Temperature Sensors

Disclaimer

The presentation is a collection of materials from the various sources mentioned.

The presentation does not include any original work

Introduction

- Temperature is an important parameter in many control systems
- Several distinctly different transduction mechanisms are employed
- These include non electrical as well as electrical methods
- A thermometer is the most common non electrical sensor
- Common electrical sensors include thermocouples, thermistors and resistance thermometers

Sensors Covered

- Thermocouple
- Thermistor
- Resistance Temperature Detectors (RTD)
- Liquid in glass
- Bimetallic

Thermocouples

- Based on the Seebeck effect
- When any conductor is subjected to a thermal gradient, it will generate a voltage
- The magnitude of the effect depends on the metal in use

- To measure the generated voltage we need to connect another conductor
- This conductor also experiences the Seebeck effect and its voltage tends to oppose the original
- So the conductor used to measure the voltage must be different
- A small difference voltage can be made available by use of dissimilar metals
- Difference increases with temperature, and can typically be between 1 and 70 μV/°C

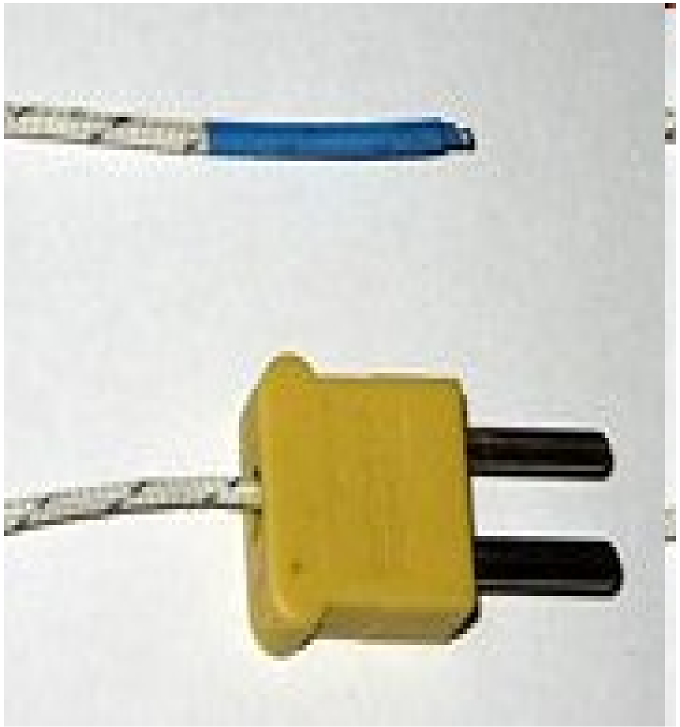
- Thermocouples measure the temperature difference between two points and not the absolute temperature
- The **relationship** between the temperature difference and the output voltage of a thermocouple is nonlinear and is approximated by polynomial:

$$\Delta T = \sum_{n=0}^{N} a_n v^n.$$

- To achieve accurate measurements the equation is usually implemented in a digital controller or stored in a look-up table

Types

- A variety of thermocouples are available, suitable for different measuring applications
- They are usually selected based on the temperature range and sensitivity needed
- Thermocouples with low sensitivities (B, R, and S types) have correspondingly lower resolutions



K Type

S and K Type

Advantages and Disadvantages

- They are simple, rugged, need no batteries, measure over very wide temperature ranges
- The main limitation is accuracy; System errors of less than 1°C can be difficult to achieve

Applications

- Thermocouples are most suitable for measuring over a large temperature range, up to 1800 °C
- These are widely used in the steel industry, heating appliances, manufacturing of electrical equipments like switch gears etc

Thermistor

- A thermistor is a type of resistor with resistance varying according to its temperature. The resistance is measured by passing a small, measured direct current through it and measuring the voltage drop produced.
- There are basically two broad types

1. *NTC-Negative Temperature Coefficient:* used mostly in temperature sensing
2. *PTC-Positive Temperature Coefficient:* used mostly in electric current control.

