

## HM Wire International, Inc.

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# Temperature Coefficient of Resistance

You might have noticed that on most tables for specific resistances that all figures were specified at a temperature of 20°C Celsius. If you suspected that this meant specific resistance of a material may change with temperature, you were right!

Resistance values for conductors at any temperature other than the standard temperature (usually specified at 20 Celsius) on the specific resistance table must be determined through yet another formula:

$$R = R_{\text{ref}} [1 + \alpha(T - T_{\text{ref}})]$$

*Where,*

**R = Conductor resistance at temperature "T"**

**R<sub>ref</sub> = Conductor resistance at reference temperature  
T<sub>ref</sub>, usually 20° C, but sometimes 0° C.**

**α = Temperature coefficient of resistance for the  
conductor material.**

**T = Conductor temperature in degrees Celsius.**

**T<sub>ref</sub> = Reference temperature that α is specified at  
for the conductor material.**

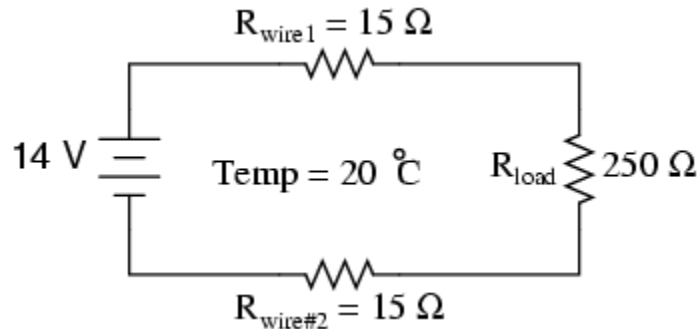
The "alpha" (α) constant is known as the temperature coefficient of resistance, and symbolizes the resistance change factor per degree of temperature change. Just as all materials have a certain specific resistance (at 20°C), they also change resistance according to the temperature by certain amounts. For pure metals, this coefficient is a positive number, meaning that resistance increases with increasing temperature. For the elements carbon, silicone, and germanium, this coefficient is a negative number, meaning that resistance decreases with increasing temperature. For some metal alloys, the temperature coefficient of resistance is very close to zero, meaning that the resistance hardly changes at all with variations in temperature (a good property if you want to build a precision resistor out of metal wire). The following table gives you the temperature coefficients of resistance for several common metals, both pure and alloy:

**TEMPERATURE COEFFICIENTS OF RESISTANCE, AT 20 DEGREES C**

Material	Element/Alloy	"alpha" per degree Celsius
Nickel	Element	0.005866
Iron	Element	0.005671
Molybdenum	Element	0.004579
Tungsten	Element	0.004403
Aluminum	Element	0.004308
Copper	Element	0.004041
Silver	Element	0.003819
Platinum	Element	0.003729
Gold	Element	0.003715
Zinc	Element	0.003847
Steel*	Alloy	0.003
Nichrome	Alloy	0.00017
Nichrome V	Alloy	0.00013
Manganin	Alloy	+/- 0.000015
Constantan	Alloy	-0.000074

\* Steel alloy at 99.5 percent Iron, 0.5 percent Carbon.

Lets take a look at an example circuit to see how temperature can affect wire resistance, and consequently circuit performance:



This Circuit has a total of wire resistance (wire 1 + wire 2) of 30  $\Omega$  at standard temperature. Setting up a table of voltage, current, and resistance values we get:

	Wire <sub>1</sub>	Wire <sub>2</sub>	Load	Total	
E	0.75	0.75	12.5	14	Volts
I	50 m	50 m	50 m	50 m	Amps
R	15	15	250	280	Ohms

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At 20°C, we get 12.5 volts across the load and a total of 1.5 volts (0.75 + 0.75) dropped across the wire resistance. If the temperature were to rise to 35° Celsius, we could easily determine the change of resistance for each piece of wire. Assuming the use of copper wire ( $\alpha = 0.004041$ ) we get:

$$R = R_{\text{ref}} [1 + \alpha(T - T_{\text{ref}})]$$

$$R = (15 \Omega)[1 + 0.004041(35^\circ - 20^\circ)]$$

$$R = 15.909 \Omega$$

Recalculating our circuit values, we see what changes this increase in temperature will bring:

	Wire <sub>1</sub>	Wire <sub>2</sub>	Load	Total	
E	0.79	0.79	12.42	14	Volts
I	49.677m	49.677m	49.677m	49.677m	Amps
R	15.909	15.909	250	281.82	Ohms

As you can see, voltage across the load went down (from 12.5 volts to 12.42 volts) and voltage drop across the wires went up (from 0.75 volts to 0.79 volts) as a result of the temperature increasing. Though the changes may seem small, they can be significant for power lines stretching miles between power plants and substations, substations and loads. In fact, power utility companies often have to take line resistance changes resulting from seasonal temperature variations into account when calculating allowable system loading.