HybridPACK™ Drive

Assembly Instructions for the HybridPACK™ Drive Performance

About this document

This application note describes the recommended process for mounting the HybridPACK™ Drive Performance power modules which have silicon nitride ceramic (SIN) implemented for the internal isolation. The document is applicable to HybridPACK™ Drive Performance power module products, listed in the section 1.1.

Scope and purpose

General information about the assembly process can be found under the application note **AN-HPD-ASSEMBLY**, which describe assembly processes of the HybridPACK Drive family. The HybridPACK Drive Performance power modules can be mounted with similar processes.
This specific application (AN-HPDPERF-ASSEMBLY) describes one possible assembly process for the HybridPACK™ Drive Performance power modules, which showed during Infineon internal tests the best robustness performance.

Intended audience

Engineers and operators involved in the assembly of the HybridPACK™ Drive Performance power module into power electronics systems.

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1 General Information

The **HybridPACK™** Drive power module family is designed to meet the high volume production, high robustness, high power density, and low cost requirements of the automotive market. Different product derivatives with e.g. different power tab sizes and different baseplates are available within the HybridPACK Drive product family.

General information about the assembly process can be found under the application note AN-HPD-ASSEMBLY. The HybridPACK Drive Performance power modules can be mounted with similar processes. After implementation of final design and assembly it is necessary to perform a system qualification, where system robustness is tested according to the specific application needs (see also e.g. system qualification tests in LV124).
This specific application describes one possible assembly process for the HybridPACK™ Drive Performance power modules, which showed during Infineon internal tests the best robustness performance.

The application note can be applied to HybridPACK™ Drive Modules listed in the section 1.1.

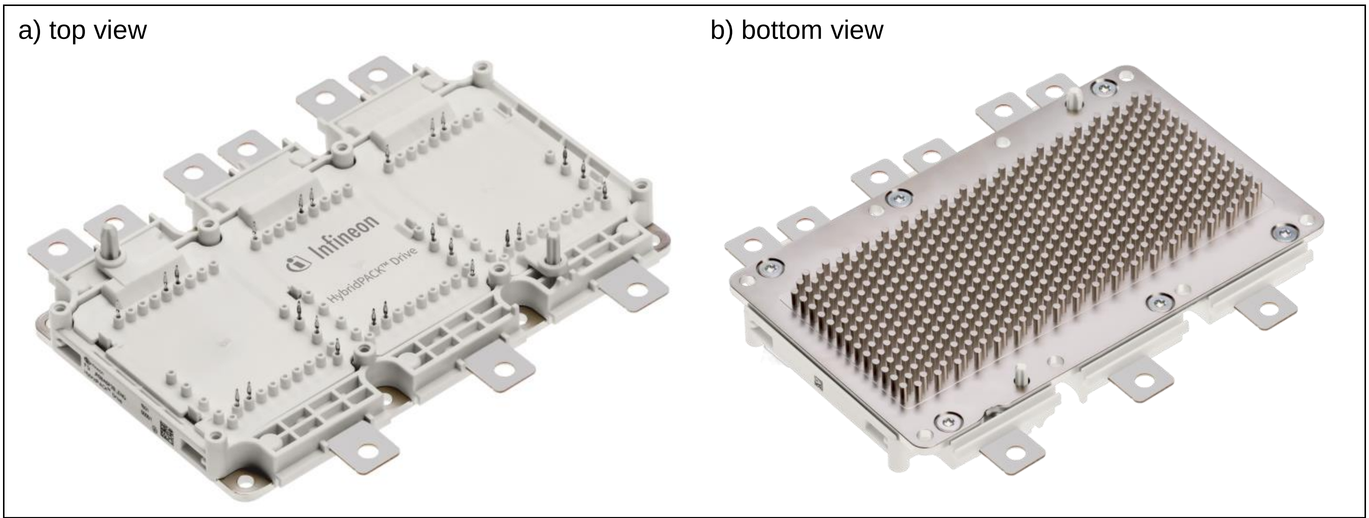

Figure 1 HybridPACK™ Drive Power Module (example shows FS950R08A6P2B typical appearance).

1.1 HybridPACK™ Drive product list in scope of this application note

The scope of the application note is for the following products:

Type Designation	SP order number	Status
FS950R08A6P2B	SP001720776	in production
FS950R08A6P2LB	SP002290988	in production
FS380R12A6T4B	SP001632438	in production
FS380R12A6T4LB	SP002516834	in production
FS05MR12A6MA1B	SP005247420	in production
FS03MR12A6MA1B	SP001720764	in production
FS03MR12A6MA1LB	SP002725554	in production

Product not listed? Please ask your Infineon sales representative.

2 Recommended Mounting Order

All datasheet drawings specify the power module at the state of delivery. Deformations on the product can occur when the power module is mounted to a cooling system (i.e. depending on cooler flatness and screw torque). As the pin position tolerance is important for PCB assembly, it is recommended to press the PCB on the power module first, and assemble the power module into the cooling system next. In order to avoid putting unnecessary mechanical stress on the PCB, it should be fixed by screws on the inverter housing subsequent to mounting the power module to the cooling system.

As a summary, the following mounting order can be recommended:

1. **Align PCB to the power module (the X-Pins will support this process).**
2. **Press-in PCB (recommended press-tool with distance keeper).**
3. **Prepare cooling system with the sealing ring.**
4. **Attach power module with PCB to the prepared cooling system.**
5. **Fix module baseplate on the cooler by screws.**
6. **Fix the PCB at the inverter housing.**
7. **Connect the module power tabs to busbar, capacitor, etc.**

When self-clinching nuts are chosen for the connecting type of the module power tabs it is recommended to press-in these nuts in the assembly line before the PCB mounting step 1 starts.

3 PressFit Assembly

3.1 Requirements for the PCB

The pressfit technology used in the HybridPACK™ Drive is designed based on IEC 60352-5 for standard FR4 printed circuit boards with immersion tin plating. The PCB material must be compliant with IEC 60249-2-4 or IEC 60249-2-5 for double-sided printed circuit boards and IEC 60249-2-11 or IEC 60249-2-12 for multilayer printed circuit boards.

The requirements for the PCB are in Table 1. In case the requirements are not met, there is risk of a not gas tight signal pin connection or of pin and/or PCB via damage. The recommendations for the PCB for the X-pin holes are in Table 2.

Please note that the pressfit hole specifications are only valid for assembled PCBs. In case of unassembled PCBs, e.g. for testing purposes, it is recommended to perform a standard reflow solder process before starting the power module assembly process.

Table 1 Requirements to the PCB.

No	Description	Unit	min.	typ.	max.	Remarks and known common mistakes
1	Drill tool diameter	mm	1.12	1.15		Wrong drill tool applied. Specify clearly the pressfit hole positions and required drill tool size to the PCB manufacturer.
2	Copper thickness in hole	um	25		50	In case the via metallization is lower than specification, the risk is a damaged/cracked via.
3	End hole diameter	mm	1.02		1.10	End hole diameters lower than spec may lead to increased press-in forces (typically >115 N per pin) and may damage the pins. Larger holes than spec may lead to low press-in forces (typically <40 N per pin) and can cause not gas tight connections.
4	Copper thickness of conductors	um	35	70 105	400	No results available for thinner or thicker copper layers.
5	Hole to hole pattern tolerance	um			±100	In typical PCB manufacturing hole to hole pattern is lower than ±80um.
6	Recommended PCB thickness	mm		1.6		Target value with +/-10% thickness tolerance
7	Recommended PCB fixing: On Inverter Housing (External, not on module)					Experiments have shown that HybridPACK Drive Performance modules show best robustness when PCB is mounted externally to the module. See also section 3.3
8	Metallization of circuit board		Immersion Tin (Sn chemically)			Immersion tin has typ 1-5um metallization in the hole. Other metallization types should be avoided which can lead to strong deviation in press-in forces. E.g. HAL leadless show high variations in press-in forces and risk is a not gas tight pin connection, which can fail over application lifetime. PCB with ENIG plating can lead to increased press forces due to hard surface and this PCB type was not tested at Infineon module qualification tests.
9	Metallization of pin		Ni/Sn (galvanic)			The Sn plated pin with nickel under layer avoids potential whisker growth out of the upper galvanic tin layer.

Table 2 Recommendations for the printed circuit board X-pin holes

No	Description	unit	min.	typ.	max.	Remark
1	End hole diameter X-Pin[1]	mm	5.82	5.90		The hole should be drilled with 6.0mm drill tool and not milled in order to avoid additional unnecessary hole position tolerances.
2	End hole diameter Y-Pin[1]	mm	4.82	4.90		The hole should be drilled with 5.0mm drill tool and not milled in order to avoid additional unnecessary hole position tolerances.
3	Hole to hole pattern tolerance	um			±100	Plated holes are preferred in order to achieve a minimum "X-pin hole" to "pressfit hole" pattern tolerance.

Please take note that the PCB pressfit holes should not be specified just by the finished end hole diameter. The risk is that wrong processes are applied by the PCB manufacturer. Please give your PCB manufacturer the information that all holes for the signal pins must be manufactured according to Table 1. As PCB design tools typically do not differentiate between "normal" and "pressfit holes" it is a well-known workaround to use a "unique hole size e.g. 1.06mm" in the PCB design for all pressfit holes. Then the pressfit holes are separate in the NC drill files and thus the PCB manufacturer knows exactly the positions where to apply the spec according to Table 1. An example for such a workaround is shown in Figure 2.
Experience has shown that it is best practice to place additionally a text on the drill drawing layer, where it is clearly specified that the 1.06mm holes are the pressfit holes according to the specification of Table 1. This text is also visible in the gerber files which are the typical exchange format between the PCB designer and the manufacturer.

NCDrill File Report

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Layer Pair : Top Layer to Bottom Layer

Tool	Hole Size	Hole Type	Hole Count	Plated	Tool Travel
T1	1.1mm (39.37mil)	Round	24		543.04 mm (21.38 Inch)
T2	**1.06mm (42.13mil)**	**Round**	**24**		**428.69 mm (16.88 Inch)**
SEE PRESSFIT SPEC!					
T3	3.6mm (141.732mil)	Round	8		459.55 mm (18.09 Inch)
T4	4mm (157.48mil)	Round	4		635.11 mm (25.00 Inch)
T5	4.9mm (192.913mil)	Round	1		0.00 mm (0.00 Inch)
T6	5.9mm (232.283mil)	Round	1		0.00 mm (0.00 Inch)
T7	10mm (393.701mil)	Round	8	NPTH	447.98 mm (17.64 Inch)

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Figure 2 Example NC Drill File (tool header only) of a PCB design where all pressfit holes are specified with 1.06mm and a note to the manufacturer is added. The PCB manufacturer can now easily distinguish between a normal and a pressfit hole (see tool T2).

[1] Experience has shown that PCB hole diameter should be significantly larger than the module frame element for a seamless assembly process. The given relative large hole diameters in the PCB is the best compromise between Module and PCB alignment and the necessary play during this assembly step. The specified relative large hole sizes avoid an unnecessary rotation of the PCB with respect to the signal pin coordinate system.

A structure of a PCB according to the spec in Table 1 is illustrated in Figure 3. The hole in the PCB is drilled with a drill tool size of 1.15 mm. It is normal that PCB material shrinks after drilling. Therefore, this shown hole size with 1.15mm should not be understood as a check gauge after drilling rather than an illustration for understanding the PCB stack.

Later in the process, the holes will be plated. It is important to have minimum 25um copper in the hole otherwise the press forces may damage/crack the via. According to experience, larger annular rings are typically more robust to mechanical forces and thus large annular rings (e.g. 0.5 mm) should be used wherever possible in the design.

The metallization/plating in the holes has to be manufactured in an immersion tin (i.e. chemical tin) process. This process is known to generate very uniform layer thicknesses (typically about 1um) and ensures the correct press-in forces as well as an appropriate contact surface for achieving gas tight pressfit connections.

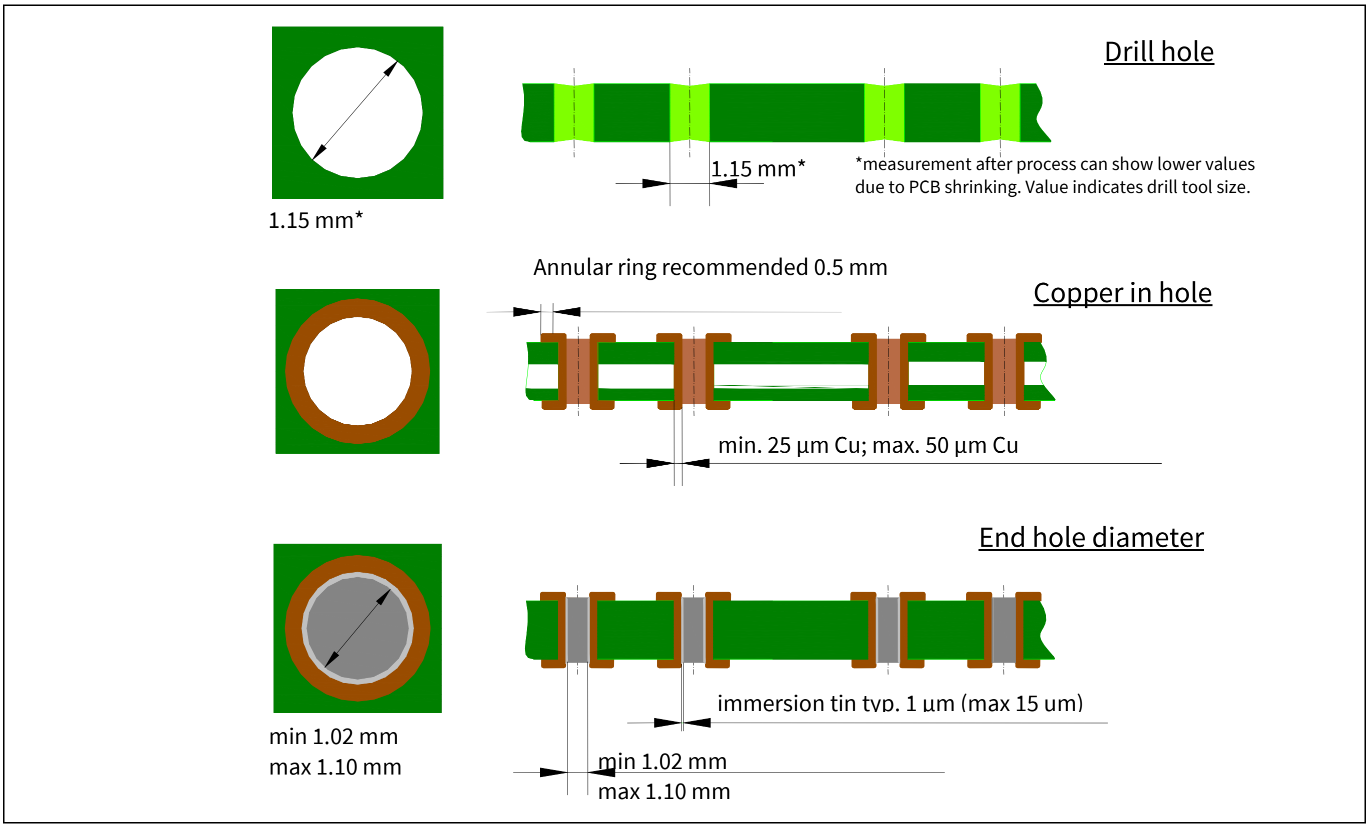


Figure 3 Structure of a PCB according to the specification in Table 1.

