Unit II : Transducers
Module Name : Inductive transducer Part 2
Module No : 11

Differential Output Transducers

The differential output transducer consists of a coil which is divided into two parts, as (Inductive transducers using self inductance as a variable use one coil, while those using mutual inductance as a variable use multiple coils.) Normally the change in self inductance, ΔL, for inductive transducers, (working on the principle of change of self inductance) is not sufficient for detection of subsequent stages of the instrumentation system. However, if successive stages of the instrument respond to ΔL or ΔM, rather than $L + \Delta L$, or $M + \Delta M$, the sensitivity and accuracy will be much higher. The transducers can be designed to provide two outputs, one of which represents inductance (self or mutual) and the other the decrease in inductance (self or mutual). The succeeding stages of the instrumentation system measure the difference between these outputs. This is known as differential output.

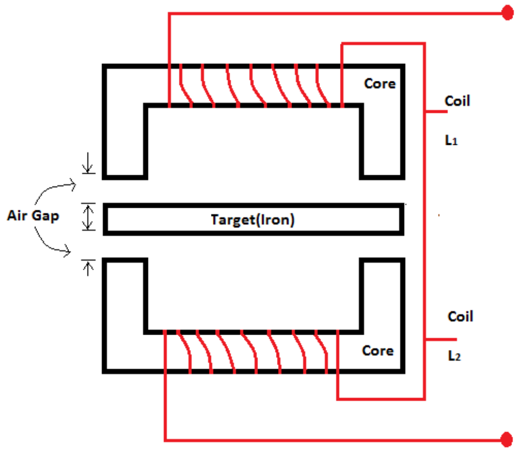


Fig 1 Differential Output Transducer

Advantages of Differential Output

1. Sensitivity and accuracy are increased.
2. Output is less affected by external magnetic fields.
3. Effective variations due to temperature changes are reduced.
4. Effects of change in supply voltages and frequency are reduced.

In response to a displacement, the inductance of one part increases from L to $L + \Delta L$, while that of the other part decreases from L to $L - \Delta L$. The change is measured as the difference of the two, resulting in an output of $2\,\Delta L$ instead of ΔL, when one winding is used. This increases the sensitivity and also eliminates error.

Linear Variable Differential Transducer

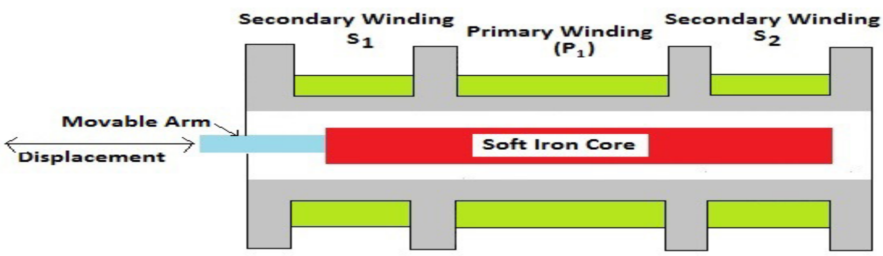


Fig 2. LVDT

The transformer consists of a single primary winding P1 and two secondary windings S1 and S2 wound on a hollow cylindrical former. The secondary windings have an equal number of turns and are identically placed on either side of the primary windings. The primary winding is connected to an ac source. The frequency of the ac applied to the primary winding ranges from 50 Hz to 20 kHz. An movable soft iron core slides within the hollow former and therefore affects the magnetic coupling between the primary and the two secondaries. The displacement to be measured is applied to an arm attached to the soft iron core.

When the core is in its normal (null) position, equal voltages are induced in the two secondary windings. The output voltage of the secondary windings S1 is ES1 and that of secondary winding S2 is ES2.
In order to convert the output from S1 to S2 into a single voltage signal, the two secondaries S1 and S2 are connected in series opposition, as shown in Fig. 3.

