Connector Press-Fit Technology for space-flight applications

12-14 October 2016
ESA/ESTEC, Noordwijk, The Netherlands

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Introduction

The European space industry aims to reduce space-flight equipment manufacturing times to improve their competitiveness because time is money. One way to reduce electronics equipment manufacturing times is to use as much as possible automatic mounting of components on boards. Presently, connectors are the last components to be manually mounted on PCBs (Printed Circuit Boards) by soldering. The connector terminations are attached to the PCB by being inserted into holes that pass through the PCB. Usually the connector terminations are secured by soldering but they can also be secured by pressing the contact terminations into the PCB holes by achieving an interference fit (press-fit). Thus press-fit contact technology is a special form of through-hole technology that does not require soldering. Consequently, contacts featuring press-fit terminations allow for full or semi-automatic mounting of connectors onto printed circuit boards or bus bars and therefore they yield significant gain of production times. Press-fit technology is the only solder-less method used in PCB and bus-bar applications that ensure reliable electro-mechanical connections. Successful assembly of press-fit connectors rests in designing a hole size small enough to create a solid connection with the pins while ensuring that the hole is large enough to permit the insertion of the pin without fracturing the hole barrel. Reliability of a press-fit connectors rests in not damaging hole plating when the insertion-removal operation is done.
By using press-fit, thermal stress on PCB from the soldering process can be avoided. Since it is an element that requires very little energy, press-fit minimizes material (without solder), and does not require any chemical component or reaction for its application, thus being better for the environment.
Press fit technology seems to be convenient, cost efficient, reliable, environmentally friendly and the connectors can be easily replaced. But compatibility of press-fit terminations for space-flight use shall be demonstrated. This paper presents the press-fit technology, its advantages/disadvantages and the space mounting testing performed to evaluate this connector technology.

Brief history of the press-fit concept

Early Press-fit technology has initially evolved in the 1960s from square tail "wire-wrap" contact terminations which were forced into round PCB holes hence notching a square into the PCB and capturing stretched portions of the copper trace between the wall of the PCB and the body of the contact. Interestingly, this method has been accepted in various applications as it proved a good factor of reliability as long as not much mechanical interference challenged the connection. The ease of achieving a gas-tight connection by pressing action has led to further innovation of this type of connection. The telecommunications industry was first to adopt this method of connection in large scale applications from the late 1970s onwards and since then, many specifications have been written around press-fit performance requirements by various industry groups such as IEC (International Electrotechnical Commission), Bellcore (Bell Communications Research) and PICMG (PCI Industrial Computers Manufacturers Group). Product development aimed to meet or exceed conformance to these specifications enabled connector manufacturers to gain significant expertise leading to securing product design-in position through the late 2000s in the aerospace sector.
For example, modern aircraft such as the Boeing 787 and the Airbus A350 are currently utilizing sophisticated power distribution and control systems employing various types of press-fit Sub-D connectors manufactured by Positronic.

Press-fit contact classification

There are two main types of press-fit termination configurations: rigid and compliant. The rigid termination having a solid press-in zone and the compliant termination having an elastic press-in zone. Compliant terminations further classify in high insertion force and low insertion force types which further minimize stress on the PTH (plated thru-hole) in a PCB. This classification is outlined in Table 1 which indicates some of the inherent characteristics of each termination type.

Press-Fit contact termination types	Rigid terminations	Very High Insertion force	Destructive interference	x
			One-time connection	x
			Susceptible to vibration failure	x
			Susceptible to temperature cycling failure	x
			Susceptible to oxidation at the interface	x
	Compliant terminations	High Insertion Force	Non-repeatable one time connection	x
			Destructive interference with PTH because of sharp edges and high stress on the PTH wall	x
			Removes plating finish on contact termination	x
		Low Insertion Force	Repeatable connection	√
			Non-destructive interference with PTH	√
			Maintains plating finish on contact termination	√
			Secure gas-tight connection between surfaces	√

Table 1: Press-fit contact termination types and their characteristics

In compliant terminations, the tail configuration will deform (or comply) during insertion and thus will significantly reduce stress on the PCB holes compared to rigid types and will sustain a permanent contact normal force to enable a reliable electrical and mechanical connection over lifetime. See figure 1.

