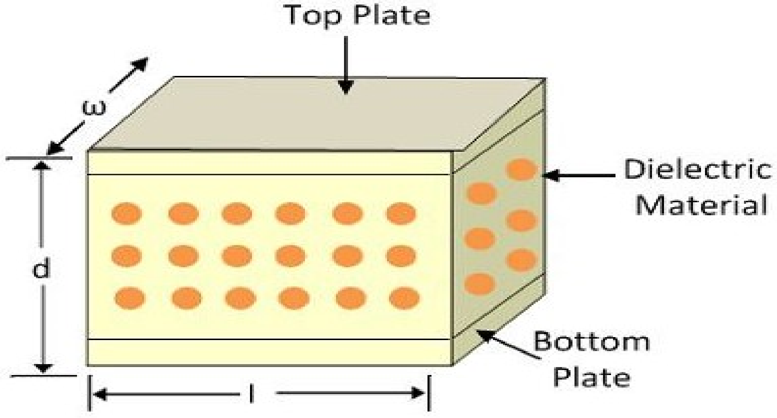
Capacitive & Inductive Transducers

Capacitive Transducer

The principle of operation of capacitive transducers is based on the familiar equation of capacitance of parallel plate capacitor

$$\boxed{C = \varepsilon_0 \varepsilon_r \frac{A}{d}}$$



Parallel Plate Capacitive Transducer

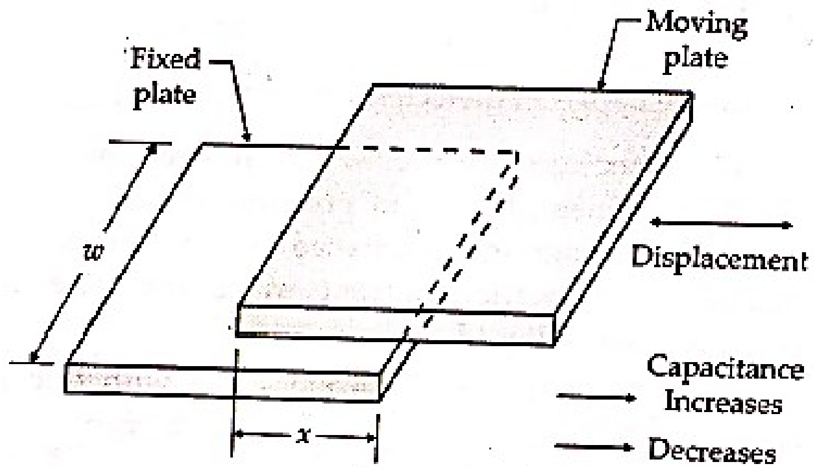
d= distance between plates
A=overlapping area
ε_0 = 8.85x10-^{12} F/m is the absolute permittivity,
ε_r =dielectric constant (ε_r =1 for air and ε_r =3 for plastics)

The capacitive transducer is work on the principle of change in capacitor which may be caused:

I. Change in overlapping Area (*A*) of capacitor plates.
II. Change in distance *d* between the plates.
III. Capacitance changes because of dielectric constant.

Transducer using the change in the Area of Plates

The capacitive transducers are used for measuring the large displacement approximately from a mm to several cms. The area of the capacitive transducer changes linearly with the capacitance and the displacement.



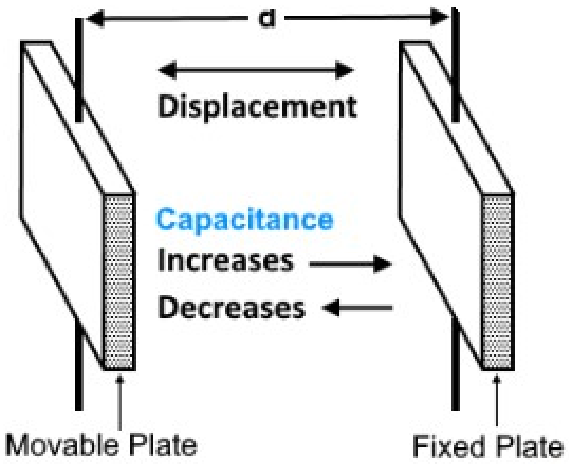
The equation below shows that the capacitance is directly proportional to the area of the plates. The capacitance changes correspondingly with the change in the position of the plates.

