Department of Mechanical Engineering

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INTRODUCTION TO LVDT and RVDT

INSTRUMENTATION AND CONTROL

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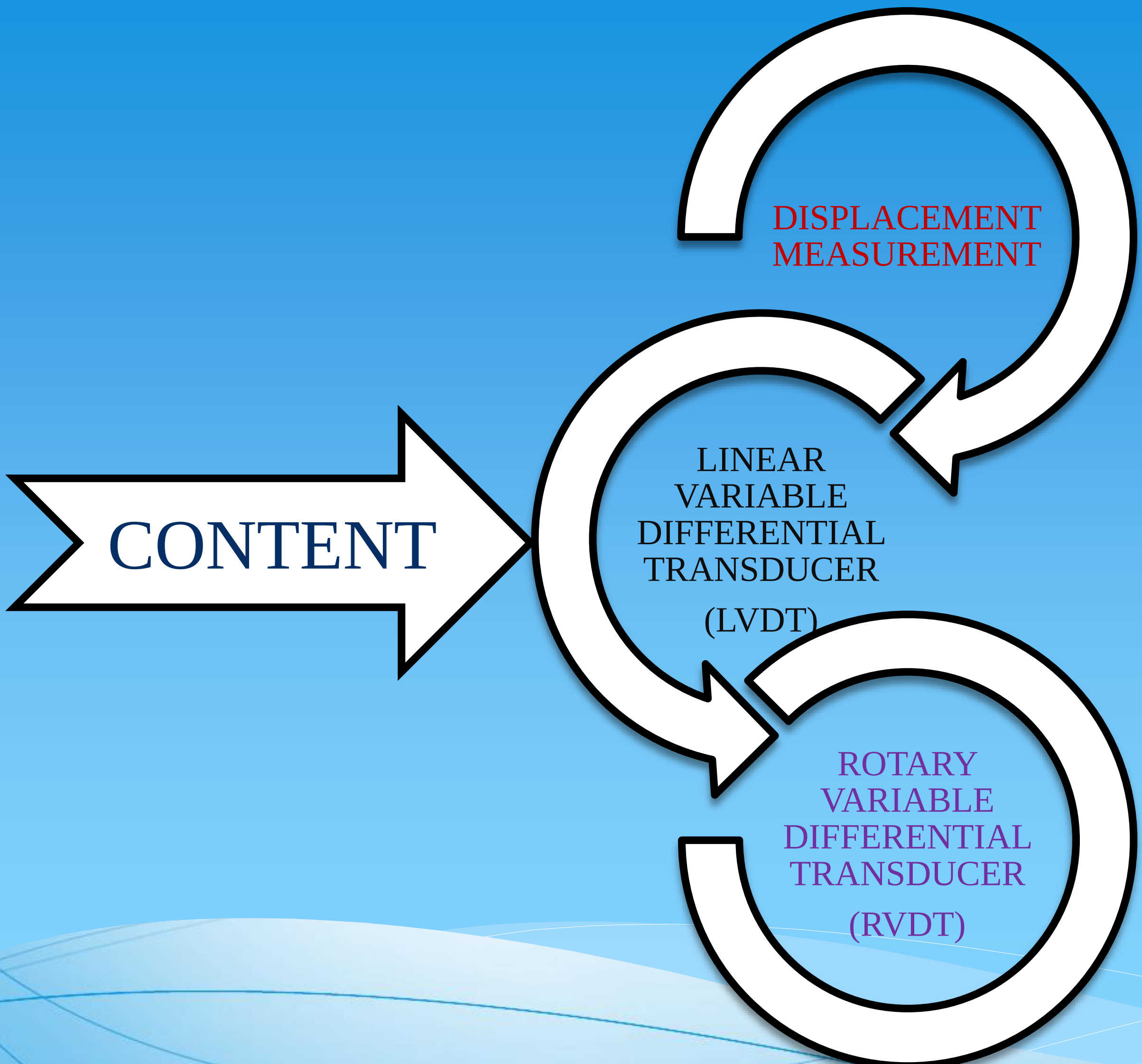
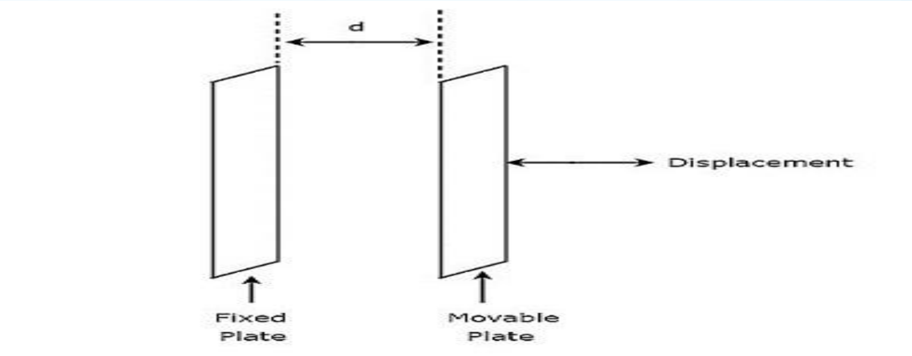

CONTENT
DISPLACEMENT MEASUREMENT
LINEAR VARIABLE DIFFERENTIAL TRANSDUCER
(LVDT)
ROTARY VARIABLE DIFFERENTIAL TRANSDUCER
(RVDT)

Displacement Measurement:

Displacement: A displacement transducer, or DT, is an electrical transducer used in measuring linear position. Linear displacement is the movement of an object in one direction along a single axis. Measuring displacement indicates the direction of motion.

Displacement is the distance between an object's initial position and its final position and is usually measured or defined along a straight line. Since this is a calculation that measures distance, the standard unit is the meter (m).

A displacement sensor (displacement gauge) is primarily used to measure the range of where an object has to travel and in relation to a reference position. Displacement sensors have multiple uses. Its primary use is for dimension measurement to figure out an object's width, height, and thickness.



Displacement is a basic variable whose value is measured and involved in many other physical parameters such as velocity, force, acceleration, torque and so on. The transducer used for the measurement of displacement can be classified in many ways. One of the most common classification is given below.

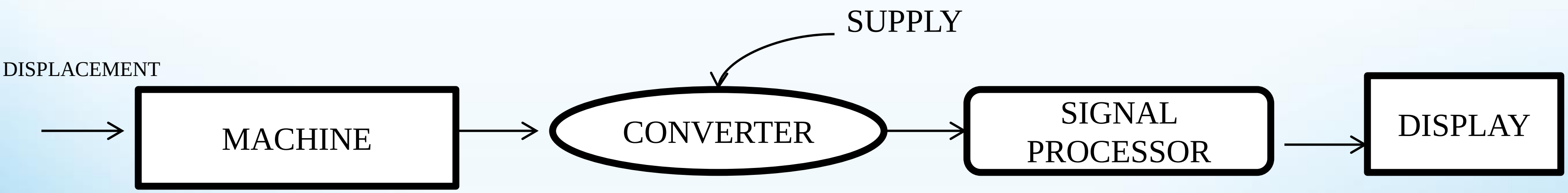
- Mechanical
- Pneumatic
- Electrical
- Optical

In order to obtain an electrical output, a mixture of two or more methods is also used. For example, optical methods using photo-detectors present the output as an electrical quantity like voltage, current and so on. Thus, the combined mechanical and optical method is desired.

