

# Adapting Press-Fit Connection Technology for Electronic Modules in Harsh Environments.

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## Abstract:

*Press-Fit Technology has been widely used in the telecom and industrial markets for over 50 years. The Press-Fit Technology available for those markets works well in most non-mobile, controlled environment applications. However, the move to develop electronic modules that operate under aggressive environmental conditions, such as automotive, has created additional challenges that most existing press-fit parts were not designed to withstand. In addition to the added rigors of vibration, thermal shock, etc., press-fits for such applications have much higher ampacity requirements than their telecom counterparts.*

*As module requirements become more demanding and raw material costs are increasing the challenge to limit precious metals in designs and increase performance are challenging packaging designers and manufactures to develop new interconnection solutions Applications for multiple chip packages, power conversion and generation, MEMs devices, Solar, LED and Automotive Interfaces are seeing higher operational temperatures. The needs for improved thermal dissipation, resistance to shock and hermetic sealing are some of the technologies that are demanding performance extremes from electronic module designs.*

*Press-Fit technology allows for the insertion of a specially stamped terminal into a plated-through hole (PTH) in a printed circuit board (PCB) in such a way that an electro-mechanical connection is established without using solder. The press-fit joint can be a more permanent connection and needs to generate both the electrical and mechanical connections without the aid of a housing.*

*This paper will show how the designs have developed to suit these harsh environment requirements, in terms of the interactions between materials, the effects of accelerated testing, and the test processes undertaken. The data provided will provide the basic information required for modelling and design of interconnection technology ideally suited to high stress applications.*

**Key words:** Interconnection, solder-less, terminals, modules, materials.

## Introduction

The needs for different methodologies of interconnection have been ever present in the Electronics Industry for many years. A number of methods of male/female pin and socket connections are used by the “connector” industry and are these are well documented. However now that the connectors, the boards and the housings are all becoming integrated into ‘plug and play’ type modules the interconnects, normally soldering between wires, boards and connector pins, are proving to be problematic. The need for Lead (Pb) Free connections, and concerns of thermal

mismatches with new soldering processes has created the demand for solderless connectivity. Methods for such solderless connection are well known. Initially utilised by the connector industry and latterly developed for many applications where a reliable, low cost, quick and easy interconnection is required, the press-fit connection is a key technology for making reliable electronic joints. One long standing such technology is the Insulation displacement connector (IDC) which is widely utilised in consumer applications such as telephone sockets, networking and signal connections

between parts of an electronic or computer system. When properly made, the connector blade cold-welds to the wire, making a highly reliable gas-tight connection. But for more reliability in harsh environments, such as automotive modules, the “Press-Fit” connection, and interference fit style of ‘blade’ connector is the new solution.

### Press-Fit Basics

Press-Fit technology allows for the insertion of a specially stamped terminal into a plated-through hole (PTH) in a printed circuit board (PCB) in such a way that an electro-mechanical connection is established without using solder.

This solderless connection functions like the blade and socket pair in a connector, except the genders are reversed. In a traditional blade-and-socket pair, the socket has flexible beams that provide the necessary normal force for an electrical connection and the blade is rigid. In a press-fit joint, the “blade”- called either a compliant pin or a Press-Fit pin – has the flexible beams, and the socket, which is the plated through hole or PTH, remains rigid. (See Figure 1)

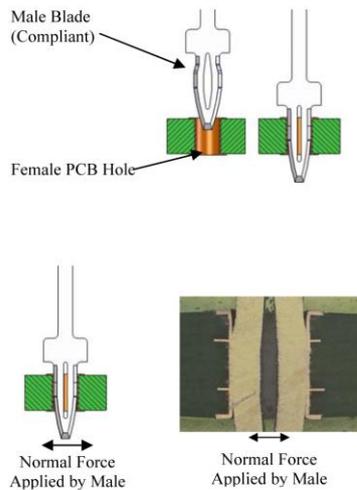


Figure 1: Typical Press-Fit Male/ Female Interconnect

While the press-fit joint and its blade-and-socket cousin both employ a pressure connection, the similarity ends there. The blade-and-socket is intended to be mated and unmated numerous times, so it is designed with lower normal forces. It is also surrounded with an insulative housing that ensures that the connector stays together during use. The press-fit joint on the other hand, is a more permanent connection and needs to generate both the electrical and mechanical connections without the aid of a housing therefore, its normal forces are much higher.

