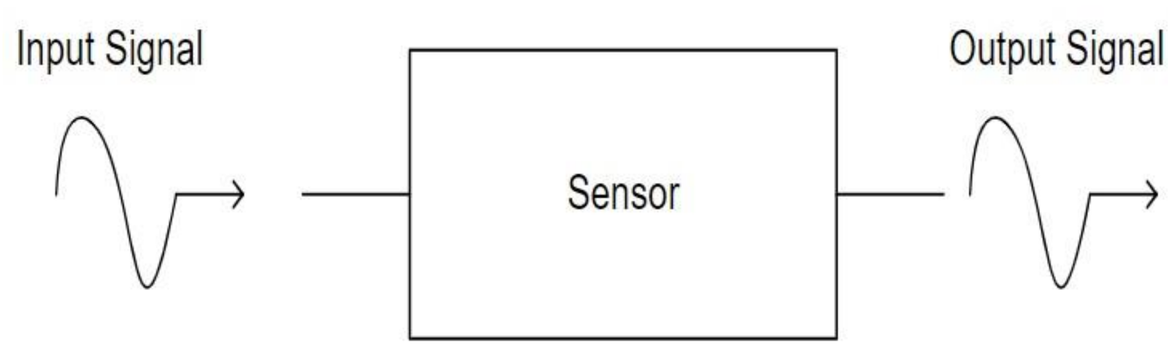
Sensors

What are Sensors?

Sensor is a device which provides a usable output in response to a specified measurand.

Here, the output is usually an ‘electrical quantity’ and measurand is a ‘physical quantity, property or condition which is to be measured.



Need for Sensors

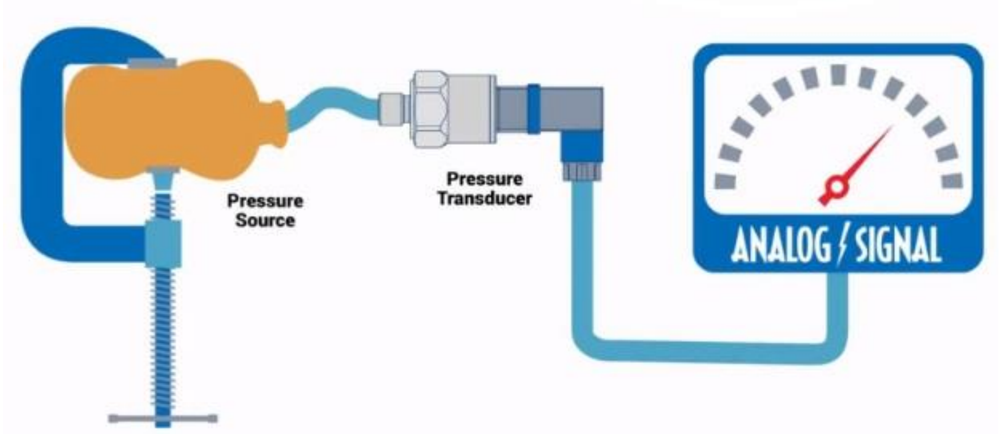
- Sensors are omnipresent. They embedded in our bodies, automobiles, airplanes, cellular telephones, radios, chemical plants, industrial plants and countless other applications.

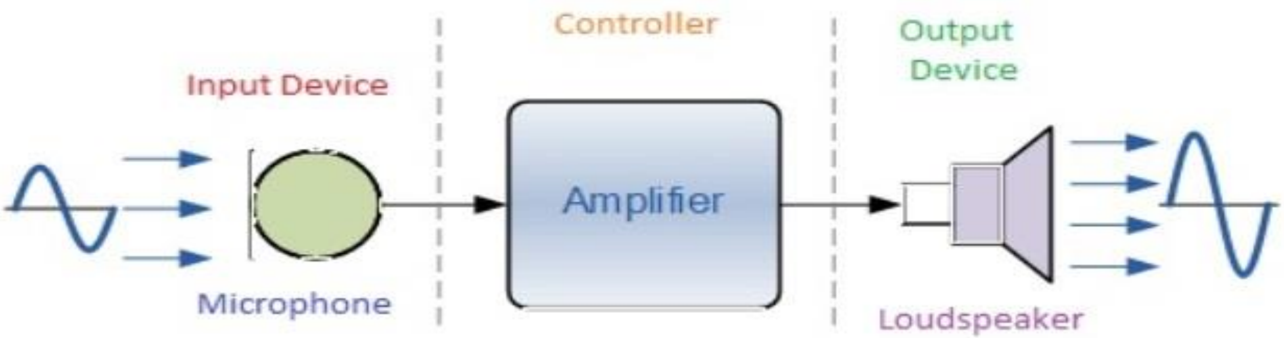
- Without the use of sensors, there would be no automation !!

Transducer

It is defined as an element when subjected to some physical change experiences a related change or an element which converts a specified measurand into a usable output by using a transduction principle.

