UNIT – 1

TRANSDUCERS: Classification of Transducers, Characteristics, Basic Requirements of a Transducer, Resistive Transducer, Strain Gauge, Inductive Transducer, Capacitive displacement transducer, LVDT, Load cell Transducers, Thermocouple, Thermistor, Radiation Pyrometers.

INTRODUCTION:

A transducer is defined as a device that receives energy from one system and transmits it to another, often in a different form. Broadly defined, the transducer is a device capable of being actuated by energizing input from one or more transmission media and in turn generating a related signal to one or more transmission systems. It provides a usable output in response to a specified input measurand, which may be a physical or mechanical quantity, property, or conditions. The energy transmitted by these systems may be electrical, mechanical or acoustical. The nature of electrical output from the transducer depends on the basic principle involved in the design. The output may be analog, digital or frequency modulated.

CLASSIFICATION OF TRANSDUCERS

The transducers may be classified in various ways such as on the basis of electrical principles involved, methods of application, methods of energy conversion used, nature of output signal etc.

1. Primary and Secondary Transducers:Transducers, on the basis of methods of applications, may be classified into primary and secondary transducers. When the input signal is directly sensed by the transducer and physical phenomenon is converted into the electrical form directly then such a transducer is called the primary transducer.

For example, in case of pressure measurement, bourdon tube is a primary sensor which converts pressure first into displacement, and then the displacement is converted into an output voltage by an LVDT. In this case LVDT is secondary transducer.

2. Active and Passive Transducers: Transducers, on the basis of methods of energy conversion used, may be classified into active and passive transducers.Self-generating type transducers i.e. the transducers, which develop their output the form of electrical voltage or current without any auxiliary source, are called the active transducers. Such transducers draw energy from the system under measurement. Normal such transducers give very small output and, therefore, use of amplifier becomes essential.

Transducers, in which electrical parameters i.e. resistance, inductance or capacitance changes with the change in input signal, are called the passive transducers. These transducers require external power source for energy conversion. In such transducer electrical parameters i.e. resistance, inductance or capacitance causes a change in voltages current or frequency of the external power source. These transducers may draw sour energy from the system under measurement. Resistive, inductive and capacitive transducer falls in this category.

3. Analog and Digital Transducers: Transducers, on the basis of nature of output signal, may be classified into analog and digital transducers. Analog transducer converts input signal into output signal, which is a continuous function of time such as thermistor, strain gauge, LVDT, thermocouple etc. Digital transducer converts input signal into the output signal of the form of pulse e.g. it gives discrete output. These transducers are becoming more and more popular now-a-days because of advantages associated with digital measuring instruments and also due to the effect that digital signals can be transmitted over a long distance without causing much distortion due to amplitude variation and phase shift. Sometimes an analog transducer combined with an ADC (analog-digital convector) is called a digital transducer.

4. Transducers and Inverse Transducers: Transducer, as already defined, is a device that converts a non-electrical quantity into an electrical quantity. Normally a transducer and associated circuit has a non-electrical input and an electrical output, for example a thermo-couple, photoconductive cell, pressure gauge, strain gauge etc. An inverse transducer is a device that converts an electrical quantity into a non-electrical quantity. It is a precision actuator having an electrical input and a low-power non-electrical output.

For examples a piezoelectric crystal and transnational and angular moving-coil elements can be employed as inverse transducers. Many data-indicating and recording devices are basically inverse transducers. An ammeter or voltmeter converts electric current into mechanical movement and the characteristics of such an instrument placed at the output of a measuring system are important. A most useful application of inverse transducers is in feedback measuring systems.

CHARACTERISTICS OF TRANSDUCER

1. **Accuracy**: It is defined as the closeness with which the reading approaches an accepted standard value or ideal value or true value, of the variable being measured.

2. **Ruggedness**: The transducer should be mechanically rugged to withstand overloads. It should have overload protection.

3. **Linearity**: The output of the transducer should be linearly proportional to the input quantity under measurement. It should have linear input - output characteristic.

4. **Repeatability:** The output of the transducer must be exactly the same, under same environmental conditions, when the same quantity is applied at the input repeatedly.

5. **High output**: The transducer should give reasonably high output signal so that it can be easily processed and measured. The output must be much larger than noise. Now-a-days, digital output is preferred in many applications;

6. **High Stability and Reliability:** The output of the transducer should be highly stable and reliable so that there will be minimum error in measurement. The output must remain unaffected by environmental conditions such as change in temperature, pressure, etc.

7. **Sensitivity**: The sensitivity of the electrical transducer is defined as the electrical output obtained per unit change in the physical parameter of the input quantity. For example, for a transducer used for temperature measurement, sensitivity will be expressed in mV/' C. A high sensitivity is always desirable for a given transducer.

8. **Dynamic Range:** For a transducer, the operating range should be wide, so that it can be used over a wide range of measurement conditions.

9**. Size:** The transducer should have smallest possible size and shape with minimal weight and volume. This will make the measurement system very compact.

10. **Speed of Response:** It is the rapidity with which the transducer responds to changes in the measured quantity. The speed of response of the transducer should be as high as practicable.

