Training Note

TR-08RD

Thermocouple temperature sensors

Introduction

Thermocouples are a general purpose temperature sensor consisting of two wires of dissimilar metals. When one end is heated or cooled the temperature difference causes a Voltage to flow. By measuring the temperature at the termination end and precisely measuring the Voltage the temperature at the other end of the thermocouple can be calculated.

The *DT80* range of data loggers support thermocouple types B, C, D, E, G, J, K, N, R, S and T, and provide reference junction compensation and linearization over the temperature range for each of the thermocouple types.
Any mix of thermocouples can be used in the same project.

Prerequisite

This worked example assumes basic knowledge of;
1. *dEX interface or DeTransfer*
2. *dataTaker* programming language. (When using DeTransfer)

Requirements

Hardware;
1. *DT80* Range *dataTaker* data logger. Version 8.06.0001 firmware or later.
2. Thermocouple. (K type used in this example)

Software;
1. *dEX interface*.

or

2. *DeTransfer*.

Manuals;
1. *DT80* User manual Version UM-0085-B1 or later
2. Thermistor data sheet.

Quick start

Thermocouples are a two wire device that outputs a Voltage that is proportional to the temperature difference at each end. Due the very small magnitude of the output Voltage, in the order of tens of micro Volts per degree centigrade, care needs to be taken to ensure a quality reading is measured.

Sampling the Thermocouple.

1. Connect the thermistor to the + and - terminals of a *dataTaker* analog channel.

Note: Cable shielding is to be connected to either the Digital Ground or the ground screw terminal.

2. When using *dEX* web based configuration interface

a. Open your web browser and enter the TCP/IP address of your *DT80* series Geologger.

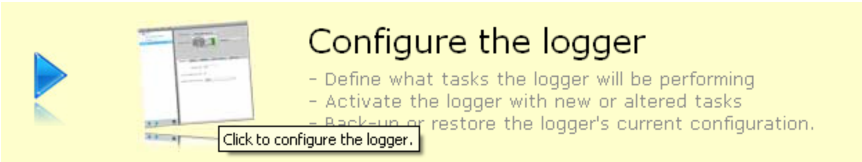

Figure 1 Accessing *dEX* configuration builder

b. In the Menu tree select Schedule_1 then click on "Add" in the menu bar

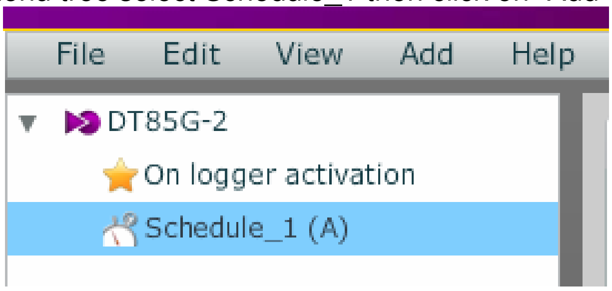

Figure 2 Adding a measurement

c. Expand out the add menu following the path Measurement -> Temperature and click on Thermocouple.