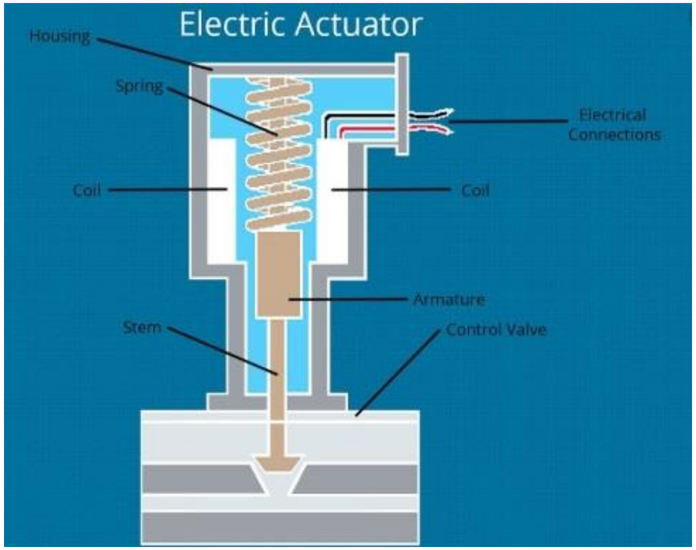
It can also be defined as a device that converts a signal from one form of energy to another form.

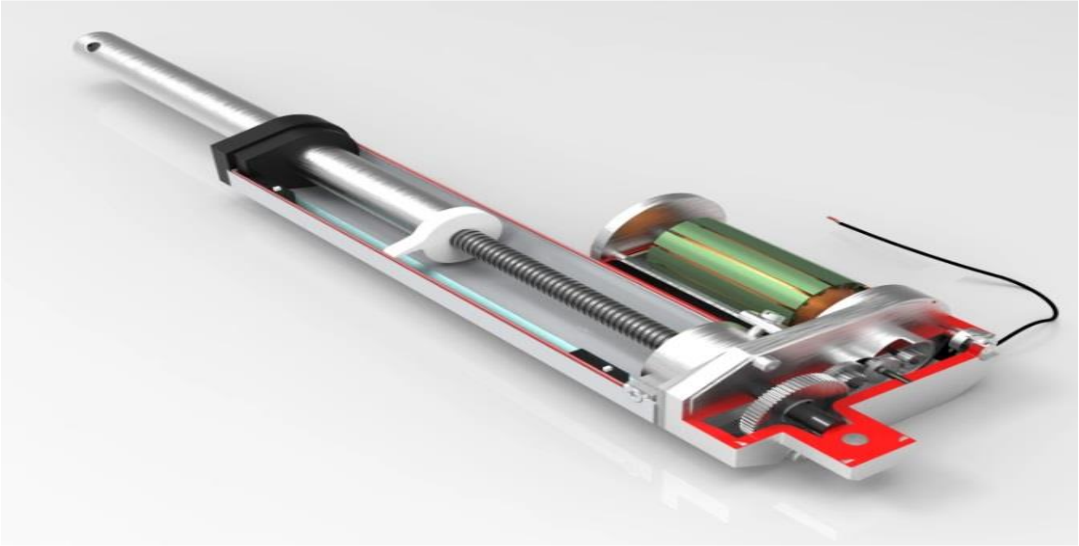


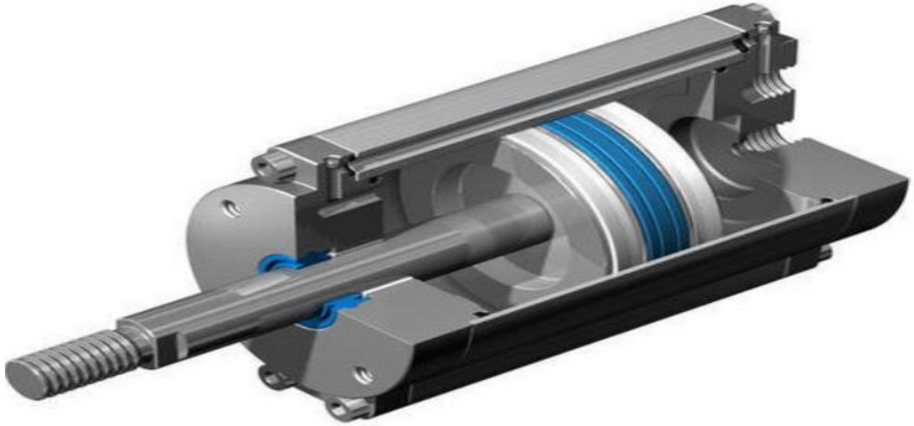


Actuator

An **actuator** is a component of a machine that is responsible for moving and controlling a mechanism or system.







Detectable Phenomenon

Stimulus	Quantity
Acoustic	Wave (amplitude, phase, polarization), Spectrum, Wave Velocity
Biological & Chemical	Fluid Concentrations (Gas or Liquid)
Electric	Charge, Voltage, Current, Electric Field (amplitude, phase, polarization), Conductivity, Permittivity
Magnetic	Magnetic Field (amplitude, phase, polarization), Flux, Permeability
Optical	Refractive Index, Reflectivity, Absorption
Thermal	Temperature, Flux, Specific Heat, Thermal Conductivity
Mechanical	Position, Velocity, Acceleration, Force, Strain, Stress, Pressure, Torque

Characteristics of Sensor

1.Range

The range of a sensor indicates the limits between which the input can vary.

For example, a thermocouple for the measurement of temperature might have a range of 25 - 225 °C.

2. Span

The span is difference between the maximum and minimum values of the input.

Thus, the above mentioned thermocouple will have a span of 200 °C.