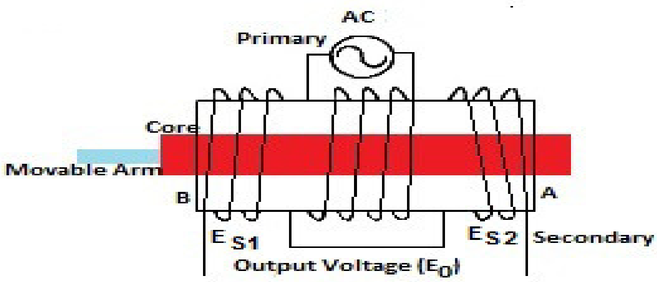


Fig 3. Construction of LVDT

Hence the output voltage of the transducer is the difference of the two voltages. Therefore the differential output voltage Eo = ES1 ~ ES2.
When the core is at its normal position, the flux linking with both secondary windings is equal, and hence equal emfs are induced in them. Hence, at null position ES1 = ES2. Since the output voltage of the transducer is the difference of the two voltages, the output voltage Eo is zero at null position.
Now, if the core is moved to the left of the null position, more flux links with winding S1 and less with winding S2. Hence, output voltage ES1 of the secondary winding S1 is greater than ES2. The magnitude of the output voltage of the secondary is then ES1 – ES2, in phase with ES1 (the output voltage of secondary winding S1).
Similarly, if the core is moved to the right of the null position, the flux linking with winding S2 becomes greater than that linked with winding S1. This results in ES2 becoming larger than ES1. The output voltage in this case is Eo = ES2 – ES1 and is in phase with ES2.
The amount of voltage change in either secondary winding is proportional to the amount of movement of the core. Hence, we have an indication of the amount of linear motion. By noting which output is increasing or decreasing, the direction of motion can be determined. The output ac voltage inverts as the core passes the centre position. The farther the core moves from the centre, the greater the difference in value between ES1 and ES2 and consequently the greater the value of Eo. Hence, the amplitude is function of the distance the core has moved, and the polarity or phase indicates the direction of motion, as shown in Fig. 5.

The diagram in Fig 4(a), (b) and (c) shows the core of an LVDT at three different positions.
In Fig. 4(a), the core is at O, which is the central zero or null position. Therefore, ES1 = ES2 and Eo = 0.
When the core is moved to the left, as in Fig. 4(b) and is at A, ES1 is more than ES2 and Eo is positive. This movement represents a positive value and therefore the phase angle, is f = 0°.
When the core is moved to the right towards B, ES2 is greater than ES1 and hence Eo is negative. Therefore, S2 the output voltage is 180° out of phase with the voltage which is obtained when the core is moved to the left. The characteristics are linear from O – A and O – B, but after that they become non-linear.

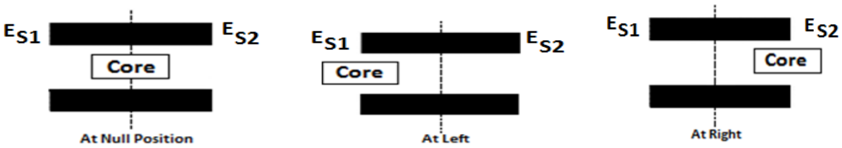
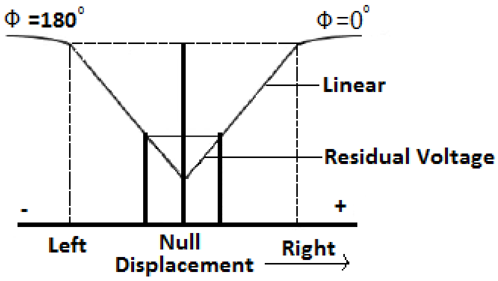


Fig 4 (a) Fig 4 (b) Fig 4 (c)



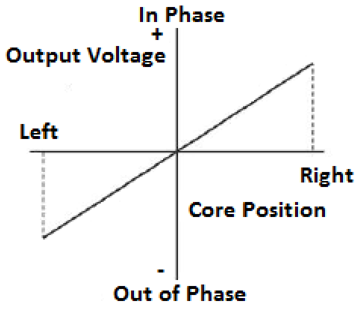


Fig 5 shows the variation of the output voltage against displacement for various position of the core. The curve is practically linear for small displacements (up to 5 mm). Beyond this range, the curve starts to deviate.

Advantages of LVDT

1 Linearity The output voltage of this transducer is practically linear for displacements upto 5 mm (a linearity of 0.05% is available in commercial LVDTs).
2 Infinite resolution The change in output voltage is stepless. The effective resolution depends more on the test equipment than on the transducer.
3 High output It gives a high output (therefore there is frequently no need for intermediate amplification devices).
4 High sensitivity The transducer possesses a sensitivity as high as 40 V/mm.
5 Ruggedness These transducers can usually tolerate a high degree of vibration and shock.
6 Less friction There are no sliding contacts.
7 Low hysteresis This transducer has a low hysteresis, hence repeatability is excellent under all conditions.
8 Low power consumption Most LVDTs consume less than 1 W of power.

Disadvantages

1. Large displacements are required for appreciable differential output.
2. They are sensitive to stray magnetic fields (but shielding is possible).
3. Temperature also affects the transducer.