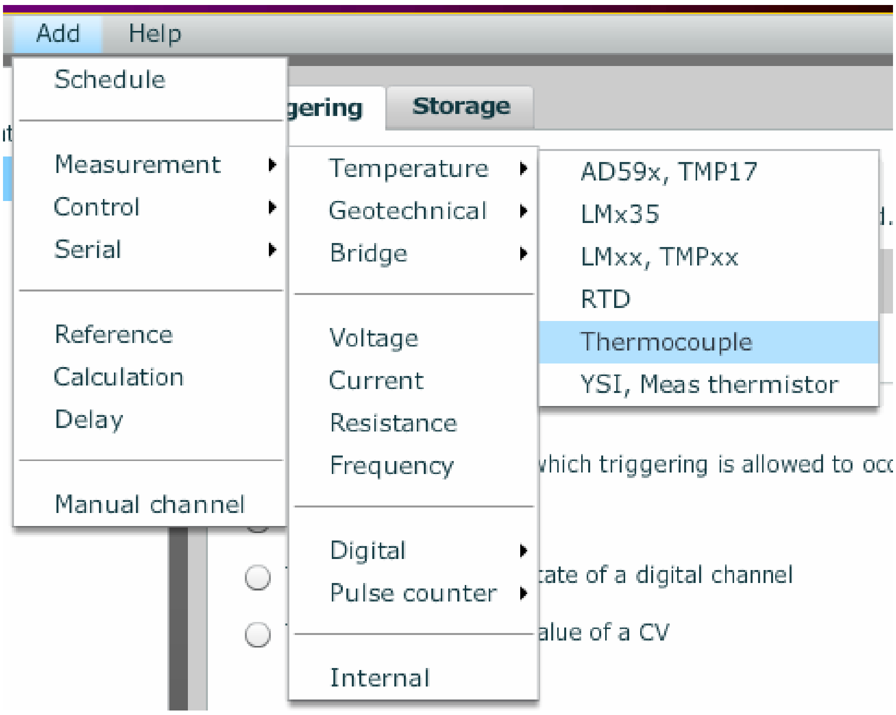

Figure 3 Adding a thermocouple channel type

d. In the tree view give the channel a unique and meaningful name. To accept the name click on the tick. Note: This name will be referred to in later calculations.

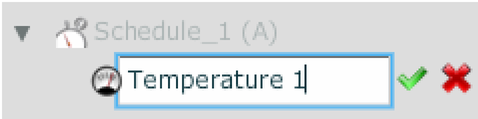

Figure 4 Naming the channel

e. In the pane view click the down arrow and click on the type of thermocouple you are using. (K type in this example)

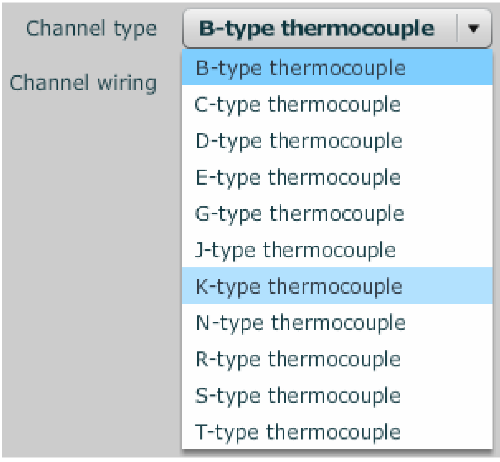

Figure 5 Selecting the type of thermocouple

f. In the view pane, click on “Select wiring” and select the first wiring option.

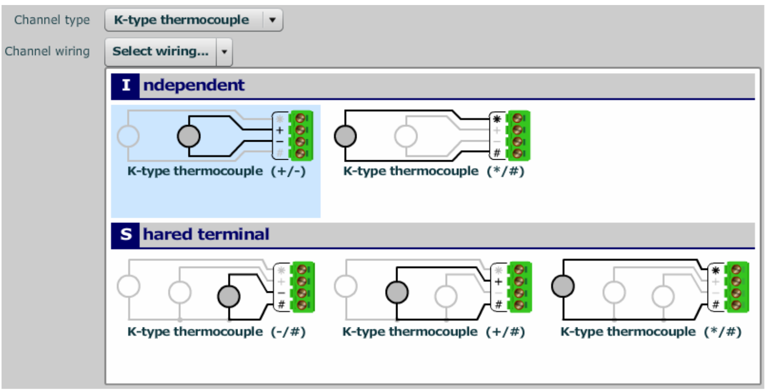

Figure 6 Selecting wiring type

g. In the view pane, click on the channel selector and select the analog channel number the vibrating wire sensor is physically connected to.

