MicroControl
Systemhaus für Automatisierung

AN3002

Thermocouple measurement

This application note illustrates the correct measurement of thermocouple sensors.

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1 Introduction

A thermocouple is a junction between two different metals that produces a voltage related to a temperature difference. Thermocouples are a widely used type of temperature sensor for measurement and control.

Thermocouples measure the temperature difference between two points, not absolute temperature. To measure a single temperature one of the junctions — normally the cold junction — is maintained at a known reference temperature, and the other junction is at the temperature to be sensed. Precise measurement devices like the µCAN.4.ti-BOX measure the temperature of the input connections, with special care being taken to minimize any temperature gradient between terminals. Hence, the voltage from a known cold junction can be simulated, and the appropriate correction applied. This is known as cold junction compensation.

This application note demonstrates the effects of

- using wrong wires for thermocouple connection
- wrong sensor type configuration
- shorted inputs

in respect to the measured temperature. The tests are performed at different ambient temperatures with the 4-channel temperature acquisition module µCAN.4.ti-BOX.

Figure 1: µCAN.4.ti-BOX for temperature measurement

2 Test configuration

For all tests the following input setup is used:

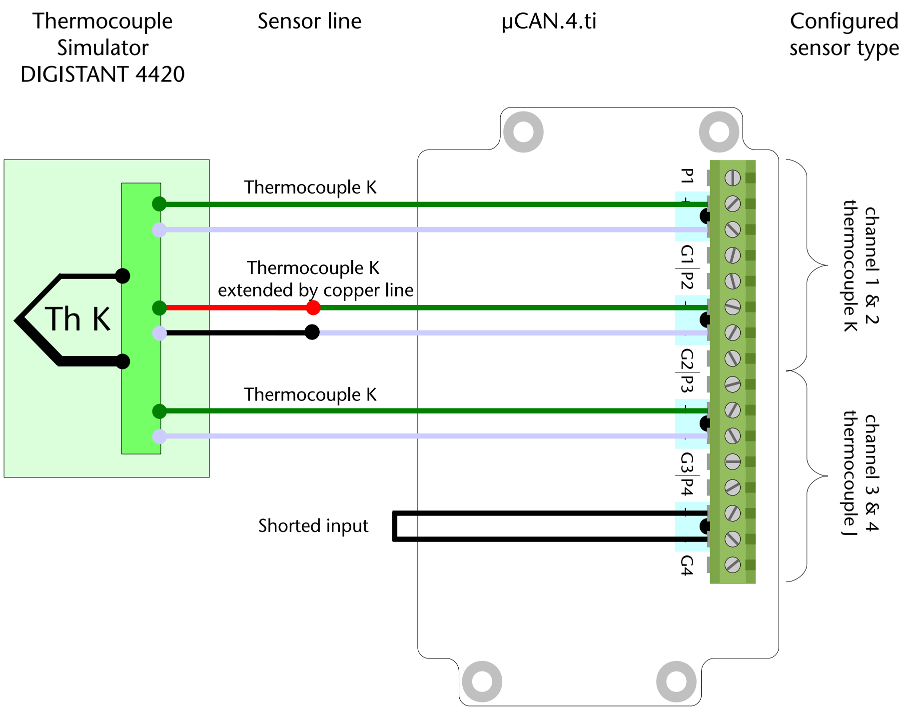


Figure 2: Block diagram of test arrangement

Channel	Input configured to	Input connected to
1	Thermocouple Type K	Thermocouple Type K
2	Thermocouple Type K	Thermocouple Type K, extended by copper wire
3	Thermocouple Type J	Thermocouple Type K
4	Thermocouple Type J	shorted input, copper wire

