INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

LAB-MANUAL

Experiment No:-8

Study of Displacement Transducer

TRANSDUCERS AND INSTRUMENTATION

VIRTUAL LAB

Experiment No:-8

Aim: - Study of Displacement Transducers.

A) Resistive Displacement Transducer.
B) Capacitive Displacement Transducer.
C) Inductive Displacement Transducer.

Apparatus Requirement: -

- Personal computer
- Lab view 2009 Runtime engine
- Internet facility (for online experiment and for offline experiment just download the executable file from the experiment download link given in website)

Theory:-

Transducer:-

A transducer is an electronic device that converts energy from one form to another. Common examples include microphones, loudspeakers, thermometers, position and pressure sensors, and antenna.

Displacement Transducer:-

Displacement Transducers is position sensor that provides contactless **linear displacement** measurement of absolute piston position in hydraulic and pneumatic cylinders. A position or linear displacement transducer is a device whose output signal represents the distance an object has travelled from a reference point.

Linear Displacement Measurement:-

Linear displacement is movement in one direction along a single axis. A displacement measurement also indicates the direction of motion (See Figure 1).

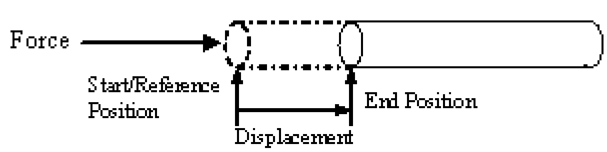


Figure 1: Linear Displacement Measurement

A linear displacement typically has units of millimeters (mm) or inches (in.) and a negative or positive direction associated with it.

Aim: - A) To study the Resistive Displacement Transducer.

Apparatus Requirement: -

- Personal computer
- Lab view 2009 Runtime engine
- Internet facility(for online experiment and for offline experiment just download the executable file from the experiment download link given in website)

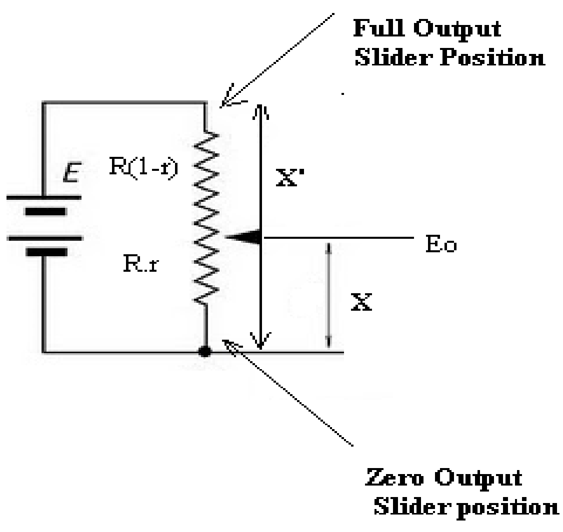
Theory:-

Resistive Displacement Transducer: -

The principle of the resistive position transducer is that the measured quantity causes a resistance change in the sensing element.
A common type of resistive displacement transducers uses a resistive element with a sliding contact linked to the object being monitored (a contact type transducer). For this purpose, a variant of the voltage divider called a potentiometer (or simply a pot) can be used.

Linear Displacement: -

A voltage divider can be equipped with a sliding contact which is linked to the object. The resistance of the potentiometer now varies linearly with displacement, as shown below:



Let the fractional displacement be defined as $r = x/x'$. *Then, the* corresponding resistance across which the output voltage is taken is $R*r$. Where R is the total resistance of the potentiometer, using the voltage divider equation, we find the output to be-

$$E = \frac{R.r}{R}.E = r.E$$

The resistive track element may be a wire-wound track or a film of conductive plastic.

Example: -

A linear resistive displacement transducer has a shaft stroke of 5 cm, total resistance of 3kΩ, and source voltage of 6V. When the slider contact is 2 cm from the zero output position, what will be the output voltage?

Solution: -

Given that x' = 5 cm, x = 2 cm, E = 6 V, the output voltage will be

E_{out} = (2/5)*6 =2.4 V

Rotary Displacement: -

If the resistive element and a contact are arranged in a rotary manner, the resistance change can be related to an angular position of the contact.