3.2 General hints for the PCB Footprint

PCB footprint typically depend on PCB manufacturing processes and customer specific design rules. The following table can be understood as a best practice and starting point for system design.

Table 3 Hint for PCB footpint holes. PCB bottom layer is defined on side of the power module.

No	Type	PCB Implementation Hint
1	**X-Pin holes**	Hole at 0/0 Position* End hole Diameter: 5.90 mm (see Table 2) Top Layer Copper Diameter: >= 6.40 mm Mid Layer Copper Diameter: >= 6.40 mm Bottom Layer Copper Diameter: >= 8.00mm Hole at 87/82 Position* End hole Diameter: 4.90 mm (see Table 2) Top Layer Copper Diameter: >= 5.40 mm Mid Layer Copper Diameter: >= 5.40 mm Bottom Layer Copper Diameter: >= 8.00mm
2	Signal pressfit pin holes	See Table 1
3	Components Keepout around pressfit Pins	Uncritical packages like SO, TSSOP, QFP or not safety relevant SMD resistors: >=3mm radius from the hole center Others: >=4mm radius from the hole center
4	OPTIONAL for external PCB mounting PCB fixing screw holes	OPTIONAL for external PCB mounting End hole Diameter: 3.60 mm Top Layer Copper Diameter: >= 7.00 mm Mid Layer Copper Diameter: >= 6.50 mm Bottom Layer Copper Diameter: >= 6.60 mm

*: The x-pin holes can be designed both as plated or un-plated holes. Plated holes with annular rings as noted in the table are the preferred solution. All plated holes are drilled at the PCB manufacturers within the same process and leads to best hole to hole pattern tolerances as a consequence.

3.3 Press-In Tool with distance keeper for PCB external mounting

This chapter describes a sample press-in tool, which can be adapted to project specific details like PCB assembly locations, maximum height of other PCB parts, etc. to avoid mechanical collisions during the press-in process. The press-in tool is made of two parts (see Figure 4).

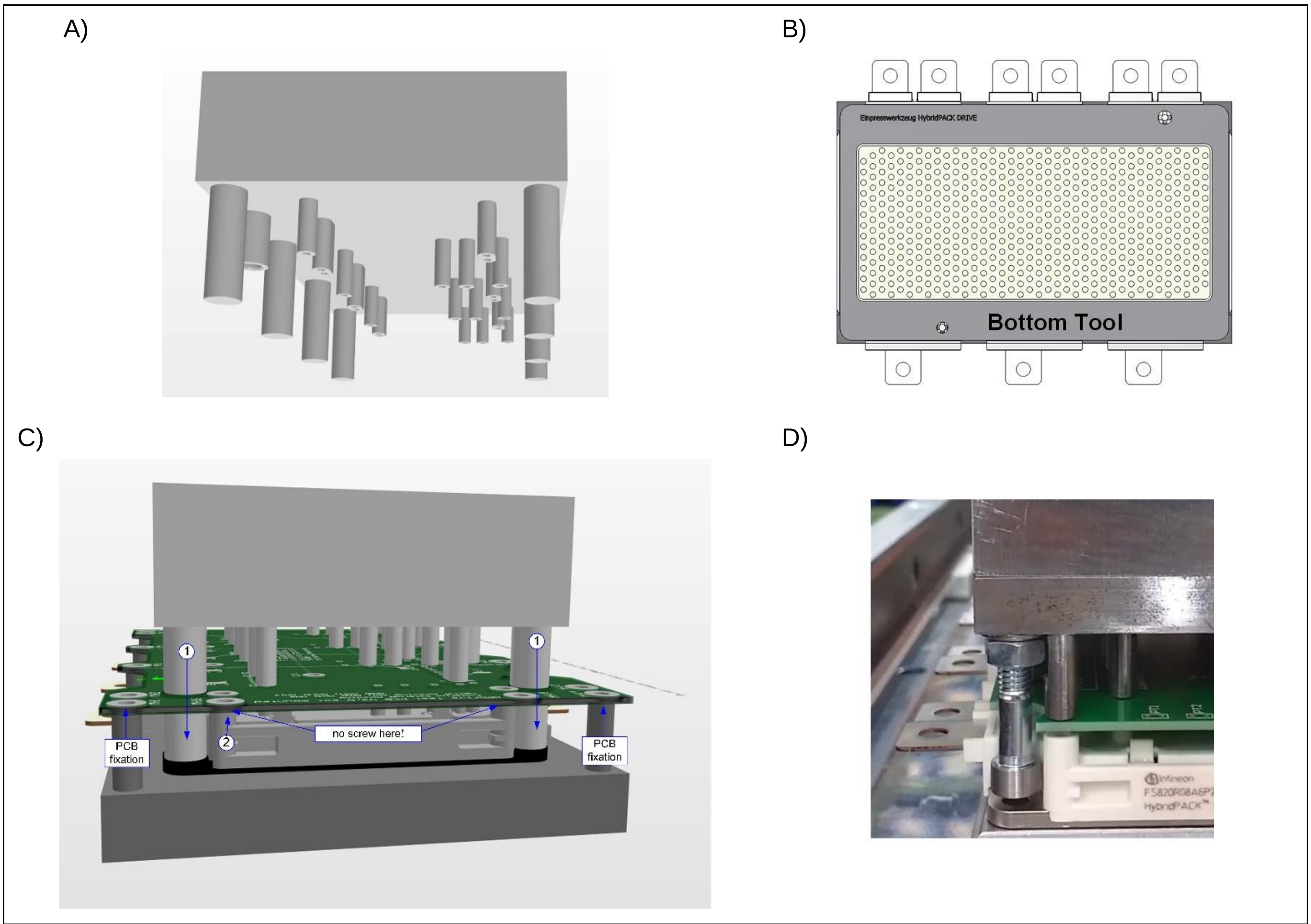
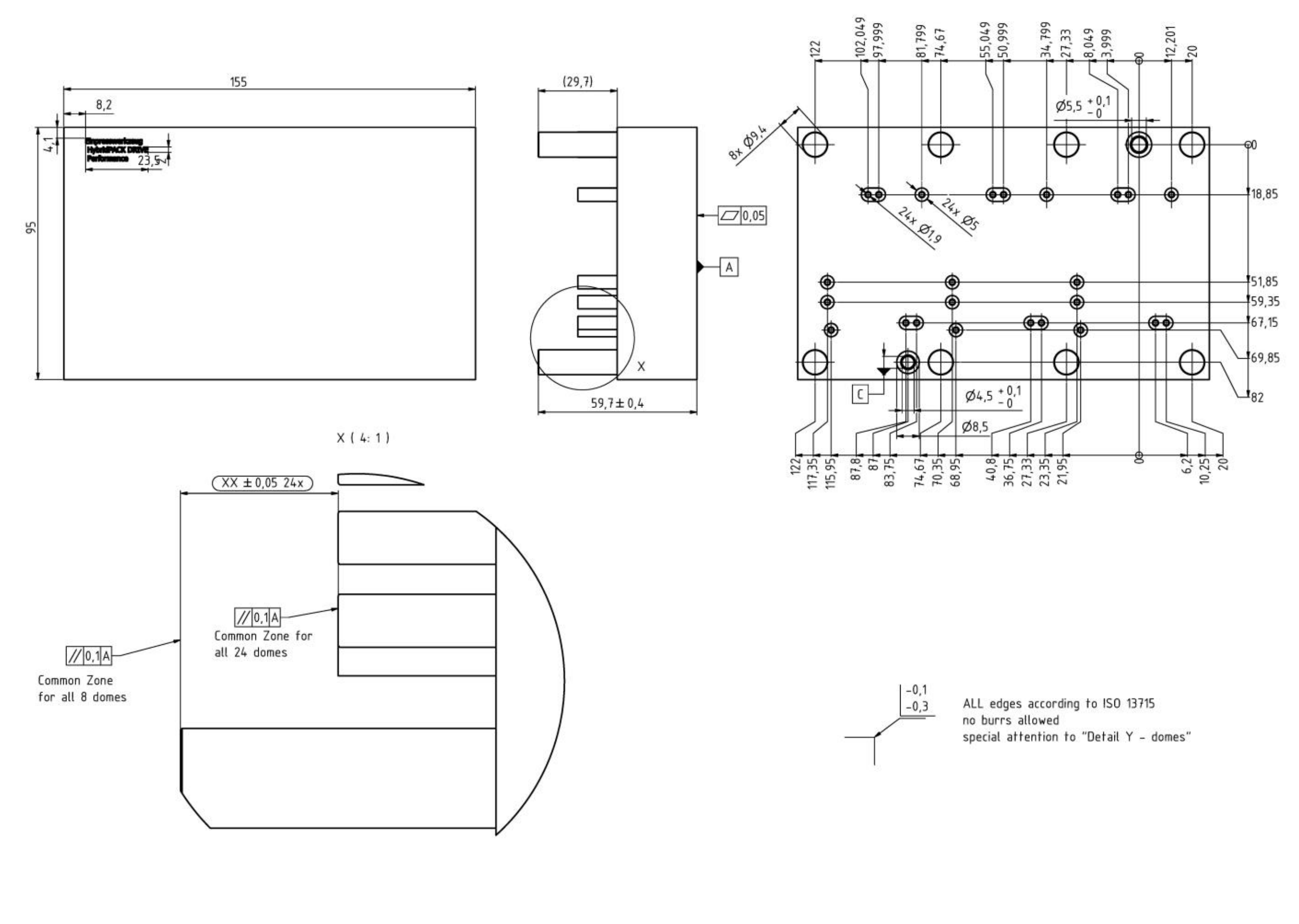


Figure 4 Press-tool schematic top (A) and bottom (B). The top tool is designed with standoffs which provide a distance to the baseplate surface (C). The picture in (D) show a implementation example with adjustable distance keepers.

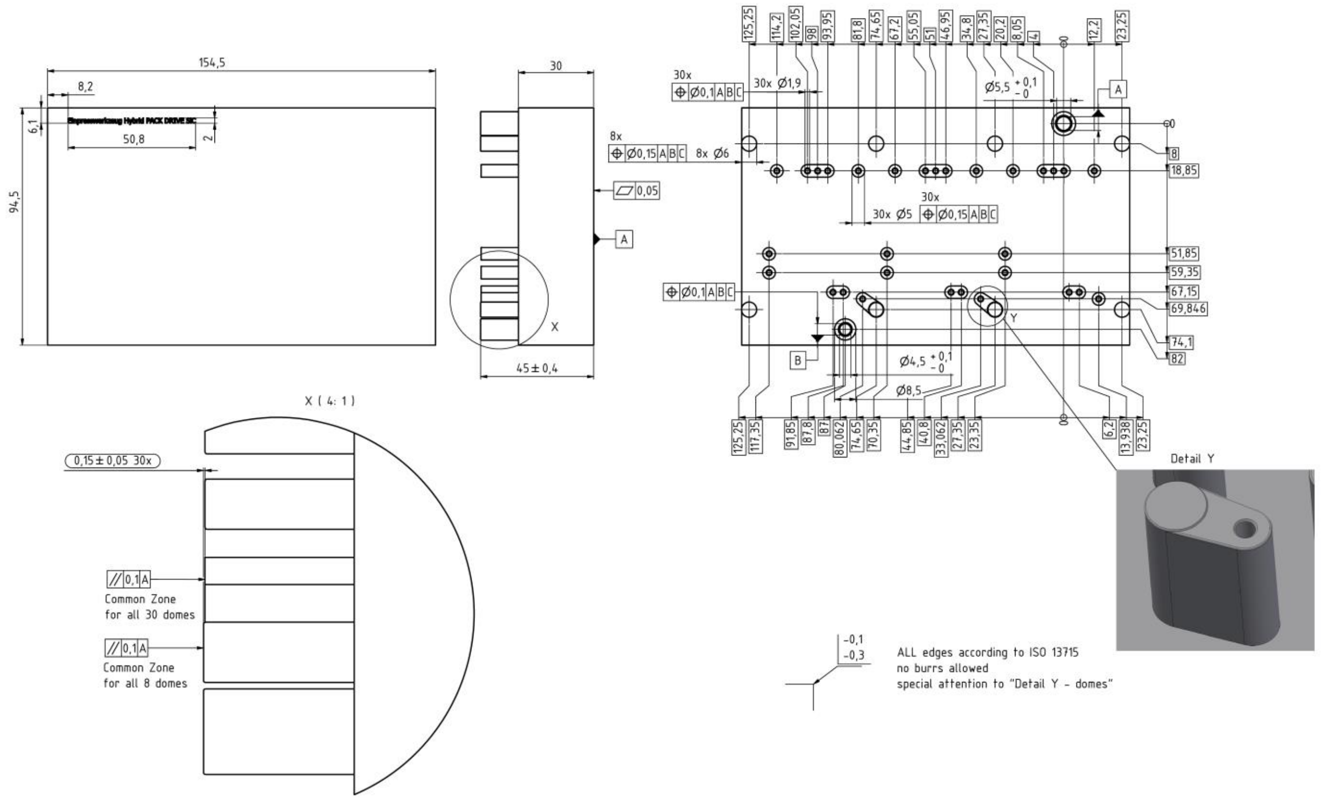
The bottom tool supports the power module baseplate and has to avoid damage of the pin-fin cooling area. The material and/or plating of the bottom part of the tool has to be selected in order to avoid scratches and damage of the baseplate sealing area. The holes for the X-pins avoid, by the poka yoke concept, a wrong orientation of the power module in the press-tool.
The top tool supports the PCB around the pressfit pins with cylindrical shapes and support the PCB during the press-in process. This part of the tool should be made of material, which can withstand the press-in forces. The top tool also has cylindrical shapes around the X-pins in order to avoid a press-in process with an incorrectly oriented tool or power module.
Please note that the top tool height (height of the cylinders) must be adjusted according to the maximum PCB assembly height. Collision of PCB top side assembly must be avoided.

