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AN-4167
Mounting Guideline for F1 / F2 Modules with Press-Fit Pins

Figure 1. F1 Module

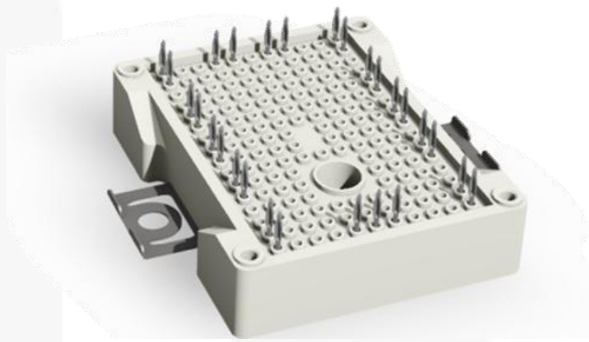


Figure 2. F2 Module

1. Introduction

Fairchild introduced the F1 and F2 High Power Module (HPM) family using the press-fit technology for the connection of a module to a Printed Circuit Board (PCB), as shown in Figure 1 and Figure 2.

The press-fit technology is known as a cold-welding connection between pins and plated through holes (PTH) of the PCB. It is not only an easy assembly method without extra heating and contamination but also provides good mechanical and electrical performance, press-fit technology has been adopted as a connection method for power semiconductor devices too.

The press-fit pin used in the F1/F2 modules is designed to provide a gas-tight metal to metal contact between the press-fit pin and the plated through hole (Figure 3).

Fairchild has performed mechanical and electrical application tests following the international standard IEC 60352-5 and verified F1 and F2 modules have maintained good performance and long-term reliability under various environmental influences.

The purpose of this application note is to provide recommendations for the PCB and to guide mounting / dismounting methods with proper tools to achieve adequate press-fit connections and reliability and performance.

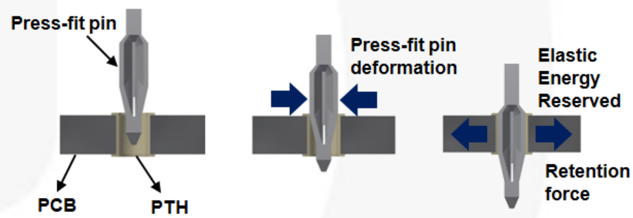


Figure 3. Press-in Process

2. PCB Requirements

2.1. Specification of PCB

An adequate design of the Plated through Holes (PTH) of a PCB is essential to obtain good quality of the press-fit connections. The schematic structure of a plated through hole is shown in Figure 4. If the final hole diameter of the PTH is too small, the press-in force into the plated through hole may become too high and mechanical damage on both press-fit pin and PTH can occur. On the contrary, if the final hole diameter is too large, it may not provide a reliable connection between plated through hole and press-fit pin.

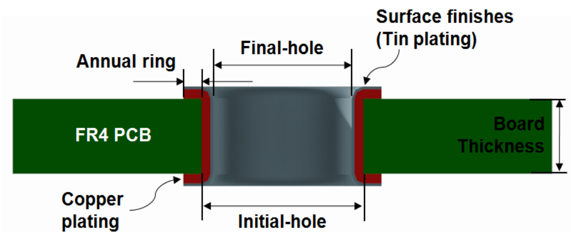


Figure 4. Structure of Plated Through Hole in PCB

Table 1 lists the recommended PCB specification based on the evaluation of the press-fit technology according to the IEC 60352-5 standard. Double layer and multi-layer FR4 PCBs according to IEC 60249 were evaluated. The initial hole diameter prior to plating is important in determining the reliability of press-fit connections.

IEC 60352-5 specifies that the initial hole diameter prior to plating should be 1.15 mm.

The thickness of the copper plating applied to the initial hole shall be minimum 25 µm to maximum 50 µm. Then, a surface finish of about 1 µm chemical tin is applied to the hole. Other tin finish technologies should be avoided before verification. HAL plating method is not recommended because of uneven plating on the hole. Consequently, the final hole diameter, after copper and tin plating, should neither be smaller than 0.98 mm nor bigger than 1.09 mm.

Table 1. Specification of PCB Requirements

	Min.	Typ.	Max.
Initial (Drill) Hole Ø [mm]	1.12	1.15	
Cu Thickness in the Hole [µm]	25		50
Sn Thickness [µm] (Chemical Tin)			15
Final Hole Ø [mm]	0.98		1.09
Annular Ring [µm]	200		
Thickness of Conductive Layer [µm]	35	70-105	400
Board Thickness [mm]	1.6		

2.2. Design Restriction within Mounting Area

PCB bending during press-in process can cause mechanical stress to other PCB components, such as capacitors and resistors. Experiments to verify a safe minimum distance between passive components and the plated through hole were conducted with FR4 PCB. Various sizes (0603, 0805, 1206, 1210, 1812, and 2220) of mechanically sensitive components were evaluated. Based on experimental results, the recommended minimum space between center of the plated through hole and the edge of the component is 4 mm, as shown in Figure 5**.**

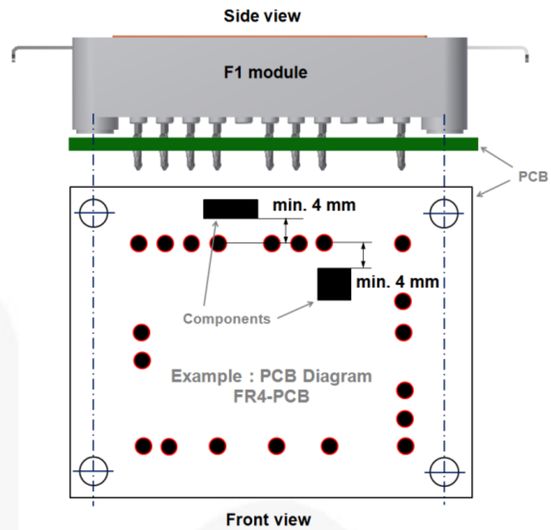


Figure 5. PCB Design Restriction: Distance from Center of PTH to Edge of Components

3. Module Mounting onto PCB

3.1. Press-in Process

The press-fit process is a cost-effective way to assemble power modules without introducing additional thermal load. The press-fit connection generates a good electrical, and also strong mechanical, connection between the module and the PCB. This section deals with the mounting process to achieve suitable press-fit connections of F1/F2 modules.

There are several types of presses available; from simple toggle presses to the automated pneumatic presses shown in Figure 6. If possible, monitor the press-in / press-out distance, speed, and force to achieve mechanical stability and high reliability of the press-fit connection. The travel distance during the press-in process should be controlled to ensure that the press-fit zone of the pins sits properly in the plated through hole. The speed also influences the quality of the press-fit connection; therefore, speed recommended by IEC standard should be applied.