Formula Used:-

$$E = \frac{R.r}{R}.E = r.E$$

Where-
E= supply voltage
R= resistance of wire
r = fractional displacement, $r = x/x'$

Procedure: -

- Select the experiment, (Study of Displacement transducer).
- Now if you opted for Resistive Displacement Transducer,
  1) Click to ON the Switch.
  2) After switch on, the tap will open and water level in beaker starts to increases.

3) When water level reaches at desired level then a message will display. Press OK on message.
4) After that the tap will close and the outlet valve will open so that water level starts to decrease in beaker.
5) When water level is low a message will display. Press OK again.
6) According to change in water level in the beaker the graph will generate between Voltage and water level.
7) Another graph is showing the Actual versus Measured level according to Analog Scale and Digital Meter.
8) Switch OFF the supply to STOP the Experiment.
9) With the help of chart you can find the Actual versus Measured level.

Observational table: -

Sr. No.	Actual Level(mm)	Measured Level (mm)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Plot the graph between Actual Level versus Measured Level and study the graph.

Result: - The characteristics of Resistive Displacement Transducer have shown in graph.

Precaution: -

- Follow instructions carefully.
- For fetching correct value, wait until the process gets complete.
- Runtime engine should be properly installed.
- Switch OFF the supply after you completed the experiment.

Aim: - **B)** To study the Capacitive Displacement Transducer.

Apparatus Requirement: -

- Personal computer
- Lab view 2009 Runtime engine
- Internet facility

Theory: -

Capacitive Displacement Transducer: -

A typical capacitor is comprised of two parallel plates of conducting material separated by an electrical insulating material called a dielectric. The plates and the dielectric may be either flattened or rolled. The purpose of the dielectric is to help the two parallel plates maintain their stored electrical charges. The relationship between the capacitance and the size of capacitor plate, amount of plate separation, and the dielectric is given by-

$$C = K_{\varepsilon} \frac{A}{d}$$

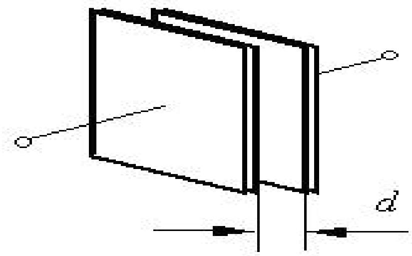
d = is the separation distance of plates (m)
C = is the capacitance (F, Farad)
K_{ε} = is the dielectric constant, $K_{\varepsilon} = \varepsilon_0 . \varepsilon_r$
ε_0 = **8.854 pF/m**, absolute permittivity of vacuum
ε_r = relative permittivity
A = is the effective (overlapping) area of capacitor plates (m2)

Material	Relative Permittivity
Vacuum	1.0
Air	1.0006
Mica	5.0
Paper	2.5
Glass	7.5
Ceramic	7500

In this type of transducers, the measured quantity causes a change in the transducers capacitance, which can be achieved by changing *d*, *A*, or Kε.

- If the displacement *x* causes the plate separation to increase by *x*, the capacitance of the sensor becomes-

$$C = K_{\varepsilon} \frac{A}{d + x}$$



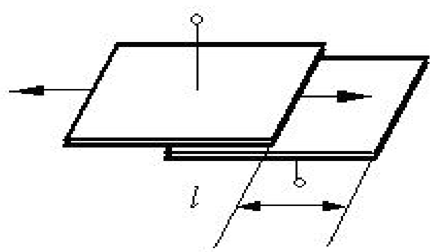
Spacing variation

Which shows the nonlinear relationship between the capacitance *C* and the displacement *x*.

- If the displacement *x* causes the effective area to decrease by *ax*, the capacitance of the sensor becomes-

$$C = \frac{K_\varepsilon}{d}(A - ax)$$

This is linear in x.



