Resistance Thermometer Transducer:

The resistance of a conductor changes when its temperature is changed. This property is utilised for the measurement of temperature. The Resistance Thermometer Transducer is an instrument used to measure electrical resistance in terms of temperature, i.e. it uses the change in the electrical resistance of the conductor to determine the temperature.

The main part of a resistance thermometer is its sensing element. The characteristics of the sensing element determine the sensitivity and operating temperature range of the instrument.

There are three common types of temperature sensitive resistive elements in use; the wire wound resistance, the thermistor and the PTC (Positive Temperature Coefficient) semiconductor resistance.

The sensing element may be any material that exhibits a relatively large resistance change with change in temperature.

Desirable characteristics of Sensing element:

1) The material used should be stable in its characteristics, i.e. neither its resistance nor its temperature coefficient of resistance should undergo permanent change with use or age.
2) Should be linear: Linear change in resistance with change in temperature.
3) Should have high Speed of response: The resistive element should respond with high speed for the rapid change of temperature. The smaller a given sensing element, the less heat required to raise its temperature, and the faster its response.

Platinum, nickel and copper are the metals most commonly used to measure temperature. Platinum is a commonly used material for resistance thermometers. The temperature range over which platinum has stability is — 260°C to +1100°C.

Figure 13.11(a) shows an industrial platinum resistance thermometer. The changes in resistance caused by changes in temperature are detected by a Wheatstone bridge, as shown in Fig. 13.11(b).

The temperature sensing element, which may be nickel, copper or platinum contained in a bulb or well, along with the balancing bridge, form the essential components of a temperature measuring system based upon this principle.

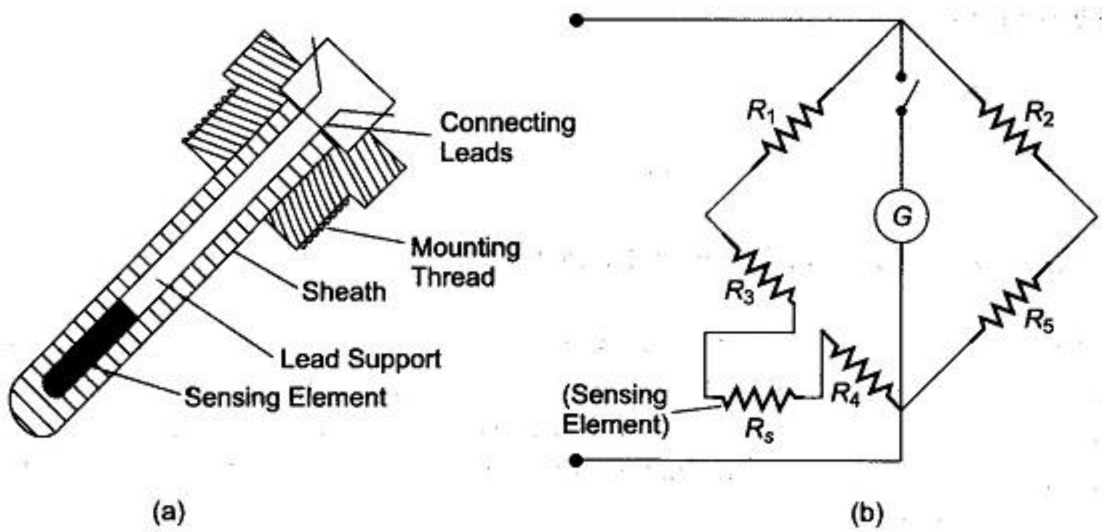

Fig. 13.11 (a) Industrial Platinum Resistance Thermometer (b) Bridge Circuit

The sensing element R_s is made of a material having a high temperature coefficient, and R_1, R_2, and R_5 are made of resistances that are practically constant under normal temperature changes.

