XHP™

Application and Mounting Instructions

About this document

Scope and purpose

This guide providesall required information for a design-in of the XHP module.

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1 General

XHP™ power semiconductors are electrical components. Important aspects in the construction of the mechanical layout include the application conditions at which the components are operated. These application conditions must be observed in the mechanical, electrical and thermal design.

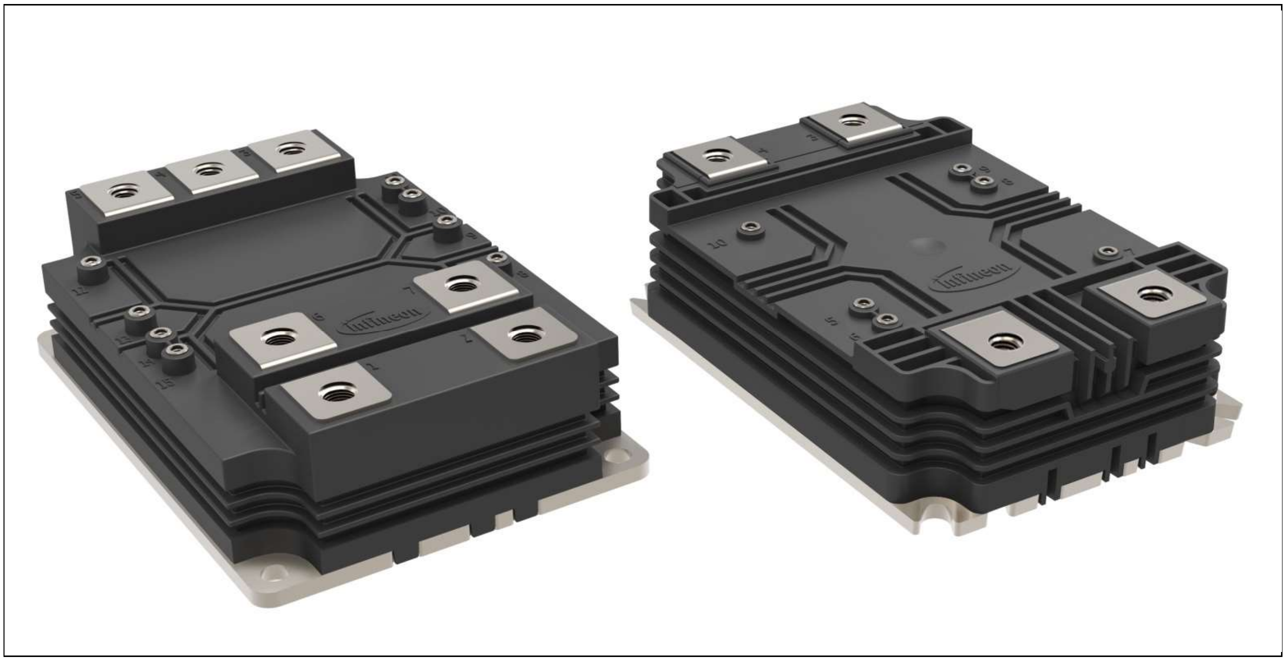

Figure 1 XHP™ product family: XHP™ 2 (left) and XHP™ 3 (right)

The notes and recommendations in this guide cannot cover all applications and conditions. This application note therefore, will in no way replace a thorough assessment and evaluation of the suitability for the purpose envisaged by the user with the technical departments. The suitability of the application for the user's intended purpose should therefore be thoroughly assessed and evaluated with the technical departments.

2 Supply quality

All IGBT modules undergo a final test before delivery according to IEC60747-9 and IEC60747-15. Inwards goods tests of the components at the recipient's site are therefore not required.

After the final visual inspection, the components ready for shipping are packaged in an ESD protected transport box. Deflection of the base plate in the µm-range is permissible within valid Infineon specification limits and therefore bear no influence on the thermal, electrical or reliability characteristics of the power modules.

Once the user has removed the components from the ESD-protected shipping box, further processing should be done in accordance with the directive in chapter 4.

Infineon XHP™ modules comply with the RoHS directives. Data sheets listing product materials, the Material Contents Data Sheets (MCDS), are available online from Infineon on the respective product page.

3 Storage and Transport

During transport and storage of the modules extreme forces such as shock and/or vibration loads are to be avoided as well as extreme environmental influences. The storage conditions recommended by Infineon [1] are also to be observed.

Storing the modules at those temperature limits specified by the data sheet is possible but not recommended.

The storage time at the recommended storage conditions according to [1] should not be exceeded.

A pre-dry process of the module packages before assembly, as is recommended with molded components like micro controllers or TO-packages, is not required with XHP™ modules.

Package inside view | Single-module package | “P2” module set | “P4” module set

Figure 2 XHP™ product package

XHP™ modules may be ordered as preselected devices for paralleling. All modules which are grouped together can be identified by a unique grouping number placed on the label.

Each single module is delivered in its own (single usage) paper box. Every type of grouped modules (e.g. extension “P4” → a group of four modules selected for paralleling) has its own ordering code. The individual modules are packed together in one set.

4 IGBT modules are electrostatic-sensitive devices (ESD)

IGBT semiconductors are electrostatic-sensitive devices which require handling according to the ESD directives. Uncontrolled discharge, voltage from non-earthed operating equipment or personnel as well as static discharge or similar effects may destroy the devices. The gate-emitter control terminals are electrostatic-sensitive contacts. Take care not to operate or measure IGBT modules with open-circuit gate-emitter terminals.

Electrostatic discharge (ESD) may partially or even completely damage IGBT modules.

Figure 3 ESD label

The user must observe all precautions in order to avoid electrostatic discharge during handling, movement and packing of these components.

Important notice:

In order to avoid destruction or pre-damage of the power semiconductor components by electrostatic discharge the devices are delivered in suitable ESD packaging according to the ESD directives.

The installation of ESD workstations is required for unpacking the modules and removing the ESD protection as well as for handling the unprotected modules.

Subsequent work steps are only to be carried out at special work stations complying with the following requirements

- High impedance ground connection
- Conductive workstation surface
- ESD wrist straps

All transport equipment and PCBs have to be brought to the same potential prior to further processing of the ESD-sensitive components.

Further information can be provided by the currently valid standards.

