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**Press-Fit Standard for
Automotive Requirements and
Other High-Reliability Applications**

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Automotive Requirements
and Other High-Reliability
Applications**

Developed by the Cold Joining Press-Fit Task Group (5-21m) of
the Assembly and Joining Committee (5-20) of IPC

Users of this publication are encouraged to participate in the
development of future revisions.

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Press-Fit Standard for Automotive Requirements and Other High-Reliability Applications

1 SCOPE

This standard prescribes practices for the characterization, qualification and acceptance requirements of compliant press-fit technology for printed boards that cover the manufacturability and reliability needs for high-reliability applications intended for use in harsh environments such as automotive and aerospace.

Additional requirements for aerospace applications in Appendix B may apply.

For a more complete understanding of this document's practices and requirements, one may use this document in conjunction with IPC-HDBK-9798.

1.1 Purpose This standard prescribes practices for the characterization, qualification and acceptance requirements of compliant press-fit technology for printed boards.

Standards may be updated at any time, including with the use of amendments. The use of an amendment or newer revision is not automatically required. The revision in effect **shall** be as specified by the user.

1.2 Classification

CLASS 1 General Electronic Products

Includes products suitable for applications where the major requirement is function of the completed assembly.

CLASS 2 Dedicated Service Electronic Products

Includes products where continued performance and extended life is required, and for which uninterrupted service is desired but not critical. Typically, the end-use environment would not cause failures.

CLASS 3 High Performance/Harsh Environment Electronic Products

Includes products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support or other critical systems.

All requirements in this standard pertain to IPC Class 3. When this standard is contractually required, IPC class 3 requirements **shall** be adopted for all other contractually required standards.

1.3 Measurement Units This standard uses International System of Units (SI units) per 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 zeroes (for example, 0.0012 mm becomes 1.2 µm) or as an alternative to powers-of-ten (3.6 x 10³ mm becomes 3.6 m).

1.3.1 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 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.

1.4 Definition of Requirements The words "**shall**" or "**shall not**" are used in the text of this document wherever there is a requirement for materials, preparation, process control or acceptance.

The word “should” reflects recommendations and is used to reflect general industry practices and procedures for guidance only.

Line drawings and illustrations are depicted herein to assist in the interpretation of the written requirements of this standard. The text takes precedence over the figures.

1.4.1 Acceptance Criteria Criteria are given in the Acceptance section as four conditions: Target, Acceptable, Defect or Process Indicator.

“Not Established” means that there are no specified criteria for that class and may need to be established between Manufacturer and user.

1.4.1.1 Target Condition A condition that is close to perfect/preferred; however, it is a desirable condition and not always achievable and may not be necessary to ensure reliability of the assembly in its service environment.

1.4.1.2 Acceptable Condition This characteristic indicates a condition that, while not necessarily perfect, reflects the commonly accepted state-of-the-art for the press-fit connection.

Note: Design for reliability considerations are additionally required to assure the reliability of the assembly in its service environment.

1.4.1.3 Defect Condition A defect is a condition that may be insufficient to ensure the form, fit or function of the assembly in its end use environment. Defect conditions **shall** be dispositioned by the manufacturer based on design, service, and customer requirements.

It is the responsibility of the user to define unique defect categories applicable to the product.

A defect for Class 1 automatically implies a defect for Class 2 and 3. A defect for Class 2 implies a defect for Class 3.

Note: This would not be the case where criteria for a particular class have not been established.

1.4.1.3.1 Disposition The determination of how defects should be treated. Dispositions include, but are not limited to, rework, use as is, scrap or repair. Repair or “use as is” may require customer concurrence.

1.4.1.4 Process Indicator Condition A process indicator is a condition (not a defect) that identifies a characteristic that does not affect the form, fit or function of a product:

- Such condition is a result of material, design and/or operator/machine related causes that create a condition that neither fully meets the acceptance criteria nor is a defect.
- Process indicators should be monitored as part of the process control system. When the number of process indicators indicate abnormal variation in the process or identify an undesirable trend, then the process should be analyzed. This may result in action to reduce the variation and improve yields.
- Disposition of individual process indicators is not required.