BASIC REQUIREMENTS OF A TRANSDUCER

1. **Ruggedness:** It should be capable of withstanding overload and some safety arrangement should be provided for overload protection.
2. **Linearity:** Its input-output characteristics should be linear and it should produce these characteristics in symmetrical way.
3. **Repeatability:** It should reproduce same output signal when the same input signal is applied again and again under fixed environmental conditions e.g. temperature, pressure, humidity etc.
4. **High Output Signal Quality:** The quality of output signal should be good i.e. the ratio of the signal to the noise should be high and the amplitude of the output signal should be enough.
5. **High Reliability and Stability:** It should give minimum error in measurement for temperature variations, vibrations and other various changes in surroundings.
6. **Good Dynamic Response:** Its output should be faithful to input when taken as a function of time. The effect is analyzed as the frequency response.
7. **No Hysteretic:** It should not give any hysteretic during measurement while input signal is varied from its low value to high value and vice-versa.
8. **Residual Deformation:** There should be no deformation on removal of local after long period of application.

RESISTIVE TRANSDUCER

Resistive transducers are those in which the resistance changes due to a change in some physical phenomenon. The change in the value of the resistance with a change in the length of the conductor can be used to measure displacement. Strain gauges work on the principle that the resistance of a conductor or semiconductor changes when strained. This can be used for the measurement of displacement, force and pressure. The resistivity of materials changes with changes in temperature. This property can be used for the measurement of temperature.

i. Potentiometer

A resistive potentiometer (pot) consists of a resistance element provided with a sliding contact, called a wiper. The motion of the sliding contact may be translatory or rotational. Some have a combination of both, with resistive elements in the form of a helix, as shown in Fig. 13.1(c). They are known as helipots. Translatory resistive elements, as shown in Fig. 13.1(a), are linear (straight) devices. Rotational resistive devices are circular and are used for the measurement of angular displacement, as shown in Fig. 13.1(b). Helical resistive elements are multi turn rotational devices which can be used for the measurement of either translatory or rotational motion. A potentiometer is a passive transducer since it requires an external power source for its operation.

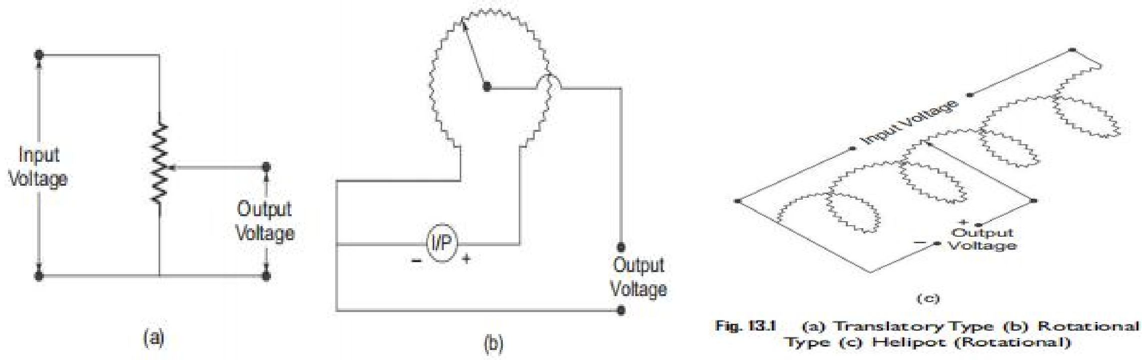


Fig. 13.1 (a) Translatory Type (b) Rotational Type (c) Helipot (Rotational)

ii. Resistance Pressure Transducer

Measurement in the resistive type of transducer is based on the fact that a change in pressure results in a resistance change in the sensing elements. Resistance pressure transducers are of two main types. First, the electro-mechanical resistance transducer, in which a change of pressure, stress, position, displacement or other mechanical variation is applied to a variable resistor. The other resistance transducer is the strain gauge, where the stress acts directly on the resistance. It is very commonly used for stress and displacement measurement in instrumentation.

In the general case of pressure measurement, the sensitive resistance element may take other forms, depending on the mechanical arrangement on which the pressure is caused to act. Figure 13.1(d) and (e) show two ways by which the pressure acts to influence the sensitive resistance element, i.e. by which pressure varies the resistance element. They are the bellow type, and the diaphragm type. (Yet another is the Bourdon tube of pressure gauge). In each of these cases, the element moved by the pressure change is made to cause a change in resistance. This resistance change can be made part of a bridge circuit and then taken as either ac or dc output signal to determine the pressure indication.