- IEC 61340-5-2, Electrostatics–protection of electronic devices from electrostatic phenomena – general requirements
- ANSI/ESD S2020
- MIL-STD 883C, Method 3015.6 for testing and Classification
- DIN VDE 0843 T2, identical with IEC801-2

5 Module labeling and type designation

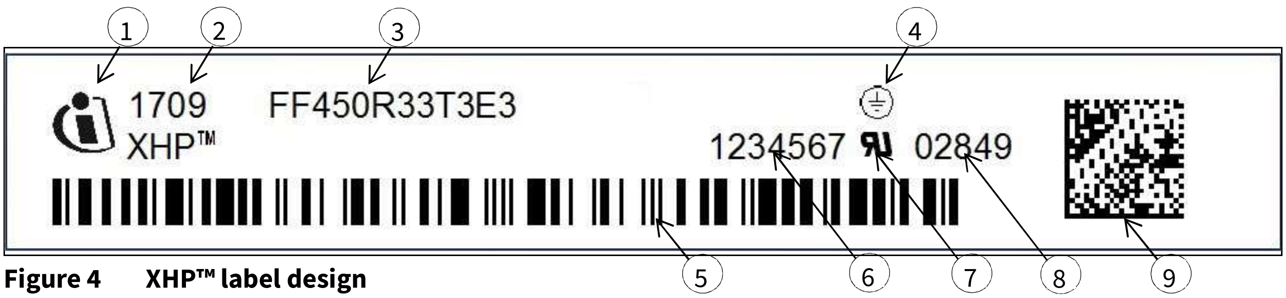

Figure 4 XHP™ label design

1. Infineon Logo
2. Date code

   1st - 2nd digit: production year

   3rd - 4th digit: production week
3. Type designation acc. Table 1
4. Grounding symbol; basic isolation acc. EN / IEC 61140
5. Barcode (Code 128)

   1st - 5th digit: module serial number

   6th – 11th digit: module material number (internal)

   12th – 19th digit: production order number (internal)

   20th – 21th digit: date code (production year)

   22th – 23th digit: date code (production week)
6. Grouping number (for modules selected for paralleling)
7. Component mark according UL 1557 (if applicable)
8. Module serial number; 5 digits, unambiguous in combination with date code
9. DMX code

Table 1 XHP™ module type designation overview

FF	450	R	33	T3	E	3	_P	
FF								dual switch
FD								chopper configuration
DD								dual diode
	450							nominal DC-collector current in A
		XT						.XT joining technology
		R						reverse conducting
		S						fast diode
			33					collector-emitter voltage in 100 V
				T2				XHP™2
				T3				XHP™3
					E			low sat & fast IGBT
						1..n		chip generation
							_P2..x	number of selected devices for paralleling

6 Selecting the module voltage class and operation of modules at elevated altitudes

When selecting the appropriate voltage class, the IGBT has to exhibit a blocking capability appropriate to the application conditions.

Table 2 shows possible IGBT voltage classes for different supply voltages. This table can be used for an initial IGBT module selection. The maximum collector-emitter voltage V_{CEmax} must not be exceeded even for short periods during switching, and has to be considered in the selection of a suitable IGBT voltage class over the entire temperature range.

Table 2 IGBT blocking capability as a selection criterion of the supply voltage

Nominal DC link line voltage	Preferred IGBT voltage class
400 V_{RMS} (620V_{DC})	1200 V
600 V_{DC} (max. appr. 900 V_{DC})	
690 V_{RMS} (1070V_{DC})	1700 V
750 V_{DC} (max. appr. 1100 V_{DC})	
1500 V_{DC} (max. appr. 2100 V_{DC})	3300 V
up to 3000 V_{DC} controlled	4500 V
3000 V_{DC} (max. appr. 4400 V_{DC})	6500 V

Operation of IGBT components at heights >2000m above sea level or high DC voltages may necessitate limiting the operating range.

- Due to the lower air pressure the cooling capability of air cooling systems needs to be evaluated.
- The isolation properties, especially the clearance distances need to be adjusted due to the lower dielectric strength of the air.
- Possible statistical failure rates due to the operation of the power semiconductors at elevated altitudes (cosmic radiation) and/or at high voltage have to be considered when selecting a suitable voltage class and generally during the design phase.
- With operating temperatures $T_{op} < 25°C$, the reduced blocking capability typical for IGBTs and the switching behavior of the components at these temperatures in the particular application has to be kept in mind and should be studied independently in the user's design. The specification of the blocking capability in dependence of the temperature T_{op} is available upon request through your sales representative for Infineon power devices.

The power cycling capability for the envisaged lifetime needs to be calculated on the basis of the load profile. Further information on the subject is available on request and in [3].

7 Environmental classification for XHP™ 3 modules

XHP™ modules are not hermetically sealed. The housings and the molding compound, used for the electrical isolation within the housing, are permeable for humidity and gases in both directions. Therefore humidity differences will be equalized in both directions.

A general overview about the environmental conditions according to IEC 60721-3-5 are given in the following table:

Table 3 Overview

Climatic conditions	Class 5K2
Biological conditions	Class 5B1
Chemically active substances	Class 5C2
Mechanically active substances	Class 5S2
Contaminating fluids	Class 5F1

Corrosive gases must be avoided during operation and storage of the devices.

The operation of the modules in humid atmosphere caused by condensation and/or the operation in climatic conditions beyond class 5K2 of EN60721-3-5 must be avoided and additional countermeasures need to be taken in such cases.

The climatic conditions for Infineon XHP™ 3 modules in active, current-carrying operation are specified as per EN60721-3-5 class 5K2. The climatic conditions according to class 5K2 are as follows.