3. Error

Error is the difference between the result of the measurement and the true value of the quantity being measured.

A sensor might give a displacement reading of 29.8 mm, when the actual displacement had been 30 mm, then the error is – 0.2 mm.

4. Accuracy

The accuracy defines the closeness of the agreement between the actual measurement result and a true value of the measurand.

It is often expressed as a percentage of the full range output or full scale deflection.

For e.g. ±1% of full scale,

5. Sensitivity

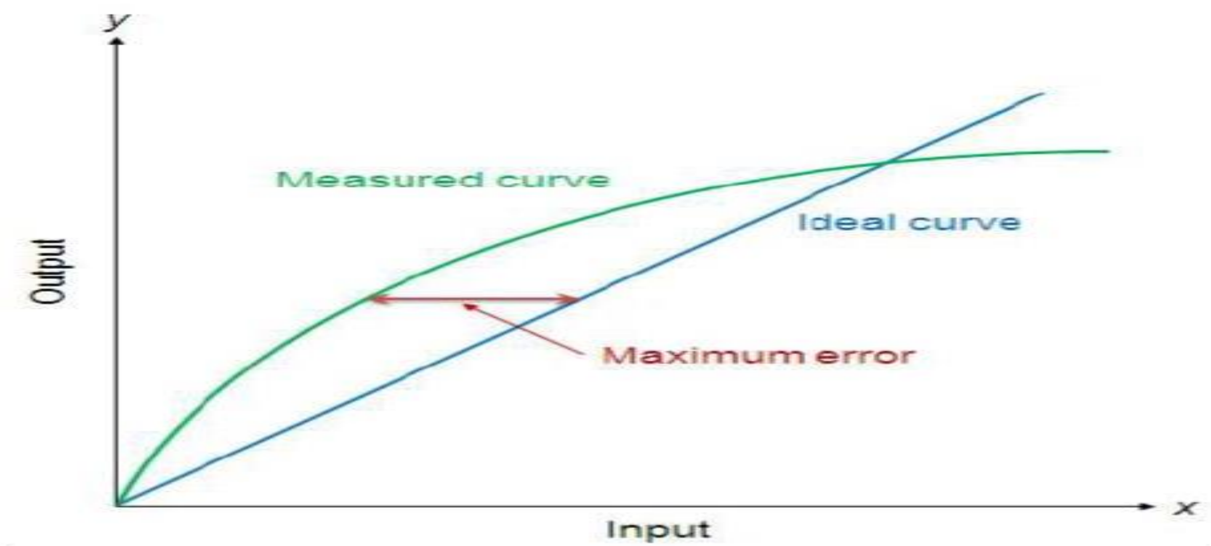
Sensitivity of a sensor is defined as the ratio of change in output value of a sensor to the per unit change in input value that causes the output change.

For example, a general purpose thermocouple may have a sensitivity of 41 µV/°C

6. Non linearity: The nonlinearity indicates the maximum deviation of the actual measured curve

Percentage of nonlinearity, which is defined as:

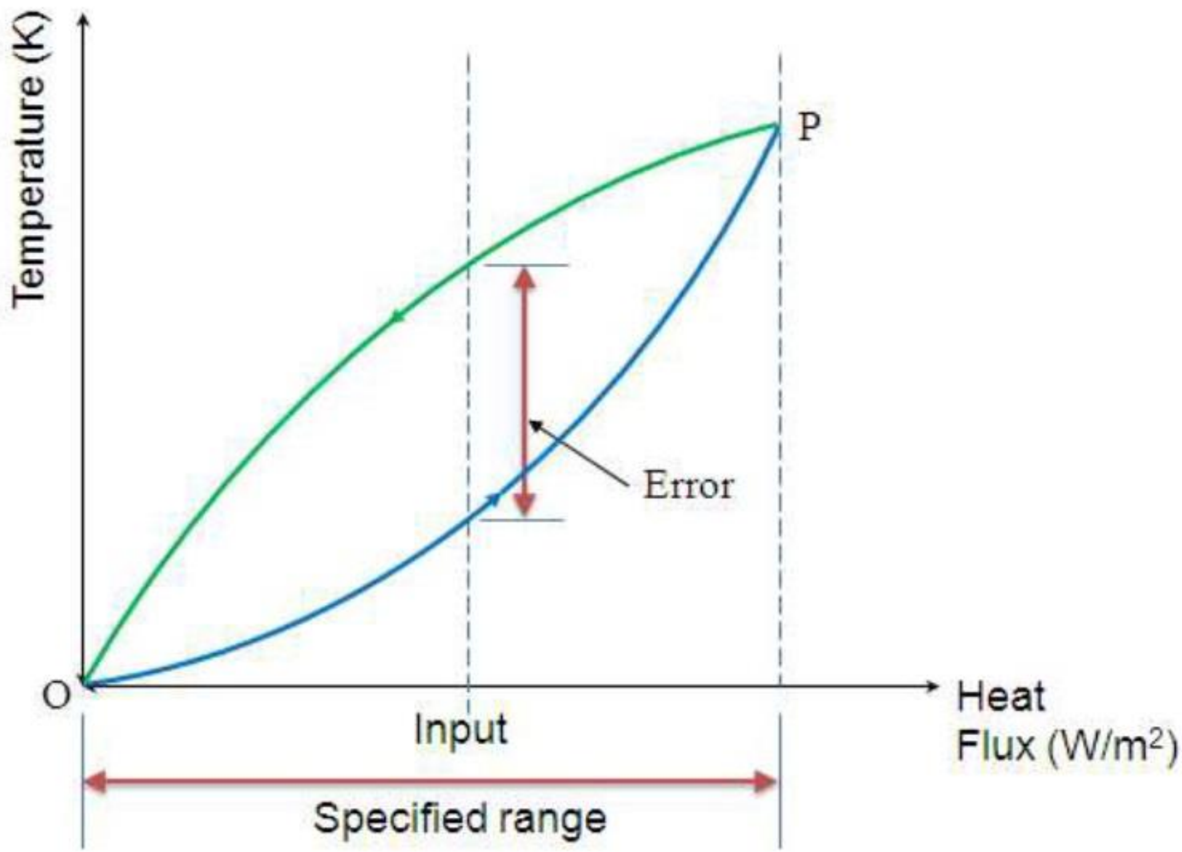
Nonlinearity (%) = Maximum deviation in input ⁄ Maximum full scale input