### Harsh Environments Connections

For over 50 years a variety of Press-Fit connectors have been widely used in the telecom and industrial markets. The technology available for those markets works well in most controlled environment applications where mobility, vibration and harsh environmental conditions are not encountered. However, the development of electronic systems for use in such applications as automotive and transportation equipments requires the units to operate under quite aggressive conditions and severe ambient environments. This has created additional challenges that most existing press-fit parts were not designed to withstand. In addition to the added rigors of vibration, thermal shock, etc., the required connections utilising press-fits often have much higher ampacity requirements than telecom counterparts. For example, where telecom press-fit pins can be made from material of 0.64mm (.025”) thick and less, Press-Fits used in automotive modules are made from 0.64mm (.025”) for signal pins and 0.80mm (.032”) for power pins. Automotive Press-Fit pins therefore have to be available in a range of materials that offer higher conductive capabilities than telecom pins.

The growing consumer and regulatory demand for electronically controlled features in Automotive, such as anti-lock brakes, vehicle stability control, navigation, hybrid drive trains, and tyre pressure monitors, coupled with a strong movement to lower costs, has created a significant demand for Press-Fit interconnections. This has also seen developments for applications in other harsh environments such as Transport systems and renewable Energy system designs.

The major developments have been undertaken to suit automotive assemblies as there are several factors that make Press-Fit technology a popular interconnect component:

- Press-Fit Technology can reduce or eliminate the need to perform secondary solder operations on PCB assemblies. Not only does this reduce labour and work-in-process, it removes an extra heat cycle that can degrade existing components on the board, and it reduces the amount of solder used in the assembly.
- The press-fit joint is not subject to quality problems associated with solder such as cold spots, voids, splatter and cracks. Press-fit joints are highly reliable.

- Press-Fit parts can be readily customized to enable package designers to meet their envelope and manufacturability targets.
- Material costs can be reduced when compared to pin and socket interconnects.
- The high strength of the press-fit joint eliminates the fretting risk associated with pin and socket interconnects. Precious metals are not required.
- Press-Fit Technology is RoHS compliant

There have been several design upgrades and changes to past Telecom press-fit designs that were needed to move the technology to support harsher environments such as automotive applications. These design upgrades now make press-fit technology more compatible to other industrial and mobile applications where before they hadn't been considered.

Some of these upgrades are:

- Stronger beam designs with increased coining to help with retention but maintain reduced insertion forces.
- Introduction of alloys such as CuNiSi for higher operating temperatures and added conductivity.
- Improved platings for example, thin tin in the press fit sections as well as Ag and SnAg options.

### Test methodologies

There is presently no industry-standard performance specification for an automotive Press-Fit pin or for that matter any other environment. Each industry supplier set has assembled their own set of requirements culled from existing standards such as IEC 60352-5, USCAR-2, EIA-364, and internal specifications.

In general, these require that the press-fit joint show very little change in electrical resistance throughout the following types of tests:

- Insertion force and retention force
- Vibration
- Thermal shock
- High temperature exposure
- Temperature and humidity cycling
- Mixed flowing gas
- Current carrying capacity
- Plated through hole integrity

The temperatures used in the tests are determined by the operating temperature in the application, for example in automotive they are usually higher than

the 85°C specified in telecom applications. The most common automotive applications have set temperature classifications and applications are specified to comply with operating within one of the classifications. Examples of these classifications are shown in table 1 below. Applications categorized as class 1 (105°C ambient) are typically passenger compartment locations and class 2 (125°C ambient) under-hood locations. Class 3 applications, such as engine mount or near engine mount applications are less common but are becoming more popular as press-fit technology develops to become more widely accepted.

