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Technical Tidbits

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Do your connectors keep their cool ? This issue of Technical Tidbits is an overview on how to select a material based on the thermal properties of a connector design.

- Contact Resistance
- Ambient Temperature
- Bulk Resistance

The next issue of Technical Tidbits will discuss Current Carrying Capacity.

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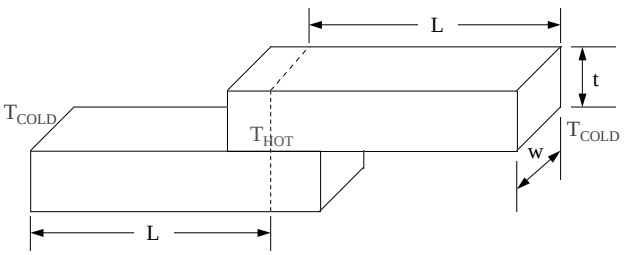
Connector Temperature Rise

Temperature is an important variable to keep in mind when designing electrical contacts. Higher temperatures typically lead to stress relaxation, which reduces contact force. Reduced contact force creates higher **contact resistance**, which impairs the electric signal and may ultimately lead to an open circuit. Therefore, when selecting a material, it is important to consider whether the material is capable of maintaining adequate performance at operating temperature.

Operating temperature has three components. The first is the **ambient temperature** (the temperature surrounding the connector). For automotive contacts, this can range from below freezing to 600 ºF in underhood applications. Cell phone contacts experience any temperature to which the user subjects it. Computer contacts range from room temperature to significantly higher, depending on how close they are to the processor and memory. The second component is the temperature rise generated by the contact resistance of the interface. The third and final component is the **t**emperature rise from the **bulk resistance** of the contact material itself.

The resistance of the contact interface itself is virtually impossible to calculate. Its value depends on many variables including shape, hardness, electrical and thermal conductivities of the contact surfaces, normal force, thickness of the oxide film, and relative motion of the contact surfaces. The contact resistance can be minimized by using sufficient normal force and the proper choice of plating material.

In 1976, Dr. R.E. Collin proposed the following approximation for temperature rise in an electronic connector. It is by no means precise and requires many assumptions. First, the connection is made of two contacts of equal conducting length and equal and constant cross-sectional area. Second, the fixed ends of the contacts are assumed to function as heat sinks at ambient temperature. Third, there is negligible resistance at the contact interface. Fourth, thermal energy is generated at a constant rate in the material, based entirely on resistive heating. Fifth, the maximum temperature occurs at the contact interface. Sixth, all excess thermal energy is carried away by conduction through the base metal. Seventh, there is no heat transfer by convection or radiation. The model of the connection is shown below. The equation for the temperature rise is shown as follows.



$$\Delta T = \frac{J^2 \cdot L^2}{2 \cdot \gamma \cdot k \cdot A^2}$$

Table 1. Temperature Rise Equation based on model developed by Dr. R.E. Collin in 1976.

Here, J is the current in Amps, L is the conducting length, A is the cross sectional area, γ is the electrical conductivity in Amps/(Volt-cm) or Amps/(Volt-in), and k is the thermal conductivity in (Volt-Amps)/(cm-ºC) or (Volt-Amps)/(inch-ºF). The equation is based on the solution of a second order differential equation, so no derivation will be presented here. The electrical and thermal conductivities are in unusual units, so they must be converted from standard units.

To convert electrical conductivity, multiply the conductivity in percent IACS by 5814 to get amps/(volt-cm) or by 14700 to get amps/(volt-in). For example, 22% IACS = 22*5814= 127,907 amps/volt-cm. Please note that 22% IACS is treated as 22 and not 0.22 in the conversion equation. To convert thermal conductivity to the appropriate units, multiply conductivity in W/(m-K) by 0.01 to get (Volt-amp)/(cm-ºC) or multiply conductivity in BTU/(ft-hr-ºF) by 0.0244 to get (Volt-Amp)/(in-ºF).

The number of assumptions and simplifications used to create this equation limits its usefulness as a predictive tool. In other words, any resemblance to the actual temperature rise of a real contact is purely coincidental. However, it does allow a designer to make comparisons between different materials, so it is more a measure of relative performance than actual performance. Also, the variables used in the equation are those that will affect the temperature rise regardless of contact shape.

Note that connector temperature rise is proportional to the square of the current passing through it. This is negligible in signal contacts but more important in power contacts and switches. The change in temperature is also proportional to the square of the conducting length. As length increases, bulk resistance increases, and the heat sinks are farther away from the hottest point on the connector. With the current miniaturization trend in connectors, this becomes an advantage. However, the temperature rise is inversely proportional to the square of the cross-sectional area. With a larger cross-section, the current can pass through more efficiently and can better carry away heat. The smaller cross-sectional areas associated with miniaturization will thus offset the gains made by decreasing the length.

Temperature rise is inversely proportional to both thermal and electrical conductivity of the material. Higher conductivity materials will perform better than lower conductivity materials in any given contact. Additionally, higher conductivity materials will allow for thinner and narrower cross-sections and smaller contacts, resulting in cost savings for the connector manufacturer.

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Reference:

Colin, Dr. R.E. "Material Properties Affecting Electrical Switch Design."

Case Western Reserve University, Cleveland, OH 1977.

Please contact your sales representative, for further information about contact physics or other questions pertaining to Brush Wellman or our products.

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