AN 2009-09

Assembly Instruction for SmartPIM1 and SmartPACK1 modules

Industrial Power

Never stop thinking

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1 General Information

Whenever new IGBT module generations are developed, simplified handling and assembly is one focus of development.
This is based on the fact that today's inverter designs require components which are easier, faster to assemble and on top of all safer to contact and to mount.
PressFIT technology can be considered as the most attractive way of connecting the control- and load terminals of IGBT modules with the printed circuit board. This technology fulfils the requirements of more reliabilty and meets the trend towards increased temperatures, is RoHS conform, and leads to a highly simplified handling.
In the automotive segment this connection technology has been applied successfully for several years under more severe conditions and at medium currents. In telecommunication area, such connections have been used since the beginning of the 80th for signal transmission. Following from that, this technology has been thoroughly tried and tested and is particularly suitable for the use in IGBT modules, where both, the requirements on load and signal connections have to be fulfilled and combined with each other.

The electrical and thermal contacts with the circuit board are implemented by means of cold welding. The contacts can be used in standard FR4 printed circuit boards with the tolerances typical of manufacturers.
In this assembly technology the module can be mounted on either side of the circuit board.

The combination of press fitting and mounting to the heatsink is one further logical step for simplification of the process.
This means, during SmartPIM1- and SmartPACK1 assembly, a gas-tight connection to the PCB is realised.
At the same time, the IGBT module is fixed onto the heatsink. By tightening only one screw, the entire mounting process can be completed within a few seconds.

Figure 1 SmartPIM1 self-acting assembly

The PressFIT contacts in SmartPIM and SmartPACK have an area approximately 1.7 mm long that adapts itself to the hole in the printed circuit board during the press-in process. Permanent deformation takes place as a result. This deformation is intended for tolerance accommodation and it provides the basis for the cold welding.

The forces resulting during the press-fitting process ensure that the welded materials on the PCB and pin show a continuously consistent – and unlike other contact technologies – very small electrical contact resistance (approximately 0.05 mΩ).

Due to the flexible Pin grid, with 145 possible Pin positions, different and even customer-specific configurations can be integrated with an easy PCB layout. Standard configurations like PIM (Rectifier, Brake and Six PACK) and PACK (Six PACK) in 600V and 1200V were in focus and have been integrated. Those are available with the newest Chip technologies and allow an optimized power density.

The well-known Al_2O_3 ceramic ensures the high isolation capability. Together with the Duplex frame concept the ceramic offers an optimized thermal contact to the heatsink. A thermal sensor (NTC) is integrated to check the module temperature.

2 Requirements for Printed Circuit Boards

The PressFIT technology used in the Easy modules has been inspected and qualified by Infineon AG for standard FR4 printed circuit boards with tin (chemically) (IEC 60352-5 + IEC60747-15). If other surface finishing technologies are to be used in the production of printed circuit boards, they will have to be tested, inspected, and qualified.

Demand on the PCB material
Double-sided printed circuit board according to IEC 60249-2-4 or IEC 60249-2-5.
Multilayer printed circuit board according to IEC 60249-2-11 or IEC 60249-2-12.

	min.	**typ.**	**max.**
Hole diameter	1.12 mm	1.15 mm	
Copper thickness in hole	> 25 µm		< 50 µm
Metallization in hole			< 15 µm
End hole diameter	0.94 mm		1.09 mm
Copper thickness of conductors	35 µm	70 µm 105 µm	400 µm
Metallization of circuit board	Tin (chemically)		
Metallization of pin	Tin (galvanic)		

Table 1 Demand on a printed circuit board

In order to ensure that the PressFIT contact sits securely in the printed circuit board, the specification of the hole given in Table 1 must be adhered to.

If the specification of PressFIT holes is limited to just the finished dimension (i.e. the metalized hole), different drill sizes might be used depending on the printed circuit board manufacturer and his production philosophy, and also different metallization thicknesses might be provided. As a consequence, different results would be observed, which for quality reasons have to be rejected.

We recommend to drill the hole in the printed circuit board during manufacture by a drill size of 1.15 mm. It should not be milled. Experience has shown that a final hole diameter of between 1.12 mm and 1.15 mm is obtained, considering the runout tolerances of the spindles after drilling due to the shrinking of the FR4 material.

With a copper thickness of 25 µm to 50 µm in the hole and a tin layer of about 1 µm for tin applied chemically, an end hole diameter is obtained as the test dimension. Due to the thinner tin layer thickness compared to, for example, HAL printed circuit boards, this diameter is always higher than the value of 1 mm stated in the standard (IEC 60352-5). The final hole diameter, under consideration of the drilling diameter, copper thickness and tin layer, is typically between 1.02 mm and 1.09 mm.