When no current flows through the galvanometer, the normal principle of Wheatstone' s bridge states the ratio of resistance is $\frac{R_1}{R_2} = \frac{R_s}{R_5}$

In normal practice, the sensing element is away from the indicator, and its leads have a resistance, say R_3**,** R_4**.**

Therefore,

$$\frac{R_1}{R_2} = \frac{R_3 + R_s + R_4}{R_5}$$

Now it resistance R_s changes, balance cannot be maintained and the galvanometer shows a deflection, which can be calibrated to give a suitable temperature scale.

Advantages of Resistance Thermometer Transducer

The measurement of temperature by the electrical resistance method has the following advantages and characteristics.

1. The measurement is very accurate.
2. It has a lot of flexibility with regard to choice of measuring equipment.
3. Indicators, recorders or controllers can also be operated.
4. More than one resistance element can be clubbed to the same indicating/ recording instrument.
5. The temperature sensitive resistance element can be easily installed and

6. The accuracy of the measuring circuit can be easily checked by substituting a standard resistor for the resistive element.
7. Resistive elements can be used to measure differential temperature.
8. Resistance thermometers have a wide range without loss of accuracy, and can be used for temperature ranges (-200°C to + 650°C).
9. They are best suited for remote indication.
10. The resistive element response time is of the order of 2 to lOs
11. The limits of error of a resistive element are ± 0.25% of the scale reading.
12. The size of the resistive element may be about 6 — 12 mm in diameter and 12 — 75 mm in length.
13. Extremely accurate temperature sensing.
14. No necessity of temperature compensation.
15. Stability of performance over long periods of time.

Limitations of Resistance Thermometer Transducer

1. High cost
2. Need for bridge circuit and power source
3. Possibility of self-heating
4. Large bulb size, compared to a thermocouple

Thermistors:

The electrical resistance of most materials changes with temperature. By selecting materials that are very temperature sensitive, devices that are useful in temperature control circuits and for temperature measurements can be made.

Thermistor (THERMally sensitive resISTOR) are non-metallic resistors (semiconductor material), made by sintering mixtures of metallic oxides such as manganese, nickel, cobalt, copper and uranium.

Thermistors have a Negative Temperature Coefficient (NTC), i.e. resistance decreases as temperature rises. Figure 13.12 shows a graph of resistance vs temperature for a thermistor. The resistance at room temperature (25°C) for typical commercial units ranges from 100 Ω to 10 Ω They are suitable for use only up to about 800°C. In some cases, the resistance of thermistors at room temperature may decrease by 5% for each 1°C rise in temperature. This high sensitivity to temperature changes makes the thermistor extremely useful for precision temperature measurements, control and compensation.

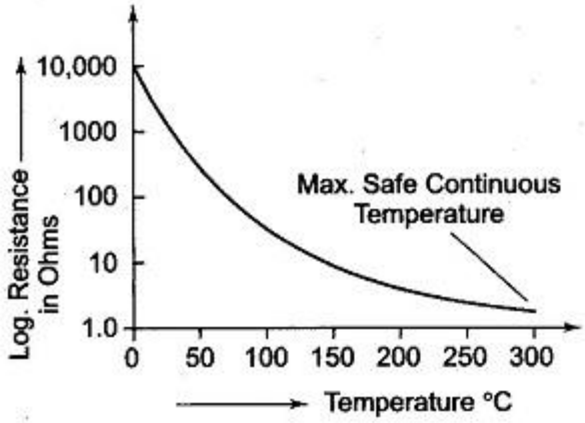

Fig. 13.12 Resistance vs Temperature Graph of a Thermistor

Shape of Thermistors:

The smallest thermistors are made in the form of beads. Some are as small as 0.15 mm (0.006 in.) in diameter. These may come in a glass coating or sealed in the tip of solid glass probes. Glass probes have a diameter of about 2.5 mm and a length which varies from 6 — 50 mm. The probes are used for measuring the temperature of liquids.
The resistance ranges from 300 Ω to 100 Ω.

Where greater power dissipations is required, thermistors may be obtained in disc, washer or rod forms.