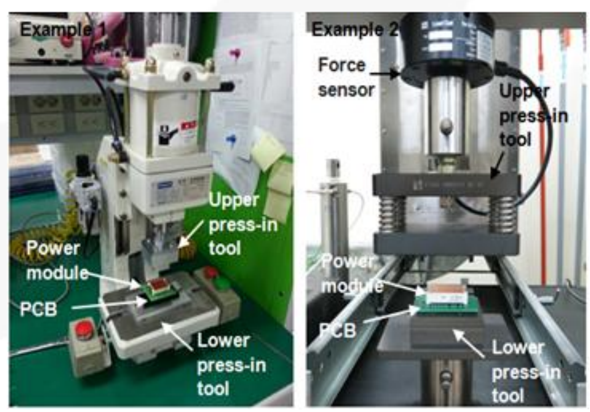


Figure 6. Types of Equipment for Press-In and Out

Generally, a module can be pressed in until the stand-offs on the four corners of the module touch the PCB, as described in 3.1.1. If, for example, more than one module is mounted on a PCB at short distances or assemblies are subjected to mechanical shocks in the application, the press-in method as described in 3.1.2 is recommended.

3.1.1. General Press-in Process

Figure 7 shows the general sequence of the press-in procedure. The press-in tool is comprised of two parts: the upper press-in tool is flat to contact with the module backside evenly and the lower press-in tool has engraved spaces to accommodate the press-fit pins.

The two parts of the tool need to be aligned to each other (a). In the first step of the assembly, the printed circuit board is placed on the alignment pins of the lower part of the press-in tool (b).

Then, the module is placed on top of the printed circuit board using the alignment pins. It is necessary to check if the module and the printed circuit board are in alignment (c). In the next step, the press-in force is applied via the upper part of the press-in tool to the backside of the module evenly. The module should be pressed-in with a speed of 25~50 mm/min until the stand-offs on the four corners of the module touch the surface of the printed circuit board while press-in distance and force are monitored at the same time (d).

It is required to adjust the traveling distance of the press to avoid damages to the module case due to pressure being applied. A simple manual press does not use a distance sensing system, so a distance keeper should be designed on the press-in tool to terminate press-in process appropriately. Section 3.1.2 describes the function of the distance keeper more in detail.

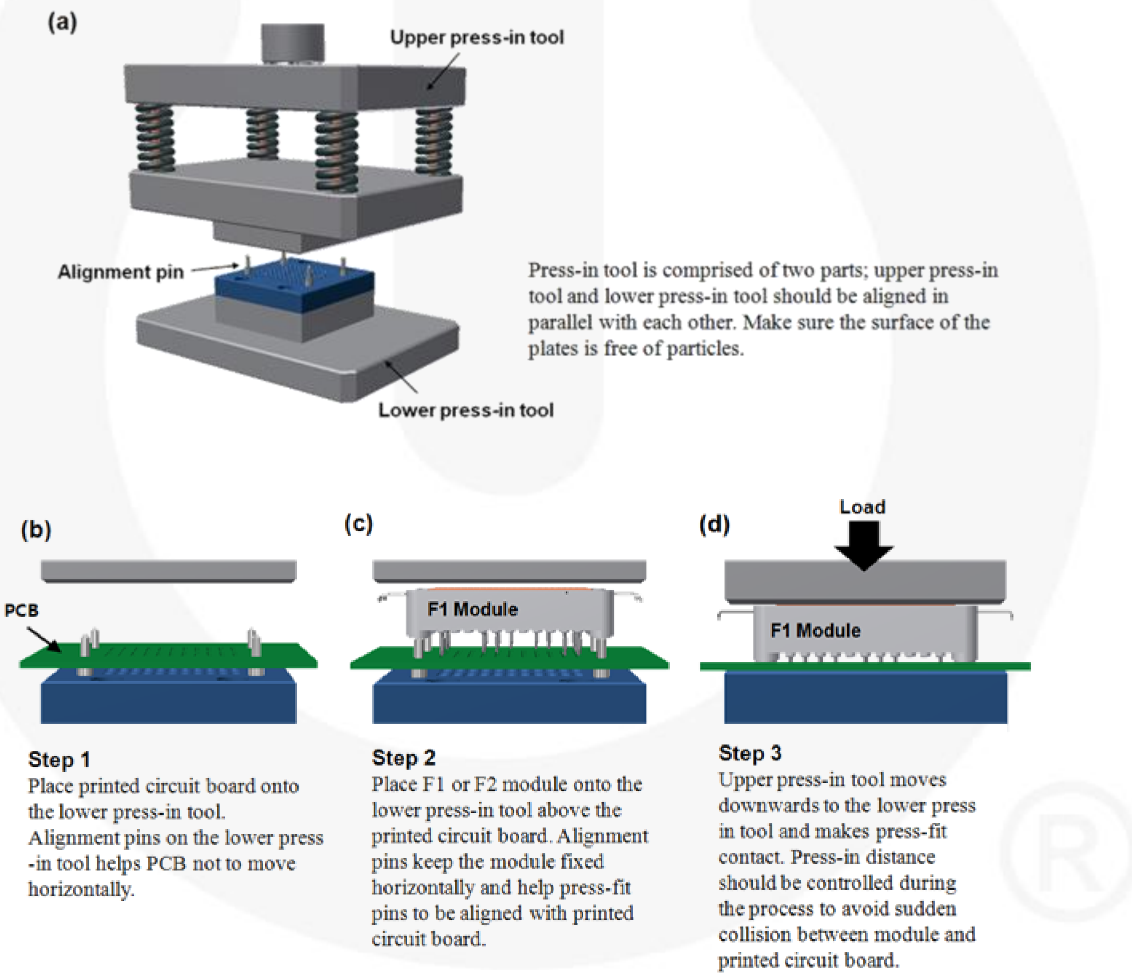


Figure 7. General Sequence of Press-in Process

3.1.2. Press-in Process for Multiple Modules

In case multiple modules are assembled to the same PCB and heat sink, height tolerances can result in unintended bending of the PCB or inappropriate heat sink contact.

Therefore, if more than one module is mounted on the same PCB, it is required to minimize the height tolerances between those modules. This section presents a modified press-in process related to that.

Figure 8 shows a press-in tool including distance keepers. The distance keeper terminates the press-in process and limits the press-in depth.

By contacting the printed circuit board ahead of the module case, it prevents direct contact between the case and the PCB. If the distance keeper contacts the surface, press-in force rises sharply and the press-in process can be terminated by reaching the limit of the press-in force. The distance keeper should be designed to avoid the collision with other PCB components.

The press-in process using the distance keeper is described in Figure 9. First, the PCB should be placed on the lower press-in tool (a). Then, a module is placed on the lower press-in tool and aligned with the PCB (b). The press-in stroke is applied to the backside of the module until the distance keeper touches the surface of the PCB (c).

