Welcome To Computer Science HUB

CS HUB

Radiation

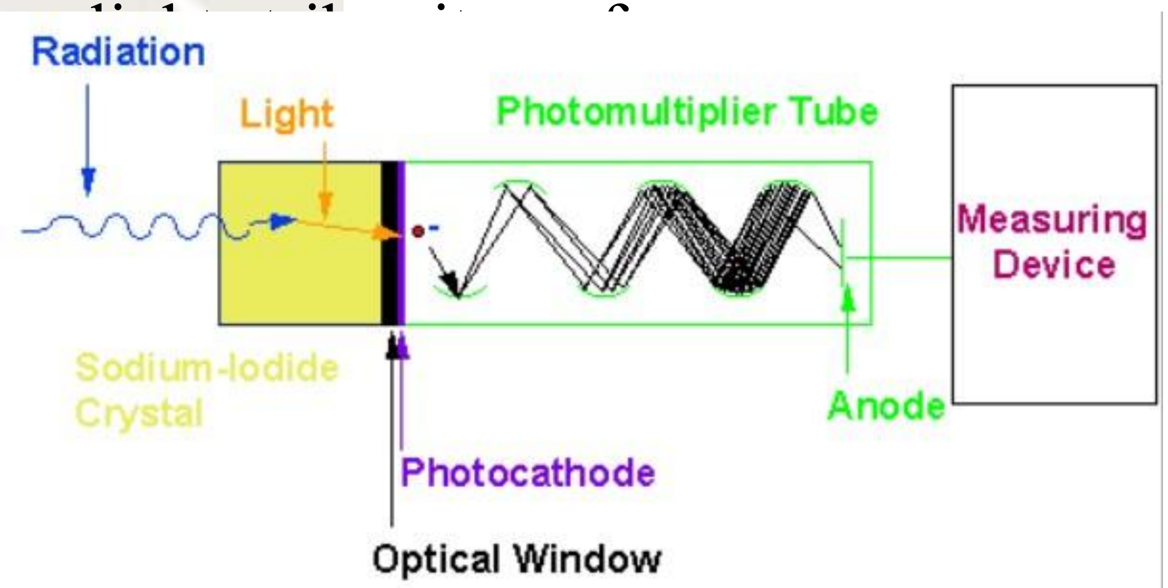
- Radiation is the emission of energy from matter in the form of rays or high-speed particles.
- Broadly, radiation can be characterized as being of two primary classes:
- 1)Electromagnetic radiation, which can be thought of as emission of pure energy. Examples of electromagnetic radiation include radio waves, cosmic radiation (sunlight), or X-rays.
- 2)Particle radiation, which involves the emission of fast-moving particles that have both energy and mass associated with its release. This form of radiation many include alpha particles, beta particles, or neutrons, for example.

Radiation Sensors

- Radiation Sensors or Radiation Detectors or particles detector are devices that can sense and measure radiation.
- It measures the ionization of many types of radiation like beta radiation, gamma radiation, and alpha radiation.
- The radiation detector is an instrument used to detect or to identify high-energy particles such as those produced by nuclear decay, cosmic radiation, or reactions in particle acceleration.
- Depending on the specific needs of the device , common Types of Radiation Sensors are
- Gas-filled radiation detectors.
- Scintillation radiation detectors.
- Solid-state radiation detector.

