

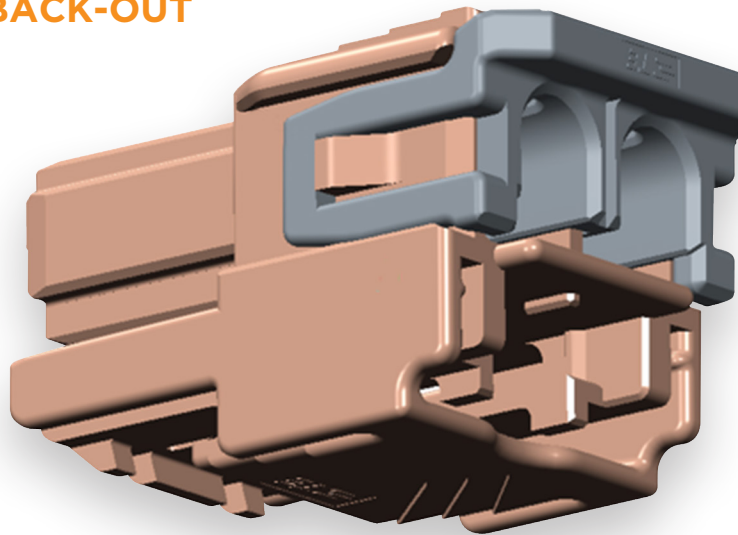
TERMINAL POSITION ASSURANCE

An Added Layer of Connector Reliability

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ADVANCED CONNECTOR DESIGNS INCORPORATE FEATURES DESIGNED TO REDUCE CONTACT BACK-OUT



Low-cost “soft shell” connectors featuring crimp/snap technology have been used to address interconnection requirements since the 1960s. Although they provide a cost-effective option for a wide range of everyday applications – ranging from cars and personal computing devices to TVs and refrigerators – conventional crimp/snap connectors have been plagued with contact back-out issues from the start. Another long-time technology called terminal position assurance, or TPA, offers an often overlooked interconnection solution that can provide a more secure and reliable alternative when designing appliances. With recent enhancements in connector housing and contact design, designers now can choose from improved TPA solutions that can reduce and potentially eliminate back-out issues.

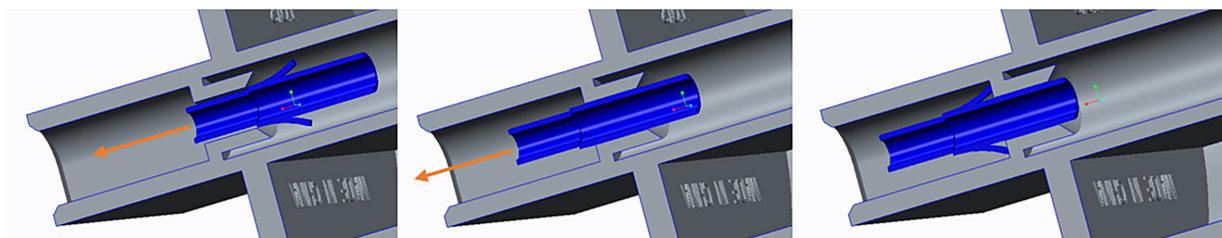
This paper provides a background on traditional crimp/snap technology and explains why these products can result in unreliable interconnections. It describes the emergence of TPA technology and explains why connectors utilizing TPA devices offer a more robust solution. TE Connectivity’s (TE) products are offered as examples of the most advanced connector technology offered today.

Back-Out Issues

Early in the evolution of connector technologies there were relatively few molding resins that met the criteria needed for electrical connectors. Molding techniques were relatively crude and process controls lacked the level of sophistication now commonly expected.

Some crimp/snap contact systems still rely exclusively on metal locking lances formed in manufacturing dies that were designed when they were first introduced. They use conductive metal contacts (terminals), which are typically pins and sockets, tabs and receptacles or some other contact form. They are crimped or soldered individually to lead wires and the terminated contacts are subsequently snapped (inserted) into the connector housings. These connector housings are usually made of nylon or of a similar thermoplastic material.

Figure 1 illustrates the locking process of a crimp/snap connector. When inserting the contact into the connector housing's circuit cavities (image 1), the locking lances get depressed (image 2) and spring back into their formed position once the contact is fully inserted (image 3). These lances hold the contact into the connector housing circuit cavity by resting behind an internal plastic ledge.