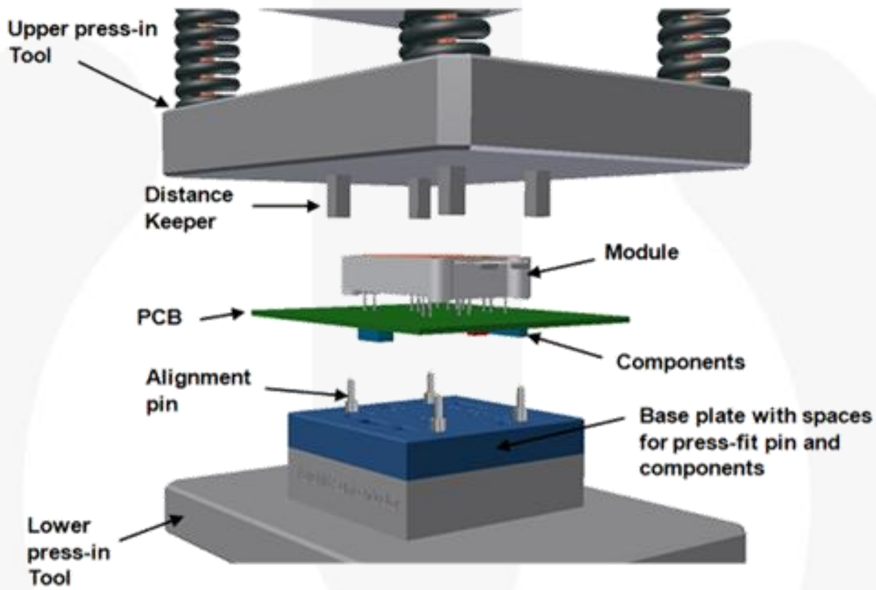


Figure 8. Press-in Process with Distance Keepers

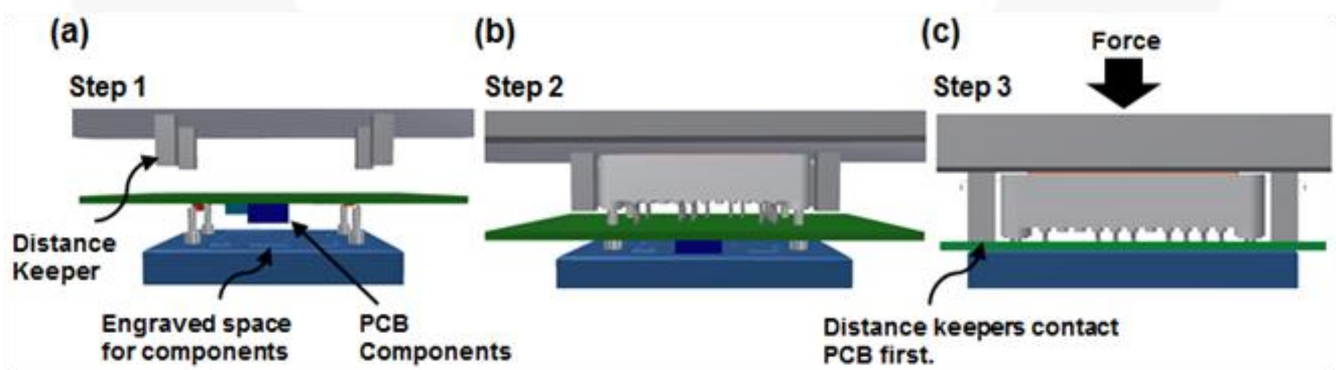


Figure 9. Schematic Description of the Press-in Process using Distance Keeper

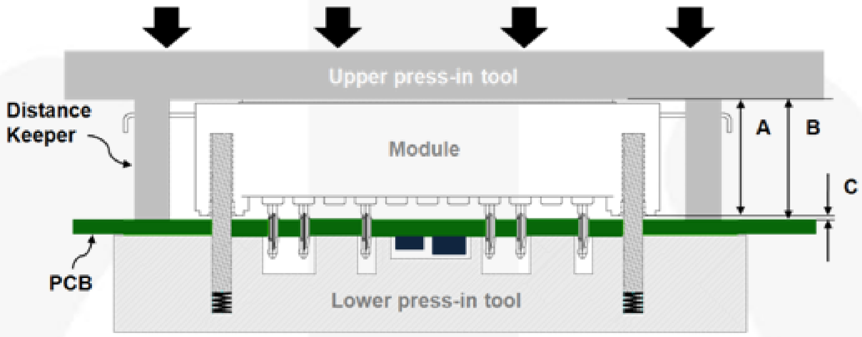
As illustrated in Figure 10, depending on the length of the distance keeper, the contact length between press-fit pins and the plated through hole is determined. The total height of the module is 12.00 ±0.30 mm for both F1 and F2 modules. It is recommended that the length of the distance keeper should be 12.40 (+0.05/-0) mm to achieve a stable contact length.

Consequently, an air gap between the top of the case and the surface of the PCB remains. Screwing the PCB down to the stand-offs of the module case, as shown in Section 5, is not allowable. Instead, the assembly should use space posts to support the PCB. Mounting to the heat sink is described in Sections 6 and 7.

3.2. Press-in Force

The diameter of the plated through hole is smaller than the width of the press-fit zone of the pin. The press-fit pin is designed to compress during the insertion process; plastic-elastic deformation takes place at the interface zone. The forces remaining at the interface maintain a tight metal-to-metal contact between the pin and the plated through hole during the expected life time of the module, considering the stress relaxation of the contact partners.

The press-in force depends on the contact area between press-fit pin and plated through hole, shown in Table 2.



A: Package height (DBC bottom to case top) is 12.00 +0.30/-0.30 (mm)
B: Distance keeper height is 12.40+0.05/-0 (mm)
C: Air gap between case top and surface of the PCB

Figure 10. Press-in Depth in Accordance with Length of Distance Keeper

3.3. Press-in Tool Design

Some design options should be considered to avoid press-in failure. First, the contact plate of the upper press-in tool must be larger than the module DBC substrate size. If the contact area of the upper press-in tool is smaller than the module substrate and pressure is applied to the center area of the module only, the module can be mechanically damaged during the press-in process. The press-in tool design should consider the size of the module.

If other components (capacitors, resistors) are assembled on the PCB next to the module mounting area, the press-in tool design should avoid collision during the press-in process. As shown in Figure 8, the lower press-in tool is designed with engraved spaces for the press-fit pin and other PCB components. It is also important to keep a certain area to provide support for the PCB.

As mentioned in Section 2.2, based on experimental results, components did not exhibit mechanical or electrical damages due to board bending during the press-in process when the distance between the center of the plated through hole and the edge of the component is 4 mm or more.

The press-in force should be in the range of 60 N – 150 N per single pin, depending on the PTH diameter.

Table 2. Specification of the Press-in Force

	Min.	Max.
Press-in Force (per Single Pin)	60 N	150 N
Press-in Speed	25 mm/min ~ 50 mm/min	
PTH Hole Diameter	Upper Limit of PTH Hole Diameter (1.09 mm)	Lower Limit of PTH Hole Diameter (0.98 mm)

The total press-in force is the result of the number of pins in a module, multiplied with the force required for a single pin. Press-in forces lower than 60 N/pin mean that press-fit pin may have a less secure connection in the plated through hole. The primary reason for the low press-fit force is that the diameter of plated through hole is too large for the press-fit pins. Press-in forces higher than 150 N/pin can cause mechanical damage to the press-fit terminal, the PTH, or to the tracks on the PCB. The recommended press-in speed ranges from 25 mm/min to 50 mm/min in accordance with the recommendations in IEC 60352-5.

4. Module Dismounting from PCB

4.1. Press-out Process

In some situations, it is necessary to remove power modules from the PCB. It is possible to disconnect the contact between module pins and PTH. The press-out process can be performed with the same equipment used in the press-in process.

Careful handling in the press-out process is essential to avoid mechanical damage to both the module and the PCB. PCB can be re-used once with a new module. Experiments regarding PCB repair cycle according to IEC 60352-5 did not show a degradation of the performance with the recycled PCB. For modules previously removed from PCB, the pins can be soldered to PCB.