Disc thermistors about 10 mm in diameter, either self supporting or mounted on a small plate, are mainly used for temperature control. These thermistors are made by pressing thermistors material under several tons of pressure in a round die to produce flat pieces 1.25 — 25 mm in diameter and 0.25 — 0.75 mm thick, having resistance values of 1 Ω to 1 MΩ. These are sintered and coated with silver on two flat surfaces.

Washer thermistors are made like disc thermistors, except that a hole is formed in the centre in order to make them suitable for mounting on a bolt. Rod thermistors are extruded through dies to make long cylindrical units of 1.25, 2.75, and 4.25 mm in diameter and 12.5 — 50 min long. Leads are attached to the end of the rods. Their resistance usually varies from 1 — 50 Ω

The advantage of rod thermistors over other configurations is the ability to produce high resistance units with moderately high power handling capability.

Thermistors can be connected in series/parallel combinations for applications requiring increased power handling capability. High resistance units find application in measurements that employ low lead wires or cables.

Thermistors are chemically stable and can be used in nuclear environments. Their wide range of characteristics also permits them to be used in limiting and regulation circuits, as time delays, for integration of power pulses, and as memory units.

Typical thermistor configurations are as shown in Fig. 13.13(a). Figure 13.13(b) shows a bush type thermistor.

A thermistor in one arm of a Wheatstone bridge provides precise temperature information. Accuracy is limited, in most applications, only by the readout devices.

Thermistors are non-linear devices over a temperature range, although now units with better than 0.2% linearity over the 0-100°C temperature range are available. The typical sensitivity of a thermistor is approximately 3 mV/°C at 200°C.

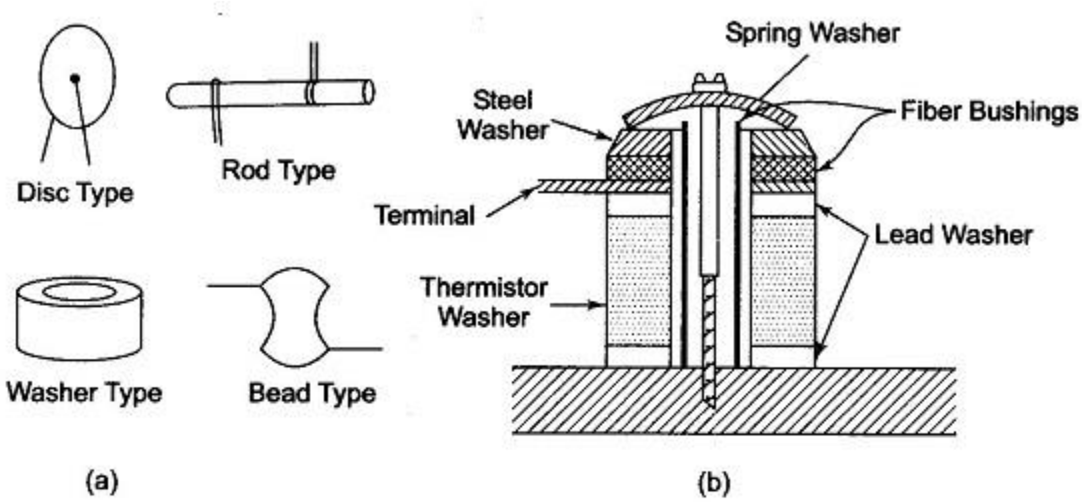

Fig. 13.13 (a) Various Configurations of Thermistor (b) Bush-Type Thermistor

Advantages of Thermistors:

1. Small size and low cost.
2. Fast response over narrow temperature range.
3. Good sensitivity in the NTC region.
4. Cold junction compensation not required due to dependence of resistance on absolute temperature.
5. Contact and lead resistance problems not encountered due to large R_{th} (resistance).

Limitations of Thermistors:

1. Non-linearity in resistance vs temperature characteristics.
2. Unsuitable for wide temperature range.
3. Very low excitation current to avoid self-heating.
4. Need of shielded power lines, filters, etc. due to high resistance.

Linear Variable Differential Transducer (LVDT):

The differential transformer is a passive inductive transformer. It is also known as a Linear Variable Differential Transducer (LVDT). The basic construction is as shown in Fig. 13.19.

