Unit II : Transducers
Module Name: Temperature Transducer: Thermocouple, Thermistor, RTD
Module No : 16

TEMPERATURE TRANSDUCERS

Temperature is one of the most widely measured and controlled variable in industry, as a lot of products during manufacturing requires controlled temperature at various stages of processing. A wide variety of temperature transducers and temperature measurement systems have been developed for different applications requirements.

Most of the temperature transducers are of Resistance Temperature Detectors (RTD), Thermistors and Thermocouples. Of these RTD's and Thermistor are passive devices whose resistance changes with temperature hence need an electrical supply to give a voltage output.

On the other hand thermocouples are active transducers and are based on the principle of generation of thermoelectricity, when two dissimilar metals are connected together to form a junction called the sensing junction, an emf is generated proportional to the temperature of the junction. Thermocouple operate on the principle of seeback effect. Thermocouple introduces errors and can be overcomed by using a reference junction compensation called as a cold junction compensation. They have the highest speed of response. Thermocouples can be connected in series/parallel to obtain greater sensitivity called a Thermopile.

RTD commonly use platinum, Nickel or any resistance wire whose resistance varies with temperature and has a high intrinsic accuracy. Platinum is the most widely used RTD because of its high stability and large operating range. RTD's are usually connected in a Wheatstones bridge circuit. The lead wire used for connecting the RTD's introduces error, hence compensation is required.

A thermistor is a thermally sensitive resistor that exhibits change in electrical resistance with change in temperature. Thermistors made up of oxides exhibit a negative temperature coefficient (NTC), that is, their resistance decreases with increase in temperature. Thermistor are also available with positive temperature coefficient (PTC), but PTC thermistor are seldom used for measurement since they have poor sensitivity. Thermistors are available in various sizes and shapes such as beads, rods, discs, washers and in the form of probes.

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. Thermistors can be connected in series/parallel combinations for applications requiring increased power handling capability. 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. 1. The advantage of rod thermistors over other configurations is the ability to produce high resistance units with moderately high power handling capability.

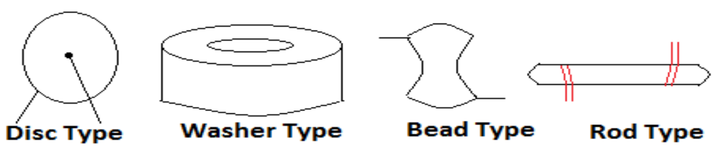

Fig 1. Different types of Thermistors

Advantages of Thermistor

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 Rth (resistance).

Limitations of Thermistor

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.

Resistance Temperature Detector (RTD)

Resistance temperature detector commonly use platinum, nickel or any resistance wire whose resistance varies with temperature and which has a high intrinsic accuracy. They are available in many configuration and sizes; as shielded or open units for both immersion and surface applications. The relationship between temperature and resistance of conductors in the temperature range near 0°C can be calculated using the equation (1).

$R_t = R_{ref}\ (1+ \alpha\ \Delta t)$ (1)

where Rt = resistance of conductor at temperature t°C

Rref = resistance of the reference temperature, usually 0°C

α = temperature coefficient of resistance

Δ t = difference between operating and reference temperature

Almost all metals have a positive temperature coefficient (PTC) of resistance, so that their resistances increases with increase in temperature. Some materials, such as Carbon and Germanium have a negative temperature coefficient (NTC) of resistance. A high value of ‘α’ is desired in a temperature sensing element, so that sufficient change in resistance occurs for a relatively small change in temperature. This change in resistance (ΔR) can be measured with a Wheatstone’s bridge which can be calibrated to indicate the temperature, that caused the resistance change rather than the resistance itself. The sensing element of the RTD is selected according to the intended applications. RTD’s are wire-wound resistance with moderate resistance and a PTC of resistance. Platinum is the most widely used resistance wire type because of its high stability and large operating range. However, Nickel and Copper are also used in RTDs.

Advantages of Platinum RTDs:

1. Linearity over a wide operating range.
2. Wide operating range
3. Higher temperature operation
4. Better stability at high temperature

Disadvantages of RTD

1. Low sensitivity
2. It can be affected by contact resistance, shock and vibration
3. Requires no point sensing
4. Higher cost than other temperature transducers

Thermocouple

One of the most commonly used methods of measurement of moderately high temperature is the thermocouple effect. 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. 2.

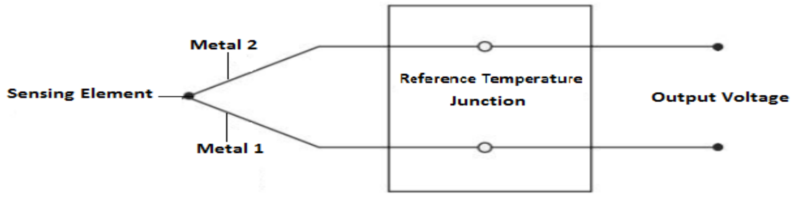

Fig 2 Basic Thermocouple Connection.

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. 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 and the junction is called the cold junction.
A thermocouple, therefore consists of a pair of dissimilar metal wires joined together at one end (sensing or hot junction) and terminated at the other end (reference or cold junction), which is maintained at a known constant temperature (reference temperature). When a temperature difference exists between the sensing junction and the reference junction, an emf is produced, which causes current in the circuit. When the reference end is terminated by a meter or a recording device, the meter indication will be proportional to the temperature difference between the hot junction and the reference junction. The magnitude of the thermal emf depends on the wire materials used and in the temperature difference between the junctions.

Advantages

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
5. No Contact and lead resistance problems
6. It has rugged construction.
7. It has a temperature range from –270 °C–2700 °C.
8. Bridge circuits are not required for temperature measurement.
9. Comparatively cheaper in cost.
10. Speed of response is high compared to the filled system thermometer.
11. Measurement accuracy is quite good.

Disadvantages

1. Cold junction and other compensation is essential for accurate measurements.
2. They exhibit non-linearity in the emf versus temperature characteristics.
3. To avoid stray electrical signal pickup, proper separation of extension leads from thermocouple wire is essential.
4. Stray voltage pick-up are possible.
5. In many applications, the signals need to be amplified.