Table 4 Climatic conditions for XHP™ 3

Environmental parameter	Specification	Normative reference	Remark
Low air temperature	-40°C	IEC 60721-3-5: 5K2, 5K3 covered IEC 62498: all T-classes covered	Specification can be extended to lower values if Tstg<-40°C according to IFX data sheet
High air temperature in ventilated compartments (except engine compartments) or outdoor air	+45°C	IEC 60721-3-5: 5K2, 5K3 covered IEC 62498: all T-classes covered except T6, TX	
High air temperature, air in unventilated compartments (except engine compartments)	+70°C	IEC 60721-3-5: 5K2, 5K3 covered IEC 62498: all T-classes covered except T6, TX	
Change of temperature air/air	-40/+30°C	IEC 60721-3-5: 5K2, 5K3 covered	Specification can be extended to lower values if Tstg<-40°C according to IFX data sheet
Gradual change of temperature, air/air, except in engine compartments	-40/+30°C 5°C/min	IEC 60721-3-5: 5K2, 5K3 covered	Specification can be extended to lower values if Tstg<-40°C according to IFX data sheet

Change of temperature, air/water, except in engine compartments	No	IEC 60721-3-5: 5K2, 5K3 covered	No direct exposure to water allowed
Relative humidity, not combined with rapid temperature changes, except in engine compartments of vehicles powered by internal combustion engines.	95% RH +45°C Limitation of $c_{abs} \leq 30 g/m^3$	IEC 60721-3-5: 5K2, 5K3 covered IEC 62498: partly covered („occasionally 95…100%" not allowed; this is handled via parameter „wetness" → see below)	C_{abs} limitation according to IEC 62498 and maximum values occuring in reality
Relative humidity combined with rapid temperature changes, air/air at high relative humidities. Not in close proximity to refrigerated air conditioning systems.	95% RH -40/+30°C	IEC 60721-3-5: 5K2, 5K3 covered	
Absolute humidity combined with rapid temperature changes, air/air at high water content	$30 g/m^3$ +70/+15	IEC 60721-3-5: 5K2, 5K3 require $60 g/m^3$ but this is not possible under natural conditions → reduction to value c_{abs} required in IEC 62498	
Low relative humidity	10% 30°C	IEC 60721-3-5: 5K2, 5K3 covered	
Low air pressure	70 kPa	IEC 60721-3-5: 5K2, 5K3 covered	Consider cosmic-ray fit rate at high altitudes
Movement of surrounding medium, air	20 m/s	IEC 60721-3-5: 5K2, 5K3 covered	
Precipitation, rain	No	IEC 60721-3-5: 5K2 covered (not 5K3)	
Water from sources other than rain	No	IEC 60721-3-5: 5K2, 5K3 not covered	
Wetness	Only by condensation $t \leq 0{,}5 h/d$	IEC 60721-3-5: 5K2, 5K3 covered with constriction	Condensation and icing is allowed for a maximum of 0.5 hours per day

8 Module creepage and clearance distances

When calculating the isolation characteristics, application-specific standards, particularly regarding clearance and creepage distances, must be taken into consideration.

The module-specific XHP™ 3 package drawings can be taken from the data sheets or can be acquired in electronic form as a 3D CAD model via your sales partner for Infineon modules.

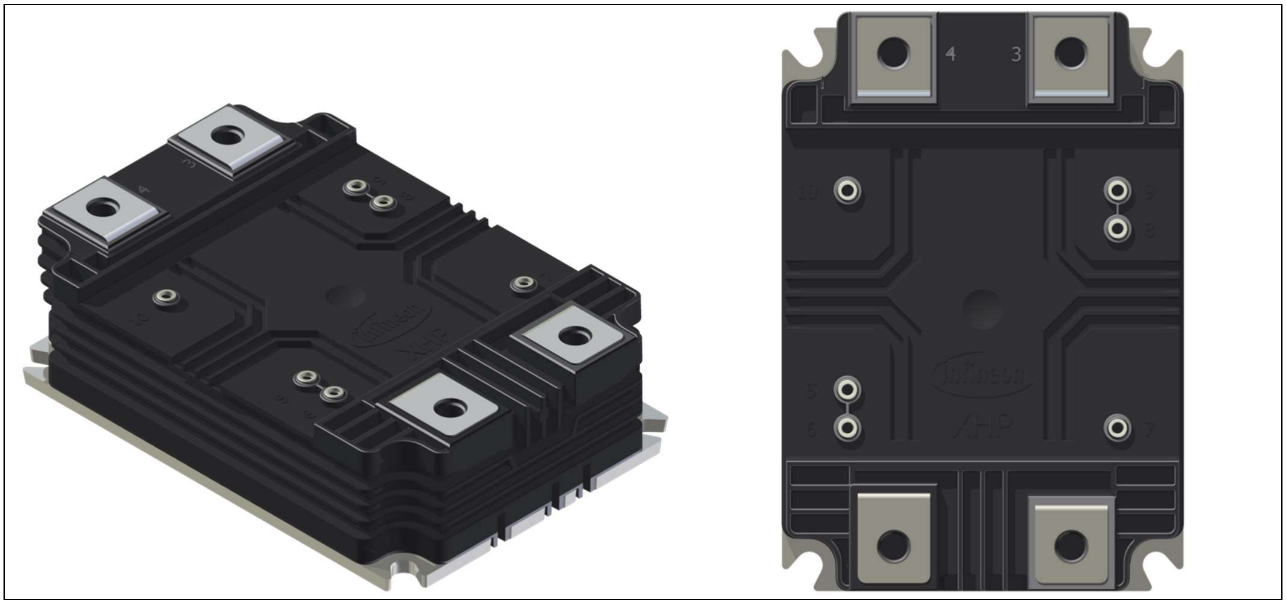

Figure 5 XHP™ 3D CAD model

In particular when selecting bolts and washers, sufficient clearance and creepage distances must be considered. In order to meet the application requirements, avoid electrically conducting components or plated-through holes, or take isolation measures, e.g. lacquer.

The clearance and creepage distances indicated in the module data sheets are those specified for unassembled and unconnected modules. These values are the shortest clearance and creepage distances of the module.

In any case, clearance and creepage distances for the application are to be examined and compared with the requirements from the user-specific standards, and, if necessary, are to be verified by design measures.

9 Module assembly and connections

9.1 Quality of the heat sink surface

The energy occurring as losses in the module must be dissipated by a suitable heat sink, in order not to exceed the maximum temperature during switching operation T_{vjop}, specified in the data sheets. For more information concerning junction temperature limits see AN2008-01 [4]. The quality of the heat sink surface within the area of the module placement is of great importance, since this contact between the heat sink and the module is of crucial influence to the heat dissipation of the module.