The press-out tool consists of an upper and a lower press-out tool, as shown in Figure 11. The upper press-out tool should be parallel and aligned to the lower press-out tool (a). The assembled board should be placed on the lower press-in tool (b). The upper press-out tool moves down and contacts the projecting part of the pins. Press-out force should be applied to all pins evenly within 3-12 mm/min of press-out speed according to IEC 60352-5 (c). The module falls down to the lower tool as it is disassembled from the PCB. The press-out distance should be monitored to ensure the upper press-out tool does not apply unnecessary pressure on the PCB after the module is fully pressed-out (d).

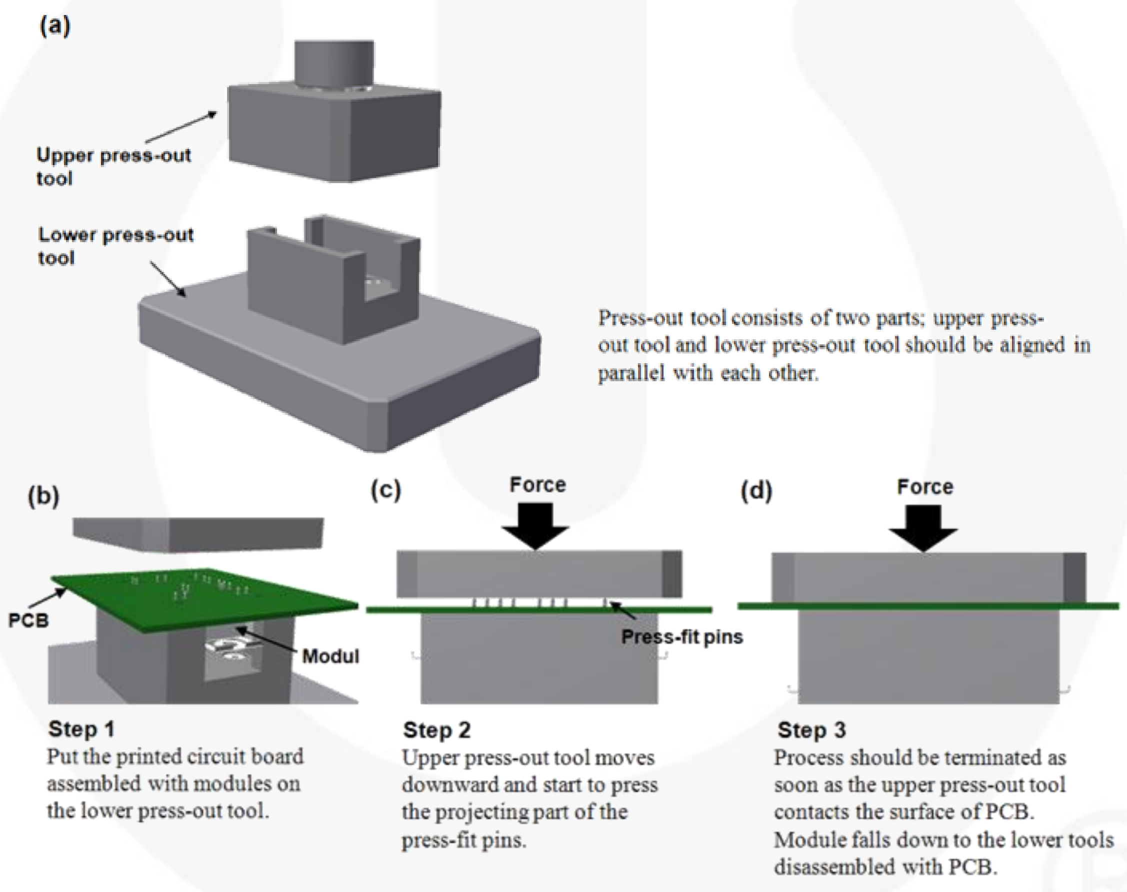


Figure 11. Press-out Process

4.2. Press-out Tool Design

The upper and lower press-out tools should be parallel to each other to prevent stress on the module during press-out process, as shown in Figure 12. Some pins may have contact with the upper press-out tool while other pins have no contact with tool. Pulling force can be exerted on the press-fit pins where upper the press-out tool does not contact.

The press-out tool design should consider other components assembled on the PCB next to the module mounting area to avoid collision during the press-out process.

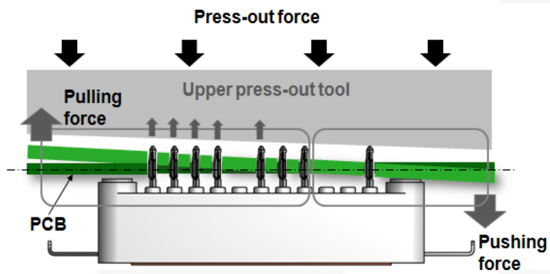


Figure 12. Press-out Failure Mode: Upper and Lower Press-out Tools Not Parallel

4.3. Press-out Force

Due to the stress relaxation between contact partners, the initial contact force tends to reduce over time. In addition, the press-out force varies in relation to the contact ratio between press-fit pin and plated through hole. As shown in Table 3, the press-out force should be higher than 40 N per pin.

Table 3. Press-out Force and Speed Specification

	Min.	Typ.	Max.
Press-Out Force (per Pin)	40 N		
Press-Out Speed	3 mm/min – 12 mm/min		

5. PCB to Module Mounting

Screwing the PCB to the stand-offs on the module is one of the assembly methods if the general press-in process is used as introduced in Section 3.1.1. By adding this screw connection to the stand-offs, securing the assembly of module and PCB can be expected. Figure 13 shows the key dimensions of the stand-off. Self-tapping screws are recommended so that the screws form the thread in the hole.

Metric screws, self-tapping, with dimensions of 2.5xL or 2.6xL have been verified on F1 and F2 modules. The length of the screws (L) may differ depending on the thickness of the PCB. Typically, an 8 mm long screw (M2.5X8) can be used with 1.6 mm-thick PCB. Recommended mounting torque is 0.4~0.5 Nm for each screws.

Figure 14 shows the recommended sequence for mounting the PCB to the module. Straight inserting avoids mechanical damage to the module case. An electric screwdriver helps achieve uniform force and speed for inserting the screws.