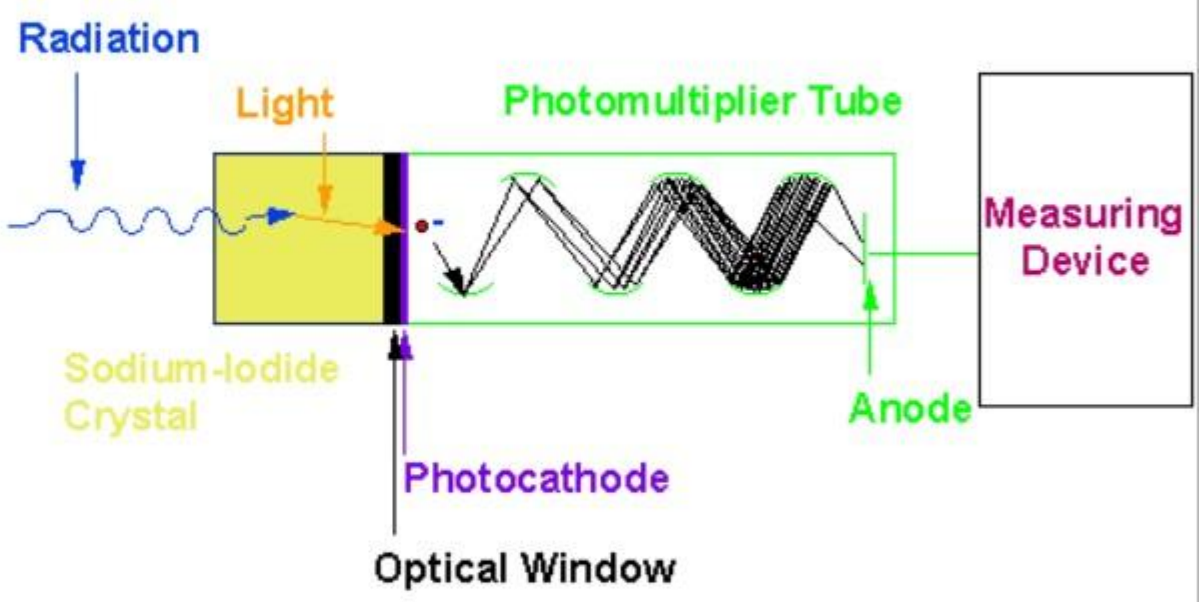
Scintillation detectors

- The basic principle behind this instrument is the use of a special material that glows or "scintillates" when radiation interacts with it.
- The most common type of material is a type of salt called sodium-iodide.
- The light produces from the scintillation process is reflected through a clear window where it interacts with a device called a photomultiplier tube.
- The first part of the photomultiplier tube is made of a photocathode.
- The photocathode produces electrons wh
- These electrons pulled towards a series of plates called anode through the application of a positive high voltage.