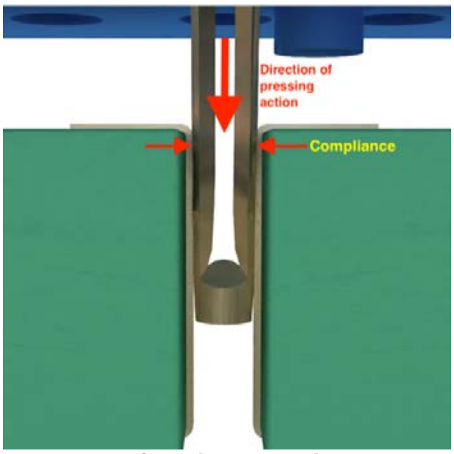

Fig. 1: Action of compliant contact design

Furthermore, the mechanical stability of the connector is significantly supported however additional mechanical support is required in order to entirely separate the mechanical functions from the electrical functions of the connector as shown in figure 2.

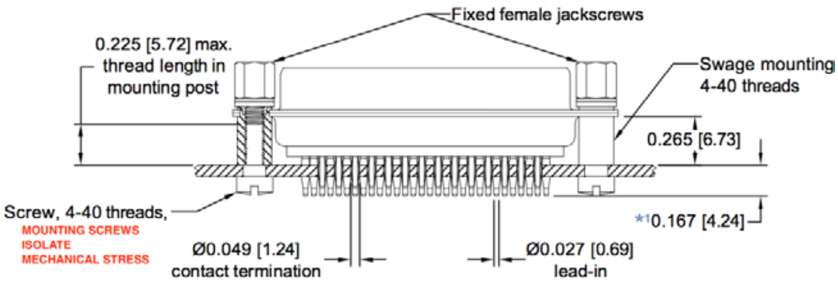

Fig.2: Press-fit connector installed on PCB with mounting screws

Technology of the compliant contact

Various designs of press-fit zones can be employed to obtain a compliant press-fit termination. The “eye of the needle” design is most commonly used. The “eye of the needle” combines many attributes of a reliable connection:

- relatively low press-in force with low impact on the copper sleeve (easy to repair)

- high flexibility offers good durability (reliability)
- only little variance in press-in force
- similar press-in and press-out force
- suitable for the application of different contact materials

In Figure 3, the “eye of the needle” design can be observed in two perpendicular cross-sections.

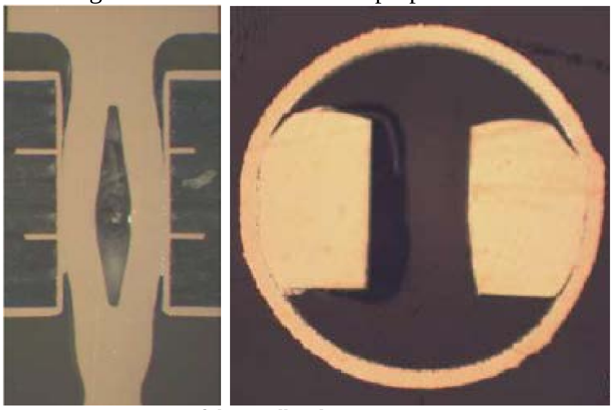

Fig. 3: “eye of the needle” design cross-sections

For thinner contacts, the shape of the press-fit section is generally modified in a shape which can be observed cross-sectionally as the profile of the letter “C”. The reasons this configuration is employed are:

- Due to the thin wall thickness of the compliant section more metal body is needed in order to ensure the mechanical and electrical properties of the contact are not compromised
- A higher area of contact between the termination and the PTH needs to be achieved since for small diameter terminations the “eye of the needle” design is not practical.

Therefore, for power contacts (AWG16 and below) the eye of needle is mostly used whereas for signal contacts (size 20 and 22) other shapes are used like the one shown on Fig. 4.