Types

- A **NTC thermistor** is one in which the zero-power resistance decreases with an increase in temperature
- A **PTC thermistor** is one in which the zero-power resistance increases with an increase in temperature

- Assuming, as a first-order approximation, that the relationship between resistance and temperature is linear, then:

  $\Delta R = k\Delta T$

where

ΔR = change in resistance

ΔT = change in temperature

k = first-order temperature coefficient of resistance

For PTC k is positive while negative for NTC

Advantages and Disadvantages

- Thermistors, since they can be very small, are used inside many other devices as temperature sensing and correction devices
- Thermistors typically work over a relatively small temperature range, compared to other temperature sensors, and can be very accurate and precise within that range

Applications

- PTC thermistors can be used as current-limiting devices for circuit protection, as replacements for fuses. Current through the device causes a small amount of resistive heating. This creates a self-reinforcing effect that drives the resistance upwards
- PTC thermistors can be used as heating elements in small temperature-controlled ovens. As the temperature rises, resistance increases, decreasing the current and the heating, resulting in a steady state
- NTC thermistors are used as resistance thermometers in low-temperature measurements of the order of 10 K.
- NTC thermistors can be used as inrush-current limiting devices in power supply circuits. They present a higher resistance initially which prevents large currents from flowing at turn-on, and then heat up and become much lower resistance to allow higher current flow during normal operation.
- NTC thermistors are regularly used in automotive applications.
- Thermistors are also commonly used in modern digital thermostats and to monitor the temperature of battery packs while charging.

RTD

- Resistance Temperature Detectors (RTD), as the name implies, are sensors used to measure temperature by correlating the resistance of the RTD element with temperature
- As they are almost invariably made of platinum, they are often called **platinum resistance thermometers** (**PRT**s)

Construction

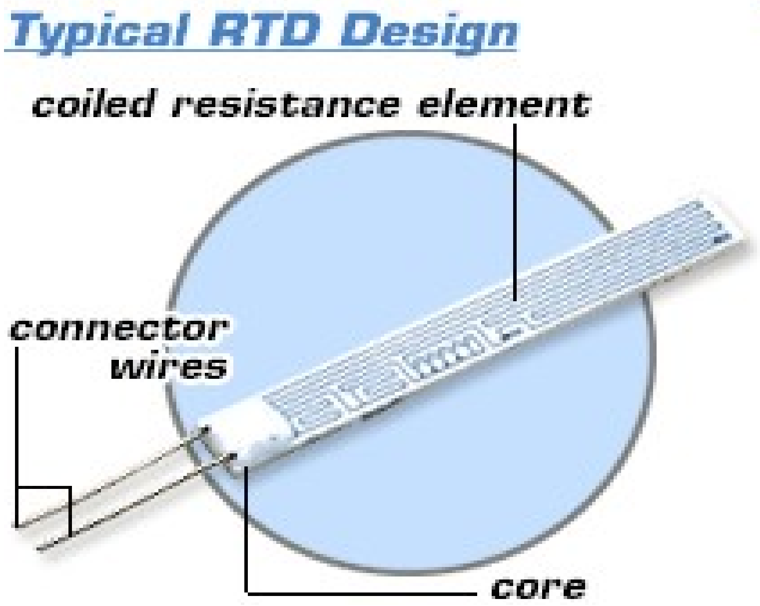
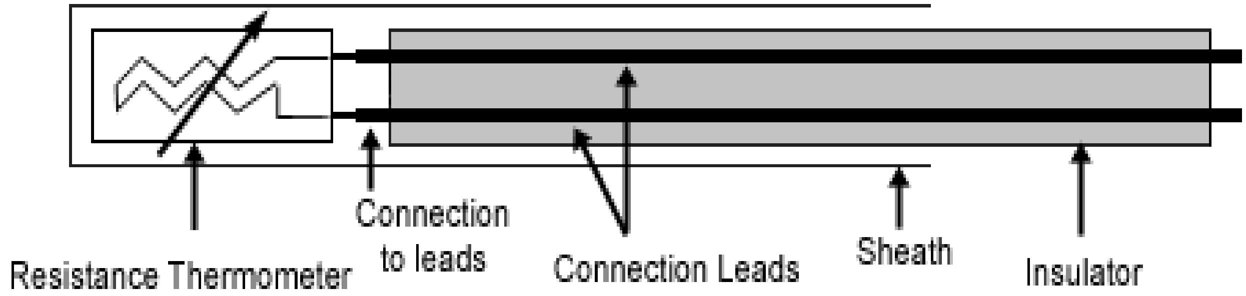


Image obtained from www.omega.com

Common Resistance Materials for RTDs:

Platinum (most popular and accurate)
Nickel
Copper
Tungsten (rare)



Construction

- RTD elements consist of a length of fine coiled wire wrapped around a ceramic or glass core
- The element is usually quite fragile, so it is often placed inside a sheathed probe to protect it
- The RTD element is made from a pure material whose resistance at various temperatures has been documented. The material has a predictable change in resistance as the temperature changes; it is this predictable change that is used to determine temperature

Types

- There are two broad categories, "film" and "wire-wound" types.