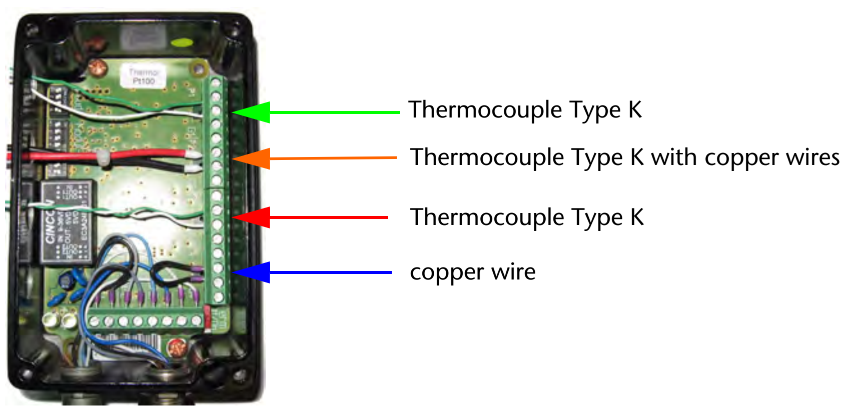
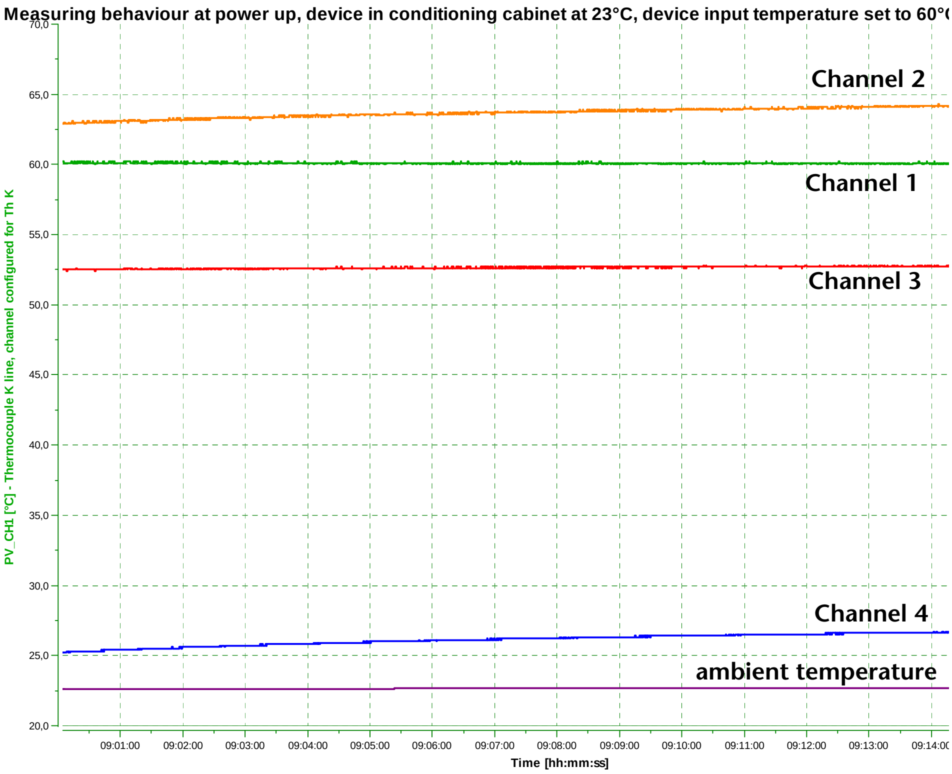


Figure 3: Sensor connection at µCAN.4.ti-BOX

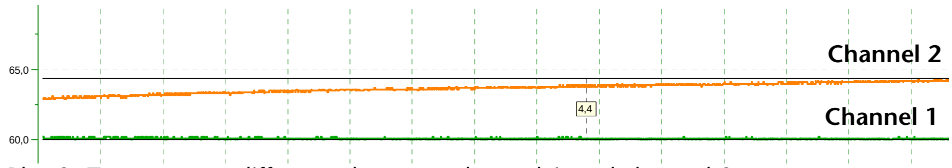
2.1 Test at ambient temperature

For simulation of the thermocouple signals a high precision temperature reference (DIGISTANT 4420) was used. The reference was connected to inputs 1 to 3 simulating a value of 60°C for thermocouple type K. The ambient temperature was 23°C.