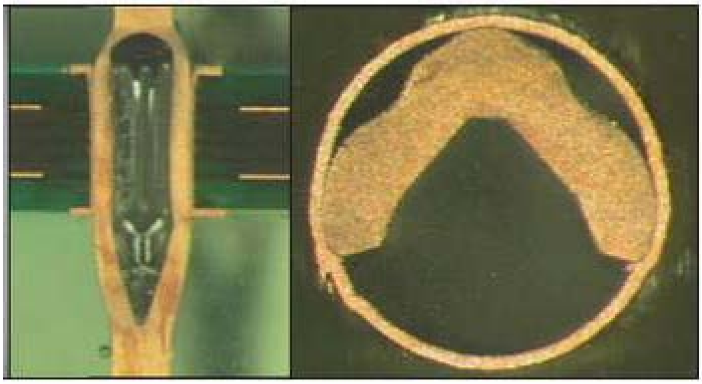

Fig. 4: modified “eye of the needle” design cross-sections

The functionality of press-fit system is dependent of the properties and characteristics of both press-fit pin and plated through hole components and of their interactions. The plated through hole for press-fit technology consists of a copper sleeve with an appropriate finish. For the protection of the copper surface, different finishes are available:

- Immersion Tin, with a thickness of about 1.0µm, is the most commonly used finish for press-fit technology
- Electroless Nickel barrier, Immersion Gold (ENIG), with a thickness of 5µm

For space applications only the Ni/Au finish is considered as pure Tin is forbidden because of whiskers concerns.

In order to use less PCB space the press-fit contact system is compatible with contact termination pitch up to 2mm (distance between two adjacent contacts) in combination with a finished PTH size of 1mm. As space is an important factor in flight applications the press-fit technology provides high density termination solution on PCB for miniaturization purposes which would be very difficult to realize with a conventional soldering process.

Installation procedure and tooling required to install press-fit connectors on PCBs

The press-fit pin insertion process is fast, cheap and reliable and allows the repair of the press-fit pin usually admitted up to two times.

For the press-in process the following parts and tools are necessary:

- printed circuit board
- press-fit connector
- press-fit tool with press action on the individual contacts (see Fig.4a and Fig.4b)
- PCB support tool
- press-in equipment with the capability to distribute the total force required by the the press-fit component.

During the process neither the PCB nor the connector should be damaged. Therefore, dedicated tools for the support of the PCB bottom side are necessary. During the press-in process, it is essential that both the PCB and connector insulation body are not placed under excessive stress, otherwise damage may occur.
For right angle connectors a “flat-rock” style tool applies uniform force onto the connector insulator directly above the termination side until the connector is inserted into the PCB (see Fig.4a). It is interesting to notice that for straight connectors the press-in tool head design differs for male or female connectors because the tool applies the force directly onto the contact tips and not on the plastic insulator. This prevents altering the position of the contacts into their insulator (see Fig.4b).