1.4.1.5 Combined Conditions Cumulative conditions **shall** be considered in addition to the individual characteristics for product acceptability even though they are not individually considered defective. The significant number of combinations that could occur does not allow full definition in the content and scope of this standard, but manufacturers should be vigilant for the possibility of combined and cumulative conditions and their impact upon product performance.

Conditions of acceptability provided in this standard are individually defined and created with separate consideration for their impact upon reliable operation for the defined production classification. Where related conditions can be combined, the cumulative performance impact for the product may be significant, i.e., the maximum jet effect when combined with minimum copper thickness may cause a significant reduction of the robustness of the connection. The Manufacturer is responsible for identification of such conditions.

The user is responsible to identify combined conditions where there is significant concern based upon end use environment and product performance requirements.

1.4.1.6 Conditions Not Specified Conditions that are not specified as defective or as a process indicator may be considered acceptable unless it can be established that the condition affects user defined form, fit or function.

1.4.1.7 Specialized Designs This standard, as an industry consensus document, cannot address all of the possible components and product design combinations. Where uncommon or specialized technologies are used, it may be necessary to develop unique requirements or acceptance criteria. However, where similar characteristics exist, this document may provide guidance for product acceptance criteria. Often, unique definitions are necessary to consider the specialized characteristics while considering product performance criteria. The development **shall** include customer involvement or consent.

Whenever possible these criteria should be submitted to the IPC Technical Committee to be considered for inclusion in upcoming revisions of this standard.

1.5 Process Control Requirements The primary goal of process control is to continually reduce variation in the processes, products, or services to provide products or processes meeting or exceeding user requirements. Process control tools such as IPC-9191, JESD 557 or other user-approved system may be used as guidelines for implementing process control. Manufacturers of Class 3 products **shall** develop and implement a documented process control system.

A documented process control system, if established, **shall** define process control and corrective action limits.

This may or may not be a statistical process control system. The use of “statistical process control” (SPC) is optional and should be based on factors such as design stability, lot size, production quantities, and the needs of the Manufacturer.

Process control methodologies **shall** be used in the planning, implementation and evaluation of the manufacturing processes used to produce soldered electrical and electronic assemblies. The philosophy, implementation strategies, tools and techniques may be applied in different sequences depending on the specific company, operation, or variable under consideration to relate process control and capability to end-product requirements.

When it is required to use a documented process control system, failure to implement process corrective action and/or the use of continually ineffective corrective actions **shall** be grounds for disapproval of the process and associated documentation.

1.6 Order of Precedence The contract **shall** take precedence over this standard, referenced standards and drawings.

In the event of conflict, the following order of precedence applies:

- 1) Procurement as agreed and documented between customer and supplier.
- 2) Master drawing reflecting the customer’s detailed requirements.
- 3) When invoked by the customer or per contractual agreement, this standard.

When documents other than this standard are cited, the order of precedence **shall** be defined in the procurement documents.

The user has the opportunity to specify alternate acceptance criteria.

1.6.1 Conflict In the event of conflict between the requirements of this standard and the applicable drawing(s) and documentation, the applicable user-approved drawing(s) and documentation govern.

Some examples of documentation include the contract, purchase order, technical data package, engineering specification or performance specification. In the event of a conflict between the text of this standard and the applicable documents cited herein, the text of this standard takes precedence. In the event of conflict between the requirements of this standard and drawing(s) and documentation that has not been user approved, this standard governs.

1.6.2 Appendices Appendices to this standard are not binding requirements unless separately and specifically required by this standard, the applicable contracts, assembly drawing(s), documentation or purchase orders.

1.7 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.

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

1.9 Terms and Definitions Other than those terms listed below, the definitions of terms used in this standard are in accordance with IPC-T-50.