Area variation

Formula Used:-

If the displacement *x* causes the effective area to decrease by *ax*, the capacitance of the sensor becomes-

$$C = \frac{K_\varepsilon}{d}(A - ax)$$

This is linear in x.
Where -

d = is the separation distance of plates (m)
C = is the capacitance (F, Farad)
K_ε = is the dielectric constant, $K_\varepsilon = \varepsilon_0 . \varepsilon_r$
ε_0 = **8.854 pF/m**, absolute permittivity of vacuum
ε_r = relative permittivity
A = is the effective (overlapping) area of capacitor plates (m2)

Procedure: -

- Select the experiment, (Study of Displacement transducer).
- Now if you opted for Capacitive Displacement Transducer

1) Click to ON the Switch.
2) After switch on, the tap will open and water level in beaker starts to increases.
3) When water level reaches at desired level then a message will display. Press OK on message.
4) After that the tap will close and the outlet valve will open so that water level starts to decrease in beaker.
5) When water level is low a massage will display. Press OK again.
6) According to change in water level in the beaker the graph will generate between Change in capacitance and water level.
7) Another graph is showing the Actual versus Measured level according to Analog Scale and Digital Meter.
8) Switch OFF the supply to STOP the Experiment.
9) With the help of chart you can find Actual versus Measured level.

Observational table: -

Sr. No.	Actual Level (mm)	Measured Level (mm)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Plot the graph between Actual Level versus Measured Level and study the graph.

Result: - The characteristics of Capacitive Displacement Transducer have shown in graph.

Precaution: -

- Follow instructions carefully.
- For fetching correct value, wait until the process gets complete.
- Runtime engine should be properly installed.
- Switch OFF the supply after you completed the experiment.

Aim: - C) To study the Inductive Displacement Transducer with Linear Variable Differential Transformer.

Apparatus Requirement: -

- Personal computer
- Lab view 2009 Runtime engine
- Internet facility(for online experiment and for offline experiment just download the executable file from the experiment download link given in website)

Theory:-

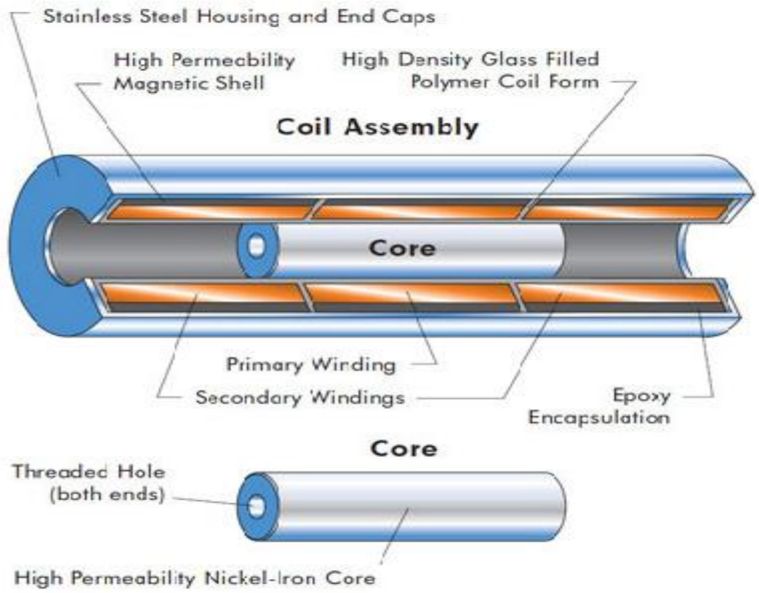
Introduction of L.V.D.T.: -

The letters LVDT are an acronym for Linear Variable Differential Transformer , a common type of electromechanical transducer that can convert the rectilinear motion of an object to which it is coupled mechanically into a corresponding electrical signal. LVDT linear position sensors are readily available that can measure movements as small as a few millionths of an inch up to several inches, but are also capable of measuring positions up to ±20 inches (±0.5 m).

Linear Variable Differential Transformer is a sensor that uses a differential transformer with a sliding magnetic core to sense displacement. LVDTs are driven by an AC excitation source(0 to 15Vrms), typically a sine wave in the 50 to 20 kHz range, and generate an AC output signal that is proportional to the mechanical position of the core.

Construction of L.V.D.T.: -

The basic construction of an LVDT is shown in Figure 2. The device consists of a primary coil, two secondary coils, and a moveable magnetic core which is connected to an external device whose position is of interest. A sinusoidal excitation is applied to the primary coil, which couples with the secondary coils through the magnetic core (ie voltages are induced in the secondary coils). The position of the magnetic core determines the strength of coupling between the primary and each of the secondary cores, and the difference between the voltages generated across each of the secondary cores is proportional to the displacement of the core from the neutral position, or null point.



