Technical Information

Electrical temperature measurement in the hot runner with thermocouples

This “technical info” provides information on the operating principles of a thermocouple and how it can be applied in a hot runner system.

Thermoelektrischer Effekt:
The thermocouple is based on the effect described by Johann Seebeck in 1821 that a small current flows when two metallic conductors made of different materials are connected and there is a temperature difference along the two conductors. The two connected conductors are called a thermocouple. The voltage itself depends on both the two materials and the temperature difference.

The thermoelectric effect works because free electrons are distributed evenly in each metal. If the entire length of a metallic conductor is at a consistent temperature, the electrons move within the crystal structure due to their thermal energy. Outwardly, the conductor shows no charge concentration - it is neutral (Figure 1 above). If one side of the metal is heated, thermal energy is added to the free electrons and their average velocity increases in comparison with the cold end of the conductor. This causes the free electrons to shift to the cold side. A negative charge concentration is created at the cold end (Figure 1 below). This shift causes a small electrical voltage between the warm and cold sides.

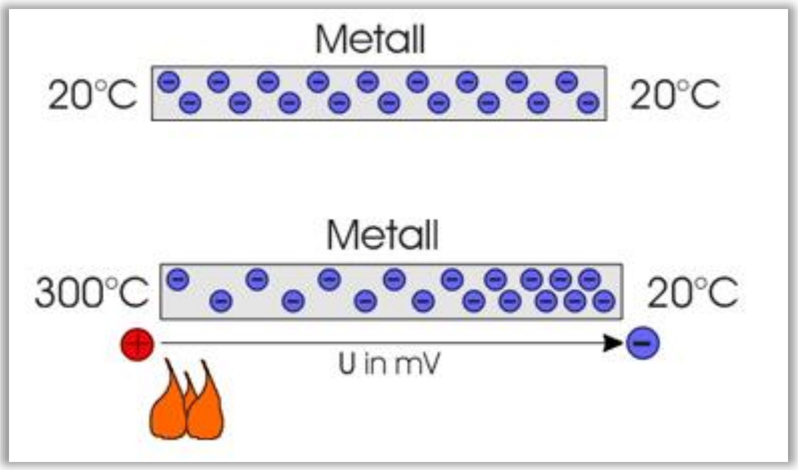


Figure 1: "Electron migration" due to heating

If the voltage difference between the warm and cold ends of the conductor is to be measured, the warm end of the conductor must be connected to an electrical conductor. This conductor is subjected to the same temperature gradient and thus forms the same dynamic equilibrium. If the second conductor is made of the same material, there is a symmetrical structure with equal charge concentrations at the two open ends. No voltage difference can be measured between the two charge concentrations (Figure 2).

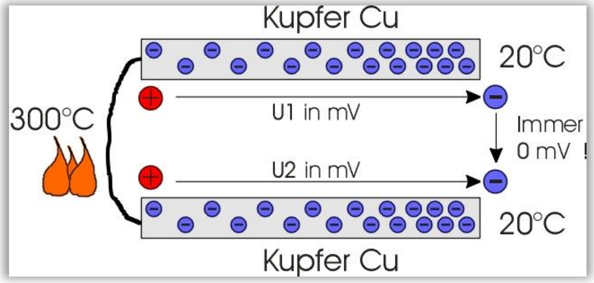


Figure 2: "Thermocouple" consisting of two identical metals (Cu)

If the second conductor consists of a different material with a deviant electrical conductivity, a different dynamic equilibrium is also established within the wire. As a result, different centers of charge are formed at the two ends of the conductor, which can be measured with a voltmeter (Fig. 3).

Depending on the requirements and the temperature range to be measured, different thermocouples (material combinations) can be used. In hot runner technology, iron (Fe) and copper-nickel (CuNi/Constantan) are commonly used. This combination - also known as "FeCuNi" for short - is suitable for a temperature range from - 40°C to + 750°C.

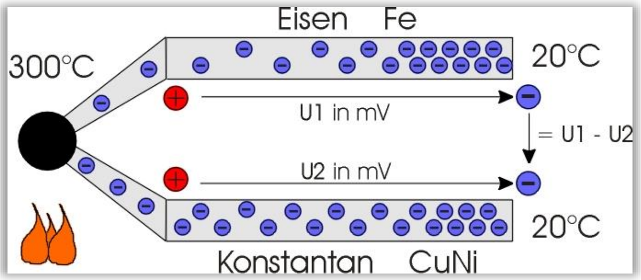


Figure 3: Thermocouple made of iron - constantan (FeCuNi)

In order for the thermoelectric voltage to cause a current flow, however, the two metals must also be connected to each other at the other end so that a closed circuit is created. Therefore, a thermoelectric voltage is also formed at the second junction. In order to determine the temperature in [°C], the absolute temperature at the cold ends must also be measured. The temperature-dependent signals are determined exclusively by the alloy of the metals used. The length or cross-section of the wire have no influence.