Non-linearity error

7. Hysteresis:

The hysteresis is an error of a sensor, which is defined as the maximum difference in output at any measurement value within the sensor's specified range when approaching the point first with increasing and then with decreasing the input parameter



8. Resolution

Resolution is the smallest detectable incremental change of input parameter that can be detected in the output signal. Resolution can be expressed either as a proportion of the full-scale reading or in absolute terms.

For example, if a LVDT sensor measures a displacement up to 20 mm and it provides an output as a number between 1 and 100 then the resolution of the sensor device is 0.2 mm

9. Stability

Stability is the ability of a sensor device to give same output when used to measure a constant input over a period of time.

The term ‘drift’ is used to indicate the change in output that occurs over a period of time. It is expressed as the percentage of full range output.

10. Dead Band: The dead band or dead space of a transducer is the range of input values for which there is no output. The dead time of a sensor device is the time duration from the application of an input until the output begins to respond or change.

11.Repeatability

It specifies the ability of a sensor to give same output for repeated applications of same input value. It is usually expressed as a percentage of the full range output:

12.Response time

Response time describes the speed of change in the output on a step-wise change of the measurand. It is always specified with an indication of input step and the output range for which the response time is defined.

Choosing a Sensor

Environmental Factors	Economic Factors	Sensor Characteristics
Temperature range	Cost	Sensitivity
Humidity effects	Availability	Range
Corrosion	Lifetime	Stability
Size		Repeatability
Overrange protection		Linearity
Susceptibility to EM interferences		Error
Ruggedness		Response time
Power consumption		Frequency response
Self-test capability		

Classification of Sensors and Actuators

- **Based on physical laws**
- **Based on any convenient distinguishing property**
- **Possible to a certain extent - some devices defy classification**

1. **Active and Passive sensors**
2. **Contact and non-contact sensors**
3. **Absolute and relative sensors**
4. **Other schemes**

1. Active and passive sensors

Active sensor: a sensor that requires external power to operate. Examples: the carbon microphone, thermistors, strain gauges, capacitive and inductive sensors, etc.

Other name: parametric sensors (output is a function of a parameter - like resistance)

Passive sensor: generates its own electric signal and does not require a power source. Examples: thermocouples, magnetic microphones, piezoelectric sensors.

Other name: self-generating sensors

Note: some define these exactly the other way around

2. Contact and noncontact sensors

Contact sensor: **a sensor that requires physical contact with the stimulus. Examples: strain gauges, most temperature sensors**

Non-contact sensor: **requires no physical contact. Examples: most optical and magnetic sensors, infrared thermometers, etc.**

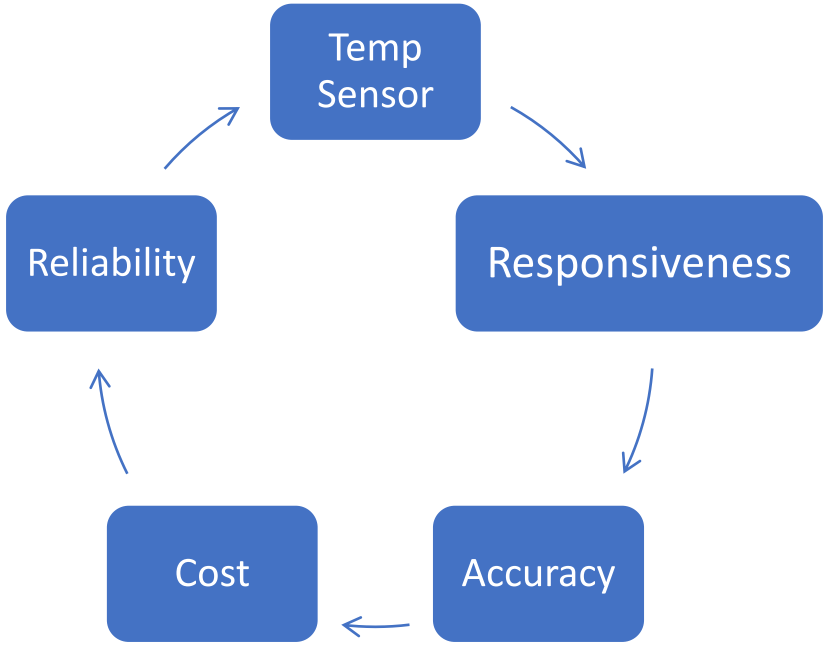
3. Absolute and relative sensors

Absolute sensor: **a sensor that reacts to a stimulus on an absolute scale: Thermistors, strain gauges, etc., (thermistor will always read the absolute temperature)**