For optimal heat dissipation the contact area conditions of the heat sink relative to each XHP™module may not exceed the following values:

Surface roughness ≤ 15 µm

Surface flatness ≤ 30 µm

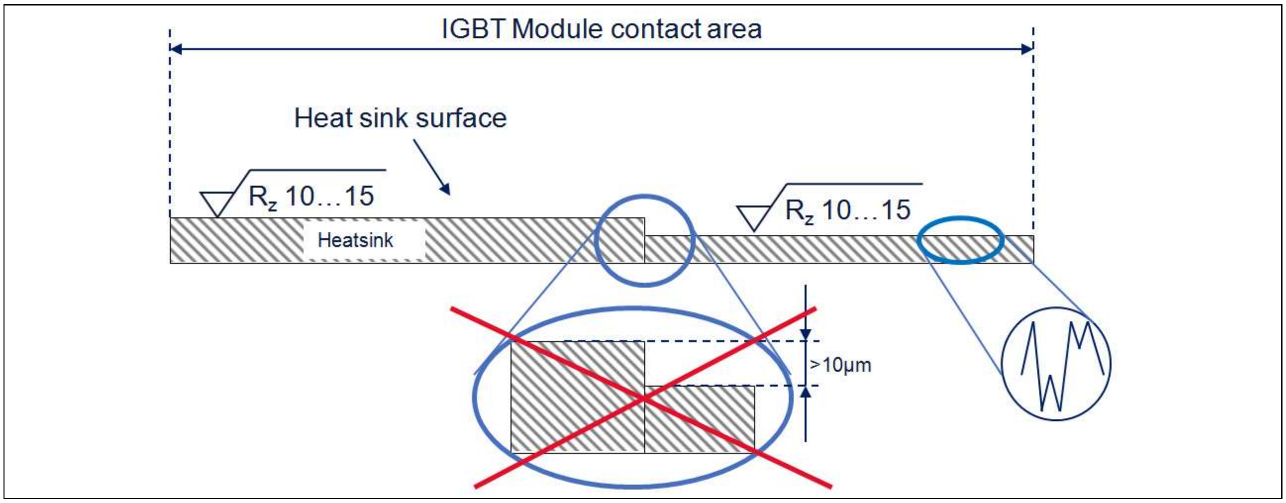

Figure 6 Graphic explanation of the heat sink surface roughness before module assembly

The contact areas, the base plate of the module and the surface of the heat sink must be free of damage and contamination, which would worsen the thermal contact. Before the module is mounted it is recommended to clean the contact areas with a lint-free cloth.

The heat sink must be of sufficient stiffness for the assembly and the subsequent transport, so it will not exert additional mechanical stress on the base plate of the module. During the entire assembly process the heat sink must have an anti-twist support, e.g. be positioned on a suitable carrier jig.

9.2 Thermal interface material

To dissipate the power losses occurring in the module and to allow a good flow of heat into the heat sink, all air gaps between the module base plate and the heat sink need to be filled with a suitable heat-conductive material. This can be done with thermal grease, alternatively described as thermal paste or thermal compound.

The thermally conductive material should have long-term stability properties appropriate to the application and ensure a consistently good thermal contact resistance. This must be qualified by the user. If long-term stability is not warranted, there is a risk of overheating of the semiconductors in long term and thus the module's lifetime will be reduced. The grease should be applied in such a way that the mounting holes are not contaminated as this could influence the torque values.

9.3 Application of thermal paste in a screen-printing process

The user has to select and qualify the thermal paste used for suitability and long-term stability. The suitability of applying heat-conductive material, e.g. thermal grease, in combination with screen printing, has to be verified independently by the user.

To achieve an optimal result, the module, the geometry of the application, the contact area of the heat sink as well as the applied material have to be considered as one unit.

Applying thermal paste manually with a layer thickness in the µm-range is inherently problematic because an optimally filled layer should close all gaps but not prevent the metallic contact between the base plate and heat sink surface. Therefore it is recommended to apply thermal grease with a stencil printing process. With this method it is possible not only to have a customized application according to the type of module but a reproducible adjustment of the layer thickness.

Further information on the use of screen-printing stencils for the application of thermal compound can be found in the guidelines [5]. The module-specific drawings of a printing stencil can be obtained from the distribution partner for Infineon modules. For a proper amount of thermal compound the material thickness of the stencil has to be 100µm.

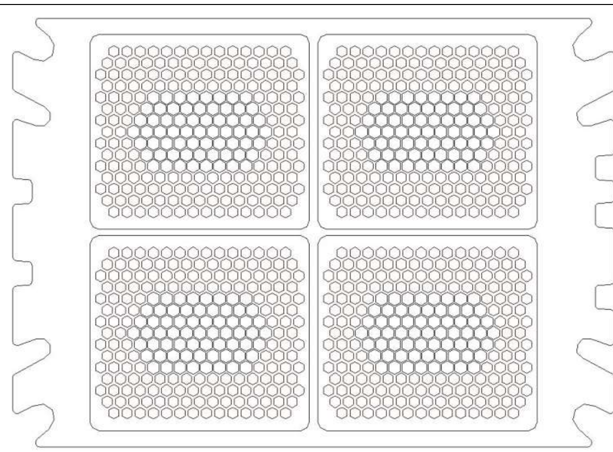

Figure 7 Stencil for XHP™ 3 modules

When screen printing with thermal paste follow this process:

1. Clean the stencil of possible thermal grease residues. This step can be carried out with suitable solvents like isopropanol or ethyl alcohol. Observe the safety regulations when handling these materials.

2. Align stencil and module with a jig holding the module.

3. Lower the stencil onto the module base plate.

4. Apply the thermal paste over the stencil. It is imperative that all stencil holes are filled properly.

5. Lift the template and remove the module.

6. Visual inspection after application of the material ensures that every point of the template is filled. A manual application of paste may be affected by a poor alignment of the stencil and small variations in the amount of paste. The measurement of the thickness of the deposited material is therefore strongly recommended and ensures that an adequate amount of material was applied.

After a settling time the heat sink and the module should show an even distribution of the paste.