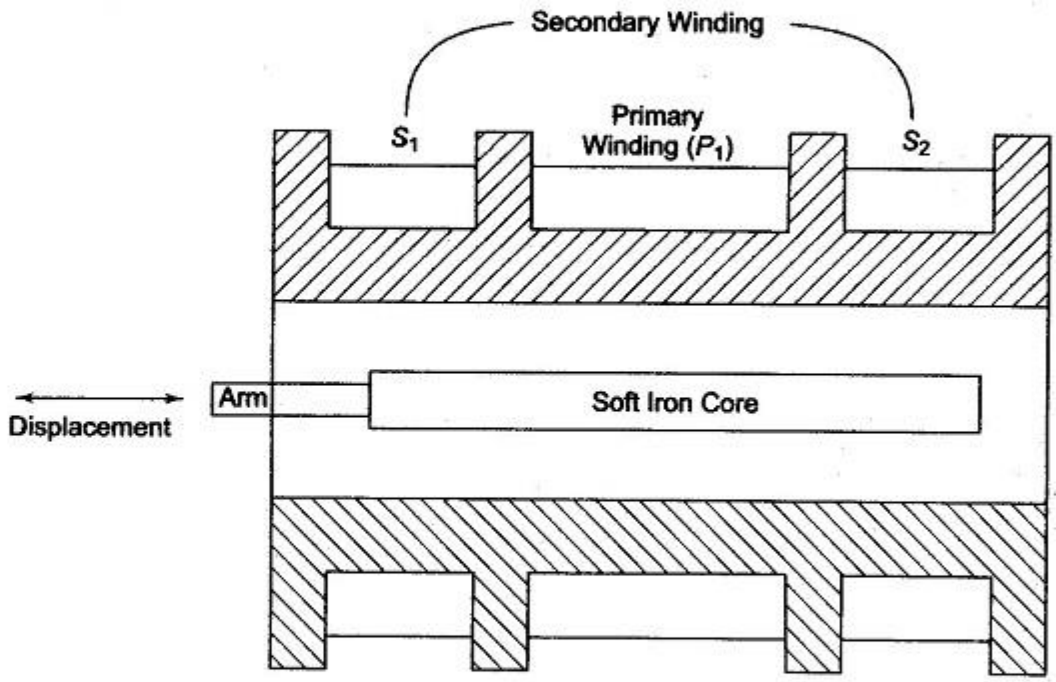

Fig. 13.19 Construction of a Linear Variable Differential Transducer (LVDT)

The transformer consists of a single primary winding P_1 and two secondary windings S_1 and S_2wound 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.

A 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. (In practice, the core is made up of a nickel-iron alloy which is slotted longitudinally to reduce eddy current losses.)

When the core is in its normal (null) position, equal voltages are induced in the two secondary windings. The frequency of the ac applied to the primary winding ranges from 50 Hz to 20 kHz.

The output voltage of the secondary windings S_1 is E_{s1} and that of secondary winding S_2 is E_{s2}.

In order to convert the output from S_1 to S_2 into a single voltage signal, the two secondaries S_1 and S_2 are connected in series opposition, as shown in Fig. 13.20.