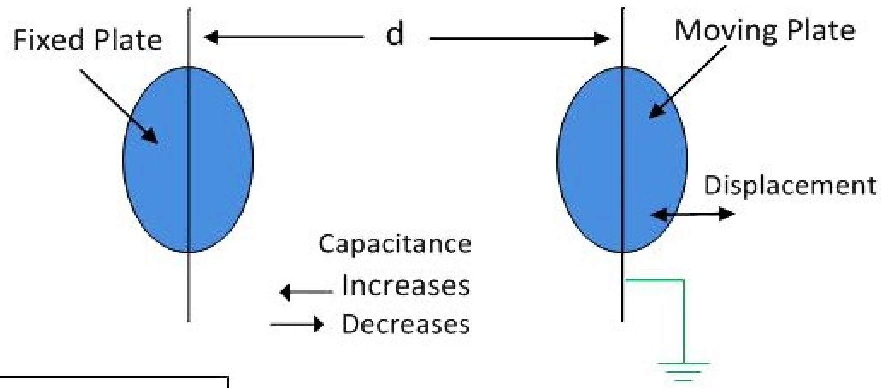
$$C = \frac{\varepsilon A}{d} = \frac{\varepsilon x \omega}{d} F$$

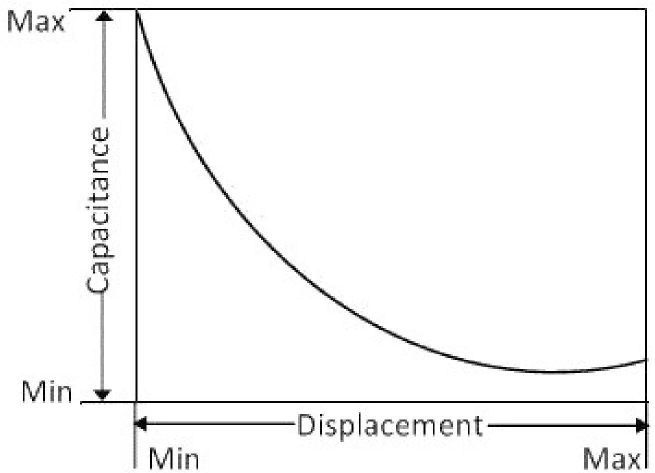
x – the length of overlapping part of plates
ω – the width of overlapping part of plates.

Transducer using the change in the distance of plates

The capacitance of the transducer is inversely proportional to the distance between the plates. The one plate of the transducer is fixed, and the other is movable. The displacement which is to be measured links to the movable plates.