Table 1: Automotive Temperature classes

Temperature class	Temperature range	
	T <sub>lo</sub>	T <sub>up</sub>
1	-40 °C	+105 °C
2	-40 °C	+125 °C
3	-40 °C	+150 °C
4	-40 °C	+175 °C

### Plated Through hole Integrity

The plated through hole integrity is tested in accordance with IEC 60352-5. Transverse and longitudinal cross sections are done after each test sequence to determine that minimum hole deformation exists and a good electrical interconnect is maintained throughout the life of a product. These requirements are all the same regardless of the thickness gauge of the press-fit zones.

The three measurements done to confirm plated through hole integrity are: (See figure 3a & 3b)

- 1.) Drilled hole contour should not exceed 70 µm. (a)
- 2.) The plating maintained in the hole shall be a minimum of 8 µm. (b)
- 3.) The deformation of any outer and inner layers connection to the plated through hole shall not exceed 50 µm. (c)

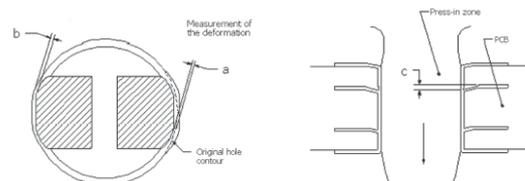
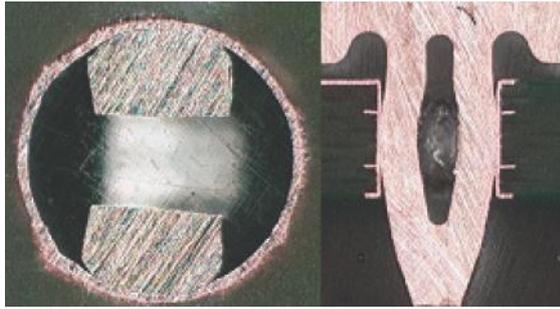


Figure 3a: Transverse and Longitudinal Cross-sectioning Measurement Locations



PTH #	Drill Hole Ø [mm]	Plated Hole Ø [mm]	a	b	c
1	1.660	1.527	22 µm	47 µm	26 µm
2	1.668	1.526	21 µm	40 µm	31 µm
3	1.660	1.522	43 µm	47 µm	28 µm

Figure 3b: Transverse and Longitudinal Cross-sectioning of .8mm press-fit section and measurements of three samples.

### Insertion and Retention Force Testing

Figure 4 shows the results of the testing carried out on the 0.8 mm press-fit zone. These results show forces for PCB holes on the high and low end of the tolerance zone. Retention force data is shown after seven days to determine if the cold weld effect is present and retention force is also done after each test sequence.

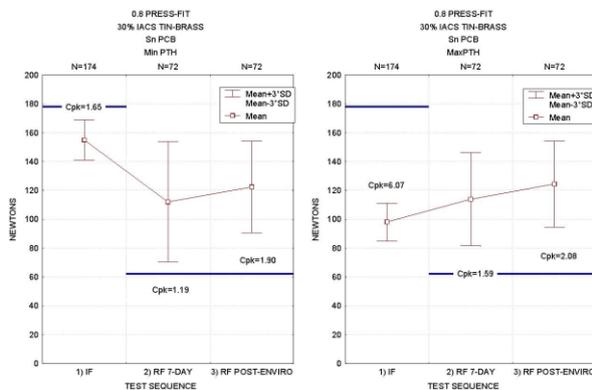


Figure 4: Summary of 0.8 Press-Fit IF/RF Testing in Sn PCB's

Whereas Figure 5 shows the representative force curves during the insertion and push out of the press-fit zone to the PCB. This helps to determine that the press-fit zone is functioning as designed. The spike shown on the push out force curve is a result of the cold weld effect that occurs with similar platings between the press-fit section and the PCB.

