Application Note AN2009-08
V2.0, March 2015

AN2009-08 V2.0 Application and Assembly Notes for PrimePACK^{TM} Modules

www.infineon.com

Edition 2009-08 V2.0
Published by
Infineon Technologies AG
59568 Warstein, Germany

Attention please!

THE INFORMATION GIVEN IN THIS APPLICATION NOTE IS GIVEN AS A HINT FOR THE IMPLEMENTATION OF THE INFINEON TECHNOLOGIES COMPONENT ONLY AND SHALL NOT BE REGARDED AS ANY DESCRIPTION OR WARRANTY OF A CERTAIN FUNCTIONALITY, CONDITION OR QUALITY OF THE INFINEON TECHNOLOGIES COMPONENT. THE RECIPIENT OF THIS APPLICATION NOTE MUST VERIFY ANY FUNCTION DESCRIBED HEREIN IN THE REAL APPLICATION. INFINEON TECHNOLOGIES HEREBY DISCLAIMS ANY AND ALL WARRANTIES AND LIABILITIES OF ANY KIND (INCLUDING WITHOUT LIMITATION WARRANTIES OF NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS OF ANY THIRD PARTY) WITH RESPECT TO ANY AND ALL INFORMATION GIVEN IN THIS APPLICATION NOTE.

Information

For further information on technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies Office (www.infineon.com).

Warnings

Due to technical requirements components may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies Office. Infineon Technologies Components may only be used in life-support devices or systems with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system, or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body, or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.

AN2009-08
Revision History: new version AN2009-08 V2.0
Previous Version: replaces AN2009-08 V1.0
Page: complete revision, all pages

Department: Application Engineering - IFAG IPC APS AE

We Listen to Your Comments

Any information within this document that you feel is wrong, unclear or missing at all? Your feedback will help us to continuously improve the quality of this document. Please send your proposal (including a reference to this document) to: [IGBT.Application@infineon.com]

Table of contents

1 Introduction

This application note, AN2009-08 Rev.2.0 Application Note and Mounting Instructions for PrimePACK^{TM} modules, replaces the Application Note AN2009-08 V1.0.

In a typical application PrimePACK^{TM} power semiconductor modules are embedded into a power stage setup that has to fulfill electrical, mechanical and thermal requirements according to the application's needs and conditions. These application conditions have to be considered during design-in of power semiconductor modules as they can influence the lifetime of the modules.

Hints and recommendations in this document cannot cover all cases of applications and conditions, therefore this application note will never replace a thorough assessment and evaluation of the suitability for the purpose envisaged by the user with the technical departments. Hence, the application notes do under no circumstances become part of the supply contractual warranty, unless the supply contract determines any different in writing.

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

The PrimePACK^{TM} modules are ESD protected with copper strips between Gate and Emitter. Further processing at the user’s site should occur in accordance with the directive according to chapter 4.

3 Storage and transport

During transport and storage of the modules, extreme forces such as shock and / or vibrational loads are to be avoided as well as extreme environmental conditions exceeding the storage conditions recommended by Infineon [1].

Storing the modules at the temperature limits specified in the data sheet is permissible but not recommended.

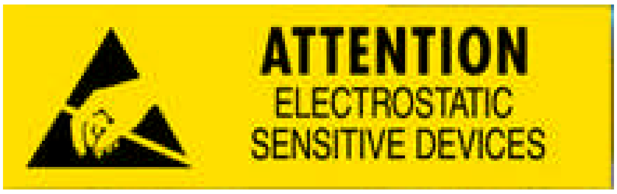
The storage time at the recommended storage conditions according to [1] should not be exceeded.

A pre-drying process of the module before assembly, as it is recommended with molded components like microcontrollers or TO-packages, is not required for PrimePACK^{TM} modules.

4 IGBT modules are electrostatically sensitive devices (ESD)

IGBT semiconductors are electrostatically sensitive devices which require to be handled 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 electrostatically 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.



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 through electrostatic discharge, the devices are delivered in suitable ESD packaging according to the ESD directives.

The installation of ESD workstations is required to unpack the modules and thus remove the ESD protection as well as 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 derived from the standards in their valid versions:

- IEC 61340-5-2, Electrostatic–protection of electronic devices from electrostatic phenomena – general requirements
- ANSI/ESD S2020
- MIL-STD 883C, Method 3015.6 for testing and classification

5 Module labeling, RoHS & Green Product

Infineon PrimePACK^{TM} power semiconductor modules comply with the RoHS directive. Data sheets and Material Content Data Sheets (MCDS) are available online from Infineon on the respective product page.

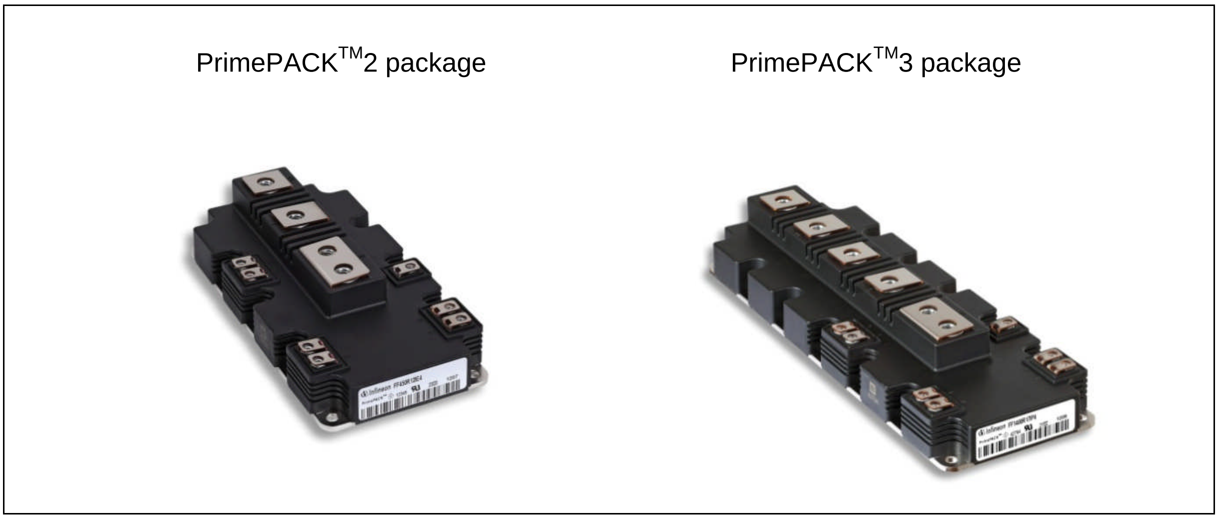


Fig. 1: PrimePACK^{TM}2 and PrimePACK^{TM}3 packages

5.1 Module label

Fig. 2: PrimePACK^{TM} label design

(1) Infineon Logo
(2) Type designation
see Table1 on page 8 for details
(3) Barcode (Code 128)
1. - 5. digit: module serial number
6. - 11. digit: module material number (internal)
12. - 19. digit: production order number (internal)
20. - 21. digit: date code (production year)
22. - 23. digit: date code (production week)
24. - 25. digit: V_{CEsat}-class
26. - 27. digit: V_F-class
(4) V_{CEsat} / V_F class at main terminals
2 digit averaged terminal value @ 125°C
(5) Date code
1. - 2. digit: date code (production year)
3. - 4. digit: date code (production week)
(6) Grounding symbol
(7) Production number
5 digits, unambiguous in combination with date code
(8) Component mark according to UL 1557

6 Module selection

PrimePACK^{TM} modules are available in various configurations as well as voltage and current classes with differently optimized IGBTs and diodes.

The overall product spectrum including datasheets and the simulation program IPOSIM is available online at www.infineon.com.

Maximum values in the product data sheets and application notes are maximum allowed values, which - even for brief periods - must not be exceeded, as this may cause pre-damage or destruction of the components. Further explanations of semiconductor module parameters can be found in the application note AN2011-05 [2].

Selecting the most suitable component requires the consideration of various criteria. The overview in Table1 displays the different configurations of available products.