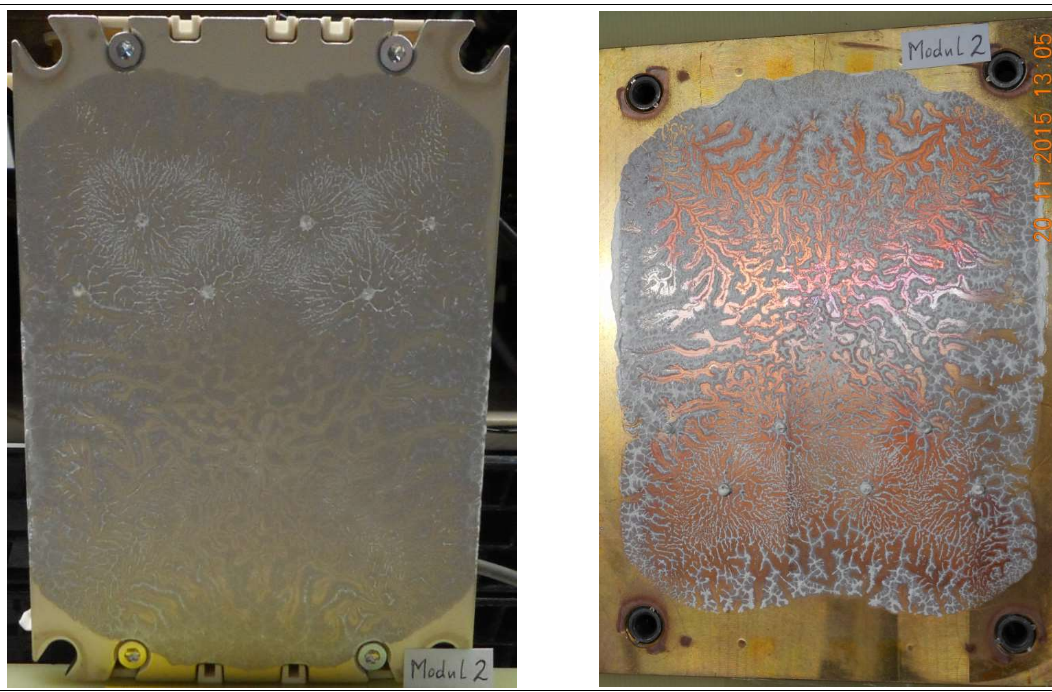

Figure 8 Distribution of the paste on the surface of module (left) and heat sink (right)

When applying the paste on the template with the aid of a tool, the possible wear of the template and the concomitant reduction in the layer thickness should be checked at regular intervals. Templates are to be replaced if they no longer have the predetermined thickness..

9.4 Alternative ways to apply thermal paste

If it is not possible to apply the thermal compound by the recommended screen printing process, the paste can alternatively be applied manually. Typically a uniform layer thickness of 100 µm thermal paste is sufficient on the base plate of the module. The suitability and long-term stability of the thermal compound used and its application is to be qualified by the user.

The amount can be measured from a syringe or applied from a tube.

Common rollers or fine-toothed spatulas like notched trowels can be used to apply the thermal grease. Regarding homogeneity and reproducibility of the paste thickness the manual application is subject to large tolerances. With the help of a wet film comb the thickness can be checked after applying the thermal compound; see Figure 9. Place the comb perpendicular to the surface of the heat sink and scrape the comb slowly over it through the thermal paste layer. Wet film combs have teeth of various lengths on their sides. The paste thickness lies between the biggest value of the "coated" or "wet" teeth and the smallest value of the "uncoated" or "dry" teeth.

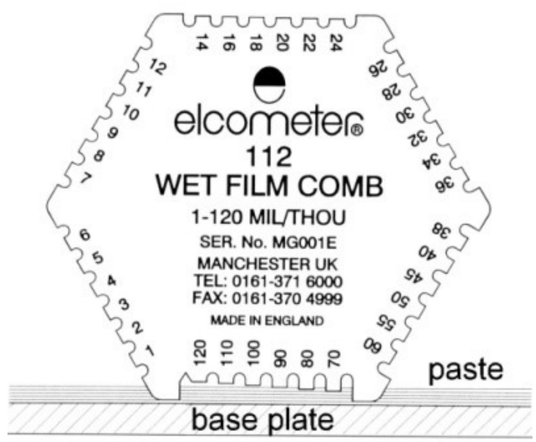

Figure 9 Wet film gauge to check the layer thickness of the thermal compound

The application guidelines, the thermal contact and the long-term stability of the thermal interface materials to be considered in the selection must always be qualified by the user for the proposed procedure and the intended application, and may be discussed with the compound manufacturer.

9.5 Module assembly onto the heat sink

The module assembly must comply with the tolerances specified in the module data sheets. The module-specific outline drawings can be taken from the data sheets.

The bolt mounting of the module on the heat sink has to be such that the sum of all occurring forces does not result in exceeding the yield point of the joined parts. Setting devices, such as spring washers, will increase the elasticity of the connection and thus compensate the settling effects. Thereby the pre-tension force will largely be retained, and a loosening of the assembly counteracted.

Table 5 Technical data of the mounting bolts

Description	Value	Note
Mounting bolt	M6	1.
Maximum recommended torque	M_{max} = 5.75 Nm	2.
Recommended property class of the bolt	8.8	
Minimal thread length into the heat sink	1.6 – 2.2 x d	3.

1. According to ISO4762, DIN6912, DIN7984, ISO14581 or DIN7991 in combination with a suitable washer, e.g. according to DIN433 or DIN125 or complete combination bolts according to DIN6900 are recommended for module assembly.

2. Threads should be clean and not lubricated or contaminated by thermal grease

3. Into aluminum; according to technical literature depending on material properties of heat sink and screw; d: diameter of bolt

Other material combinations of bolts and / or heat sink material may require an adjustment of the mechanical parameters and an evaluation of the corrosion stability.

To avoid unnecessary strain and tension of the base plate, the heat sink has to show sufficient stiffness and has to be handled distortion free during assembly and transport.

All mounting screws have to be uniformly tightened with the specified mounting torque. A preferred tool for this is an electronically controlled or slow-moving electrical screwdriver. The work can also be accomplished manually with the aid of a torque wrench. We advise against the use of pneumatic screwdrivers due to their lack of accuracy and precision.

For good thermal contact to the heat sink, we recommend that the M6 screws should be tightened in the order 1 - 2 - 3 - 4 with final torque. This sequence is also applicable for the paralleling of multiple modules placed side by side.