Measurements can be made in the direct and indirect way. In direct method, the displacement is measured directly. But indirect methods are mostly used as the associated variables like force, acceleration, torque, velocity and so on can be obtained.

In electrical conversion method, the displacement is converted to an electrical quantity like voltage or current. This value is then recorded or displayed on a screen.

A basic displacement scheme is shown in the figure below.



Displacement Transducer

Some of the most commonly used methods are listed below. Though some of these methods can be used for the measurement of other physical quantities, the electrical signals derived from such transducers always depend on a displacement parameter.

- Linear Potentiometer Transducer
- Linear Motion Variable Inductance Transducer
- Proximity Inductance Transducer
- Capacitive Transducer
- Linear Voltage Differential Transformer (LVDT)
- Piezoelectric Transducer
- Photo-Electric Transducers

L.V.D.T

AN LVDT (LINEAR VARIABLE DIFFERENTIAL TRANSFORMER): is an electromechanical sensor used to convert mechanical motion or vibrations, specifically rectilinear motion, into a variable electrical current, voltage or electric signals, and the reverse.

LVDT or Linear Variable Differential Transformer is a robust, complete linear arrangement transducer and naturally frictionless. They have an endless life cycle when it is used properly. Because AC controlled LVDT does not include any kind of electronics, they intended to work at very low temperatures otherwise up to 650 °C (1200 °F) in insensitive environments.

The applications of LVDTs mainly include automation, power turbines, aircraft, hydraulics, nuclear reactors, satellites, and many more.

THE DIFFERENT TYPES OF LVDTS ARE AS FOLLOWS:

- ✓ Captive Armature LVDT
- ✓ Unguided Armatures
- ✓ Force Extended Armatures

Captive Armature LVDT:

These types of LVDTs are superior for lengthy working series. This LVDTs help to prevent incorrect arrangement because they are directed and controlled by low resistance assemblies.

Unguided Armatures

These types of LVDTs have unlimited resolution behavior, the mechanism of this type of LVDT is a no-wear plan that doesn't control the motion of calculated data. This LVDT is connected to the sample to be calculated, fitting limply in the cylinder, involving the linear transducer's body to be held independently.

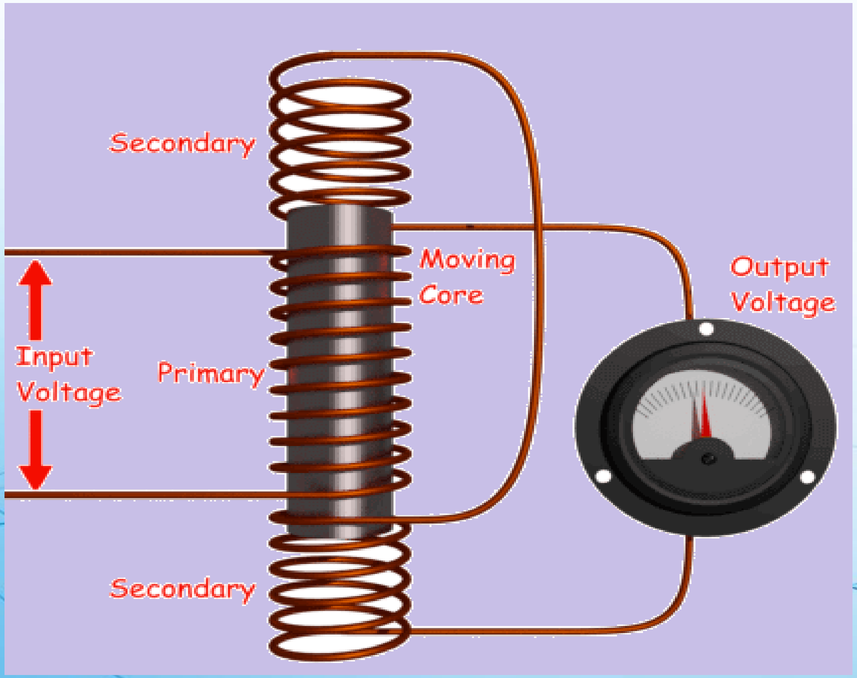
Force Extended Armatures

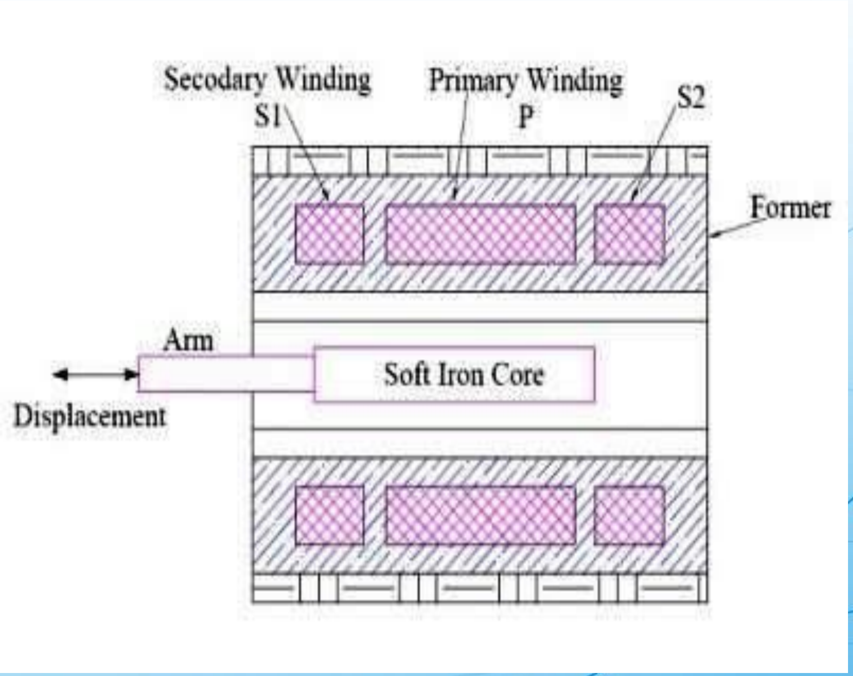
Utilize internal spring mechanisms, electric motors to move forward the armature constantly to its fullest level achievable. These armatures are employed in LVDT’s for sluggish moving applications. These devices don’t need any connection between the armature and specimen.