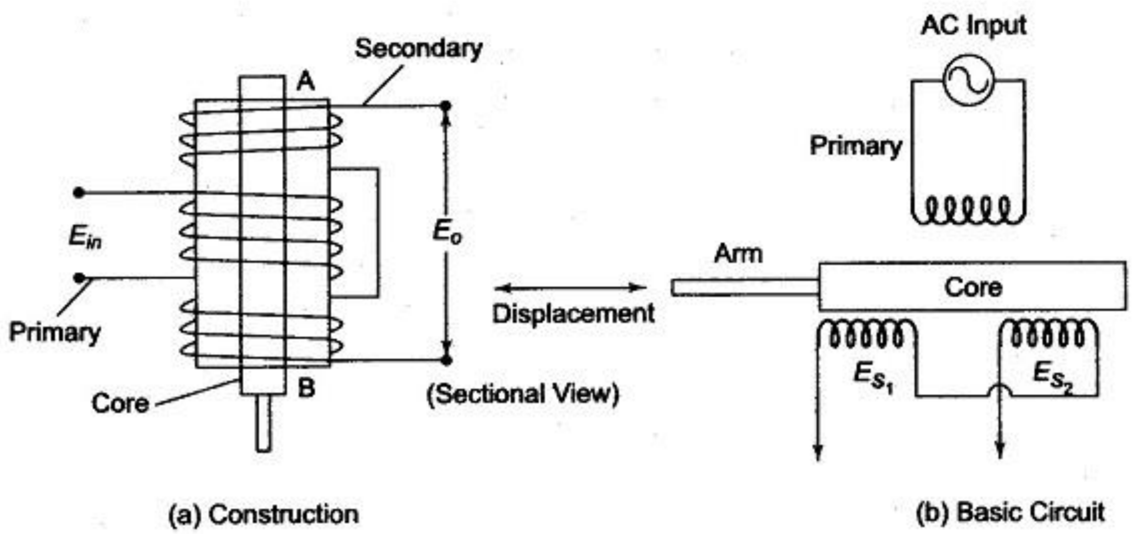

Fig. 13.20 Secondary Winding Connected for Differential Output

Hence the output voltage of the transducer is the difference of the two voltages. Therefore the differential output voltage $E_o=E_{s1}\sim E_{s2}$.

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 $E_{s1} = E_{s2}$. Since the output voltage of the transducer is the difference of the two voltages, the output voltage E_o is zero at null position.

Now, if the core is moved to the left of the null position, more flux links with winding S_1 and less with winding S_2. Hence, output voltage E_{s1} of the secondary winding S_1 is greater than E_{s2} . The magnitude of the output voltage of the secondary is then $E_{s1} — E_{s2}$, in phase with E_{s1} (the output voltage of secondary winding S_1).

Similarly, if the core is moved to the right of the null position, the flux linking with winding S_2becomes greater than that linked with winding S_1. This results in E_{s2} becoming larger than E_{s1}. The output voltage in this case is $E_o = E_{s2} — E_{s1}$ and is in phase with E_{s2}.

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 E_{s1} and E_{s2} and consequently the greater the value of E_o. Hence, the amplitude is a function of the distance the core has moved, and the polarity or phase indicates the direction of motion, as shown in Fig. 13.21.

As the core is moved in one direction from the null position, the difference voltage, i.e. the difference of the two secondary voltages increases, while maintaining an in-phase relation with the voltage from the input source. In the other direction from the null position, the difference voltage increases, but is 180° out of phase with the voltage from the source.

By comparing the magnitude and phase of the difference output voltage with that of the source, the amount and direction of the movement of the core and hence of the displacement may be determined.

The amount of output voltage may be measured to determine the displacement. The output signal may also be applied to a recorder or to a controller that can restore the moving system to its normal position.

The output voltage of a Linear Variable Differential Transducer is a linear function of the core displacement within a limited range of motion (say 5 mm from the null position).

Figure 13.21(d) 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.

The diagram in Figs 13.21(a), (b) and (c) shows the core of a Linear Variable Differential Transducer at three different positions.

In Fig. 13.21(b), the core is at 0, which is the central zero or null position. Therefore, $E_{s1} = E_{s2}$, and $E_o = 0$.

When the core is moved to the left, as in Fig. 13.21(a) and is at A, E_{s1} is more than E_{s2} and E_o is positive. This movement represents a positive value and therefore the phase angle, is $\Phi = 0°$.

When the core is moved to the right towards B, E_{s2} is greater than E_{s1} and hence E_o is negative. Therefore, S_2 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 0 — A and 0 — B, but after that they become non-linear.

One advantage of a Linear Variable Differential Transducer over, the inductive bridge type is that it produces higher output voltage for small changes in core position. Several commercial models that produce 50 mV/mm to 300 mV/mm are available. 300 mV/mm implies that a 1 mm displacement of the core produces a voltage output of 300 mV.