A sample drawing of the sample press-in tools is given in Figure 5, Figure 6 and Figure 7 and can be adjusted to project specific needs.



Edges: ISO 13715; Tolerance: ISO 2768 – mK; Surface: EN ISO 1302; Material: 1.4301 (V2A)

Figure 5 Technical drawing of the sample press-in tool with distance keeper (Top Tool). The shown tool is for HybridPACK Drive modules with silicon IGBTs 750V and 1200V.

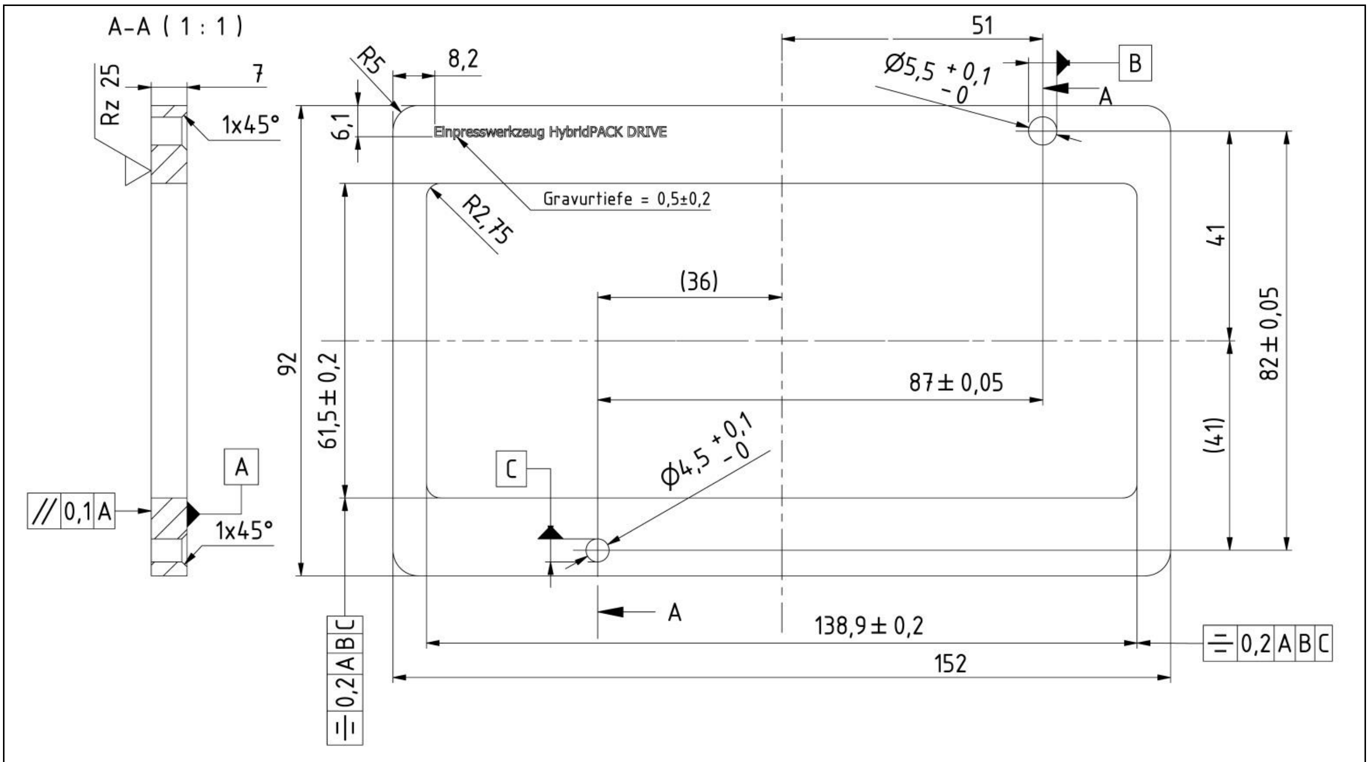


Edges: ISO 13715; Tolerance: ISO 2768 – mK; Surface: EN ISO 1302; Material: 1.4301 (V2A)

Figure 6 Technical drawing of the sample press-in tool with distance keeper (Top Tool). The shown tool is for HybridPACK Drive modules with SiC MOSFETs.

The 8 distance keeper can be designed with fixed standoff height but can be implemented as shown in the picture also as adjustable distance keeper (see Figure 4). Following items have to be considered.

- Press-tool distance keeper (1) should be designed at the positions of the 8x module baseplate holes.
- Press-tool distance keeper (1) should have a minimum 8mm diameter (9.4mm diameter in the sample tool).
- Maximum force press-in force of 3.5kN should not be exceeded.
- Press-tool distance keeper height (see XX value in the sample tool): Gap between PCB and module housing domes should be at least 100um after the press-in process. For most projects with typical 1.6mm thick PCB this value will be XX = 14.7mm.



Edges: ISO 13715; Tolerance: ISO 2768 – mK; Surface: EN ISO 1302; Material: ABS plastic

Figure 7 Technical drawing of the sample press-in tool (Bottom Tool).

The bottom tool can protect the underside of the power module (especially the PinFin and sealing area) against damage/scratching during the press-in process.

The press-tool can be used in a simple toggle lever press for engineering purpose or in a controlled machine for serial production.

3.4 Press-In Process

3.4.1 PCB alignment before the press-in process

The PCB can be assembled to the power module only in a correct orientation due to the poka-yoke mechanism of the X-pins. The PCB has to be positioned with a manual or automated handling tool to the X-pins without tilt. It is recommended to design a handling tool, which enables a significant play of the PCB in x-y direction. During the positioning of the PCB to the module the soft and round shaped X-pins will guide the PCB to the right position before the PCB will touch the pins. The signal pins itself will do kind of a “fine-alignment” while moving the PCB further down to the module. A low force in the range up to 10..20N in z-axis is allowed on the PCB to support the final alignment process. In final position (before the press-in process) the signal pins will appear clearly at the PCB topside for 1.6mm thick PCBs.
The system is ready for the press-in process when all pins are correctly inserted. They also appear on the topside of PCB. This status can be checked e.g. manually, by automatic optical inspection (AOI) or PCB height level (see Figure 8 for typical appearance after correct PCB alignment process).

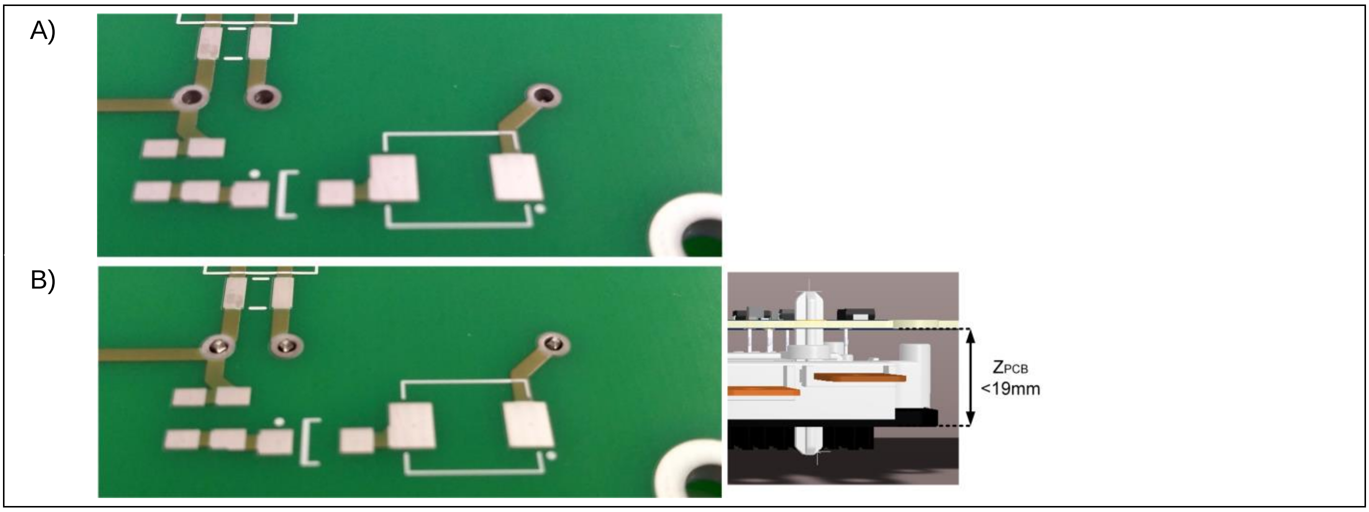


Figure 8 PCB at beginning of alignment process (A). After correct alignment, the pins are inserted in the PCB and are clearly visible at the PCB top side (B). The system is now ready for the press-in process.

3.4.2 Press-in process description

The press-in process is recommended with a controlled force-distance method for serial production. For testing under laboratory conditions, a manual toggle-press also typically gives good results.

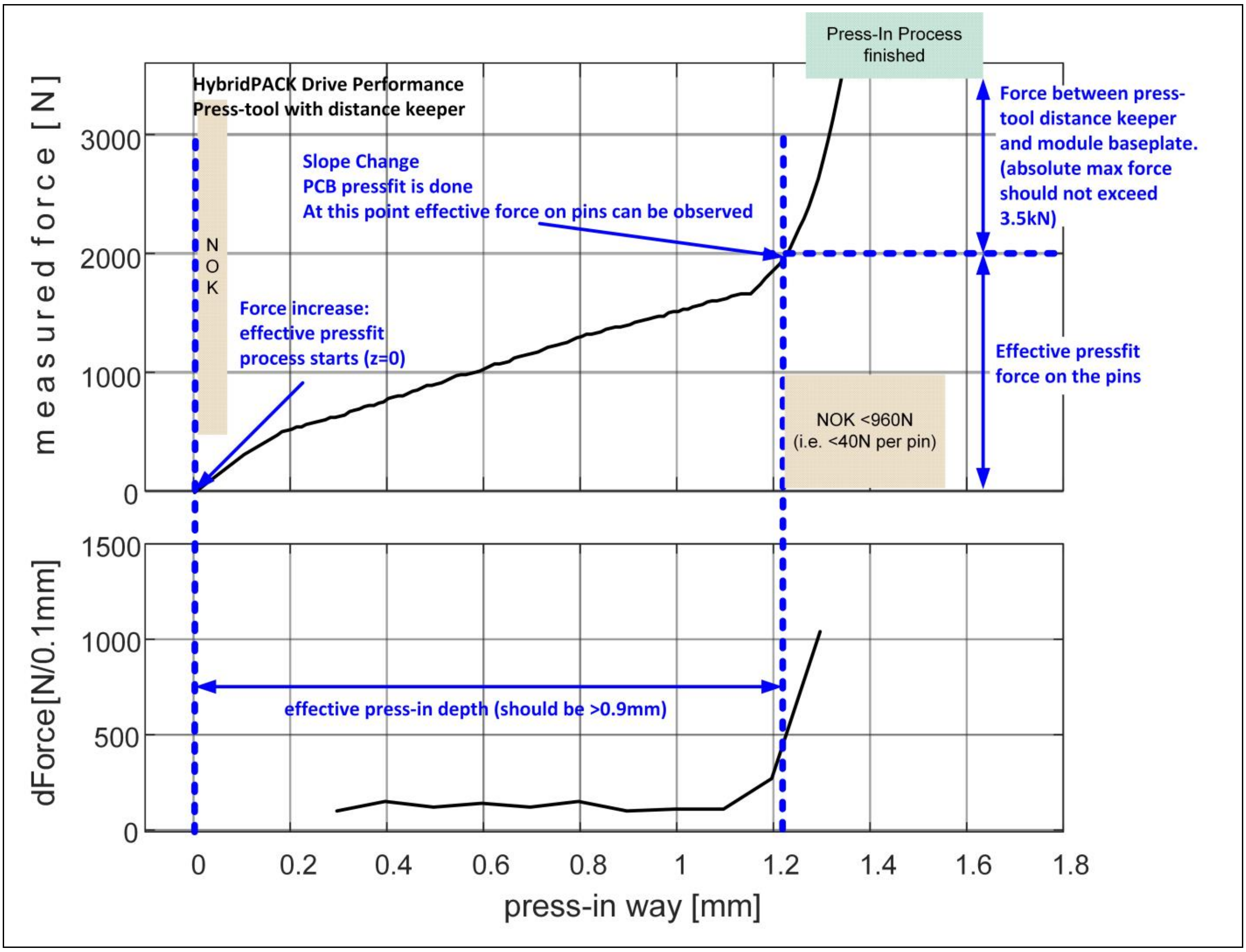


Figure 9 Typical way-force press-in diagram from a HybridPACK™ Drive Performance module with 24 signal pins using press-tool with distance keeper and maximum 3.5kN press-in force.

The Figure 9 show an example of a HybridPACK Drive press-in process. The press-in process starts when the force increases. At this point the z-axis is set to 0 mm in this diagram. In case an initial high peak is detected it may indicate a failure in the process like PCB hole plugged with solder, not properly inserted PCB before the process starts, machine collision with other external parts, etc.
The force curve will increase smoothly while pressing down the PCB (see diagram 0 to 1.2mm). This force curve will have same appearance for different press-in speeds. Lower press-in speeds as noted in Table 4 are not allowed as the press-in forces can increase and damage the pin. Higher press-in speeds are uncritical for the module. The maximum speed is noted with respect to press-in equipment limitation. A higher speed was not tested and is therefore not recommended.
The dF curve, which is the 1st derivate of the force-distance diagram is optional for press-in tools with distance keeper. But the dF curve give a useful indication for the effective press-in depth of the pins as well as the effective force at the pins.

Please note it is important that the press-in equipment is designed for the expected high forces. During the press-in process the bottom and top press tool must be parallel to each other and should be mechanically fixed without tilt.

Table 4 Overview press-in process

No	Description	unit	min.	typ.	max.	Remarks
1	Press-in speed	mm/s	0.4	2..4	8	During the press-in process it is not allowed to come under the minimum speed (no multistep press-in process). The maximum press-in speed is typically limited due to non ideal press machine. See explanation “stop criteria”
2	Recommended press-in stop force using press-tool with distance keeper (external mounted PCB)	kN			3.5	stop criteria only to be applied for press-tool with distance keeper and external mounted PCB.
3	Recommended effective press-in length	mm	0.9			The pin might be also gas tight at lower effective press-in length in case sufficient force was applied.

3.5 PCB design for module external mounting

With the described press-tool and process the PCB is pressed with at certain distance to the power module (see also Figure 10A). After the press-in a gap between PCB bottom side and the power module housing domes remain (see indicated area (2) in the Figure 10). Inverter system designer can implement a PCB fixing point outside of the power module (see indicated area (3) in the Figure 10). This fixing point has to be designed with a slightly lower height in order to provide PCB push force on the power module after fixing the PCB by screws to the fixing point. **It has to be clearly mentioned that no screws (i.e. the Ejot screws) are allowed at the module domes in case of module external fixation method.** A small gap between module and PCB is intended and has to remain after the final assembly.