1.9.1 Compliant Press-Fit Pin The compliant press-fit pin has at least one compliant press-fit zone and is designed to be inserted into a press-fit plated through hole (PPTH) of a printed board.

1.9.2 Compliant Press-Fit Pin Connection A compliant press-fit pin connection is a solder-free electromechanical connection that is achieved by pressing a compliant press-fit pin into a PPTH of a printed board.

Note: This can be achieved by intimate metal-to-metal contact.

1.9.3 Compliant Press-Fit Tip The compliant press-fit tip is the end of the pin that points in the direction of the insertion, see Figure 1-1.

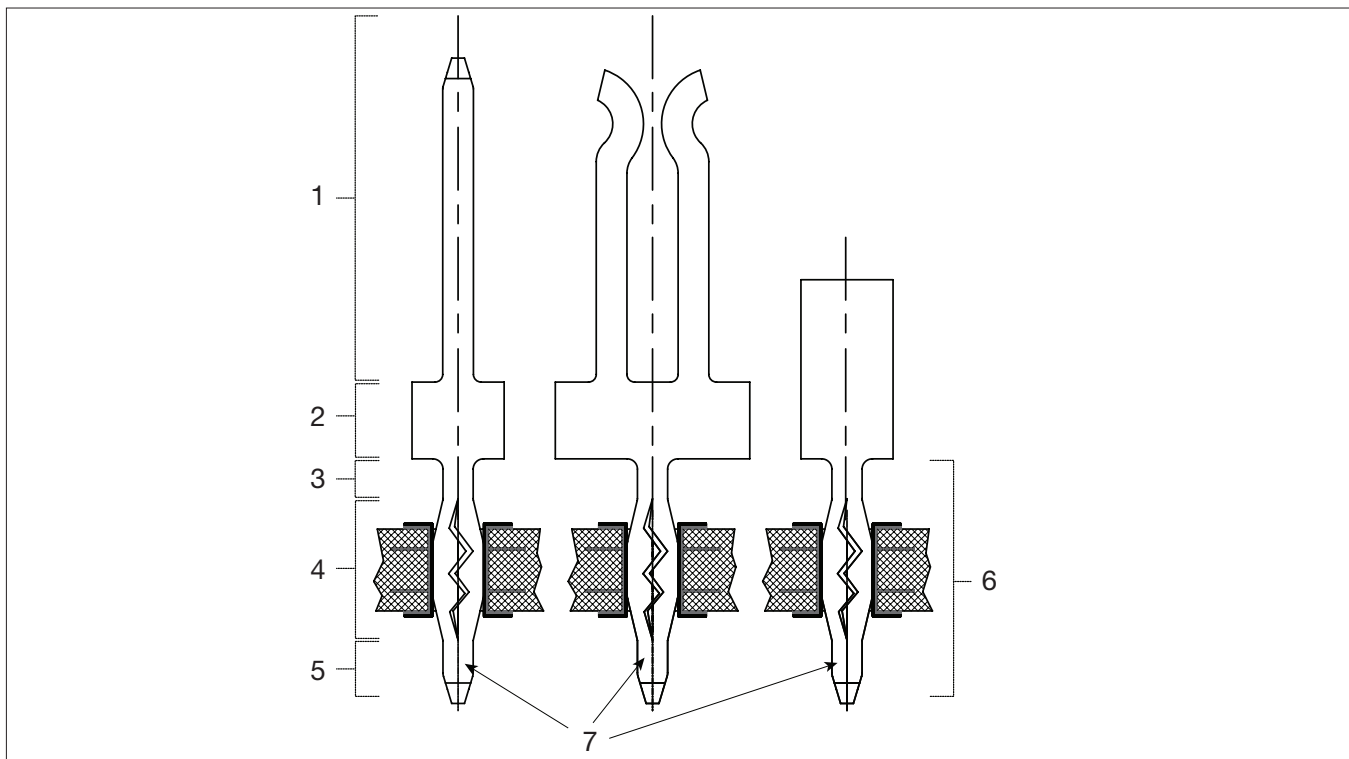


Figure 1-1 Examples of Interface Contacts, Compliant Press-Fit Pin and PPTH

Note: The notions in the figure pertain to the compliant press-fit pin and not the assembly, i.e., compliant press-fit zone means the compliant part of the pin and not the assembly of a pin with the printed board.