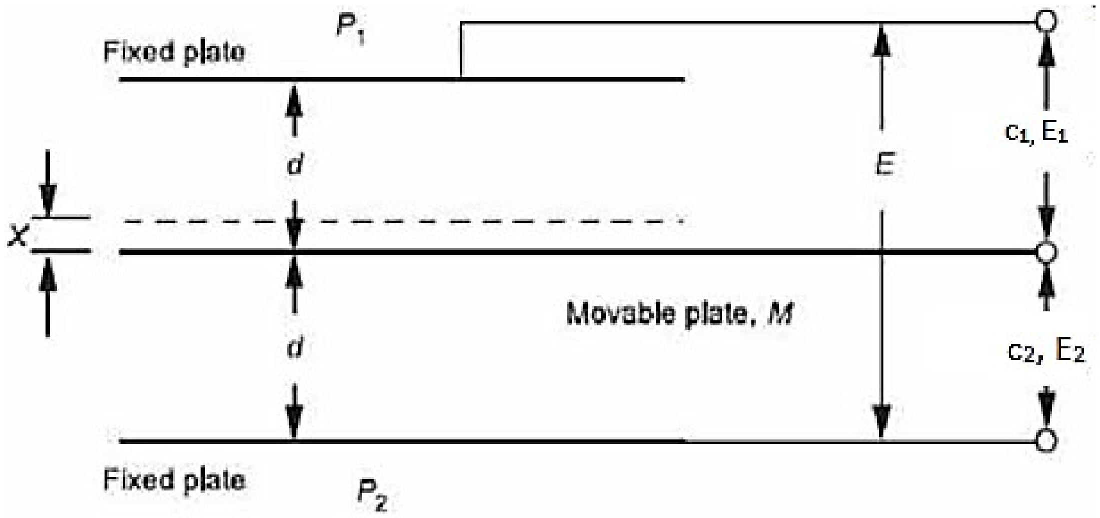




$$\boxed{C = \varepsilon_0 \varepsilon_r \frac{A}{d}}$$

Differential Arrangement of Capacitive Transducers

A linear characteristics can be achieved by using a differential arrangement for the capacitive displacement transducers.



$$\boxed{C = \varepsilon_0 \varepsilon_r \frac{A}{d}}$$

Here P 1 and P 2 are fixed plates and M is the movable plate to which the displacement to be measured is applied. Thus, two capacitors are there whose differential output is taken.

Let the capacitance of these capacitors be $C1$ and $C2$ respectively, when the plate M is midway between the two fixed plates, under this condition the capacitances $C1$ and $C2$ are equal.

When the moveable plate is not moving in either direction, initially both the capacitor having same value.

$$c_1 = \frac{\in a}{d}, c_2 = \frac{\in a}{d}$$

$$c_1 = c_2 \quad \text{then } E_1 = E_2$$

voltage across the c_1 and c_2 are $E_1 = \frac{Ec_2}{(c_1 + c_2)} = \frac{E}{2} and E_2 = \frac{Ec_1}{(c_1 + c_2)} = \frac{E}{2}$

therefore differential output, $\Delta E = E_1 - E_2 = 0$

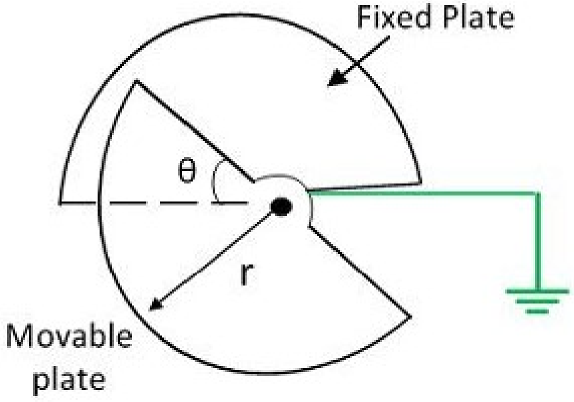
now moveable plate goes upward for a distance x, $c_1 = \frac{\in a}{d - x} and c_2 = \frac{\in a}{d + x}$

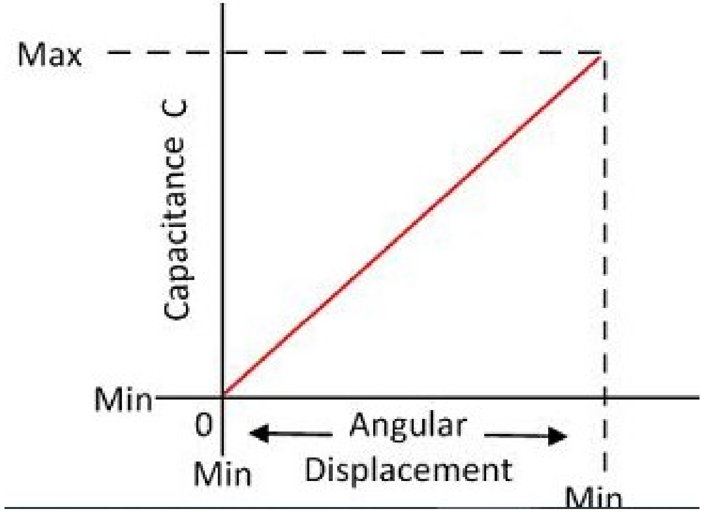
therefore, $E_1 = \frac{d - x}{2d} E$ and $E_2 = \frac{d + x}{2d} E$

differential output voltage $\Delta E = E_2 - E_1 = \frac{Ex}{d}$, so, output voltage varies linearly with displacement x. hence sensitivity,-- $s = \frac{\Delta E}{\Delta x} = \frac{E}{d}$

Capacitive Transducer for Angular Measurement

The capacitive transducer is used for measuring the angular displacement. It is measured by the movable plates shown below. One of the plates of the transducer is fixed, and the other is movable.