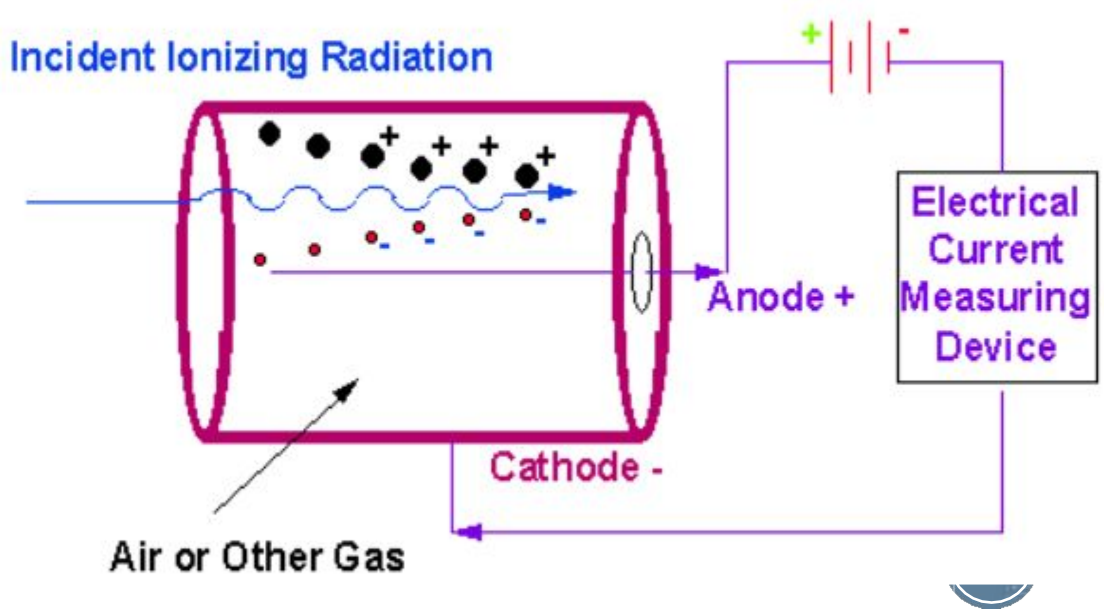
Scintillation detectors

- When an electron from the photocathode hits the first anode, several electrons are produced for each initial electron hitting its surface.
- This "bunch" of electrons is pulled toward the next anode, where more electron's multiplication takes place.
- The sequence continues until the last anode is reached, where the electron pulse is now millions of times larger than it was at the beginning of the tube.
- At this point, the electrons are collected by an anode at the end of the tube forming an electronic pulse.
- The pulse is then detected and displayed by the instrument.



Gas filled ionization detector

- When the gas in the detector comes in contact with radiation, it reacts, with the gas becoming ionized and the resulting electronic charge is measured by a meter.
- The instrument works on the principle that as the radiation passes through air or a specific gas, ionization of the molecules in the air occurs.
- When a high voltage is placed between two areas of the gas-filled space, the positive ions will be attracted to the negative side of the detector (the cathode) and the free electrons will travel to the positive side
- These charges are collected by the anode and cathode which then form a very small current in the wires from the cathode and anode, the small current has displayed a signal.
- The more radiation enters the chamber, the more current is displayed by the instrument.



Gas filled ionization detector

- The different types of gas-filled detectors are

- Ionization chambers
- Proportional counters
- Geiger-Mueller (G-M) tubes

Solid state detector

- Solid state detector, also known as Semiconductor Radiation Detector is a radiation detector in which the detecting medium is a solid state detector (semiconductor) material such as a silicon or germanium crystal.
- As a beam of ionizing radiation passes through the device, it creates a p-n junction, which generates a current pulse.
- A semiconductor device like silicon contains two materials, n-type and p-type.
- The n-type semiconductor material has electrons as majority carriers and the p-type has holes(positively charged) as majority carriers.
- When these two are joined, electrons from the n-region migrate to the p-region creating a depletion region between them.
- When radiation hits the depletion region, free electron-hole pairs are created.
- These charge carriers travel within the detector and the current pulse

Resistance Temperature Detectors [RTD]

Thermal sensors

A12- Sensors and Transducers

Unit II [16 T]

- Thermal sensors: Resistance change type: RTD - materials, types, working principle
- Thermistor- materials, working principle
- Thermo emf sensors: Thermocouple – Principle and types
- IR Radiation sensors: Principle and types

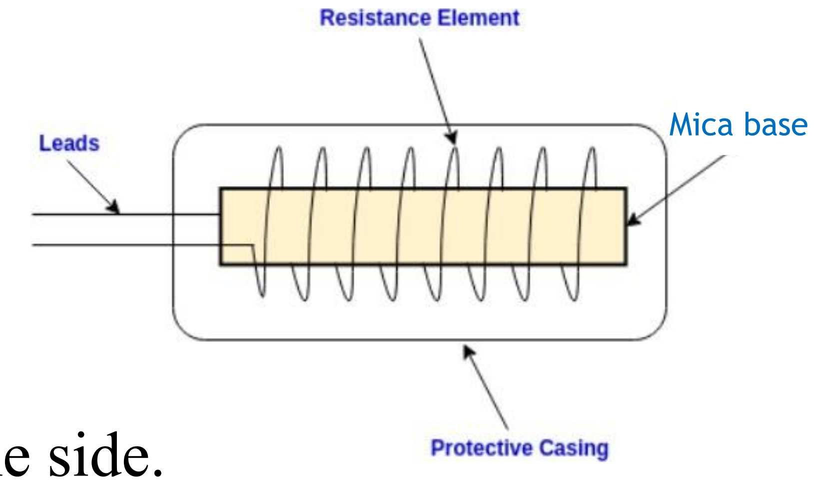
Thermal sensors

- It is an electronic device that measures the temperature of its environment and converts the input data into electronic data to record, monitor, or signal temperature changes.
- There are two basic types of temperature sensing:
- **Contact** temperature sensing requires the sensor to be in direct physical contact with the media or object being sensed.
- It can be used to monitor the temperature of solids, liquids or gases over an extremely wide temperature range.
- **Non-contact** measurement uses radiation to detect temperature changes..
- There are a wide variety of temperature sensors on the market today, including Thermocouples, Resistance Temperature Detectors (RTDs), Thermistors, Infrared, and Semiconductor Sensors.