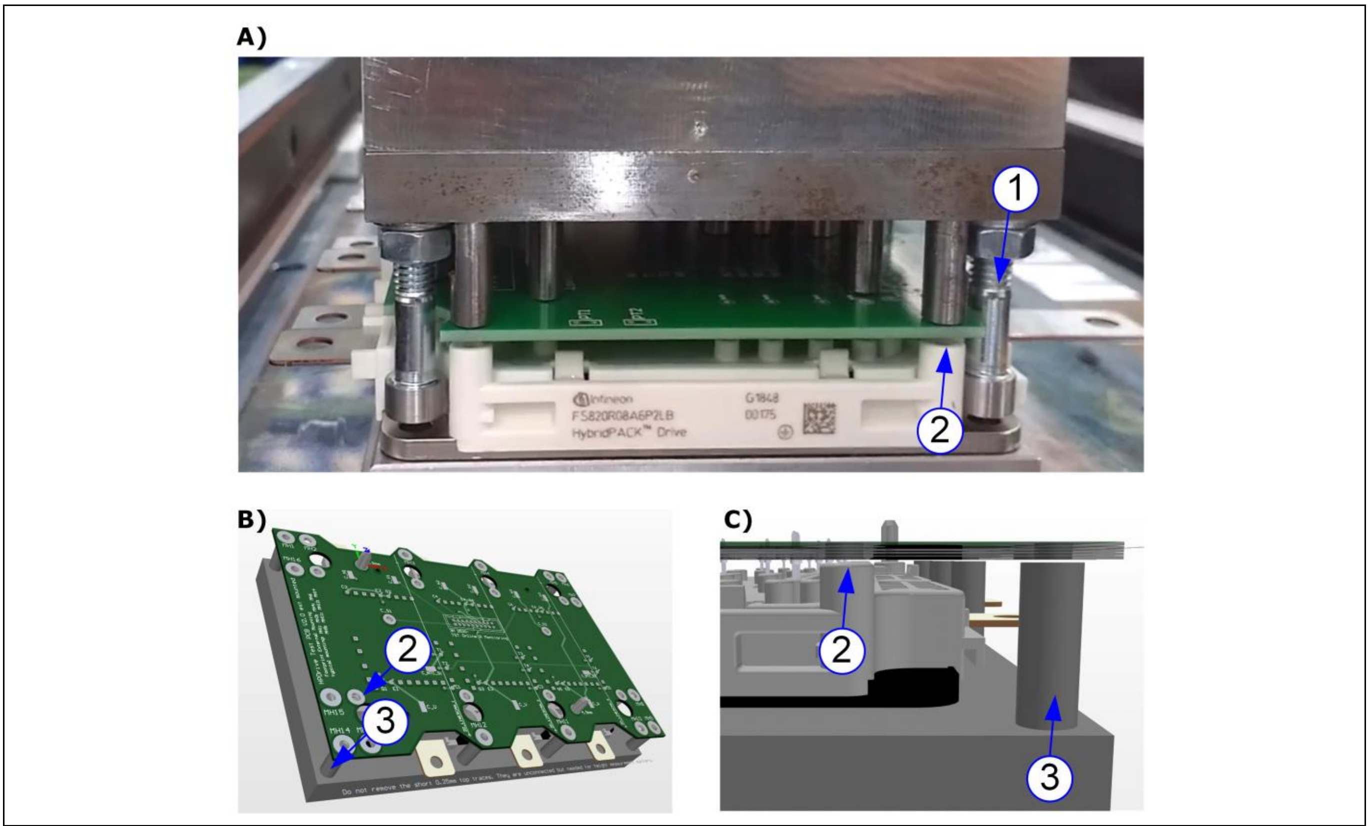


Figure 10 Example of distance press-in combined with module external mounted PCB. Distance keeper (1) ensure a certain distance of PCB to module dome (2). PCB can be fixed externally of the module (3).

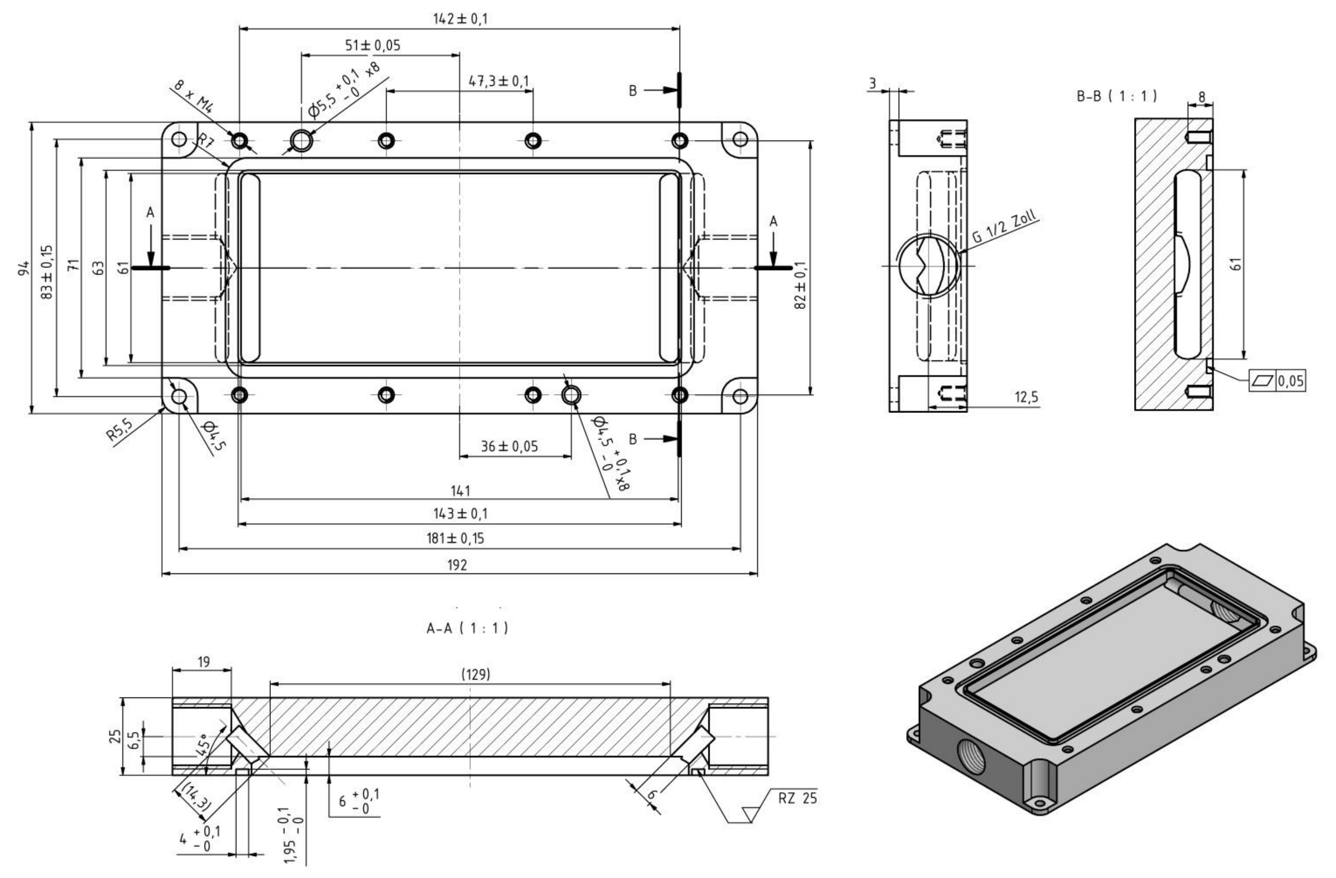
4 Power Module Cooling System

The power losses occurring in the module must be dissipated in order to not exceed the maximum permissible operating temperature specified in the datasheet. Therefore, the design of cooling system/heat sink is of great importance.
HybridPACK™ Drive Performance has a pin-fin array on the base plate, which makes liquid cooling very effective in sense of the thermal performance. The base plate is made of copper (Cu) material with nickel (Ni) plating. The pin fin structure is suitable for cooling fluids like water/ethylene glycol mixture.

PLEASE NOTE: During the mounting process, damage to the nickel plating or mechanical deformation of the pin fin structure as well as contamination, scratches or other damage in the sealing region (see Figure 12) must be strictly avoided.

4.1 Reference Cooler Design

The cooler design has a great impact on the overall cooling performance, which means the combination of thermal resistance/impedance, pressure drop, and cooling flow rate. Thus, for all of these thermal related product specifications a reference cooling system is needed, where the given specification values are valid.



DIN ISO 13715; ISO 2768-mK; DIN EN ISO1302; AlMgSi0.5

Figure 11 Reference cooler design for HybridPACK™ Drive Performance with its PinFin Cooling Structure.

The cooler can be designed differently if other tradeoffs of thermal resistance/impedance, pressure drop and flow rates must be achieved. Therefore, the reference cooler should be regarded as a design example, where the values from the corresponding product specification can be achieved.

The following requirements must be considered when either the reference design or other designs are used.

- **Roughness of the cooler: ≤ RZ25 (DIN EN ISO 1302) in area of the sealing.**
- **Cooler Flatness at the module area: ≤ 50 µm**

Exceeding the requirements above may lead to damage of the power module.

The cooler material should be AlMgSi0.5 or other alternative which is compatible to copper baseplate with nickel plating and which can withstand the mechanical stress required from a specific customer application.

The holes for the x-pins are designed in the reference cooler with a high margin (i.e. 8 mm depth holes). When necessary for the system design it is possible to reduce these holes to 6.0mm depth.

4.2 Recommendation for the sealing ring

The power module baseplate is designed with a flat region of 6.5 mm surrounding the entire pin fin area (see Figure 12). Considering a 4 mm thick groove for the sealing ring and a positioning tolerance of the sealing area and the alignment to the cooling system of better than ±1mm, it is convenient to achieve a proper sealing.

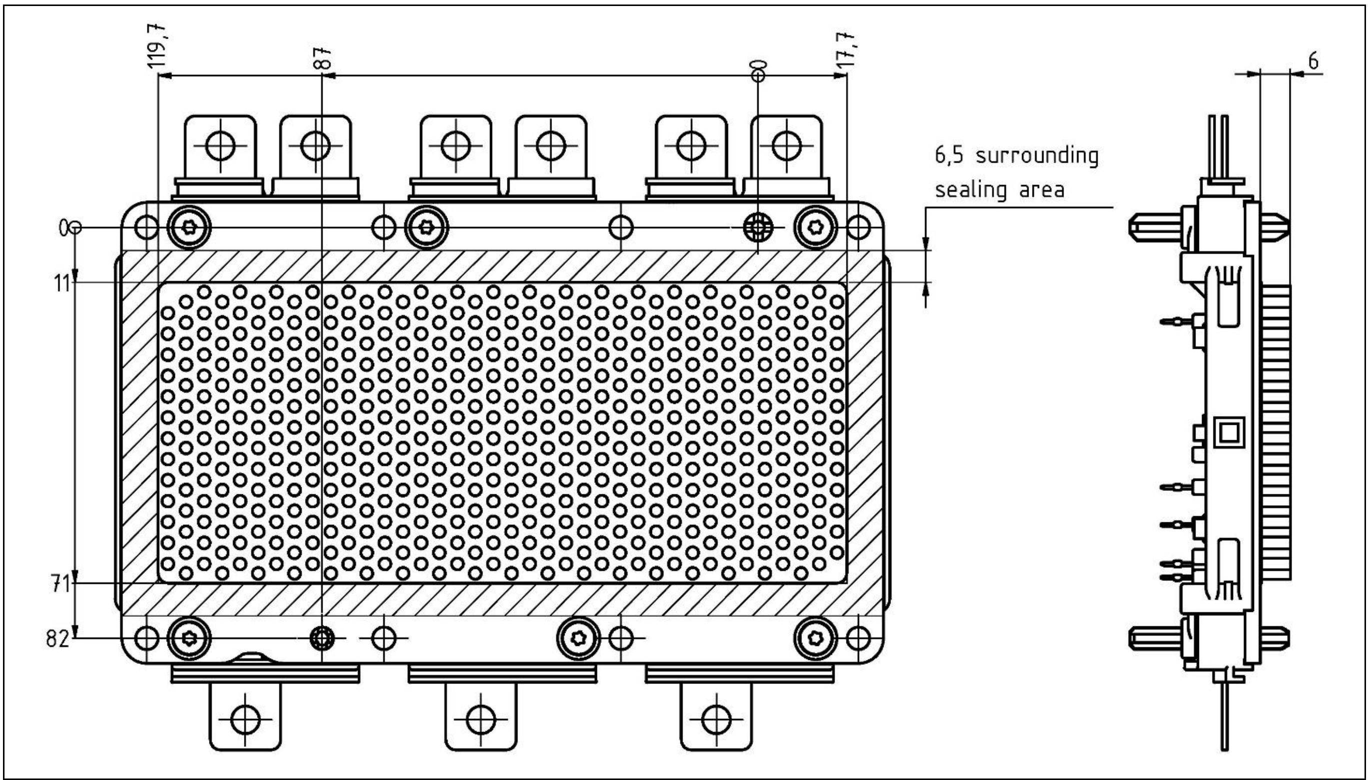


Figure 12 The sealing region with 6.5mm surrounding the pin fin area.

For initial evaluation and power module qualification tests where an assembly was required, a sample sealing ring from Dichtomatik GmbH (company of Freudenberg Sealing Technologies) part number 192944/192945 was used. This sealing ring was of EDPM 70 material and had a specification shown in Figure 13. For easier assembly and even higher robustness margin, a double sealing ring can be applied (see Figure 13).
In the meanwhile Freudenberg Sealing Technologies has developed an optimized sealing ring design under the part number OR-SF19023 and is available for open market.