Plot 1: Measured temperatures by µCAN.4.ti-BOX @ 23°C ambient temperature

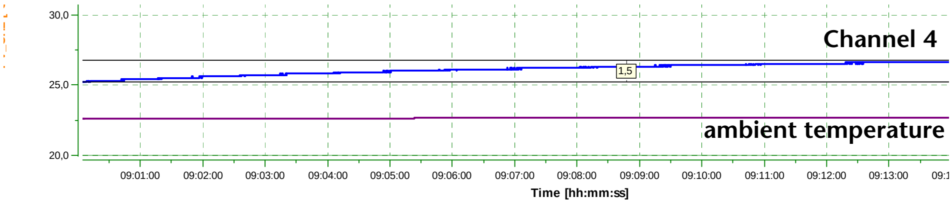
As expected, the measured temperature on channel 1 is 60°C over the complete period. Due to the wrong material connected to channel 2, the initial difference is +2,5°C on that channel. As the cold junction temperature (refer to channel 4) increases during the warm up period, the temperature offset between channel 1 und 2 increases also to a maximum of 4,4°C (see Plot 2: Temperature difference between channel 1 and channel 2).



Plot 2: Temperature difference between channel 1 and channel 2

As a result, you should never extend thermocouple wires with copper wires (or other material). The cold junction compensation works only when thermocouple wires are connected to the terminal block.

The cold junction temperature is not equal to ambient temperature. Please keep in mind that the cold junction shows the temperature of the electronics, which is normally higher than ambient temperature.

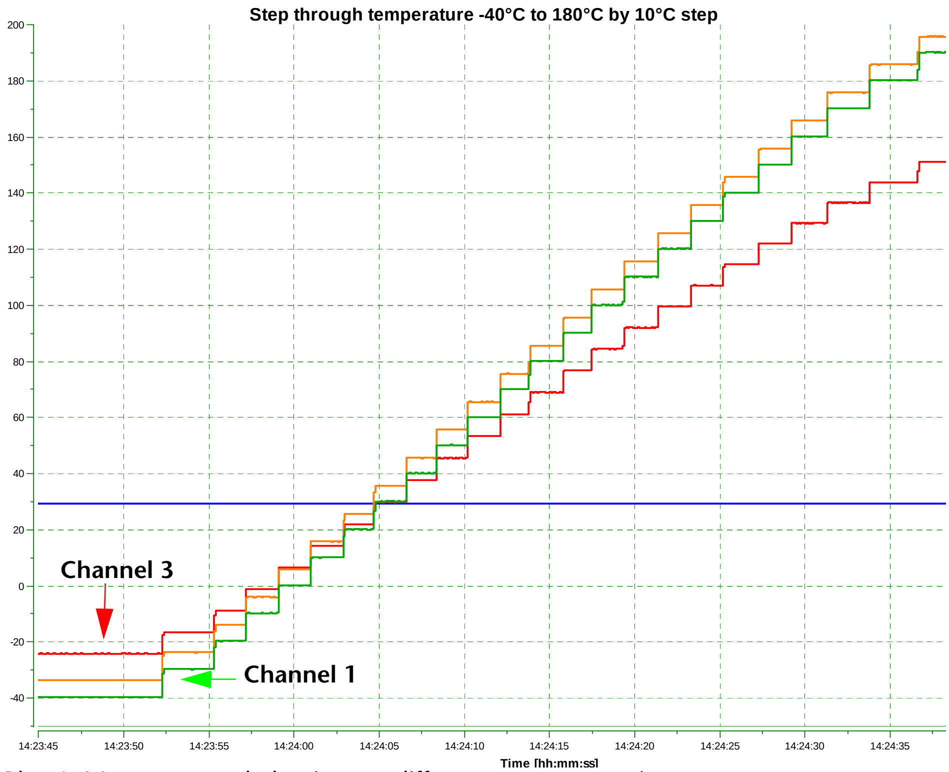


Plot 3: Temperature difference on channel 4

As depicted in plot 3, the cold junction temperature is not equal to the ambient temperature and it increases during the warm up cycle.

