
TECHNICAL TIDBITS

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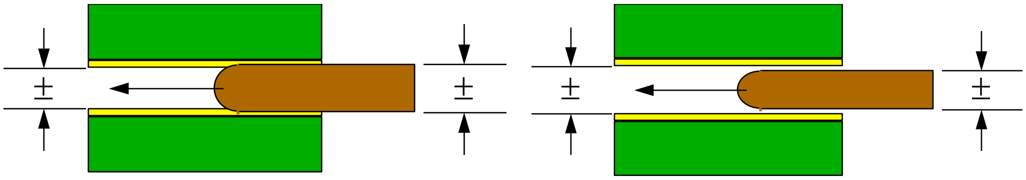
# The Cumulative Effects of Tolerances on Connector Performance – Part 2

**Ensuring that the deck isn't stacked against you! –** Continuing the discussion on why tolerances are important in connector design.

- **Stack Tolerances**
- **System Tolerances**

The previous edition of Technical Tidbits explored possible sources and effects of variation present in manufactured items. As a quick review, material tolerances, which are imposed by the material manufacturer, limit dimensional and property variation of the raw material. Manufacturing tolerances, imposed by the design engineer, limit variation in the dimensions of components manufactured from that raw material. Eventually, these components are assembled into finished devices. At this point, there are two additional tolerances that must now be considered: stack and system tolerances. Only if the stack and system tolerances are met will the parts be deemed acceptable.

**Stack tolerances** are the cumulative superposition of tolerances of individual components. For example, consider a compliant pin inserted into a plated through-hole in a circuit board (Figure 1). If the hole diameter is at the low end of the tolerances while the pin diameter is at the high end, the parts will fit together tightly. This would ensure a high insertion and retention force. However, an excessively high insertion force may make assembly difficult. At the other extreme, if the hole diameter is at the high end of the tolerances while the pin diameter is at the low end, the parts might create a looser fit. If the fit is too loose, the connection could be easily disrupted by vibrations or shock loads. The design example in the January 2000 edition of Technical Tidbits provides an example of stack tolerance issues in a curved cantilever beam style contact.



Small hole, large pin

Large hole, small pin

**Figure 1.** Tolerance Stack-up of Plated Through-Hole and Pin

**System tolerances** are imposed by the end component manufacturer. These tolerances control the interaction of the individual components. An example is the specification of a range of values for the normal (contact) force created in an interconnection device. If the force is too low, there will not be good electrical contact between the two sides of the interconnection. This increases contact resistance, and may make contacts plated with tin or nickel more susceptible to fretting corrosion. On the other hand, if the normal force is too high, repeated insertions and removals of the contact will quickly wear off the protective plating. This will also increase contact resistance and make the surfaces susceptible to all types of corrosion. In addition, if the insertion force is too high, it may even be impossible to make the electrical connection in the first place. Therefore, the optimum contact force will be specified, along with an acceptable range of values.

Part dimensions may also be specified in an effort to meet the system tolerances. For example, consider a high-density connector used in computer applications. In order to fit the maximum number of pins into a connector, there must be a matching number of receptacles for those pins on the opposite side. The female contacts of the connection must not exceed a certain maximum size or they will not all fit within the required space. Since connection devices continue to shrink in size and increase in contact density, dimensional tolerances will continue to increase in importance.

*The next issue of Technical Tidbits will include an informative discussion about strip formability and bend testing.*

## Cumulative Effects of Tolerances on Connector Performance – Part 2 (continued)

Furthermore, stack-up of positional tolerances may have an effect as well. For example, the first few pins in a row on a high density contact will probably line up fairly well with the corresponding sockets on the female side of the connector. However, if the positional tolerances on the male side do not match those on the female side, the pins on the other end of the row may not line up at all (Figure 2). This can be especially problematic when the male and female sides of the connector are made by different manufacturers.

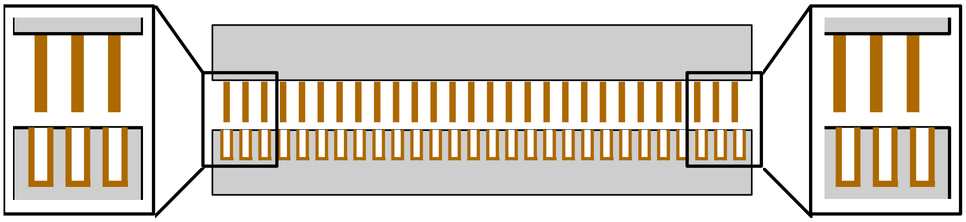


**Figure 2.** Misalignment due to stack-up of positional tolerances

Insertion force also becomes critical in high density connectors. For an individual contact, if the insertion force is 10 grams too high, there may be no consequence. However, if the connector has a hundred or more contacts, and each is equally above tolerance by 10 grams, the total insertion force for the connection becomes at least one kilogram too high. This may create difficulties for people making connections by hand or for automated machines placing chips in lead frames onto circuit boards. If the force per contact is too low, accidental disengagement of the contact could result.

System tolerances may also cover electrical performance. For example, high frequency circuits require careful matching of the impedance (resistance, capacitance, and inductance) of every part of the circuit, including any possible interconnection devices. Significant changes in impedance along the circuit will cause part of the signal to be reflected back, reducing the strength of signal transmission and creating error if there are multiple reflections. High conductivity materials can minimize the difference in total impedance because they are closer in resistance to the conductors in the circuit board.

All of these factors will place high demands on both the materials used and on those who shape them. The materials must have the strength necessary to withstand overstressing, yet be robust enough to handle the tight forming demands placed on them by space limitations. As operating frequencies continue to increase, the electrical properties of the materials become as important as the mechanical properties. Above all, the properties and mechanical tolerances must be consistent with a minimum of variation. This is where the use of high performance alloys like copper beryllium can provide the designer with confidence that the component will work as intended.

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