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Keeping your contacts in touch with each other! - This discussion will explain how contact force affects connector performance.

- **Bulk Resistance**
- **Contact Resistance**
- **Contact Force**
- **Asperities (A-spots)**
- **Constriction Resistance**
- **Film Resistance**

The next issue of Technical Tidbits will include an informative discussion about the cumulative effects of tolerances on connector performance.

The Importance of Contact Force

Electrical connectors are designed to pass electric currents or signals across a separable interface with as few changes to the signal as possible. However, the signal will lose some of its power along the way when it encounters electrical resistance. There are two types of resistance that the signal will encounter: bulk resistance and contact resistance. **Bulk resistance** is the resistance of the material along the current's path. This is a constant value. **Contact resistance**, however, is variable resistance that occurs at the interface between the two contact surfaces. Contact resistance is made up of constriction resistance and film resistance, and is dependent upon the **contact force** between the two surfaces in contact.

Bulk resistance is dependent on the electrical resistivity of the contact material and the shape of the contact. It is easier to pass a signal through a material with low resistivity (high conductivity) than a material with high resistivity (low conductivity). A contact of a given length will have higher resistance than a similar contact of shorter length since the signal has a longer distance to travel. Conversely, a contact with a larger cross-sectional area will offer less resistance than a thinner, narrower contact. In the same way, Santa Claus will have an easier time getting down a short, wide, greased chimney (short, wide, high conductivity contact) than he would getting down a long, narrow, rough chimney (long, narrow, low conductivity contact).

A closer look at the contact interface reveals that all surfaces have some amount of roughness. A surface that appears smooth to the naked eye will appear to be covered with peaks and valleys when viewed under a microscope. Two mating surfaces will make contact with each other only where the surface peaks meet (Figure 1). These contact points are called **asperities**, or **A-spots**. The sum total of these contact areas is typically much smaller than the apparent surface area of the contact interface. **Constriction resistance** occurs as the electrical current must squeeze through the asperities to cross the interface. (In the same way, Santa Claus is slowed by a chimney that suddenly narrows.) **Film resistance** is created by thin layers of oxides and dirt that form on material surfaces. Oxides have higher resistivity which requires more effort for the signal to travel through the film. (In the same way, outdoor Christmas lights are seen much better when they are not covered with snow. As the layers of snow increase, less light is able to pass through and the Christmas lights are dimmer.)

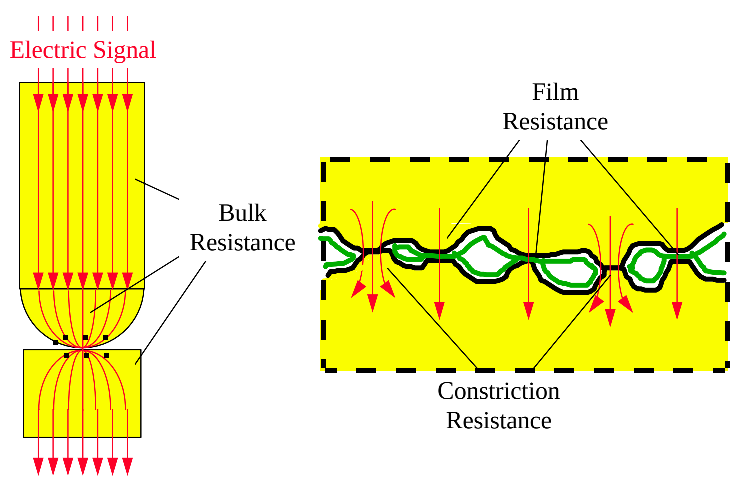

Figure 1. Sources of Electrical Resistance at the Contact Interface

The Importance of Contact Force (continued)

As the contact force increases, the Hertz stress (highly localized stress created by contact) experienced by the areas in contact will increase. This means that the highest peaks in contact will yield, expanding the contact area in an effort to counter the additional force. The mating surfaces will then move closer together which allows contact to be made at shorter, wider peaks on both surfaces. This decreases the constriction resistance since there are now more and larger paths for the signal to travel through. Since the contacting surfaces are wider, the signal can more easily pass through any film that might exist. Therefore, the film resistance decreases as well. Figure 2 shows how the increased force allows the signal to travel across the interface much more easily. At very high contact forces, most of the total resistance of the connector comes from the bulk resistance. The resistance is stable, since a small change in force will result in a minimal change in contact resistance

Conversely, as contact force decreases, fewer areas will remain in contact. In this situation, film resistance becomes the dominant component of overall contact resistance. If separation between the surfaces continues to increase (i.e. normal force drops nearly to zero), film resistance approaches infinity, and no signal will pass through the interface at all. At low forces, the contact resistance is unstable, since a small change in force can result in a large change in resistance. Figure 3 shows the relationship between contact force and contact resistance. Note that bulk resistance does not change with changes in contact force.

The electrical resistance of a connector can be minimized by selecting the most conductive material that also provides the highest normal force without overstressing the contact. This can be done by selecting a material with a high elastic modulus, high conductivity, high yield strength, and good stress relaxation resistance.

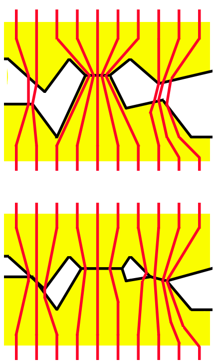

Figure 2. Effect of Increased Force on Constriction Resistance

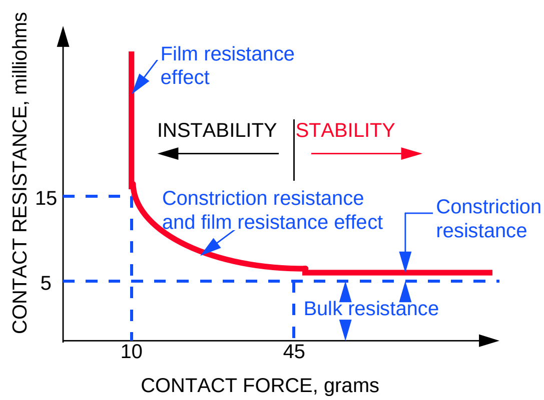

Figure 3. Contact Resistance vs. Normal Force

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