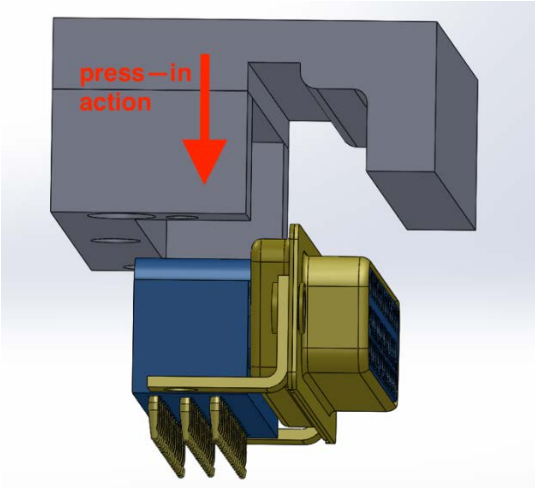

Fig.4a: 90º Flat-Rock style tool with alignment section

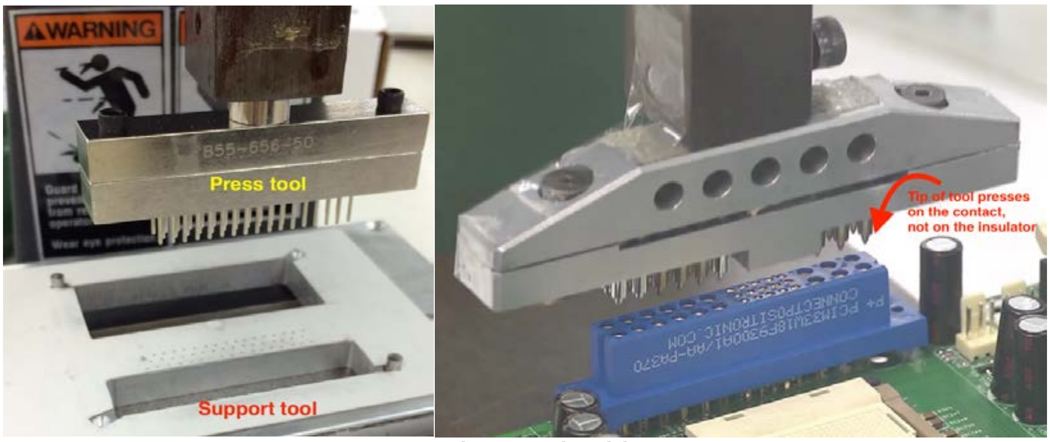

Fig.4b: Press tools and their action

Advantages of press-fit etchnology

Press-fit technology is a solder-less termination enabling a permanent electrical and mechanical terminal-to-PCB connection with several distinctive advantages:

- Fast processing
- Use of standard resins instead of cost intensive heat stabilized resins in the header
- Prevents thermal treatment to the header
- Lubrication and flux aid free processing
- Prevents solder paste printing and pre-heating
- Environmental friendly
- No shading-off issues with large header components in post-soldering insertion
- Prevents soldering defects like bridges, bad wetting, flux residuals, solder balls, spider webs thermal load and cold solder joints
- Hybrid assembly possible (together with soldered components)
- For multilayer boards with various thickness

Another important aspect of press-fit technology is reliability. The press-fit connection is considered as one of the most reliable connection techniques. The reliability shown in the IEC1709 norm, shows that the press-fit connection has a fit rate of 0.005 (see Table 2), which is at least 10 times more reliable than soldering.

Type of connection	Details	Conductor cross section (mm2)	Failure rate λ_{ref} in FIT	Notes: Standards/Guide
Solder	manual machine		0.5 0.03	IPC 610, class 2
Wire bond for hybrid circuits	Al Au		0.1 0.1	28µm / Wetch bond 25µm / Ball bond
Wire-wrap		0.05 - 0.5	0.002	DIN EN 60352-1/IEC 60352-1
Crimp	manual machine	0.05 - 300	0.25	DIN EN 60352-2/IEC 60352-2
Termi-point		0.1 - 0.5	0.02	DIN 41611-4
Press-fit		0.3 - 2	0.005	IEC 60352-5
Insulation displacement		0.05 - 1	0.25	IEC 60352-3, IEC 60352-4
Screw		0.5 - 16	0.5	DIN EN 60999-1
Clamp	elastic force	0.5 - 16	0.5	DIN EN 60999-1

Table 2: Reliability table shows comparison between different electrical connection technologies from IEC1709

Disadvantages of press-fit etchnology

Press-fit technology may also have some disadvantages:

- Connector removal maximum admitted up to two times
- Specific tooling needed to press-in
- Specific tooling might be needed to press-out
- Press-in and press out may damage the pin through hole barrel
- Connector price is slightly higher than the price of a connector with solder terminations

Positronic's heritage with press-fit connectors

Positronic is a connector manufacturer specialized in high-reliability, high performance machined contact technology and has been involved with PICMG (PCI Industrial Computers Manufacturers Group) in industry group development work related to press-fit connectors for power and signal applications since the 1990s. Positronic's latest generation of connector products using compliant, low-force repeatable press-fit terminations spreads across different power, signal and mixed density connector series as shown in figure 5 below and the machined contacts always employ a solid one-piece construction from tip to tail for both straight and 90º contact configurations as seen in figure 6.

