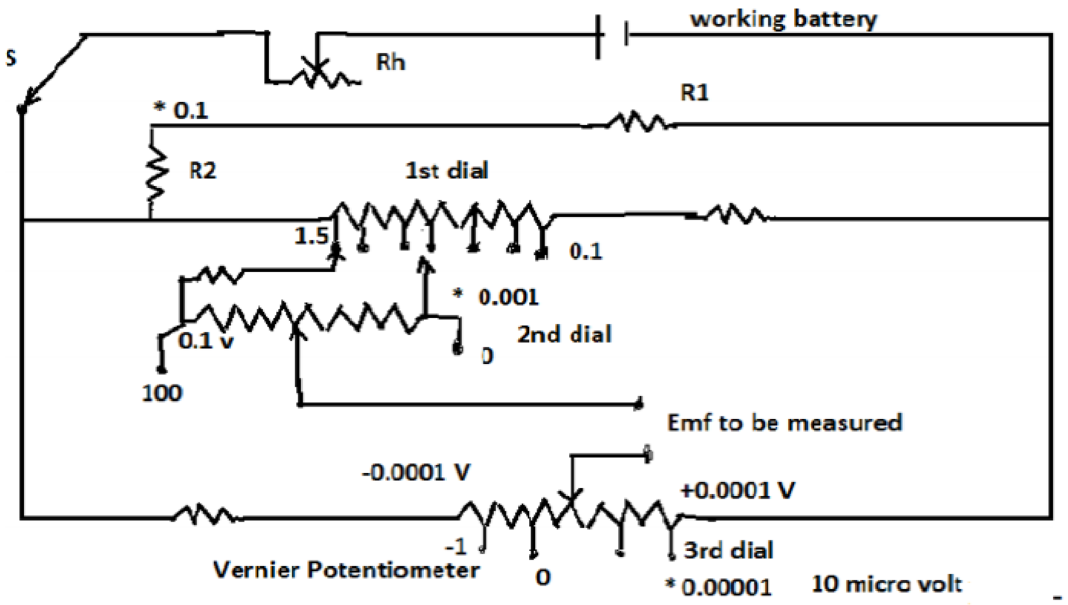
The Potentiometer is provided with a double throw switch to make connection to either the standard cell or un-known emf. To operate the Galvanometer at its maximum sensitivity, provision is made to short the protective resistance near balance condition.

STEPS TO FOLLOW TO MAKE MEASUREMENT:-

1. The combination of dial-resistor & Slide-wire is set to standard cell voltage (1.0186 volt). Dial-resistor set at 1 volt, slide- wire set at 0.0186 V.

2. Galvanometer is calibrated with switch S, connected to standard cell. Rheostat is adjusted foe zero Galvanometer deflection.
3. As the null point is approached, protective resistance is shorted to increase Galvanometer sensitivity. This completes the process of 'Standardization' of Galvanometer.
4. Now switch S is thrown to operate position to find out un-known emf. Now the potentiometer is balanced using dial- switch & slide-wire.
5. At null, the value of emf is read directly from setting of dial adjust & slide-wire.
6. Standardization is checked again.

VERNIER POTENTIOMETER: -



CONSTRUCTION:-
There are 3 measuring dials.
1 st Dial Measures upto 1.5 v in step of 0.1 v
2 nd Dial has 102 studs & read upto 0.1 V in steps of 0.001 V.
3 rd Dial has 102 studs & reads from -0.0001 v to + 0.0001 v in steps of 0.00001 v (i.e. 10 µv).
There is no Slide-wire.
The 2nd Dial shunts two of the coils of 1st Dial. The moving arm of 2nd -dial carries two arms spaced two-studs apart.
In practice, the resistance of 2nd -dial is greater than that between two studs in the main dial, so that voltage drop across 2nd -dial is greater than 0.1 v. If this is not done, voltage drop in contact resistances & leads would cause 2nd -dial voltage less than 0.1 v.
3 rd -dial is obtained from a shunt ckt which permits a true zero & a small –ve setting is obtained.
OPERATION:-
The limitations imposed on performance of ordinary potentiometers by slide-wire are eliminated in a vernier potentiometer. This instrument has two ranges.
1. Normal range of 1.6 v down to 10 µv
2. Lower range of 0.16 v to 1 µv.
The Vernier potentiometer reads to increment of 0.00001 v (10 µv) & has a readability of 1 µv on 0.1 range. If a 3rd range of * 0.01 is provided, readability becomes 0.1 µv

