

Temperature Measurement

Quick reference for instrumentation and control engineers



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Temperature units

Fahrenheit $^{\circ}\text{F} = ^{\circ}\text{C} \times 9 \div 5 + 32$

Kelvin $\text{K} = ^{\circ}\text{C} + 273.15$

Rankine $^{\circ}\text{R} = ^{\circ}\text{F} + 459.67$

Interval $1^{\circ}\text{C} \text{ (or } 1\text{ K)} = 1.8^{\circ}\text{F}$

Pt100 resistance (IEC 60751)

$^{\circ}\text{C}$	Ω	$^{\circ}\text{C}$	Ω
-50	80.31	200	175.86
0	100.00	300	212.05
50	119.40	400	247.09
100	138.51	500	280.98
150	157.33	600	313.71

Pt1000: multiply by 10. $\alpha = 0.00385$
 $\Omega/\Omega/^{\circ}\text{C}$, about $0.385\ \Omega$ per $^{\circ}\text{C}$ for Pt100.

Callendar–Van Dusen

0 $^{\circ}\text{C}$ and above $R = R_0 (1 + A t + B t^2)$

Below 0 $^{\circ}\text{C}$ $R = R_0 [1 + A t + B t^2 + C (t - 100) t^3]$

Constants $A = 3.9083 \times 10^{-3}$, $B = -5.775 \times 10^{-7}$, $C = -4.183 \times 10^{-12}$

RTD tolerance classes (IEC 60751)

Class	Tolerance ($^{\circ}\text{C}$)
AA	$\pm (0.10 + 0.0017 t)$
A	$\pm (0.15 + 0.002 t)$
B	$\pm (0.30 + 0.005 t)$
C	$\pm (0.60 + 0.01 t)$

Thermocouple types

Type	Materials	Typical range $^{\circ}\text{C}$	mV at 100 $^{\circ}\text{C}$
K	NiCr / NiAl	-200 to 1200	4.096
J	Fe / CuNi	-40 to 750	5.269
T	Cu / CuNi	-200 to 350	4.279
E	NiCr / CuNi	-200 to 900	6.319
N	NiCrSi / NiSi	-200 to 1200	2.774
R	Pt13Rh / Pt	0 to 1600	0.647
S	Pt10Rh / Pt	0 to 1600	0.646
B	Pt30Rh / Pt6Rh	600 to 1700	0.033

mV values from the IEC 60584-1 / NIST reference tables, cold junction at 0 $^{\circ}\text{C}$.

Thermocouple colours (positive / negative)

Type	IEC 60584-3	ANSI MC96.1
K	Green / white	Yellow / red
J	Black / white	White / red
T	Brown / white	Blue / red
E	Violet / white	Purple / red
N	Pink / white	Orange / red
R, S	Orange / white	Black / red
B	Grey / white	Grey / red

ANSI: the negative wire is always red.

RTD vs thermocouple

- RTD: more accurate and stable, up to about 600 $^{\circ}\text{C}$
- Thermocouple: wider range (to 1700 $^{\circ}\text{C}$), faster, rugged, needs cold junction compensation
- Use 3 wire RTD to cancel lead resistance; 4 wire for laboratory accuracy
- Use extension or compensating cable of the same type for thermocouples

Cold junction

Measured $E_{\text{meas}} = E(T_{\text{hot}}) - E(T_{\text{cj}})$

So $E(T_{\text{hot}}) = E_{\text{meas}} + E(T_{\text{cj}})$, then convert to $^{\circ}\text{C}$