1 - Contact inserted into housing

2 - Locking lances deflect

3 - Contact fully seated

Figure 1. Crimp/snap connector locking process.

Crimp/snap connectors are susceptible to contact back-out issues. Through anecdotal observation we can make an educated guess as to the most frequent culprits behind this problem. There are generally six areas of concern:

1. Connector manufacturing quality issues:
 - Short-shot and misformed features in plastic parts that do not provide a consistent surface for latching of the contact
 - Contact locking lance is not formed properly in the stamping die

Both of these problems are easy to identify during incoming inspection. As with any manufacturing process, high-quality connector manufacturing is, like the manufactured product, dependent upon well-thought-out processes that continue to operate within specified tolerances and routine maintenance practices.

2. Connectors become damaged in handling during assembly of the finished item

Many connectors in use today have designs with little or no protection from accidental damage. Pins, whether mounted in a printed circuit board or in a mating plug housing, can be unintentionally bent in the manufacturing environment. If individual posts, pins or tabs are inserted into printed circuit boards without maintaining the appropriate true position, contact stubbing can occur. As a result, the act of plugging the mating connector can easily exceed the strength of the locking lance that holds the contact into the connector housing.

3. Stresses during assembly (exceeding connector design intentions)

Multiple position, crimp/snap connectors are designed with “contact float.” This float allows contacts to align with each other during the mating process. When this does not occur, the cumulative misalignment can easily drive the required mating force beyond acceptable limits. Wire dress at the rear of a connector housing can cause the floating contact to be biased in the circuit cavity such that the tip of

the contact stubs on the mating contact when the housings are plugged together. Given enough force, this stubbing often results in the damaging of contact locking lances and, subsequently, the contacts back out. This frequently goes undetected until the interconnection system fails.

4. Contact locking lance issues (lances become damaged during crimping or handling prior to insertion into the connector housing)

Contact termination is performed by application tooling that must be set-up properly and maintained regularly. Damage to the contact can occur either during the crimping operation or by rough handling of the contact subsequent to termination.

5. Contact is damaged during testing after being loaded into housing

Frequently, a connector is part of a more complex wiring harness or other assembly. It is often subjected to one or more matings for test purposes. As a result, the test connectors can get worn or damaged to the point that they cause harm, including contact back-out on the connector or assembly being tested. For test connectors, spring-loaded, pogo pin-style contacts that do not touch the mating surface of the contact being tested are the best types to use to avoid damage.

6. Contact is not fully inserted into the connector housing

Inserting a terminated contact into a connector circuit cavity is, at first look, a simple task. But repeating this task flawlessly hundreds of times during a given workday becomes a challenge. This procedure is made more difficult as smaller gauge wire sizes are used, since smaller gauge wires have less column strength than larger gauge wires.

The Evolution of TPA Technology

As molding technology advanced, so did the ability to develop connector designs that obviate some of the issues described above. By designing contact latching features that are molded internally to each circuit cavity of a multiple circuit connector, a “clean contact” can be stamped, which means having no locking lances or other relatively delicate features that can become damaged (as described in item 2).

Although these advances improved interconnection system quality/reliability, failure levels still greatly exceeded expectations and demands. The training of set-up teams, creation of handling procedures, and the diligent industrial engineering efforts on assembly lines helped to limit the other issues. However, given the realities of global manufacturing and worker turnover, these efforts provided only partial solutions and a more reliable connector design solution became necessary.

In the late 1970s and early 1980s, the U.S. automotive industry was pressured to increase quality in their car and light truck offerings. Foreign competition set new expectation levels in the minds of the public and the industry responded accordingly. “Walk home failures” and safety issues were to be eliminated completely, and experiencing such failures due to a connector contact back-out was considered unacceptable.

From this drive in the automotive industry came the invention of the TPA (Terminal Position Assurance) device. The resulting dramatic improvement in connector reliability paved the way for the adoption of TPA technology in other applications, most notably in the appliance industry.

Advanced Connector Design

Today’s connector design guidelines and manufacturing practices are increasingly complex. Manufacturing practices and quality control plans include real-time process monitoring, such as vision systems.

