

# Temperature Sensor (4B)

---

- RTD (Resistance Temperature Detector)
- Thermistor (Thermally Sensitive Resistor)
- Thermocouple
- Diode, TR Temperature Sensor

Copyright (c) 2009 Young W. Lim.

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the license is included in the section entitled "GNU Free Documentation License".

Please send corrections (or suggestions) to [youngwlim@hotmail.com](mailto:youngwlim@hotmail.com).

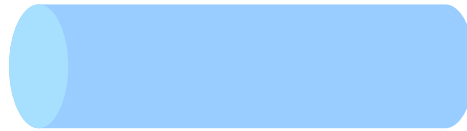
This document was produced by using OpenOffice and Octave.

Y o u n g   W o n   L i m  
1 0 / 8 / 0 9

# Electrical Resistance of Metal

**Electrical Resistance:**

$$R = \rho \frac{L}{A}$$



$\rho$  resistivity

- Nickel
- Copper
- Platinum

**L: length**

**A: cross section area**



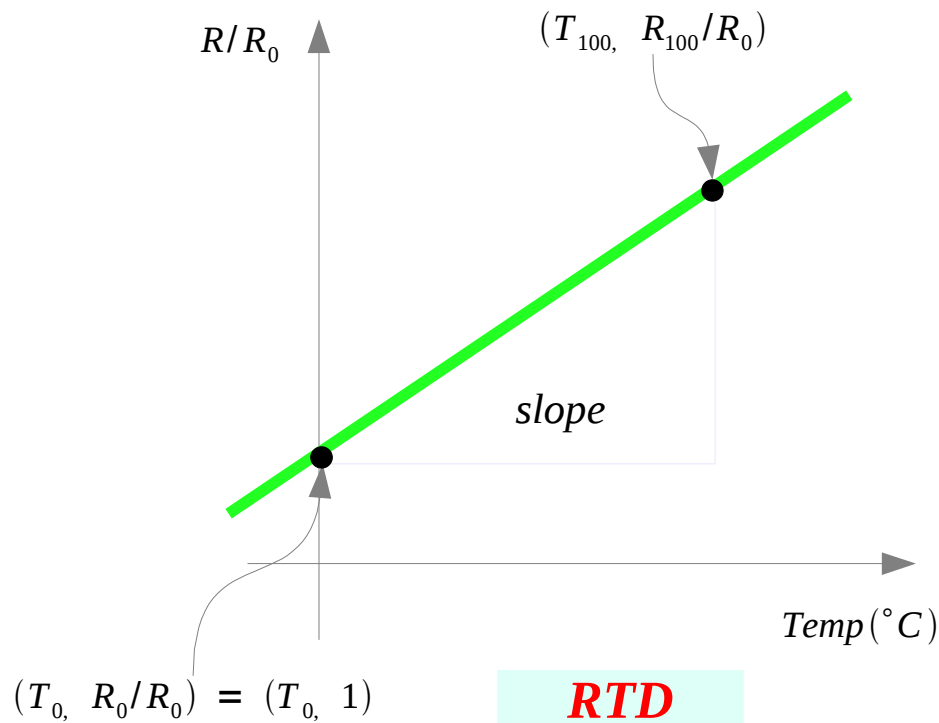
# RTD Temperature Characteristics

Temperature Coefficient of Resistance:  $\alpha$

$$R = \rho \frac{L}{A}$$



$$R = R_0[1 + \alpha(T - T_0)]$$



$$\frac{R}{R_0} = 1 + \alpha(T - T_0)$$

$$\frac{R - R_0}{R_0} = \alpha(T - T_0)$$

$$\alpha = \frac{1}{R_0} \cdot \frac{R - R_0}{T - T_0}$$

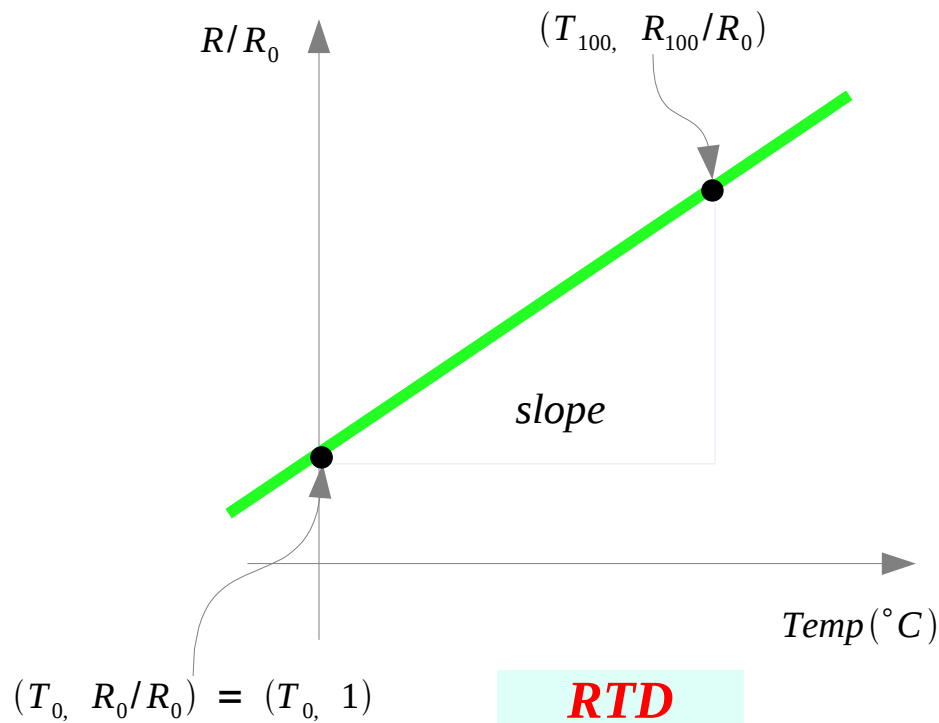
# RTD Sensitivity

Temperature Coefficient of Resistance:  $\alpha$

$$R = \rho \frac{L}{A}$$



$$R = R_0[1 + \alpha(T - T_0)]$$



$$\alpha = 0.004 [1/^{\circ}\text{C}]$$

0.4 percent change in resistance  
for 1 [ $^{\circ}$ C] change in temperature

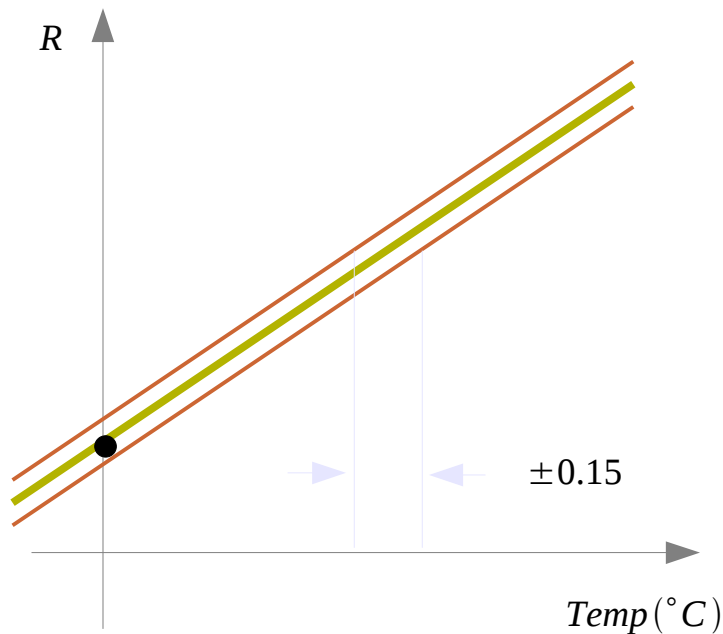
