<u>CONTACT INTERFACES -- HOW THEY WORK</u>

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It may be obvious that any component added to a circuit path makes a contribution to the overall resistance of that path. This is certainly true of a set of mating connectors having a separable interface. However, the elements making up that contribution may not be so obvious.

Each of the mating connectors includes three different regions that contribute to resistance. The portion of each connector that physically touches the other is the region of Interface Resistance. As electrons flow into or out of this region, they follow a path that takes advantage of the available cross-sectional area. This is the region of Constriction Resistance. Lastly, the region farthest from the interface that accommodates such things as crimping, positioning and contact spring properties is the source of Bulk Resistance to the overall connection.

To understand the mechanism behind **<u>Interface Resistance</u>**, it is necessary to consider a microscopic view of the interface. As depicted in Figure 1, the interface between the contacts is not simply two perfectly smooth surfaces touching each other, but rather occurs as two sets of opposing peaks and valleys. The locations where opposing peaks touch each other are referred to as asperities or A-spots, and are illustrated in Figure 2. Collectively, these features define the electrical paths from one connector to the other such that Interface Resistance becomes a function of A-spot size and quantity.

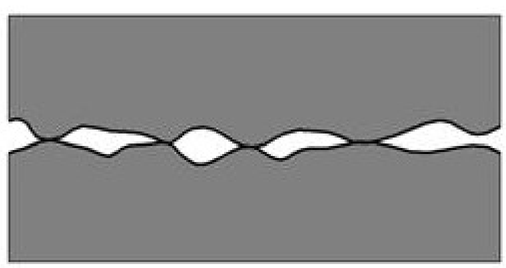

Figure 1 - **Contact occurs only at A-Spots, regardless of the overall interface geometry.**

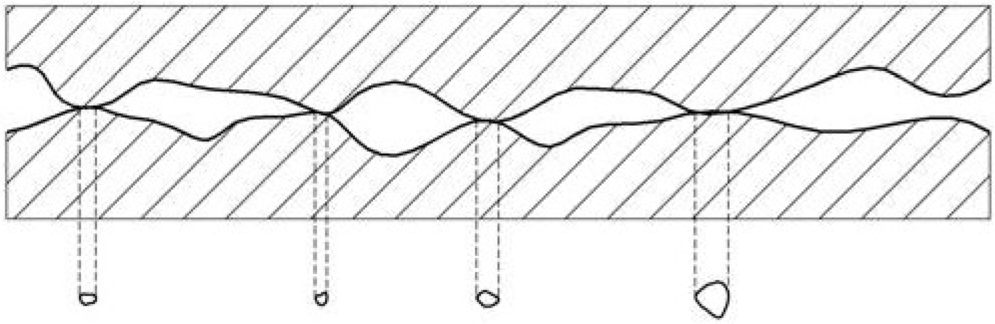

Figure 2 - **True (actual) contact area is the sum of all A-Spot areas.**

The softer a material's surface, the more the peaks will compress and the larger the A-spots will be for a given applied force. For example, since gold is softer than nickel, the sum of A-spot areas will be larger for gold plated surfaces than for nickel surfaces. To get the same A-spot areas, two nickel surfaces must be pushed together with a higher force than for gold surfaces. So, ignoring such things as corrosion and engagement wipe, and only looking at the total cross section of the interface, nickel needs a higher contact force than does gold to achieve a given desired resistance level.

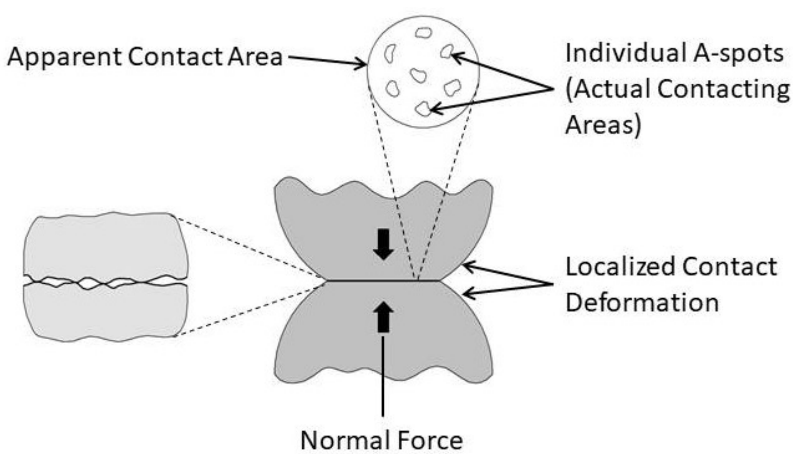

Figure 3 – **A-spots distributed within apparent contact area, provided by overall interface geometry.**

As contact normal force is increased, the resistance of a contact system will decrease, as the peaks compress more and the number and size of A-spots increases. However, this affect has its limits, with the resistance decrease tapering off. Therefore, increasing the normal force above a minimum value necessary to penetrate films and oxides (to achieve lower resistance at the contact interface) is an option, within reasonable limits. Excessive normal force, however, can potentially increase plating wear and impact mating/unmating forces, in addition to possibly overstressing the spring members.

Contact interface pressure (in contrast to contact normal force) is another factor that might be considered in the evaluation of Interface Resistance. However, the area that is used to determine this value is not simply the apparent or gross contact area, but rather the sum of the A-spot areas - whose precise size and number are difficult and impractical to determine. But since the deformation of A-spots is directly related to contact force, only normal force is required to establish expected conductivity at the interface.