Connector designs are created with these refined capabilities in mind. Because connector development engineers now have a better understanding of how their designs are processed by customers, robust contact designs rarely have locking lances that can be misformed in the stamping process or that could become damaged through subsequent processes.

TE offers connectors, for example, with contacts featuring “windows” that accept internal plastic features formed inside connector circuit housings (Figure 2).



Figure 2. Economy Power II connector offers a clean contact with a “window” for a plastic latching feature.

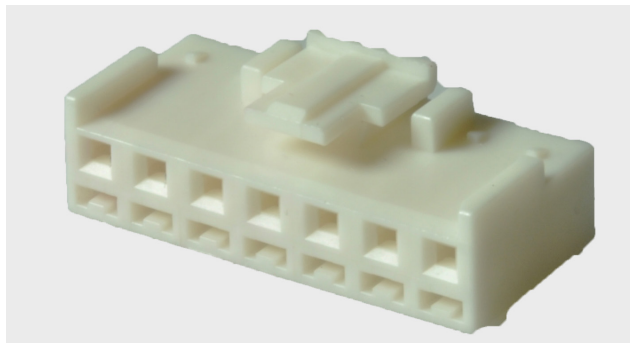


Figure 3. Economy Power II connector's housings contain window slots for continuity testing simultaneously with contact back-out check.

Since testing on the front end can be essential, connectors can be designed with probe windows that allow for test probing without touching the interface region of the electrical contact (Figure 3).

As illustrated in Figure 4, when space is available, TE offers advanced connectors designed with silos surrounding individual circuits. This approach not only has the potential of achieving increased voltage ratings for any given connector circuit centerline, it also helps to protect the contacts from being damaged through the elimination of unguarded pin fields.

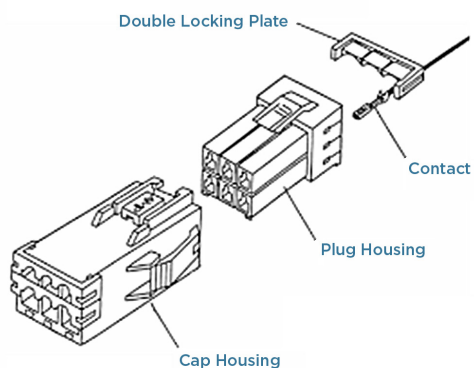


Figure 4. Power Double Lock connectors are among several connector products offering silos surrounding their circuits.



Figure 5. Circular metal shelled connector.

Benefits of TPA Technology

Many connector designs, such as metal shell-style connectors, used in military and other harsh environments, lack the robustness features offered by the TE connectors described above. For example, the circular metal shelled connector shown in Figure 5 offers little protection to keep the pins from becoming damaged.

This lack of pin protection results in two areas of concern when seeking to understand and fully address the causes of contact back-out. The first is that the contacts are not fully inserted into connector circuit cavities. Figure 6 illustrates this. On the left, the contact is fully inserted. Note how far lances extend beyond ledge in the circuit cavity. On the right, the contact is partially inserted; in this case, note how lances are resting on the ledge in the circuit cavity.

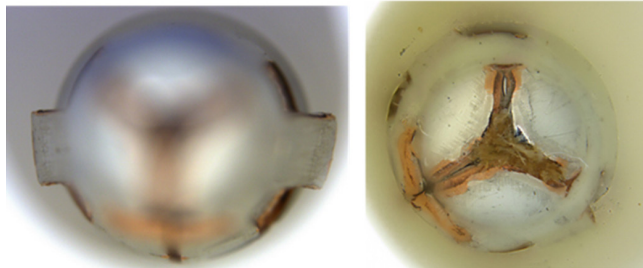


Figure 6. Properly inserted contact, left. Improperly inserted contact, right.

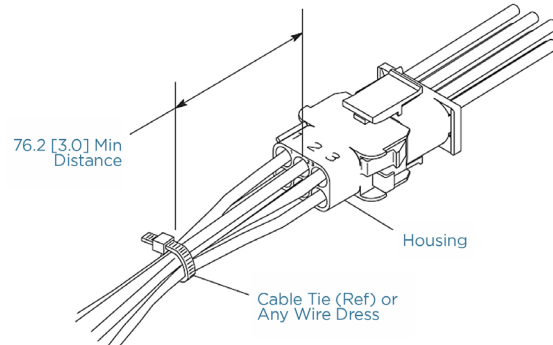


Figure 7. Example of a cable tie secured at the appropriate minimum distance from the connector.