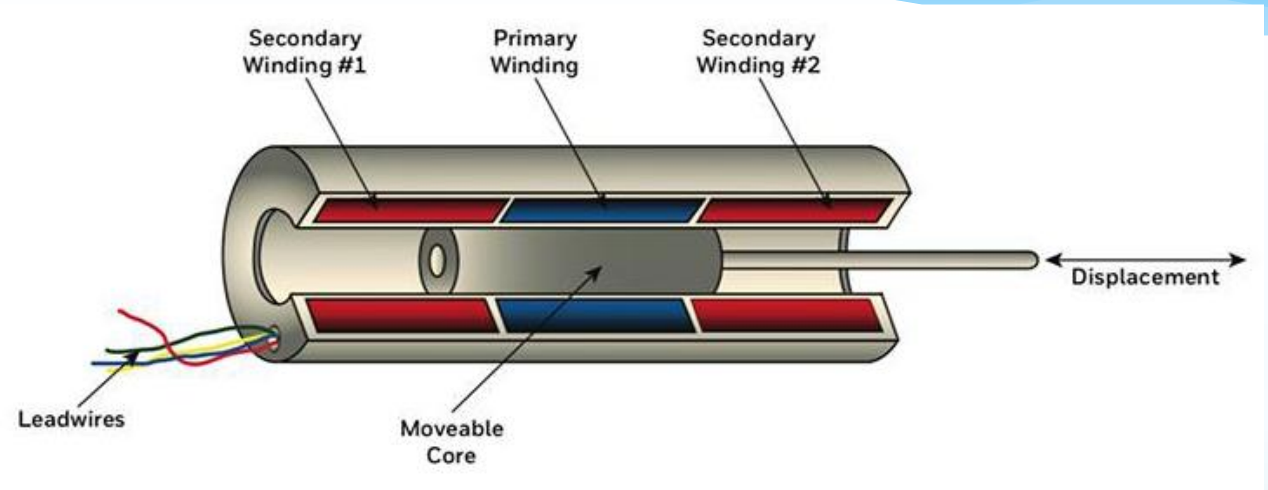
Linear Variable Displacement Transducers are usually used in current machining tools, robotics, or motion control, avionics, and automated. The choice of an applicable kind of LVDT can be measured using some specifications

LVDT CONSTRUCTION:

LVDT consists of one primary winding P and two secondary windings S1 & S2 mounted on a cylindrical former. Both the secondary windings (S1 & S2) has an equal number of turns and placed identically on either side of the primary winding in such a way that the net output will be the difference of the voltage of both secondary windings.







There is a movable soft iron core placed inside the former. Hydrogen annealing is done on Iron core to reduce harmonics, residual voltage of core and thus provides high sensitivity. The movable core also is laminated in order to reduce the eddy current losses. The displacement to be measured is attached to this movable soft iron core. LVDT is placed inside the stainless steel housing because it will provide electrostatic and electromagnetic shielding.

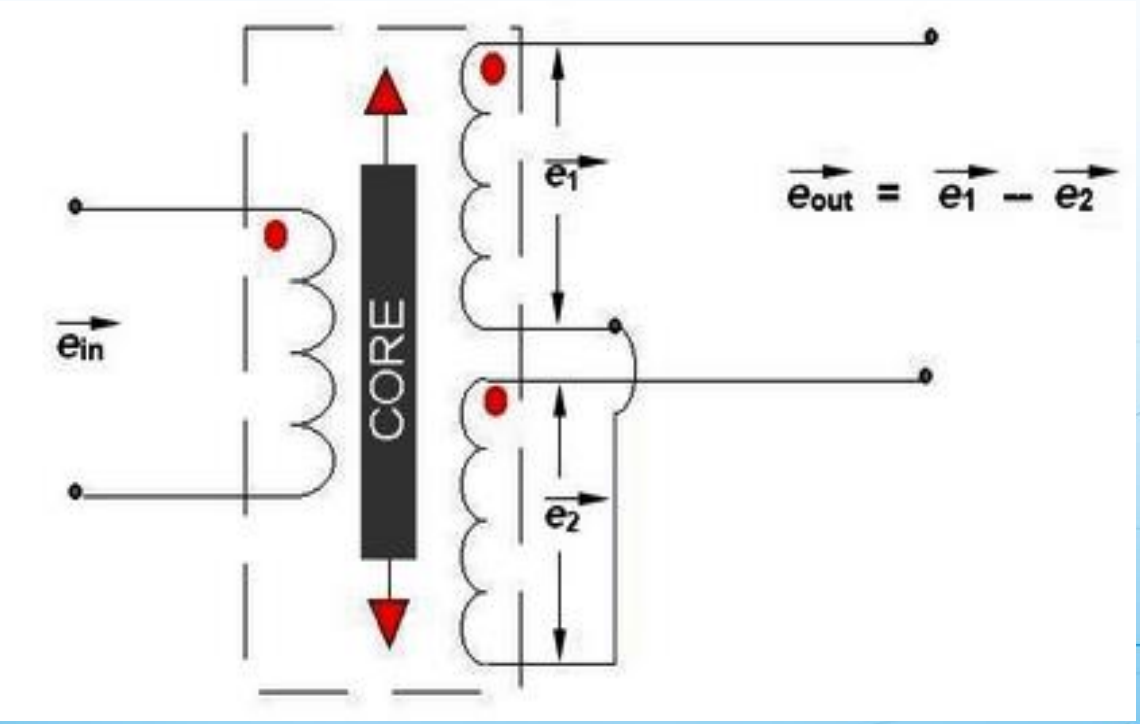
LVDT WORKING PRINCIPLE: The working principle of LVDT is based on the mutual induction principle. When AC excitation of 5-15 V at a frequency of 50-400Hz is applied to the primary winding, then a magnetic field is produced.

This magnetic field induces a mutual current in secondary windings. Due to this, the induced voltages in secondary windings (S1 & S2) are E1 & E2 respectively.

Since both the secondary windings are connected in series opposition, So the net output voltage will be the difference of both induced voltages (E1 & E2) in secondary windings.

Hence Differential Output of LVDT will be:

E0 = E1 – E2



WORKING OF LVDT:

Now three cases arise according to the locations of core which explains the working of LVDT are discussed below as,

CASE I

When the core is at null position (for no displacement)
When the core is at null position then the flux linking with both the secondary windings is equal so the induced emf is equal in both the windings. So for no displacement the value of output e_{out} is zero as e_1 and e_2 both are equal.