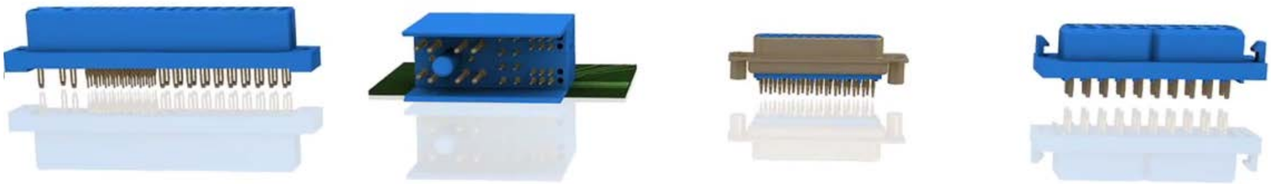

Fig. 5: various connector series from Positronic employing press-fit contacts

Fig. 6: press-fit contact sizes available from Positronic

Press-fit evaluation testing performed:

In 2015 CNES and Positronic decided to evaluate the compatibility of press-fit technology for space-flight applications by performing a mounting evaluation of such technology according to ECSS-Q-ST-70-38C. This evaluation focus on two aspects:

- PCB integrity evaluation after several press-fit mounting and un-mounting
- Press-fit reliability in harsh environment

The evaluation test plan outline is presented in table 3.

Stage	Operation	Details
1	Mount the connector on the PCB	Press-in all connector
2	Visual inspection	Look for burrs, particles, damages
3	Remove the connector	Press-out 2 over 3 of connectors
4	Visual inspection	PCB barrel and contact termination
5	Mount the connector on the PCB	Press-in all connectors removed
6	Visual inspection	Look for burrs, particles, damages
7	Remove the connector	Press-out 1 over 2 of the removed connectors
8	Visual inspection	PCB barrel and contact termination
9	Mount the connector on the PCB	Press-in all connectors removed
10	Visual inspection	Look for burrs, particles, damages
12	Electrical tests	Low level contact resistance
13	Vibrations	Sine and Random
14	Visual inspection	Look for burrs, particles, damages
15	Electrical tests	Low level contact resistance
16	Thermal cycle	200 cycles -55°C/+100°C, sloop 10°/min max
17	Visual inspection	Look for burrs, particles, damages
18	Electrical tests	Low level contact resistance
19	Thermal cycle	300 cycles -55°C/+100°C, sloop 10°/min max
20	Visual inspection	Look for burrs, particles, damages
21	Electrical tests	Low level contact resistance
22	PCB Micro section	Destructive physical analysis

Table 3: Outline of evaluation test plan.

At beginning of testing all connectors will be mounted once. Then some connectors will be un-mounted and re-mounted one more time to evaluate the impact of a repair. At last some of the connectors previously repaired will be un-mounted and re-mounted again to evaluate the robustness of the procedure and thus to assess the margin associated with a repair. The harsh tests to be performed to evaluate reliability of press-fit are vibration and thermal cycling. The sinusoidal and random vibration levels are defined in ECSS-Q-ST-70-08 and are presented in table 4 and 5:

Perpendicular to plane (Z)		Parallel to plane (X, Y)	
Range (Hz)	Level	Range (Hz)	Level
25 – 100	20 g	25 – 100	20 g
100 - 200	15 g	100 - 200	15 g
1 sweep up with a sweep rate of 1 oct/mn			

Table 4: Sine levels

Perpendicular to plane (Z)		Parallel to plane (X, Y)	
Range (Hz)	Level	Range (Hz)	Level
20 - 100	+ 6 dB/oct	20 - 100	+ 6 dB/oct
100 – 500	1 g^2/Hz	100 – 800	0.5 g^2/Hz
500 - 2000	- 6 dB/oct	800 - 2000	- 3 dB/oct
Total : 28.5 g RMS	5 min/axis	27.1 g RMS	5 min/axis

Table 5: Standard random levels

On one test vehicle the random vibration level to be applied will be significantly higher for evaluation proposes.

Parallel to plane (X, Y)	
Range (Hz)	Level
20 - 100	+ 6 dB/oct
100 – 800	1,54 g²/Hz
800 - 2000	- 3 dB/oct
50 g RMS	5 min/axis

Table 6: Extended random levels

The thermal cycling test will be performed in two steps to evaluate the impact of the first 300 cycles as it cover most of mission needs and then 200 cycles will finished the testing.
The test vehicles to be evaluated are made with harness connectors plugged into PCB connectors (straight and right angle) mounted on boards. The connector to be evaluated are Positronic high-density connectors using size 22 contacts (78 contacts), standard density D-Sub using size 20 (50 contacts), combo-D connectors using size 20 and size 8 contacts and Amphenol VHDM high data rate connector (3.125Gbps).