FF	**1400**	**R**	**12**	**I**	**P**	**4**				
FF										Dual Switch
DF										Chopper (diode on high side)
FD										Chopper (diode on low side)
	1400									DC-collector current in A
										Type:
		R								Reverse conducting
										Collector-emitter-voltage ∗100 :
			12							1200V
			17							1700V
				I						Package: PrimePACK^{TM}
										IGBT Chip characteristic:
					P					Soft switching trench IGBT
					S					Fast short tail 2nd gen IGBT Chip
					E					Low V_{CEsat} & fast trench IGBT Chip
						1…n				Internal reference number e.g. 4=IGBT 4th generation
							D			Higher diode current
							F			Fast diode (e.g. SiC)
								P		With pre applied TIM
								V		CAV qualified
									_B2	Traction version

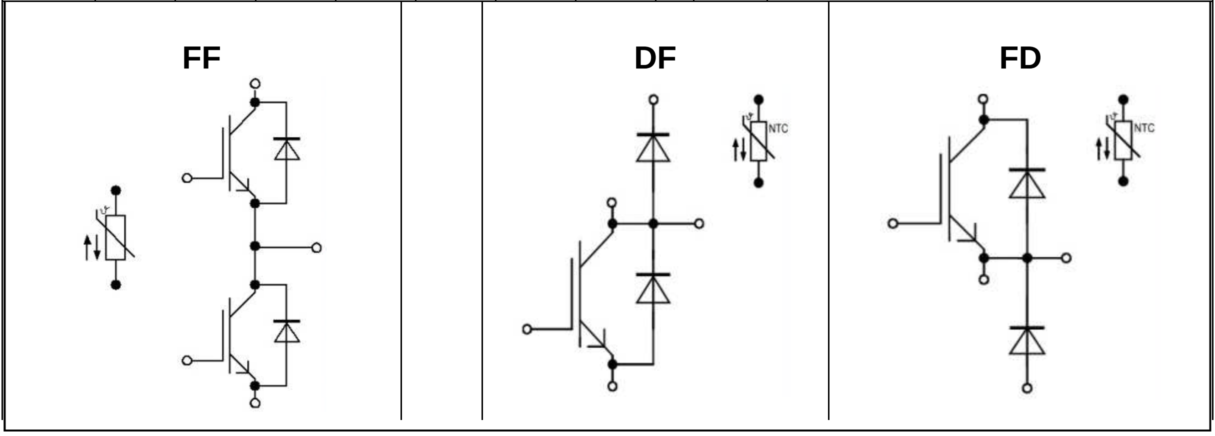


Table1: PrimePACK^{TM} module type designation overview

6.1 Selecting module voltage class and operation at elevated altitudes

The selection of the module voltage class has to be done under consideration of the mechanical setup of the DC link busbars. This design has to be as low-inductive as possible to limit the voltage overshoot occurring at turn off of the IGBT. An example for a DC link design is shown in chapter 10.

It is to be ensured that the maximum blocking voltage is never exceeded.

As a selection guide, Table 2 displays typical voltage classes selected in dependence of the line voltage. Keep in mind that this is no guarantee for not exceeding the blocking voltage, as this can only be tested in operation with the setup and DC link design in use.

typical Line voltage Nominal DC link voltage	Preferred IGBT voltage class
400 V_{RMS} / 620V_{DC}	1200 V
600 V_{DC}	
690 V_{RMS} / 1070V_{DC}	1700 V
750 V_{DC}	

Table 2: typical line voltages as selection criteria for the IGBT blocking voltage

Operation of IGBT modules in elevated altitudes may limit the operating range:

- Due to the lower air pressure, the cooling capability of air cooling systems needs to be re-evaluated.

- The isolation properties, especially the clearance distances, need to be adjusted due to the lower dielectric strength of the air. See also Chapter 7.

- Possible statistical failure rates due to cosmic radiation effects, especially at the operation of the power semiconductors at elevated altitudes and / or at high voltage have to be considered during the design phase when selecting a suitable voltage class.

- 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 $T_{op} = -40°C$ to $T_{op} = +25°C$ is available on request through sales representative for Infineon power devices.

For exceptionally high DC link voltages compared to the typical voltages given in Table 2 statistical failure rates due to cosmic radiation should be considered even at sea level.

6.2 Cyclic load conditions

The power cycling capability for the targeted lifetime needs to be calculated on the basis of the load profile. Further information on this subject is available on request and described in AN2010-02 [3] and AN2008-01 [4].

6.3 Climatic conditions for PrimePACK^{TM} modules during active, current carrying operation

PrimePACK^{TM} modules are not hermetically sealed. The housing and the molding compound, used for the electrical isolation inside the housing, are permeable to humidity and gases in both directions. Therefore, humidity differences will be equalized in both directions.
Corrosive gases must be avoided during operation and storage of the devices.

The climatic conditions for Infineon PrimePACK^{TM} modules in active, current carrying operation are specified as per EN60721-3-3 class 3K3 for fixed installations.

The operation of the modules in humid atmosphere caused by condensation and/or the operation in climatic conditions beyond class 3K3 of EN60721-3-3 must be avoided and additional countermeasures need to be taken in such cases.

7 Module creepage and clearance distances

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

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

In particular with the selection of the bolts and washers, clearance and creepage distances must be reconsidered. Please also note the information in Chapter 6.1.

The values indicated in the PrimePACK^{TM} module data sheets are those specified with the not assembled and unconnected module. These values are the existing shortest clearance and creepage distances for pollution degree PD3 and overvoltage class 2 in accordance with IEC60664-1. Table 3 shows the housing clearance and creepage distances. Fig. 3 illustrates the distances in a picture.

Description	**Values**
minimal Creepage distances	
terminal to heat sink terminal to terminal	33.0 mm 33.0 mm
minimal Clearance distances	
terminal to heat sink terminal to terminal	19.0 mm 19.0 mm

Table 3: Clearance and creepage distances for unconnected and unmounted PrimePACK^{TM} modules

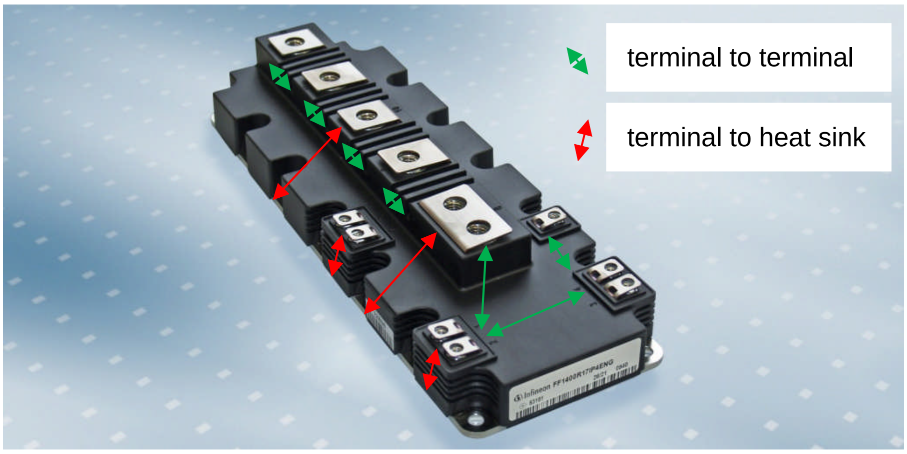


Fig. 3: Creepage distances of a bare and unconnected PrimePACK^{TM} module exemplary for PrimePACK^{TM} 3 housing

In any case, clearance and creepage distances in the application are to be examined and to be compared with the requirements from the user-specific standards and, if necessary, to be assured by design measures. The housing material for PrimePACK^{TM} is specified with a CTI ≥ 400.

8 Module assembly and connections

All protective measures against electrostatic discharge during handling and assembly of the IGBT modules have to be properly implemented by the user. For details see section 4.

8.1 Quality of the heat sink surface for module assembly

The thermal energy generated by power losses must be dissipated by a suitable heat sink, in order not to exceed the maximum temperature during switching operation T_{vjop}. For more information concerning junction temperature limits see AN2008-01 [4]. The quality of the heat sink surface in the mounting area is of great importance for thermal conductivity and distribution of the thermal energy.

The condition of the heat sink contact area should not exceed the values in Table 4, otherwise inhomogeneous heat dissipation can lead to partial overheating of the semiconductors.