$$100 \Omega \rightarrow 0.4 \Omega$$

# RTD Accuracy

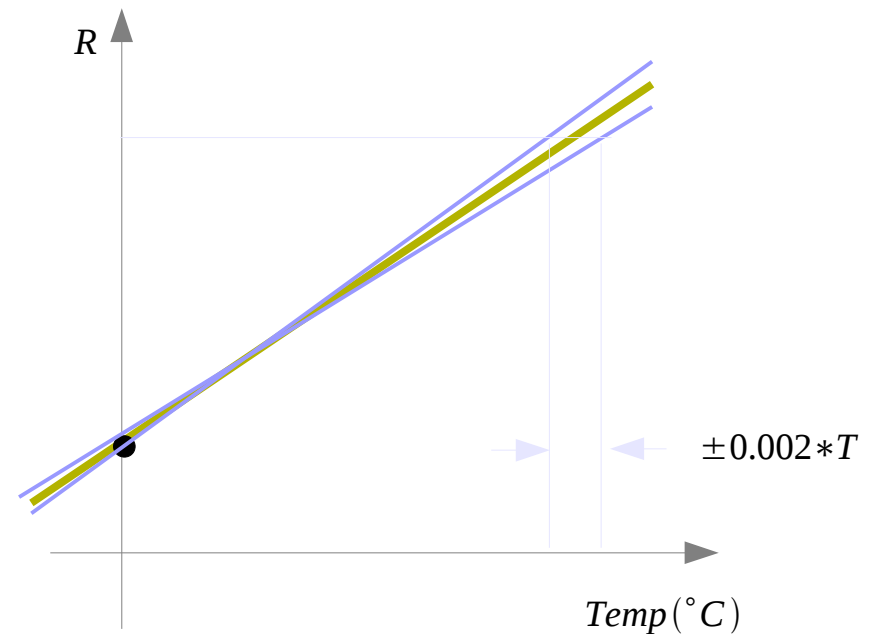
Temperature Coefficient of Resistance:  $\alpha$

Class A:  $\pm(0.15 + 0.002T)$  [ $^{\circ}\text{C}$ ]

Class B:  $\pm(0.30 + 0.005T)$  [ $^{\circ}\text{C}$ ]



**RTD**

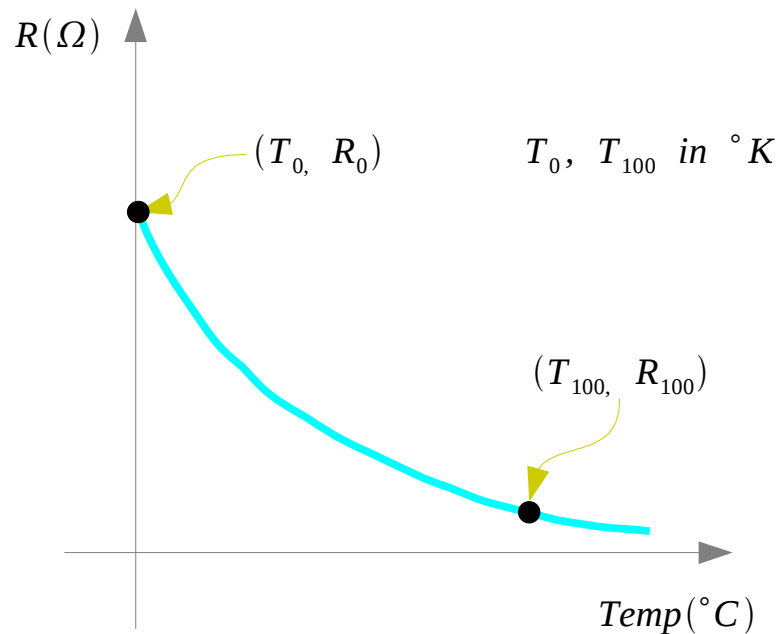


**RTD**

# NTC Thermistor Temperature Characteristics (1)

Characteristic Temperature:  $\beta$

$$R = R_0 \exp \left[ \beta \left( \frac{1}{T} - \frac{1}{T_0} \right) \right]$$



**NTC Thermistor**

$$\ln R = \ln R_0 + \beta \left( \frac{1}{T} - \frac{1}{T_0} \right)$$

$$\ln R - \ln R_0 = \beta \left( \frac{1}{T} - \frac{1}{T_0} \right)$$

$$\beta = \frac{1}{\left( \frac{1}{T} - \frac{1}{T_0} \right)} \ln \frac{R}{R_0}$$