Resistance Temperature Detectors [RTD]

- A Resistance Temperature Detector (also known as a Resistance Thermometer or RTD) is an electronic device used to determine the temperature by measuring the resistance of a mechanical wire.
- This wire is referred to as a temperature sensor whose resistance varies with temperature.
- When the temperature changes resistance of a conductor changes . This property is used to measure temperature in RTD
- If we want to measure temperature with high accuracy, an RTD is the ideal solution, as it has good linear characteristics over a wide range of temperatures.
- Resistance thermometers are often used in applications that call for the measurement of very high temperatures

Structure



- The resistance temperature detector is constructed by wounding the resistance wire on a mica base.
- The wire is wound like a helical coil on the support to reduce the inductance effect
- Both terminals of the wire are brought out of the pipe at the same side.
- The coil is protected by a stainless steel case
- Copper, Nickel and Platinum are the most used RTD materials.
- These metals have positive temperature co-efficient and possess poor thermal sensitivity.
- Also, the resistance-temperature characteristics of these materials are approximately linear.
- Mostly, platinum is used in resistance thermometer.
- The platinum has high stability, and it can withstand high temperature

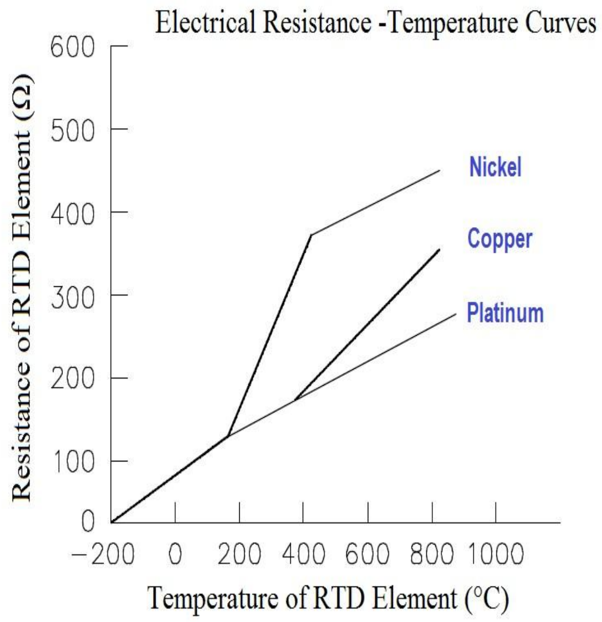
Working Principle

- The RTD device works on the principle that the resistance of a conductor changes due to a change in temperature.
- resistance ,$R = \rho\, l / a$
- Where, R = Resistance of the wire,ρ = Resistivity of the material,

  l = length of wire,a = cross-sectional area of the wire
- Resistivity ρ depends on the type of material as well as its temperature.
- Since the length & the area of the wire remains constant throughout RTD operation, the resistance becomes the function of only temperature.
- Therefore the resistance of a metal at a given temperature 't' is given by
- $R_t = R_o (1 + \alpha t)$
- Where Rt = Resistance at temperature t , Ro = Resistance at a reference temperature
- α = coefficient of temperature
- The resistance value depends on α, the coefficient of temperature.
- It is different for different metals. Therefore such metals are best suited for the RTD element that has the highest α value.