Base plate size	**Surface roughness**	**Surface flatness**
PrimePACK^{TM} 2: 172 mm x 89 mm	**≤ 15 µm**	**< 30 µm**
PrimePACK^{TM} 3: 250 mm x 89 mm	**≤ 15 µm**	**< 50 µm**

Table 4: Heat sink surface requirements for PrimePACK^{TM} 2 and 3 modules

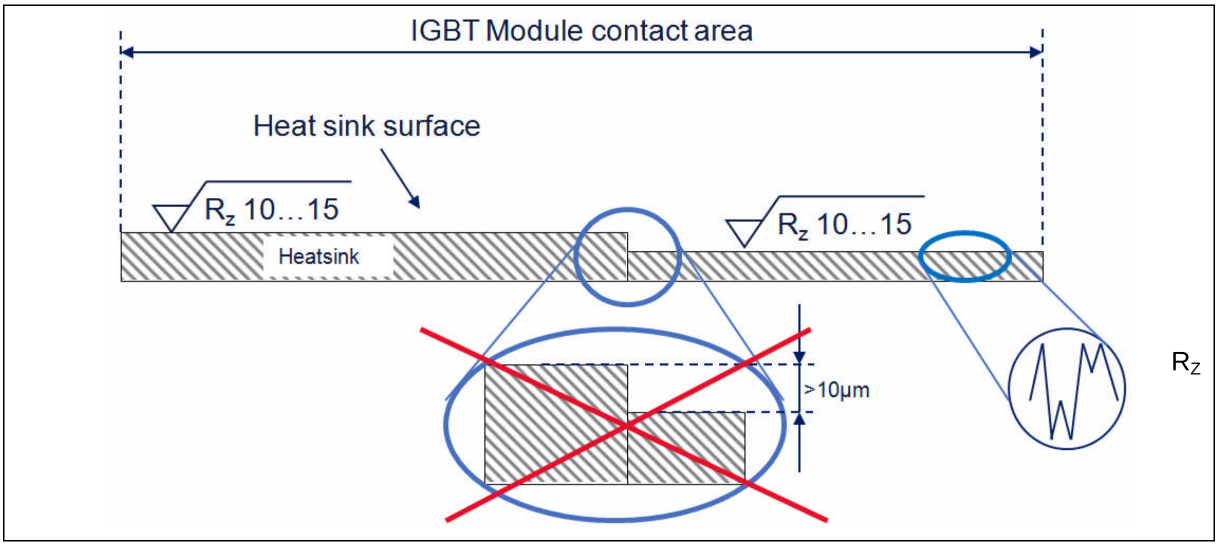


Fig. 4: Graphical explanation of heat sink surface roughness

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 stresses on the base plate of the module. During the entire assembly process the heat sink must remain free of twisting, e.g. on a suitable carrier jig.

8.2 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 occurring 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 a manner that the mounting holes are not contaminated as this could influence the torque values.

8.2.1 Infineon’s thermal interface material – TIM

For maximum long-term stability and thermally excellent properties Infineon has developed a material optimized for IGBT power modules called TIM.

PrimePACK^{TM} modules may be purchased with TIM applied in an optimized structure from your Sales partner for Infineon components. These bear the addition P in the type designation.
Further information can be found in AN2012-07 [11].

An example of a print image on the baseplate of an IGBT module after the TIM has been applied is illustrated in Fig. 5.

Fig. 5: PrimePACK^{TM} module with TIM

If you are using PrimePACK^{TM} modules which have TIM already applied, modules with the extension P, then please continue with section 8.3.

8.2.2 Application of thermal grease in a screen printing process

When using PrimePACK^{TM} modules in which the thermal interface material - TIM - has not been applied by the manufacturer, the user himself has to select and qualify the thermal paste used for suitability and long-term stability.

To achieve an optimal result, the module, the geometry of the application, the contact area of the heat sink as well as the applied grease have to be developed properly.
The contact area between heat sink and module base plate splits into two different paths, the metal-to-metal contact which is highly heat conductive and the thermal grease that is better compared to air, but worse compared to metal-to-metal contact regarding conductivity.
According to that, the optimal heat conducting area maximizes the metal-to-metal contact whereas air gaps are filled by thermal grease. It has to be ensured that the thermal compound does not prevent the metal contact. Therefore, it is recommended to apply thermal grease with a stencil printing process. With this method it is possible to adjust the layer thickness and distribution to get a reproducible layer with well-defined thickness.
Fig. 6 displays an example for a screen printed module with non-uniform distribution of the grease across the base plate. The distribution depends on the macroscopic geometry of the base plate and assures that grease is only placed where it is needed.

The module-specific drawings of a printing stencil can be obtained from the distribution partner for Infineon modules. Typically used printing stencils feature a nominal thickness of 100µm. The proper thickness needs to be determined in the application and depends on different parameters, for example the grease in use or the surface roughness. At selection of the stencil thickness, a possible abrasion of the stencil in use has to be taken into account. The filling factor determines the amount of grease that is placed across the entire area.

Further information on the use of screen printing stencils for the application of thermal compound can be found in the guidelines AN2006-02 [5].

Fig. 6: Example of a screen printed PrimePACK^{TM} module with properly applied thermal grease

The screen printing process has to be stable in order to deliver a reproducible thermal grease layer. One method to ensure this is to use an applicator jig like displayed in Fig. 7.

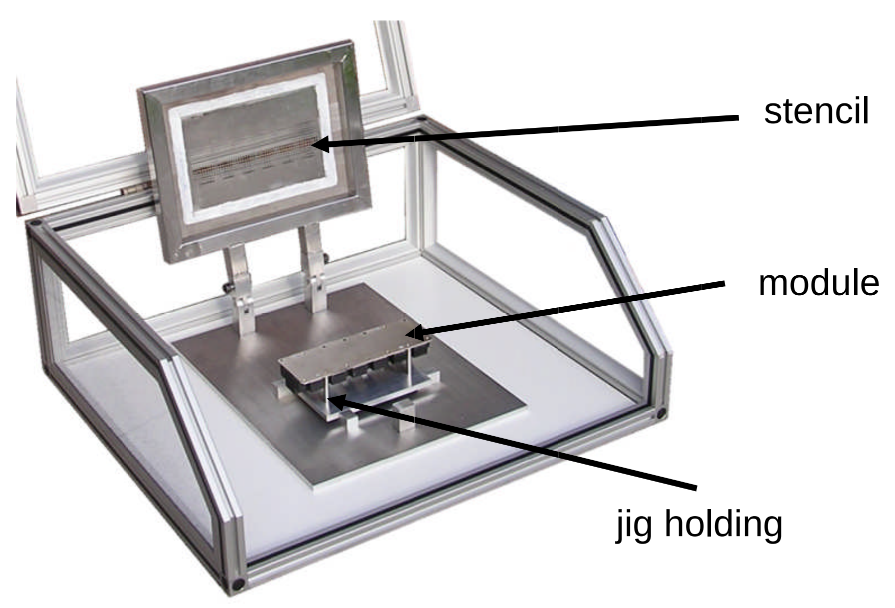


Fig. 7: Applicator jig to apply thermal paste in a screen printing process

To apply the thermal grease properly:

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. Also ensure that solvents are compatible to the grease in use.
2. Align stencil and module with a jig holding as shown in Fig. 7 for example.
3. Lower the stencil onto the module base plate.
4. Apply the thermal grease over the stencil. It is an imperative that all stencil holes are filled properly.
5. Lift the stencil and remove the module.
6. Visual inspection after application of the material ensures that every point of the screen is filled. The application of grease, using a screen, especially when performed manually, can be affected by a poor alignment of the stencil and small variations in the amount of grease and thus increase the expected temperature by a few degrees.
7. Therefore the measurement of the thickness of the deposited material is strongly recommended and ensures that an adequate amount of material was applied.

If this process is done properly the grease material is applied where it is needed. There is less need for it to migrate or flow and so only a minimum amount of grease is required. The metal-to-metal contact is maximized.

In the past it was often tried to derive a correlation between the imprint of a certain thermal grease and its thermal qualities. This approach lead to massive misjudgments and therefore is not recommended.

When applying the grease with the aid of a tool on the stencil, the possible wear of the stencil and the possible reduction in the layer thickness needs to be checked at intervals. Stencils are to be replaced if they no longer have the predetermined thickness.

8.2.3 Alternative ways to apply thermal grease

When using PrimePACK^{TM} modules in which the thermal interface material - TIM - has not been applied by the manufacturer, the user himself has to select and qualify the thermal paste used for suitability and long-term stability.

If it is not possible to apply the thermal grease using the recommended screen printing process, it can alternatively be applied manually, without a stencil. Typically, a uniform layer thickness of 50µm…70µm applied on the base plate of the module is sufficient. The available thermal grease materials differ in their ability to flow and fill the cavities of the heat sink and base plate in a settling phase during mounting of the module and first operation. If the material features a very low viscosity it has a good ability to flow and thus the result is a low uniform thickness. Such low viscous materials have the disadvantage that grease can be pumped out easily and air gaps can be formed. If the grease features a high viscosity it rather stays in place where it is applied and therefore a higher uniform layer thickness, near 70µm, should be targeted to fill all the cavities.

The first step should be the cleaning of the heat sink and the base plate surface with suitable solvents. Use a lint-free cloth and wear gloves. The contact surface of the module and the heat sink must be free of damage and contaminants like grease, paste residues or particles.

The manual application of such a thin layer by using rollers or toothed spatulas is problematic. Homogeneity and reproducibility of the grease thickness is always questionable. A verification of the paste layer thickness can be done by a wet film comb like illustrated in Fig. 8. Place the comb perpendicular to the surface of the heat sink and scrape the comb slowly over it through the thermal grease 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" tooth and the smallest value of the "uncoated" or "dry" tooth.