Linear Variable Differential Transducer are available with ranges as low as ± 0.05 in. to as high as ± 25 in. and are sensitive enough to be used to measure displacements of well below 0.001 in. They can be obtained for operation at temperatures as low as — 265°C and as high as + 600°C and are also available in radiation resistance designs for nuclear operations.

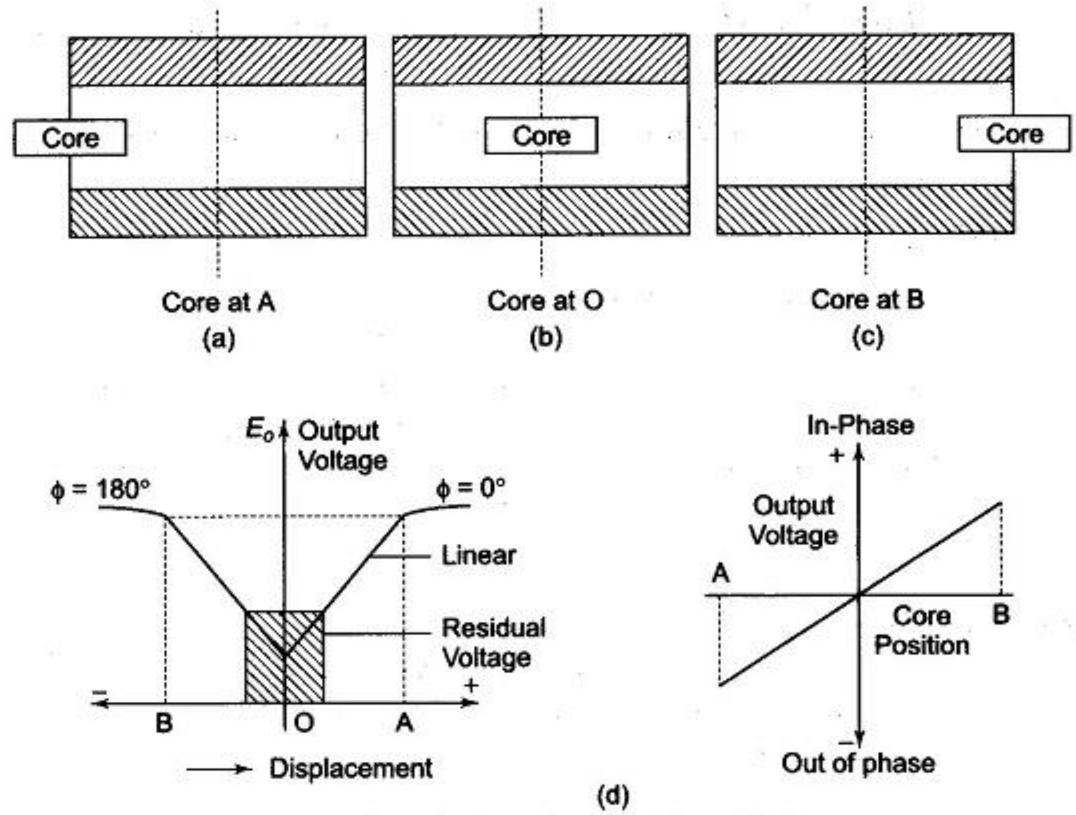

Fig. 13.21 (a), (b), (c) Various Core Position of LVDT
(d) Variation of Output Voltage vs Displacement

Advantages of Linear Variable Differential Transducer

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 step less. The effective resolution depends more on the test equipment than on the
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.
9.

Disadvantages of Linear Variable Differential Transducer

1. Large displacements are required for appreciable differential output.
2. They are sensitive to stray magnetic fields (but shielding is possible).

3. The receiving instrument must be selected to operate on ac signals, or a demodulator network must be used if a dc output is required.
4. The dynamic response is limited mechanically by the mass of the core and electrically by the applied voltage.
5. Temperature also affects the transducer.