The voltage caused by the thermoelectric effect is very low and amounts to only a few microvolts per Kelvin. Thermocouples are therefore generally not used for measurement in the range from -30 to +50°C, since the difference to the reference junction temperature is too small here to obtain a measurement signal which is free of interference. Incidentally, it is not possible to specify an "absolute" thermoelectric voltage, but only the difference between the thermoelectric voltages assigned to the two temperatures.

The mostly stable room temperature at the controller is taken as the reference temperature. This is identical for all zones.

The thermocouple integrated in the hot runner nozzle or in the mold only partially represents the complete thermocouple. Up to the reference junction (room temperature), the two wire legs of the thermocouple, as well as the compensating cable, must be made of iron (Fe) and constantan (CuNi). The compensating cable from the mold to the controller is part of the complete thermocouple (Figure 4).

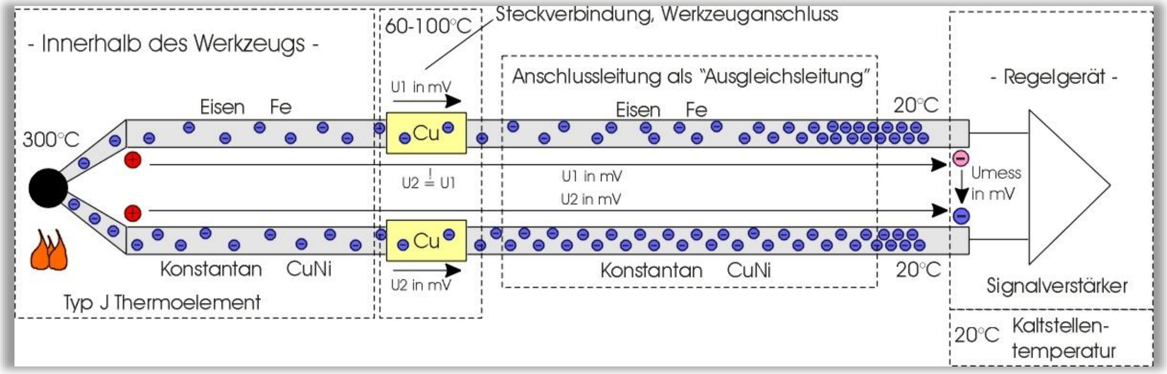


Figure 4: Thermocouple with connector and compensating cable

Only compensating cables made of the same material as the element itself (or with the same thermoelectric properties) may be used.

Where the compensating cable is connected to a different material, the reference junction or a new thermocouple is created.
This leads to an incorrect temperature measurement and thus to an incorrect control behaviour of the hot runner nozzle / manifold. An extension with copper cable or compensating cable of a different type is therefore not permitted.

If a plug connection made of a different metal (brass inserts) is inserted into the thermocouple, an additional thermoelectric voltage can occur within the plug. It is important to ensure that both legs are contacted using identical, adjacent connectors. The ambient temperature of both contacts should be as equal as possible. The more solid the connector is designed, the lower the temperature difference is within the brass contact.