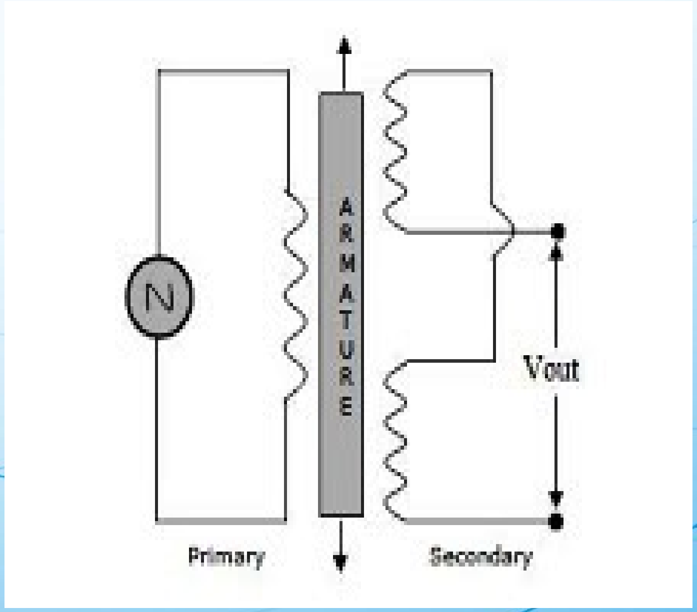
Hence the Net differential output voltage

E0 = E1 – E2

will be zero

(E0 = E1 – E2 = 0).

It shows that no displacement of the core.



CASE II

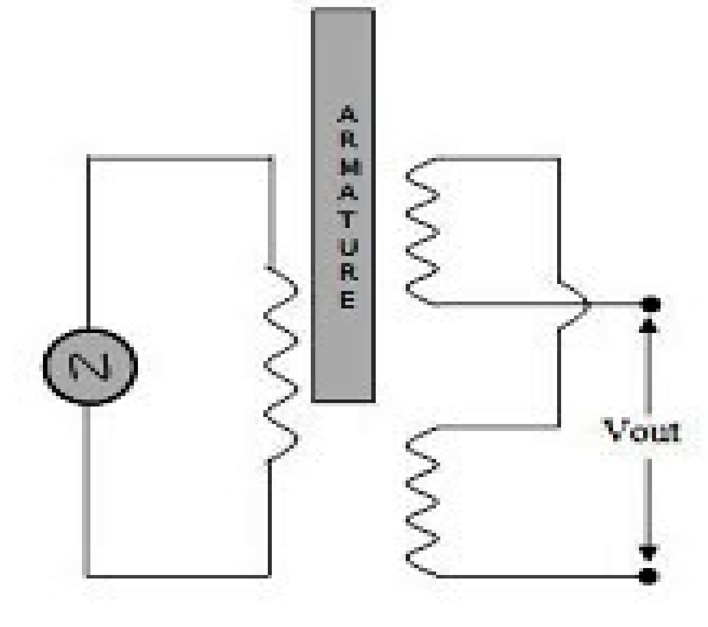
When the core is moved to upward of null position (For displacement to the upward of reference point). In the this case the flux linking with secondary winding S_1 is more as compared to flux linking with S_2.

Hence **E1>E2** and

Net differential output voltage

E0 = E1 – E2 will be positive.

This means the output voltage E0 will be in phase with the primary voltage.



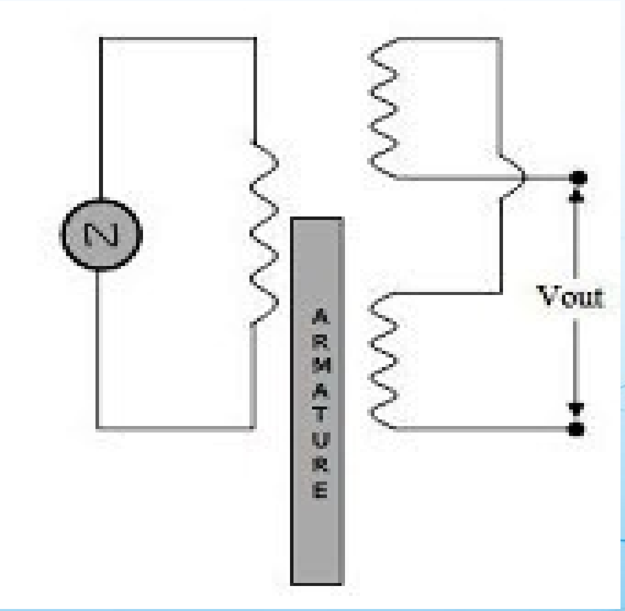
CASE III

When the core is moved to downward of Null position (for displacement to the downward of the reference point). In this case magnitude of e_2 will be more as that of e_1..

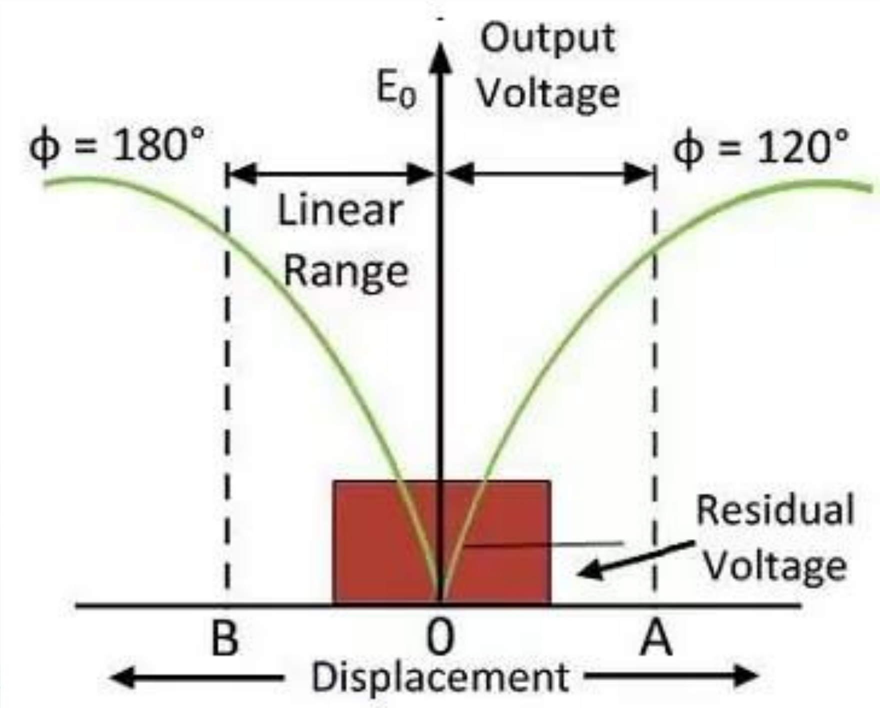
Hence **E2>E1** and Net differential output voltage

E0 = E1 – E2 will be negative.

This means the output voltage **E0** will be in phase opposition (**180** degrees out of phase) with the primary voltage.



The Graph of variation of output with respect to its position is shown in the below figure.