AC Potentiometer: A potentiometer is an instrument which measures unknown voltage by balancing it with a known voltage. The known source may be DC or AC. The working phenomenon of DC potentiometer and AC potentiometer is same. But there is one major difference between their measurements, DC potentiometer only measures the magnitude of the unknown voltage. Whereas an AC potentiometer measures both the magnitude and phase of unknown voltage by comparing it with a known reference.

There are two types of AC potentiometers:

1. Drysdale-Tinsley Potentiometer/ Polar type potentiometer
2. Gall-Tinsley Potentiometer / Coordinate type potentiometer.

Polar type Potentiometer : In such type of instruments, two separate scales are used to measure magnitude and phase angle on some reference of the unknown e.m.f. There is a provision on the scale that it could read phase angle up to 3600. It has electrodynamometer type ammeter along with DC potentiometer and phase-shifting transformer which is operated by single phase supply.

In a phase-shifting transformer, there is a combination of two ring-shaped laminated steel stators connected perpendicularly to each other as shown in the figure. One is directly connected to power supply and the other one is connected in series with variable resistance and capacitor. The function of the series components is to maintain constant AC supply in the potentiometer by doing small adjustments in it.

Between the stators, there is laminated rotor having slots and winding which supplies voltage to the slide-wire circuit of the potentiometer. When current start flowing from stators, the rotating field is developed around the rotor which induces an e.m.f. in the rotor winding.

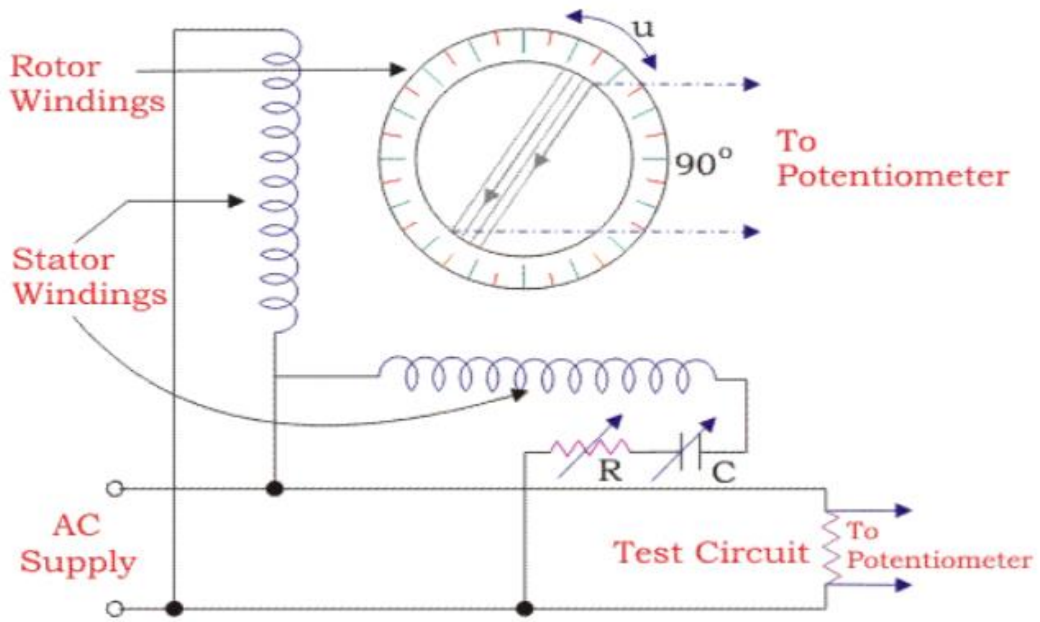


Figure Poler Type potentiometer

The phase displacement of the rotor emf is equal to rotor movement angle from its original position and it is related to the stator supply voltage. The whole arrangement of the winding is done in such a way that the magnitude of the induced emf in the rotor may change but it does not affect the phase angle and it can be read on the scale fixed on the top of the instrument.