The capacitance between them is maximum when these plates overlap each other. The maximum value of capacitance is expressed as:

$$C_{max} = \frac{\varepsilon A}{d} = \frac{\pi \varepsilon r^2}{2d}$$

$$S = \frac{\partial C}{\partial \theta} = \frac{\varepsilon r^2}{2d}$$

The capacitance at angle θ is given expressed as: $$C = \frac{\varepsilon \theta r^2}{2d}$$

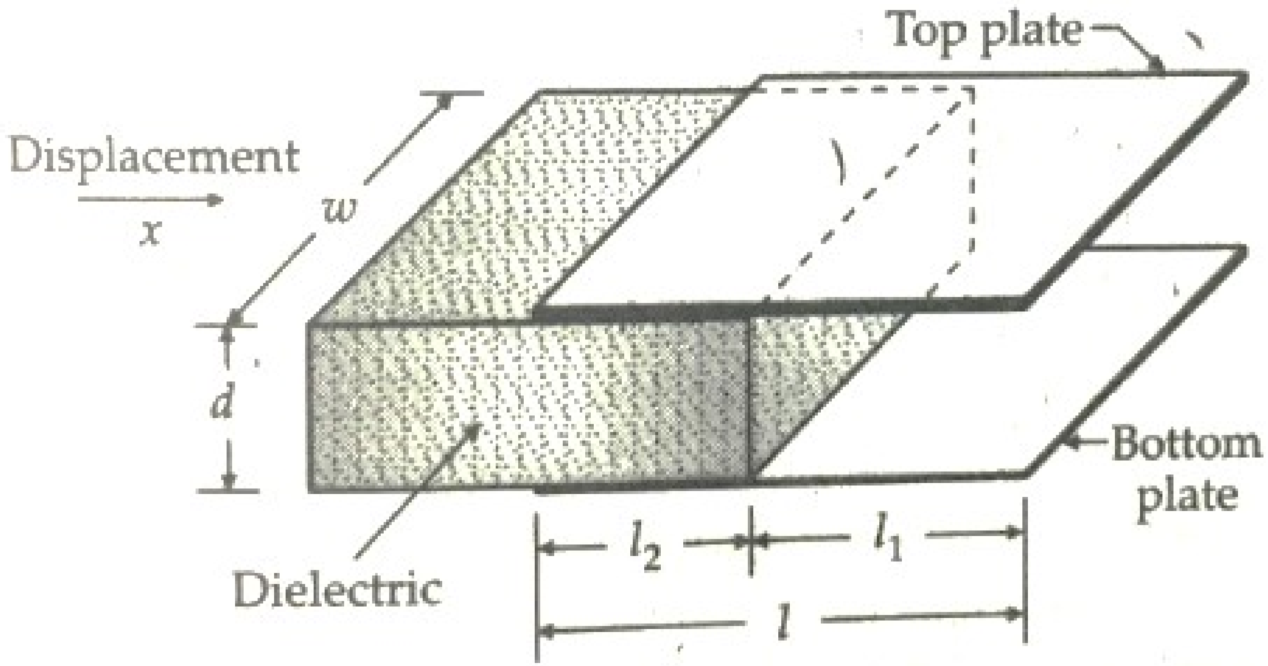
Transducer using the change in the dielectric constant

The third principle used in capacitive transducer is the variation of capacitance due to change in dielectric constant.

The initial capacitance of transducer can be given as:

$$C = \varepsilon_0 \frac{wl_1}{d} + \varepsilon_0 \varepsilon_r \frac{wl_2}{d}$$

$$= \varepsilon_0 \frac{w}{d} [l_1 + \varepsilon_r l_2]$$



Advantages, Disadvantages and Uses of Capacitive transducer

Advantages

- The sensitivity of capacitive transducer is high.
- It has good frequency response.
- It requires small power to operate.
- The loading effect is less due to high input impedance.

