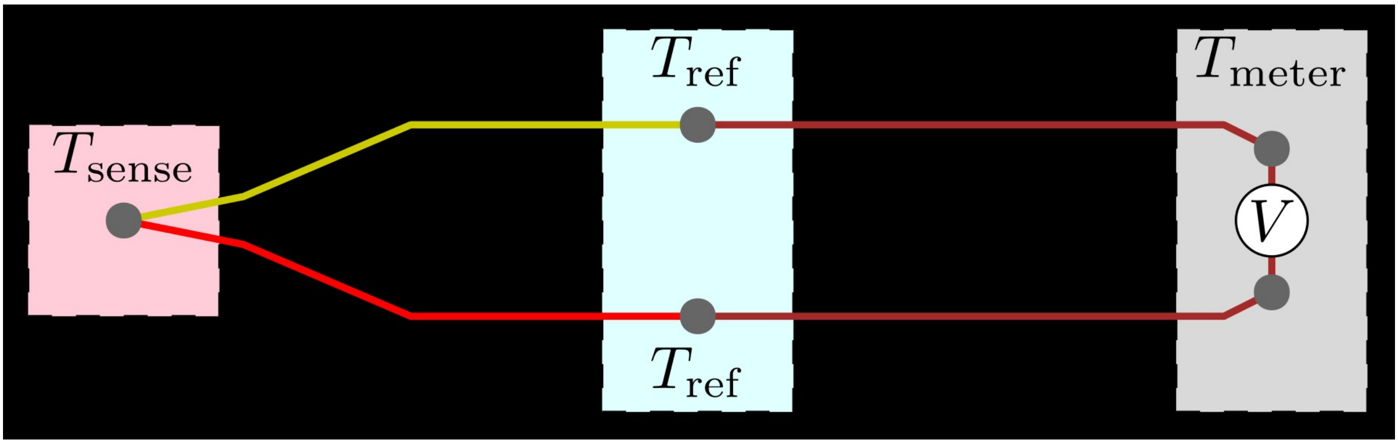
## Thermocouple

(Partly from Wikipedia, the free encyclopedia)

A thermocouple is an electrical device consisting of two dissimilar electrical conductors forming an electrical junction. A thermocouple produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature. Thermocouples are a widely used type of temperature sensor.




The standard configuration for thermocouple usage is shown in the figure. Briefly, the desired temperature $T_{\mathrm{sense}}$ is obtained using three inputs—the characteristic function $E(T)$ of the thermocouple, the measured voltage $V$, and the reference junctions' temperature $T_{\mathrm{ref}}$. The solution to the equation $E(T_{\mathrm{sense}}) = V + E(T_{\mathrm{ref}})$ yields $T_{\mathrm{sense}}$. These details are often hidden from the user since the reference junction block (with $T_{\mathrm{ref}}$ thermometer), voltmeter, and equation solver are combined into a single product.

## Requirement for a reference junction

To obtain the desired measurement of T_sense, it is not sufficient to just measure V, The temperature at the reference junctions T_ref must be already known. Two strategies are often used here:

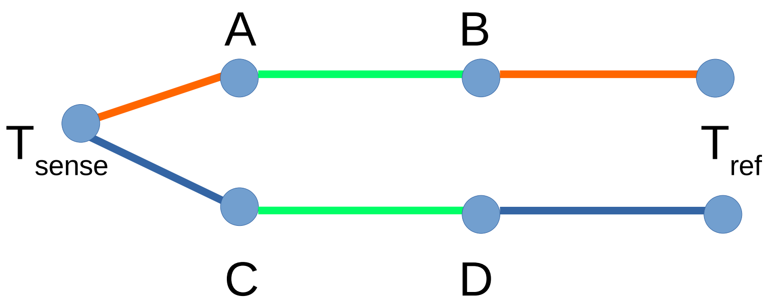
"Ice bath" method: The reference junction block is immersed in a semi-frozen bath of distilled water at atmospheric pressure. The precise temperature of the melting point phase transition acts as a natural thermostat, fixing T_ref to 0 °C.

Reference junction sensor (known as "cold junction compensation"): The reference junction block is allowed to vary in temperature, but the temperature is measured at this block using a separate temperature sensor. This secondary measurement is used to compensate for temperature variation at the junction block. The thermocouple junction is often exposed to extreme environments, while the reference junction is often mounted near the instrument's location. Semiconductor thermometer devices are often used in modern thermocouple instruments.
In both cases the value V+Eref + E_re is calculated, then the function E(T) is searched for a matching value. The argument where this match occurs is the value of T_sense.