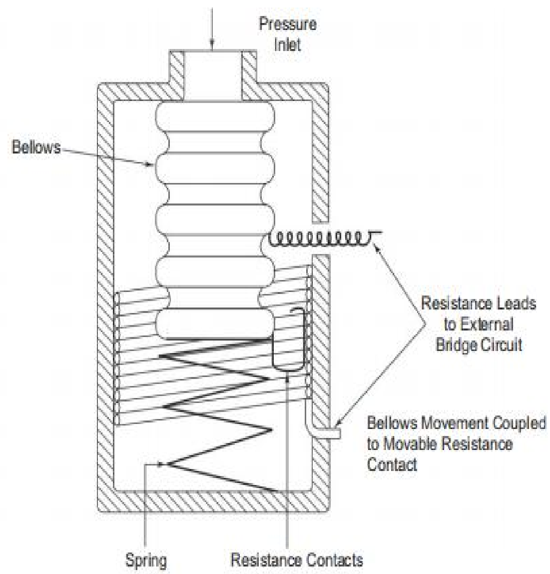


Fig. 13.1(d) Resistance pressure transducer

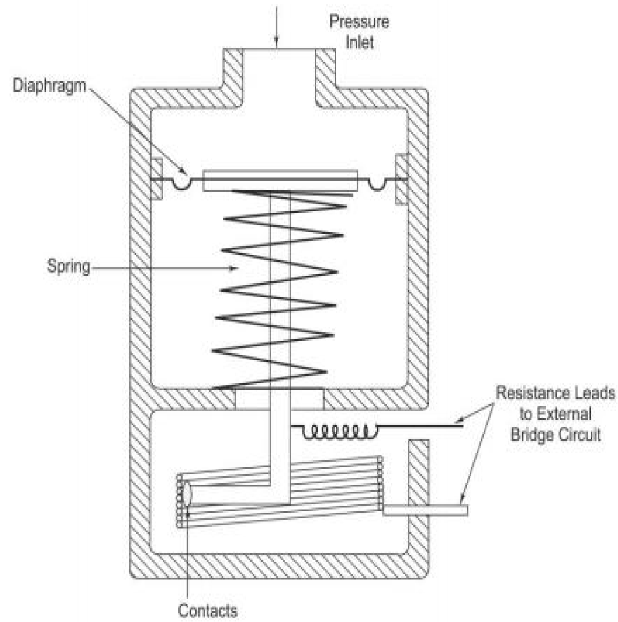


Fig. 13.1(e) Sensitive diaphragm moves the resistance contact

STRAIN GAUGES

The strain gauge is an example of a passive transducer that uses the variation in electrical resistance in wires to sense the strain produced by a force on the wires. It is well known that stress (force/unit area) and strain (elongation or compression/unit length) in a member or portion of any object under pressure is directly related to the modulus of elasticity.

Since strain can be measured more easily by using variable resistance transducers, it is a common practice to measure strain instead of stress, to serve as an index of pressure. Such transducers are popularly known as strain gauges. If a metal conductor is stretched or compressed, its resistance changes on account of the fact that both the length and diameter of the conductor changes. Also, there is a change in the value of the resistivity of the conductor when subjected to strain, a property called the piezo-resistive effect. Therefore, resistance strain gauges are also known as piezo resistive gauges.

Many detectors and transducers, e.g. load cells, torque meters, pressure gauges, temperature sensors, etc. employ strain gauges as secondary transducers. When a gauge is subjected to a positive stress, its length increases while its area of cross-section decreases. Since the resistance of a conductor is directly proportional to its length and inversely proportional to its area of cross-section, the resistance of the gauge increases with positive strain. The change in resistance value of a conductor under strain is more than for an increase in resistance due to its dimensional changes. This property is called the piezo-resistive effect.

The following types of strain gauges are the most important.

1. Wire strain gauges

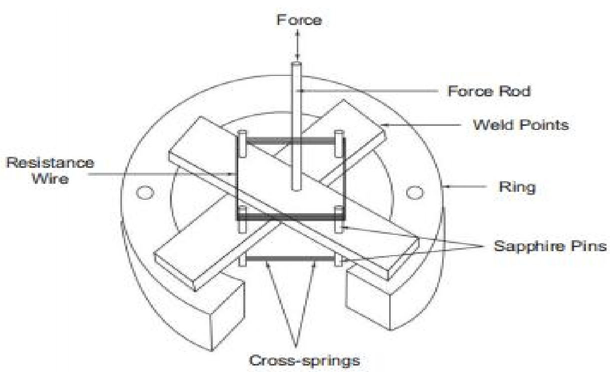
2. Foil strain gauges

3. Semiconductor strain gauges

1. **Resistance Wire Gauge**

Resistance wire gauges are used in two basic forms, the unbonded type, and the bonded type.

a. Unbonded Resistance Wire Strain Gauge: An unbonded strain gauge consists of a wire streched between two points in an insulating medium, such as air. The diameter of the wire used is about 25 mm. The wires are kept under tension so that there is no sag and no free vibration. Unbonded strain gauges are usually connected in a bridge circuit. The bridge is balanced with no load applied as shown in Fig. 13.3.



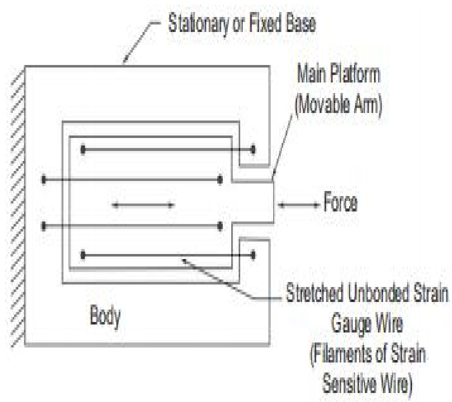


Fig. 13.3 Unbonded strain gauge

When an external load is applied, the resistance of the strain gauge changes, causing an unbalance of the bridge circuit resulting in an output voltage. This voltage is proportional to the strain. A displacement of the order of 50 mm can be detected with these strain gauges.

b. Bonded Resistance Wire Strain Gauges: A metallic bonded strain gauge is shown in Fig. 13.4. A fine wire element about 25 mm (0.025 in.) or less in diameter is looped back and forth on a carrier (base) or mounting plate, which is usually cemented to the member undergoing stress. The grid of fine wire is cemented on a carrier which may be a thin sheet of paper, bakelite, or Teflon.