3 Thermocouple selection

The thermoelectric coefficients of the wires depend on the thermocouple material. The impact of wrong thermocouple type (type J for channel 3 instead of type K) is shown in plot 4.



Plot 4: Measurement behaviour at different temperature input

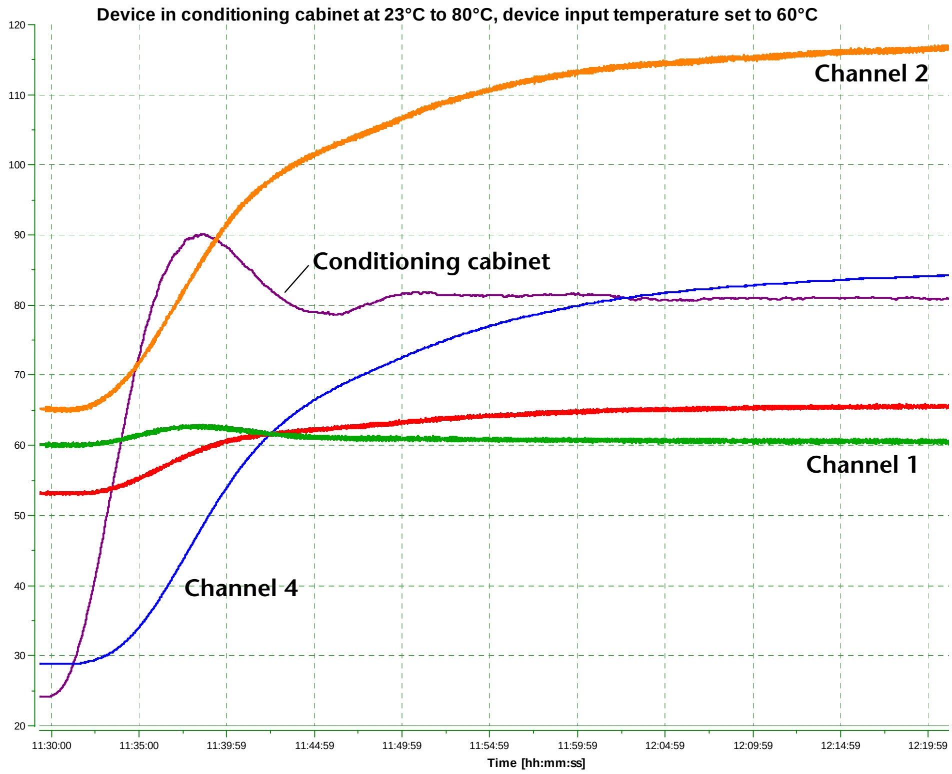
The simulated input temperature is changed from -40°C to +200°C in steps of 10°C with the calibrator DIGISTANT 4420. Channel 1 shows the correct temperature, whereas channel 3 temperature value is too high for negative input values. For positive input values the measured temperature value is too low, e.g 200°C input value are measured as 146°C with thermocouple type J.

4 Influence of ambient temperature

As the ambient temperature changes, the value of the cold junction temperature (i.e. the temperature of the terminal block) has to be evaluated. The ambient temperature of the module was changed from 23°C to 80°C in a conditioning cabinet.