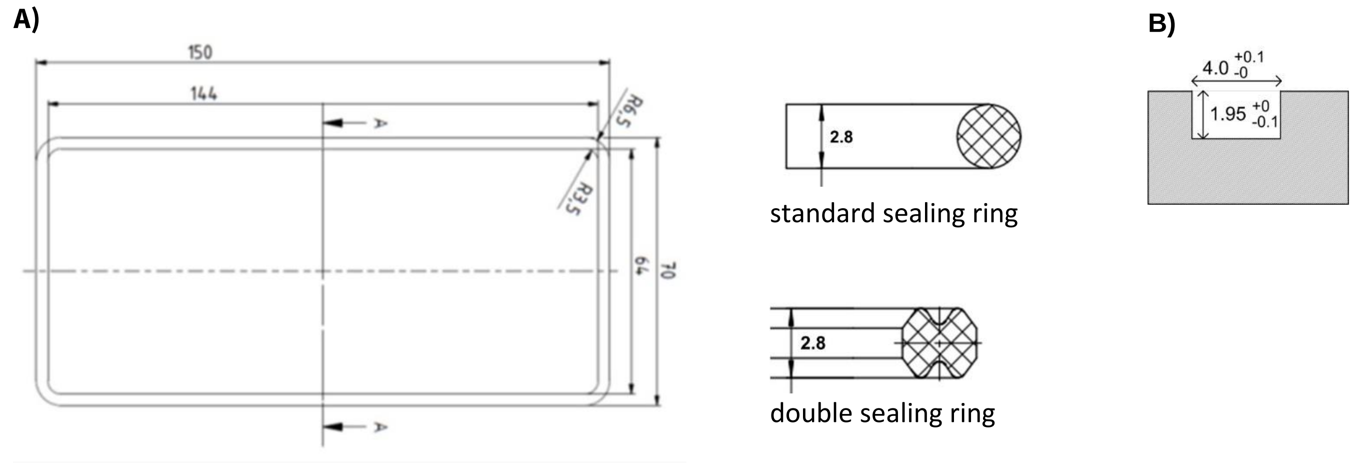


Figure 13 Drawing of a EPDM 70 sample o-ring (A) and corresponding groove size in the cooler (B).

The company Shanghai Transtech Sealing Technology designed a derivate of this initial design with the article number: YA-15070-E7061. This sample design was also applied in monitoring qualification and release of new products in the HybridPACK Drive modules, where mounting on cooler system was required for the test.
This design has "assembly knobs" supporting an easier assembly process. These knobs can fix the sealing ring after it is attached to the cooler groove and will avoid the risk of displacements during the module assembly process.

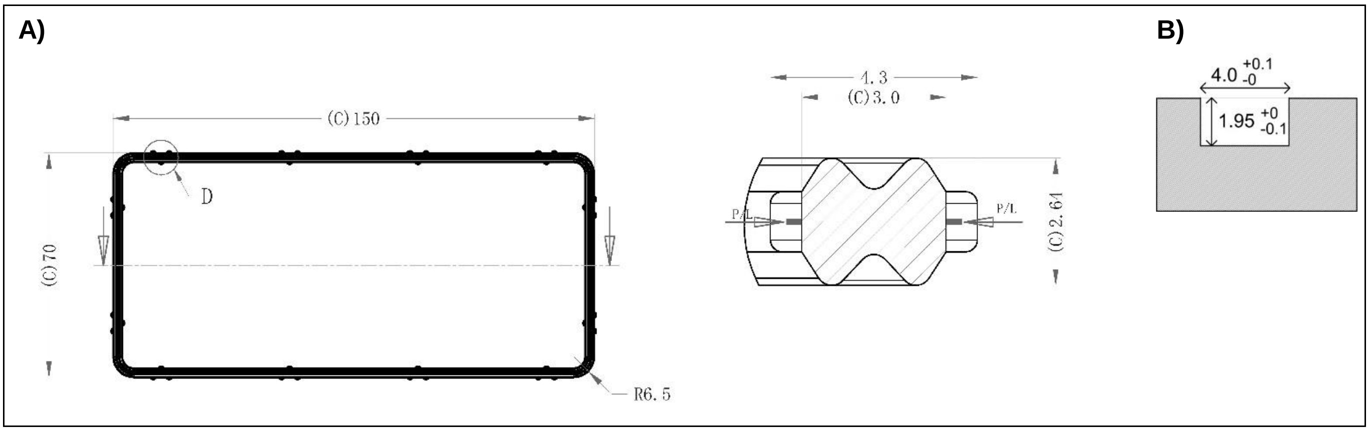


Figure 14 Drawing of sample sealing ring designed by Transtech with knobs supporting the assembly process (A). Corresponding groove size in the cooler (B).

The sealing ring is held in a groove, which must be designed in the cooling system.
It should be noted that the sample sealing rings shown above lead to positive results in power module qualification tests. Nevertheless, it is necessary to perform system qualification test (e.g. according to LV124) if final system design and assembly meets the project specific application needs.

PLEASE NOTE: Infineon does not recommend the usage of a silicon gasket or other sealing methods. The usage of sealing methods different than sealing ring can cause damage on HybridPACK™ Drive module.

4.3 Cooling fluid

A general recommendation for a specific cooling fluid cannot be provided, as the power module is only one single part in the entire cooling system. Following items have to be considered at the system supplier to find appropriate coolant fluid:

- Coolant fluid with its corrosion protection has to be compatible with the aluminium of the cooler material and the nickel overplated Cu module baseplate.
- Also other parts in the coolant system has to be compatible to the fluid type (e.g. Zn screws and chrome parts are typically not allowed in the cooling system).
- The fluid mixture has to provide enough anti-freeze for the application conditions. Freezing events of the fluid has to be strictly avoided. Freezing fluid will lead to plastic deformation of the power module baseplate and may lead to fluid leakage and/or isolation failure consequently.

For power module tests at Infineon where cooling is required (e.g. thermal characterization, power cycling tests) typically BASF Glysantin™ G30™ with an organic-acid-technologie (OAT) silicate-free corrosion protection is applied.

5 Screw types and processes

5.1 Baseplate Mounting Screws

The power module baseplate is designed to be fixed on the cooling system by means of M4 screws.
A standard screw M4x10 ISO 4762 (DIN 912 A2) with washer M4 ISO 7090 (DIN 125 A2) may be possible, depending on mechanical application constraints (e.g. vibration, max pressure test,…). Considering production complexity and highest mechanical robustness, we recommend the following screw type to fix the baseplate to the AlMgSi0.5 cooler:

Table 5 Recommended baseplate fixing screw M4x10 ISO 7380-2 A2 (TX)

No	Description	min.	typ.	max.	Remarks
1	Mounting torque	1.8 Nm	2.0 Nm	2.2 Nm	
2	Max mounting speed			400rpm	
3	Effective length of screw in cooler	6mm			AlMgSi0.5 cooler material. Typical M4x10 screws are used.

Figure 15 Picture of recommended screw type M4x10 ISO 7380-2 A2 (typical appearance). The correct type has -2 suffix to the ISO norm and is a screw with flattened round head (German: Linsen-Flanschkopfschraube). The recommended screw type is also available with a TX20 screw head: ISO 7380-2-A2-TX.

Table 6 List of suitable baseplate fixing screw types for HybridPACK™ Drive

Type	Description	Remarks
M4x10 ISO 4762 screw M4 ISO 7090 washer	Standard M4 screw and washer	Due to production complexity/cost only for lab testing recommended.
M4x10 ISO 7380-2 A2	M4 screw with integrated washer	
M4x10 ISO 7380-2 A2 TX	M4 screw with integrated washer and TX20 screw head.	Recommended for low to high volume production
EJOT ALtracs Plus WN5152 AP 40x12/10	Self-tapping screw (see section 5.1.1 for requirements)	Recommended for high volume production.

5.1.1 Alternative: self-tapping screws for baseplate mounting

Self-tapping screws are well known for use in plastic materials but are also available and established since several years for metal materials. The main advantages are the elimination of drilling and thread cutting as well as the corresponding cleaning processes. This can lead to significant cost reduction and process time reduction for cooler manufacturing at high production volumes. Furthermore, such self-tapping screws are known to be extremely rugged during vibration stress

The following rules and recommendations are given for the screw type:

EJOT ALtracs Plus WN5152 AP 40x12/10

The baseplate fixing points in the cooler has to be adjusted as shown in the drawing of Figure 16.
The self-tapping screw should not be used in standard M4 threads.

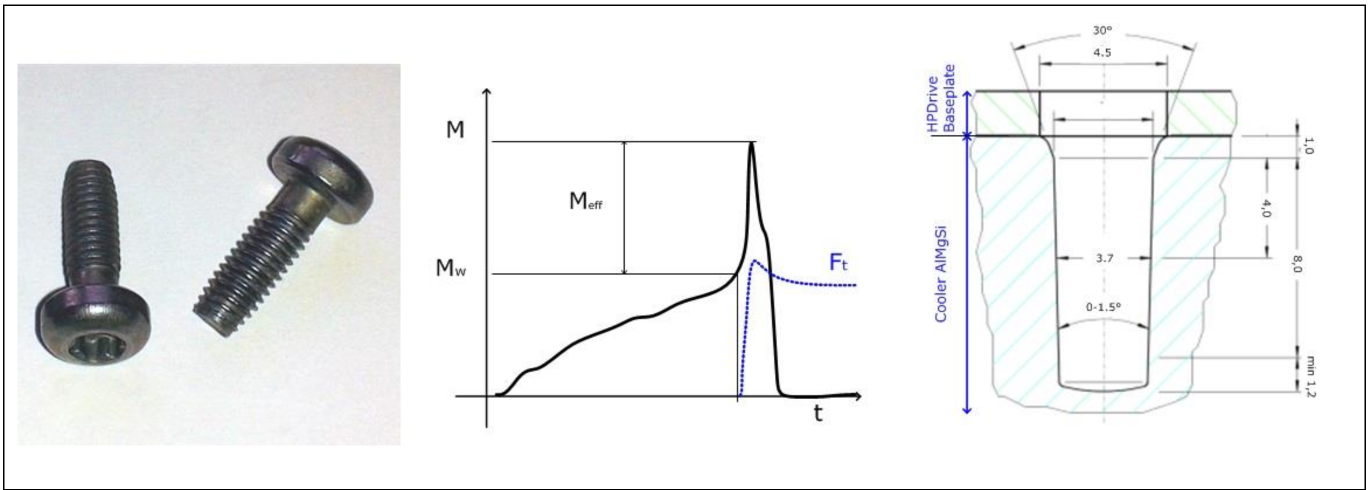


Figure 16 Picture of the self-tapping EJOT ALtracs Plus WN5152 AP 40x12/10. A typical torque and mounting force diagram as well as drawing of the required fixing holes in the cooler. The holes can be also drilled with a standard drill tool (3.7mm 0°).

Table 7 Alternative baseplate fixing screw EJOT ALtracs Plus WN5152 AP 40x12/10:

No	Description	min.	typ.	max.	Remarks
1	Mounting torque M_{eff}	1.6 Nm	1.8 Nm	2.0 Nm	Approx. Mw=2 Nm torque is required for the self-tapping. This torque is not effective for the mounting force Ft. Self-tapping force strongly depends on cooler material.
2	Recommended mounting speed	400rpm		600rpm	Lower than 200rpm is not recommended
3	Module Clamping/Fixation during mounting		2 kN		Self-tapping screws require single step mounting and appropriate module clamping. See section 5.2

Further important notes to avoid burrs and flakes in the final system:

The fixing holes in the cooler must be blind holes (no clearance holes).

Only one time mounting is feasible.

The geometry of the EJOT screw is designed such that the burrs and flakes are only generated at the bottom of the screw thread.

The screw self-tapping moment depends on the cooler (housing) material. Infineon recommends to perform mounting experiments with final cooler material. In these experiments the screw torque should be recorded. The cooler material specific self-tapping torque can be observed from the recorded data as shown in the example with the reference cooler made of AlMgSi0.5 material.

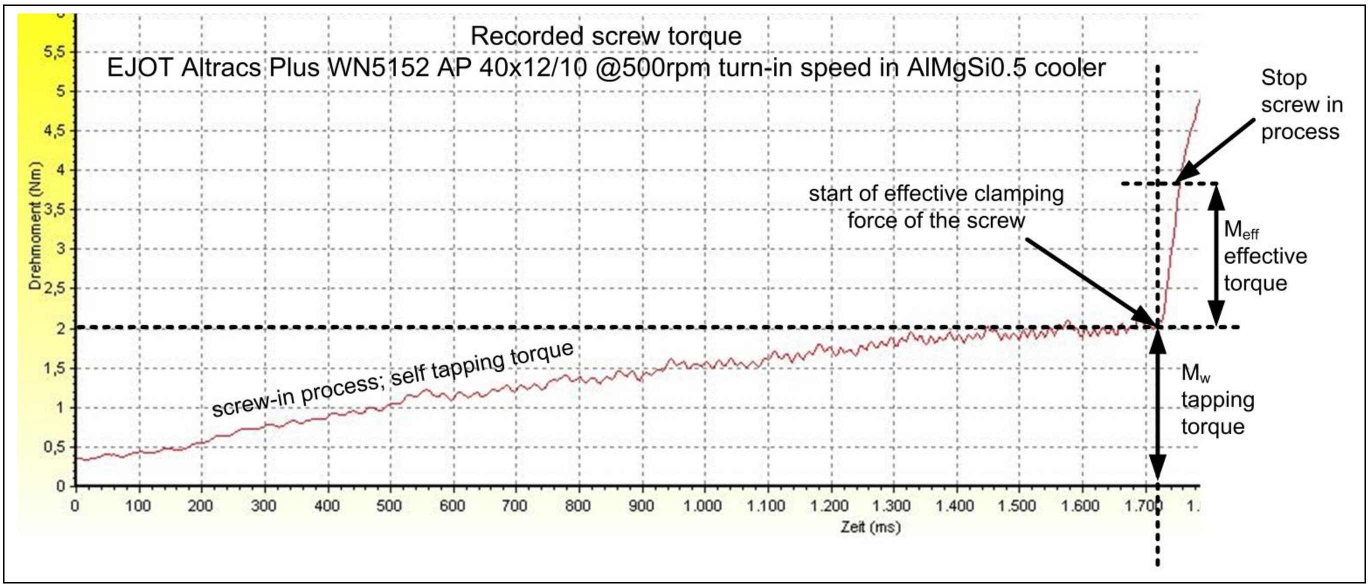


Figure 17 Recorded screw torque in CNC machined cooler from AlMgSi0.5 material. The self tapping torque was at several experiments was in average 2.0Nm. For this part a total screw torque of 3.8Nm would lead to an effective screw torque of the required M_{eff} = 1.8Nm.

5.2 Fixation/clamping of the module during the baseplate screw process

It is required to fix properly the power module to the cooler during the screwing process in order to avoid tilting of the module with a possible damage (i.e. plastic deformation of the baseplate).

Following methods are preferred for module fixation. Screw orders are listed in section 5.4:

1. **Multi-Step Screw Mounting:** Place screw number 1 & 2 and fix with lowest torque (this avoids only module tilting and will not to provide a high clamping force). Fix screw 3 to 8 with low torque (e.g. 0.4-0.6 Nm). Fix screws with final torque as specified.