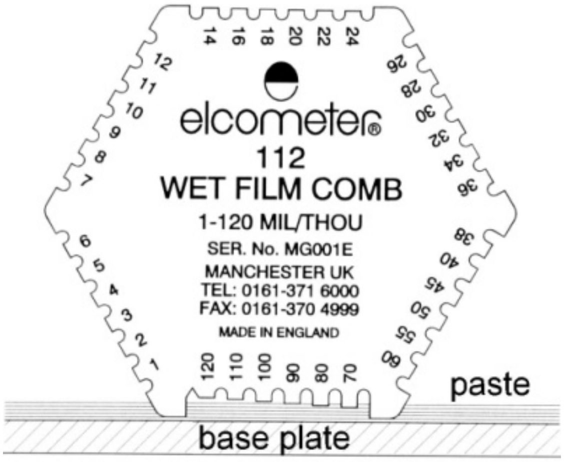


Fig. 8: Wet film comb to check the layer thickness of the thermal paste

8.3 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 onto the heat sink has to be done in a manner that the sum of all occurring forces does not result in exceeding the yield point of the material 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 thus a loosening of the assembly is counteracted.

To avoid a loosening of the module a minimum preload force per screw as defined in the following table should be fulfilled.

Description	Preload Force
Minimum Preload Force	2kN / screw

Recommended is an ISO 4762 screw class 8.8 in combination with a DIN 125 washer. Screwed into a dry thread of the heat sink, the mounting torque defined in the following table is recommended.

Description	Mounting bolt	Mounting torque
Recommended Mounting torque for base plate mounting screw	M5	5± 1 Nm

Table 5: Technical data of the mounting bolts

Threads have to be clean and not lubricated or contaminated by thermal grease.

When screwing to the heat sink, the minimum screw length has to be chosen depending on the used heat sink material.

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

All mounting screws have to be uniformly tightened with the specified mounting torque. A preferred tool for this is an electronically controlled or at least slow moving electrical screwdriver. The work can also be accomplished manually with the aid of a torque wrench. Due to missing accuracy and precision pneumatic screwdrivers should not be used.

Allow the paste to flow and fill remaining voids. Depending on its viscosity, this may take up to several hours. A small quantity of thermal grease may be squeezed out laterally when tightening the module to the heat sink.

For a good heat sink to base plate contact and an optimal distribution of the thermal grease, Infineon recommends the following procedure of tightening the 10 screws for 172mmx89mm, or 14 screws for 250mmx89mm modules after the application of the grease and the positioning of the module on the heat sink:

1. Fix module loosely with two diagonal screws e.g. screws # 7 – 8 for PrimePACK^{TM}2, or 11 – 12 for PrimePACK^{TM}3.
2. Tighten the screws with 5±1 Nm crosswise, like shown in Fig. 9: 1 – 10 for PrimePACK^{TM}2 and 1 – 14 for PrimePACK^{TM}3.

By using thermal grease with high viscosity it is recommended to add an additional step 1.a between 1 and 2:

1.a Tighten the screws with 2Nm±15% in the same sequence as before. By this additional step the thermal compound can start to flow and fill the cavities. The waiting time between step 1 & 2 depends on the thermal grease viscosity.

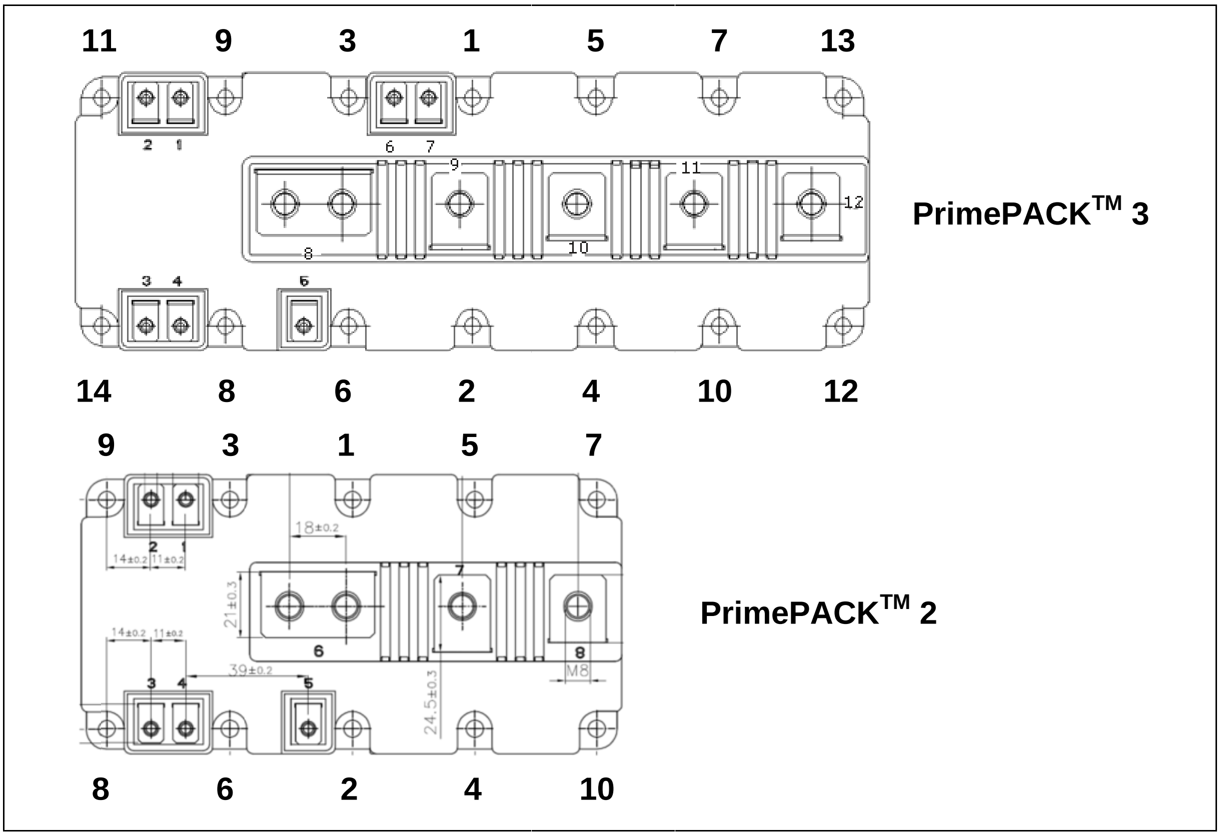


Fig. 9: Recommended bolt-down sequence for PrimePACK^{TM} 3 and 2 modules

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

For assembly process qualification and verification 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 needs to be reviewed by thermal measurements. The junction temperature must not exceed the maximum allowed junction temperature under switching conditions (T_{vjop}), specified in the module data sheet [4].

8.4 Thermal validation at operation

For thermal measurements close to the chip it is necessary to place the temperature sensing probe under the chip like illustrated in Fig. 10. Knowledge of the exact chip positions is essential. The module-specific chip positions are available via the sales and distribution organization of Infineon IGBT power modules.

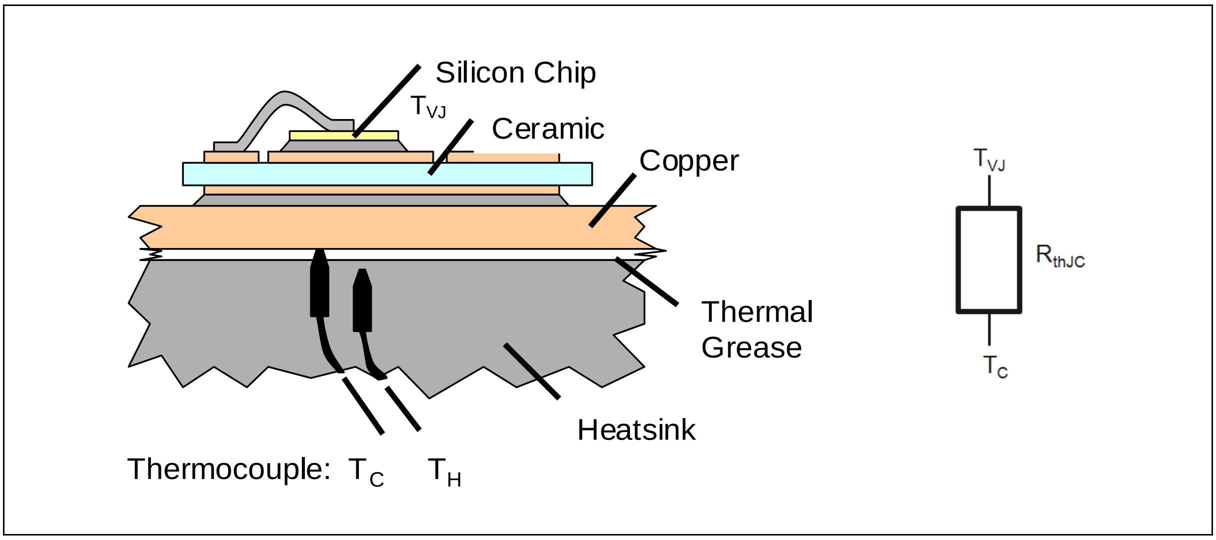


Fig. 10: Example of a temperature measurement set-up using a thermocouple

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 P_V as well as the base plate temperature T_C must be given for the calculation:

T_{VJ}: virtual junction temperature

T_C: case temperature

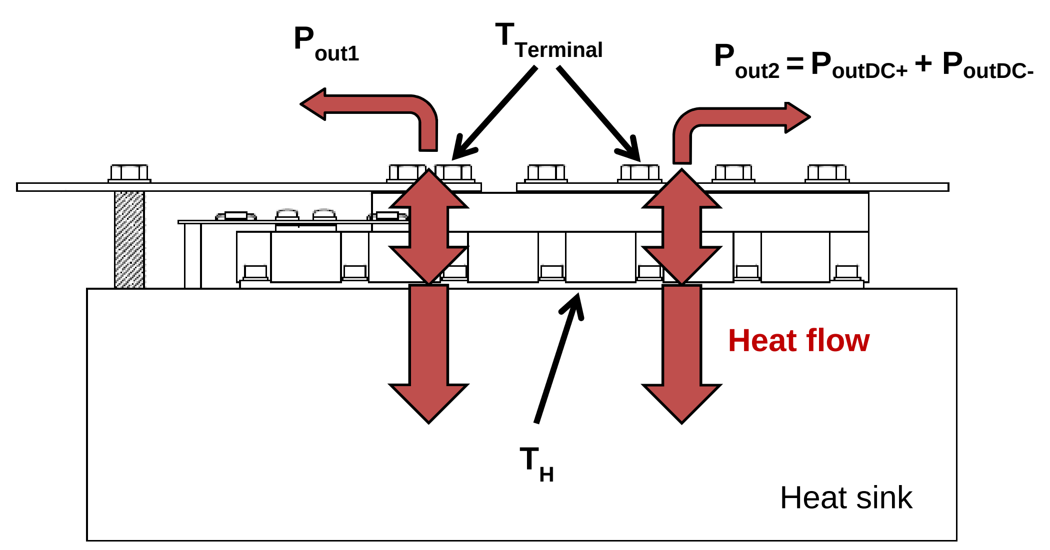
P_V: total power losses per switch

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

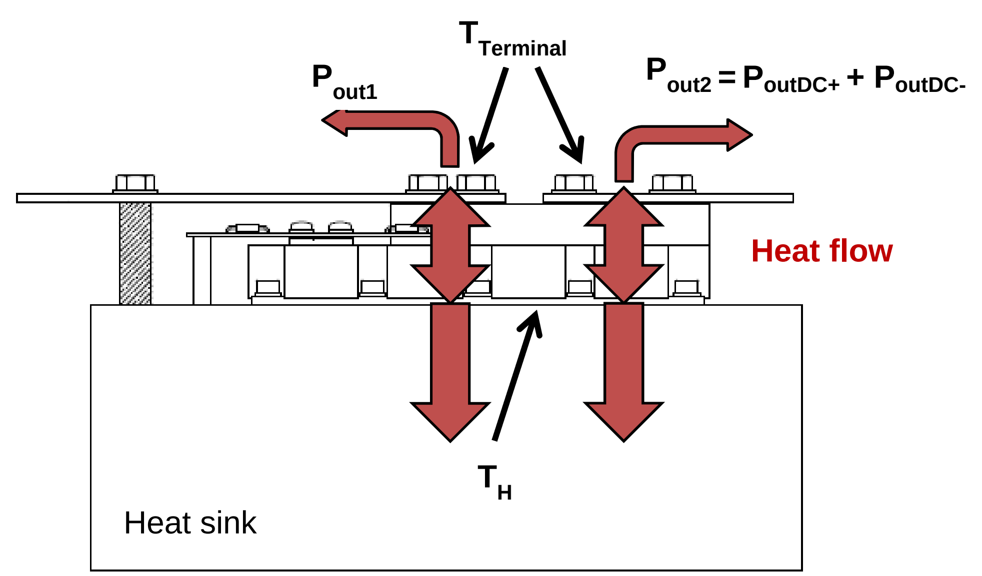
For the design-in of a module into a system it should be noted, that a minor share of the power losses of the power semiconductors and a significant share of the internal busbar losses are transferred through the power terminals. The temperature increase and its effect on the lifetime of the joint and the isolation of the external busbar have to be considered.

Fig. 11 illustrates the possible heat flow. A simulation of the heat flow under defined conditions leads to the results shown in Table 6 and Table 7. A fixed temperature of the power terminals is assumed. P_{out1} and P_{out2} define the thermal power which has to be dissipated via the power terminals to keep the temperature $T_{Terminal}$ constant.

$\mathbf{P_{out1}}$	Thermal power to be transferred via the AC power terminal to keep $T_{terminal}$ constant
$\mathbf{P_{out2} = P_{outDC+} + P_{outDC-}}$	Thermal power to be transferred via the DC power terminals (DC+ and DC-) to keep $T_{Terminal}$ constant
$\mathbf{T_{Terminal}}$	Temperature of the Terminals (AC, DC+, DC-)
$\mathbf{T_H}$	Heatsink Temperature as defined in IEC 60747-15, illustrated in Fig. 10



PrimePACK^{TM} 3 schematic



PrimePACK^{TM} 2 schematic

Fig. 11: Power to be dissipated via the power terminals at constant terminal temperature

Conditions:

The simulation result represents the worst case of a wide range of air and liquid cooling systems and a varying loss distribution between IGBT and diode as well as upper and lower system. The impact of these details is visible, but moderate. The heat sink temperature is defined to a fixed value of

T_H = 100°C. $T_{Terminal}$ is fixed as displayed in Table 6 and Table 7.

PrimePACK^{TM} 2

Each terminal AC, DC+ and DC- loaded with **720A DC current, T_H = 100°C.**

$T_{Terminal}$ [°C] fixed to	**P_{out1} [W] AC Terminal**	**P_{out2} [W] for both DC Terminals (DC+ and DC-)**
125	13	22

Table 6: Simulation results PrimePACK^{TM} 2

PrimePACK^{TM} 3

Each terminal AC, DC+ and DC- loaded with **1080A DC current, T_H = 100°C.**

$T_{Terminal}$ [°C] fixed to	**P_{out1} [W] AC Terminal**	**P_{out2} [W] for both DC Terminals (DC+ and DC-)**
125	33	28

Table 7: Simulation results PrimePACK^{TM} 3

This simulation covers a specific set of conditions. For other operation conditions the thermal situation is to be evaluated individually.

If applied with an AC current an additional effect on the ohmic resistance is seen due to the skin effect. The resistance of the conductors increases depending on the frequency of the current.

Fig. 12 shows the ohmic resistance of the conducting paths:

- 🟦 DC- Terminal to AC Terminal
- 🟥 DC+ Terminal to AC Terminal

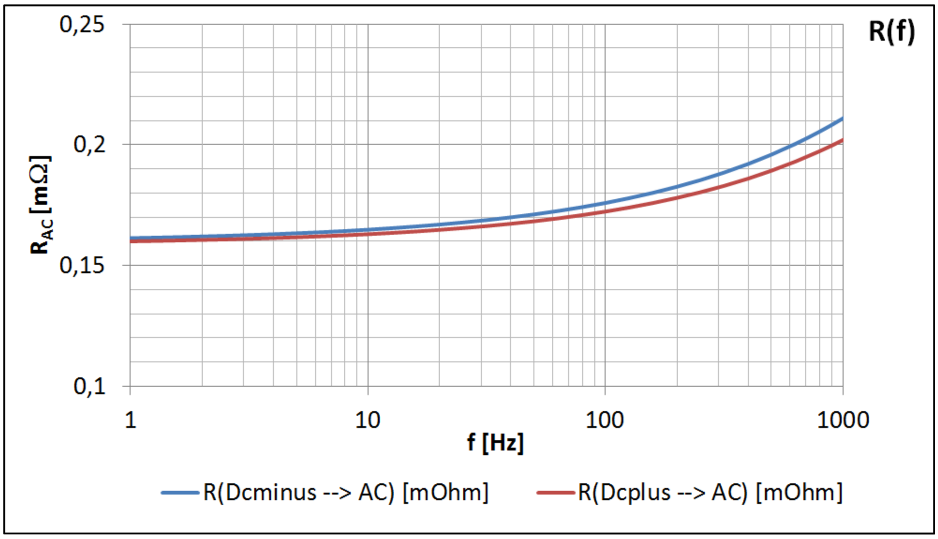


Fig. 12: Increase of conductor resistance depending on frequency

8.5 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 sheet. The position and tolerance of adjacent components such as PCBs, DC-bus, mounting bolts or cables have to be defined in such a manner, that after the connection no sustained effect on the static and / or dynamic tensile forces are exerted to 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 PrimePACK^{TM} modules, M8 bolts are required.