Relative scale: **The stimulus is sensed relative to a fixed or variable reference. Thermocouple measures the temperature difference, pressure is often measured relative to atmospheric pressure.**

Temperature Sensors

A temperature sensor plays an important role in many applications. For example, maintaining a specific temperature is essential for equipment used to fabricate medical drugs, heat liquids, or clean other equipment. For applications like these, the responsiveness and accuracy of the detection circuit can be critical for quality control.



More frequently, however, temperature detection is part of preventative reliability.

For example, while an appliance might not actually perform any high temperature activities, the system itself could be at risk to overheating. This risk arises from specific external factors such as a harsh operating environment or internal factors like self-heating of electronics. By detecting when overheating occurs, the system can take preventative action.

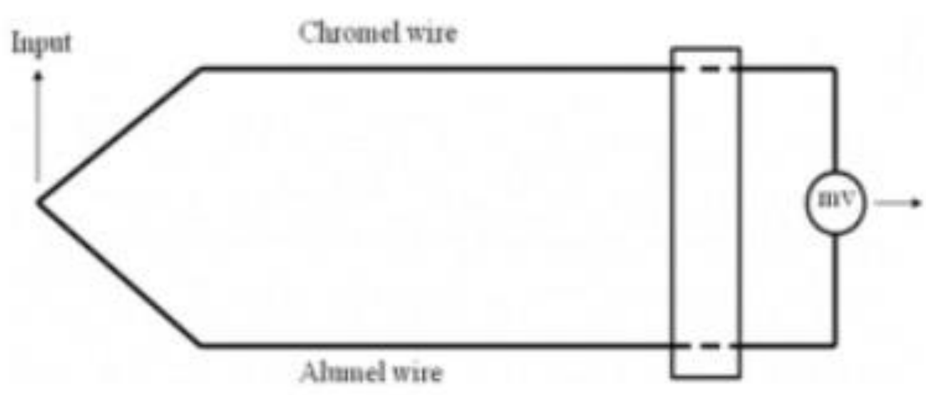
Thermocouple

Thermocouple they convert a non-electrical quantity (temperature) into voltage (electrical quantity). They are also called as transducers.

Since the do not require any external power source to operate, so they are active transducers.

Seeback effect:

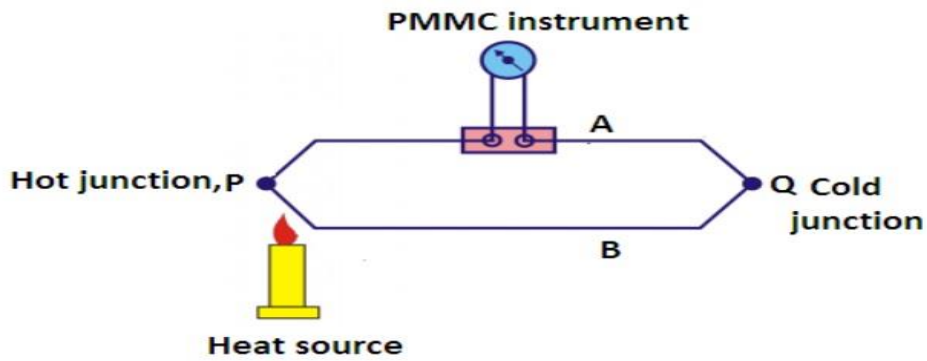
This type of effect occurs among two dissimilar metals. When the heat offers to any one of the metal wire, then the flow of electrons supplies from hot metal wire to cold metal wire. Therefore, direct current stimulates in the circuit.



Thermocouple

Working:

A typical circuit diagram of a thermocouple is shown. Two dissimilar metals ‘A’ and ‘B’ are joined at the two junctions ‘P’ and ‘Q’. Here the ‘P’ junction is measuring junction or hot junction whereas the junction ‘Q’ is the reference junction or cold junction.



When these junctions are kept at different temperatures, generally cold junction is kept at 0^oC and measuring junction is kept at an unknown temperature which we want to measure (i.e. the temperature of the junction is raised by heating it). An e.m.f. will be generated in this circuit due to the temperature difference of the junctions.

This e.m.f. is in the order of millivolts. And the e.m.f. can be measured with the help of a PMMC instrument by connecting it in the circuit as shown in Figure.