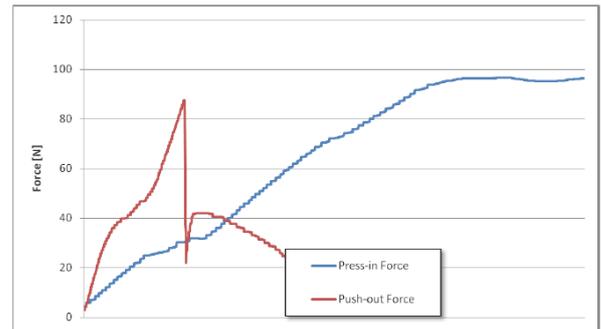


Figure 5: Representative force curve

### Approvals

For use in automotive applications press fit connections are subjected to a range of performance Specifications:

#### • Insertion/withdrawal forces:

- .64mm (.025") thick- insertion force max. 97N (22.0 lbs.) in the minimum PCB hole. Retention force min. 25N (5.6 lbs.) in the maximum PCB hole.

- 0.81mm (.031") thick- insertion force max. 170N (40.0 lbs.) in the minimum PCB hole. Retention force min. 62N (14 lbs.) in the maximum PCB hole.

- Contact resistance : ( $\Delta R_{max} < 0.5 \text{ m}\Omega$ )
- Random vibration (12g to 20g over temperature range)
- Thermal shock (500 cycles,  $-40^{\circ}\text{C}$  30 min, transfer 30 sec, +  $T_{up}$  30 mins)
- Temperature / humidity cycle (40 cycles,  $-40^{\circ}\text{C}$  to +  $T_{up}$  @ 95% RH)
- High temperature exposure (+ $T_{up}$   $^{\circ}\text{C}$  1008 hours)
- Plated through hole integrity analysis per IEC-60352-5
- Current carrying capacity test per EIA – 364- TP-70. Optional SAE USCAR section 5.3.3
  - Data to be managed for both current/heat rise chart and a 20% de-rating curve
- Mix Flowing Gas- 4 Gas Test. 75%RH - 21 days

## Module development

The automotive market has settled on two PTH sizes to be used in press-fit joints. These are  $\text{\O}1.016\text{mm}$  ( $\text{\O}.040''$ ) for 0.64mm thick signal pins, and  $\text{\O}1.486\text{mm}$  ( $\text{\O}.0585''$ ) for 0.81mm thick power pins. There is general agreement as to how these holes should be constructed and toleranced. While the tolerances are fairly tight from the PCB manufacturer's viewpoint, they are large from the viewpoint of the Press-Fit pin designer. The (half) tolerance of the finished hole diameter is nearly as large as the nominal deflection of the pin's active feature, or "beam". On top of that, the beam has a stamping tolerance that must be taken into consideration. The net effect of these large tolerances (relative to the hole size) is that the beam cannot be designed as a purely elastic device; it must undergo some amount of plastic deformation. Fortunately automotive requirements presently do not require a pin to be re-used after it has been pulled out of a hole.

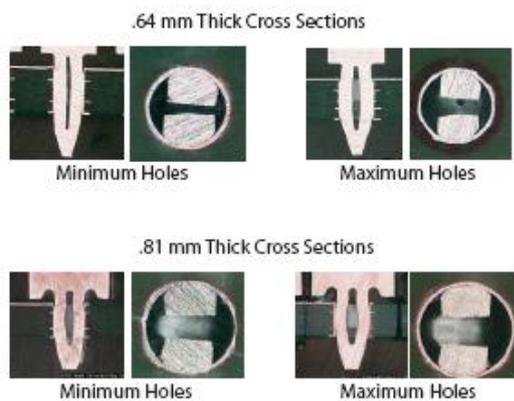


Figure 6: Cross sections

The beam's geometry, its deflection, and its composition will determine the pin's insertion force (I/F) and to a large extent, its retention force (R/F) for a given hole. The Press-Fit pin designer needs to adjust the beam parameters so that in a worst-case "tight" condition, the pin goes in without damaging the PTH barrel and in the opposite "loose" condition, the joint strength is adequate to pass all the environmental requirements. (See figure 6). The designer must also ensure that the part can be manufactured economically and reliably.

The beam design should be readily stamp-able and not favour the formation of flash or slivers. The required tooling should be fairly conventional and capable of long runs with normal set-up, monitoring and maintenance. Of utmost importance is a beam design that lends itself to tooling and that can hold the required tight tolerances. Another factor in the design of Press-Fit pins is plating.