# NTC Thermistor Temperature Characteristics (2)

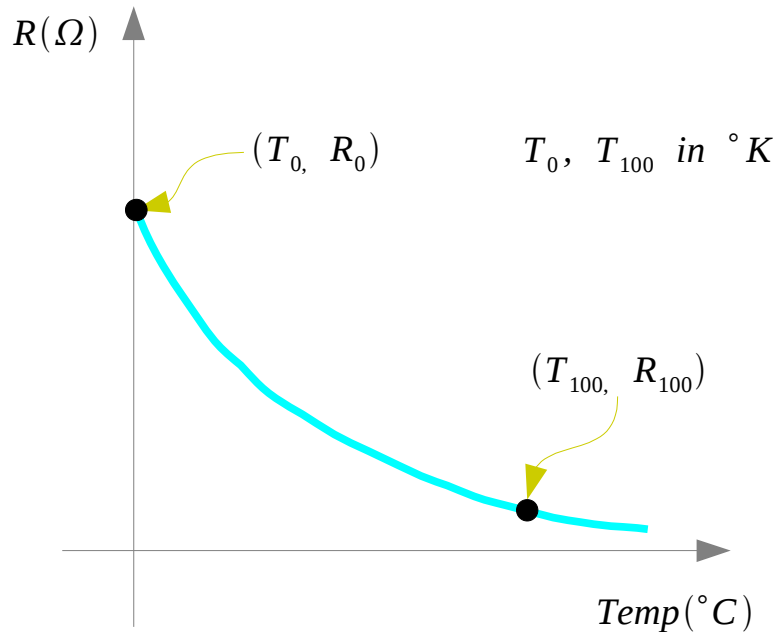
$$\beta = \frac{1}{\left(\frac{1}{T} - \frac{1}{T_0}\right)} \ln \frac{R}{R_0}$$

$$\beta = T_{100} \cdot T_0 \cdot \text{slope}$$

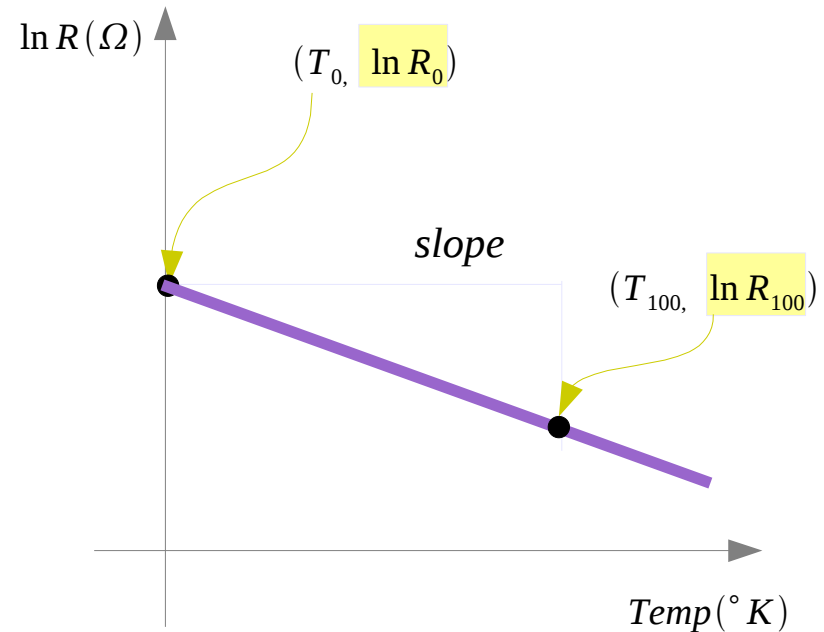
$$\text{slope} = \frac{\ln R_{100} - \ln R_0}{T_{100} - T_0}$$