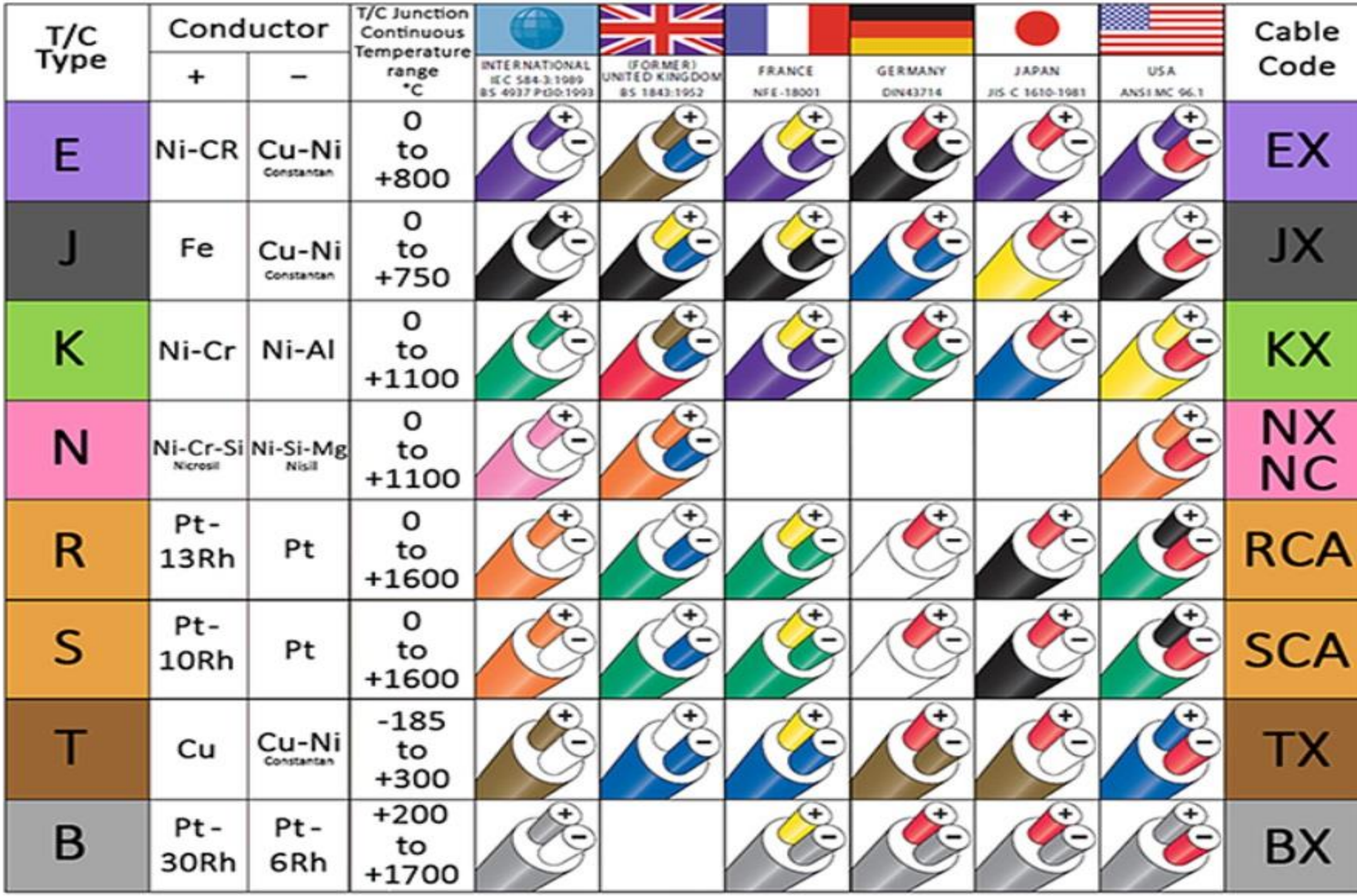
The e.m.f. generated in a thermocouple is given by:

$$E = a(\Delta\theta) + b(\Delta\theta)^2$$

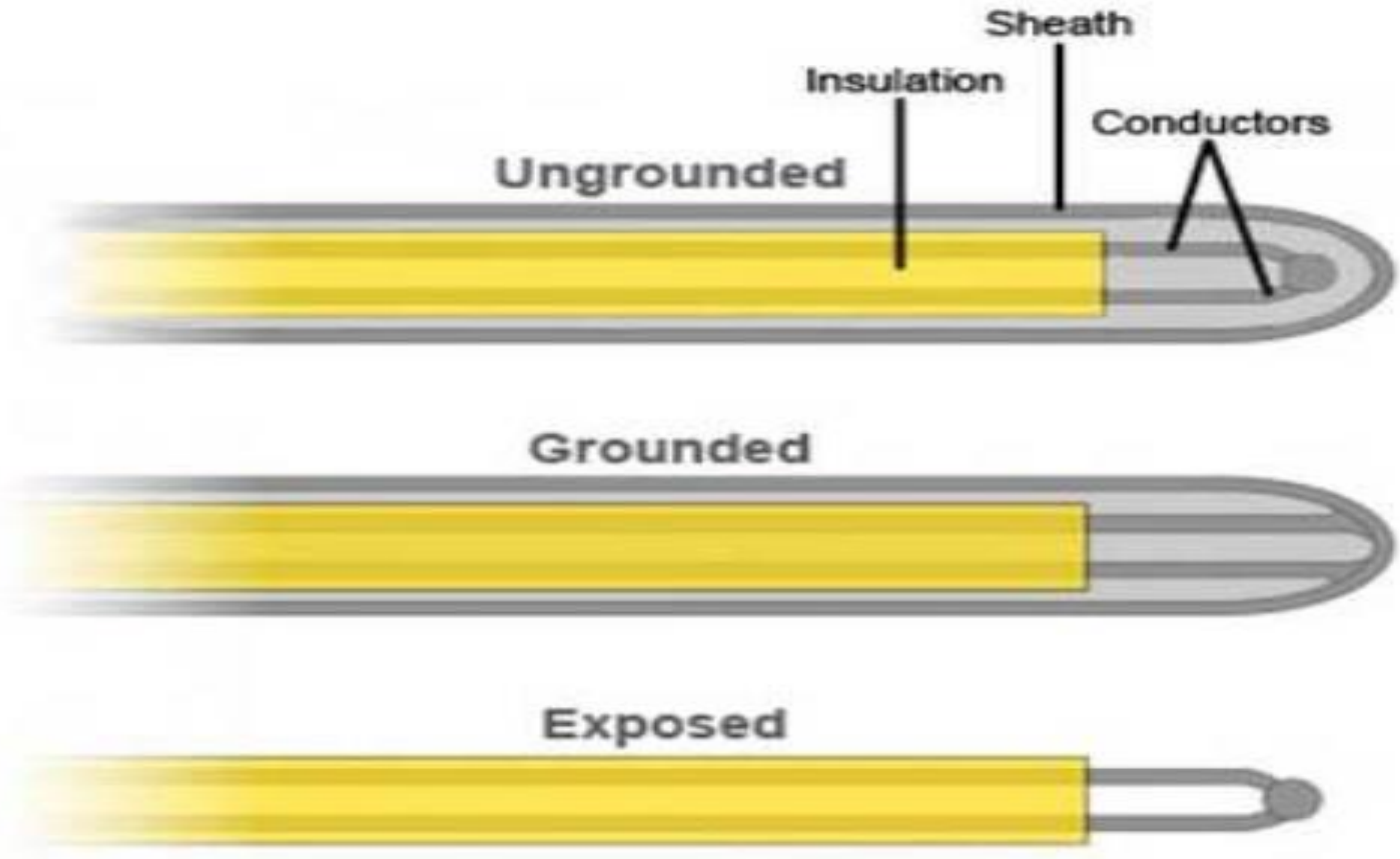
$\Delta\theta$ = difference in temperature between two junctions (in ^oC)

a, b = constants

Standard chart



Thermocouple Junction



Advantages:

- They follow the temperature changes with a small time-lag. So it can be used in the applications where very rapid changes in temperature take places. It responds to those changes very quickly.
- These are very convenient for measuring the temperature at one particular point in any apparatus or setup
- It is Robust and can be used in environments like harsh as well as high vibration.
- The operating range of the temperature is wide.
- Cost is low and extremely consistent

Disadvantages:

- They have very low accuracy. So they cannot be used for very high precision measurement.
- They have to protect against contamination to ensure long life.
- They are placed at a very large distance from the measuring device. This increases errors in the result
- Nonlinearity
- Low voltage

Applications:

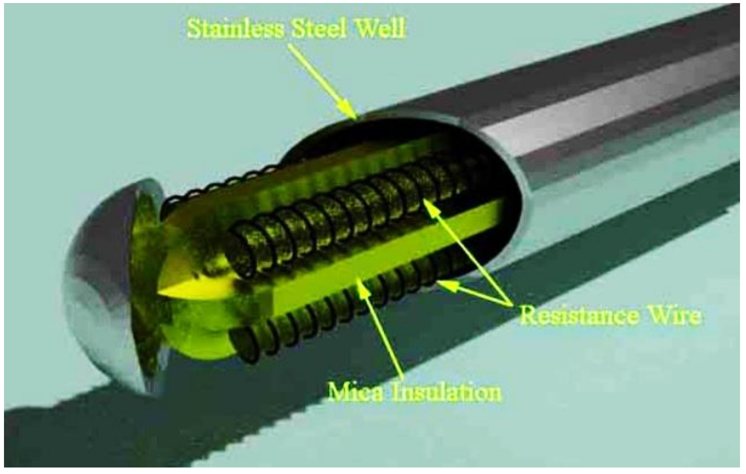
- These are used in industries for monitoring temperatures of metals in iron, aluminum, and metal.
- These are used in the food industry for cryogenic and Low-temperature applications. Thermocouples are used as a heat pump for performing thermoelectric cooling.
- These are used to test temperature in the chemical plants, petroleum plants.

RTD (Resistive temperature detector)

A **Resistance Thermometer** or **Resistance Temperature Detector** is a device which used to determine the temperature by measuring the resistance of pure electrical wire. This wire is referred to as a temperature sensor. If we want to measure temperature with high accuracy, **RTD** is the only one solution in industries. It has good linear characteristics over a wide range of temperature.