Disadvantages:

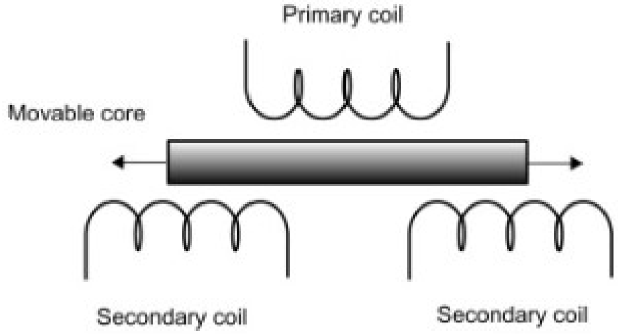
- The capacitive transducers are temperature sensitive.
- It gives non linear behavior.
- The capacitance may get changed by dust particle and moisture which produce error.

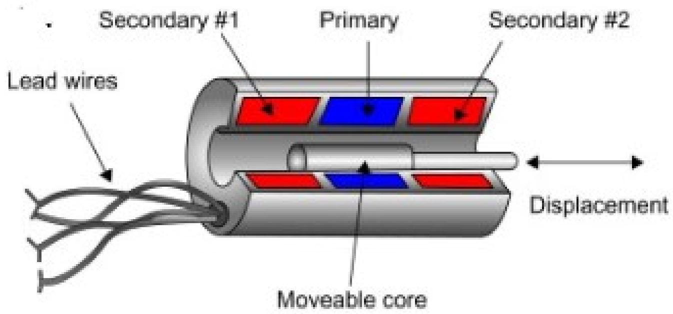
Applications:

- The capacitive transducers are used to measure humidity in gases.
- It is used to measure volume, liquid level, density etc.
- It is used for measurement of linear and angular displacement.

Linear Variable Differential Transformer (LVDT)

Linear variable differential transformers (LVDT) are used to measure displacement. An LVDT consists of a coil assembly and a core. The coil assembly is typically mounted to a stationary form, while the core is secured to the object whose position is being measured. A core can slide freely through the center of the form. The inner coil is the primary, which is excited by an AC source. Magnetic flux produced by the primary is coupled to the two secondary coils, inducing an AC voltage in each coil.