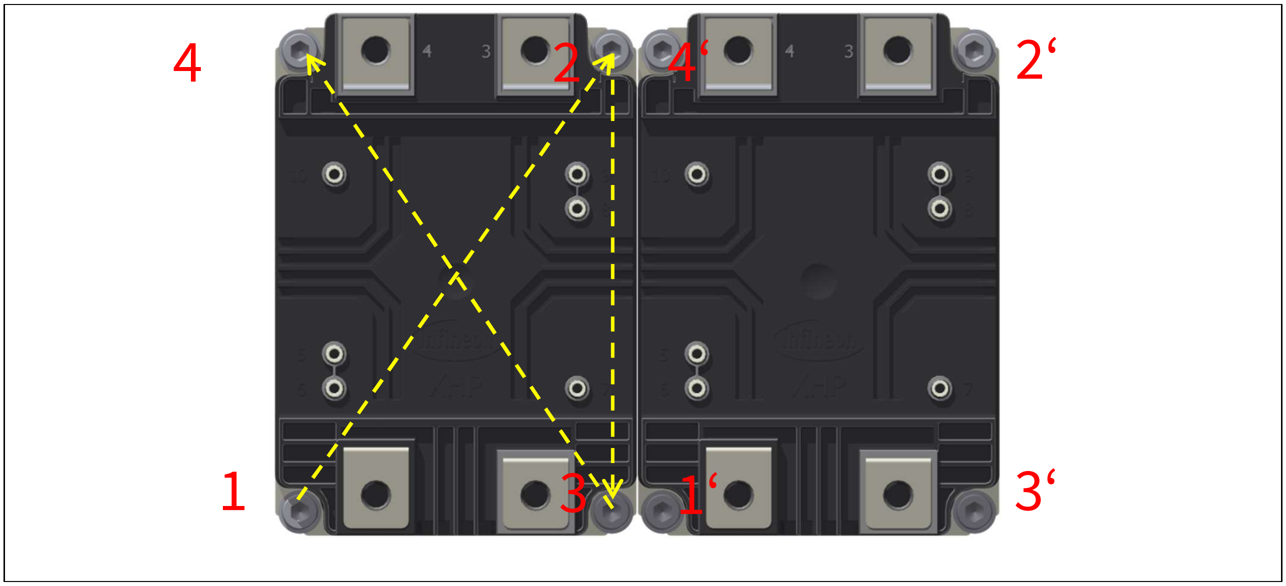

Figure 10 Tightening sequence for paralleled XHP™ modules

When using standard thermal compound, it may be necessary, depending on the nature of the paste, to check the tightening torques for the correct value of the bolts after a burn-in period. When using phase change film for heat conduction instead of thermal grease it is recommended that the additional verification step must be carried out. The use of solid foil cannot be recommended due to unsuitable properties for power devices.

For the qualification and verification of the assembly process and the suitability of the thermal design some experiments and measurements are essential with the thermal compound or an alternative material provided. The maximum junction temperature occurring under application conditions is to be reviewed by thermal measurements. The maximum junction temperature T_{vjop} in pulsed operation must not exceed the specified maximum junction temperature in the data sheet!

9.6 Thermal validation at operation

For thermal measurements close to the chip, it is necessary to place the sensor probe under the chip, like in Figure 11. Knowledge of the exact chip positions is essential. The module-specific chip positions may be enquired via the distribution of Infineon IGBT power modules.

For more details see the application note on transient thermal measurements and thermal equivalent circuit models. [6]

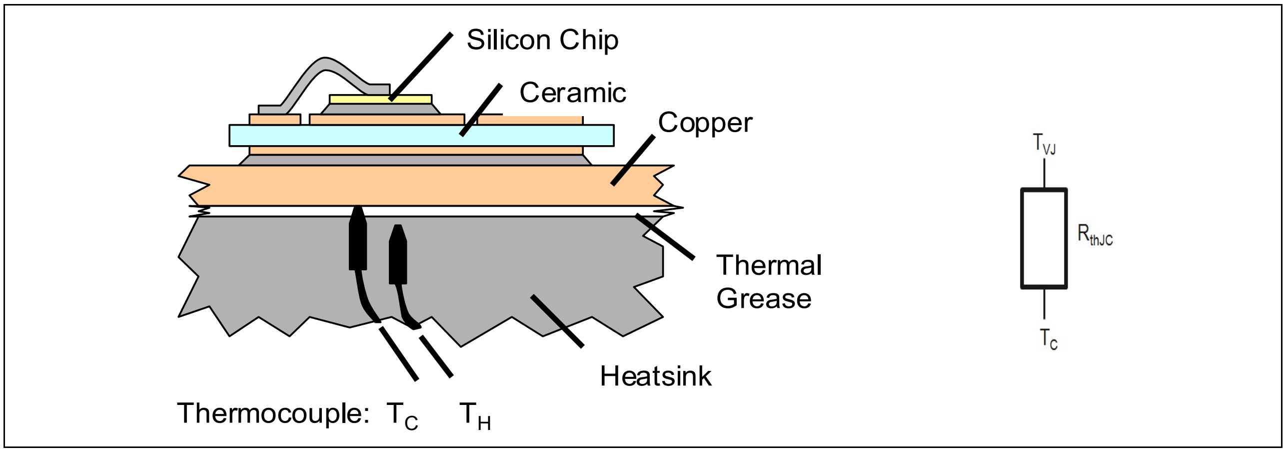

Figure 11 Example of temperature measurement set-up using a thermocouple

The junction temperature T_{vj} can be determined by the formula

$$T_{vJ} = T_C + P_V \cdot R_{thJC}$$

The switching and conduction losses PV as well as the base plate temperature TC must be given for the calculation:

T_{vJ}: virtual junction temperature

T_C: case temperature

P_V: total power losses per switch

R_{thJC}: thermal resistance, junction to case per switch

9.7 Connection of the power and auxiliary terminals

The module must be connected within the permissible module tolerances specified in the outline drawings in the respective data sheets. The position and tolerance of adjacent components such as PCBs, DC-bus, mounting bolts or cables has to be designed such that, after the connection, no sustained effect on the static and / or dynamic tensile forces are exerted on the terminals. The power terminals are built from copper with a nickel coating. The following recommendations are valid for copper busbars, bare or with suitable plating.

To connect the power terminals of XHP™ modules M8 bolts are required. The bolts should be selected according to ISO4762, DIN7984 or DIN7985 with at least property class 8.8, in combination with a DIN 125 washer and lock washer or combination screws according to DIN6900. The thread should be clean and not lubricated. The screws are to be tightened with a torque specified in the datasheet. Recommended is the use of a torque value near the maximum torque. The maximum torque values in Table 6 must not be exceeded, however.

The tightening torque must be chosen so that the applied pre-tension force leads to a pure frictional bond of the components. Knowledge of the friction coefficient µ is a prerequisite to accurately determine preload and tightening torque. The friction depends on many different factors, such as material combination, surface, lubrication, temperature, etc. The torque values specified in Table 6 assumes the use of galvanised metric steel bolts. Should the coefficient of friction in the construction differ from this, adjust the torque value accordingly.