2. **Module Clamping:** After the power module (with PCB) is placed onto the cooling system the module should be clamped in z axis of the module with a total force of **Fc = 2 kN** to ensure that the sealing ring is fully compressed during the screwing process. The clamping can be performed in the area where the PCB mounting domes are located. Eight 2.3mm (-0.1) diameter stamps can be used to apply the force in the corresponding module housing blind holes. It is important that the PCB is not further pushed down during the clamping especially in the mounting methods where the PCB is pressed with a certain distance to the module domes. A schematic 3D drawing with a sample clamping tool as described in shown in the Figure 18.

Please note that the described 1st fixing method with multi step screw mounting is not suitable for self-tapping screws. For self-tapping screws it is mandatory to use proper clamping which enables a single step screw mounting.

It is important for external mounted PCBs, which have a gap between PCB and module housing that the PCB is not pushed down to the module!

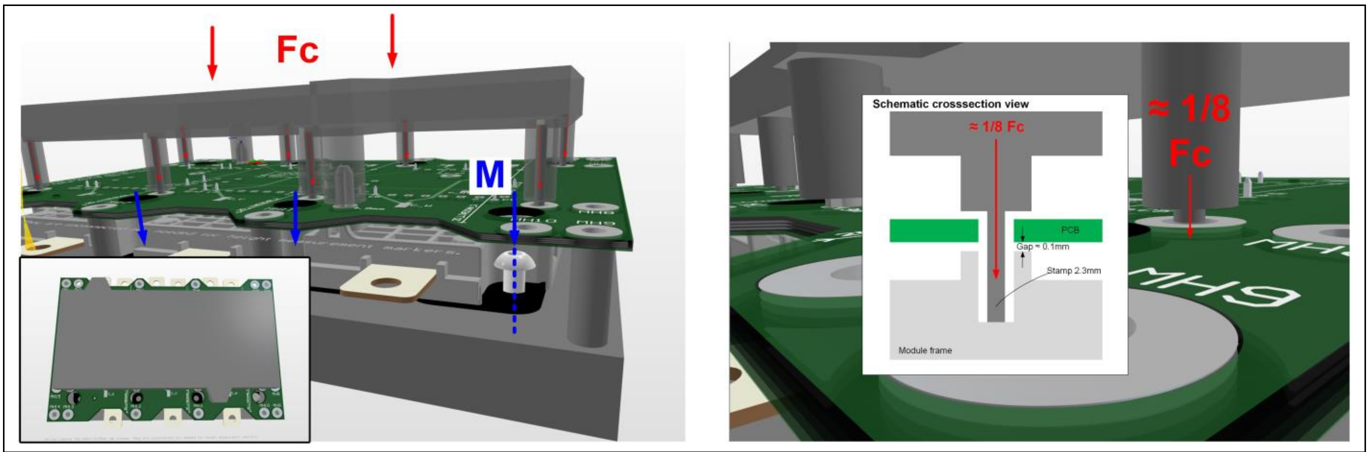


Figure 18. Module clamping with force Fc during the baseplate screw process. The shown clamping tool uses 2.3mm (-0.1) stamps in blind holes of the frame dome to apply the force directly to the module. The clamping tool does not apply a force to the PCB.

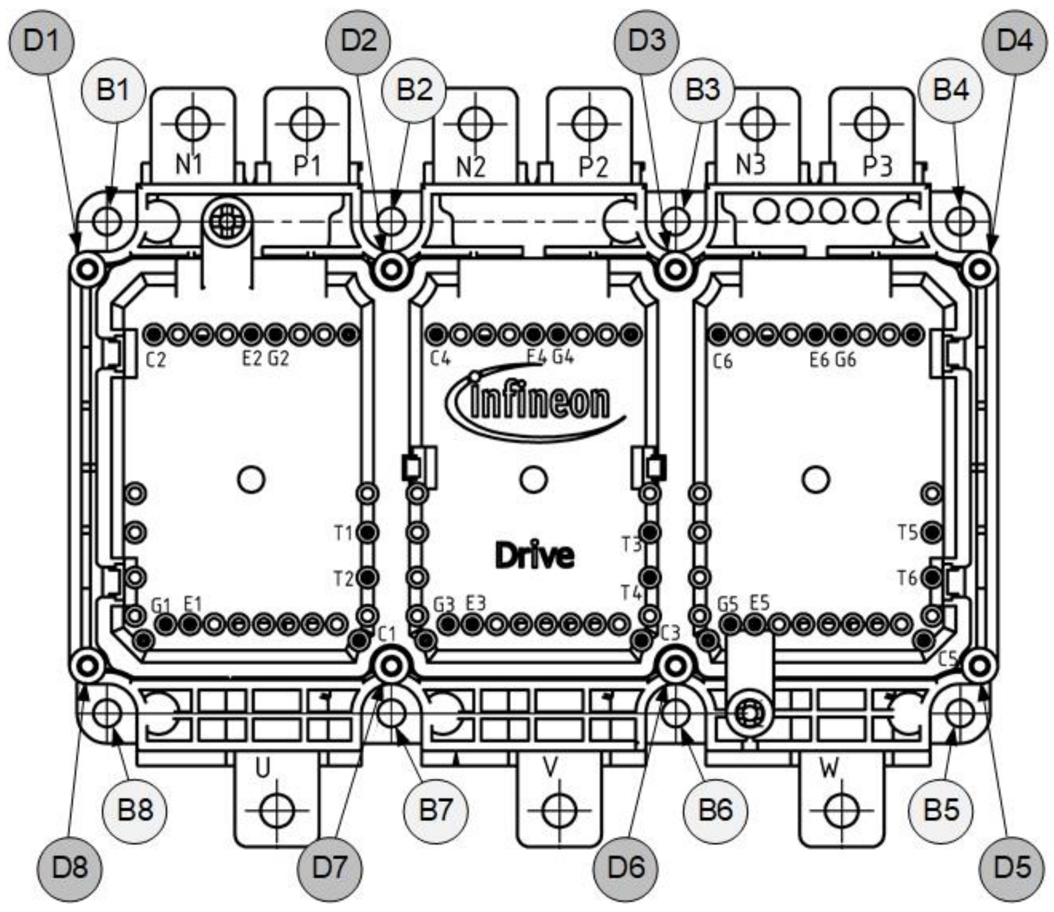
5.3 PCB mounting (module external)

For the described assembly method in this application note the PCB is fixed externally to the module directly at the inverter housing. Please align with the responsible engineer of the inverter housing for the appropriate fixation type and process.

It has to be clearly mentioned that no screws (i.e. the Ejot screws) are allowed at the module domes in case of the described module external fixation method.

5.4 Screw Orders (Baseplate and PCB)

The screw order as shown in Figure 19 is very important in order to avoid damage on the part. Please see section 5.1 and 5.3 for specification of screw type and torque as well as required processes like module fixation/clamping during the baseplate screw process.



Baseplate fixing after module assembly into cooler			PCB fixing after base plate screwing	
baseplate screw order	Position		PCB screw order	Position
1	B2		n.a. (module external)	n.a. (module external)
2	B6		n.a. (module external)	n.a. (module external)
3	B3		n.a. (module external)	n.a. (module external)
4	B7		n.a. (module external)	n.a. (module external)
5	B4		n.a. (module external)	n.a. (module external)
6	B8		n.a. (module external)	n.a. (module external)
7	B1		n.a. (module external)	n.a. (module external)
8	B5		n.a. (module external)	n.a. (module external)

Figure 19 Screw order for baseplate and PCB screws.

6 Connecting to the Power Terminals

6.1 Mounting Options

The copper power tabs are tin-plated and are thus well suited for screw type connections including clinch processes as well as welding processes.
Several mounting options are suitable and some examples are illustrated in Figure 20 where the HybridPACK™ Drive is connected to a DC-link capacitor. It is possible to have the mounting order:

screw – power tab – busbar – nut (Figure 20 Opt. 1),
nut – power tab – busbar – screw (Figure 20 Opt. 2),

In the examples the busbar is always a single part/sheet, but also two or three busbar sheets are possible to be mounted in the stack and thus it is also possible to have instead of the screw head/nut only busbars as a direct interface to the power tabs:

e.g. screw – busbar - power tab – busbar – nut.

Further beneficial mounting options are given by the use of self clinching nuts. Standard M4 self clinching nuts can be used in mounting holes designed for M5 screws. Thus, a M4 self clinching nut can be pressed into the power tab hole and busbars can be connected with a M4 screw (preferred the same screw type as used for mounting the baseplate to the cooling system). In case the mounting order is reversed it is possible to use a M5 self clinching nut in a busbar and to use a M5 screw on the power tab side as counterpart (i.e. mounting option 4 in Figure 20 and Table 8).

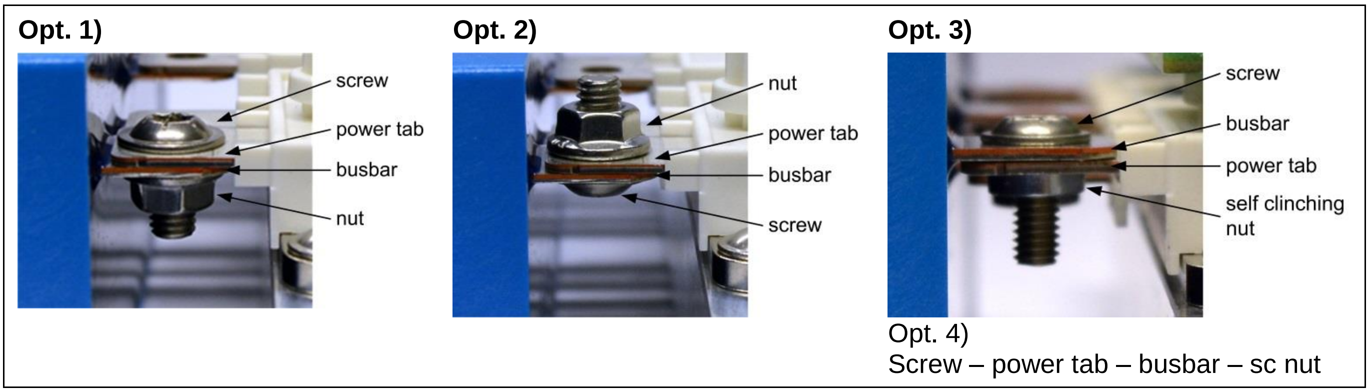


Figure 20 Examples of power tab connection options.

Table 8 Power tab mounting options and recommended screw torque

Mounting Option	Screw/Nut type	Mounting torque			Remarks
		min.	typ.	max.	
1,2	M5 ISO 4762 screw (M5 ISO 7090 washer) M5 ISO4032 nut	3.6 Nm	4.0 Nm	4.4 Nm	low volume production & lab testing
1,2	M5 ISO 7380-2-A2-(TX) screw M5 ISO6923 nut	3.6 Nm	4.0 Nm	4.4 Nm	low volume production & lab testing
3	M4 ISO 7380-2-A2-(TX) M4 self-clinching nut e.g. “TR-S-M4-1” PEM “S-M4-0ZI”	1.8 Nm	2.0 Nm	2.2 Nm	Low to high volume production & lab testing

4	M5 or M4 ISO 7380-2-A2-(TX) screw M5 or M4 self-clinching nut in busbar/capacitor (depending on busbar/capacitor design)	3.6 Nm	4.0 Nm	4.4 Nm	Low to high volume production & lab testing
5	welding	-	-	-	high volume production

The screw types in table give only a rough overview. Different types may be possible with same mounting torque in case the base of head or the spot face are comparable to the given types and the busbar material is suitable for such mounting.

6.1.1 Additional Information for Welding Processes

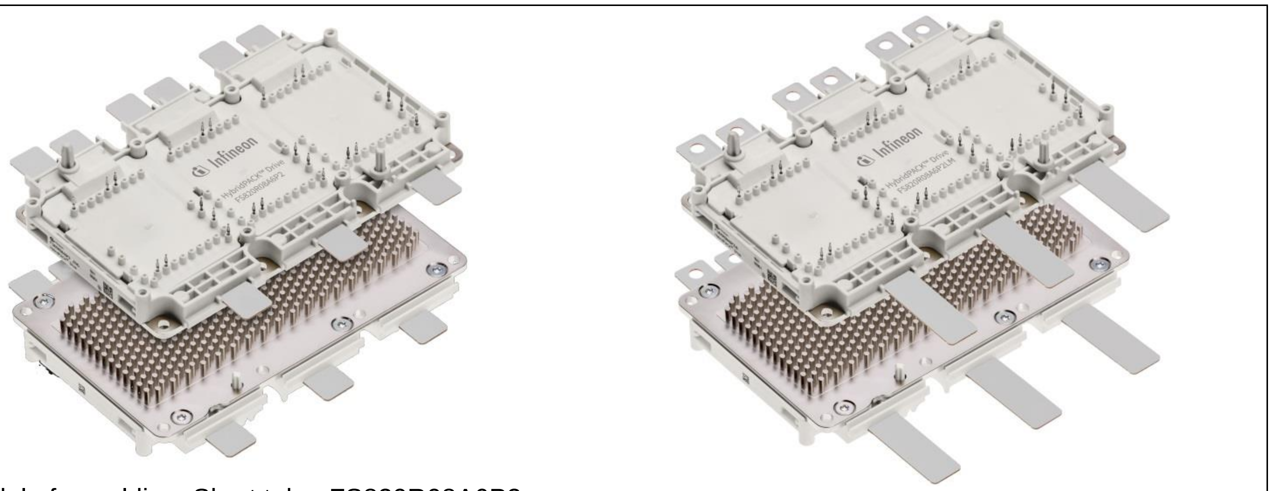
The HybridPACK™ Drive power modules without an 'B' in the ending of the type designation (e.g. FS820R08A6P2~~B~~) indicates a module frame, which has no mounting hole in the power tab. Examples of these module types can be seen in Figure 21 . These plain power tabs of these products can be connected by means of welding processes. The welding process with its specific parameters have to be evaluated by the customer. A general recommendation to the process type or parameters is not possible as it is also depending on the companion material of the busbar and the available welding equipment at the customer. Studies of institutes give a comprehensive guide for the pre-selection of applicable welding process types and can be found e.g. at [1] table 3.3 or [3].

Material property of the power tabs for selecting the welding process:

Copper Type: oxygen free copper type
Plating: galvanic tin

Please note that the power module frame has to be limited to 150°C during the welding process.

A laser welding machine supplier, which has already successfully performed pre-tests on the HybridPACK Drive power tabs can be found under [4].



Module for welding. Short tabs. FS820R08A6P2 (no B at the end of type designation)

Mixed version (LM). DC side screws and AC side long tab for welding FS820R08A6P2**LM.**

Figure 21 HybridPACK Drive Modules suitable for welding.