Constriction Resistance is a function of how the actual current flows within a material, and in particular how it is channeled from the relatively large bulk cross section to the much smaller collection of A-spots.

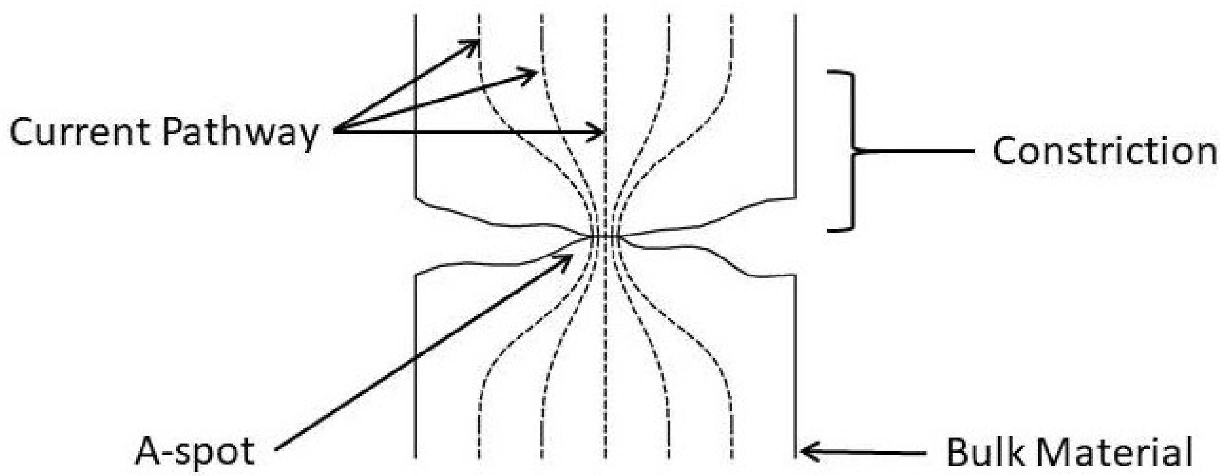

Figure 4 – **Current follows a constricted path from the bulk material to an interface A-spot.**

In general, the constriction region can be thought of as being a conical shape, whose exact dimensions are a function of interface properties, bulk resistance, and temperature. Constriction Resistance affects both power and signal contacts.

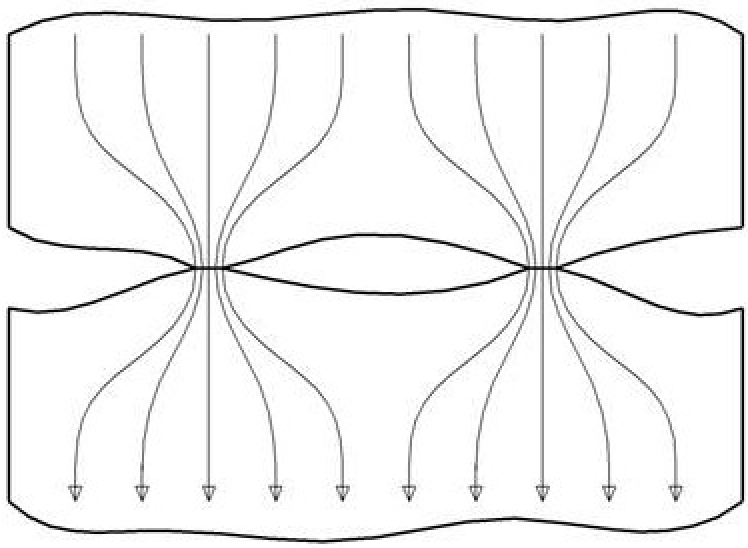

Figure 5 **- Current flow constricts in multiple parallel pathways through the A-Spots.**

Bulk Resistance is a function of the resistivity of a base material, operating temperature and the cross-sectional areas along the length of each contact, and excludes the constriction region and interface. Typically, this value of resistance will be the lowest, followed by that of the constriction region and then the interface. In the case of power connectors, large cross sections are preferred to minimize joule heating. With high frequency signal contacts, complex geometries may increase the impedance of the connection.

Additional consideration must also be given to **Film/Oxide Resistance**, which depends upon any insulators that are present at the surfaces of plated metals at the interface. These films and oxides interfere with conduction and need to be penetrated so that a clean metal-to-metal interface can be achieved. The force required to break through this film/oxide depends upon the plating material. The end-of-life normal forces shown below are generally effective at penetrating associated films and oxides:

- Gold – 40 grams minimum
- Rhodium – 40 grams minimum
- Silver – 125 grams minimum
- Tin – 200 grams minimum
- Nickel – 500 grams minimum

The entire design of the connector must be taken into consideration when evaluating its performance. The largest and most obvious features generally contribute the least to resistance of the mated connectors, whereas the smallest features have the greatest impact on overall resistance. The overall shape of the two contacting interfaces not only impacts the characteristics of the A-spots, but also affects the ability to penetrate or displace contaminants, and impacts durability through wipe-induced wear.

There are many trade-offs when optimizing the design of a connector - with an optimal interface being dependent on the application, the anticipated operating environment, and expected lifetime. While each of these factors applies to both power and signal contacts, each has a different impact in terms of its relative effect on the performance and reliability of a separable contact system.

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