  Film thermometers have a layer of platinum on a substrate; the layer may be extremely thin, perhaps 1 micrometer.

  Wire-wound thermometers can have greater accuracy, especially for wide temperature ranges.

Advantages

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

Limitations

- RTDs in industrial applications are rarely used above 660 °C. Difficult to maintain the purity of Platinum at high temperatures
- At low temperatures the resistance is independent of temperature as there are a very few phonons and resistance is determined by impurities
- Compared to thermistors, platinum RTDs are less sensitive to small temperature changes and have a slower response time. However, thermistors have a smaller temperature range and stability.

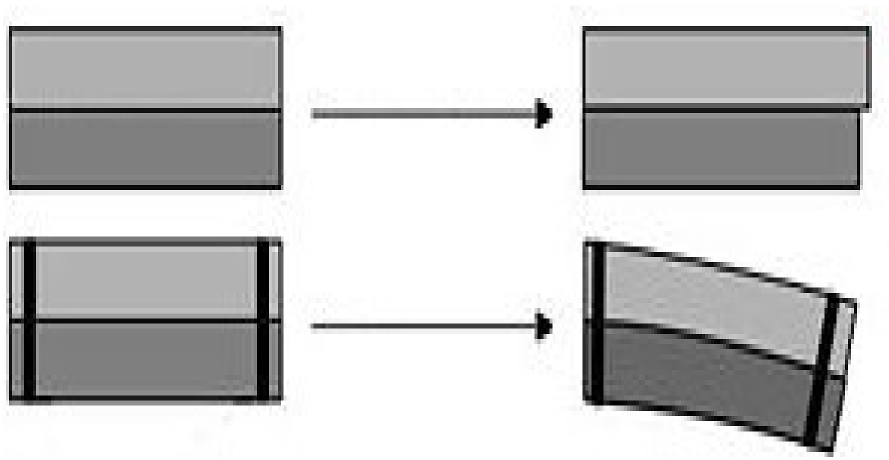
Liquid in Glass

- These are the most commonly used sensors. The most common liquid is Mercury
- The commonly used thermometer falls under this category
- Basically consist of a glass cylinder with a bulb at one end, a capillary hole down the axis, connected to the reservoir in the bulb filled with silvery mercury or perhaps a red-colored fluid

Due to the health reasons mercury is being replaced by galinstan, a liquid alloy of gallium, indium, and tin

Bimetallic Sensors

- A **bi-metallic strip** is used to convert a temperature change into mechanical displacement and thus acts as a temperature sensor
- The strip consists of two strips of different metals which expand at different rates as they are heated, usually steel and copper



The different expansions force the flat strip to bend one way if heated, and in the opposite direction if cooled below its normal temperature. The metal with the higher expansion is on the outer side of the curve when the strip is heated and on the inner side when cooled.

Applications

- Mechanical clock mechanisms are sensitive to temperature changes which lead to errors in time keeping. A bimetallic strip is used to compensate for this in some mechanisms
- In the regulation of heating and cooling, thermostats that operate over a wide range of temperatures the bi-metal strip is mechanically fixed and attached to an electrical power source while the other (moving) end carries an electrical contact.

- A direct indicating dial thermometer uses a bi-metallic strip wrapped into a coil. One end of the coil is fixed to the housing of the device and the other drives an indicating needle

Semiconductor Thermometer Devices

- Semiconductor thermometers are usually produced in the form of ICs, Integrated Circuits
- These devices have temperature measurement ranges that are small compared to thermocouples and RTD, but, they can be quite accurate and inexpensive and very easy to interface with other electronics for display and control.

- The major uses are where the temperature range is limited to within a minimum temperature of about -25°C to a maximum of about 200°C
- Also the recent advances in electronics and telemetry have resulted in non contact thermometers
- These include IR thermometers, IR imagers and optical pyrometers

Resources

- www.temperatures.com
- www.wikipedia.org
- www.omega.com
- www.howstuffworks.com

THANK YOU