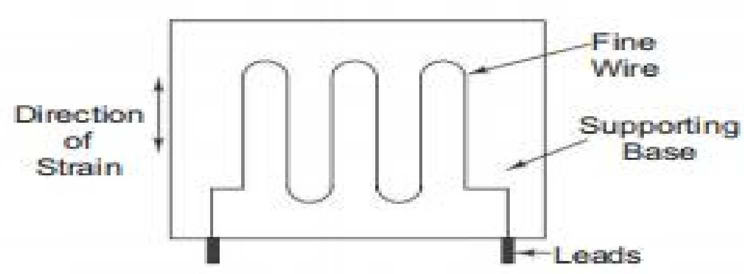


Fig. 13.4 Bonded resistance wire strain gauge

The wire is covered on the top with a thin material, so that it is not damaged mechanically. The spreading of the wire permits uniform distribution of stress. The carrier is then bonded or cemented to the member being studied. This permits a good transfer of strain from carrier to wire. A tensile stress tends to elongate the wire and thereby increase its length and decrease its cross-sectional area. The combined effect is an increase in resistance, as seen from the following equation

$R = \rho \, l / A$

where

ρ = the specific resistance of the material in Wm

l = the length of the conductor in m

A = the area of the conductor in m^2

As a result of strain, two physical parameters are of particular interest.

1. The change in gauge resistance.

2. The change in length.

The measurement of the sensitivity of a material to strain is called the gauge factor (K).

INDUCTIVE TRANSDUCER

The self generating type utilises the basic electrical generator principle, i.e. a motion between a conductor and magnetic field induces a voltage in the conductor (generator action). This relative motion between the field and the conductor is supplied by changes in the measured. An inductive electromechanical transducer is a device that converts physical motion (position change) into a change in inductance. Transducers of the variable inductance type work upon one of the following principles.

1. Variation of self inductance

2. Variation of mutual inductance

Inductive transducers are mainly used for the measurement of displacement. The displacement to be measured is arranged to cause variation in any of three variables

1. Number of turns

2. Geometric configuration

3. Permeability of the magnetic material or magnetic circuits

$$L = \mu N^2 A / l$$

l = length of the air gap

A = area of the flux path through air

μ = permeability

N= No. Of turns

i. Change in Self Inductance with Numbers of Turns

The output may be caused by a change in the number of turns. Figures 13.14(a) and (b) are transducers used for the measurement of displacement of linear and angular movement respectively.

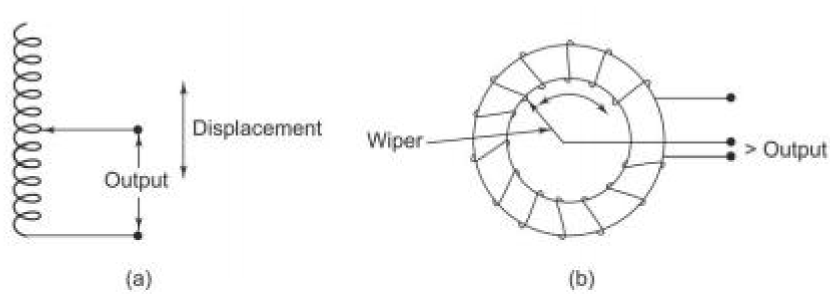


Fig. 13.14 (a) Linear inductive transducer (b) Angular inductive transducer

Figure 13.14(a) is an air cored transducer for measurement of linear displacement. Figure 13.14(b) is an iron cored coil used for the measurement of angular displacement. In both cases, as the number of turns are changed, the self inductance and the output also changes.

ii. Change in Self Inductance with Change in Permeability

Figure 13.15 shows an inductive transducer which works on the principle of the variation of permeability causing a change in self inductance. The iron core is surrounded by a winding. If the iron core is inside the winding, its permeability is increased, and so is the inductance. When the iron core is moved out of the winding, the permeability decreases, resulting in a reduction of the self inductance of the coil. This transducer can be used for measuring displacement.

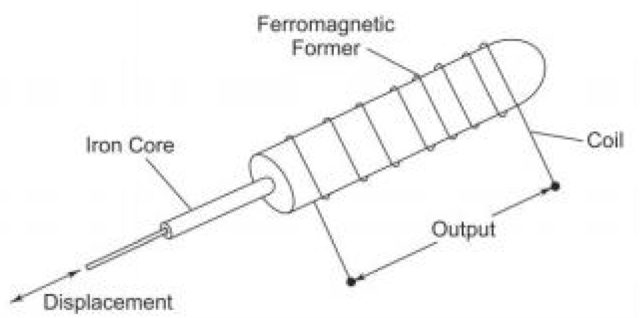


Fig. 13.15 Inductive transducer working on the principle of variation of permeability

iii. Variable Reluctance Type Transducer

A transducer of the variable type consists of a coil wound on a ferromagnetic core. The displacement which is to be measured is applied to a ferromagnetic target. The target does not have any physical contact with the core on which it is mounted. The core and the target are separated by an air gap, as shown in Fig. 13.16(a)