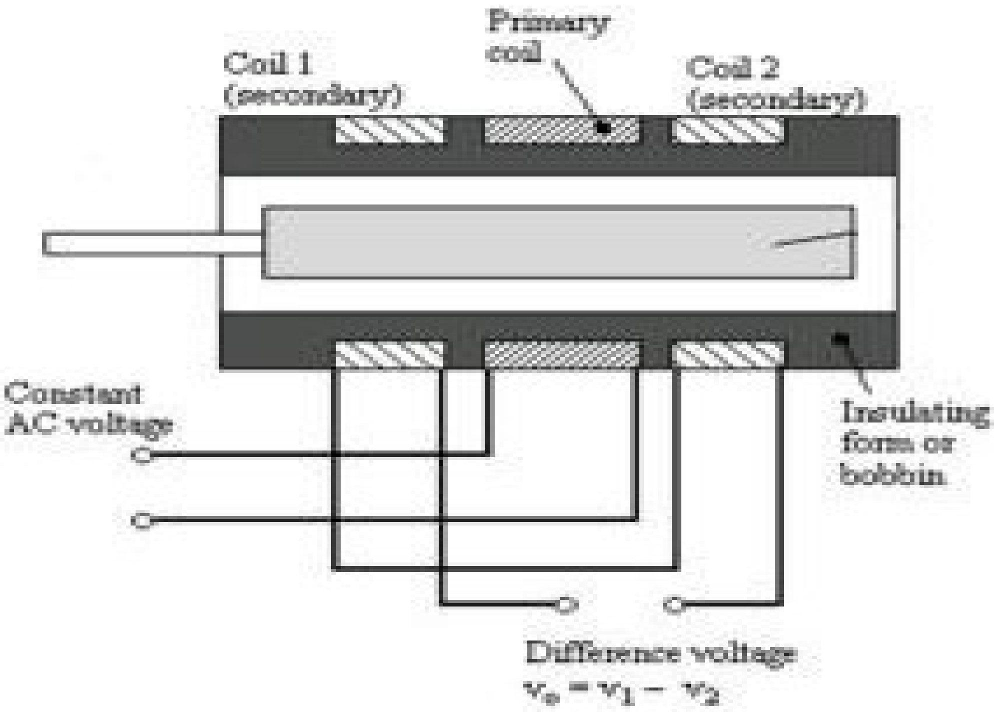


Working of LVDT

Case 1

On applying an external force which is the displacement, if the core remains in the null position itself without providing any movement then the voltage induced in both the secondary windings are equal which results in net output is equal to zero.

$$V_1 - V_2 = 0$$

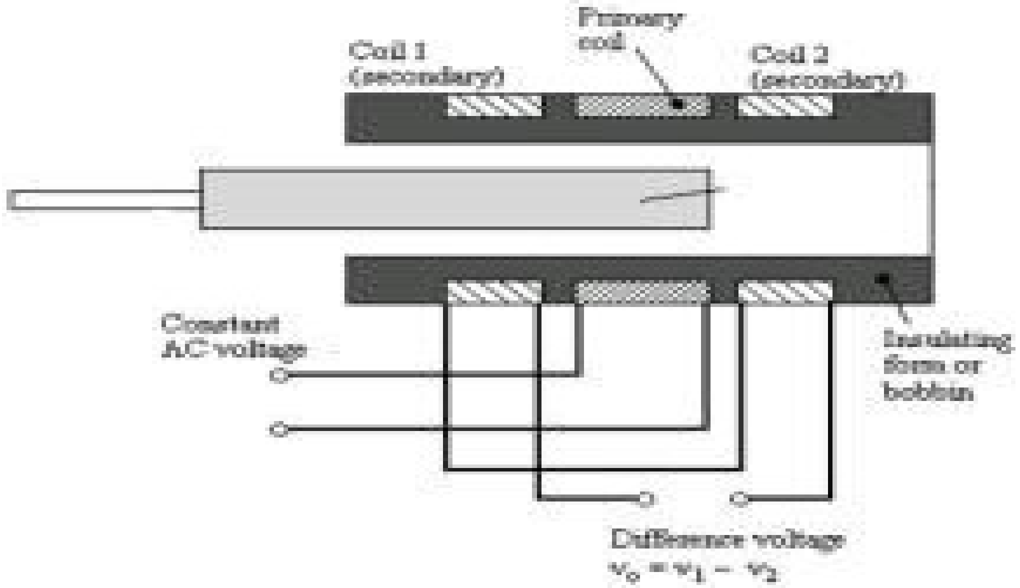


Case 2

When an external force is applied and if the steel iron core tends to move in the left hand side direction then the emf voltage induced in the secondary coil 1 is greater as compared to the emf induced in the secondary coil 2.

Therefore the net output will be:

$$V_o = V_1 - V_2$$

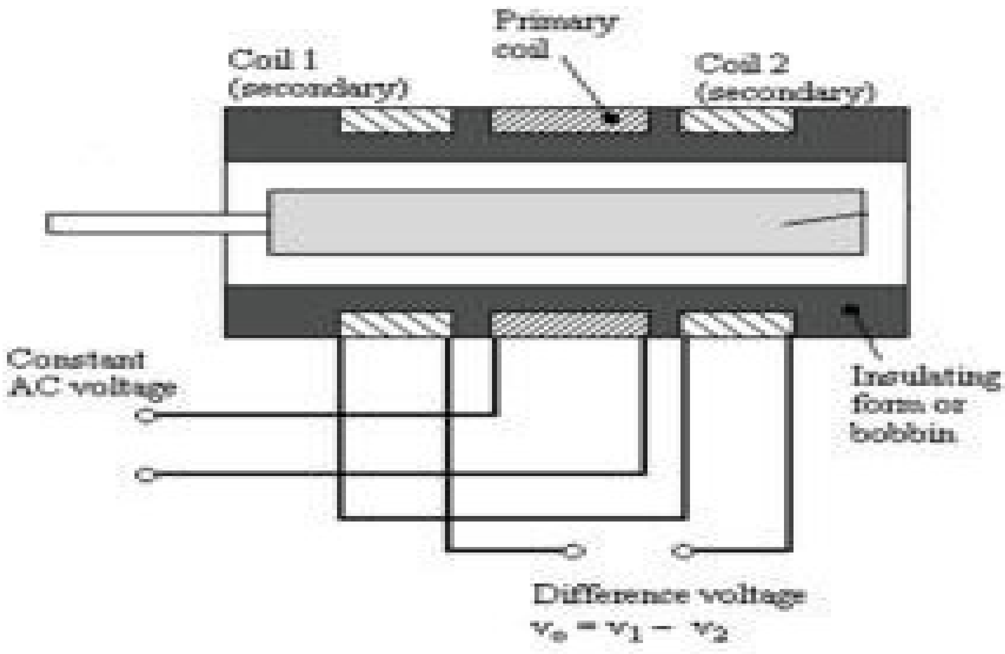


Case 3

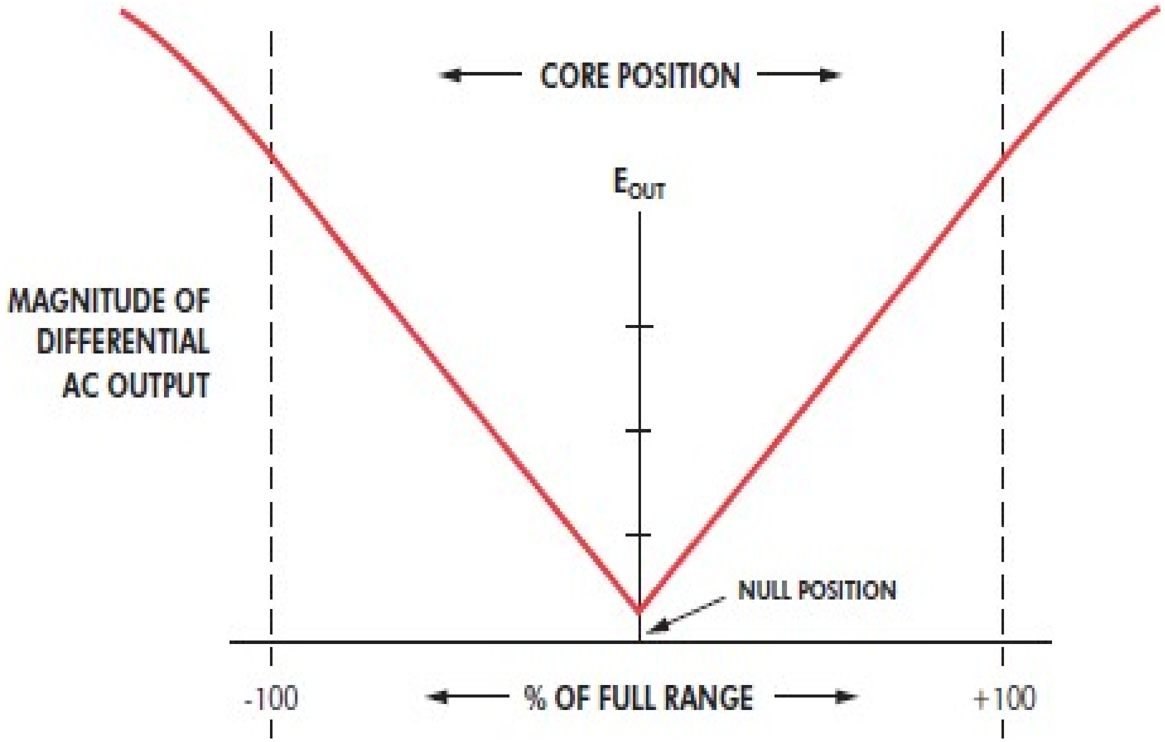
When an external force is applied and if the steel iron core moves in the right hand side direction then the emf induced in the secondary coil 2 is greater when compared to the emf voltage induced in the secondary coil 1.