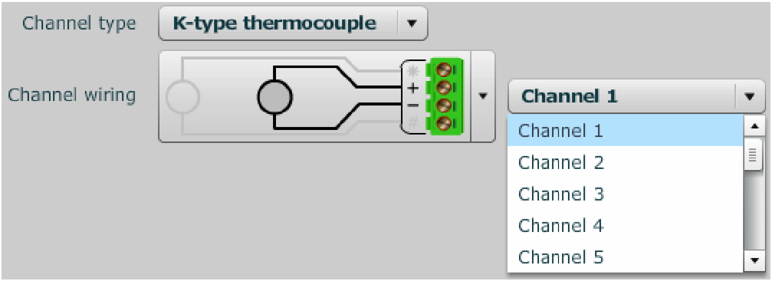

Figure 7 Selecting analog channel number

h. To send the configuration to the logger, on the menu bar, Click on “File” -> “Save to logger”

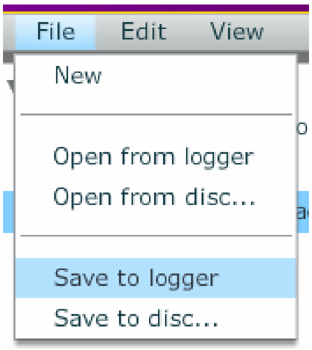

Figure 8 Sending configuration to logger

3. When using the *dEX* command window or *DeTransfer*.

a. Connect to the *DT80* range logger.

b. In the send window type the command nTK. Where n is the analog channel number the thermistor is connected to and K is the thermocouple type (K type in this instant). This will cause the *DT80* to take a single reading from the thermocouple.

c. Sample result will be returned to the receive window.

Thermocouple Support in detail

Basic Concepts of Thermocouples

A practical thermocouple consists of two wires of dissimilar metals that are electrically joined at one end (the measurement junction), and thermally joined at the other end (the reference junction).

A low DC voltage is produced by the thermocouple when the two junctions are at different temperatures. This voltage is referred to as the thermoelectric voltage. This thermoelectric voltage is produced by the temperature gradient along the thermocouple wires. The thermoelectric voltage is not produced by the junctions themselves.

It is important that the purity of the two thermocouple wires is rigidly maintained, particularly at points where there are significant temperature gradients.
A typical thermocouple circuit, in this case a type J thermocouple, is illustrated below.

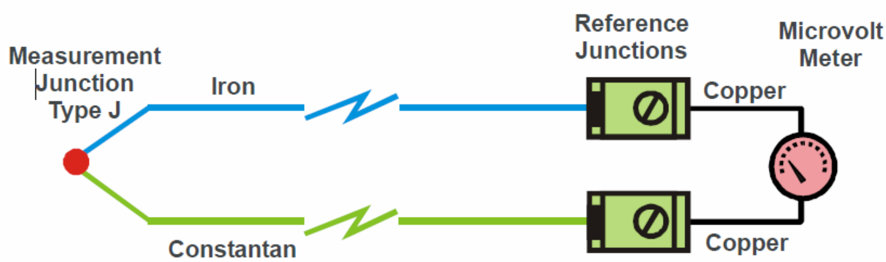

Figure 9 Typical thermocouple measurement system

Thermocouple Reference Junction Temperature

The reference junctions of thermocouples are traditionally maintained at 0°C. This is assumed in thermocouple calibration tables. While this requirement can be provided by maintaining the reference junctions in melting ice baths or electronically cooled enclosures, this is impractical for portable or remote applications.

An alternative and more practical approach is to maintain the thermocouple reference junctions at ambient temperature, and allowed to drift with ambient temperature.
In this approach, the thermocouple reference junctions are all maintained at an equal temperature by placing them in close thermal proximity to a heat conductor, and ideally enclosed in thermal insulation. The heat conductor is generally referred to as an isothermal block, and is usually a block of aluminium, copper or similar material with a high thermal conductivity.

