

# IPC-HDBK-9798

2022 - April

## Handbook for Press-fit Standard for Automotive Requirements and other High-Reliability Applications

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**IPC-HDBK-9798**

# **Handbook for Press-fit Standard for Automotive Requirements and other High-Reliability Applications**

Developed by the Cold Joining Press-fit Handbook Task Group (5-21n)  
of the Assembly & Joining Committee (5-20) of IPC

Users of this publication are encouraged to participate in the  
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# Handbook for Press-fit Standard for Automotive Requirements and other High-Reliability Applications

## 1 SCOPE

This document provides guidelines and supporting information for manufacturing electronic assemblies using compliant press-fit technology. The intent is to explain the “how-to” and “why” information, and fundamentals for these processes.

Additional detailed information can be found in documents referenced within each individual section. Users are encouraged to use those referenced documents to better understand the applicable subject areas.

This handbook is supporting the IPC-9797 standard.

**1.1 Applicability** This handbook is for guidance only. The design concepts, guidelines, and procedures presented in this document are not requirements, and this document is not binding, unless separately and specifically included by the applicable contract, approved drawing(s), or purchase order.

**1.2 Measurement Units** This standard uses International System of Units (SI units) per ASTM SI10, IEEE/ASTM SI 10, Section 3 [Imperial English equivalent units are in brackets for convenience]. The SI units used in this standard are millimeters (mm) [in] for dimensions and dimensional tolerances, Celsius (°C) [°F] for temperature and temperature tolerances, grams (g) [oz] for weight, and lux (lx) [footcandles] for illuminance.

**Note:** This standard uses other SI prefixes (ASTM SI10, Section 3.2) to eliminate leading zeros (for example, 0.0012 mm becomes 1.2 µm) or as an alternative to powers-of-ten (3.6 x 10<sup>3</sup> mm becomes 3.6 m).

**1.2.1 Verification of Dimensions** When an inspection is done on an assembly, measuring dimensions and determining percentages listed in the standard are not required unless there is a doubt or a question is raised about the acceptance of the product. When there is a doubt or a question is raised, then a referee determination should be implemented, at which time measurements should be made or percentages calculated using the referee magnifications defined in the standard. For determining conformance to the specifications in this standard, round all observed or calculated values “to the nearest unit” in the last right-hand digit used in expressing the specification limit, in accordance with the rounding method of ASTM Practice E29. For example, specifications of 2.5 mm max, 2.50 mm max, or 2.500 mm max, round the measured value to the nearest 0.1 mm, 0.01 mm, or 0.001 mm, respectively, and then compare to the specification number cited.

**1.3 Use of “Lead”** For readability and translation, this document uses the noun “lead” only to describe leads of a component. The metallic element “lead” is always written as Pb.

**1.4 Abbreviations and Acronyms** Periodic table elements are abbreviated in the standard. See Appendix A for abbreviations, including elements and acronyms used in this standard.

**1.5 Terms and Definitions** Other than those terms listed in IPC-9797, the definitions of terms used in this handbook are in accordance with IPC-T-50.

## 2 APPLICABLE DOCUMENTS

### 2.1 IPC Documents<sup>1</sup>

**IPC-T-50** Terms and Definitions for Interconnecting and Packaging Electronic Circuits

**IPC-6012** Qualification and Performance Specification for Rigid Printed Boards

**IPC-6012EA** Automotive Applications Addendum to IPC-6012E, Qualification and Performance Specification for Rigid Printed Boards

**IPC-9797** Press-fit Standard for Automotive Requirements and other High-Reliability Applications

**IPC-A-600** Acceptability of Printed Boards

**IPC-4552** Specification for Electroless Nickel/Immersion Gold (ENIG) Plating for Printed Boards

**IPC-4553** Specification for Immersion Silver Plating for Printed Boards

<sup>1</sup> [www.ipc.org](http://www.ipc.org)  
<sup>2</sup> [www.iec.ch](http://www.iec.ch)  
<sup>3</sup> [www.astm.org](http://www.astm.org)

**IPC-4554** Specification for Immersion Tin Plating for Printed Circuit Boards

**IPC-1602** Standard for Printed Board Handling and Storage

**IPC-TM-650** Test Methods Manual

2.6.25 Conductive Anodic Filament (CAF) Resistance Test: X-Y Axis

## 2.2 International Electrotechnical Commission Documents<sup>2</sup>

**IEC 60512-2-1** Connectors for electronic equipment – Tests and measurements – Part 2-1: Electrical continuity and contact resistance tests – Test 2a: Contact resistance – Millivolt level method