6.2 Forces on Power Tabs

The system mounting should be designed in a way that minimal force is applied on the power tabs of the power module. The tested and allowed forces on the power tabs are given in Figure 22. The specified force shown on one single tab is allowed simultaneously at all power tabs.

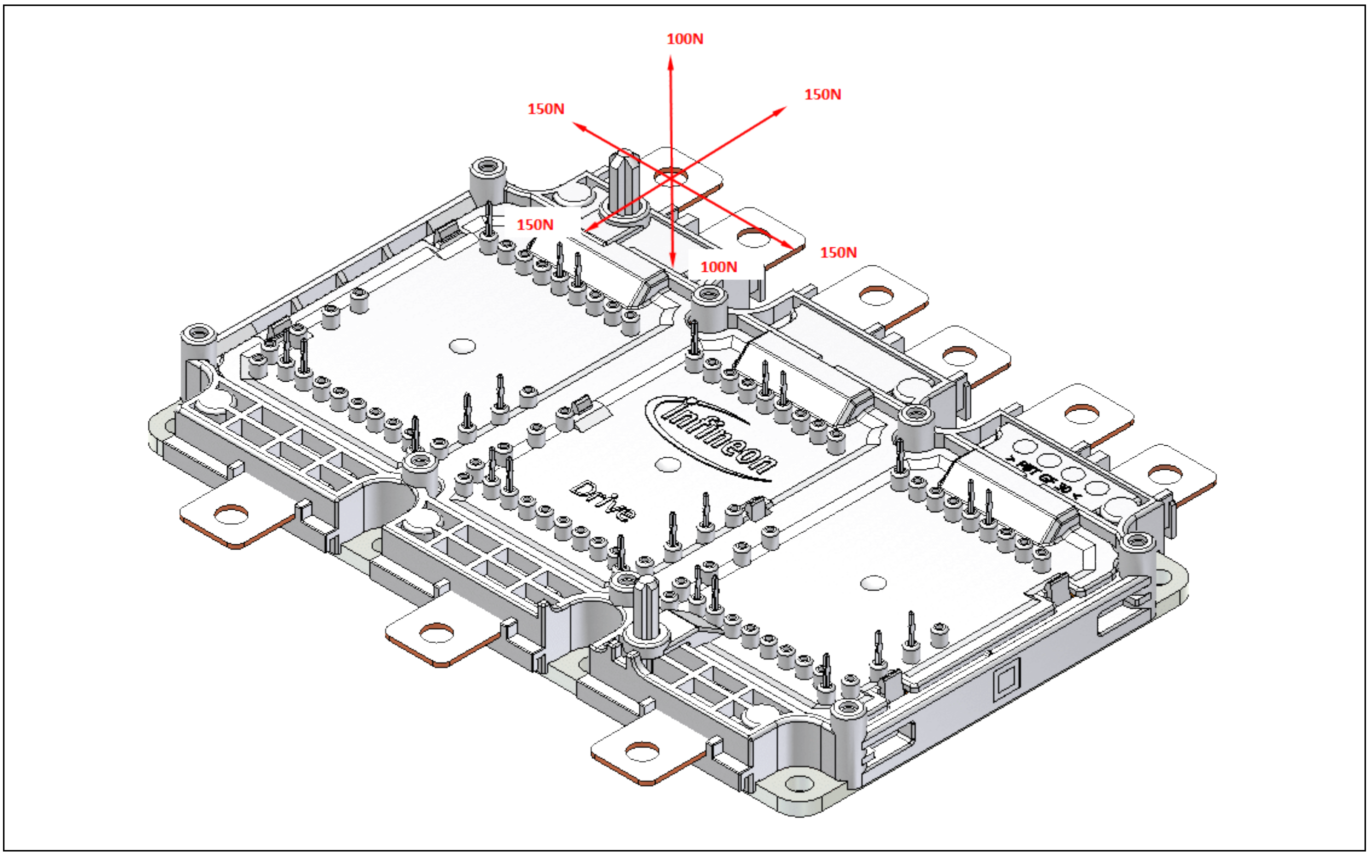


Figure 22 Allowed forces on the power tabs.

7 System Assembly Clearance & Creepage Distances

The datasheet of the HybridPACK™ Drive specifies clearance & creepage distances of the product itself. It is obvious that external parts can modify these distances in the system and thus it is mandatory to check clearance and creepage distances of the entire final system assembly.

Figure 23 shows an example where the power terminals are connected with screws by means of a standard hexagonal nut.

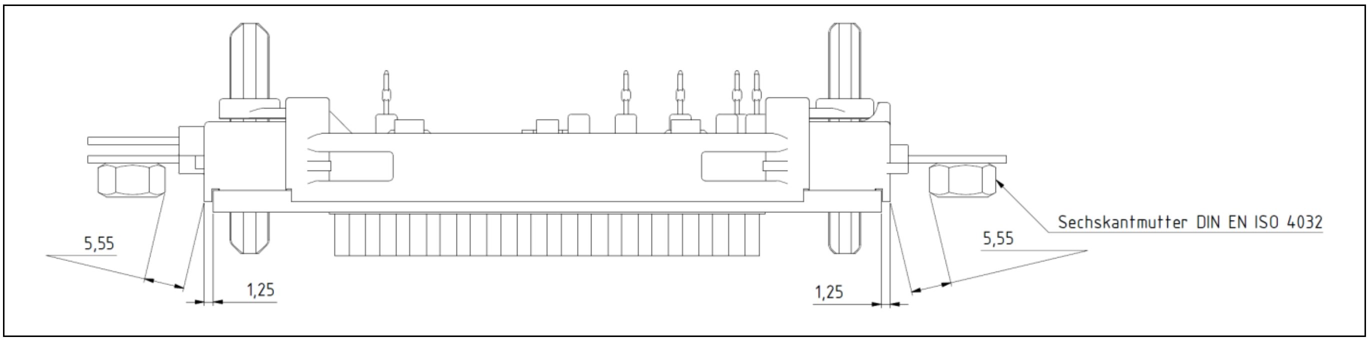


Figure 23 HybridPACK™ Drive with a hex nut (ISO 4032) for the power tab connection. The clearance shown in the drawing is uncritical as it is higher than the minimum product clearance itself of 4.5mm.

Even considering a fixing tolerance of ±0.25mm the clearance distance shown above is higher than the minimum clearance in the module product itself, which is 4.5mm according to the product datasheet.

Please note: The distance to the cooler, housing, (all external parts), must also be checked. For example, the distance from the hex nut to the cooler. This can be done only on system level. Appropriate keep out or covering with isolating parts (plastic) can typically increase critical distances in the system design.

8 Traceability, Data Matrix and Part Markings

Traceability of materials, equipment and processes is a must for key automotive components. Therefore, the HybridPACK™ Drive is produced at Infineon in a seamless traceability environment. Nevertheless, traceability must not be aborted after the modules are shipped to the customer and assembled into the inverters. In order to reap the full benefit of a traceability chain, the unique module number (module ID) should be linked to the inverter ID at customer side.
Figure 24 shows the module labels and where to find the DMX-code necessary for tracing the module-ID.

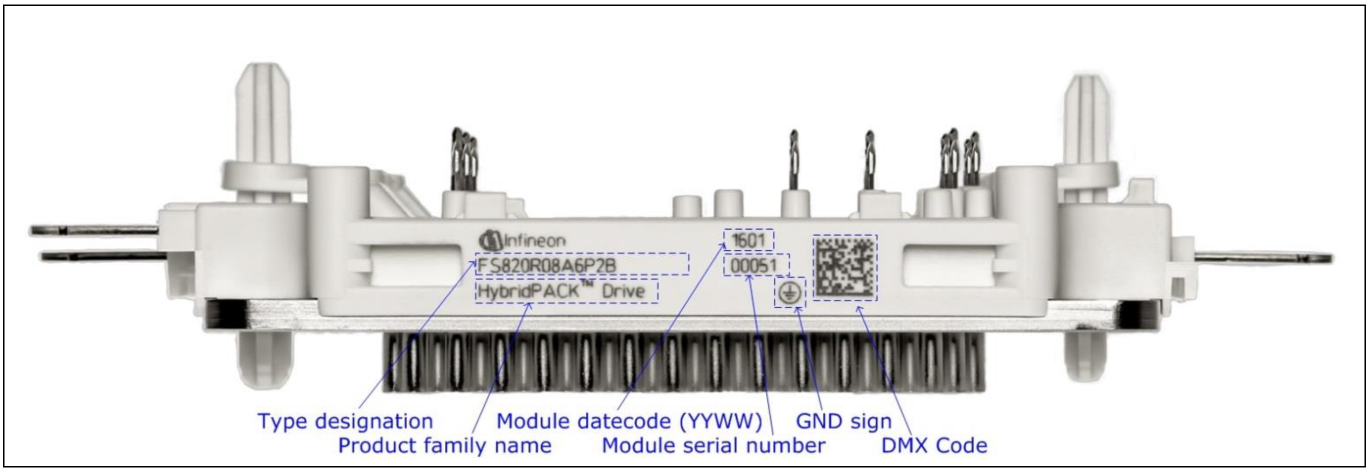


Figure 24 Picture of module labels (typical appearance). For a seamless traceability the DMX code which is the module ID (or alternative the type designation + date code + serial number) should be recorded and linked to the inverter ID.

The DMX code is readable with all professional data matrix code scanners compatible to the IEC24720 and IEC16022 standard.

Engineers in the lab can also use free DMX code reader apps on their smartphones.

Android: QR Extreme, QR Droid, and many others supporting data matrix codes.

iOS: i-nigma QR, and many others supporting data matrix codes

9 Technical Drawing

9.1 Basic Explanation Coordinate System

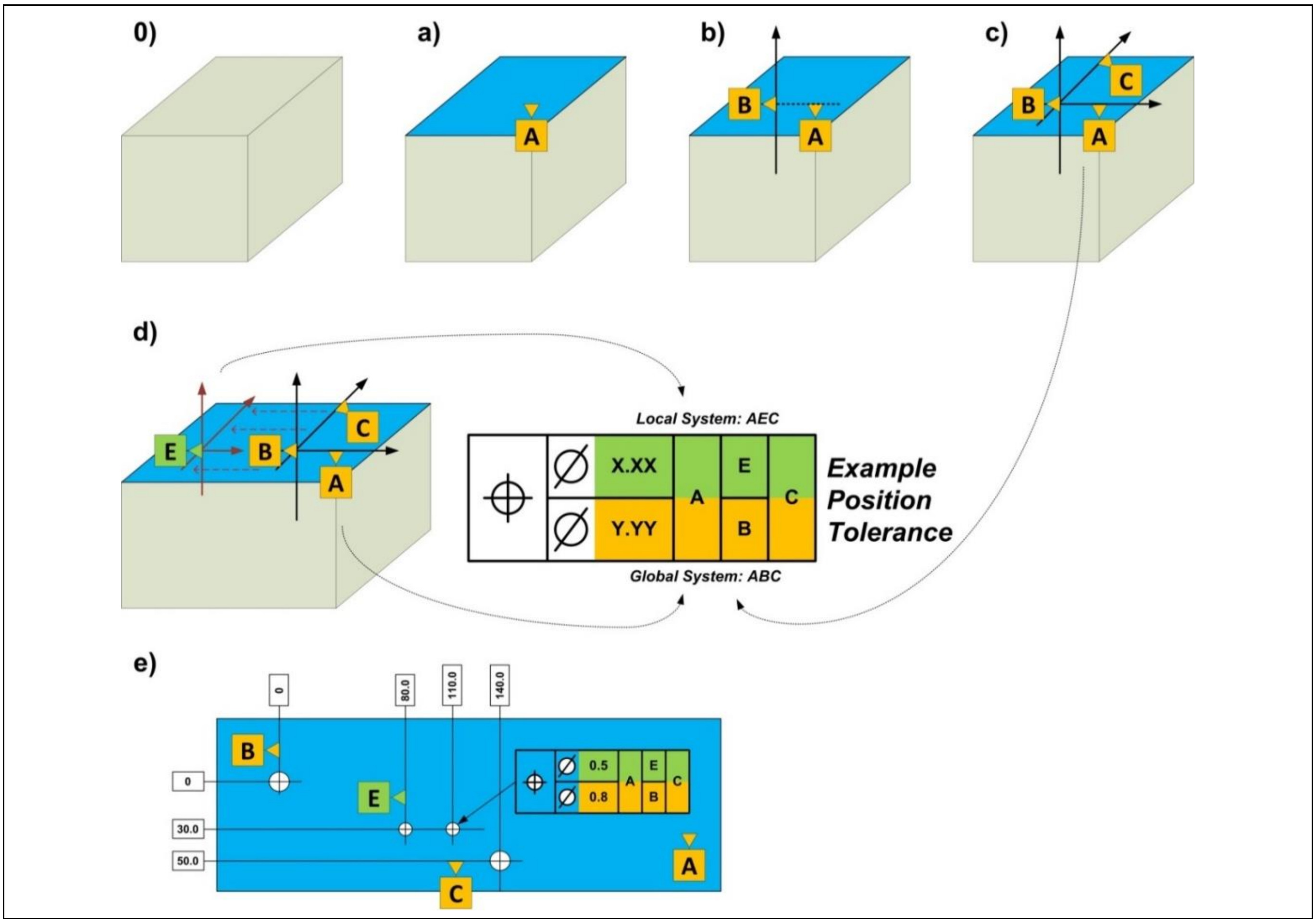


Figure 25 Technical drawing with global and local coordinate systems as utilized by the HybridPACK Drive.

The drawing of the HybridPACK Drive utilizes a global coordinate system, which is defined by the X-Pins and is mainly used for pre-alignment. The position of all elements like signal pins, mounting domes, etc. are given in this global system and makes it simple for designing companion parts like the PCB, busbar and housing.
Furthermore, important interfaces like mounting domes, signal pins are also defined in local coordinate systems, where position tolerances can be defined more precise.
With such a drawing, the companion parts will be typically designed with respect to the relative tolerances from the corresponding local systems and the positioning of the companion part to the power module can be best designed/checked in the common global coordinate systems.
Figure 25 show the basics of technical drawings with global and local coordinate systems. A coordinate system is here defined by three elements. The 1st element defines a surface (see Figure 25a). The position where the line of the 2nd element vertical crosses the surface of the 1st element defines the origin (see Figure 25b). A further line from the 3rd element to the origin defines the rotation of the final 3D Cartesian coordinate system (see Figure 25c).
An additional local coordinate system can be defined when one or more elements are shifted. In the example of Figure 25d, the 2nd element (B) is replaced by element (E). The result is a local coordinate system, which is linear transformed to the global system. These local systems enables a comprehensive way to define relative tolerances of e.g. pin positions, mounting domes, etc. .

