Electrical Connector Mechanics

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by Jonathan Goodwin

There are reams and reams of information on electrical connectors and contact theory. My goal is to not get too much into the weeds, but to present specifics terms and factors that should be considered when designing or choosing an electrical connector.

I was once told by an old friend that the definition of "Perfect" is "serves its intended purpose." In that case, a perfectly designed connector is one that performs predictably and meets the needs of the application for the life of the product. An over-designed connector for a specific application can be costly; ultimately, the design should match the need. This is critical for high volume applications. There are multiple factors that contribute to a proper connector design and all are important. Some are more critical than others, but they all work together and need to be considered. The list can be long when you dig into the details, so here are what I consider to be the primary ones.

Mechanical alignment (connector geometric tolerance called "true position") for proper contact-to-contact mating is most critical, because "if you can't plug it in, it ain't gonna work." Another critical factor is normal force. Maintaining the appropriate normal force between mating contacts, even at worse case tolerances, or over the required cycles, is especially important for field-use applications when low-level contact resistance is key. Optimized contact designs, which considers material and shape, can allow for improved normal force performance by gaining a larger mechanical working range. This helps when considering mechanical set and yield of the contact over the full range of tolerances to maintain minimum required normal force. Finite Element Analysis is very helpful for this. A simple example of mechanical yield is when you bend a paperclip to the point that

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it does not fully return to its original position. This is because the tensile strength of the metal has been surpassed. Materials like Beryllium copper have a higher tensile strength than phosphorous bronze and copper and will have a larger working range without yielding. This is a higher cost material and may not be required but various contact material options should to be considered.

Along with contact design and normal force, plating material, thickness, and roughness are important when considering cycle life and maintaining contact integrity over connector life. Gold over nickel is preferred for contact plating but, depending on thickness, can have significantly higher costs than other plating and is not always necessary. Thirty micro inches of gold over 100 micro inches of nickel is ideal for computer signals and medical device applications (when low-level contact resistance is critical) and for high cycle applications but comes at a high price. This high thickness of precious metal is not always needed, especially in applications that are disposable or have low cycle count requirements (under 50). Gold flash (3 to 4 micro-inches of gold) over 25 micro-inches of nickel is sufficient and can be a major cost saver especially as position counts increase.

Contact-to-contact rub, or “Contact Wipe” as it is called, must be considered to break through oxide layers that sometimes form. The criticality depends on the required low-level contact resistance, environment and other factors. I have touched on some of the primary considerations in connector design but there is so much more...for another day.

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