**IEC 60068-1** Environmental testing – Part 1: General and guidance

**IEC 60352-5** Solderless connections – Part 5: Press-in connections – General requirements, test methods and practical guidance

**IEC 60721-3-1** Classification of environmental conditions – Part 3-1: Classification of groups of environmental parameters and their severities – Storage

**Future IEC/TR 60068-3-82** (to be published 2022) Environmental Testing – Part 3-82: Supporting documentation and guidance – confirmation of the performance of whisker test method

## 2.3 American Society for Testing and Materials<sup>3</sup>

**ASTM E29** Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

**ASTM SI10, IEEE/ASTM SI 10** American National Standard for Metric Practice

## 3 INTRODUCTION TO PRESS-FIT TECHNOLOGY

**3.1 Background of Press-fit Technology** Press-fit technology is going back to the 1970s. It was initially used in the telecommunication industry, starting with solid pins and moving later to compliant variants. Press-fit pins with compliant press-fit zones were standardized in the 80s, becoming a standalone IEC standard (IEC 60352-5) in 2004. The press-fit technology was further developed to meet the requirements of high performance/harsh environment (IPC Class 3) electronic products. This finally triggered the preparation of the IPC-9797 Press-fit Standard for Automotive Requirements and Other High Reliability Applications. Typical fields of application are single-pin insertion as well as the assembly of connectors integrated in housings.

**3.2 Press-Fit Technology** Press-fit technology establishes an electro-mechanical connection between a compliant press-fit zone and press-fit plated-through hole (PPTH) of a printed board (PB). In the contact areas, between the surfaces of the compliant

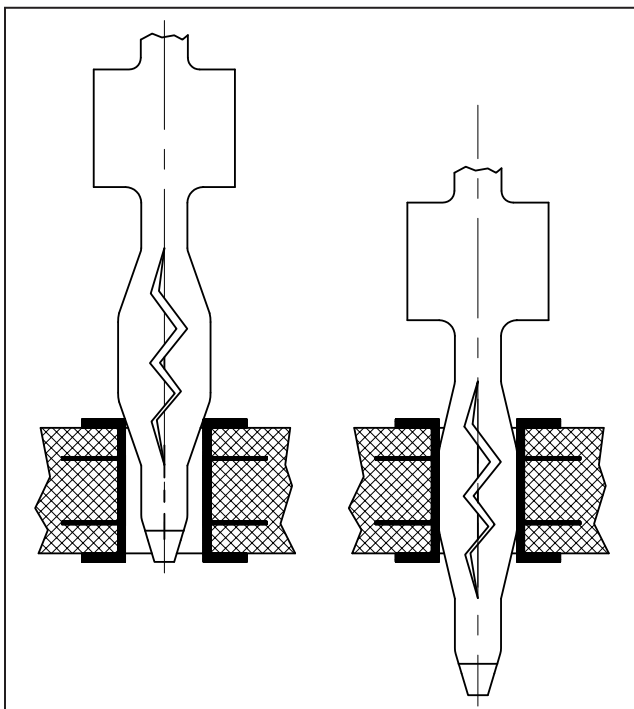


Figure 3-1 Compliant Press-Fit Zone in PPTH

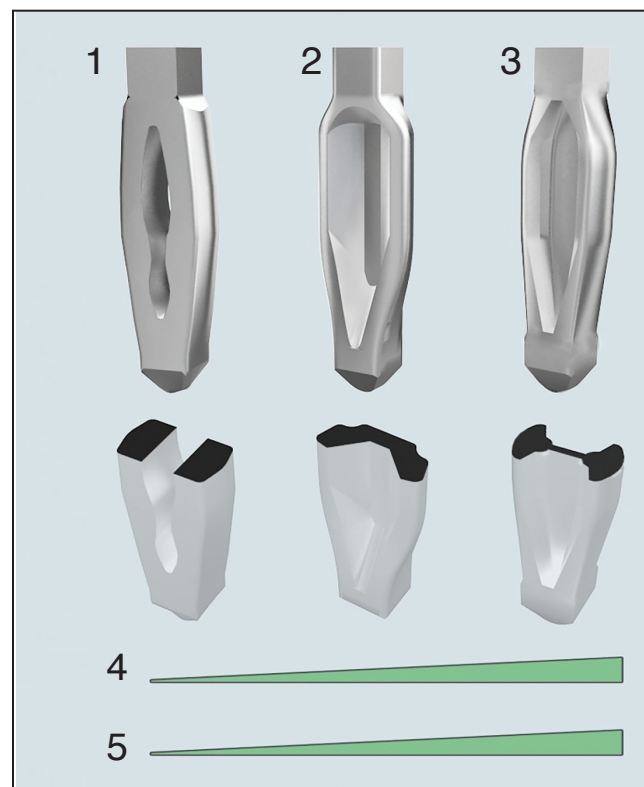


Figure 3-2 Examples of Different Styles of Compliant Press-Fit Zones [1]