AC Output of Conventional LVDT Versus Core Displacement

CONCLUSIONS FROM ALL THREE CASES :

1. The direction of the movement of an object can be identified with the help of the differential output voltage of LVDT. If the output voltage E0 is positive then this means an object is moving towards Left from the Null position.

2. Similarly, If the output voltage E0 is negative then this means the object is moving towards the Right of the Null position.

3. The amount or magnitude of displacement is proportional to the differential output of LVDT. The more the output voltage, the more will be the displacement of the object.

4. If we take the core out of the former then the net differential the output of LVDT will be zero.

5. In fact corresponding to both the cases, whether the core is moving either Left or Right to the Null position. Then the output voltage will be increased linearly up to 5mm from the Null position and after 5 mm output E0 will be non-linear.

ADVANTAGES:

1. The measurement of the displacement range of LVDT is very high, and it ranges from 1.25 mm -250 mm.

2. The LVDT output is very high, and it doesn’t require any extension. It owns a high compassion which is normally about 40V/mm.

3. When the core travels within a hollow former consequently there is no failure of displacement input while frictional loss so it makes an LVDT as a very precise device.

4. LVDT demonstrates a small hysteresis and thus repetition is exceptional in all situations.

5. The power consumption of the LVDT is very low which is about 1W as evaluated by another type of transducers.

6. LVDT changes the linear dislocation into an electrical voltage which is simple to progress.

DISADVANTAGES:

1. LVDT gets damaged by temperature as well as vibrations.

2. LVDT is responsive to move away from magnetic fields, thus it constantly needs a system to keep them from drift magnetic fields.

LVDT APPLICATIONS:

1. The applications of the LVDT transducer mainly include where dislocations to be calculated that are ranging from a division of mm to only some cms.

2. LVDT is used to measure the weight, force and also pressure

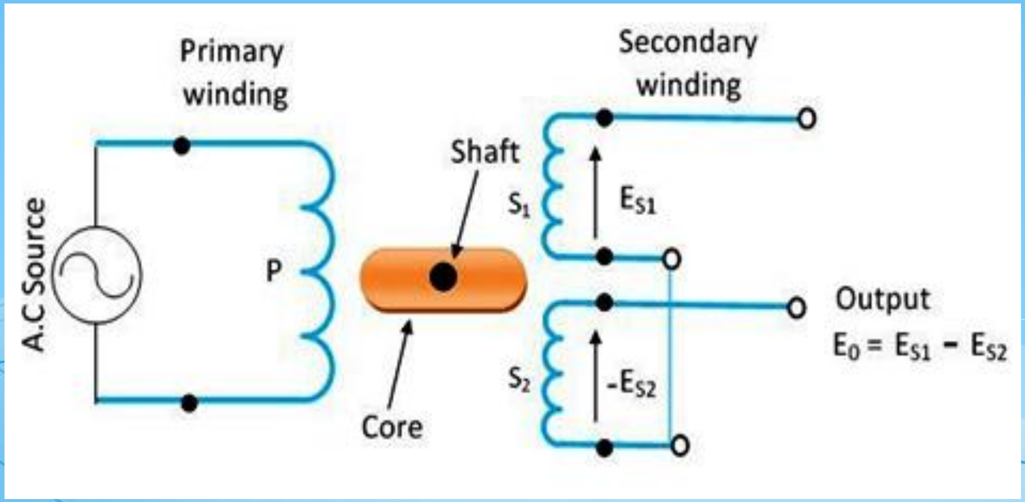
3. Some of these transducers are used to calculate the pressure and load

4. LVDT’s are mostly used in industries as well as servomechanisms.

5. Other applications like power turbines, hydraulics, automation, aircraft, and satellites

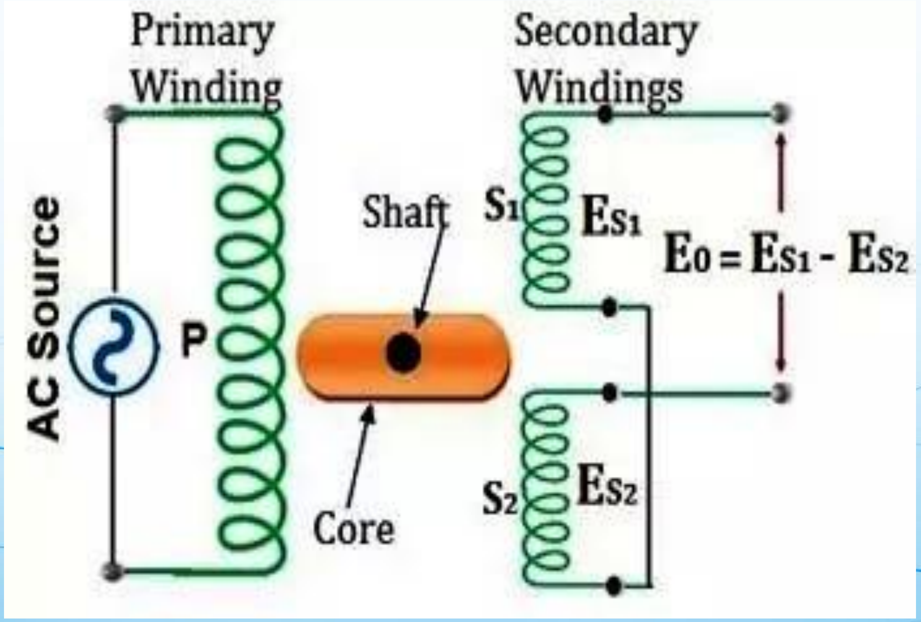
R.V.D.T

RVDT full form stands for a Rotary variable differential transformer. It is an electro-mechanical type of inductive transducer that converts angular displacement into the corresponding electrical signal. As RVDT is an AC controlled device, so there is no any electronics component inside it. It is the most widely used inductive sensor due to its high accuracy level. Since the coil of RVDT is designed to measure an angular position, so it is also known as an angular position sensor. The electrical output of RVDT is obtained by the difference in secondary voltages of the transformer, so it is called a Differential Transformer. Unlike LVDT, RVDT is also a passive transducer.



RVDT CONSTRUCTION:

The design and construction of RVDT is similar to LVDT. The only difference is the shape of the core in transformer windings. LVDT uses the soft iron core to measure the linear displacement whereas RVDT uses the Cam-shaped core (Rotating core) for measuring the angular displacement. For understanding the construction of RVDT in detail, please follow our previous article about LVDT construction.



RVDT WORKING PRINCIPLE:

The working principle of RVDT and LVDT both are the same and based on the mutual induction principle. When AC excitation of 5-15V at a frequency of 50-400 Hz is applied to the primary windings of RVDT then a magnetic field is produced inside the core. This magnetic field induces a mutual current in secondary windings. Then due to transformer action, the induced voltages in secondary windings (S1 and S2) are Es1 and Es2 respectively. Hence the net output voltage will be the difference between both the induced secondary voltages.