Another problem can result from stresses that bias or restrict the floating contact in housings. This includes tight wire dress or taping or tying the wires too close to the rear of the connector. Figure 7 shows a cable tie secured at the appropriate minimum distance from the connector.

Both of these concerns are overcome by the use of TPA devices. One philosophy behind the design of a connector is to prevent the connector mating process from being completed without the assurance that the contacts are properly positioned.

An example of this approach is TE's Universal MATE-N-LOK II connector. The plug housing and cap housing are each comprised of two pieces of plastic, as illustrated in Figure 8. These two pieces of plastic are pushed together after the contacts have been loaded. By design, if the contacts are only partially inserted into the housings, the two pieces of plastic cannot be pushed together. If the contact is so far back in the circuit cavity that plastic pieces can be pushed together, then a portion of the contact is left hanging out of the circuit cavity. In either case, the error is obvious and can easily be addressed. Figure 9 illustrates the connector in the desired fully assembled connection.

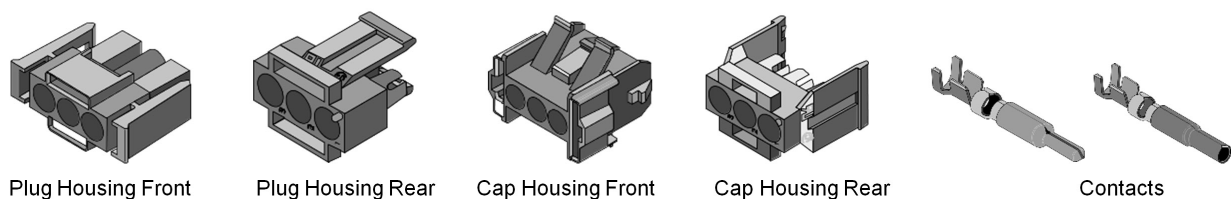


Figure 8. Universal MATE-N-LOK II connector components.

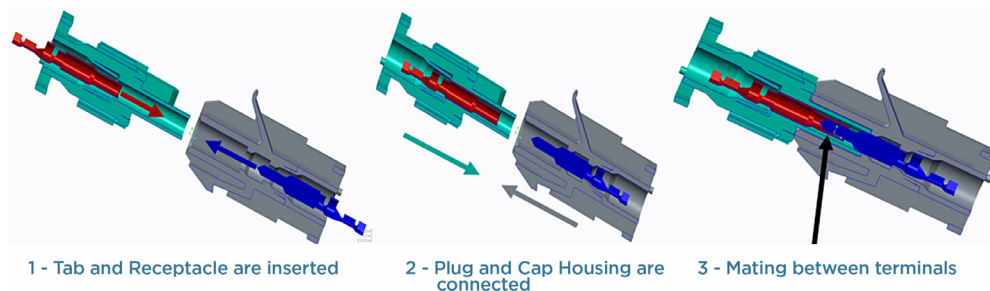


Figure 9. The Universal MATE-N-LOK II in the desired position.

Another more common design approach is using a separate plastic piece for TPA. As shown in Figure 10, the TPA is inserted into the wire exit face of the connector after all the terminated contacts have been inserted and will latch in place onto the housing. If any contact is not fully seated into its respective circuit cavity, the TPA will not fully latch onto the housing. This will alert the assembler to check for any unseated terminals. (It is key to note that the TPA is not considered a functional seating tool.) Once any unseated terminals are in place, the TPA will fully latch onto the housing. This style of TPA is especially useful when using smaller gage wires with minimal column strength which contributes to the higher chance of an unseated condition. Unlike an insertion tool, these TPA devices remain with the connector. They can provide some level of redundancy if, for any reason, the primary latching features fail.