1. Eye of the Needle
2. Spring Shape
3. Cracking Zone
4. Spring Stiffness
5. Plastic Deformation

press-fit zone and the PPTH, a gas tight connection can be established. This interconnection is widely used in automotive, telecommunication, industrial, aerospace and many other applications. Advantages and challenges are discussed in chapter 3.3.

The compliant press-fit zone is slightly larger than the PPTH. During the push-in process, the compliant press-fit zone is deformed elastically and plastically to a defined hole size and thereby establishes the compliant press-fit connection (see Figure 3-1).

There are many different compliant press-fit zone designs in use (see Figure 3-2). They differ by their spring stiffness and the extent of plastic deformation occurring during the push-in operation (see bottom part of Figure 3-2).

**3.3 Advantages and Challenges** The main advantage of press-fit technology is not only the high reliability of the electrical and mechanical connection, but also the robust assembly process: relatively simple mounting process, requiring neither auxiliary materials nor external heating, provides high repeatability and reproducibility.

A press-fit connection can be even more reliable than a solder connection regarding mechanical, thermal and electrical properties.

**Table 3-1 Advantages and Common Challenges of Press-Fit Technology with Reference to Selective Soldering**

| Advantages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Challenges                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>• Fast, well controllable assembly process</li> <li>• Assembly is possible on both sides of the printed board</li> <li>• Electrical and mechanical connection</li> <li>• No heat treatment required</li> <li>• No auxiliary materials required:               <ul style="list-style-type: none"> <li>• Flux</li> <li>• Solder alloy</li> <li>• Cleaning agent</li> </ul> </li> <li>• No risk of solder balls or any other soldering anomalies</li> <li>• Highly reliable connection under harsh environments (thermal cycling, vibration, corrosive atmosphere, humidity)</li> <li>• Recycling possible through simple push-out of the pins</li> </ul> | <ul style="list-style-type: none"> <li>• Strict tolerance requirements for PB and assembly process:               <ul style="list-style-type: none"> <li>• Drill hole size</li> <li>• PPTH copper thickness</li> <li>• Finished hole size</li> <li>• True position tolerance</li> <li>• Push-in depth tolerance for complex assemblies</li> </ul> </li> <li>• Hot air leveling PB finishes not suitable for high reliability applications</li> <li>• Selection of PB material suitable for press-fit technology</li> <li>• Keep out zones and design of supporting tool around individual PPTH</li> <li>• Mechanical strain around PPTH</li> <li>• Risk of whisker growth and metal slivers, depending on material combinations</li> </ul> |

The performance of a press-fit connection is highly linked both to the design and materials of the compliant press-fit zone and the PB. Well controlled materials and process parameters assure repeatable and reproducible electrical and mechanical properties.

**3.4 Current and Future Trends** As the press-fit technology is becoming more widely used in different industries, new requirements evolve. Some of these technology trends which can be seen already are:

- Miniaturization through reduced pitch, compliant press-fit zone diameter, strip material thickness and reduced PPTH copper thickness.
- Enabling higher current densities by using new materials.
- Increasing ampacity by use of larger strip thickness/compliant press-fit zone diameter.
- Extension of press-fit technology to other industries: e.g., space applications, medical, defense.
- Improved whisker mitigation through new surface finishes.
- Increasing availability of components and sub-systems with press-fit technology.

## 4 CONTACT PHYSICS

There are multiple ways to produce a press-fit connection, which involve different contact physics mechanisms. For example, as stated in the IPC-9797 chapter 1.9.10, a compliant press-fit connection can be achieved by an intimate metal-to-metal connection. An intimate metal-to-metal connection may also be referred to as a cold-welding connection. During push-in, plastic and elastic deformation occur in both the PB and the compliant press-fit zone. Once a compliant press-fit pin is pressed into the smaller diameter of the PPTH, there exists a very strong normal force between the pin and PPTH, bringing the surfaces firmly together, with only an order of Ångströms separation. This convergence of surfaces can result in a sharing of electron clouds into one common electron cloud. Although this is perhaps the most commonly referred to contact mechanism for compliant press-fit connections, there are

various other mechanisms, which also establish a press-fit to PPTH connection on their own without generating a common electron cloud between metals.