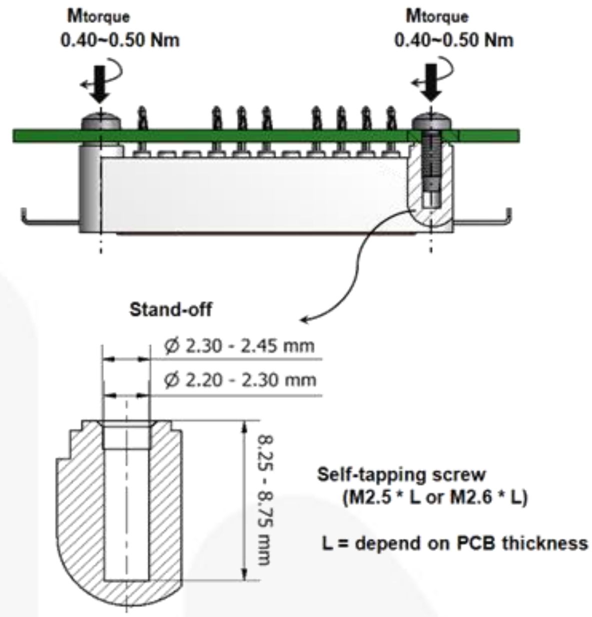


Figure 13. Screw Clamping on Stand-offs and Key Dimensions of Screw Hole

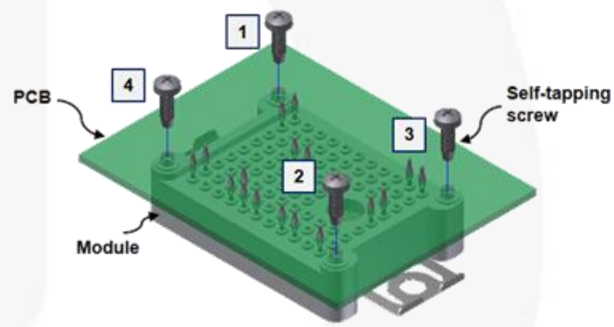


Figure 14. Recommended Sequence for Attaching PCB to Module

Note: Do not screw the PCB down to the stand-offs of the module if an air gap remains between case top and PCB after press-in! This can lead to deformation of the PCB or other mechanical damages.

6. Module to Heat Sink Mounting

Power semiconductor modules generate heat that needs to be dissipated to protect against overheating. In general, module operation temperature should not exceed the maximum allowable junction temperature (T_{Jmax}) specified in the datasheet. Thermally conductive metal heat sinks that absorb and disperse heat are commonly used for cooling high-power electronics. The thermal performance of a module, in combination with a heat sink, can be characterized by the thermal resistance $R_{\theta ja}$, which is the sum of all thermal resistances in the thermal path: junction-to-case ($R_{\theta jc}$), case-to-heat sink ($R_{\theta cs}$), heat sink ($R_{\theta sink}$), and heat sink-to-ambient ($R_{\theta sa}$), as shown in Figure 15.

Generally, air convection is the dominant heat transfer mechanism in electronics. The heat transfer by air convection strongly depends on the air velocity and the area of the heat-transferring surface. Proper contact between module substrate and the surface of the heat sink is crucial for managing the overall thermal efficiency of the system. Thermal Interface Materials (TIMs) are thermally conductive materials used to achieve good mating of the two surfaces and improve heat transfer.

This section presents the application of thermal interface material and heat sink mounting for F1 and F2 modules.

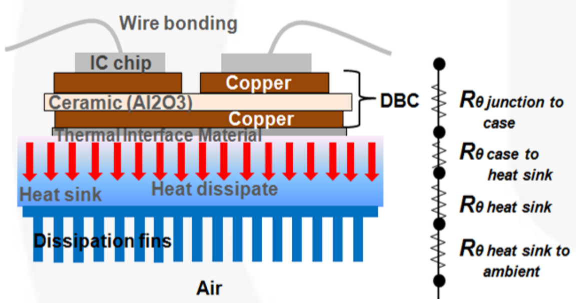


Figure 15. Thermal Model of Power Module & Heat Sink

6.1. Heat Sink Specification

The contact surface of a heat sink must be flat and clean to maximize heat transfer. Rough surfaces result in large voids between the substrate of the module and the surface of the heat sink. The following surface qualities are required for the heat sink to achieve a good thermal conductivity, according to DIN 4768-1. Roughness (Rz) should be 10 µm or less and flatness, based on a length of 100 mm, should be 50 µm or less.

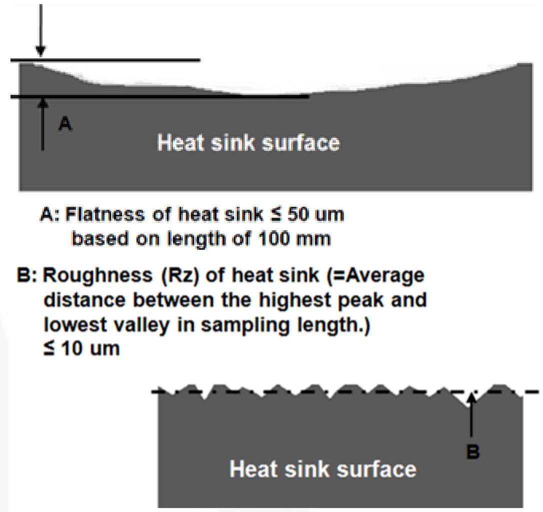
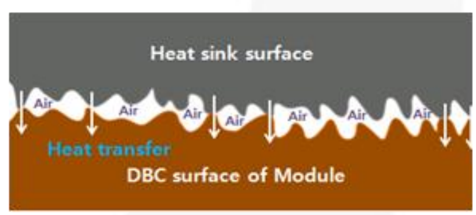


Figure 16. Microscopic view of Surfaces. A is Flatness and B is Roughness (Rz)

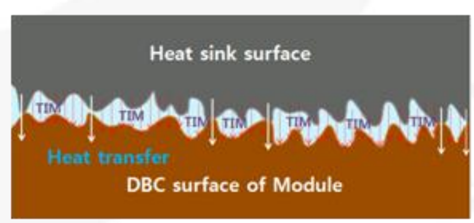
The interface surface of the heat sink must be free of particles and contamination. Avoid handling the heat sink surface with bare hands or contacting any foreign materials. If it is necessary to remove contaminations from heat sink, cleaning can be accomplished using dry cloth soaked with solvent, such as isopropyl or ethylene alcohol.

6.2. Applying Thermal Interface Material

The surfaces of the heat sink and the substrate of the module are not perfectly flat. After the module is mounted to a heat sink, air gaps can form between these two surfaces and the effective contact is limited to the area shown in Figure 17. Air is a poor heat conductor with 0.03 W/m·K thermal conductivity. It acts as a thermal barrier that limits the efficiency of heat transfer from the device.



(a)



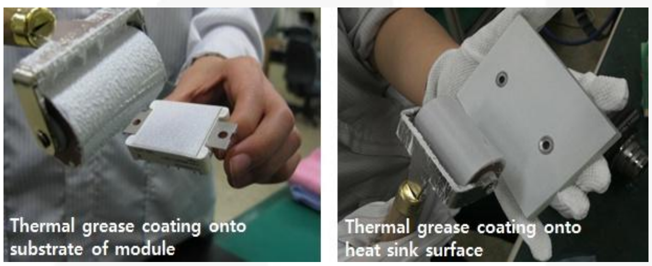
(b)

Figure 17. (a) Heat Transfer, Module to Heat Sink, (b) Heat Transfer with Thermal Interface Material

Thermal interface materials are widely used in the industry to fill air gaps between contact surfaces. Thermal interface material provides better thermal performance than air and compensates for imperfect mating surfaces, such as roughness and flatness shown in Figure 17. There are various thermal interface materials available in the market. The right choice of material is an essential factor for the application. It should be selected considering the following features:

- High Thermal Conductivity
- Ease of Distribution with Low Contact Pressure
- Minimal Thickness
- Degradation of Characteristics Over Time
- Stability of Characteristics Over Time
- Toxicity (Non-Toxic Optimal)
- Ease in Handling during Application or Removal

The most common thermal interface materials are thermal greases. Thermal grease can be applied to the heat sink or the module substrate using a rubber roller or spatula or by screen printing. A rubber roller, as shown in Figure 18**,** is an easy and fast method for applying thermal grease.



a. Choose one side of the surface, module substrate, or heat sink to apply thermal grease.

b. Coat a rubber roller with thermal grease.

c. Paint the surface repeatedly using the rubber roller to create a uniform layer of thermal grease around 80 µm – 100 µm thick.

