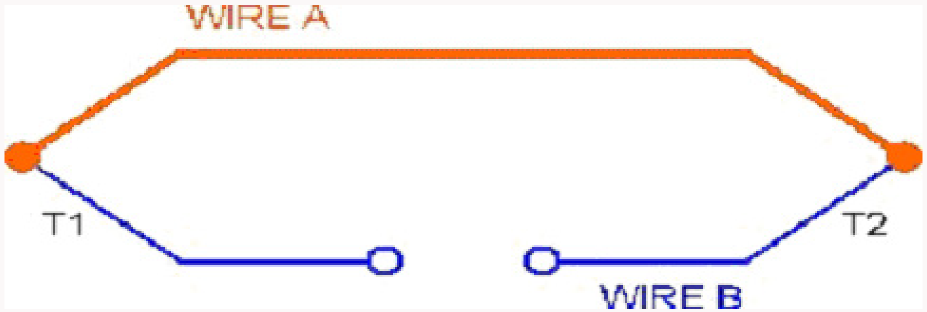
Thermocouple Theory

thermocouples are a widely used type of temperature sensor. They are cheap, interchangeable, have standard connectors and can measure a wide range of temperatures. The main limitation is accuracy; system errors of less than 1 °C can be difficult to achieve.

Principle of operation

In 1822, an Estonian physicist named Thomas Johann Seeback discovered that when any conductor (such as a metal) is subjected to a thermal gradient, it will generate a small voltage. Thermocouples make use of this so-called Peltier-Seeback effect.

Thermocouples produce an output voltage which depends on the temperature difference between the junctions of two dissimilar metal wires. It is important to appreciate that thermocouples measure the temperature difference between two points, not absolute temperature.



In most applications, one of the junctions — the "cold junction" — is maintained at a known (reference) temperature, whilst the other end is attached to a probe. For example, in the image below, the cold junction will be at copper tracks on the circuit board. Another temperature sensor will measure the temperature at this point, so that the temperature at the probe tip can be calculated.

Different types

A variety of thermocouples are available, suitable for different measuring applications (industrial, scientific, food temperature, medical research, etc.).

Type K (Chromel (Ni-Cr Alloy) / Alumel (Ni-Al alloy))

The "general purpose" thermocouple. It is low cost and, owing to its popularity, it is available in a wide variety of probes. They are available in the −200 °C to +1200 °C range. Sensitivity is approximately 41 µV/°C.

Type E (Chromel / Constantan (Cu-Ni alloy))

Type E has a high output (68 µV/°C) which makes it well suited to low temperature (cryogenic) use. Another property is that it is non-magnetic.

Type J (Iron / Constantan)

Limited range (−40 to +750 °C) makes type J less popular than type K. The main application is with old equipment that cannot accept "modern" thermocouples. J types cannot be used above 760 °C as an abrupt magnetic transformation causes permanent decalibration.

Type N (Nicrosil (Ni-Cr-Si alloy) / Nisil (Ni-Si alloy))

High stability and resistance to high temperature oxidation makes type N suitable for high temperature measurements without the cost of platinum (B, R, S) types. Designed to be an "improved" type K, it is becoming more popular.

Thermocouple types B, R, and S are all Noble Metal thermocouples and exhibit similar characteristics. They are the most stable of all thermocouples, but due to their low sensitivity (approximately 10 µV/°C) they are usually only used for high temperature measurement (>300 °C).

Type B (Platinum-Rohium/Pt-Rh)

Suited for high temperature measurements up to 1800 °C. Unusually type B thermocouples (due to the shape of their temperature-voltage curve) give the same output at 0 °C and 42 °C. This makes them useless below 50 °C.

Type R (Platinum / Rhodium)

Suited for high temperature measurements up to 1600 °C. Low sensitivity (10 μV/°C) and high cost makes them unsuitable for general purpose use.

Type S (Platinum / Rhodium)

Suited for high temperature measurements up to 1600 °C. Low sensitivity (10 μV/°C) and high cost makes them unsuitable for general purpose use. Due to its high stability type S is used as the standard of calibration for the melting point of gold (1064.43 °C).

Type T (Copper / Constantan)

Suited for measurements in the −200 to 0 °C range. The positive conductor is made of copper, and the negative conductor is made of constantan.

Thermocouples are usually selected to ensure that the measuring equipment does not limit the range of temperatures that can be measured. Note that thermocouples with low sensitivity (B, R, and S) have a correspondingly lower resolution.