4.1 Measurement values during heating-up

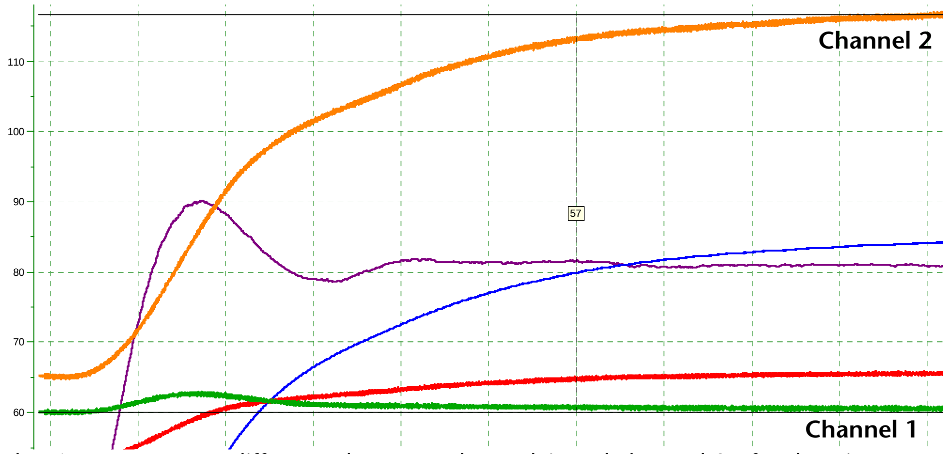
During the heating-up period the nominal temperature of 60°C on channel 1 changes to 62,1°C and goes back to 60°C. This effect is caused by the cold junction temperature, which can be monitored on channel 4.



Plot 5: Measurement behaviour during heating-up the conditioning cabinet

Since the ambient temperature in the conditioning cabinet changes by 12°C/min, which is not typical for real life applications, the temperature error on channel 1 can be tolerated.

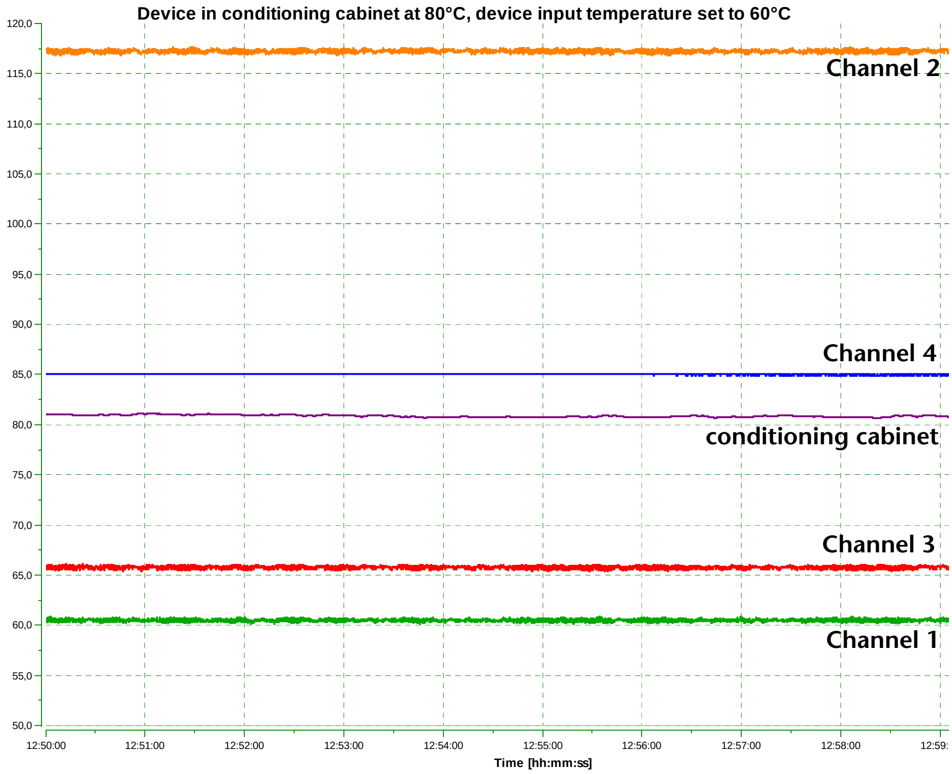
The effect of the cold junction temperature is quite impressive for channel 2, where the thermocouple wires are extended with copper wires. Starting with an initial error of 4,4°C, the error grows to 57°C, showing a temperature of 117°C instead of 60°C.