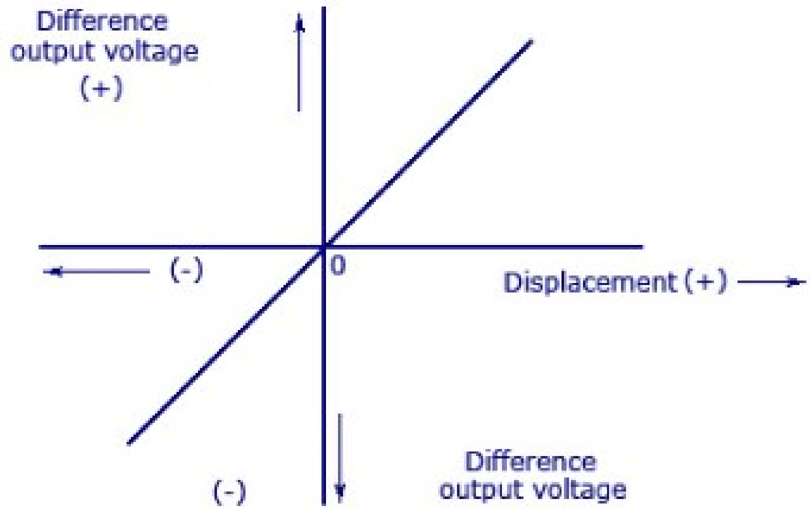
The net output voltage will be:

$$V_o = V_2 - V_1$$



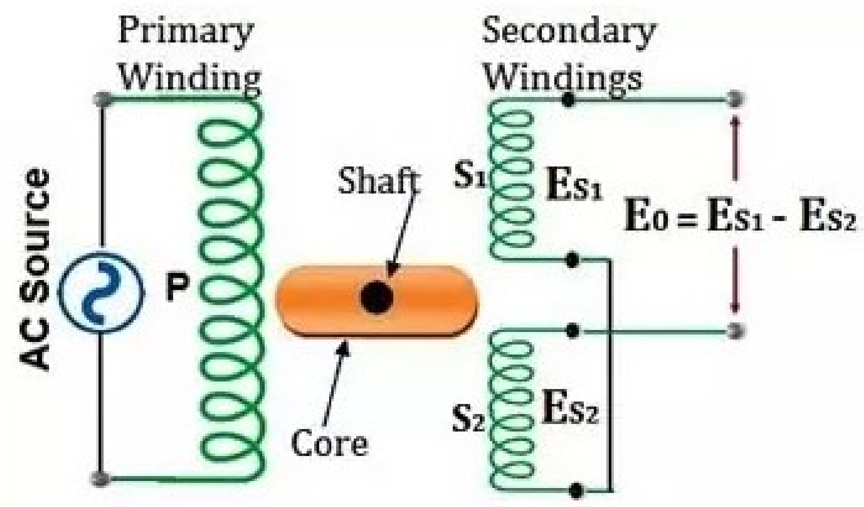
Characteristics of LVDT





Rotary Variable Differential Transformer

Rotary Variable Differential Transformer (RVDT) converts angular displacement into the corresponding electrical signal. The electrical output of RVDT is obtained by the difference in secondary voltages of the transformer, so it is called a differential transformer. like LVDT, RVDT is also a passive transducer. 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.



Working

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. **($E_o = Es_1 - Es_2 = 0$)**. 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 S_2. $E_0 = Es_1 - Es_2$ 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 S_2 will be more as compared to S_1. Hence $Es_2 > Es_1$ and Net differential output voltage $E_0 = Es_1 - Es_2$ will be negative. This means the output voltage E_0 will be in phase opposition (180 degrees out of phase) with the primary voltage.

Advantages of LVDT:

1) Infinite resolution is present in LVDT
2) High output
3) LVDT gives High sensitivity
4) Very good linearity
5) Ruggedness
6) LVDT Provides Less friction
7) Low hysteresis
8) LVDT gives Low power consumption.

Thank You