Fig. 6: press-fit contact sizes available from Positronic

Two different PCB are used. One is made with 8 layers of glass-polyimide (1.6mm thick) and the other is 4 layers of glass-polyimide (2.4mm thick). Both PCB have a PTH finish of 5µm of Gold. The internal routing of the PCB and the cabling of the harness connector are designed to create a daisy chain that enable to monitor the electrical resistance of all the connector termination in series to check for termination failure during vibration or thermal cycling. A mounting example is shown in figures 7 and 8:

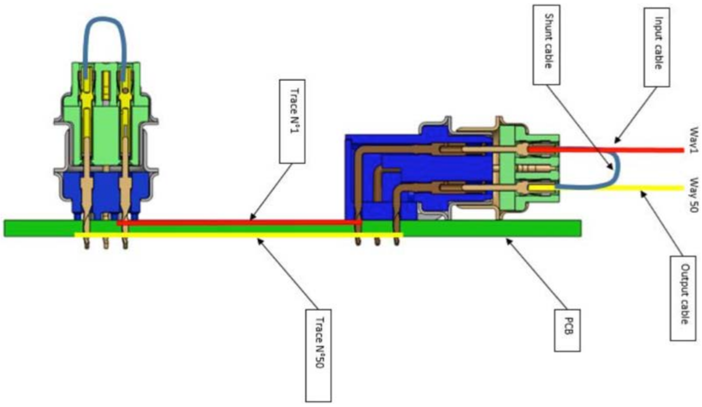

Fig.7: Conceptual representation of the daisy chain

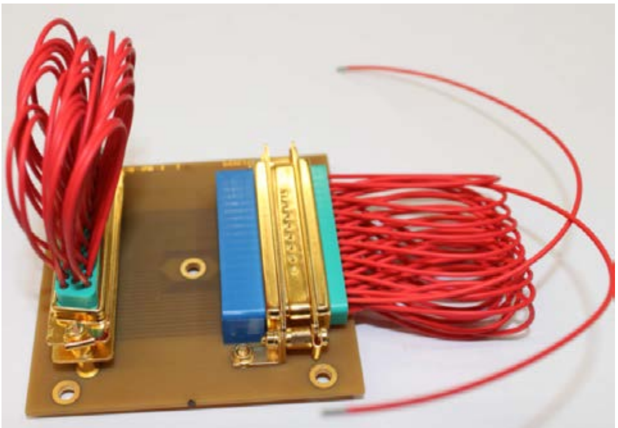

Fig.8: Actual representation of mounting example

Conclusion:

Unfortunately all testing results are not yet available to include them in the article. The testing will be done during summer 2016 and therefore extended results will be presented during the SPCD symposium. Presently the test vehicles have passed the test sequence up to thermal cycling (stage 1 to 16). The mounting and un-mounting operations have not induced damages in the PTH (no burrs, no chip). Only the contact area between press-fit termination and PTH can be observed. Indeed the roughness of gold in this area has been decreased because of contact pressure therefore the gold layer looks brighter (see Fig.9).

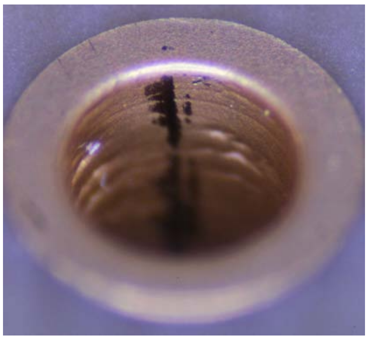

Fig.9: Image of a PTH after connector un-mounting

The vibration testing has also shown good results has no µ-cuts has been measured and no damages has been observed. After the thermal cycling a detailed inspection and a micro section on PCB PTH will give us more technical information. The results of press-fit technology evaluation for space application will be available soon and depending on testing results press-fit technology could be considered as an acceptable contact termination for space application.

Sample References

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