9.2 Pin Position and Pin Gauge

For power modules which have in product specification a note as shown in Figure 26A, a pin gauge test is implemented in the production line at Infineon. The specification of this pin gauge is shown in Figure 26B for pinning as implemented in FS950R08A6P2B. For other signal pin pattern like for the SiC MOSFET modules the positions of the signal holes are different but hole size spec will remain same. At power module production the parts are tested if pin gauge can be applied to the module. A low force in module z-direction on the gauge are allowed (typical up to 10..20N, which is uncritical for the module and its pins). When the pin gauge can be smoothly attached to the module the test is rated as PASS and can be seen as a test if customer can later smoothly assembly their PCBs on the power module.
The basic description of the test and pin gauge specification is placed only for information how these modules are tested at Infineon production. It is not needed at customer side to test power modules at incoming inspection again.

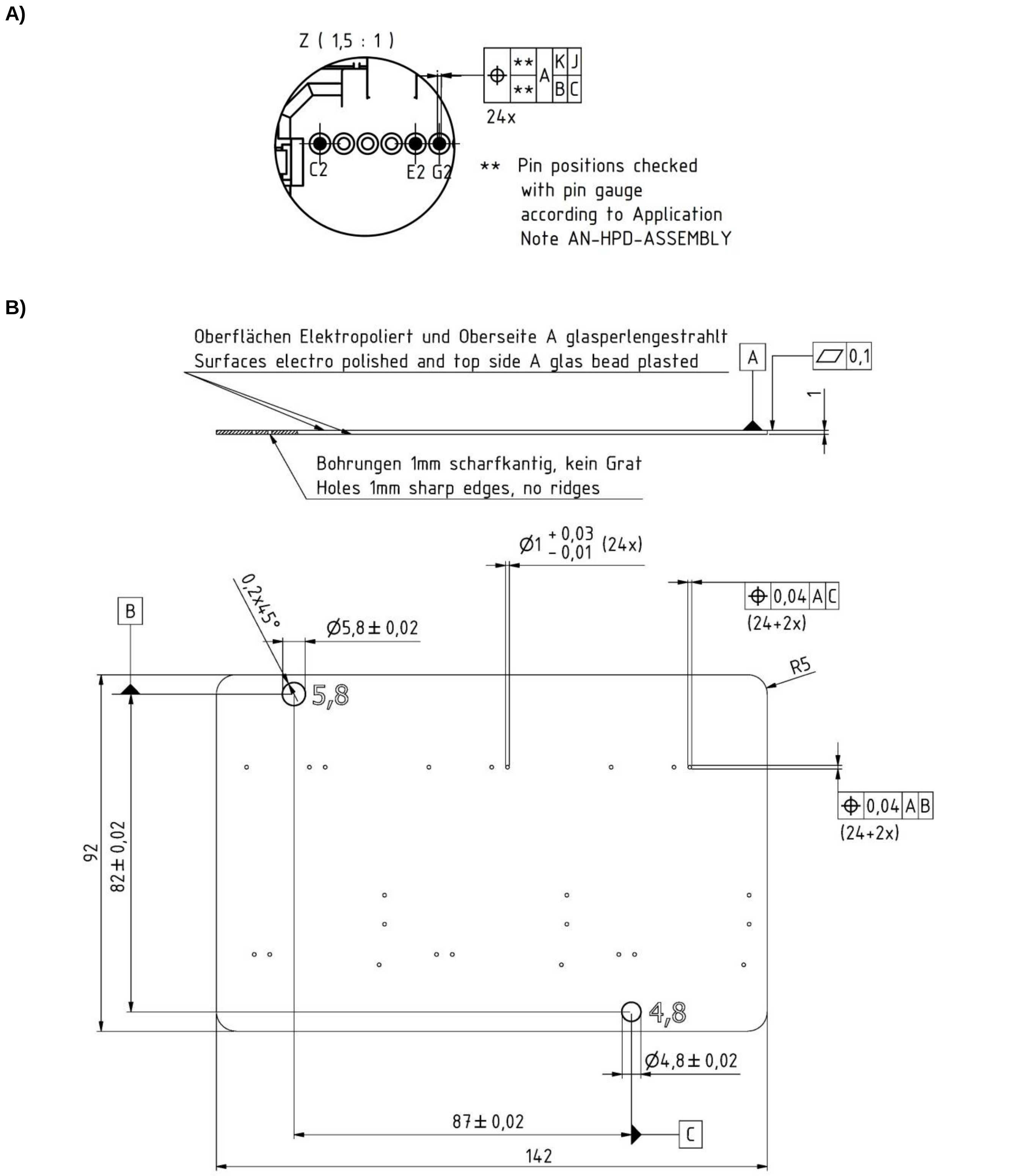


Figure 26 Extract of datasheet regarding pin positions on example of FS950R08A6P2B (A). Specification of Infineon pin gauge for power module production test (B). Hole pattern can be adjusted for other signal pinning with same hole size spec (e.g. SiC MOSFET Module).

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: Tmaxair=+40°C
Min. air temperature: Tminair=+5°C
Max. relative humidity: 85%
Min. relative humidity: 5%
Condensation: not permissible
Precipitation: not permissible
Icing: not permissible

Pre-drying of the power module prior to the press-in process (as is recommended for molded discrete components, such as microcontrollers, TO-cases etc.) is not required for the HybridPACK™ Drive power modules.

11 Power Module Appearance

This chapter explains frequent questions about the typical power module appearance.

11.1 Pin Rotation

The position tolerance is an important value and ensures that a PCB designed according to the recommendations fits to the power module. The positions of the pins are clearly specified in the product datasheet.
The pin rotation is not fixed as the interface (PCB via) is totally symmetric. A pin rotation is clearly visible due to the asymmetric pin geometry (i.e. three contact pressfit pin). An example is shown in Figure 27, where the rotation is indicated. Typically about 45° pin rotations can be seen. Nevertheless, different angles may occur in the final product and it is no reason for an objection and has no influence on the final contact quality.

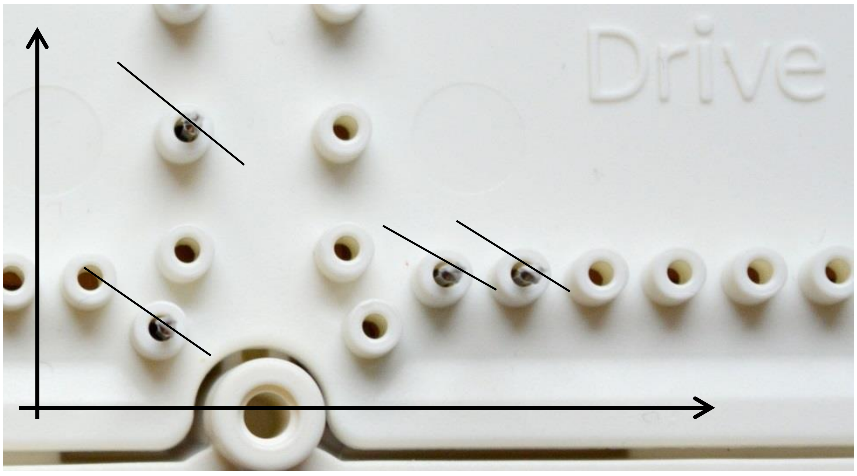


Figure 27 Pins are not symmetrical (three contact pressfit pins) and thus a rotation angle is visible. Different angles may occur in final product but are uncritical for the contact quality and is no reason for an objection.

11.2 Module Lid to PCB Distance

The power module lid is also guided with the module x-pins. In the area of the x-pins the module lid is in contact to the PCB even before it is pressed down. After final assembly this ensures that the lid has contact to the PCB and thus avoids noise during typical application vibration profiles. The force of the lid to the PCB is low and uncritical for the PCB.

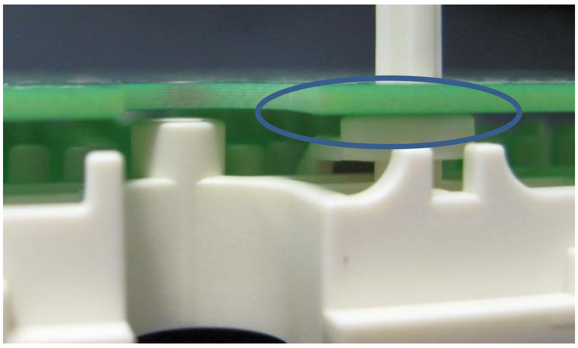


Figure 28 The module lid has contact to the PCB before it is pressed onto the power module. This ensures a contact after the PCB is assembled and avoids noise during vibration profiles.

11.3 Power Tab Tin Plating

The power tabs are made of copper with a tin plating. The plating has the role to avoid visual discoloration and oxidation of the copper between power module production and the mounting processes. After assembly, the tin plating has no function and the contact resistance is the same as an un-plated pure copper power tab. In order to provide the maximum possible compatibility to various connecting techniques like screw type connections, clinching and welding, it is mandatory to make the plating as soft as possible. Due to the desired compatibility and the required softness, visible scratches (see Figure 29a) and/or not completely over-plated edges due to the stamping process (see Figure 29b) are of logical consequence and is no reason for an objection as it does not influence the product performance or quality.

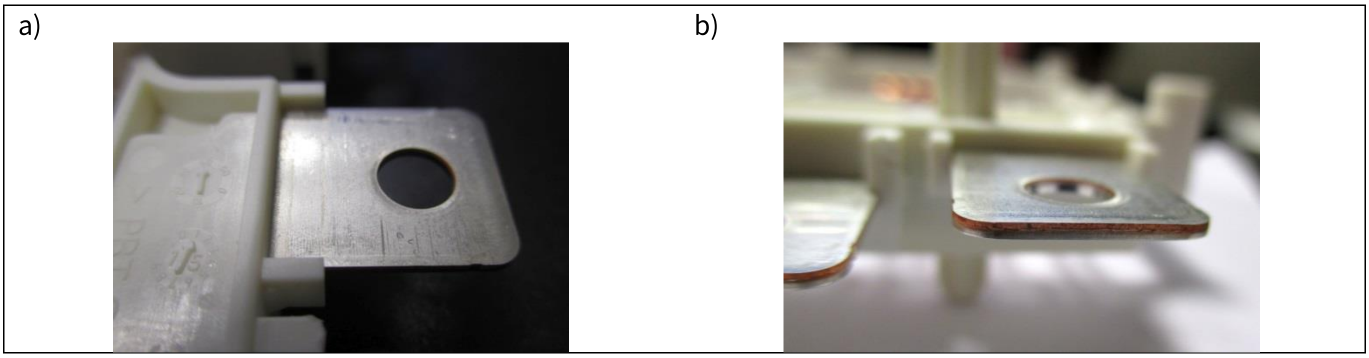


Figure 29 Typical appearance of the copper power tabs, which have a very soft tin plating and provides maximum compatibility to different mounting processes.

11.4 Baseplate Surface

A typical appearance of the baseplate surface is a so called “marbling” or “white spots” structure. This structure can be observed after the galvanic nickel and its cleaning process of the baseplates. The roughness of the baseplate, the chemical structure as well as the thickness of the Ni layer is not different to baseplates where this structure is not visible by naked eye. Such an appearance as shown in the Figure 30 is a normal appearance and is no reason for an objection as it does not influence the product performance or quality.

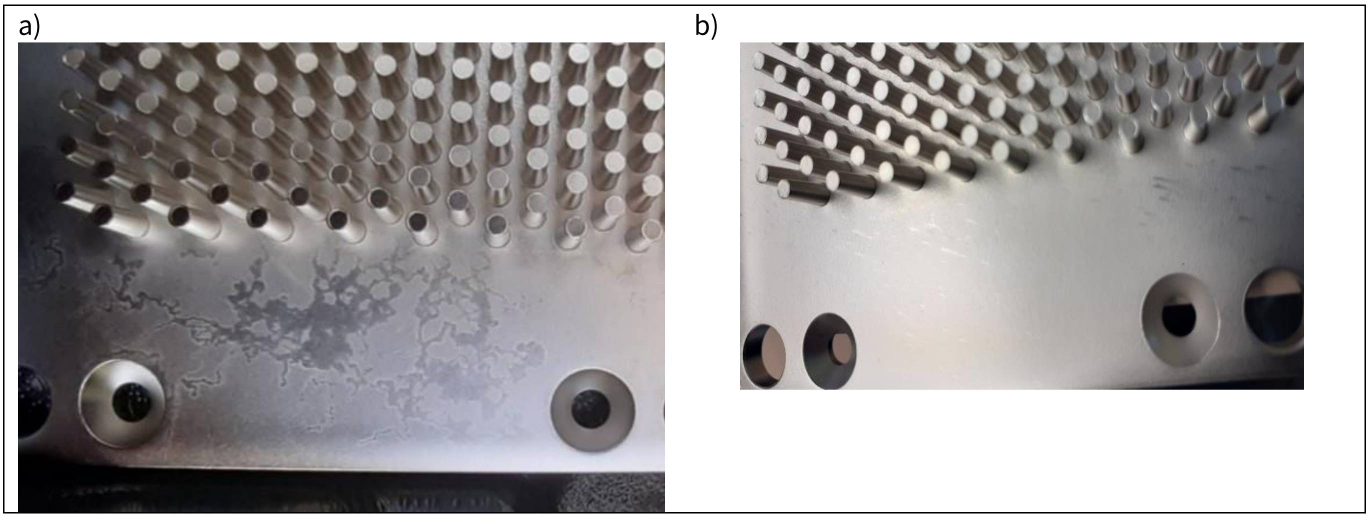


Figure 30 Typical appearance of power module baseplate surface with a “marbling” or “white spots” structure.

12 References and Revision History

The referenced application notes can be found at http://www.infineon.com

[1] Copper Development Association, "Welding copper and copper alloys", http://www.copper.org/publications/pub_list/pdf/a1050.pdf

[2] Harting Technology Group, http://www.harting.com

[3] Deutsches Kupferinstitute, "Schweißen von Kupfer und Kupferlegierungen" http://copperalliance.de/docs/librariesprovider3/i012-mit-info-deutsches-kupferinstitut-pdf

[4] Trumpf Laser- und Systemtechnik GmbH, https://www.trumpf.com

[5] Alpitronic GmbH, http://www.alpitronic.it

Revision History

Date	Version	Changed By	Change Description
2019-09	1.0	T. Reiter (IFAG ATV HP HMD AE)	Initial Version for HybridPACK Drive Performance power modules.
2021-02	1.1	T. Reiter, D. Jiang	Added SiC MOSFET modules in scope. Presstool drawing for SiC Modules added. Added section and pictures for typical appearance of module baseplate. Gauge drawing corrected to match calibration specification of gauge. Corrected typers.

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