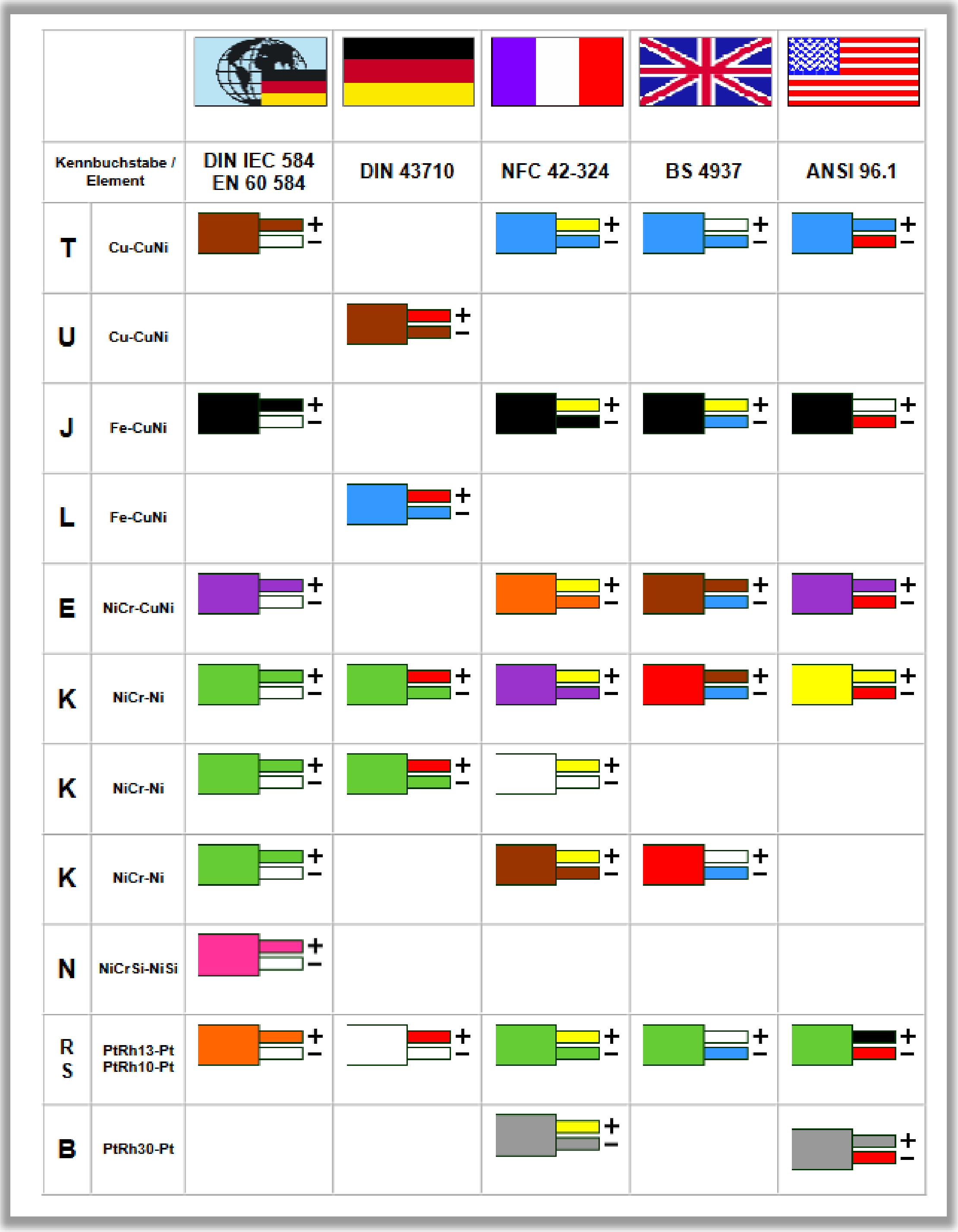
Thermocouples are standardized worldwide (IEC 584) and according to European law (DIN EN 60584-1) with regard to the thermoelectric voltage and its tolerance. According to these standards, the thermocouple consisting of FeCuNi is designated as type J or L.

The correct selection of the thermocouple in the control device must be ensured. If another thermocouple type is selected, temperature deviations may occur due to the different sensor characteristics.

Table 1 shows the possible material combinations for thermocouples.

Element	Typ	Sheath	Plus	Minus	Maximum temperature [°C]	Remark
Cu-CuNi	T	Brown	Brown	White	350	**Low distribution**
Fe-CuNi	**J**	Black/ **Blue**	Black/ **Red**	White/ **Blue**	**750**	High distribution
NiCr-CuNi	K	Green	Green	White	700	**Low distribution; high thermoelectric voltage**
Ni-CrNi	N	Pink	Pink	Orange	1000	**Often used in the 800-1000°C range**
NiCrSi-NiSi	E	Violett	Violett	White	1300	**Little widespread; can partially replace more noble elements**
Pt10Rh-Pt	S	Orange	Orange	White	1500	**High cost; very good long-term stability**
Pt30Rh-Pt6Rh	**R**	**Orange**	**Orange**	**White**	**1700**	**High cost; lowest thermoelectric voltage**

Table 1: Thermocouples according to IEC 584-1



Quelle: Plöger Sensor GmbH

Table 2: Color coding for thermocouples (terminal colors and lead identification)

Further information on the subject of "electrical temperature measurement" can be found, for example, in the documentation of the thermocouple manufacturers (e.g. https://en.jumo.de/; https://www.tuerk-hillinger.com/).

The information provided is based on our current knowledge and is intended to offer technical background information.