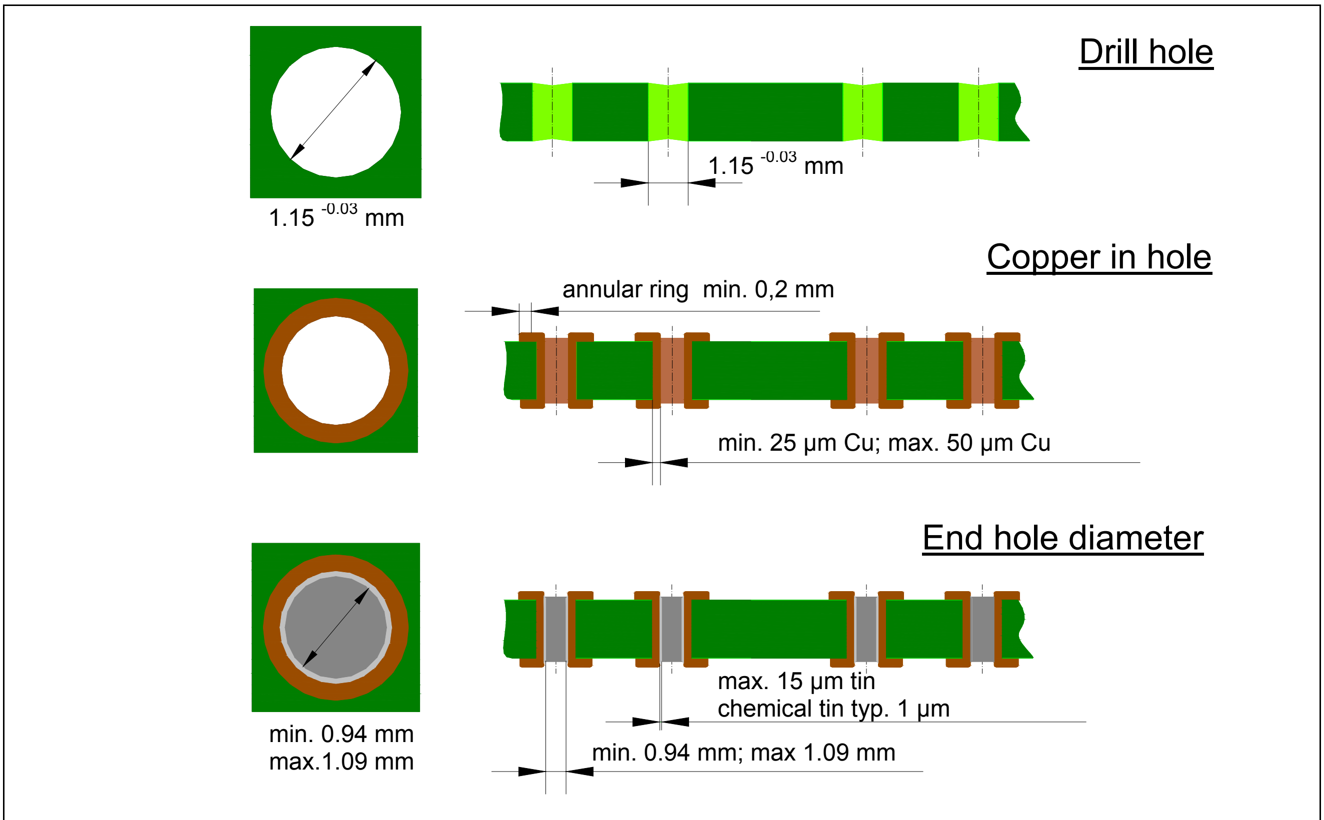


Figure 2 Structure of a printed circuit board

PressFIT technology is qualified for FR4 printed circuit board material.

After a reflow soldering process has been carried out on a printed circuit board, the module can be pressed into the board without difficulty. The retention forces of the press-fitted pins are not influenced.

As with Econo PressFIT modules, a distance of 5 mm from the middle of the pins to other components on the printed circuit board must be observed. The dimensions in the case of Press-tools developed by the user himself must be considered when positioning components.

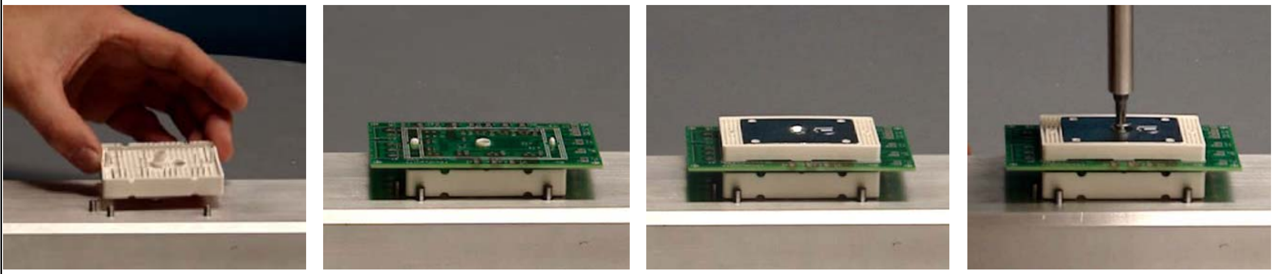
A PressFIT module can be replaced up to two times. This means a printed circuit board can be used a total of three times. Correct handling of the components is essential.