Hence Output will be

$$E_0 = E_{s1} - E_{s2}$$

Now according to the position of the core, there are three cases:

Case 1: When the core is at Null position.

When the core is at the null position then the flux linkage with both the secondary windings will be the same. So the induced emf **(Es1 & Es2)** in both the windings will be the same. Hence the Net differential output voltage **E0 = Es1 – Es2** will be zero **(E0 = Es1 – Es2 = 0)**. It shows that no displacement of the core.

Case 2: When the core rotates in the clockwise direction.

When the core of RVDT rotates in the clockwise direction. Then, in this case, the flux linkage with **S1** will be more as compared to **S2.** This means the emf induced in **S1** will be more than induced emf in **S2.**

Hence **Es1>Es2** and Net differential output voltage

E0 = Es1 – Es2 will be positive.

This means the output voltage E0 will be in phase with the primary voltage.

Case 3: When the core rotates in the anti-clockwise direction.

When the core of RVDT rotates in the anti-clockwise direction. Then, in this case, the flux linkage with S2 will be more as compared to S1. This means the emf induced in S2 will be more than induced emf in S1.

Hence **Es2>Es1** and Net differential output voltage **E0 = Es1 – Es2** will be negative.

This means the output voltage E0 will be in phase opposition (180 degrees out of phase) with the primary voltage.

Advantages of RVDT:

1. Following are the main advantages of RVDT:
2. High Accuracy.
3. Compact and strong construction.
4. The consistency of RVDT is high.
5. Long life span.
6. Very high Resolution.
7. Low cost.
8. High durability
9. Linearity is excellent.
10. The performance is repeatable.
11. Easy to handle

Disadvantages of RVDT

1. The disadvantages of RVDT mainly include the following.
2. Since the output of RVDT is linear (about +40 degrees or -40 degrees), So it restricts its usability.
3. The contact among the measuring exteriors as well as the nozzle is not possible for all time.

Applications of RVDT:

RVDT is most commonly is used as a sensor nowadays, also it doesn't experience any functional problem due to its contactless structure. Hence the main applications of RVDT include the following.

1. Actuators for controlling flight as well as engine.
2. Fuel valve as well as hydraulics.
3. Brake with a cable system.
4. Modern machine tools.
5. Nose wheel steering systems.
6. Weapon and Torpedo system.
7. Engine fuel control system
8. Aircraft and avionics.
9. Engines bleed air systems.
10. Robotics.

POTENTIOMETERS

Potentiometers:-an instrument for measuring an electromotive force by balancing it against the potential difference produced by passing a known current through a known variable resistance.

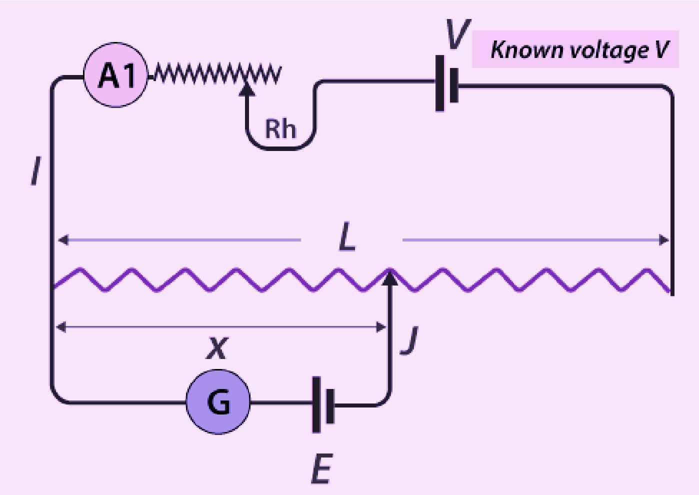
A **potentiometer** is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider. If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat.

The Potentiometer is an electric instrument that **used to measure the EMF** (electro motive force) of a given cell, the internal resistance of a cell.

Potential gradient is calculated as **K = V/L**, where V is the voltage across the potentiometer wire and the L is the length of the wire in the potentiometer. So the unit of potential gradient is volts/meter. We know that by **Ohm's law Voltage V = I R,** where I is current flowing through the circuit and R is the resistance.

POTENTIOMETER WORKING PRINCIPLE:

The potentiometer consists of L which is a long resistive wire and a battery of known EMF V whose voltage is known as driver cell voltage. Assume a primary circuit arrangement by connecting the two ends of L to the battery terminals. One end of the primary circuit is connected to the cell whose EMF E is to be measured and the other end is connected to galvanometer G. This circuit is assumed to be a secondary circuit.



The working principle depends on the potential across any portion of the wire which is directly proportional to the length of the wire that has a uniform cross-sectional area and current flow is constant. Following is the derivation of used to explain the potentiometer working principle:

$$V = I.R$$

Where,
I: current
R: total resistance
V: voltage

$$R=P.L/a$$
$$V=I.(PL/a)$$

Where,
ρ: resistivity
A: cross-sectional area
With ρ and A constant, I is constant too for a rheostat.

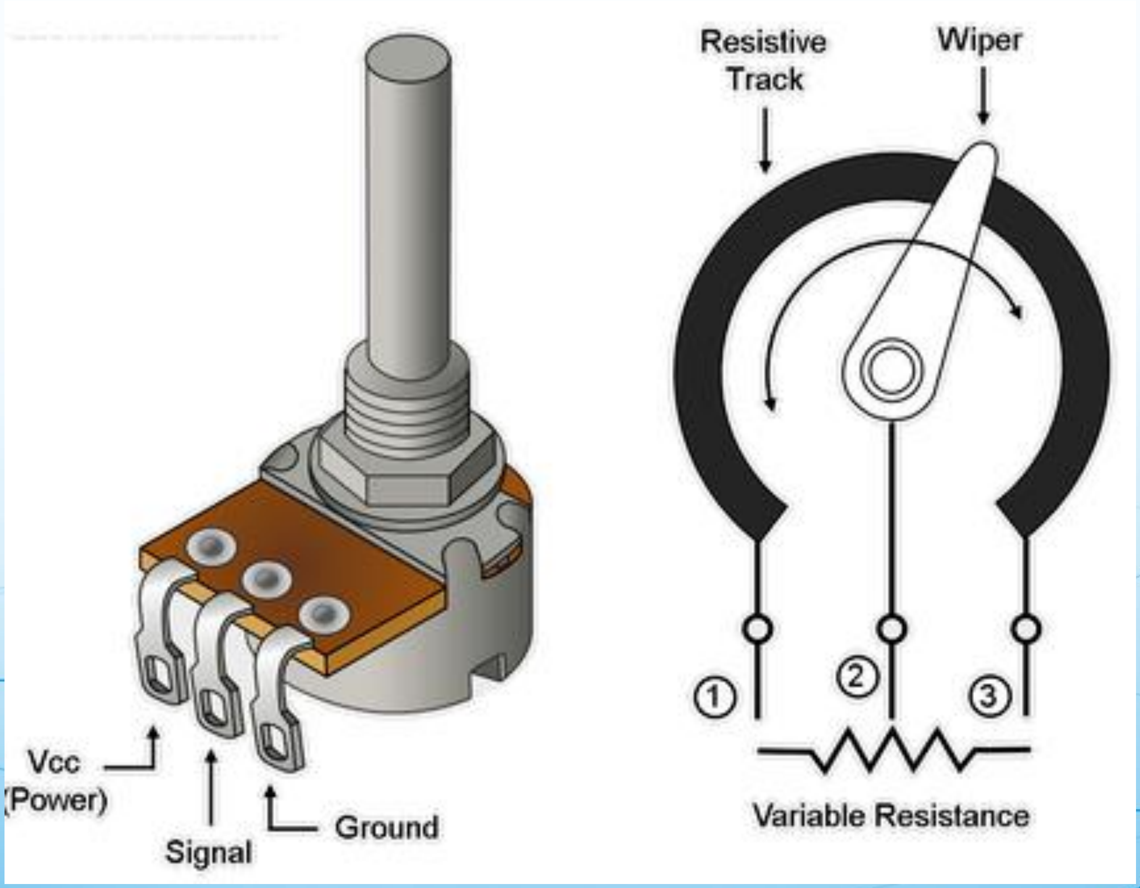
$$L\rho/A=K$$
$$V= K.L$$
$$E=L\rho x/A=Kx$$

