Thermocouple Temperature from mV with Cold Junction Compensation

Hot-junction temperature from a measured thermocouple mV and the terminal (cold-junction) temperature, by the NIST ITS-90 functions, and the error without compensation.

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)	
Measured EMF at the terminals	15.000	mV
Cold junction (terminal) temperature	25.000	°C

Calculated results

Parameter	Value	Unit
Hot junction temperature	390.60	°C
EMF added for the cold junction	1.0002	mV
Compensated EMF (vs 0 °C)	16.000	mV
Reading without cold junction compensation	366.84	°C
Error if the compensation is left out	23.755	K

Formula and method

$$E(T) = E_m + E(T_{cj})$$

$$T = E^{-1}\left(E_m + E(T_{cj})\right)$$

$$\Delta T = T - E^{-1}(E_m) = T - T_u$$

Variables

type	thermocouple type (letter designation)	-
E_m	EMF measured at the terminals	V
T_{cj}	cold junction (terminal) temperature	K
$E(T_{cj})$	EMF corresponding to the cold junction temperature	V
$E(T)$	compensated EMF, referred to 0 °C	V
T	hot junction temperature	K
T_u	temperature read if no compensation is applied	K
ΔT	error when the compensation is left out	K
E^{-1}	inverse of the NIST reference function, solved numerically	-

Method and standards

Cold-junction compensation adds the EMF of the terminal temperature to the measured EMF, then converts the total to temperature through the ITS-90 reference function of NIST Monograph 175 (SRD 60). The conversion solves the reference function itself rather than NIST's approximate inverse polynomials, so it carries no extra error (NIST's inverses are good to about ±0.05 °C). Type B is inverted only from 50 °C, as its EMF is not single-valued below about 42 °C.

Assumptions and limits

- Reference functions for standard thermocouple wire; sensor tolerance class not included.
- The cold junction temperature is that of the point where the thermocouple or matching extension cable ends on copper.
- The measured EMF is assumed free of noise, lead-voltage drop and ground loops.

References

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

Report details

Report reference	FCC-8A9D-7FFP (the same inputs always give the same reference)
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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-temperature-from-mv

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Reopens the calculator with the inputs of this report.