A module that first was pressed in and then pressed out, can no longer be pressed in again. Instead, the module can be fixed to a new printed circuit board by soldering. The plastic deformation of the PressFIT zone does not permit further press-fitting.

3 Self-acting PressFIT Assembly

After the module and the board have been positioned on the heatsink, a screw is put through the counter-holder, the PCB and the module into the thread of the heatsink. By fastening the screw, the counter-holder presses the pins of the module into the holes of the PCB, fixes the module on the heatsink and simultaneously the PCB.

Shortly before the press-in process is over, the outer frame of the module fully contacts the heatsink.



1. Step:	**2. Step:**	**3. Step:**	**4. Step**
The module is positioned on the heatsink.	By help of the two centering guides, the PCB is adjusted on the module in the right way.	The counter-holder, too, is positioned by help of the centering guides.	The module is screwed in place on the heatsink. The contacts are pressed into the holes of the board, the thermal contact to the heatsink is realised and the module is fixed.

Figure 3 Mounting process of a Smart1 module by help of a screw

Once the module has been placed on the heatsink, the board by help of two centering domes of different diameters - which make a 180° wrong positioning impossible - is adjusted precisely on the module.

The electrical contacts this way are inserted into the respective drillings of the board. Then, the counter-holder, which equally by help of the two centering domes of different diameters is correctly positioned above the module, is put on the PCB.

Wrong assembly turned by 180° is prevented by an additional, visual aspect, i.e. by the arrangement of the Infineon Logo in the steel part of the counter-holder and the big drilling on the module top side. In case of correct assembly, the drilling and the logo can be found on the same side and exactly on top of each other. The drilling – after fixing the PCB – can no longer be seen but it just as the stamped logo still is suitable for correct assembly, because heatsink as well as PCB normally are constructed in an asymmetric mode.

Now the screw via the counter-holder can be put through the combination of counter-holder, PCB, module and heatsink and can be fixed.

By fixing the screw, the electrical contacts are pressed into the PCB and are connected. Module, PCB, and heatsink are mechanically fixed to each other.

While fixing the screw, the below instructions have to be followed.

3.1 Module Fixation

All following information has to be considered as advice and has to be checked for the individual application on your own responsibility. Basically, while screwing the module, one has to make sure that a turning of the PCB is being avoided.

Concerning the selection of the screw and the respective screwing torque, the values indicated in table 2 have to be taken into account.

Table 2 Technical data of fixing screws

Description	Values
Fixing screw	M6 vertical head screw 1)
Recommended screwing torque	Ma = 8,5 ± 0.5Nm 2)
Recommended property class of the screw	8.8
Recommended screw penetration	1,6 x d = 9,6mm 3)

1) As per ISO 14581 or DIN7991.
2) Determined for a friction coefficient of μ=0.14 (screw connection clean and dry, aluminum heatsink, screw as per ISO 14581, zinc-plated, rolled thread)
3) In aluminum, as per technical literature

While defining the screw connection, as usual, the friction coefficient has to be monitored. For a typical, clean matching of an aluminum heatsink and a zinc-plated, metric screw a coefficient of ~μ=0,14 will result. If the value in the assembly differs, the torque has to be adjusted respectively. A possible variation of the torque based on changed friction coefficients is shown in figure 4.