<u>Construction:</u>

The construction is typically such that the wire is wound on a form (in a coil) on notched mica cross frame to achieve small size, improving the thermal conductivity to decrease the response time and a high rate of heat transfer is obtained. In the industrial RTD's, the coil is protected by a stainless steel sheath or a protective tube

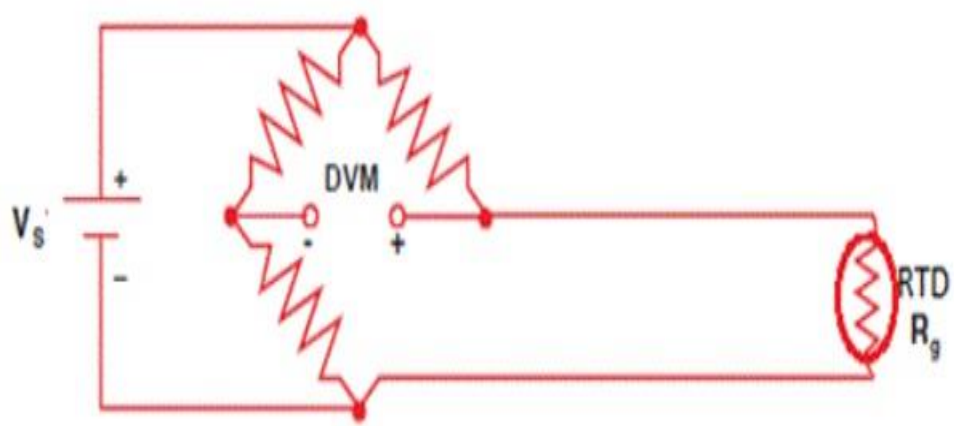


Signal Conditioning of RTD:

In this RTD, the change in resistance value is very small with respect to the temperature. So, the RTD value is measured by using a bridge circuit.

By supplying the constant electric current to the bridge circuit and measuring the resulting voltage drop across the resistor, the RTD resistance can be calculated. Thereby, the temperature can be also determined.

This temperature is determined by converting the RTD resistance value using a calibration expression.



Two wires RTD Bridge

Advantages:

- High Accuracy
- Low drift
- Wide operating range
- Suitability for precision applications

Disadvantages:

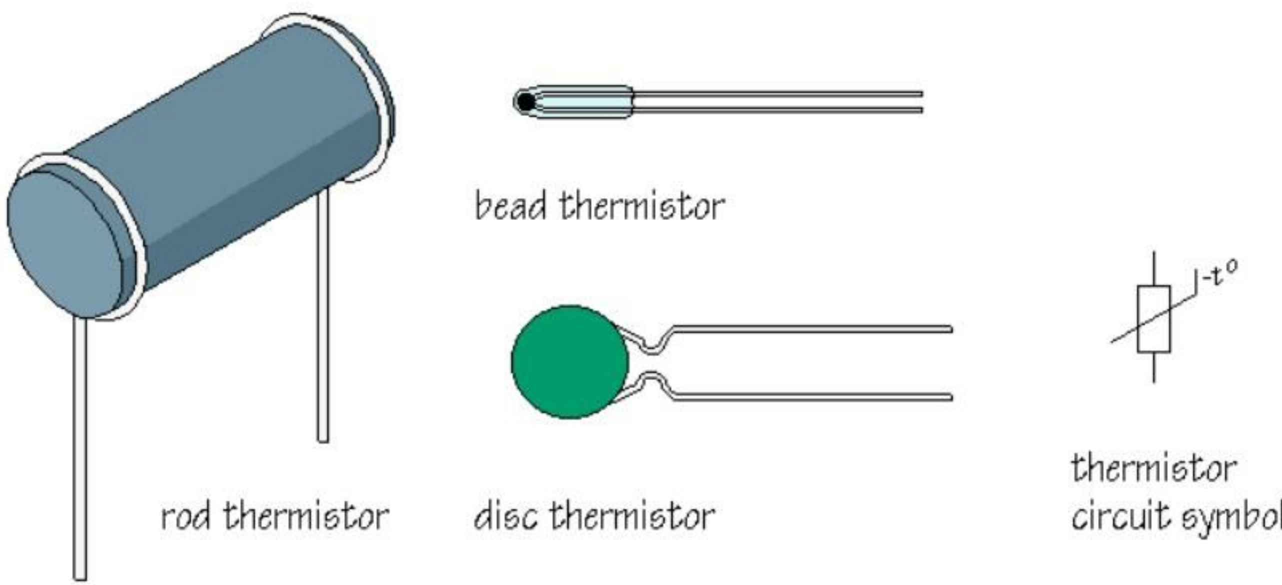
- RTD in industrial applications are rarely used above 660 °C.
- At low temperatures RTD is less responsive.
- Compare to Thermistor, RTD are less sensitive to small temperature changes and have a slower response time.

Thermistor

Thermistors are temperature sensitive semiconductors that exhibit a large change in resistance over a relatively small range of temperature.

There are two main types of thermistors, positive temperature coefficient (PTC) and negative temperature coefficient (NTC). NTC thermistors exhibit the characteristic of resistance falling with increasing temperature.

A thermistor is similar to an RTD, but a semiconductor material is used instead of a metal. A thermistor is a solid state device and has larger sensitivity than does an RTD. Unlike RTD’s, the temperature-resistance characteristic of a thermistor is non-linear, and cannot be characterized by a single coefficient. Furthermore, unlike RTDs, the resistance of a thermistor decreases with increasing temperature



Two Types:

PTC (Positive Temperature Coefficient) – resistance increases with increasing temperature
NTC (Negative Temperature Coefficient) - resistance decreases with increasing temperature

Advantages:

- Gives accurate reading for lower range
- Cheaper
- Can be used for small change in temperature

Disadvantages:

- Not used for Higher range

Applications:

For temperature compensation, Circuit protection, Voltage regulation, Time delay, and Volume control.

Thank You