$$= \frac{\ln \frac{R_{100}}{R_0}}{T_{100} - T_0}$$

**Log Scale**



**NTC Thermistor**



**NTC Thermistor**



# NTC Thermistor Temperature Characteristics (3)

**TCR:**  $\alpha$

**Characteristic Temperature:**  $\beta$

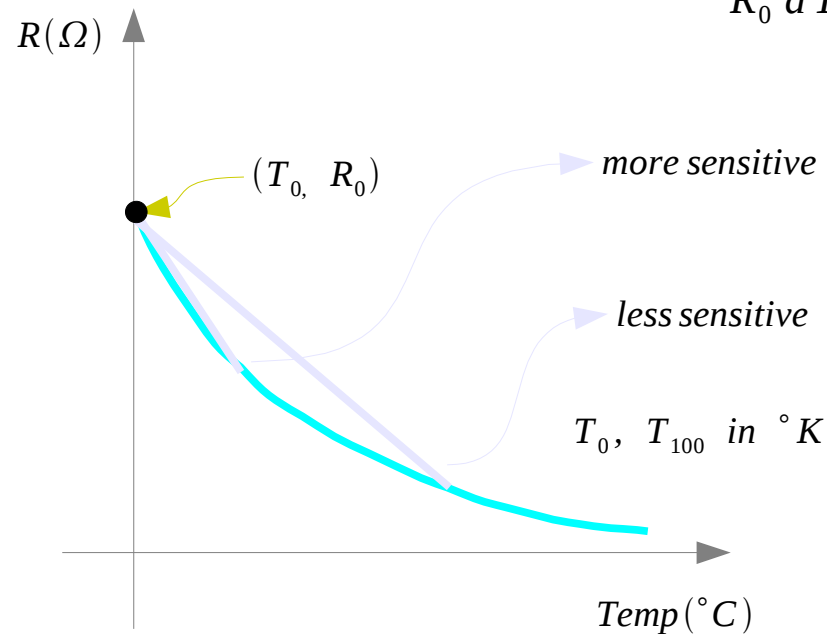
$$R = R_0[1 + \alpha(T - T_0)]$$

$$R = R_0 \exp \left[ \beta \left( \frac{1}{T} - \frac{1}{T_0} \right) \right]$$

$$\alpha = \frac{1}{R_0} \frac{dR}{dT}$$

$$\frac{dR}{dT} = \beta \left( -\frac{1}{T^2} \right) R_0$$

$$\alpha = \frac{1}{R_0} \frac{dR}{dT} = -\frac{\beta}{T^2} < 0$$



**NTC Thermistor**

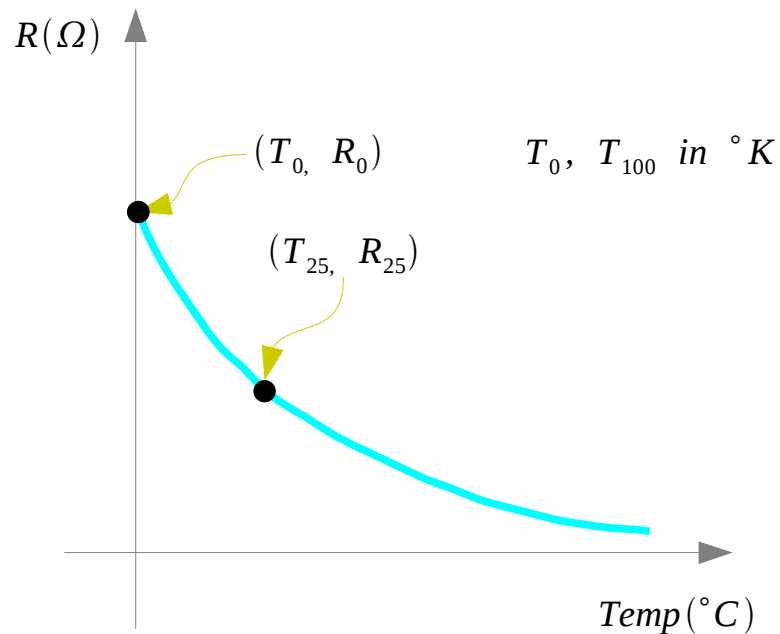
$$\alpha = -\frac{\beta}{T^2}$$

# NTC Thermistor Sensitivity

TCR:  $\alpha$

Characteristic Temperature:  $\beta$

$$R = R_0 \exp \left[ \beta \left( \frac{1}{T} - \frac{1}{T_0} \right) \right]$$



**NTC Thermistor**

$$\beta = 4000 [^{\circ}K] \text{ when } T = 25[^{\circ}C]$$

$$\alpha = -\frac{\beta}{T^2} = -\frac{4000}{(25+273.16)^2} = -0.045$$

$$\alpha = -4.5 \text{ percent}/^{\circ}K$$

## References

- [1] <http://en.wikipedia.org/>
- [2] Nam Ki Min, Sensor Electronics, Dong-il Press