The bolts should be selected according to ISO4762 or DIN7984 with at least screw class 8.8 in combination with a DIN 125 washer. For temperatures above 105°C at the joint spring elements are to be included to maintain the contact pressure even if settling effects take place. As example a conical spring washer according to DIN 6796 or a dented edge washer with Belleville shape can be used.

Also for lower temperatures at the joint this design of the connection is recommended to alleviate the effect of cyclic load.

A more detailed investigation of the physical effects of copper joints beyond 105°C can be found in [13].

The threads should be clean and not lubricated. Table 8 displays the recommended values for the mounting torque of the power terminal connection.

Description	Mounting bolt	max screwing depth	Mounting torque for Condition 1	Mounting torque for Condition 2
Power terminal connection torque	M8	16 mm	8 … 10 Nm	8 … 22 Nm
Auxiliary terminal connection torque	M4	8 mm	1.8 … 2.1 Nm	1.8 … 2.1 Nm

Table 8: Tightening torque for the mounting bolts of the electrical connections

Condition 1:

If the torque is directly passing to the nut of the module and the full torque affects the plastic housing it is limited according to Table 8, condition 1. The upper limit given here assumes a worst case condition when the full applied torque is passed into the nut insert inside the plastic housing.

Condition 2:

If the full torque is not directly passing to the nut of the module as described in condition 1 a higher mounting torque is allowed.

This can be achieved by inserting bolts into all connections of a busbar prior to final tightening. Bolts can be fixed by hand prior to final tightening, for example. It has to be checked, if the maximum allowed contact pressure of the used busbar is not exceeded.

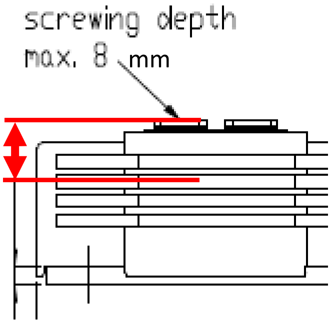


Fig. 13: Screwing depth of auxiliary terminals

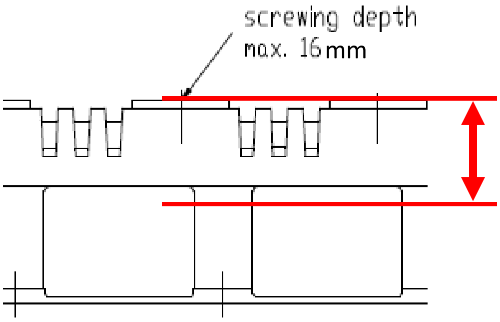
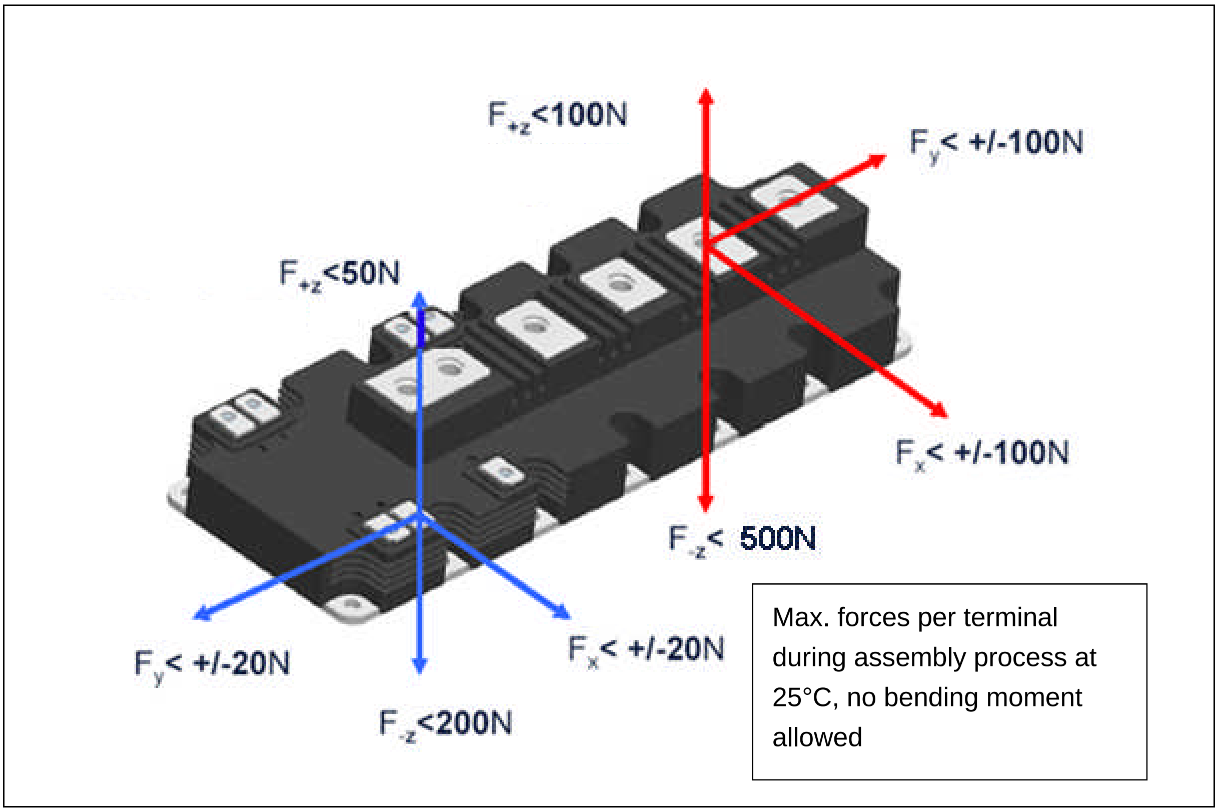


Fig. 14: Screwing depth of power terminals

The choice of bolt length depends on the maximum thread depth specified for the module and the gauge of the connection parts. The effective thread length of the bolts into the module power terminals must not exceed the maximum depth specified in Table 8 and depicted in Fig. 13 and Fig. 14. 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.

The connecting parts must be mounted onto the electrical contacts in a manner that the specified maximum permissible forces are not exceeded. The specific forces in the possible directions are illustrated in Fig. 15. Forces should only be applied during the assembly process.



Max. forces per terminal during assembly process at 25°C, no bending moment allowed

Fig. 15: Maximum permissible forces at the terminals of a PrimePACK^{TM} module

It is recommended to have a construction which leaves the power and auxiliary terminals permanently free of mechanical stress during operation. To achieve this in a wide temperature range it is advised to add suitable spacers.

It must be ensured that the direction of the force always acts towards the direction of the base plate. 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.

8.6 Mounting recommendation with strain relief

To terminate the power terminals with the best possible strain relief, an assembly similar to the drawings shown in Fig. 16 is recommended. This is especially important if the modules or busbars are subjected to vibration. It is recommended to keep the terminals in compression rather than tension as displayed in Fig. 16. The terminals should not been pulled up.

Note: It is recommended to put the modules main terminals under compression when attaching the busbars. A mounting height for the distance keepers of 37.7 mm is recommended like illustrated in Fig. 16. The forces during assembly must not exceed the values shown in Fig. 15.