Types of Material used in RTD Construction

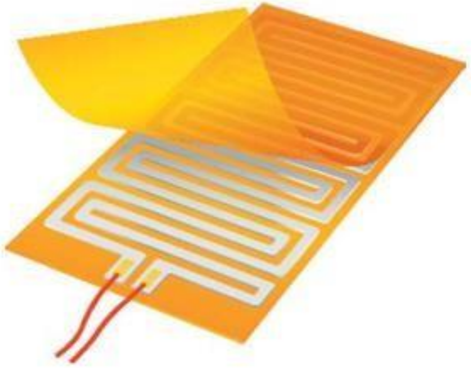
- The RTD element consists of a pure metal whose electrical resistance is directly proportional to the change in temperature
- The resistance is converted into a voltage signal that represents the proportional temperature value.
- Almost every conductor shows a change in resistance as its temperature changes.
- However, they are not that significant due to their low temperature coefficient.
- But there are certain metals that show properties that offer best performance and linear characteristics.
- They must possess the following characteristics to be used as an RTD element.
- It must have high temperature coefficient to provide high resistance change per degree of temperature.
- It must have a linear relationship between temperature and resistance.
- It must provide repeatability i.e. its resistance must not change for the same temperature over a span of time.
- It must be durable.
- It must be able to withstand the temperature that is being measured.



Types of RTDs based on Construction

- **Thin film RTD**

- Thin film RTD element is made by depositing a thin layer of the temperature sensitive material such as nickel, platinum & copper on the insulating substrate.
- The material is carved into a pattern to meet the required temperature.
- The terminals are then attached to the element & a protective sheath covers the element to protect it.
- The thin-film RTD has wide applications in automobiles, medical ther process plant instrumentation

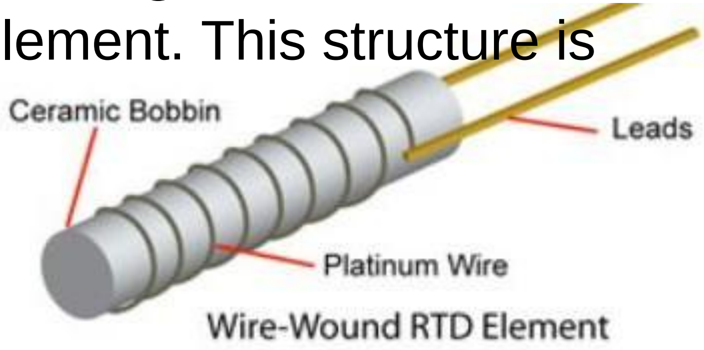


ADVANTAGES:
1. Fast response
2. Accurate temperature sensitivity [Temp rages between -0.12% to +0.12%]

Types of RTDs based on Construction

- **Wire wound RTD**

- The element of wire wound RTD is made of a helical coil. It is the most commonly used design type.
- The wire wound element can be constructed in two types.
- The most common design type is that the wound element is packaged inside the insulating as well as the protective sheath. The insulating material ceramic is used.
- The other type has the element wound around an insulating core with an additional insulating material used for covering the element. This structure is used for special purpose applications.



Advantages

- It can operate at a wide range of temperatures.
- Its readings are consistent and highly repeatable at high temperature.
- They are resistant to corrosion & best for extreme environments.
- It has more linear characteristics.
- It has excellent accuracy over a wide range of temperatures.
- It is stable & has a longer life span at high temperature measurement.
- The RTD is constructed, installed, and replaced easily.
- It can measure differential temperature.

Disadvantages

- It requires a current source.
- Its accuracy depends on the battery’s health.
- Heat is generated in the element (self-heating) which inflicts error in the measurement thus affecting the accuracy.
- It has a large size, therefore, unable to sense temperature at small points.
- It is affected by physical shock and vibration.
- It has a limited temperature operating range as compared to thermocouple.
- It has a higher initial cost as compared to thermocouple.
- It has complex operating circuitry or signal conditioning unit.
- It requires an external circuit to operate such as a bridge circuit with a power supply.
- It has low sensitivity & slower response time.