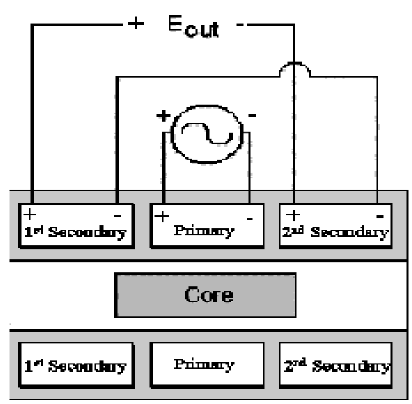


Figure 2: L.V.D.T. Basic Construction

<u>Working of L.V.D.T.:</u> -

Figure 2 illustrates what happens when the LVDT's core is in different axial positions. The LVDT's primary winding, P, is energized by a constant amplitude AC source. The magnetic flux thus developed is coupled by the core to the adjacent secondary windings, S1 and S2. If the core is located midway between S1 and S2, equal flux is coupled to each secondary so the voltages, E1 and E2, induced in windings S1 and S2 respectively, are equal. At this reference midway core position, known as the null point, the differential voltage output, (E1 - E2), is essentially zero.

Displacing the core to the left (Figure 3) causes the first secondary (S1) to be more strongly coupled to the primary than the second secondary (S2). The resulting higher voltage E1 of the first secondary in relation to the second secondary E2 causes an output voltage (E1-E2) that is in phase with the primary voltage.

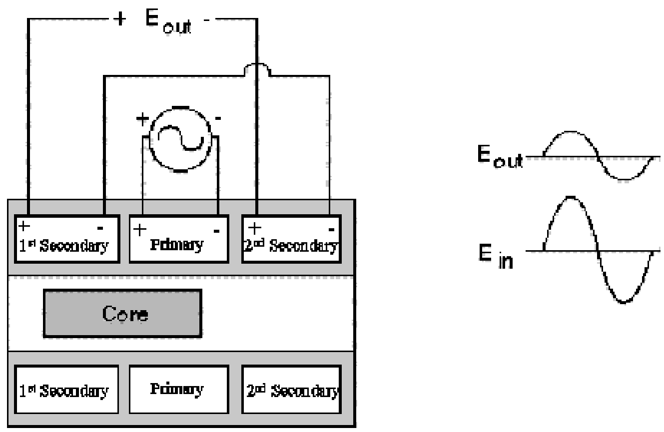


Figure 3: Coe Movement at Left Side

Likewise, displacing the core to the right (Figure 4) causes the second secondary E2 to be more strongly coupled to the primary than the first secondary E1. The greater voltage of the second secondary causes an output voltage (E2-E1) to be out of phase with the primary voltage.

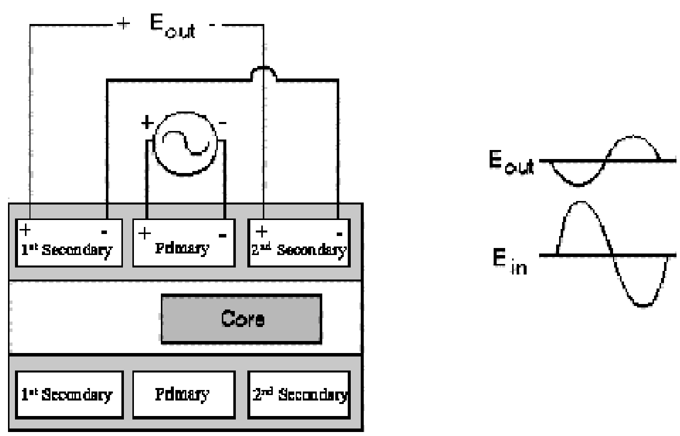


Figure 4: Coe Movement at Right Side

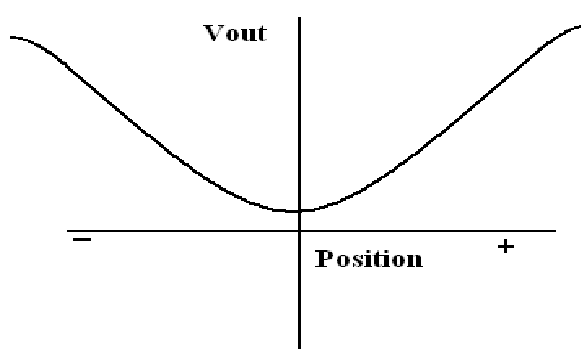


Figure6. Graph Displacement Vs Output Voltage

Note that the output is not linear as the core travels near the boundaries of its range. This is because less magnetic flux is coupled to the core from the primary. However, because LVDTs have excellent repeatability, nonlinearity near the boundaries of the range of the device can be predicted by a table or polynomial curve-fitting function, thus extending the range of device.