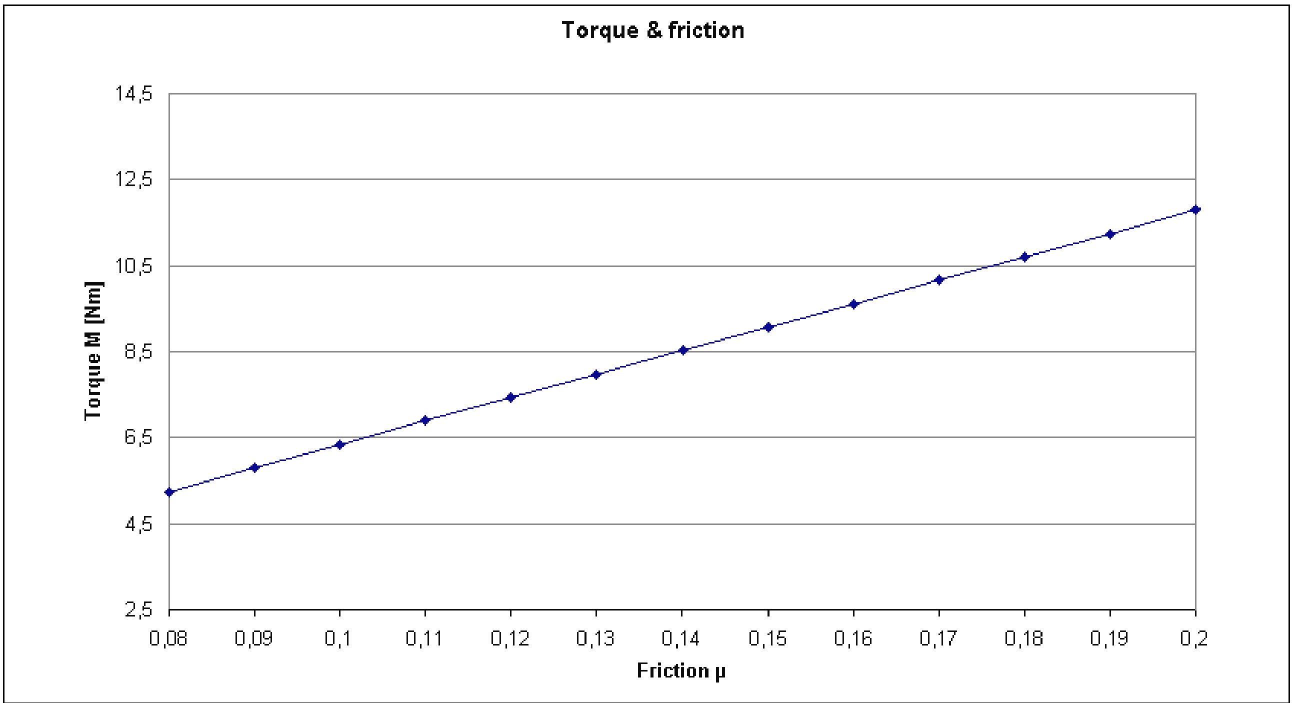


Figure 4: Torque as a function of friction coefficient

You can see from the outside that module assembly is fnished when the outer frame of the Smart-module fully contacts the heatsink.

Correct assembly of the module makes sure that the screw together with the counter-holder generates the required clamping force and guarantees in combination with the thermal paste a low thermal resistance and accordingly optimal heat dissipation.

By relaxation of the housing after mounting, the torque is reduced. This, however, has no influence on the module's thermal behaviour, e.g. a retightening of the screw is neither required nor should it be considered.

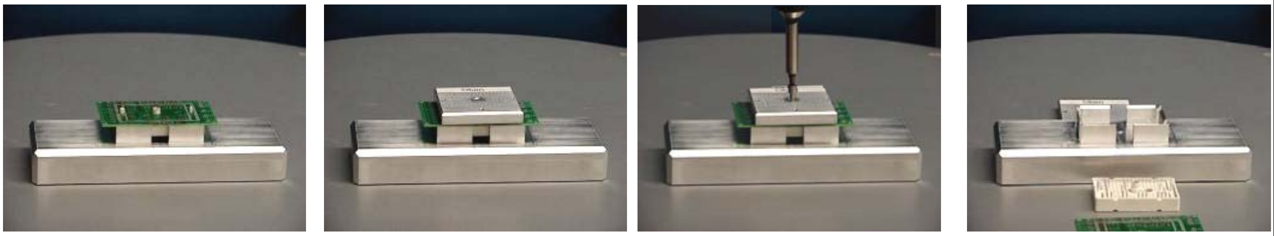
4 Press-Out Process

The press-out process can be realised in two ways.

It can be done by using a press-out tool in the same way it is done with Easy- or Econo PressFIT modules, i.e. the module including PCB is put onto a fixture (tray). By help of a press-out plate - which is part of the press - force is exerted on the Pins which protrude from the PCB. This way, the Pins are pressed out of the PCB. Once the PressFIT-area of the Pins has left the PCB, the module has been separated from it and falls onto the tray of the lower tool.

A second way of doing it is by using the middle hole which is meant for fixing the module. In this case, the force for pressing the contacts out is not applied by a press but by a screw, which via a metal plate, the PCB, and the module is screwed into the thread of the lower tool. As before, the module plus PCB is put onto the fixture (tray). By help of the screw the metal plate is screwed down and a vertical force is exerted on the contacts. This way, the Pins are pressed out of the PCB. And the module, just as before, falls onto the tray of the lower tool. This mode of disassembly is most convenient in case of mobile servce, as no heavy equipement is needed.

In order to make sure that during de-assembly the housing can be removed together with the PressFIT contacts, the PCB has to be designed in a way that there is a certain extra number of positioning holediameter. Respective information regarding the drilling tolerances is given in the modules outlines in the individual data sheets.



1. Step:	**2. Step:**	**3. Step:**	**4. Step**
The module incl. PCB is put onto the fixture.	A metal plate with integrated holes which take the positioning domes and the fixing hole is adjusted.	By fixing the upper metal plate, the same is being pressed down, and exerts vertical pressure on the Pins. The module contacts are pressed out of the PCB. The module falls into the tray of the lower tool.	PCB and module separately can be taken from the tool.

Figure 5 Press-out process of a Smart1 module by help of a screw

When designing the PCB, the outer dimensions of the press-out tool have to be taken into account so that the components near the module will not be damaged.