This approach requires that the temperature of the thermocouple reference junctions (actually the difference between the temperature of the reference junctions and 0°C) is known. This temperature is then used to correct the temperature measured by the thermocouple. This correction overcomes the errors produced by a non-zero thermocouple reference junction temperature, referred to as reference junction temperature compensation.

The *dataTaker* has a metal chassis around the analog input channel terminals, and optionally a substantial metal case. These contribute towards creating an isothermal environment around the junctions of directly connected thermocouples. However The *DT80* should be kept as close to a stable temperature as possible and away from draft or heat sources that could heat the *DT80* unevenly. If a *DT80* has been moved from one area to another that involves a temperature change then the unit should be left for long enough to allow the temperature of the unit to stabilize before commencing temperature recording. (This is true for any device that measure temperatures when using thermocouples).

Voltage to Temperature Conversion

The relationship between temperature and measured voltage for a thermocouple is not linear. The temperature-voltage relationship of all thermocouples has been accurately measured and published. These are used to calculate the thermocouple temperature from a measured voltage by a technique called thermocouple linearization. The thermocouple linearization is as defined in the ITS-90 thermocouple standard.

Thermocouple Support by the dataTaker

The *DT80* supports the thermocouple types B, C, D, E, G, J, K, N, R, S and T. When a thermocouple type is measured by the *dataTaker*, the *dataTaker* automatically performs the reference junction temperature compensation, zero voltage compensation and linearization calculations.
Readings are returned directly in degrees Celsius, Fahrenheit, Kelvin or Rankine with a resolution of 0.1 Deg C and accuracy of better than 0.5 Deg C, depending on the thermocouple.

Trouble shooting thermocouples

Thermocouples can be affected by many different noise sources. This is because the thermocouple output is typically around 0.040 milli Volts per degree C. As with any very low level signal, care must be taken to ensure correct shielding from sources of noise and electrical interference.

Some things to consider are;

Temperature stability of the logger

A thermocouple outputs a voltage that is proportional to the temperature difference between the tip of the thermocouple and the end attached to the *dataTaker*. To calculate the temperature at the thermocouple tip we must also know the temperature of the terminals of the *dataTaker* so we can apply isothermal compensation. There fore it is very important to keep the *dataTaker* Isothermal. (Isothermal means at one temperature.)

1. Keep out of any drafts.
2. Keep away from heat sources.
3. Keep out of direct sun light.
4. Allow the *dataTaker* to temperature stabilize before taking measurements.

This usually means the logger is kept in an insulated box.

Sources of electrical noise

The shorter the thermocouple the less chance of picking up noise from other sources. If you have a particularly noisy area and you need to drive long distances you should consider using a 4-20 mA signal conditioner.

Keep the thermocouples as far away from mains power cabling as possible. AC power produces a changing magnetic field around them that will induce voltages in the thermocouple.

Shielding and grounding of thermocouples

In an area where electrical noise could be a problem choose thermocouples that have shielding built in. The shield should be connected at one end only, DGND on the *DT80* range or at the contact point being measured but never both.

If using thermocouples that have a bare tip and the tip is in contact with a surface that is electrically conductive, then the thermocouple might be picking up stray currents that can affect the readings. For example; if measuring the temperature of a hot water pipe in an old house it was often the case that the water pipes were used as the grounding. This ground return means that there will be stray currents causing noise.

With conductive surfaces either electrically isolate the tip of the thermocouple from the surface with a thermocouple that has shielding or the conductive surface to the grounding point on the *DT80*. The *DT80* range can float the ground reference so should not have noise issues as long as the point being measured is within 100 VDC of the *DT80* ground.

Because the thermocouple will most likely be of different metals to the surface being measured it is possible to have a galvanic potential (Basically a small battery) being produced at the point of contact. If this is the case the only option is to electrically isolate the tip of the thermocouple from the surface being measured.