1. Examples of interface contacts

2. Pin shoulder

3. Pin neck / Transitional zone

4. Compliant press-fit zone

5. Compliant press-fit tip

6. Compliant press-fit tail

7. Axis

1.9.4 Compliant Press-Fit Zone The compliant press-fit zone is a specially shaped section which is elastically and plastically deformed during pin insertion. It is characterized by its base material, surface finish and geometry.

1.9.5 Contact Area The contact area is the common conductive area between PPTH and compliant press-fit zone providing electrical and mechanical connection, see Figure 1-2.

1.9.6 Deposition of Surface Finishes For the deposition of surface finishes, the procedures in this section are distinguished.

1.9.6.1 Deposition The deposition of one element from one plating bath, e.g., Sn.

1.9.6.2 Co-deposition The simultaneous deposition of more than one element as an alloy from one plating bath, e.g., AgSn.

1.9.7 Electrical Clearance The minimum spacing between noncommon uninsulated conductors, e.g., patterns, materials, hardware or residue. It is defined in the applicable design standard or on the approved or controlled documentation. Insulating material needs to provide sufficient electrical isolation. In the absence of a known design standard use IPC-2221. Any violation of minimum electrical clearance is a defect condition for all classes.

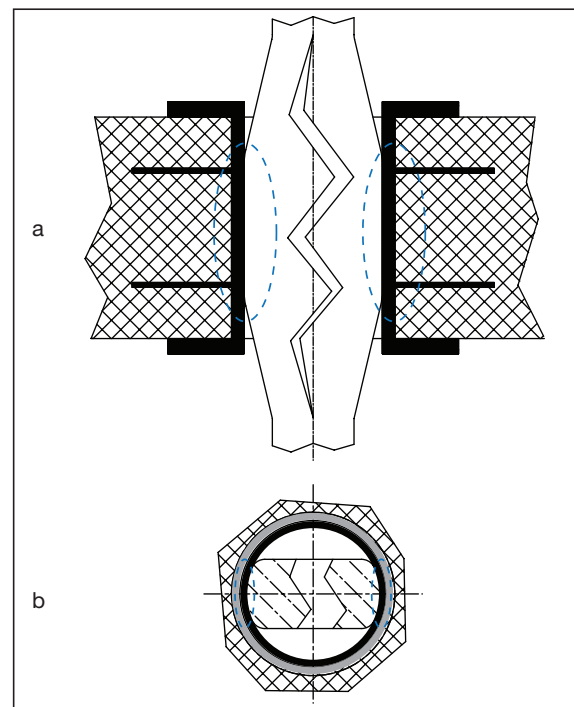


Figure 1-2 Schematic of Longitudinal (a) and Transverse (b) Cross-Section of a Compliant Press-Fit Connection

Note: Contact regions between PPTH and compliant press-fit zone in schematic cross-section examples are marked with blue dashed ellipses.

1.9.8 Intimate Metal-to-Metal Connection A connection involving the sharing of electron clouds, i.e., the formation of metallic bonding, between the pin's surface finish and the PPTH. This connection maintains a low electrical loss even if exposed to environmental conditions including also corrosive gases. It creates a connection which is gas tight.

Note: After an intimate metal-to-metal contact is achieved, interdiffusion may follow.

1.9.9 Jet effect Deformation j The maximum displacement of a Cu layer in association with a given PPTH as a result of the frictional forces during insertion of a compliant press-fit pin, see 4.3.6.

1.9.10 Laminate Buckling A separation within the laminate underneath the annular ring, where a crack is visible from the printed board surface.