All compliant press-fit connections start with a pure mechanically induced connection. This means, that after pressing-in the normal force between compliant press-fit zone and PPTH is always greater than 0 N. In fact, it can range from tens of newtons to hundreds of newtons, depending on the compliant press-fit zone design, substrate material properties and thickness as well as the PPTH diameter. This normal force is the prerequisite for the following mechanisms, which provide the mechanical and electrical properties necessary for compliant press-fit connections.

Due to the normal force present in compliant press-fit connections along with the inherent roughness of the mating surfaces, there is an interlocking of the irregularities of the surfaces on a microscopic scale, resulting in an abrasive static friction force. The contact area of the surfaces' asperities range between nm to  $\mu\text{m}$  in diameter and are often referred to as a-spots. The current between compliant press-fit zone and PPTH is transmitted over these a-spots, as depicted in Figure 4-1.

As a consequence of the a-spots and the present normal force, which brings regions of the mated surfaces closely together on the microscopic scale, to an order of Ångström separation, adhesive static friction forces also come into play. These non-covalent or metallic bonds, e.g., Van der Waals or hydrogen bonding, take place through attractive electrostatic or intermolecular forces between atoms or molecules on the surface via electron density shifts as well as dipole or multipole interactions. Although they are weaker, short range interactions, they are strong when combined in vast numbers.

In general, the rougher the mated surfaces are, the higher the abrasive static frictional forces. And vice versa, the smoother the surfaces are, the higher the adhesive static frictional forces are, which are more robust against corrosion, as these microscopic regions create a gas tight connection and are therefore often referred to as micro-welding points.

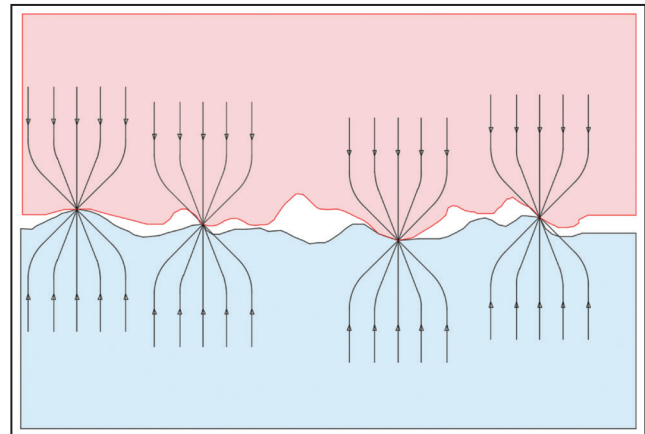


Figure 4-1 Current Flow Through the A-Spots

The mechanical normal force and resultant abrasive static friction as well as the electrostatic based adhesive friction forces produce the fundamental characteristics for a compliant press-fit connection. Such a connection is often more generally referred to as a force-fit connection; two tightly fitted mated parts, which produce a connection held together by friction due to the parts being pushed together. It is responsible for the underlying retention force and electrical contact resistance through the a-spots of the mated pin and PPTH.

Table 4-1 refers to electrical and mechanical test conditions and corresponding acceptance criteria sections in the IPC-9797, which are used to ensure the integrity of both the initial compliant press-fit connection in TG B as well as the connection after being subjected to different environmental loads in TG C - E.

Table 4-1 Mechanical and Electrical Tests in IPC-9797

|                           | Test Conditions | Acceptance Criteria |
|---------------------------|-----------------|---------------------|
| <b>Push-In Forces</b>     | 4.3.1           | 5.3.1               |
| <b>Push-Out Forces</b>    | 4.3.5           | 5.3.2               |
| <b>Contact Resistance</b> | 4.3.4           | 5.4.1               |

Since the adhesion static friction forces tend to increase over time until they eventually come to a saturation point, all pushed-in pins for TGs B-E, are to be stored at room temperature for at least 24 h (see IPC-9797 chapter 4.3.2) before further tests may be carried-out.

As mentioned above, elastic and plastic deformation occur within the contact system as a result of the larger diameter compliant press-fit zone being pushed in a PPTH of smaller diameter. This in combination with the present normal force after pushing-in, results in plastic deformation on the macroscopic scale of the bulk materials, as in a form-fit connection. Therefore, to ensure the integrity of the pushed-in press-fit zones and their corresponding PPTHs the following investigations regarding deformation should be carried-out as stated in the IPC-9797 (see Table 4-2).