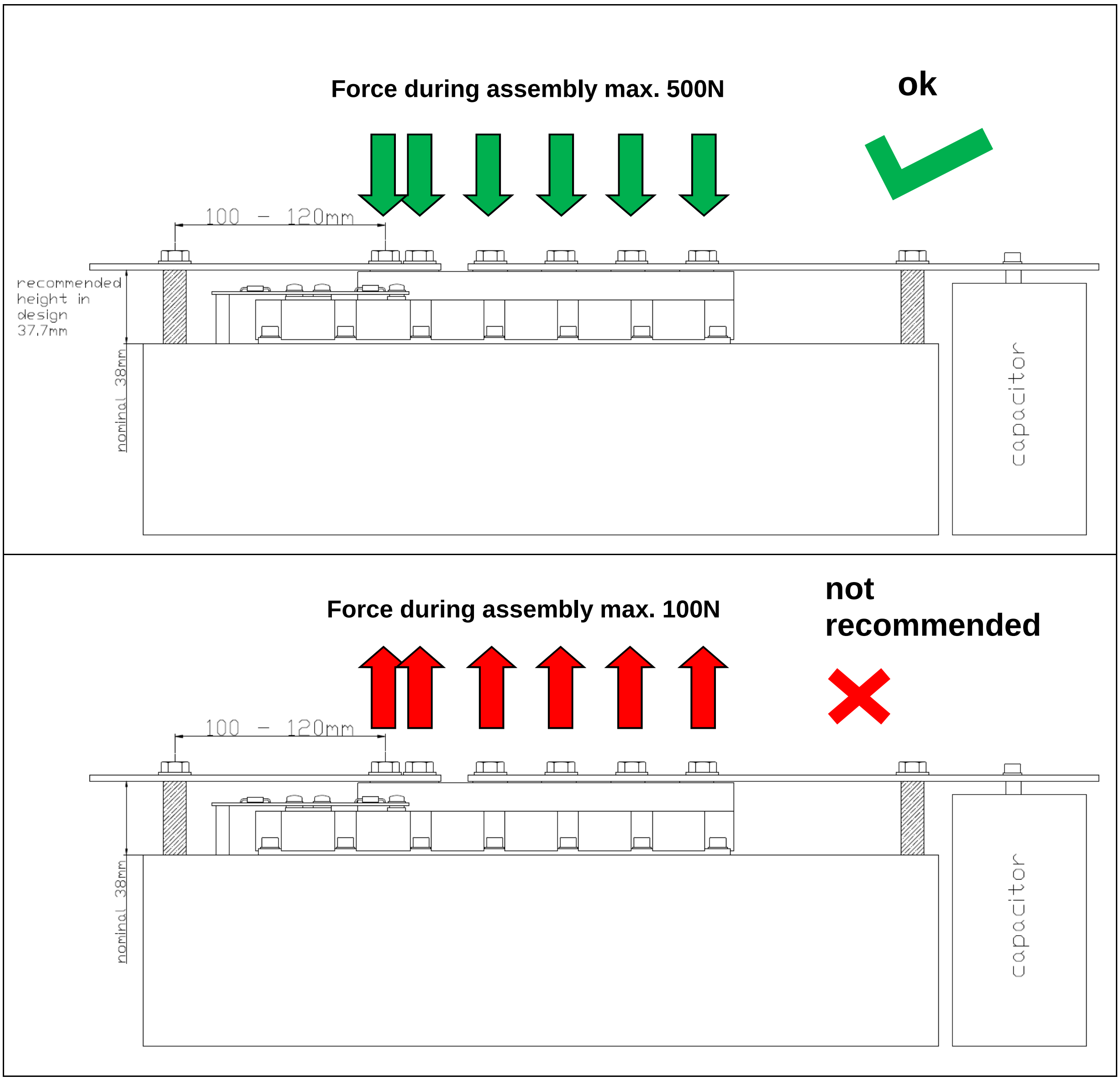
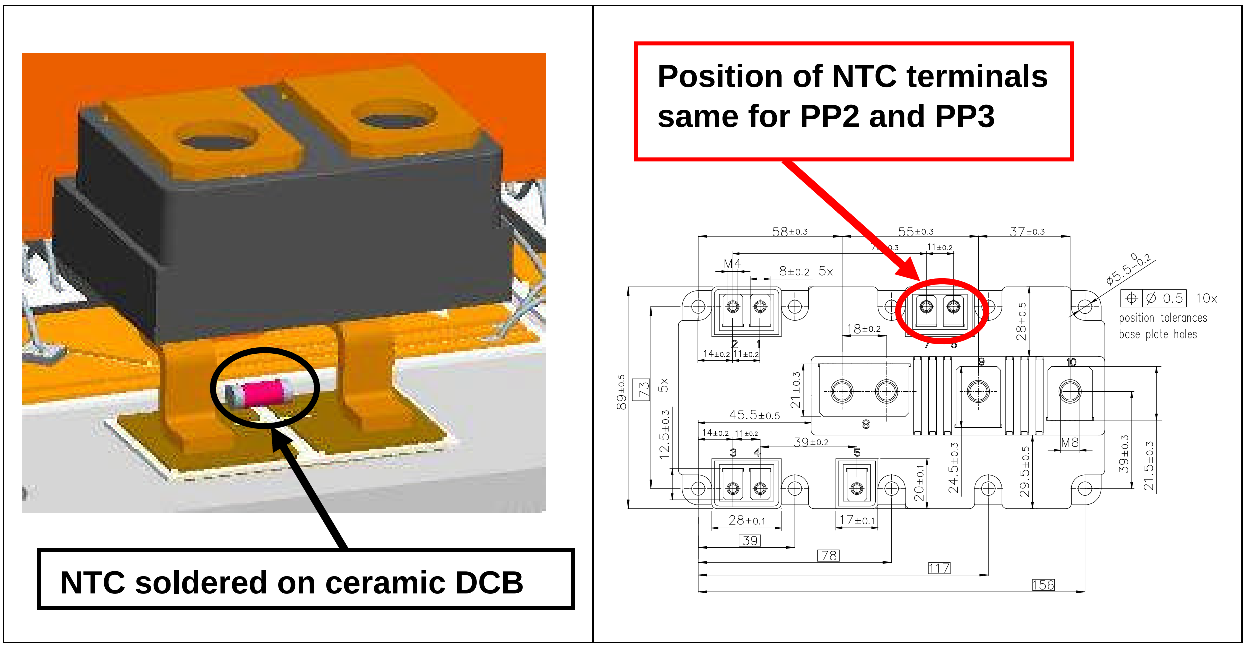


Fig. 16 : Possible configuration of PrimePACK^{TM} module with a suggested method of strain relief

9 Internal NTC characteristics

PrimePACK^{TM} modules contain a NTC resistor for thermal monitoring. With the integrated NTC an estimation of the chip junction temperature is possible by using a thermal model and measuring the base plate temperature. This provides a known point for the calculation to start from.

The NTC inside the PrimePACK^{TM} module is located near the module edge as illustrated in Fig. 17.



NTC soldered on ceramic DCB

Position of NTC terminals same for PP2 and PP3

Fig. 17: NTC position

The NTC is mounted to a separated substrate that is connected to the thermal flow inside the module as depicted in Fig. 18.

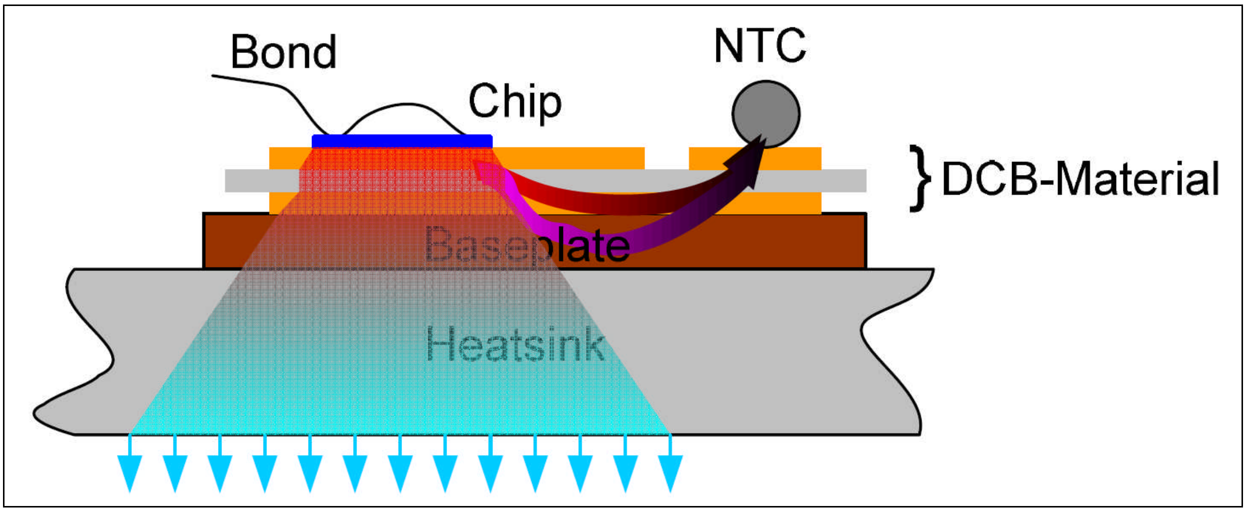


Fig. 18: Flow of thermal energy inside a power electronic module

The majority of heat generated in the chip flows directly to the heat sink from where it is dissipated to the environment. Additionally, heat flows through the DCB material and the base plate towards the NTC position. Therefore, the NTC temperature is depending of its cooling conditions. As heat does not flow instantaneously, the NTC is only suitable to represent the case temperature in static points of operation. Transient phenomena like heat generated in short circuit conditions cannot be monitored or detected as the correlating time constants are far too small.