For both tools, CAD drawings are available. The drawings can be adjusted to the users' individual demand and the tools can easily be produced by any manufacturer.

4.1 Press-Out Forces

To press a module out of a printed circuit board a force of between approximately 50 N and 70 N must be applied for each pin in the module. The extruding forces vary according to the diameter of the hole in the printed circuit board.

5 Quality of PressFIT Contacts

PressFIT is an attractive solution for connecting control and load current contacts on IGBT modules with a printed circuit board.
The requirement of greater robustness, the trend towards higher temperatures and lead-free technology, and – of course –simplified handling are continuously growing.
With PressFIT technology it is possible for the first time to improve reliability of semiconductor modules up to 100 times compared to manually soldered contacts and other contact modes (reliability analysis as per Standard SN 29500-5).

The assembly process is simple and consequently saves time and money. The process is reliable and the system is repair- and maintenance friendly.

An extract from the Siemens Norm SN 29500-5 / Edition 2004-06 Part 5 shown in Table3 shows the failure rates of different contact technologies.

Process		**Conductor diameter in mm²**	**Failure rate λ_{ref} in FIT[1)]**	**Notes: Standards/guidelines**
Solder	manual automatic	–	0.5 0.03	IPC 610[2)], class 2
Wire bonding for hybrid circuits	Al Au		0.1 0.1	28 µm / wedge bond 25 µm / ball bond
Winding		0.05 to 0.5	0.002	DIN EN 60352 – 1 / IEC 60352 – 1 CORR1
Crimping	manual automatic	0.05 to 300	0.25	DIN EN 60352 – 2 / IEC 60352 – 2 A 1+2
Clips		0.1 to 0.5	0.02	DIN 41611 – 4
PressFIT		0.3 to 2	0.005	IEC 60352 – 5
Insulation piercing connectors		0.05 to 1	0.25	IEC 60352 – 3 / IEC 60352 – 4
Screws		0.5 to 16	0.5	DIN EN 60999 – 1
Terminals (spring force)		0.5 to 16	0.5	DIN EN 60999 – 1

1) 1 FIT = 1 x 10^{-9} 1/h; (one failure per 10^{9} component hours)
2) Acceptance conditions for printed circuit boards

Table 3 Failure rates for various contact technologies
Siemens Norm SN 29500-5 / Edition 2004-06 Part 5

The PressFIT contact has been qualified in accordance with the usual standards for IGBT modules and the requirements for PressFIT connections at Infineon.

Figure 6 shows a small extract of the various tests. The extract also demonstrates that the conditions in the individual tests are to be regarded as considerably stricter than stated in the standards. This shows clearly the robustness of the system compared to traditional contact technologies.

Examples are the significantly higher temperatures or the loads during a corrosive gas test that are up to 5 times higher (H_2S concentration according to the norm: 10 ppm / H_2S concentration in the test: 50 ppm). The green fields show the differences to the less critical requirements of common tests according to the corresponding Standards.

Test	Boundaries	Requirement	Amount
Microsections of contact	min. hole	No damages	6 contacts min hole
Press-in and push out forces	min. hole max. hole	The minimum and maximum push-outforce shall be specified by the manufacturer	7 contacts min hole 7 contacts max hole
Climatic sequence (contact resistance after different serial tests)			
TST	-40°C to **+125°C**; exposure time= 30min, 10 cycles	No relevant change of resistance	100 contacts min hole 100 contacts max hole
Damp cycling	16h dry heat **120°C**; 5 cycles: damp heat (12h; 25°C; 85%-93% and 55°C; 85-93%) -> 2h cold -40°C	...change of resistance	
Dry heat	**120°C**; 1000h	No relevant change of resistance	
Flowing mixed gas corrosion	4-components-mixed gas; 240h: SO2: 0,2ppm H2S: 0,01ppm NO2: 0,2ppm Cl2: 0,01ppm	No relevant change of resistance	

standard is only 85°C

Sequential test!
2x 100 contacts have to pass all 4 tests in series!

* Example of Easy PressFIT

Single-pin qualification according to IEC 60532-5

Module Qualification acc. to IEC 60749

Test	Boundaries	Requirement	Amount
H3TRB	1000h; 85°C; 85%RH; Vce 80V; **on PCB with online resistance observation***	No relevant change of resi... 1000h	
TST	-40°C to +125°C; 50 cycles; **on PCB with online resistance observation***	No relevant change of resistance after 50 cycles	12 modules
Vibration	5g; **20g**; [illegible]-200Hz; x=7.5mm; 10h/axis; **on PCB with online resistance observation***	No rel... of resi... 10 hou...	
PC (seconds)	Tjmax=150°C; ΔT ~100K; t_{on}=1.5sec / t_{off}=5sec **on PCB**	End of life (del. of silicon... No rel...	
PC (minutes)	Tjmax=150°C; ΔT ~110K; t_{on}=9sec / t_{off}=30sec **on PCB with T_{max} ~105°C**	End o... silicon); No rel.change of R	4 modules