Figure 18. Example of the Thermal Grease Application

Since the thermal grease has the lowest thermal conductivity in the thermal path, a layer as thin as possible is necessary to keep the overall thermal resistance low. Recommended thickness of printing layer is 60 µm – 100 µm to fill the gap between two contact surfaces completely. Check the thermal grease thickness with thickness gauges, such as wet film combs or wet film wheels. Because manual controlling of the printing pressure and speed can be learned by experience, training is needed to achieve a technique for good quality printing layer in real application.

As an alternative option Fairchild can provide Phase Change Material (PCM) pre-applied modules on customer request. Refer to the Application Note for PCM pre-applied modules for further information.

6.3. Module Mounting to the Heat Sink

The module should be placed on the heat sink with two thread holes aligned to the screw clamp holes of the module. The location of the thread holes is illustrated in Figure 19.

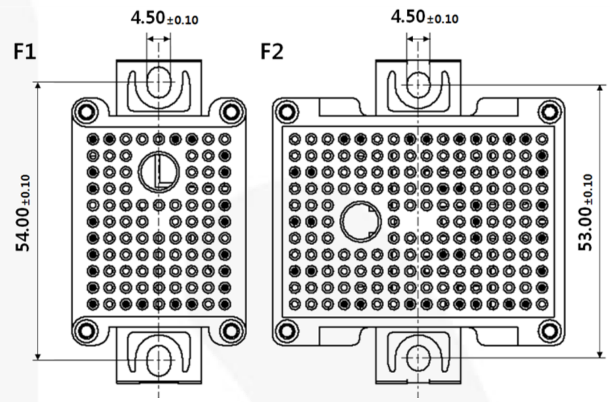


Figure 19. Dimension of Screw Clamping Zone (mm)

Screw clamping can be done in various ways. The F1 and F2 packages are mounted to heat sink using M4 screws. Figure 20 describes one method for fastening the clamps to the heat sink. Fasten two screws simultaneously, as shown in Figure 20, to prevent tilting or rising of one side of module during fastening. The recommended final mounting torque (M_{torque}) is in the range of 2.0-2.4 Nm. Electric screwdrivers can tighten the screws with the specified torque. Additional flat or spring washers are permissible, considering clearance and creepage distances specified in Section 8.

If method 1 cannot be applied, the method as described in Figure 21 is also acceptable. Fasten the first screw loosely to prevent tilting or rising of the module (step 1). Then insert the second screw with final torque so as to be fully tightened with the heat sink (step 2). Finally, apply full torque to the first screw for solid tightening with the heat sink.

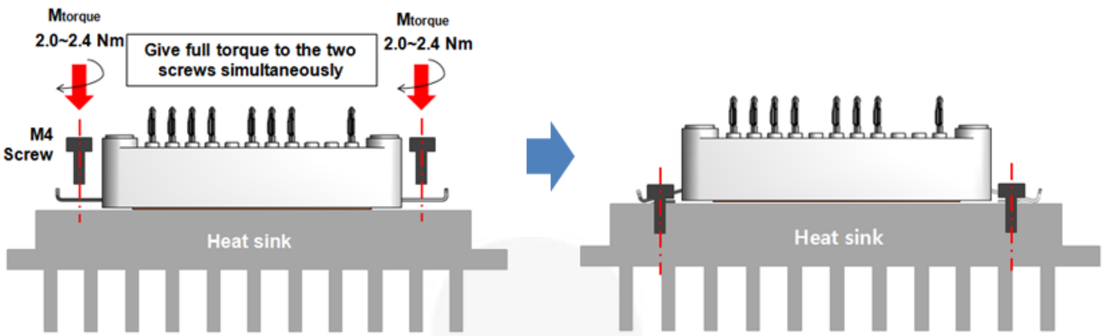


Figure 20. Illustration of Screw Clamping with Heat Sink (Method 1)

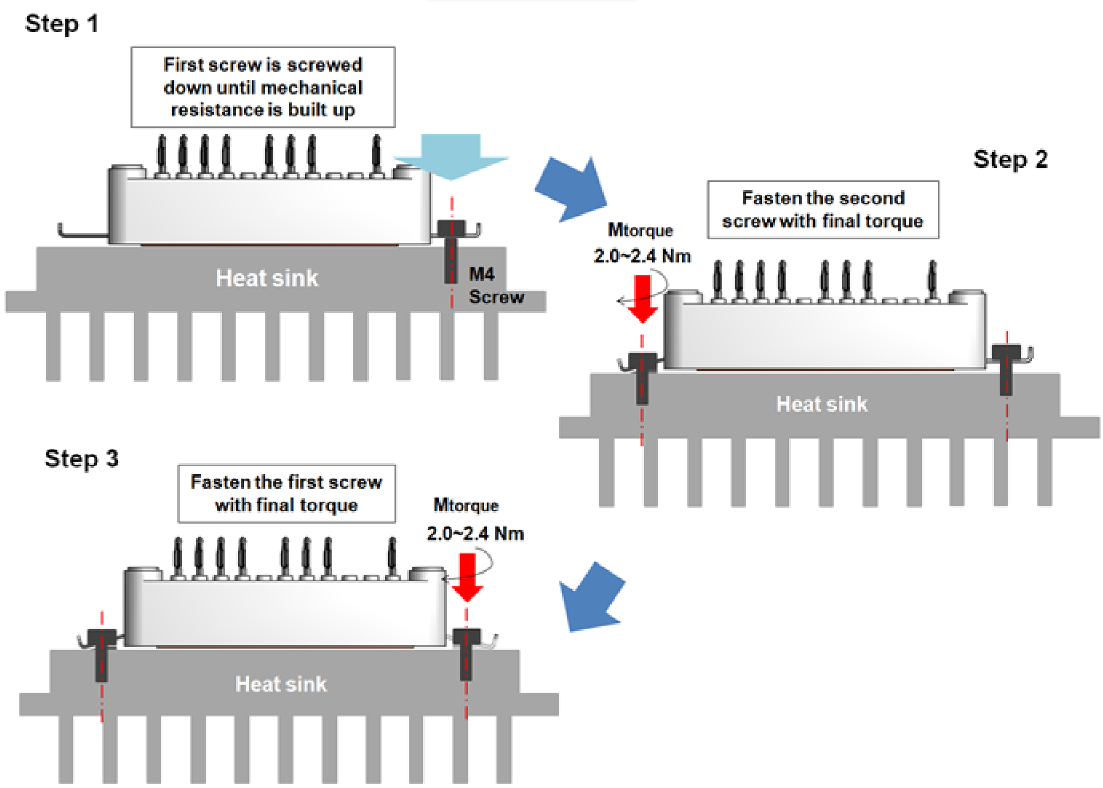


Figure 21. Illustration of Screw Clamping with Heat Sink (Method 2)

7. Assembly of the PCB and Heat Sink

After modules are assembled to the PCB and the heat sink as described above, the overall structural integrity needs to be considered to avoid mechanical stress to any of the system components.