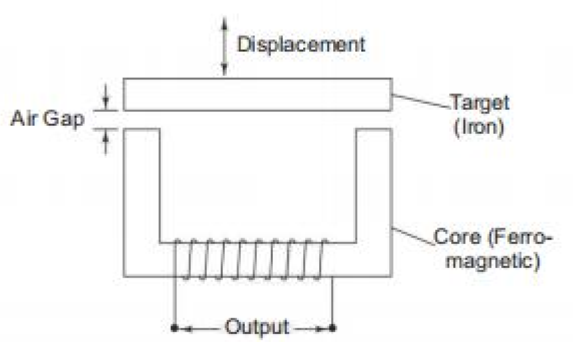


Fig. 13.16 (a) Variable reluctance transducer

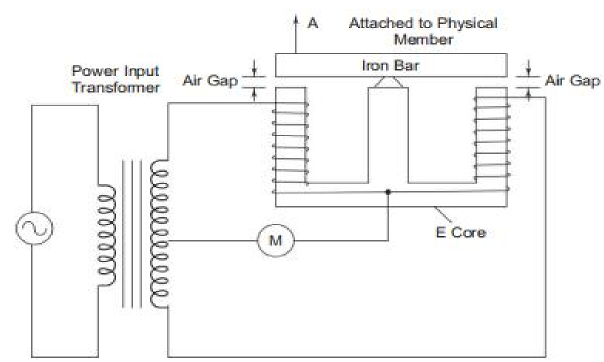


Fig. 13.16 (b) Variable reluctance bridge circuit

The reluctance of the magnetic path is determined by the size of the air gap. The inductance of the coil depends upon the reluctance of the magnetic circuits. The self inductance of the coil is given by

$$L = \frac{N^2}{R_i + R_g}$$

where N = number of turns

R_i = reluctance of iron parts

R_g = reluctance of air gap

The reluctance of the iron part is negligible compared to that of the air gap.

$$L = N^2/Rg$$

But reluctance of the air gap is given by

$$R_g = \frac{l_g}{\mu_o \times A_g}$$

where l_g = length of the air gap

A_g = area of the flux path through air

μ_o = permeability

R_g is proportional to l_g, as mo and A_g are constants.

Hence L is proportional to $1/l_g$, i.e. the self inductance of the coil is inversely proportional to the length of the air gap. When the target is near the core, the length is small and therefore the self inductance large. But when the target is away from the core the reluctance is large, resulting in a smaller self inductance value. Hence the inductance of the coil is a function of the distance of the target from the core, i.e. the length of the air gap. Since it is the displacement which changes the length of the air gap, the self inductance is a function of displacement, albeit a non-linear one. A variable reluctance bridge is shown in Fig. 13.16(b).

A separate coil is wound on each outside leg of an E core and an iron bar is pivoted on the centre leg. A magnet extends from each outside leg through an air gap and through the iron bar to the centre leg. The moving member is attached to one end of the iron bar and causes the bar to wobble back and forth, thereby varying the size of each air gap. The bridge consists of two transducer coils and a tapped secondary of the input power transformers. It is balanced only when the inductance of the two transducer coils are equal, i.e. when the iron bar is in a nearly exact horizontal position and the air gaps are equal.

Whenever the iron bar at point A moves and alters the air gap, the bridge becomes unbalanced by an amount proportional to the change in inductance, which in turn is proportional to the displacement of the moving member. The increase and decrease of the inductance with varying air gap sizes is nonlinear, and so is the output. Also, the flux density within the air gaps is easily affected by external fields.

CAPACITIVE DISPLACEMENT TRANSDUCER

A linear change in capacitance with changes in the physical position of the moving element may be used to provide an electrical indication of the element's position.

The capacitance is given by

$C = \varepsilon A / d$

where ε = the dielectric constant
A = the total area of the capacitor surfaces
d = distance between two capacitive surfaces
C = the resultant capacitance.
From this equation, it is seen that capacitance increases
(i) if the effective area of the plate is increased, and
(ii) if the material has a high dielectric constant.

The capacitance is reduced if the spacing between the plates is increased. Transducers which make use of these three methods of varying capacitance have been developed.

With proper calibration, each type yields a high degree of accuracy. Stray magnetic and capacitive effects may cause errors in the measurement produced, which can be avoided by proper shielding. Some capacitive dielectrics are temperature sensitive, so temperature variations should be minimised for accurate measurements. A variable plate area transducer is made up of a fixed plate called Stator and a movable plate called the Rotor. The rotor is mechanically coupled to the member under test. As the member moves, the rotor changes its position relative to the stator, thereby changing the effective area between the plates. A transducer of this type is shown in Fig. 13.29.

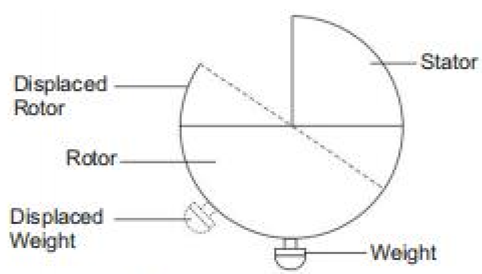


Fig. 13.29 Capacitive transducer

Such a device is used to detect the amount of roll in an aircraft. As the aircraft rolls to the left, the plates moves to the relative position shown by dashed lines in Fig. 13.29 and the capacitance decreases by an amount proportional to the degree of roll. Similarly to the right. In this case the stator, securely attached to the aircraft, is the moving element. The weight on the rotor keeps its position fixed with reference to the surface of the earth, but the relative position of the plates changes and this is the factor that determines the capacitance of the unit. Figure 13.30 shows a transducer that makes use of the variation in capacitance resulting from a change in spacing between the plates. This particular transducer is designed to measure pressure (in vacuum).