Further Qualification acc. to IEC 60068

Test	Boundaries	Requirement	Amount
Corrosive gas test	**50ppm** H2S; **40°C**; **93% RH**; 17 days; **mounted on PCB**	No rel... of resi... 17 days	8 modules
salt mist (automotive conditions)	4 spray cycles: 2h spray period (15-35°C; 5% NaCl); storage 20h (38°C - 42°C; 93% RH); after 4 cycles 3 days drying (21°C - 25°C; 45% - 55% RH); **mounted on PCB**	No relevant change of resistance after Test	8 modules

Standard is without PCB & R-online observ.
Standard is 5g & without PCB & R-online observ.
Adjusted to a PCB temperature of ~105°C
standard is without PCB @ 10ppm; 25°C; 70%-80% RH
standard is without PCB

* Online restistance observation in current free arms with ~1.3mV
* Example of Easy PressFIT

Module qualification according to IEC 60749 and 60068

Figure 6 Excerpt from qualifying test

Further information regarding the reliability of PressFIT modules can be found in various publications, such as "Reliability of PressFIT connections" under www.infineon.com/highpower

6 Condition of the heatsink for module assembly

The power losses inside the module have to be dissipated via a heatsink in order not to exceed the maximum permissible temperature T_{vjop} during operation specified in the datasheets.

The condition of the heatsink surface in the area where the module is mounted is of great importance, as this interface between heatsink and module has a decisive influence on the heat transfer of the entire system.

The contact surfaces, the bottom side of the module, and the surface of the heatsink have to be free of degradation and contamination to prevent the module from excess mechanical stress and an increase in thermal resistance.

Heatsink requirements:

- Roughness: ≤ 10 µm
- Flatness based on a length of 100 mm: ≤ 50 µm

Attention: 1. The flatness of the heatsink – considering the entire module mounting area should not exceed the values listed above.

Attention: 2. If the layer of thermal paste applied is too thick, e.g. resulting from cavities, the thermal resistance R_{th} between module and heatsink will increase.

7 Applying the Thermal Paste

Due to an individual surface shape (e.g. roughness and flatness) of the heatsink and the module, these do not touch across the entire area so that in certain places, a separation between the two components cannot be avoided.

To dissipate the losses in the module and to achieve a good heat flow into the heatsink, all existing cavities have to be filled with a thermal compound. When using a heat conductive paste, a homogenous application has to be assured.

A well-applied layer will fill all cavities and at the same time does not violate the metallic contact between module base and heatsink surface. A compound should be selected which shows permanently elastic features in order to assure a continuously favourable heat transfer resistance.

Figure 7 Mounted Smart1 Module with thermal paste visible at the module sides

Before the module is mounted onto the heatsink, an even layer of thermal paste should be applied to the complete module base or to the heatsink. This paste can be applied using either a spatula or a roller, or by a silk screen printing. The volume of thermal paste is sufficient when a small amount of paste is visible at the module sides after having assembled it to the heatsink.

Common rollers or fine toothed spatulas can be used to apply the thermal compound. The layer thickness of the compound should typically be 50µm to 100µm

Recommended is the application of thermal paste by means of a screen print process. Apart from an optimized and module-specific distribution of the heat conductive paste, a homogenous and reproducible layer thickness can be achieved by this procedure.

An average layer thickness of 50µm-70µm turned out to be reasonable. In the case of a stencil thickness of 0,08mm and the below shown gate widths, the resulting average layer thickness is approx. 50µm. By the hexagonal form of the stencil, the flow paths of the thermal compound are close to symmetrical; this supports the idea of an optimal grease distribution.

Tests of the below displayed screen printing stencil and different thermal compounds show a good distribution behaviour. This shown stencil should be considered as a suggestion only, and its suitability for a certain application always has to be verified.