Keep joints clean

Make sure there is no oil, grease or corrosion on the *dataTaker* terminals or the thermocouple. Because the low voltage output of a thermocouple can be affected by a change in terminal resistance.

Extending Thermocouples

Thermocouples can be extended but you must use the correct type of thermocouple extension wire to suit the thermocouple type in use (example Type K). These are made of the same material as your thermocouples but of a lower quality and so are cheaper in price. Using copper wire to extend the thermocouple will add error to the readings. Thermocouple extension wire can be purchased from your thermocouple supplier.

Note: DO NOT use thermocouple extension wire as thermocouples. Thermocouple extension wire is cheaper than thermocouple wire and has *similar* thermoelectric output as a thermocouple but over a much smaller temperature range. Extension wire should not be used in the temperature gradient area.

Thermocouple tolerances

Thermocouples have manufacturing tolerances. For example a standard grade K type thermocouple has a stated accuracy of 2.2Deg C or 0.75% which ever is greater. This means that thermocouples manufactured at different times or from different material batches can have up to 2.2 degrees difference in the reading and still be within tolerance.
To reduce this type of error it is recommended that all thermocouples used on an installation are made from the same roll of thermocouple wire. You can specify this when you order your thermocouples.

Programming the *DT80* data logger

DeTransfer / *WEB UI example (Differential Inputs)*

Enter the following *dataTaker* code into the send window of *DeTransfer* or the data logger WEB UI command send pane and send to the data logger.

Code example 1:

```
BEGIN"YS05"
'Sample of K type thermocouple measurement.

RA"Schedule_1"("b:",ALARMS:OV:100KB:W60,DATA:OV:1MB)5S LOGONA

'Differential Inputs.
 1TK         'Differential between +/-
 1*TK        'Differential between */#

'Single Ended Inputs.
 2*TK        'Single ended between */#
 2+TK        'Single ended between +/#
 2-TK        'Single ended between -/#
END
```

Appendix 1 Supported Thermocouple types

Type	*Alloy of +ve wire*	*Alloy of -ve wire*	*Temperature Range*
B	Platinum 30% Rhodium (70% Pt - 30% Rh)	Platinum 6% Rhodium (94% Pt - 6% Rh)	0 to 1700 Deg C 32 to 3100 Deg F
C	Tungsten 5% Rhenium (74% W - 26% Re)	Tungsten 26% Rhenium (95% W - 5% Re)	0 to 2320 Deg C 32 to 4200 Deg F
D	Tungsten 3% Rhenium (97% W - 3% Re)	Tungsten 25% Rhenium (75% W - 25% Re)	0 to 2320 Deg C 32 to 4200 Deg F
E	Chromel (55% Cu - 45% Ni)	Constantan (90% Ni - 10% Cr)	-200 to 900 Deg C -330 to 2280 Deg F
G	Tungsten (100% W)	Tungsten 26% Rhenium (74% W - 26% Re)	0 to 2320 Deg C 32 to 4200 Deg F
J	Iron (100% Fe)	Constantan (55% Cu - 45% Ni)	0 to 750 Deg C 32 to 1380 Deg F
K	Chromel (90% Ni - 10% Cr)	Alumel (96% Ni - 2% Mn - 2% Al)	500 to 1250 Deg C -330 to 2280 Deg F
N	Nicrosil (Ni-Cr-Si)	Nisil (Ni-Si-Mg)	-270 to 1350 Deg C -450 to 2370 Deg F
R	Platinum 13% Rhodium (87% Pt - 13% Rh)	Platinum (100% Pt)	0 to 1450 Deg C 32 to 2640 Deg F
S	Platinum 10% Rhodium (90% Pt - 10% Rh)	Platinum (100% Pt)	0 to 1450 Deg C 32 to 2640 Deg F
T	Copper (100% Cu)	Constantan (55% Cu - 45% Ni)	-500 to 350 Deg C -330 to 660 Deg F