TECHNICAL TIDBITS

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Connector Temperature Rise

Do your connectors keep their cool? – An overview of the properties that govern the thermal performance of an electronic connector.

- **Contact Resistance**
- **Ambient Temperature**
- **Bulk Resistance**

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 temperature 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 of Case Western Reserve University 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:

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

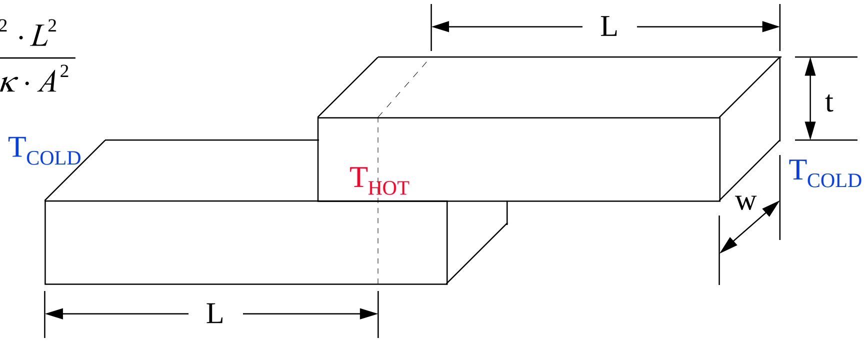

Figure 1. Model Used by Dr. Colin to Develop the Temperature Rise Equation.

The next issue of Technical Tidbits will discuss the current carrying capacity of spring contacts in electronic connectors.

Connector Temperature Rise (continued)

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 κ 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 like copper beryllium 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 local sales representative for further information on temperature rise or other questions pertaining to Brush Wellman or our products.

Health and Safety

Handling copper beryllium in solid form poses no special health risk. Like many industrial materials, beryllium-containing materials may pose a health risk if recommended safe handling practices are not followed. Inhalation of airborne beryllium may cause a serious lung disorder in susceptible individuals. The Occupational Safety and Health Administration (OSHA) has set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the Material Safety Data Sheet (MSDS) before working with this material. For additional information on safe handling practices or technical data on copper beryllium, contact Brush Wellman Inc.