If the PCB is large and heavy with other components assembled to it, there is some risk the PCB can bend, creating mechanical stress to the module and the PCB. When multiple modules are applied to the same PCB, height tolerance between modules can result in the mechanical stresses on the board and modules. To reduce stress, space posts should be added on the heat sink, as illustrated in Figure 22**,** to prevent movement of the PCB.

The recommended height of the space posts is 12.4 (+0/-0.1) mm. The effective distance between center of stand-off and the space post (= X) is 50 mm minimum. If distance keepers are used during the press-in process, as described in Section 3.1.2, resulting in tighter height tolerances; distances between the stand-off of the case and the space post (= X) smaller than 50 mm can be used.

Figure 23 shows the assembly procedure when space posts are used and the overall assembly structure:

Modules are first pressed into the PCB following the recommendations introduced in Section 3.1 before heat sink mounting. Maintaining tight height tolerances between module and PCB is important. Next, the thermal interface material is applied, as shown in Section 6.2. Then the modules and the PCB are placed on the heat sink (a).

Then the module is mounted onto the heat sink via the modules screw clamp. Refer to Section 6.3 for instructions of screw clamping (b). Finally, the PCB needs to be fixed on the space posts, as described in (c).

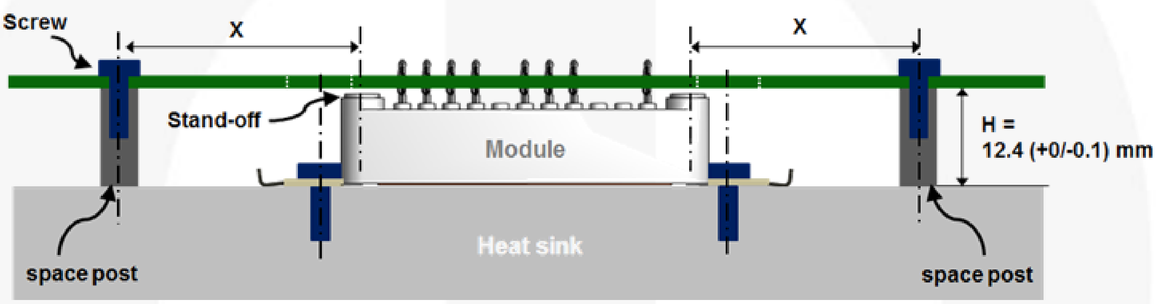


Figure 22. Space Posts for Assembly of PCB to Heat Sink

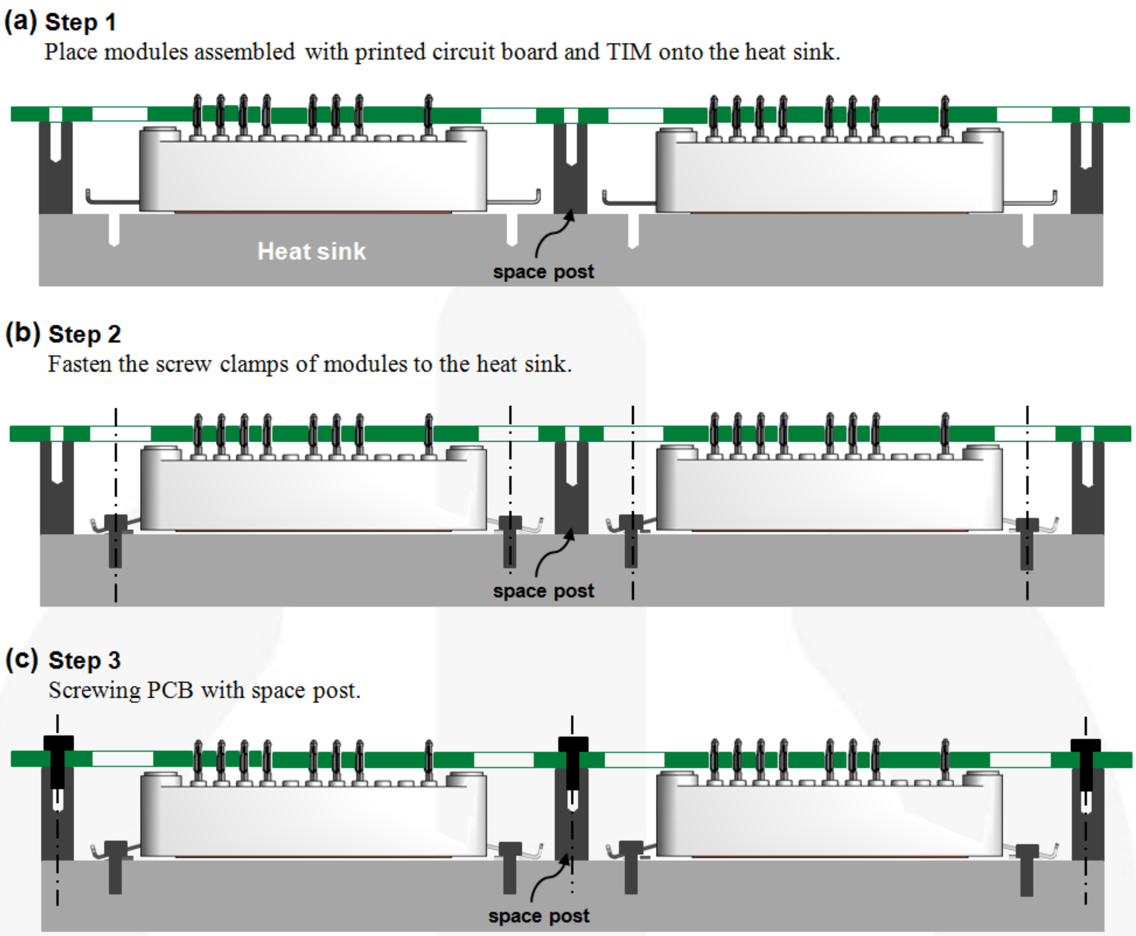


Figure 23. Example of Whole Assembly Process for PCB and Heat Sink with Space Posts

8. Creepage and Clearance

The spacing of the assembly between the module and PCB must meet the clearance and creepage distance required by the relevant standards. After F1 or F2 modules are mounted to the PCB and heat sink, the minimum clearance is the distance between the screw head and the bottom surface of the PCB. The size (height) of the screw head and potential use of an additional washer, as well as the air gap between PCB and top side of the module, influence the creepage distance between the screw and the PCB and the module pins. F1 and F2 modules are mounted on the heat sink using M4 hexagon socket head screws, according to ISO 4762. Additional washers, according to ISO 7089, can be used. A distance of 6.8 mm between the screw and the PCB, as shown in Figure 24, can be maintained.