Plot 6: Temperature difference between channel 1 und channel 2 after heating-up

4.2 Measurement values at 80°C

Plot 7 depicts the measured temperatures on each channel in a settled environment

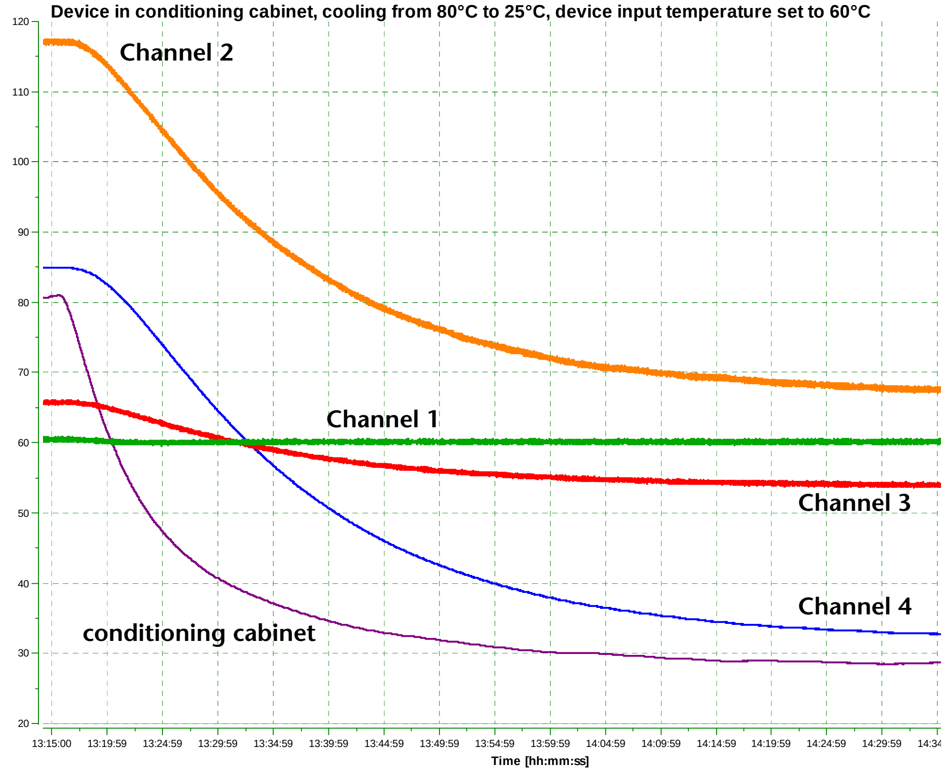


Plot 7: Measurement behaviour in conditioning cabinet at 80°C

Channel	Input configured to	Input connected to	Error
1	Thermocouple Type K	Thermocouple Type K	0°C
2	Thermocouple Type K	Thermocouple Type K, extended by copper wire	+57°C
3	Thermocouple Type J	Thermocouple Type K	+6,2°C

4.3 Measurement values during cooling-down

The situation during cooling-down is similar to the heating-up period.



Plot 8: Measurement behaviour of µCAN.4.ti-BOX during cooling-down

In contrast to the heating-up period the ambient temperature in the conditioning cabinet changes slower. As result no temperature error on channel 1 can be observed.

5 Conclusion

Thermocouples are suitable for measuring over a large temperature range, up to 2300 °C depended on the used thermocouple type. While connecting a thermocouple to a signal converter the following rules have to be observed:

- Make sure that the configured thermocouple type of the signal input fits the connected thermocouple type
- Never extend thermocouple wires with other material
- Make sure the polarity of the thermocouple fits the to signal input terminals

6 Revision history

Revision	Date	Description
01	25.08.2010	Initial version

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