Although a conventional tin over nickel is sufficient for most applications, the tin must be kept thinner than typical in the press-fit area to keep it from scraping off and creating a possible conductive particle hazard when the pin is inserted into the PCB.



Figure 7:

In the application best suited to automotive and also as shown in figure 7, the terminal materials are of a copper base alloy with a base plating of Matte-Tin over Nickel but terminal designs are compatible for select precious metal plating options as needed. The terminals shown have been tested and are compatible with PCB finishes with PTH in Immersion Tin & Immersion Silver finishes. For these, the minimum PCB thickness tested was 1.57mm (.062").

Matching the outer plating on the press-fit terminal to the plating on the PCB hole, for example tin to tin or silver to silver helps to enhance that retention force of the pin to the PCB hole. This is due to the creation of a cold weld that occurs between similar materials resulting from the high force of the press-fit interconnect.

## Applications

A key application for press fit in harsh environments is to provide Internal PCB to PCB interconnects. Many system modules, switches junction boxes and other electronic assemblies have several PCB's that interconnect together within one assembly. In most cases the final interconnect between these two PCB's will include some type of hand or customized automated soldering operation. A press-Fit can be designed in sections so that two Press-Fit sections can be placed on one terminal allowing for a solderless PCB to PCB interconnect. (See figure 8). These dual Press-Fit Terminals can either be a direct insert type of terminal or embodied into a header assembly.

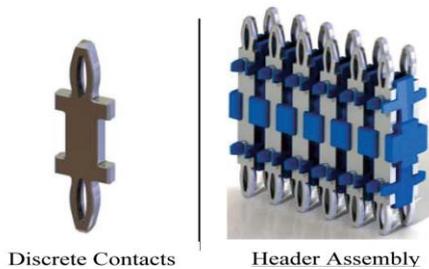


Figure 8: PCP to PCB press-fits

For transport systems, the design of engine and transmission (power) controller modules can benefit by the incorporation of press-fits. (see figure 9). The functionality of these types of modules, especially in vehicles, is increasing dramatically but is also shrinking in physical size. The input / output requirements in these assemblies still have a very high pin count, typically from 44 up to 72 plus interconnect positions. With the assemblies shrinking in size designers are using some very high density multilayer PCB's with very small surface mount (SMT) components on both sides of the PCB. After the electronics is assembled it is very difficult to introduce the additional heat needed for soldering the I/O interconnect without damage to the assembly. Press-Fit technology allows the interconnect to be pressed in to the assembly without an additional heat cycle.



Figure 9: Typical Integrated Connector module for Automotive applications

Most current designs of automotive fuse panels have integrated two primary functions, the power function (fuse panel interface) and the body controller (the computer). The basic construction of these fuse panels is moving away from typical stamped fret designs and is replacing them with multilayer circuits cards, or a combination of both. All the fuse receptacles and the harness interconnect terminals are directly connected to both sides of the PCB. The density of the terminals in these assemblies, along with the dual sided nature of these designs and the high copper content of the assembly makes soldering these

interconnects to the PCB very labour intensive and/or very difficult to automate. The use of Press-Fit terminals not only eliminates secondary soldering operations, but reduces the technical difficulty and risk out of the process of assembly.

## Conclusion

Although the development of press-fit connector technology has been driven by Automotive applications [1] it is clear that the future needs of electronic systems utilised in other typically harsh environments can benefit from these developments. Motor and power controllers for transport systems, inverter modules in renewable energy systems and wireless modules for telecomm systems are being developed to meet the needs of higher temperature excursions, higher power handling capacity and long term reliability. The adoption of Press-Fit interconnects is enabling the system designers and the module manufacturers to meet the needs of the extended operating environments that such applications demand. The technology is enabling smaller, more compact, integrated connector package modules that meet or exceed the reliability requirements and also provide cost reductions in the manufacturing processes. The technology also extends the life of products and with further development will enable the adoption of “design for dis-assembly” engineering, the next step in ensuring a more eco-friendly, reusable, recyclable interconnect.

## References

- [1] Interplex Industries Inc. Application note – Automotive Products – Press-Fit InterconnectTechnology. Rev. L