1.9.11 Manufacturer (Assembler) The individual, organization or company responsible for the assembly process and verification operations necessary to ensure compliance of assemblies to this standard, having the authority to define variations or restrictions to the requirements of this standard.

1.9.12 Pad Bulging A deformation of laminate, PPTH and annular ring, characterized by an elevation in the proximity of the PPTH above the printed board surface level without delamination of the annular ring from the laminate.

1.9.13 Pad Lifting A separation between laminate and conductor of the annular ring starting at the edge of the annular ring.

Note: Pad lifting is not commonly observed in compliant press-fit technology. The common failure mode is laminate buckling. In visual inspection it may be impossible to distinguish between these two failure modes.

1.9.14 Pin Neck The pin neck represents the transition between compliant press-fit zone and pin shoulder, see Figure 1-1.

1.9.15 Pin Shaft The pin shaft is situated above the compliant press-fit zone and may include the pin neck, the pin shoulder and the interface contact, e.g., blade, insulation displacement connection (IDC), additional compliant press-fit zone, see Figure 1-1.

1.9.16 Pin Shoulder The pin shoulder or equivalent is used to apply the push-in force to install the pin, see Figure 1-1.

1.9.17 Pull-Out Force The axial force required to irreversibly displace a compliant press-fit zone from its specified inserted position in the opposite direction of insertion by pulling on the pin from the insertion side using a constant displacement rate.

Note: Pull-out force is not used in this standard but may be used in industry.

1.9.18 Push-In Force The maximum axial force required to insert a compliant press-fit zone into a printed board to a specified depth using a constant displacement rate.

1.9.19 Push-Out Force The axial force required to irreversibly displace a compliant press-fit zone from its specified inserted position in the opposite direction of insertion by pushing on the compliant press-fit tip using a constant displacement rate.

1.9.20 Push-Through Force The axial force required to irreversibly displace a compliant press-fit zone from its specified inserted position in the same direction of insertion by pushing on the insertion side using a constant displacement rate.

Note: Push-through force is not used in this standard but may be used in industry.

1.9.21 Strip and Strip Thickness The base material from which the compliant press-fit pin is stamped is called strip, its thickness is called strip thickness.

1.9.22 Supplier The individual, organization or company responsible for supplying materials and services such as compliant press-fit pins or printed boards to the manufacturer, responsible to ensure compliance of materials to this standard.

1.9.23 User The individual, organization, company or agency responsible for the procurement or design of electrical/electronic hardware assemblies and having the authority to define the product class and variations or restrictions to the requirements of this standard, i.e., the originator/custodian of the contract detailing these requirements.

1.9.24 Whitening Discoloration of printed board generated during compliant press-fit pin insertion. This condition manifests itself in the form of white areas below the surface of the base material. It is indicative of stresses and/or delamination in the printed board. Although the visual appearance is similar to measling (due to thermal stresses) and crazing (due to mechanical stresses during printed board fabrication), requirements and acceptance criteria for measling and crazing do not apply to whitening, which is entirely due to mechanical stresses related to the press-fit process.

1.10 Additional Requirements

1.10.1 Requirements Flowdown When this standard is contractually required, the applicable requirements of this standard (including product class, see 1.2) **shall** be imposed on all applicable subcontracts, assembly drawing(s), documentation and purchase orders.

When a part is adequately defined by a specification, then the requirements of this standard should be imposed on the manufacturer of that part only when necessary to meet end-item requirements. When it is unclear where flowdown should stop, it is the responsibility of the manufacturer to establish that determination with the user.

1.10.2 Personnel Proficiency All instructors, operators, and inspection personnel **shall** be proficient in the tasks to be performed. Objective evidence of that proficiency, i.e., records of training to the applicable job functions being performed, work experience, testing to the requirements of this standard or results of periodic reviews of proficiency, **shall** be maintained and be available for review. Supervised on-the-job training is acceptable until proficiency is demonstrated.

