

UNDERSTANDING THERMOCOUPLES

APPLICATION NOTE

Thermocouples Overview

A thermocouple is a device consisting of two different conductors (usually metal alloys) that produce a voltage proportional to a temperature difference between either ends of the pair of conductors. In contrast to most other methods of temperature measurement, thermocouples are self-powered and require no external form of excitation.

Grounded vs Ungrounded

A grounded junction puts the junction in intimate contact with the surrounding case metal. This allows for a faster response time. However, a grounded tip is susceptible to electromotive forces in the environment which could cause potential errors in the measurement. Use an ungrounded junction when sensor isolation is desirable and when time response is not an issue.

Thermocouple Types

Type K Thermocouple

This is the most common thermocouple type that provides the widest operating temperature range. Type K thermocouples generally will work in most applications because they are nickel based and have a good corrosion resistance.

- Positive leg is non-magnetic (Yellow), negative leg is magnetic (Red).
- Traditional base metal choice for high temperature work.
- Appropriate for use in oxidizing or inert atmospheres at temperatures up to 1260°C (2300°F).
- Vulnerable to sulfur attack (regrain from exposing to sulfur-containing atmospheres).
- Perform best in clean oxidizing atmospheres.
- Not recommended for use under partially oxidizing conditions in vacuum, or when subjected to alternating cycles of oxidization and reduction

Type J Thermocouple

This is the second most common thermocouple. It is a good choice for general purpose applications (if moisture is not present).

- Appropriate for use in vacuum, air, reducing, or oxidizing atmospheres to 760°C (1400°F) in the heavier gage sizes.
- The expected service life of the finer sized wires is limited due to the rapid oxidation of the iron wire at temperatures above 540°C (1000°F)
- Avoid use in sulfurous atmospheres above 540°C (1000°F).
- Limited subzero use due to rusting and embrittlement of the iron conductor.
- Positive (iron) wire is magnetic (white), negative is non-magnetic (red).

Thermocouple Types (continued)

Type E Thermocouple

- Neither wire is magnetic but negative wire is red, positive is purple.
- Recommended for use to 900°C (1600°F) in oxidizing or inert atmospheres.
- Appropriate for low temperature to about -230°C (-380°F).
- Has the highest output EMF of any standard type.
- Vulnerable to sulfur attack, do not expose to this type of atmosphere.
- Performs best in clean oxidizing atmospheres.
- Not recommended for use (except in short periods):
 - Under partially oxidizing conditions
 - When subjected to alternating cycles of oxidation and reduction
 - In vacuum

Type T Thermocouple

- Neither wire is magnetic but negative wire is red, positive is blue.
- When used in air:
 - Moisture resistant
 - Very stable
 - Useful to 370°C (700°F)
- Higher temperature use possible when used in vacuum, or in reducing or inert atmospheres.
- Appropriate for use down to -200°C (370°F). Special selection may be required of the materials.

Thermocouple Tolerances

Thermocouple Initial Calibration Tolerances			
Type	Temperature	Standard Limits	Special Limits
K	-200°C to 0°C* 0°C to 1250°C	± 2.2°C or ± 2%* ± 2.2°C or ± 0.75%	N/A ± 1.1°C or ± 0.4%
J	0°C to 750°C	± 2.2°C or ± 0.75%	± 1.1°C or ± 0.4%
E	-200°C to 0°C* 0°C to 900°C	± 1.7°C or ± 1%* ± 1.7°C or ± 0.5%	± 1°C or ± 0.5%* ± 1°C or ± 0.4%
T	-200°C to 0°C* 0°C to 350°C	± 1°C or ± 1.5%* ± 1°C or ± 0.75%	± 0.5°C or ± 0.8%* ± 0.5°C or ± 0.4%

* Thermocouple wire is usually supplied to meet tolerances for temperatures above 0°C. Special selection and testing may be required for these same materials in order for them to fall within the sub-zero tolerances given.

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Thermocouple Temperature Ranges

Type	Application Range	Trade Names	Color Code
K	95-1260°C (200-2300°F)	Chromel / Alumel	Red(-) / Yellow(+)
J	95-760°C (200-1400°F)	Iron / Constantan	Red(-) / White(+)
E	95-900°C (200-1650°F)	Chromel / Constantan	Red(-) / Purple(+)
T	0-350°C (32-660°F)	Copper / Constantan	Red(-) / Blue(+)

Thermocouple Wire Temperature Limits

The table below gives the recommended upper temperature limits for the various thermocouples and wire sizes. These limits apply to protected thermocouples, that is, thermocouples in conventional closed-end protecting tubes (sheaths).

Gage	Wire Size Temperature Limit			
	K	J	E	T
20	980°C (1800°F)	480°C (900°F)	540°C (1000°F)	260°C (500°F)
24	870°C (1600°F)	370°C (700°F)	430°C (800°F)	200°C (400°F)
28	870°C (1600°F)	370°C (700°F)	430°C (800°F)	200°C (400°F)
30	760°C (1400°F)	320°C (600°F)	370°C (700°F)	150°C (300°F)

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