The induced emf in rotor winding by stator winding 1 can be expressed as

$$E_1 = K\ I\ sin\omega t\ cos\ \emptyset \ldots\ldots\ldots\ldots (1)$$

The induced emf in the rotor winding by the stator winding 2,

$$E_2 = K\ I\ sin(\omega t + 90^o)\ cos(\varnothing + 90^o)$$
$$= -K\ I\ cos\omega t\ sin\varnothing \ldots\ldots\ldots\ldots (2)$$

From equation (1) and (2), we get

$$E = K\ I\ (sin\omega t\ cos\varnothing - cos\omega t\ sin\varnothing)$$

Therefore, resultant induced emf in the rotor winding due to two stator winding

$$E = K\ Isin\ (\omega t - \varnothing)$$

Where, Ø gives the phase angle.

Coordinate type Potentiometer : In coordinate AC potentiometer, two separate potentiometers are caged in one circuit as shown in the figure. The first one is named as the in-phase potentiometer which is used to measure the in-phase factor of an unknown e.m.f. and the other one is named as quadrature potentiometer which measures quadrature part of the unknown e.m.f. the sliding contact AA' in the in-phase potentiometer and BB' in quadrature potentiometer are used for obtaining the desired current in the circuit. By adjusting rheostat R and R' and sliding contacts, the current in the quadrature potentiometer becomes equal to the current in the in-phase potentiometer and a variable galvanometer shows the null value. S1 and S2 are signs changing switches which are used to change the polarity of the test voltage if it is required for balancing the potentiometer. There are two step-down transformers T1 and T2 which isolate potentiometer from the line and give an earthed screens protection between the winding. It also supplies 6 volts to potentiometers.

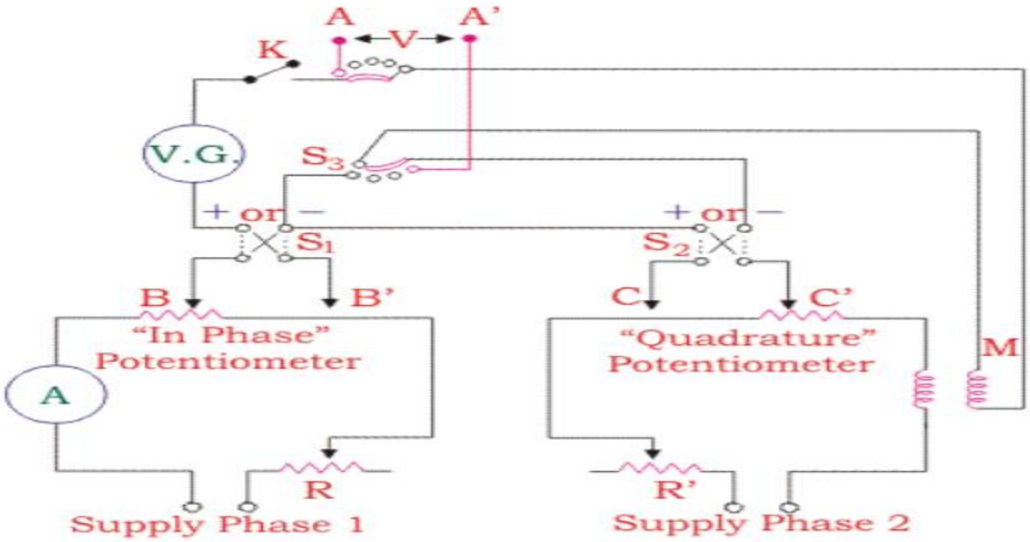


Figure Coordinate AC potentiometer

Now to measure unknown e.m.f. its terminals are connected across sliding contacts AA' using selector switch S3. By doing some adjustments in sliding contacts and rheostat, the whole circuit gets balanced and galvanometer reads zero at the balanced condition. Now the in-phase component VA of the unknown e.m.f. is obtained from the in-phase potentiometer and quadrature component VB is obtained from quadrature potentiometer.

Thus, the resultant voltage of the coordinate AC potentiometer is

$$V = (V_A^2 + V_B^2)^{1/2}$$

And the phase angle is given by

$$\varnothing = tan^{-1}(V_B/V_A)$$