All data given in this sheet are carefully checked but subject to change at any time.

www.allectra.com
allectra GmbH, Traubeneichenstr. 62-66, D-16567 Schönfliess, Tel: +49-(0)33056 787 78-0 Fax: -5, e-mail: info@allectra.com
allectra Ltd, Bluebell Business Estate, Sheffield Park, TN22 3HQ, UK T:+44 1825 721 900, F: +44 1825 723 872, uk@allectra.com

## Extension of a thermocouple with non-thermocouple materials




In the above diagram, a thermocouple is extended by the green wires.
By doing this, you get not only one thermocouple but 5 off!

At the points A, B, C, D a thermocouple voltage (TV) will be created as well.
Nevertheless, as long as the temperature at point A is identical with the temperature at point B, the two thermocouples compensate each other completely:

$TV_A = - TV_B$

This is valid, because the two joints are made with the same material combination. The temperature itself has no influence!

This is also valid for the points C and D.

What happens, if the temperature at A/C is not the same as B/D?
In this case, there is a remaining thermocouple voltage, as the thermocouples at C/D are not made out of the same material as A/B.
This will cause an error to the measurement. Compensation would be difficult, as normally the temperatures are not known.

So best practice is, to use thermocouple material from the measurement point to the measuring instrument for wires and connectors.

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## *How to create a thermocouple*

As soon as the two thermocouple materials form an electrical contact, a thermocouple (or measurement point) is created. This can be done by just twisting the two materials together. An other common method are welded tips.


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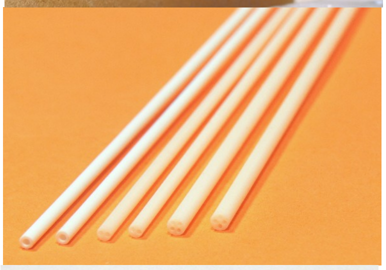
## *Temperature range*

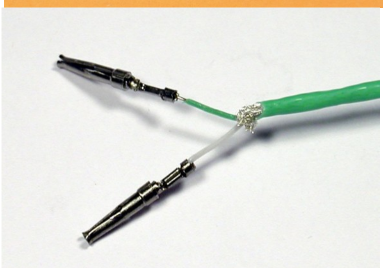
The max. temperature, which can be measured depends on:
- Thermocouple type (e.g K, N, R, S, C)
- Atmosphere (some materials might oxidize, which would result in significant errors)
  normally not relevant in vacuum
- Thickness of thermocouple wire (mechanical stability and chemical stability)
  normally not relevant in vacuum
- Temperature resistivity of insulation materials.

For high temperature measurements >300°C either blank wires or wires  with ceramic tube insulation are used. For this, ceramic tubes with two or four holes are often used.
For measurements up to 300°C, the Kapton insulated wires offered by Allectra can be used direct.

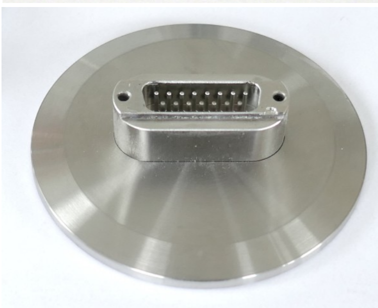
*Typical installation of a thermocouple inside an oven.
Two blank wires go through a ceramic tube with two holes. Ends are drilled together.*



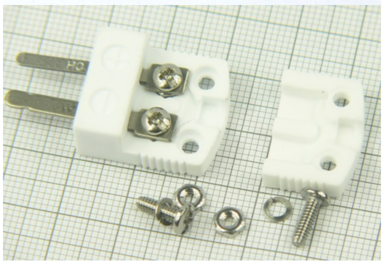
*Various ceramic tubes with one, two and four holes*



*Air side cable, prepared for a Sub-D connector.
Crimp pins are made out of thermocouple material.
Here a screened cable is used to avoid errors by other electrical fields.*



*Sub-D thermocouple feedthrough 15 pins (7 pairs) on a KF50 flange.
Upper row are the (+) pins, lower row the (-) pins.
Pins are not plated.*



*Classical thermocouple connector Type K (visible on the stapmed in „CR" and „AL" in the pins)
This version with ceramic body is suitable for UHV and very high temperatures.*



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allectra GmbH,  Traubeneichenstr. 62-66,  D-16567 Schönfliess,  Tel: +49-(0)33056 787 78-0  Fax:  -5,   e-mail: info@allectra.com
allectra Ltd,  Bluebell Business Estate, Sheffield Park,  TN22 3HQ, UK  T:+44 1825 721 900,   F: +44 1825 723 872, uk@allectra.com