Table 6 Tightening torque M for the mounting bolts of the electrical connections

Terminal	Mounting bolt	max. screw depth	Mounting torque for condition 1	Mounting torque for condition 2
Power	M8	16 mm	8 - 10 Nm	8 - 22 Nm
Auxiliary	M3	7 mm	0.9 – 1.1 Nm	0.9 – 1.8 Nm

Condition 1: If the torque is directly applied to the nut of the module and the full torque affects the plastic housing it has to be limited according to Table 6, condition 1. The upper limit given here assumes a worst case condition when the full applied torque is passed into the nut which is inserted into the plastic housing. Condition 1 reflects e.g. lab conditions, where just a cable socket is attached to the module.

Condition 2: In case of the presence of a massive busbar (M8) or a printer circuit board (M3), a higher mounting torque is allowed. The busbar or PCB prevent the introduction of excessive forces into the nut and furtheron into the housing plastic material. It has to be checked, if the maximum allowed contact pressure of the used busbar or PCB is not exceeded.

The choice of bolt length depends on the maximum thread depth specified for the module and the gauge of the connecting parts. The sum of these values must not be smaller than the selected bolt thread length. The effective thread length of the bolts into the module power terminals must not exceed the maximum specified depth of 16 mm. For the auxiliary terminals this is 7 mm. Other material combinations of bolts and / or the DC busbar material may require an adjustment of the mechanical parameters and an evaluation of the corrosion stability in combination.

The design of the threaded connection for the power terminals must be such that the sum of all loads occurring does not exceed the yield point of the joined parts. Settling devices will increase the elasticity of the connection and thus compensate the settling effects. Thereby the pre-tension force will largely be retained, and thus a loosening of the assembly is counteracted.

The connecting parts must be mounted onto the electrical contacts in a manner that the specified maximum permissible forces are not exceeded during the assembly process.

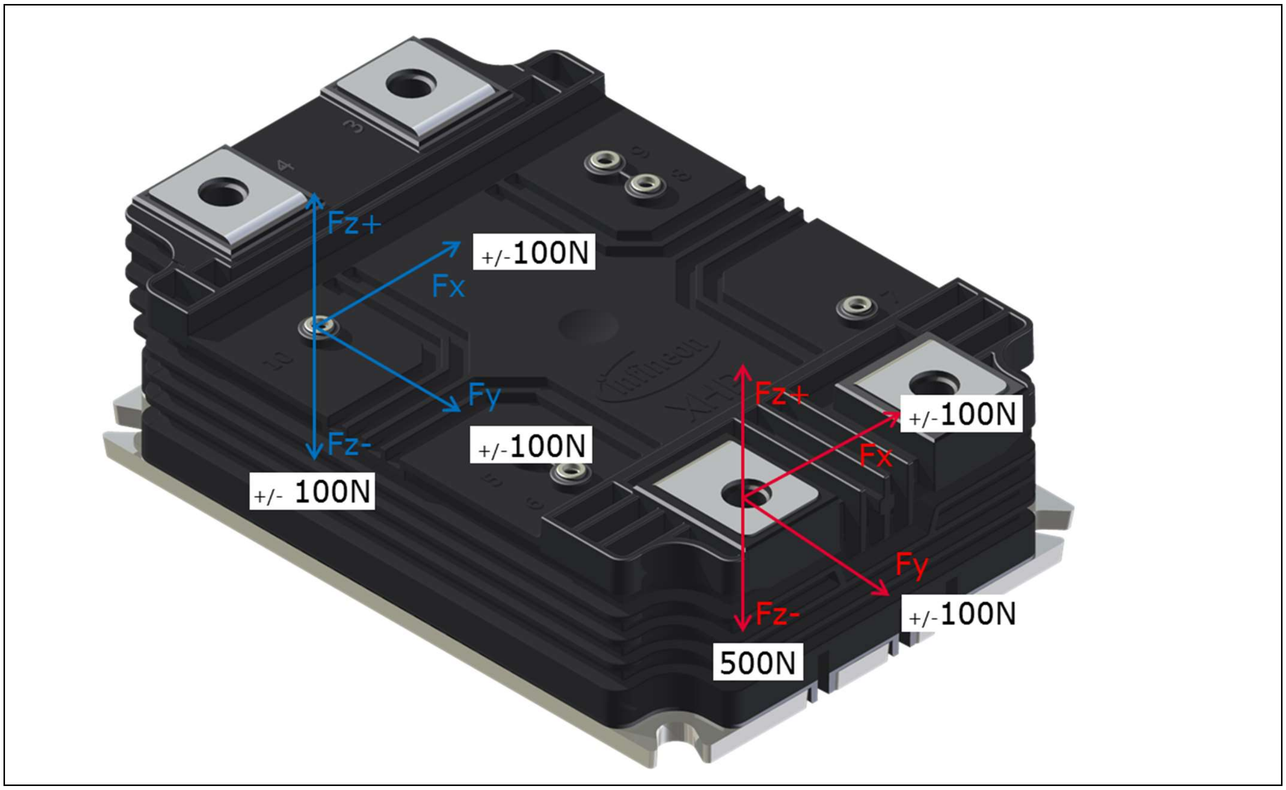

Figure 12 Maximum permissible forces during the assembly process at the terminals of a XHP™ 3 module

It is recommended to have an assembly which leaves the power and auxiliary terminals permanently free of mechanical stress. Since such an assembly is inherently problematic over the entire temperature range, the construction should be such that the power terminals as well as the auxiliary terminals exhibit a load bias by means of suitable spacers.

It must be ensured that the direction of the bias force always acts in the direction of the base plate. The suitability of the support must be evaluated individually in the structure.

Static forces in other directions as well as exposure to vibration and/or thermal expansion should be avoided.

The auxiliary terminals have to be connected accordingly, observing the common ESD guidelines. No load current is permitted to flow through the auxiliary collector.

10 Paralleling

Applications may require the paralleling of multiple XHP™ modules to achieve the necessary current rating. Infineon can provide grouped devices, which can be identified by a name extension _Px (x = 2…n) for n selected and grouped devices with an identical grouping label (see chapter 3). The grouped devices are selected based on static and dynamic electrical parameters.

Nevertheless there are additional factors, which effect static and dynamic current sharing of the paralleled modules. These are concerning the symmetry of the paralleled modules regarding DC link and AC connection, commutation inductance, driver circuitry and cooling conditions.