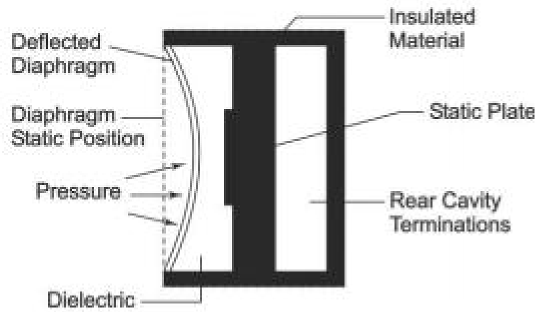


Fig. 13.30 Capacitive pressure transducer

Enclosed in an airtight container is a metallic diaphragm which moves to the left when pressure is applied to the chamber and to the right when vacuum is applied. This diaphragm is used as one plate of a variable capacitor. Its distance from the stationary plate to its left, as determined by the pressure applied to the unit, determines the capacitance between the two plates. The monitor indicates the pressure equivalent of the unit's capacitance by measuring the capacitor's reactance to the ac source voltage.

LINEAR VARIABLE DIFFERENTIAL TRANSFORMER (LVDT)

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

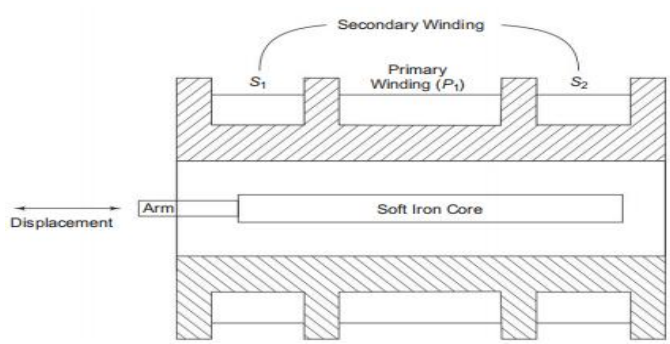


Fig. 13.19 Construction of a linear variable differential transformer (LVDT)

The transformer consists of a single primary winding P_1 and two secondary windings S_1 and S_2 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. 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. (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.

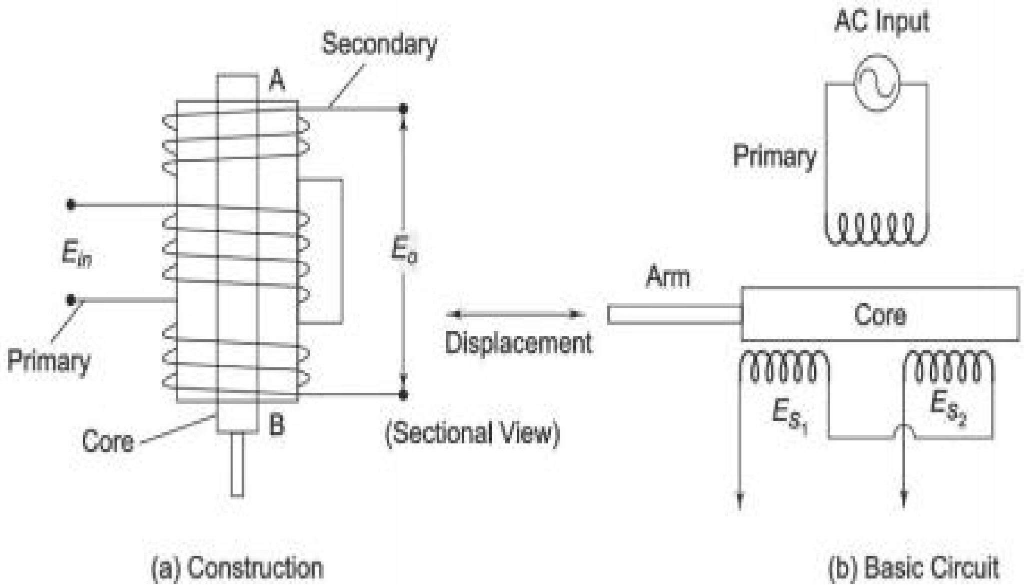


Fig. 13.20 Secondary winding connected for differential output

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_2 becomes 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}.

LOAD CELL TRANSDUCERS

The load cell is used to weigh extremely heavy loads. A length of bar, usually steel, is used as the active element. The weight of the load applies a particular stress to the bar. The amount of strain which results in the bar for different values of applied stress is determined, so that the strain may be used as a direct measure of the stress causing it.

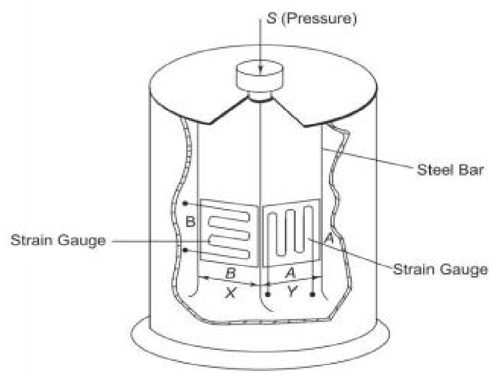


Fig. 13.31 Strain gauge load cell

The load cell shown in Fig. 13.31 is a good example of the use of strain gauges in weighing operations. As the stress is applied along the direction of S (shown by the arrow in Fig. 13.31), the steel bar experiences a compression along that axis and an expansion along the X and Y axes. As a result, gauge A experiences a decrease in resistance, while gauge B undergoes an increase in resistance. When these two gauges and the gauges on the two remaining sides of the steel are connected to form a bridge circuit, four times the sensitivity of a simple gauge bridge is obtained. This makes the load cell sensitive to very small values of applied stress, as well as to extremely heavy loads.

