Cres and Spring Probe performance

Contact Resistance (Cres)

When two separate conducting surfaces of electrical leads or connections come in contact with each other a resistance component (ECR) is created. This effect creates a potential drop that is above the intrinsic resistance of the contact material. There are three components of Contact Resistance we observe in a spring probe contact:
1) The macro effects of the contact lead surface area differences.
2) The microscopic surface effects of the material.
3) The applied load or mechanical profile.

Macro Geometric Effects

At a macro level, how the interfacing shapes of the contact leads mate are the primary determinant of the contact resistance. Ideally, one side of the contact lead (anode) should have identical surface area as the other contact lead (cathode). For instance two flat surfaces with the same surface area would mate with the lowest geometrical contact resistance or contact efficiency. In the case of a conical point structure on the probe contacting a flat surface such as a device pad, the contact efficiency is lowered which increase the contact resistance since the current must travel through the smaller surface area of the point to the flat surface of the pad. The contact resistance or potential drop in this case is due to the material properties and the cross sectional area of the contact surfaces

Microscopic Surface Effects

The contact material surface has a molecular/crystalline structure that meshes with the target material's structure. In an ideal material we would have a very smooth surface with minimal surface roughness and the atoms of the material would align very efficiently under minimal contact pressure. Thus the contact resistance would be low and the two contacts would conduct with very little local surface loss over the conductance property of the bulk material.

In reality typical contact materials have degrees of roughness or surface anomalies which compromises the conducting area of the connection point. This forces the current to find conducting paths that are non-ideal and creates a potential drop or some heat loss or resistance at the material contact barrier. Even if the macro geometries were identical, this surface contact resistance is present and creates a potential drop due to this contact resistance.

Oxidation/Contamination

In addition and assuming an atmospheric environment, the metallic contact material will oxidize and form a molecular insulating barrier in the presence of oxygen and moisture. Finally the surface structure must also include environmental contaminants. Each of these form an insulating barrier that impedes conductance. If this oxidation/insulating barrier is thick enough, there is very little conducting surface exposed and the contact leads conduct very little, IE the contact resistance is very high.

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Applied Load

In order to overcome the surface effects and oxidation of the contact material, a force must be applied to break the oxidation layer and force the surface contact areas to mesh and conduct properly with enough cross sectional area to minimize the potential drop in the contact. In a probe, spring force is used to break the oxide layers and form a decent conducting surface between the anode and cathode.
Springs are ideal for contacts that are meant to be temporary.

Total Contact Resistance is a product of the macro surface contact area, surface contact structure and excess resistance created by the surface oxidation and the applied load mechanics ability to overcome the insulating barrier.

Each of these factors can be minimized by metallurgy and material selection. For instance, copper has a very low bulk conductivity but has high oxidation potential and high surface roughness. Annealing the material can smooth the surface roughness and creating alloys or plating the copper can greatly reduce the amount of oxidation. Gold is very smooth, it does not oxidize very much, however it is soft and can be damaged under contact pressures. Modern spring probe designs use advanced copper alloys and multiple plating layers to minimize the impact of the surface area contact resistance as well as extend the contact life of the probe.

Effects of Contact resistance on Device Testing

First thing to note is that contact resistance is primarily a DC or non-variant impact on an electrical signal. Contact resistance has a number of impacts and in order of importance:

1) **DC loss** – The contact resistance creates a potential loss of some magnitude. For instance a probe with a bulk resistance of 100 m Ohm and a contact resistance of 50 m Ohms would lose 150mV under a constant 1 Amp load. In a 1 V power system this is quite large and would force a Kelvin or sense line implementation into the design to insure this loss was compensated. For a High Speed IO Line or RF channel this resistance would create a DC level shift that would add to the eye closure. Maximum eye opening is achieved with the lowest contact resistance.
2) **Contact reliability**- Contact Resistance is a proxy for contact reliability. Very high contact resistance in the ohm region will appear as an open circuit to the channel. Completely non functioning operation results. This is a big deal but can occur under any material set since this is a function of the mechanical design of the contact set. IE, if the contacts misaligned, are severely contaminated, the spring force is inadequate to break oxidation, contact shape does not optimize contact surface area, all will contribute to very high contact resistance. Low contact resistance implies mechanical sound contact design.
3) **RLC Spice model equivalents.** Contact resistance is a component of the RLC (Resistance, Inductance Capacitance) value of the equivalent network for the device load. Resistance is a component that has a nominal effect on the rise time of a signal on an IO pin. The higher the series resistance the larger the lumped RC time constant. This slows the rise time of the signal.

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Why it is better to have low contact resistance for RF/HF/Digital SERDES signals

1) Contact reliability helps insure maximum eye opening.
2) Lower DC loss insures maximum eye opening potential
3) Faster time constant helps insure minimal rise time loss and insures larger eye opening.

Faster rise time helps improve jitter, specifically ISI and Duty Cycle Distortion
Lower DC loss improves accuracy of output levels and helps improve receiver margin in either the system or test equipment.
Lower contact resistance can improve the performance of tuning circuits used to match impedance and terminate IO signals by improving the accuracy of the lumped resistors used in the circuit. In a circuit using trimmed components below 5% variance, this can help maintain design margin.

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Rev. 1.0 6/20/2016