1.11 Inspection Methodology Accept and/or reject decisions **shall** be based on applicable documentation such as contract, drawings, specifications and referenced documents.

The inspector does not select the class for the assembly under inspection, see 1.2.

Automated inspection, e.g., automated optical inspection (AOI), automated x-ray inspection (AXI), is a viable support to visual inspection and complements automated test equipment. Many characteristics in this document can be inspected with an automated system.

1.11.1 Lighting Lighting **shall** be adequate for the feature being inspected. Illumination at the surface of workstations should be at least 1,000 lux [approximately 93 foot-candles]. Light sources should be selected to prevent shadows.

Note: In selecting a light source, the color temperature of the light is an important consideration. Color temperatures ranging from 3,000-5,000 K enables users to distinguish conditions and colors of various printed circuit assembly features and contaminates with increased clarity.

1.11.2 Magnification Aids For visual inspection, some individual specifications may call for magnification aids for examining printed board assemblies.

Magnification aids, if used for inspection, **shall** be appropriate with the item being inspected. The required magnification for the various tests is defined later in this document.

If the presence of a defect cannot be determined at the inspection power, the item is acceptable. The referee magnification power is intended for use only after a defect has been determined but is not completely identifiable at the inspection power.

2 APPLICABLE DOCUMENTS

The following documents of the issue currently in effect form a part of this document to the extent specified herein.

2.1 IPC

IPC-HDBK-9798 Handbook for Press-fit Standard for Automotive Requirements and other High-Reliability Applications

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

IPC-9191 General Guidelines for Implementation of Statistical Process Control (SPC)

IPC-2221 Generic Standard on Printed Board Design

IPC-2222 Sectional Design Standard for Rigid Organic Printed Boards

IPC-2226 Sectional Design Standard for High Density Interconnect (HDI) Printed Boards

IPC-6012 Qualification and Performance Specification for Rigid Printed Boards

IPC-6012XA Automotive Applications Addendum to IPC-6012X, Qualification and Performance Specification for Rigid Printed Boards

Note: Where X is the revision of the IPC document.

IPC-A-600 Acceptability of Printed Boards**IPC-TM-650** Test Methods Manual

2.6.27 Thermal Stress, Convection Reflow Assembly Simulation

2.2 JEDEC**JESD557** Statistical Process Control Systems**2.3 International Electrotechnical Commission Documents**

IEC 60512 Connectors for electronic equipment - Tests and measurements Test 2a: Contact resistance - Millivolt level method

IEC 60068-2-82 Environmental testing - Part 2-82: Tests - Test Xw1: Whisker test methods for components and parts used in electronic assemblies

IEC 60068-2-14 Environmental Testing - Part 2-14: Tests - Test N: Change Of Temperature

IEC 60068-2-30: Environmental Testing - Part 2-30: Test Db: Damp heat, cyclic

IEC 60068-2-38: Environmental Testing - Part 2-38: Test Z/AD: Composite temperature/humidity cyclic test

IEC 60068-2-60: Environmental Testing - Part 2-60: Test Ke: Flowing mixed gas corrosion test

IEC 60068-2-2: Environmental testing - Part 2-2: Tests - Test B: Dry heat

2.4 ASTM International

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

IEEE/ASTM SI 10 American National Standard for Metric Practice

2.5 International Organization for Standardization (ISO)

ISO 16750-3 Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 3: Mechanical loads

3 REQUIREMENTS**3.1 Compliant Press-Fit Pin Requirements**

3.1.1 Cleanliness Requirements This section refers to compliant press-fit pins in the as-received condition. All cleanliness requirements for incoming compliant press-fit pins **shall** be as agreed between manufacturer and supplier.

3.1.2 Design Requirements All pin types **shall** be designed and chosen so to meet the requirements of this specification. Examples of common press-fit applications are summarized in Table 3-1.