Where,
x: length of potentiometer wire
E: cell with Lower EMF
K: constant
The galvanometer G has null detection as the potential difference is equal to zero and there is no flow of current. So, x is the length of the null point. Unknown EMF can be found by knowing x and K.

$$E = L\rho x / A = Kx$$

Since the EMF has two cells, let L_1 be the null point length of the first cell with EMF E_1 and L_2 be the null point length of the second cell with EMF E_2.

$$E_1/E_2 = L_1/L_2$$



Types of Potentiometers:

The basic construction and working principle of potentiometers are the same, they differ in one aspect that is the geometry of the moving terminal. Mostly the potentiometers what we find has a wiper that rotates over an arc shaped resistive material, there is another type of pot where the wiper slides linearly over a straight resistive strip. Based on the geometry of the resistive strip, the potentiometer can be broadly classified into two types,

There are two main types of potentiometers:

1. Rotary potentiometer
2. Linear potentiometer

Rotary potentiometer

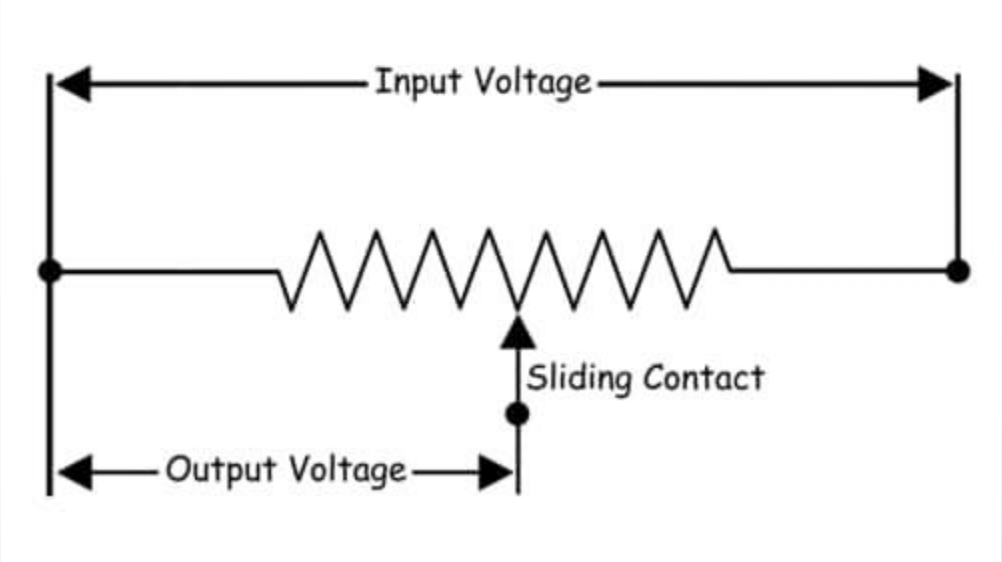
Linear potentiometer

Rotary type potentiometers: As the name suggests, this type of potentiometer has a wiper which can be rotated across the two terminals, to vary the resistance of the potentiometric. They are one of the common types of Pots. Depending upon how many times, one can turn the wiper, they are further classified into the following categories:

- ✓ **Single turn** : These pots are one of the commonly used type of pots. The wiper can take only a single turn. It usually rotates a 3/4th of the full turn.
- ✓ **Multi turn**: These pots can make multiple rotations like 5, 10 or 20. They have a wiper in the form of a spiral or helix, or a worm-gear, to make the turns. Known for their high precision, these type of Pots are used where high precision and resolution are required.
- ✓ **Dual gang**: From the name of this pot it can be assumed what it is. It is nothing but two pots with equal resistance and taper are combined on the same shaft. The two channels are set in parallel.
- ✓ **Concentric pot**: Here two pots are combined together on shafts placed ina concentric manner. The advantage of using this type of pot is that two controls can be used in one unit.
- ✓ **Servo pot**: “Servo” meaning motor pot is a motorized pot. This means its resistance can be adjusted or controlled automatically by a motor.

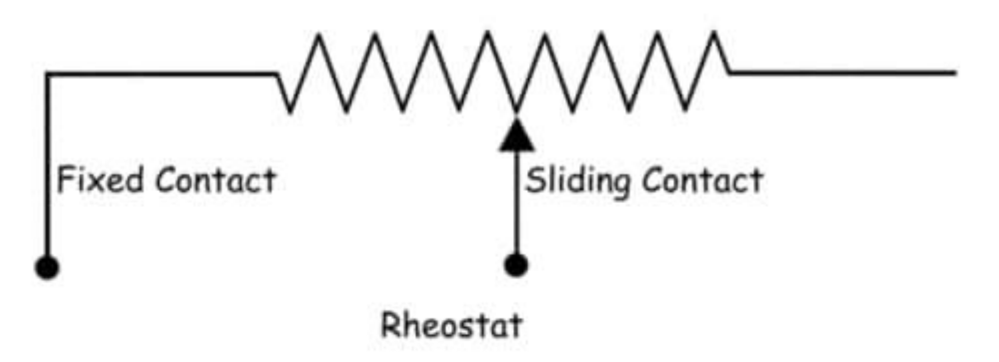
WORKING OF A POTENTIOMETER:

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.