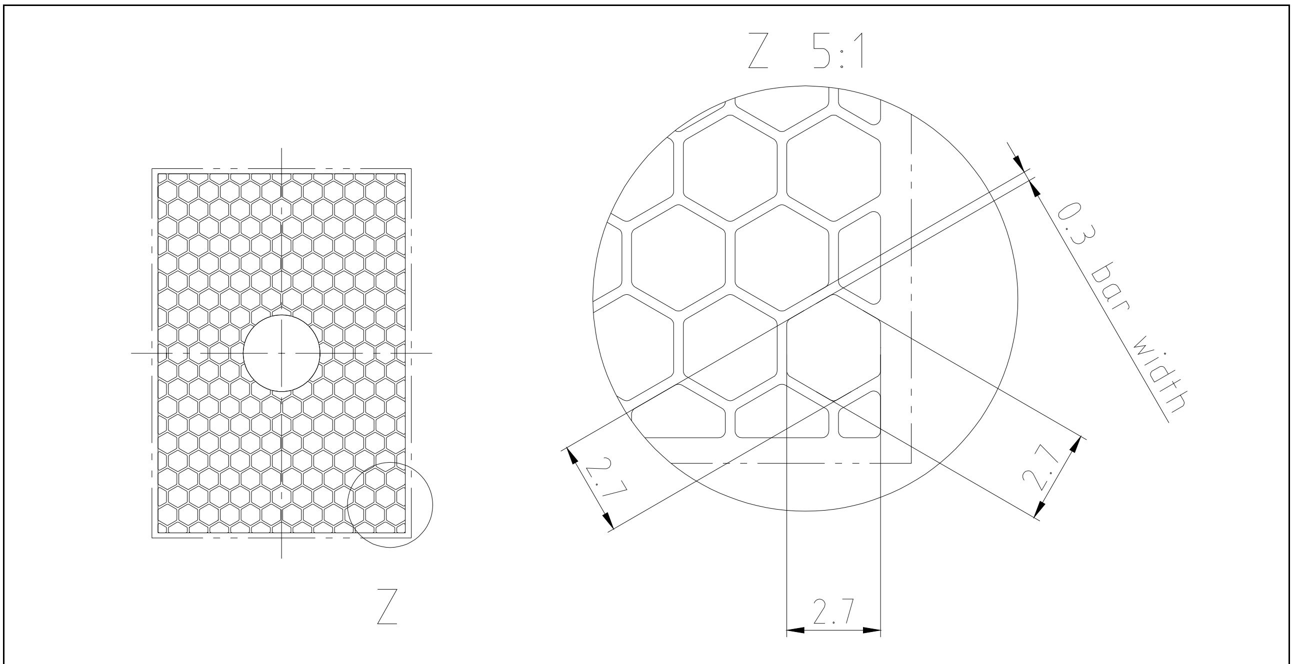


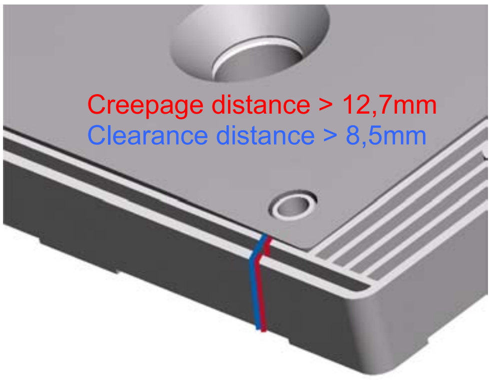
Figure 8 Drawing of a possible stencil

A CAD drawing of the stencil is available on request.

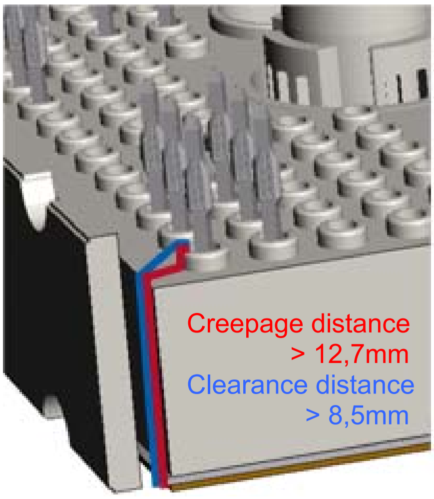
Further information regarding the use of screen printing stencils for applying thermal grease can be found in application note AN2006-02 Application of silk screen.

8 Clearance and Creepage distances

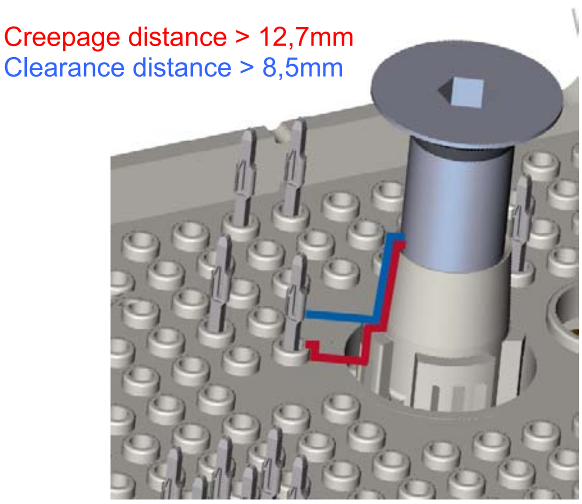
When defining the layout of the PCB, application specific standards, mainly regarding clearance and creepage distances, have to be considered. This is particularly important for the area of the screw. In order to meet the respective requirements regarding clearance and creepage distances, components or vias in this area should be avoided or additional isolation measures like coating should be taken.



Shortest distance from the metal plate of the counter-holder to the PCB



Shortest distance from one contact to the heatsink along the frame



Shortest distance from one contact to the fixing screw

Figure 9 Creepage and clearance distances of Smart1 modules

Due to structures at the module and the counter-holder, the creepage distances are enlarged in comparison to the shortest clearance distances.

