Thermocouple mV from Temperature (Types B, E, J, K, N, R, S, T)

Thermocouple EMF in mV for a hot-junction and a cold-junction temperature, by the NIST ITS-90 reference functions, with the sensitivity in µV/°C.

Method: NIST Monograph 175 / SRD 60 ITS-90 reference functions (as adopted in IEC 60584-1 and ASTM E230)

Input parameters

Unit system: SI

Parameter	Value	Unit
Thermocouple type	Type K (Chromel / Alumel)	
Measuring (hot) junction temperature	400.00	°C
Reference (cold) junction temperature The temperature at the instrument terminals, where the thermocouple or its compensating cable ends. 0 °C gives the table value.	25.000	°C

Calculated results

Parameter	Value	Unit
EMF at the instrument terminals	15.397	mV
EMF with the cold junction at 0 °C (table value)	16.397	mV
EMF of the cold junction temperature (vs 0 °C)	1.0002	mV
Sensitivity at the hot junction	42.241	µV/K

Formula and method

$$E = E(T) - E(T_{ref})$$

$$E(t) = \sum_{i=0}^{n} c_i\, t^i \quad \left(+\, a_0\, e^{a_1 (t - a_2)^2} \text{ for type K above 0 °C}\right)$$

$$S = \frac{dE}{dT}$$

Variables

type	thermocouple type (letter designation)	-
T	measuring (hot) junction temperature	K
T_{ref}	reference (cold) junction temperature	K
E	EMF at the instrument terminals	V
$E(T)$	EMF with the cold junction at 0 °C (table value)	V
$E(T_{ref})$	EMF corresponding to the cold junction temperature	V
S	sensitivity (Seebeck coefficient of the pair) at T	V/K
t	temperature in °C used inside the reference function	°C
c_i, a_0, a_1, a_2	NIST reference-function coefficients for each type and subrange	mV, °C

Method and standards

The EMF comes from the ITS-90 thermocouple reference functions published by NIST (Monograph 175, Standard Reference Database 60), the same functions on which IEC 60584-1 and ASTM E230 tables are based. Each type has one to three temperature subranges with its own polynomial; type K above 0 °C adds an exponential term. The coefficients are read from NIST's published files, and the result is checked against every point of NIST's printed tables. The sensitivity is the exact derivative of the function.

Assumptions and limits

- Reference functions for standard thermocouple wire; real sensors carry the tolerance class of their wire (not included).
- Ranges: B 0–1 820 °C, E −270–1 000 °C, J −210–1 200 °C, K −270–1 372 °C, N −270–1 300 °C, R and S −50–1 768.1 °C, T −270–400 °C.
- Extension and compensating cables are assumed to match the thermocouple up to the terminals.

References

- NIST Monograph 175 / SRD 60 ITS-90 reference functions (as adopted in IEC 60584-1 and ASTM E230)

Report details

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Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/instrumentation/temperature/thermocouple-emf

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