

Temperature Transducers

There are several different sensors or transducers that can be used for computer-based acquisition of temperature. In general, these transducers must be able to provide a voltage that can be related to the temperature to be useful since most computer acquisition systems can only directly measure voltage. A few of these transducers are discussed here.

A more complete discussion of temperature transducers is found in Section 8.1 (THE MEASUREMENT OF TEMPERATURE) of the text.

1.0 Thermocouple

Thermocouples are quite common because they are useful over a very wide range of temperatures and are quite robust. A junction of two dissimilar metals will generate a voltage that is usually temperature dependent but not necessarily linear. There are several well-defined thermocouple combinations that are in common use, each with particular characteristics that may be desirable for a given application. Some use expensive metals such as platinum. Others use common metals like iron, copper, aluminum, nickel, and chromium in various alloys and combinations. Those that use common metals are quite inexpensive to use.

Two common combinations are a type K thermocouple made of chromel (nickel/chromium alloy) and alumel (nickel/manganese/aluminum/silicon alloy). It has a useful range of 73 K to 1523 K (-200°C to 1250°C) with a sensitivity of $41\ \mu\text{V}/\text{K}$. The type J thermocouple is made of iron and constantan (copper/nickel alloy). It has a useful range of 233 K to 1023 K (-40°C to 750°C) with a sensitivity of $55\ \mu\text{V}/\text{K}$.

These thermocouples will measure temperatures below the specified lower limit but with reduced accuracy. Both of these thermocouples include magnetic materials that undergo a phase transition at the Curie temperature ($632\ \text{K}$ for type K and $1023\ \text{K}$ for type J). The major drawback of thermocouples is the low sensitivity.

A major advantage is that the junction volume is very small, so they respond very rapidly to changing temperature.

2.0 Thermistor

A thermistor (thermal resistor) is a resistor designed to have a large change of resistance with a change of temperature. They come in several different forms with some

designed to have the resistance increase with increasing temperature (PTC, positive temperature coefficient) and some to have the resistance decrease with increasing temperature (NTC, negative temperature coefficient).

PTC devices often have abrupt resistance changes and are not useful as a temperature sensor. NTC devices usually have a nonlinear relationship between resistance and temperature (often of the form $R \approx R_0 \exp[B(1/T - 1/T_0)]$).

The useful range for these devices depends on the construction, with the most common devices operating roughly 230 K to 400 K (-40°C to 130°C) but devices are available that cover some portion of the range of 0.01 K to 2000 K. Most thermistors are physically quite small and thus respond rapidly to changing temperature.

3.0 RTD, resistance temperature detector

An RTD (resistance temperature detector) also uses the temperature dependence of the resistance of a material (usually a metal in this case) to determine the temperature. A laboratory-grade RTD is often made with platinum wire, but other pure metals can be used. Common RTDs will have a sensitivity in the range of 0.375 to $0.392\ \Omega/\text{K}$ with a resistance of either $100\ \Omega$ or $1000\ \Omega$ at 0°C .

Due to the fragile nature of the metal filament used in these devices, they are usually in a protective case that reduces the rate at which they can respond to external temperature changes.

4.0 Silicon diode

A silicon diode can also be used as a temperature transducer although one made for use in electronics will not be as accurate or as reproducible as some of the previously discussed sensors. There are diodes designed specifically for use as a temperature sensor, and they are quite accurate.

A common signal diode does have the advantage that it is very cheap and most small signal diodes have very small packages, so they respond reasonably quickly to changing temperature. A 1N4148 diode has a temperature sensitivity of about $2\ \text{mV}/\text{K}$ when a constant current is passing through the forward-biased diode. Specially designed diodes can have an accuracy of $\pm 0.25\ \text{K}$ over a range of 30 K to 100 K with decreased accuracy above 100 K. This may increase to 0.5% of the measured temperature in the 300 K to 500 K range). The 1N4148 is not likely to achieve this level of

accuracy.

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