

What is the significance of the extension cable's length?

Pentronic is frequently asked how the length and thereby the resistance of the extension cable to the thermocouple influences the measurement result. In fact, several error sources are associated with the cable's length. This article discusses some of them.

The concern can stem from the former days of temperature measurement where the indicator face displayed a resistance value that a thermocouple with an extension cable had to fulfill for the temperature scale on the indicator face to be correct. Even the first-generation battery indicators could show appreciable errors of tenths of a degree if a too long and too thin cable was used.

Insignificant measuring current

Modern indicators contain a digital voltmeter (DVM) with very high input resistance, say 10 megohm. A thermocouple such as a type K has greater resistance than a copper pair cable of the corresponding diameter and length. For example, a type K with a wire diameter of 0.5 mm and a length of one metre has a resistance of 4.9 ohm per double metre (dbm) that is, including both the wires. The corresponding resistance for copper wire is 0.17 ohm/dbm.

To assess the measurement error, we can calculate what proportion of the thermoelectric voltage is lost along the length of the thermocouple's extension cable. See Figure 1. In practice, for a 100 m cable, the measurement result is reduced by approx. 0.049% due to the voltage division. This means that the absolute error caused by the voltage division also increases approximately in step with the temperature level. At 500 °C this corresponds to a reading that is approximately 0.25 °C too low. The thermocouple's sensitivity is nonlinear but can be assumed to be approx. 40 µV/°C for type K. Higher input resistance on the temperature indicator's digital voltmeter and/or increased cable diameter reduces the losses. However,

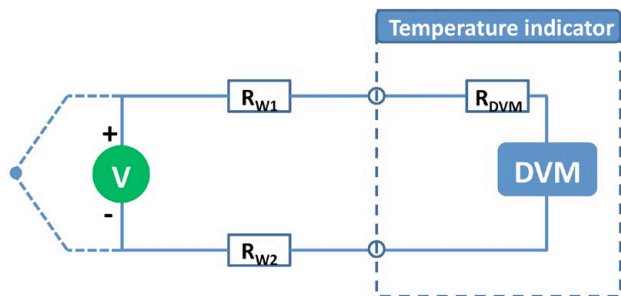
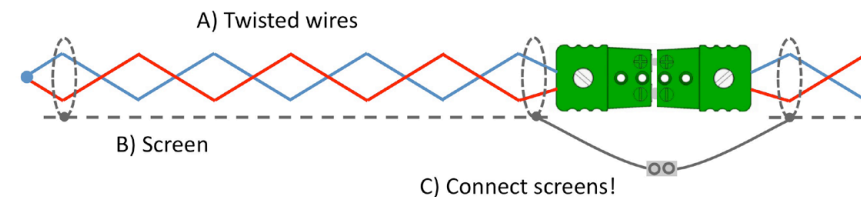


Figure 1. V = The thermocouple's generated voltage. $R_{W1} + R_{W2}$ = the cable resistance per meter of cable length for type K is 4.9 ohm for a wire diameter of 0.5 mm. $R_{DVM} \geq 10$ megohm. A 100 metre-long such cable reduces the DVM's share of V by 0.049%. At 500 °C this corresponds to approx. 0.25 °C.



increasing the cable length naturally increases the measurement error.

Already at 250 to 550 °C other phenomena exist, such as SRO hysteresis [Ref 1], which have a significantly greater influence on the measurement result. The error of 0.25 °C is not large compared with SRO hysteresis, which can make the reading vary by up to 4 to 5 degrees.

Antenna effect

A greater error source can be that the extension cable captures electrical interference signals by acting as an unintentional antenna. One common example of this is the low-frequency sine interference emitted by power cables (up to approx. 400 Hz). If the extension cable's wires are twisted, each twist basically divides the effect of the interference in half. Normally, modern transmitters and the input stages of the subsequent electronic equipment are equipped with serial or common-mode interference suppression. The interference can usually be reduced enough by using sufficiently strong attenuation, i.e. a large number of decibels. One alternative can be to place the transmitter as close to the thermocouple as possible and thereby reduce the latter's ability to absorb interference. See Figure 2.

The sensitivity of 40 µV/°C creates a small thermoelectric voltage, which, when it is superimposed on a sinusoidal interference, can cause measurement errors ranging from fractions of a degree up to causing the indicator to reach its end position. See Figure 4.

Shielding for high frequencies

For higher-frequency interferences (greater than approx. 400 Hz) generated by transient signals, "spikes", mobile phones, citizen band radios or electrically pulsed digital communications, shielding must be used. It can be necessary to shield both the cable causing the interference and the one affected by it.

Figure 2. A thermocouple consisting of an (A) twisted-pair and (B) shielded extension cable. Using a twisted multi pair cable dampens interfering frequencies up to approx. 400 Hz. Shielding dampens e.g. the influence of square waves containing high frequencies. (See further Figure 3). (C) shows a simple way to connect all the shields into a continuous length that can be grounded at a shared point.

On a shielded cable, the shielding should also cover the splicing points. Grounding should normally be done at a central point in order to avoid ground currents that can alter the voltage potential in the grounding points and thereby unintentionally modulate the measurement signal. Thermocouple connectors are available with three pins, one of which is designed to connect the shield through the splicing points. In some high-frequency situations, the exposed short length of the connector can also absorb interference, and then it may also be necessary to also shield the connectors from the surroundings. ▢

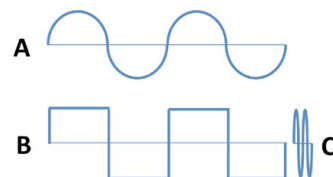


Figure 3. A) Sine wave. B) A square wave contains high sine frequencies in order to be able to create steep flanks. C) The flanks in B become steeper the greater number of high-frequency sine waves the wave contains.

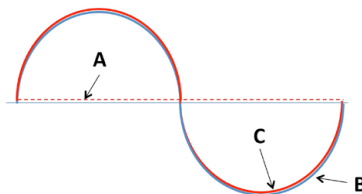


Figure 4. A) The small, low-frequency DC component from the thermocouple (the dotted line) that we want to measure. B) An interfering sine-shaped AC component (blue). C) The resulting signal to the indicator (red).

References see www.pentronic.se > News > [Ref 1] See Pentronic News 2010-1, page 4

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