The thread of the screw is fixed through the counter-holder, the PCB and the module into the thread in the heatsink. By this, the screw and the metal plate of the counter-holder automatically has the same potential as the heatsink.

To the first possible contact near the screw - as shown in fugure 9 – a creepage distance of slightly more than 12,7 mm (red) can be realised.

As the upper side of the PCB forms a part of the clearance distance, this distance depends on the tickness of boards used. At a board thickness of 1,5 mm, the clearnace distance is > 8,5 mm (blue).

The creepage and clearance distances mentioned in the data sheets are minimum values which do not take into account additional devices that could be mounted near the modules.

At any rate, the creepage and clearance distances in the individual application have to be checked and compared to the requirements mentioned in application-specific standards. If required, they have to be secured by constructive measures.

9 Type labelling

At one front side, all SmartPIM1 and SmartPACK1 modules are laser-marked. The label shows the most important data about the module can be found like module type or datecode. A "G" in front of the datecode shows that the module is RoHS compliant.

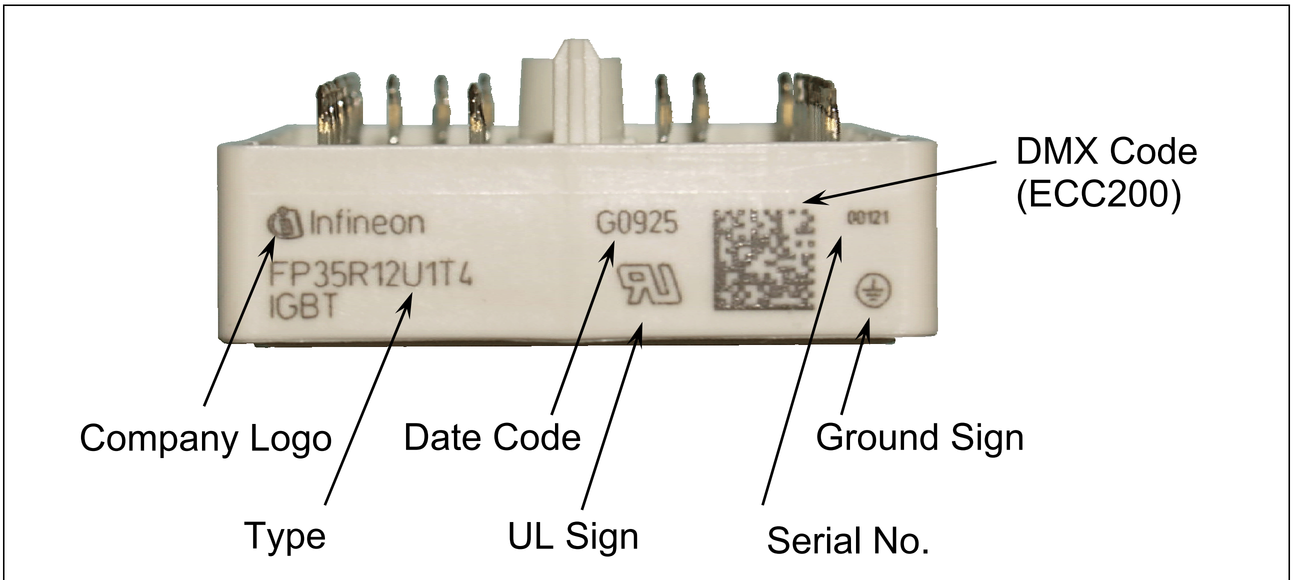


Figure 10: Type labelling of Smart1 modules

The DMX-Code (ECC200) contents a number of 23 digits

- digit 1 bis 5 Module Serial No.
- digit 6 bis 11 SAP Material-No.
- digit 12 bis19 productionorder No.
- digit 20 und 21 Date code: prod. year
- digit 22 und 23 Date code: prod. week

10 Storage and Transport

During transport and storage of the modules, extreme forces through shock or vibration have to be avoided as well as extreme environmental influences.

Storage of the modules at the limits of the temperature specified in the datasheet is possible, but not recommended.

The recommended storage conditions according to IEC60721-3-1, class 1K2 should be assured for the recommended storage time of max. 2 years.

Max. air temperature: T_{maxair}=+40°C

Min. air temperature: T_{minair}=+5°C

Max. relative humidity: 85%

Min. relative humidity: 5%

Condensation: not permissible

Precipitation: not permissible

Icing: not permissible

Pre-drying of the case prior to the press-in process as it is recommended for moulded discrete components (e.g. microcontrollers, TO-cases etc.) is not required for Smart1 modules.

11 ESD protection

IGBT modules are electrostatic sensitive components.

In order to prevent destruction or pre-damage of the components by discharge, the components are delivered according to the approved ESD regulations in appropriate ESD protection packaging.

While working to the components, grounding wristbands should be worn and the valid ESD safety instructions should be observed.

Compliance with the requirements for Infineon IGBT modules is assured by the respective reliability tests and the 100 per cent test carried out in production afterwards.

http://www.infineon.com

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