Applications

- It is used in applications where temperature control is important.
- It is used in remote areas where it is difficult to get access.
- It is used to measure the temperature of the engine & the air intake in automotive.
- In different industrial processes such as food handling and manufacturing, it is used to monitor the temperature.
- In different power electronics, medical & military electronics use RTD.
- It is also used in multiple communication and instrumentation for temperature measurement.

Thermal Resistor[Thermistor]

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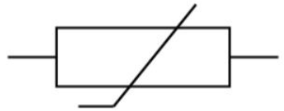
Thermistors

- A thermistor (or thermal resistor) is defined as a type of resistor whose electrical resistance varies with changes in temperature.
- Although all resistors’ resistance will fluctuate slightly with temperature, a thermistor is particularly sensitive to temperature changes
- Thermistors are an accurate, cheap, and robust way to measure temperature.
- Commonly used circuit symbol is

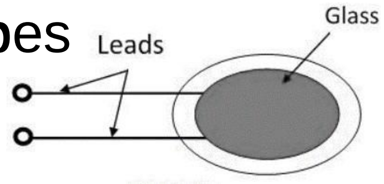


Construction

- To make a thermistor, two or more semiconductor powders made of metallic oxides ike manganese, cobalt, nickel, cobalt, copper, iron, uranium, etc are mixed with a binder to form a slurry.
- Small drops of this slurry are formed over the lead wires.
- For drying purposes, they are put it into a sintering furnace.
- During this process, the slurry will shrink onto the lead wires to make an electrical connection.
- This processed metallic oxide is sealed by putting a glass coating on it. This glass coating gives a waterproof property to the thermistors helping to improve their stability.
- They are available in the form of the bead, rod and disc

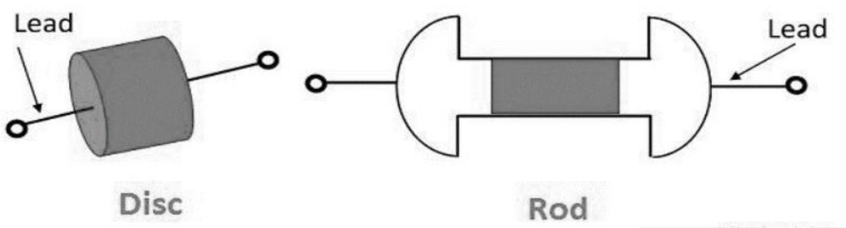
Construction

- **The bead** form of the thermistor is smallest in shape with a diameter from 0.15 millimeters to 1.5 millimeters, and it is enclosed inside the solid glass rod to form probes



0.15mm to 1.5 mm

- **The disc** shape is made by pressing material under high pressure with diameter range from 2.5 mm to 25mm.

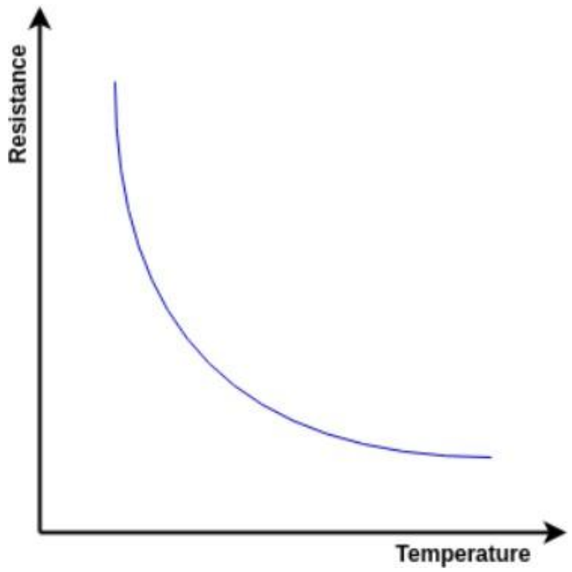
- 

Working Principle of Thermistors

- The thermistor works on the simple principle of change in resistance due to a change in temperature.
- When the ambient temperature changes the thermistor starts self-heating its elements.
- Its resistance value is changed with respect to this change in temperature.
- This change depends on the type of thermistor used.