THERMOCOUPLE

One of the most commonly used methods of measurement of moderately high temperature is the thermocouple. When a pair of wires made up of different metals is joined together at one end, a temperature difference between the two ends of the wire produces a voltage between the two wires as illustrated in Fig. 13.42

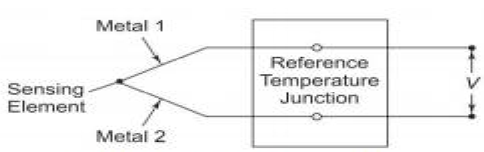


Fig. 13.42 Basic Thermocouple Connection

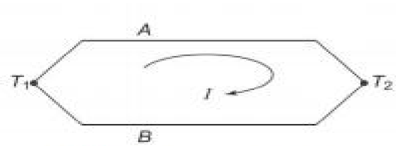


Fig. 13.43 Current through two dissimilar Metals

Temperature measurement with Thermocouple is based on the Seebeck effect. A current will circulate around a loop made up of two dissimilar metal when the two junctions are at different temperatures as shown in Fig. 13.43.

When the junction is heated a voltage is generated, this is known as *seebeck effect*. The seebeck voltage is linearly proportional for small changes in temperature. Various combinations of metals are used in Thermocouple's.

The magnitude of this voltage depends on the material used for the wires and the amount of temperature difference between the joined ends and the other ends. The junction of the wires of the thermocouple is called the sensing junction, and this junction is normally placed in or on the unit under test.

Since it is the temperature difference between the sensing junction and the other ends that is the critical factor, the other ends are either kept at a constant reference temperature, or in the case of very low cost equipment at room temperature. In the latter case, the room temperature is monitored and thermocouple output voltage readings are corrected for any changes in it.

Different Types of Thermocouples

Thermocouple type	*Materials used*	*Temperature range/ °C*	*Sensitivity µV/ °C*
Type T	Copper/Constantan	–200–400	15–60
E	Chromel/Constantan	0–850	40–55
J	Iron / Constantan	–200–900	45–57
K	Chromel/Alumel	–200–1250	40–55
R	Platinum/Platinum 13% Rhodium	0–1600	5–12
S	Platinum/Platinum 10% Rhodium	0–1500	5–12
B	Platinum 6% Rhodium/ Platinum 30% Rhodium	30–1800	0.3–0.8
G	Tungsten/Tungsten 26% Rhenium	15–2800	3–20
C	Tungsten 5% Rhenium/ Tungsten 25% Rhenium	0–2750	10–20

THERMISTOR

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 W to 10 MW. 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.

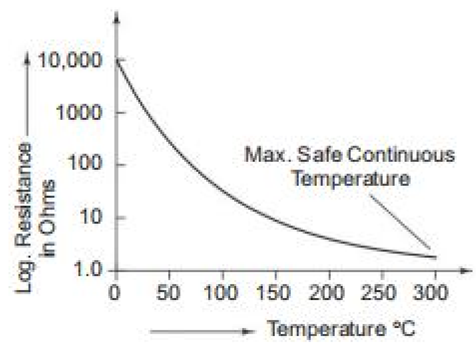


Fig. 13.12 Resistance vs temperature graph of a thermistor

Beads type thermistor are the smallest thermistors. 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 M**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 themistors 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 M**Ω**. 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 mm long. Leads are attached to the end of the rods. Their resistance usually varies from 1 – 50 kW. The advantage of rod thermistors over other configurations is the ability to produce high resistance units with moderately high power handling capability.

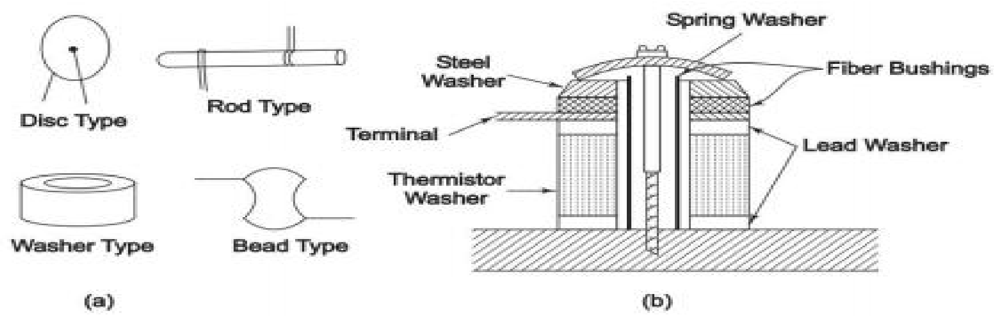


Fig. 13.13 (a) Various configurations of thermistor (b) Bush-type thermistor

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.

RADIATION PYROMETERS

When temperature being measured is very high and physical contact with the medium to be measured is impossible or impractical, optical pyrometers based on the principle of thermal radiation are used.

Radiation pyrometers measures the radiant (energy) heat emitted or reflected by a hot object. Thermal radiation is an electro magnetic radiation emitted as a result of temperature and lies in the wavelength of 0.1 –100 µm.