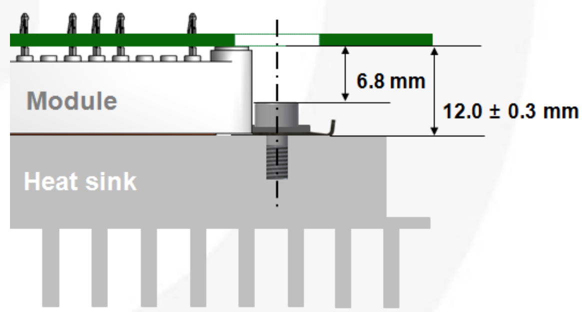


Figure 24. Distance between PCB and Screw

Appendix Ⅰ

Press-fit Pin Qualification Test (Acc. to IEC 60352-5)

In general, a consistent integrity between press-fit pin and PCB is a critical factor for achieving a reliable application performance during the expected module life time. The quality of the press-fit pin connection used in F1 and F2 modules was evaluated under various environmental influences in compliance with the IEC 60352-5 standard. All tests were passed without noticeable degradation and demonstrated good life time performance and reliability. This appendix section outlines the press-fit pin evaluation results.

Qualification according to IEC 60352-5 consists of 4 groups; test group A for visual examination, test group B for press in and out force measurements, test group C for electrical performance tests and test group D for application tests. Specifications of Press-fit pin and PCB used in those tests are described in Table 4. Investigations were executed on FR4 PCB with chemical tin as PCB finish.

Additionally, tests for the re-use of PCBs were also carried out to investigate if there is any degradation on the press-fit connection. An allowable number of PCB repair cycle is offered based on this result.

Table 4. Specification Summary of Press-Fit Pin and PCB.

Components	Specifications
Press-Fit Pin	Press-fit Zone Width: 1.20 ± 0.03 mm Material: CuSn Plating: 1 - 2 um Ni + 0.5 - 2 um Sn
Printed Circuit Board	Material: FR4 Tin thickness: 1 - 15 um Cu conductor layers: multi, double PTH: Ø 0.98 - 1.09 mm

Cross-section analysis to assure the gas tight integrity between Press-fit pin and PTH was carried out with minimum range of PTH diameters in accordance with IEC 61188-5-1. As seen in the Figure 25, substantial integrity was achieved in both transversal and longitudinal directions without crack or damage. PTH deformation is also within the design requirements and conformance with standard as described in Table 5. Additionally, once re-used PTH also show comparable quality to a new PTH.

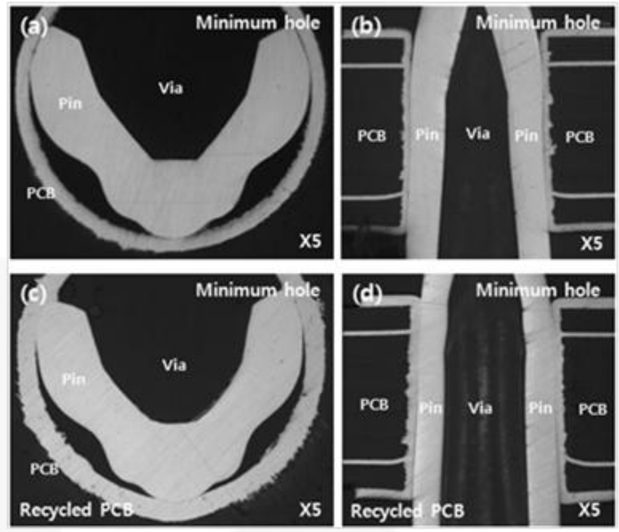


Figure 25. Micro-sectioning images of press-fit connection. (a) Transverse sectioning image, (b) Longitudinal sectioning image, (c) Transverse image of Recycled PCB, and (d) Longitudinal image of recycled PCB

Insertion and retention force is one of the key factors to determine the function of integrity. Measurement was performed with min. and max. PTH diameter of samples as specified in Table 1. Press-in and out force analyses were performed in test group B. Table 5 shows that both press in and out forces comply with the specified requirements. In addition, retention force showed no degradation for the once re-used PTH.

Table 5. Mechanical test & Optical analysis (Test group A and B)

Test Phase	Requirements	Results
Press-in Force (per single pin)	< 150 N	Passed
PCB Recycled 1x (with new pin) Press-out force	> 40 N	Passed
Transverse Sectioning (Including results of PCB Recycled 1x with new pin)	1) No Cracks, 2) Max. Deformation in the hole < 70 um, 3) Min. Remaining Plating Thick. > 8 um	Passed
Longitudinal Sectioning (Including results of PCB Recycled 1x with new pin)	1) No Cracks, 2) Max.Conductor Deformation < 50 um	Passed

Maintaining the contact resistance during the expected module life time is also a critical factor of the application. Contact resistance analysis was carried out in test group C and D. As shown in Table 6, Group C is a sequential test involving thermal shock, climatic sequence, dry heat and flowing mixed gas corrosion test. The contact resistance between Press-fit pin and PTH has to be compared before and after sequential test and should not exceed 0.5 mΩ according to IEC 60352-5. Re-used PCBs have been included in the test. As shown in Table 6, all samples (over 1000 contacts) passed all test phases without abnormality.

Table 6. Electrical Test (Test Group C)

Test **Phase**	Test **Specifications**	**Results**
Rapid Change of Temperature	-40°C to +125°C; Exposure Time = 30 min, 10 cycles	Passed
Climatic Sequence (IEC 60068-2-61)	Dry Heat;+120°C, 16h→1 cycle 1 cycle damp heat; (55°C, 85~93%, 12h →1 cycle cold; -40°C, 2h → 5 cycles of damp heat; +120°C, 16h	Passed
Dry Heat	+125°C, Test Duration = 1000 h	Passed
Flowing Mixed Gas Corrosion Test (IEC 60512-11-7, Method 4)	SO2: 0.2 ppm H2S:0.01 ppm NO2:0.2 ppm Cl2: 0.01 ppm, Duration of Exposure = 10 Days	Passed

Contact resistance analysis was also performed in application test of group D. Test group D consists of a sequence of vibration test, thermal shock and dry heat test. A change of contact resistance before and after test should not exceed 0.5 mΩ. Visual examination was performed with samples after test. As shown in the Table 7, the contact resistance change observed over all test phases didnr test. A the limit.

Table 8 shows further evaluation results conducted on press-fit pin.

Table 7. Application Test (Test Group D)

Test Phase	**Test Specifications**	**Results**
Vibration	5g, 10-500 Hz; Displacement = 0.35 mm, 6h/x,y,z	Passed
Rapid Change of Temperature	-40°C to +125°C; Duration of Exposure = 30 min, 10 cycles	Passed
Dry Heat	+125°C, Test Duration = 1000 h	Passed
Transverse Sectioning	1) No Cracks, 2) Max. Deformation in the Hole < 70 um 3) Min. Remaining Plating thick. > 8 um	Passed
Longitudinal Sectioning	1) No Cracks, 2) Max. Conductor Deformation < 50 um	Passed

Table 8. Further Application Test (IEC 60749 and 60068)

Test **Phase**	Test **Specifications**	**Results**
Salt Atmosphere Test	4 Cycles in salt atmosphere: 2h period in salt atmosphere (15-35°C;5% NaCl); storage 20h (38°C -42°C'93% RH); after 4 cycles 3 days drying (21℃-25°C; 45% - 55% RH);	ΔContact Resistance < 0.5 mΩ
Hydrogen Sulphide Test	50 ppm H2S; 40°C; 93% RH;17 Days	ΔContact Resistance < 0.5 mΩ
TST	-40°C to +125°C;Duration of Exposure = 30 min, 300 cycles	ΔContact Resistance < 0.5 mΩ

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