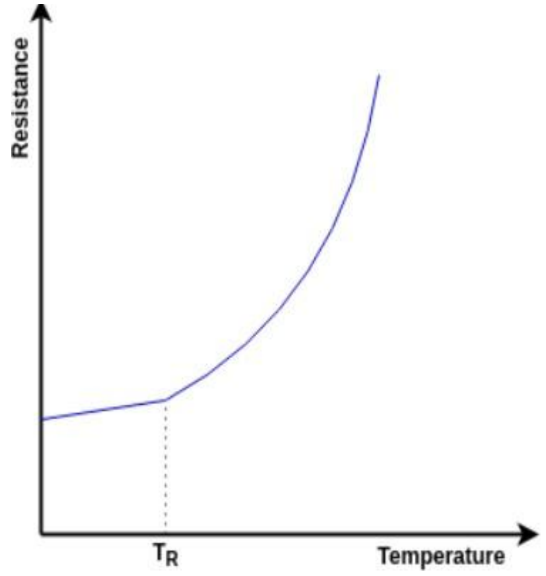
TYPES

- There are two types of thermistors:
  - Negative Temperature Coefficient (NTC) Thermistor
  - Positive Temperature Coefficient (PTC) Thermistor
- **NTC**
- They are ceramic semiconductors that have a high Negative Temperature Coefficient of resistance.
- The resistance of an NTC will decrease with increasing temperature in a non-linear manner.
- These are the most common type of thermistor
- The resistance of the negative temperature coefficient thermistor is very large due to which it detects the small variation



Types

- **PTC**
- PTC thermistors are Positive Temperature Coefficient resistors and are made of polycrystalline ceramic materials.
- The resistance of a PTC will increase with increasing temperature in a non-linear manner.
- The PTC thermistor shows only a small change of resistance with temperature until the switching point(TR) is reached.
- Although PTC thermistors are not as common as NTC thermistors, they are frequently used as a form of circuit protection.
- Similar to the function of fuses, PTC thermistors can act as current-limiting device.



Pros & Cons of thermistors

- **Pros**
- The thermistor is compact, long durable and less expensive.
- The properly aged thermistor has good stability.
- Fast response.
- **Cons**
- Limited Temperature range.
- Resistance to temperature ratio correlation is non-linear.
- An inaccurate measurement may be obtained due to the self-heating effect.
- Fragile.

Applications of thermistors

- **NTC Thermistor Application**
- Digital Thermostats.
- Thermometers.
- Battery pack temperature monitors.
- In-rush-current limiting devices
- **PTC Thermistor Application**
- Over-current protection
- In-rush-current protection

Thermocouple

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A12- Sensors and Transducers

Thermocouple

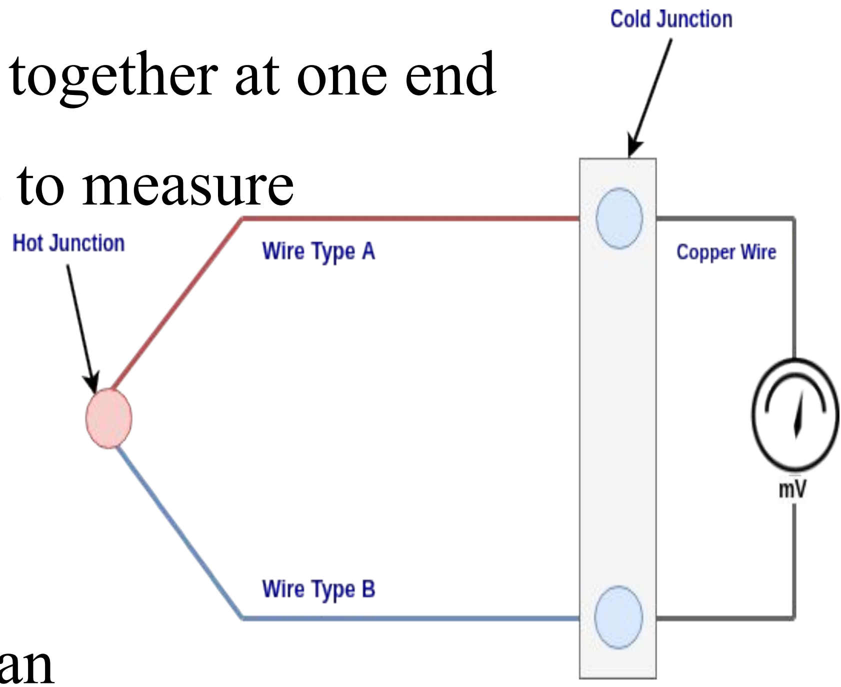
- A thermocouple is an active transducer that measures temperature
- It is used for measuring the temperature at one particular point.
- In other words, it is a type of sensor used for measuring the temperature in the form of an electric current or the EMF.
- A thermocouple can measure a wide range of temperatures.
- It is a simple, robust, and cost-effective temperature sensor used in various industrial applications, home, office, and commercial applications.