<u>Formula Used:-</u>

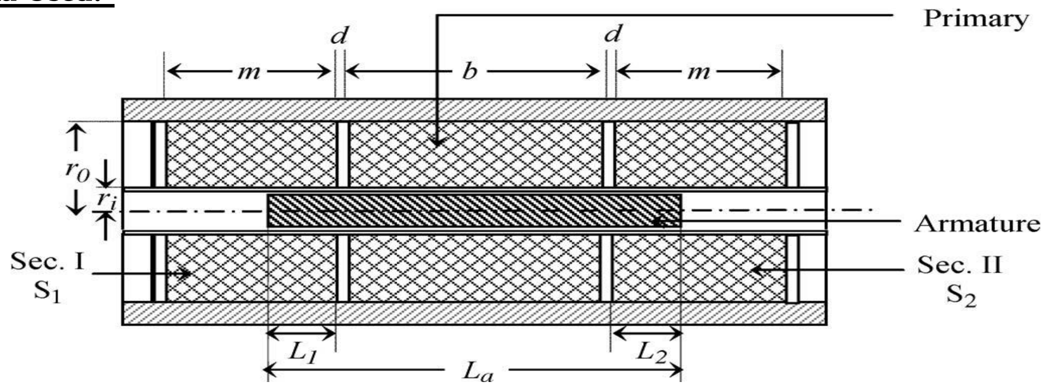


Figure 5: Cross-sectional view of an L.V.D.T.

So the RMS voltage *v*1 induced in the secondary coil *S*1 is

$$\boldsymbol{V_1 = \frac{4\pi^3}{10^7} \times \frac{f \times I_P n_P n_S}{\ln(r_0 / r_i)} \times \frac{2L_2 + b}{mL_a} \times x_1^2}$$

And that in coil S2 is

$$\boldsymbol{V_2 = \frac{4\pi^3}{10^7} \times \frac{f \times I_P n_P n_S}{\ln(r_0 / r_i)} \times \frac{2L_1 + b}{mL_a} \times x_2^2}$$

Where-

x_1 =distance penetrated by the armature toward the secondary coil *S*1;

x_2 = distance penetrated by the armature toward the secondary coil *S*2.

f = frequency

I_P = Primary (rms) current

n_p = turns in primary winding

n_S = turns in secondary winding

r_0 = bobbin internal radius

r_i = core radius

m = length of secondary winding
b = length of primary winding
La = length of core

Taking the length of armature *La* = 3*b* +2*d*, d is very small so neglecting 2*d* compared with *b*,

The differential output voltage V = V1 −*V*2

Procedure: -

- Select the experiment, (Study of Displacement transducer).
- Now if you opted for Inductive Displacement Transducer,
  1) Click to ON the Switch.
  2) Slowly Change the Position of Piston through the Displacement slider.
  3) According to change in Piston Position the Analog Scale and the Digital Meter shows the Actual Displacement and Measured Displacement of Core in LVDT.
  4) According to the Measured Displacement the graph will generate between voltage and Displacement.
  5) Another graph shows the Actual versus Measured Displacement curve.
  6) Switch OFF the supply to STOP the Experiment.
  7) With the help of chart the Actual versus Measured Displacement.

Observational table:-

Sr. No.	Actual Displacement in(+X) (mm)	Measured Displacement in(+X) (mm)	Actual Displacement in(-X) (mm)	Measured Displacement in (-X) (mm)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

Plot the graph Actual displacement versus Measured displacement and study the graph.

Result: - The characteristics of Inductive Displacement Transducer have shown in graph.

Precaution: -

- Follow instructions carefully.
- For fetching correct value, wait until the process gets complete.
- Runtime engine should be properly installed.
- Switch OFF the supply after you completed the experiment.