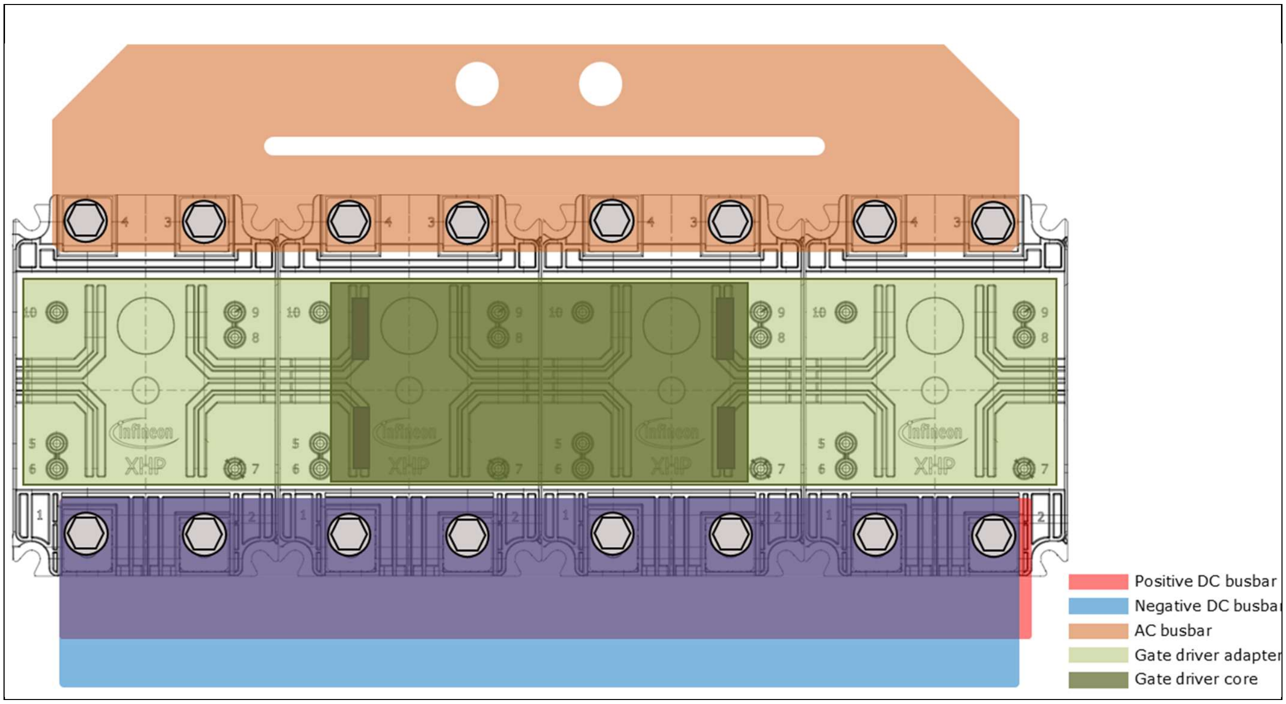

Figure 13 Example of a symmetrical busbar structure for four XHP™ 3 modules in parallel

Recommendations:

Symmetrical design of all IGBT current paths (identical stray inductances) in DC link and AC connections to ensure proper dynamic current sharing [9]

Symmetrical design of gate drivers (same driver stage, seperate gate resistors, splitted Rg with appr. 1/3 of it in the emitter leads, use of double aperture ceramic cores) to avoid equalizing currents in the gate leads and floating gate potentials [10]

Symmetrical cooling conditions (identical heat-sink temperatures and flow rates of cooling media below the paralleled devices) to ensure operation at identical case temperatures

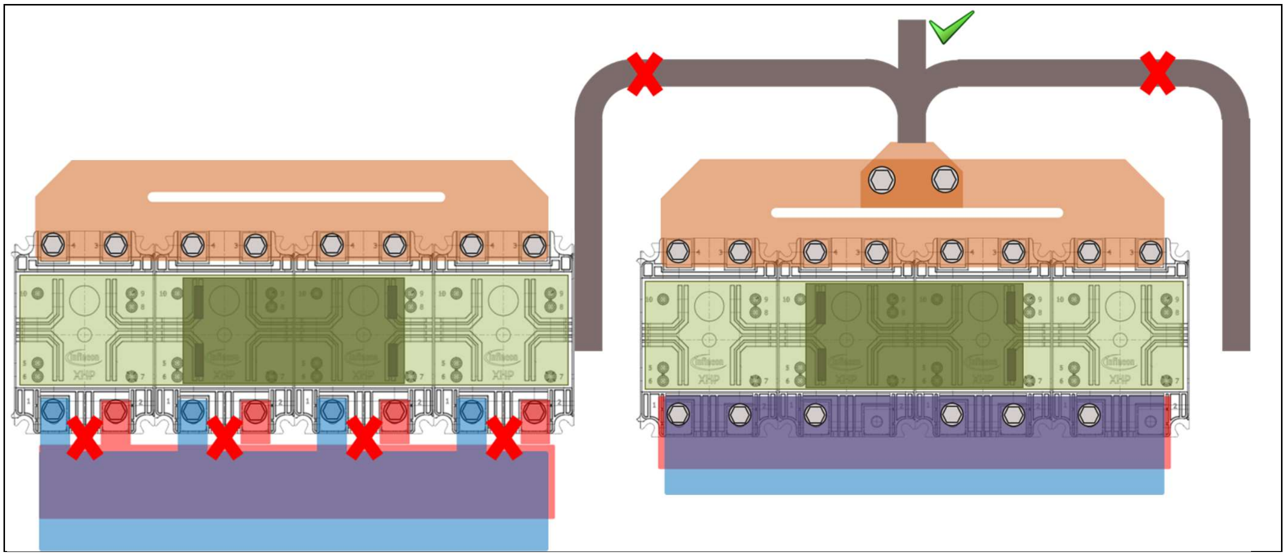

Figure 14 Don´t does regarding the DC and AC connections

Don´t open / split the DC plus / minus connections as shown in Figure 14 (left). This will lead to unsymmetric commutation loop stray inductances between inner and outer modules.

Don´t place the AC output connection laterally along the modules as shown in Figure 14 (right). Its magnetic field could lead to assymetric current distribution between the paralleled modules.

11 References

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[10] Analysis of different IGBT gate driver strategies influencing dynamic paralleling performance; Y. Jadhav, Y. Zhou, U. Jansen, PCIM 2016 Asia

Revision History

Major changes since the last revision

Page or Reference	Description of change

Edition 2018-07-20

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference
AN2018-07