Table 3-1 Examples of Common Press-Fit Applications

Nominal Strip Thickness of Compliant Press-Fit Zone, mm [in]	Nominal PPTH Diameter (finished), mm [in]
0.4 [0.016]	0.6 [0.024]
0.6 [0.024]	1.0 [0.039]
0.8 [0.031]	1.5 [0.059]
1.2 [0.047]	2.0 [0.079]

Note: Guidance on pin base metal and metallurgical requirements including formability and weldability, electrical conductivity, yield strength, resistance to thermal stress relaxation and against vibration and surface condition (defects) as well as guidance on material selection are provided in IPC-HDBK-9798 5.1 Pin Base Metal and Metallurgical Requirements.

3.1.2.1 Design Requirements for Compliant Press-Fit Pins The detailed specification **shall** contain the following characteristics. Geometrical characteristics **shall** be specified with exact measuring positions, values and tolerances. These requirements are standard throughout the automotive electronics supply chain. Other industries may have different or only subsets of these requirements. In such cases, requirements **shall** be as agreed between manufacturer and supplier.

- a. Diagonal/Width of the cross-section of a compliant press-fit zone: The maximum linear extension of the compliant press-fit zone in a plane oriented perpendicularly to the axial direction.
- b. Insertion depth: Distance between a reference plane on the pin (oriented perpendicular to the axial direction) and the upper surface plane (plane from which the pins are inserted) or the lower surface plane of the printed board depending on the push-in process. As an example, the reference plane on the pin can be the plane of the upper side of the pin shoulder.
- c. Definition of base material alloy composition, ultimate tensile strength (in tension).
- d. Thickness of base material, tolerance of thickness, if used: process of thickness reduction in the area of the compliant press-fit zone, e.g., milling, embossing.
- e. Thickness of surface plating layers within a compliant press-fit zone.
- f. Surface finish alloy compositions and sequence of plating layers.
- g. Definition of the principle of the plating process/method, e.g., sequential or co-deposition.
- h. Definition of additional treatments which are necessary to obtain the desired property of the surface.
- i. Definition of method used for surface thickness measurement.
- j. A specification of a reference printed board including base material, surface finish and hole dimensions.
- k. The minimum and the maximum for the push-in force obtained on a reference printed board subjected to two times reflow per IPC-TM-650, Method 2.6.27.
- l. The minimum push-out force obtained on a reference printed board subjected to two times reflow per IPC-TM-650, Method 2.6.27.
- m. Spring force curve as obtained per test group TG-A4, see 4.2.4 Figure 4-2.

The following design features **shall** be considered:

- a. Compliant press-fit tip, pin transitional zone and pin shoulder can be customized but this customization **shall not** change the properties of the compliant press-fit zone.
- b. In order not to excessively deform the PPTH during the insertion process, all parts of the geometry, e.g., stamping edges, stamping corners or ridges, of the compliant press-fit zone, which come into contact with the PPTH during or after insertion, should be rounded and exhibit a smooth transition between compliant press-fit tip and compliant press-fit zone as well as between compliant press-fit zone and pin transitional zone. Any sharp edges or rough surfaces should be avoided.

3.1.3 Compliant Press-Fit Pin Contact Finish Requirements The layer thicknesses of the surface finish should be measured by using x-ray fluorescence spectroscopy.

Note 1: The entire compliant press-fit pin surface should be plated with a pore-free, continuous Ni barrier layer (typical thicknesses range between 1 to 3 µm [40 to 118 µin]). The presence of a Ni barrier layer serves the purpose of impeding interdiffusion between the base material, e.g., Cu alloy, and final finish, e.g., Sn.

Note 2: Guidance on materials and processes as well as whisker mitigation and functional impact of compliant press-fit pin surface finishes is provided in IPC-HDBK-9798 5.2 Surface Finish.

3.2 Requirements for Printed Boards for Press-Fit Technology

3.2.1 Printed Board Design and Specification Requirements The guidelines for printed board design in IPC-2221, IPC-2222 and IPC-2226 and specification requirements in IPC-6012 and IPC-6012 Automotive Addendum should be followed.