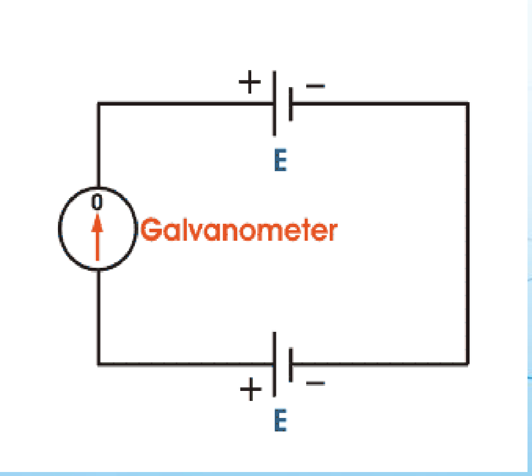


A potentiometer has the two terminals of the input source fixed to the end of the resistor. To adjust the output voltage the sliding contact gets moved along the resistor on the output side.

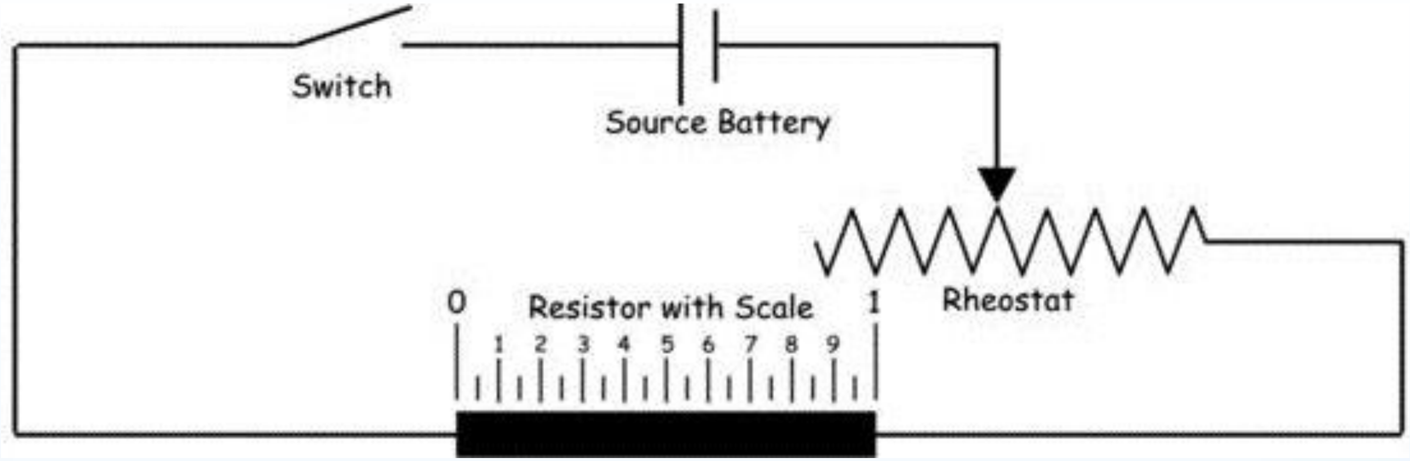
This is different to a rheostat, where here one end is fixed and the sliding terminal is connected to the circuit, as shown below.

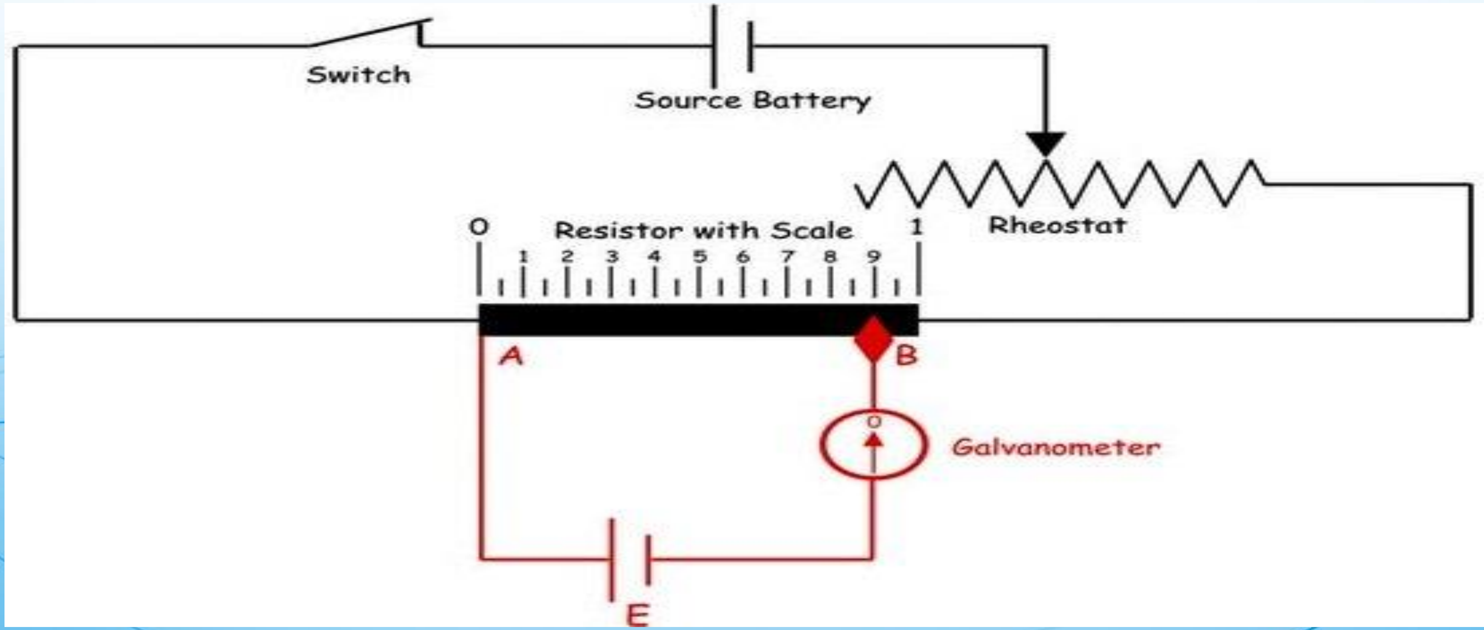


This is a very basic instrument used for comparing the emf of two cells and for calibrating ammeter, voltmeter, and watt-meter. The basic working principle of a potentiometer is quite simple. Suppose we have connected two batteries in parallel through a galvanometer. The negative battery terminals are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

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.

There are some applications of potentiometer are given below:

1. The potentiometer is used as a voltage divider in the electronic circuit.
2. The potentiometer is used in radio and television (TV) receiver for volume control, tone control and linearity control.
3. The potentiometer is used in medical equipment.
4. It is used in wood processing machine.
5. It is used in injection mold machines.
6. Potentiometers are widely used as user controls, and may control a very wide variety of equipment functions.

THANK YOU