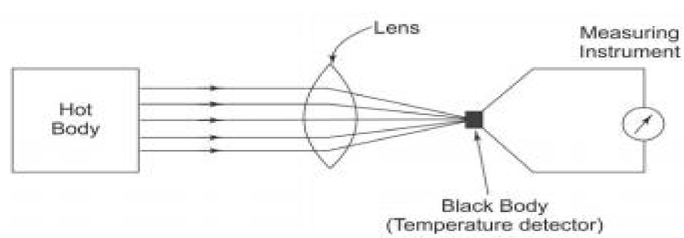


Fig. 13.55 Basic principle of pyrometer

Radiation pyrometers are of two types.

1. Total Radiation Pyrometers

2. Infrared Pyrometers

1. Total Radiation Pyrometer (TRP)

The total radiation pyrometer receives virtually all the radiation from a hot body and focuses on a hot body and focuses on a sensitive temperature transducer such as thermocouple, bolometer, thermopile, etc. Total radiation includes both visible and infrared radiation. The total radiation pyrometer consists of a radiation receiving element and a measuring device to indicate the temperature directly. Figure 13.56 shows a mirror type radiation pyrometer.

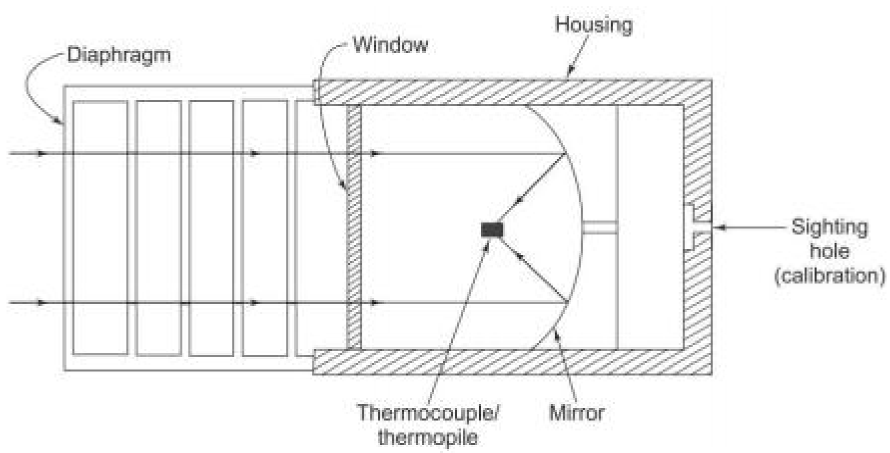


Fig. 13.56 Total radiation pyrometer

In this type of pyrometer, a diaphragm unit along with a mirror is used to focus the radiation on a radiant energy sensing transducers. The lens (mirror) to the transducer distance is adjusted for proper focus. The mirror arrangement has an advantage that since there is no lens, both absorption and reflection are absent. Presence of any absorbing media between the target and the transducers, reduces the radiation received and the pyrometer reads low. Due to the fourth Power Law (q is proportional to T4) the characteristics of total radiation pyrometer are non-linear and has poor sensitivity in lower temperature ranges. Therefore, total radiation pyrometers cannot be used for measurement of temperature lower than 600 °C, since errors are introduced at lower temperatures.

Hence, total radiation pyrometers are used mostly in the temperature range of 1200 °C – 3500 °C. The output from a total radiation pyrometers whether amplified or not, is usually taken to a PMMC instrument or to a self-balancing potentiometer. The output may be fed to a recorder or controller.

2. Infrared Pyrometers

Infrared pyrometers are partial or selective radiation pyrometers. Above temperatures of 550 °C, a surface starts to radiate visible light energy and simultaneously there is a proportional increase in the infrared energy. Infrared principles using thermocouples, thermopile and bolometers are used. Also various types of photo-electric transducers are most commonly used for infrared transducers. The most useful transducers used for industrial application are the Photo-voltaic cells. These cells used in radiation pyrometers, respond to wavelength in infrared region and may be used to measure temperature down to 400 °C.

The infrared radiation is focused on a photo-voltaic cell as shown in Fig. 13.57. It is necessary to ensure that the cell does not become overheated. The core of radiation passing to the cell is defined by the area of the first diaphragm.

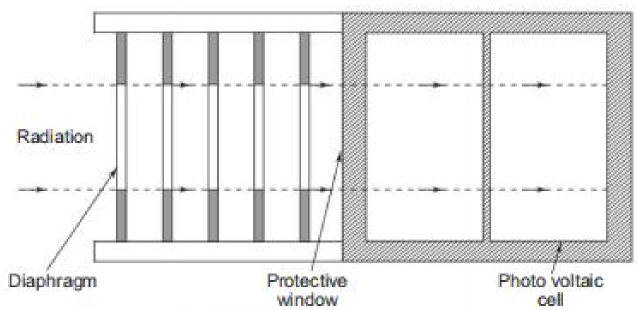


Fig. 13.57 Infrared pyrometer

The protective window is made of thin glass and serves to protect the cell and filter from physical damage. The filter is used on the range of 1000 °C to 1200 °C in order to reduce the infrared radiation passed to the photo cell. This help in preventing the photo cell from being overheated. All infrared systems depend on the transmission of the infrared radiant energy being emitted by a heated body to a detector in the measuring system.

The sensor head is focused on the object whose temperature is being measured and/ or controlled. The infrared energy falling on the detector either changes the detector resistance in proportion to the temperature as in the case of thermister or generates an emf in the detector such as a thermopile. The change in resistance or generated emf is then indicated on a meter.