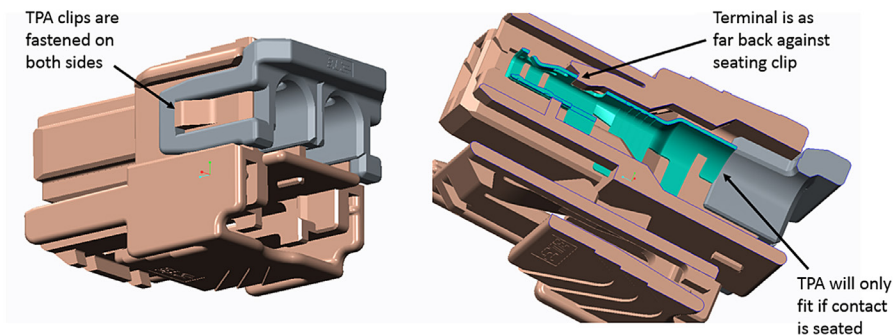


Figure 10. Connector design where the TPA is a separate piece.

Some TPA devices latch into the connector housing in just a few places (Figure 10), and some TPA devices latch into the connector housing at every circuit position (Figure 11). Some TPA devices are dedicated to a single connector row, while other TPA devices straddle two rows and serve both. These types of TPA devices are inserted after the terminated contacts have been inserted into the connector circuit cavity. In many cases, these TPA devices restrict the movement of the wire and serve the purpose of holding the contact relatively straight in the circuit cavity. In this case, the likelihood of contact stubbing during the mating of the connector is reduced. (It should be noted that for a TPA device to be fully functional, it may or may not increase the actual retention force of the contact in the housing.)

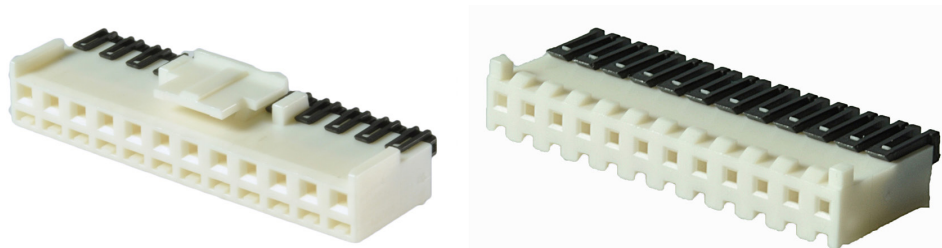


Figure 11. The economy power II connector (left) and the SL-156 connector (right) utilize TPA devices that latch into each circuit position.

It is noteworthy that a TPA device can be viewed as an optional feature. While making for a more robust connector system, not all applications call for the use of a TPA device. The added cost of the device itself and the assembly of the device into the connector can be avoided, depending on the requirements of the application. A relatively small connector with an optional TPA device may bring marginal value when it is used in a piece of instrumentation that is assembled in a bench environment. On the other hand, that same connector might be used in an application where assembly line processes require

increased robustness. In such cases, the added robustness that is offered through the uses of the TPA device offers great advantages.

TPA devices can be added to make systems more robust with minimal or no added design impact or implementation problems. Conversely, TPA devices can be deleted in a “cost out” process if properly designed experiments prove that there is only marginal benefit gained through the use of a TPA device in any specific application.

Whether selection of a connector is being done in a “design to cost” environment or in a “design for robustness” environment, choosing a connector system that offers a TPA device can result in improved reliability.

Selecting Connector Devices Featuring TPA

The table below lists many TE connector product families which offer TPA and are often used in appliance, industrial, medical, HVAC and other various industry applications. TE draws on over 70 years of connector design and manufacturing expertise. Working closely with customers, the company provides connectors that heighten reliability and meet end-applications requirements.

TE Connectivity Product Lines Featuring TPA Devices	Application: Wire-to-Wire / Wire-to-Board
Economy Power II Connectors	W-to-B
Economy Power 2.5 Connectors	W-to-B & W-to-W
Grace Inertia Connectors	W-to-B
Mini-Universal MATE-N-LOK 2* Connectors	W-to-B & W-to-W
Power Double Lock Connectors	W-to-B & W-to-W
Power Key Connectors	W-to-B
Power Triple Lock Connectors	W-to-B & W-to-W
Signal Double Lock Connectors	W-to-B & W-to-W
SL 156 w/ TPA Connectors	W-to-B
Universal MATE-N-LOK II* Connectors	W-to-B & W-to-W
VAL-U-LOK Connectors	W-to-B & W-to-W

* Integral TPA to the connector system / not optional

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