Working Principle

- The thermocouple works on the principle of seebeck effect.
- Thomas Johan Seebeck discovered that temperature difference(thermal energy) can produce electrical energy.
- In a thermocouple, two conductors of different type of metals are connected forming two common junctions.
- When these two junctions are exposed to two different temperatures, a net thermal emf is produced.
- The value also depends on the materials used and is proportional to the temperature difference between hot and cold junctions.
- The output of a thermocouple can be measured directly by a millivoltmeter.
- It can be also measured with the help of a dc potentiometer or using amplifiers with an output device.

Construction

- A thermocouple consists of two different types of metals joined together at one end
- The junction is placed on the element or surface where we want to measure the temperature. This junction is known as a hot junction.
- And the second end of the plate is kept at a lower temperature (room temperature). This junction is known as cold junction or reference junction
- When the hot junction is heated or cooled, a voltage created can be correlated back to the temperature.
- According to the Seebeck effect, the temperature difference between the two different metals induces the potential differences between two points of the thermocouple plates.
- If the circuit is closed, a very small amount of current will flow through the circuit. A voltmeter is connected in the circuit. The voltage measured by the voltmeter is a function of a temperature difference between two junctions.



Types of Thermocouples

- According to different types of combinations of alloys, the thermocouples are available in different types.
- The type of thermocouple is chosen according to the application, cost, availability, stability, chemical properties, output, and temperature ranges

TYPE	POSITIVE LEAD	NEGATIVE LEAD	TEMPERATURE RANGE
R	Platinum-Rhodium (87% Pt,13% Rh)	Platinum	0 – 1500 oC
S	Platinum-Rhodium (90% Pt, 10% Rh)	Platinum	0 – 1500 oC
K	Chromel (90%Ni, 10% Cr)	Alumel (Ni94Al2Mn3Si)	-200 – 1300 oC
E	Chromel (90%Ni, 10% Cr)	Constantan (57% Cu, 43% Ni)	-200 – 1000 oC
T	Copper	Constantan (57% Cu, 43% Ni)	-200 – 350 oC
J	Iron	Constantan (57% Cu, 43% Ni)	-150 – 750 oC

Pros & Cons

- **Pros**
- Cheaper than resistance thermometers.
- Can measure rapid changes in temperature.
- Wide temperature range.
- Offers good reproducibility.
- Fast response time
- Convenient for measuring the temperature at one particular point.
- **Cons**
- Lower accuracy.
- The induced emf-temperature characteristics are non-linear.
- Signal amplification is required in many applications.

Applications

- It is used to monitor the temperature in the steel and iron industries.
- It is used in the temperature sensors in thermostats to measure the temperature of the office, showrooms, and homes.
- The thermocouple is used to detect the pilot flame in the appliances that are used to generate heat from gas like a water heater.
- To test the current capacity, it is installed to monitor the temperature while testing the thermal stability of switchgear equipment.
- The number of thermocouples is installed in the chemical production plant and petroleum refineries to measure and monitor temperature at different stages of the plant.

Thank You !!