As an important consequence, the NTC cannot be used for short circuit protection or the direct measuring of T_{vjop}.

The isolation of the internal NTC, between NTC and IGBT chips qualifies a basic isolation.
Further details concerning isolation and usage of the internal NTC can be found in AN2009-10 [8].

The characteristic of the NTC in use can be found in the module datasheet. Fig. 19 displays an exemplary graph with a B-value of $B_{25/80} = 3411$ K according to the function taken from the datasheet $R_2 = R_{25} * \exp[B_{25/80} (1/T_2 - 1/(298{,}15K))]$.
The NTC temperature can be calculated respectively by use of the datasheet values and the measured NTC resistance R_{NTC} with the equation:

$$T_2 = \frac{1}{\frac{\ln\left(\frac{R_2}{R_{25}}\right)}{B} + \frac{1}{T_1}}$$

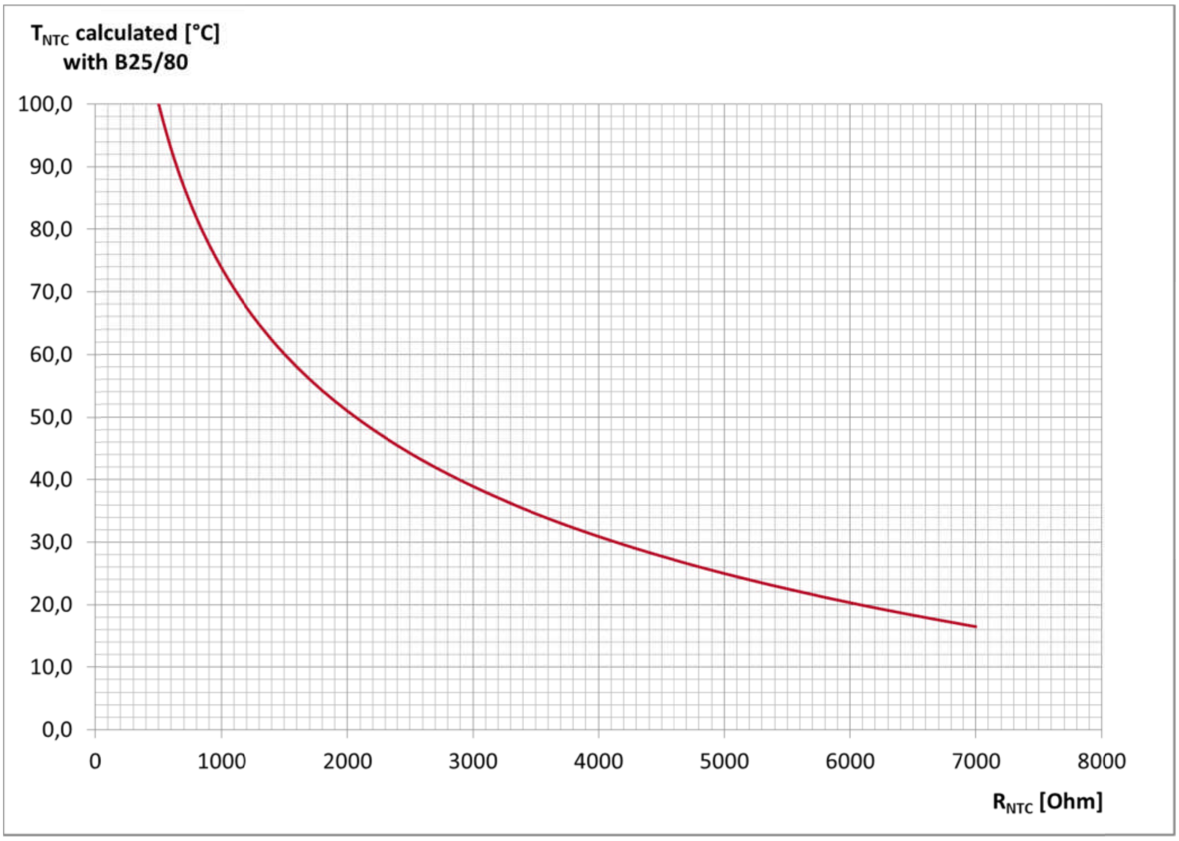


Fig. 19: NTC characteristic with $B_{25/80}$

10 Example for low inductive DC link busbar design

Fig. 20 illustrates two examples for connecting the DC link busbar to the power module. Fig. 20 a) is optimized for low switching losses. A similar design is used for characterization by Infineon. The setup b) on the other hand shows a design to obtain a very compact converter, like explained in [12]. It has to be considered that the way of connecting the busbar has a significant influence on the switching losses. The final thermal design should be based on switching losses measured in the design intended to be used in the end product. The stray inductance between DC link capacitors and module terminals should be as low as possible to limit the overvoltage at turn-off of the IGBTs. High stray inductances lead to a high voltage overshoot at turn-off. The resulting voltage peak has to be lower than the maximum blocking voltage. In addition, the switching losses need to be evaluated with the DC link design since they can differ from the datasheet values, depending on the mechanical design. If the stray inductance is reduced, the risk of exceeding the maximum blocking voltage is lowered.

A laminated busbar as illustrated in Fig. 20 is effective to reduce the DC link stray inductance.

The DC link layout, e.g. a 3-phase design with 3 modules should be as symmetric as possible. A mechanical fixture of the DC link construction, as shown in chapter 8.6, is recommended to avoid mechanical loads at the terminals.

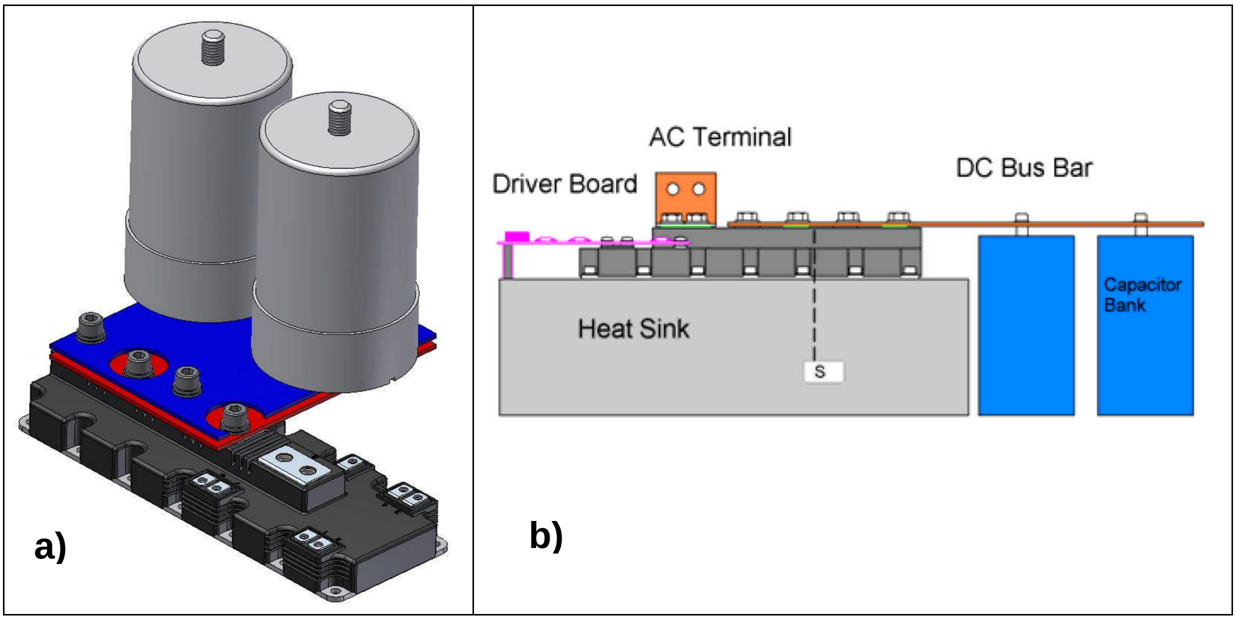


Fig. 20: Two Examples of a low inductive DC link busbar connection to the module

11 Evaluation Adapter Boards for PrimePACK^{TM}

To evaluate the modules in operation, the evaluation adapter boards MA300E12 and MA300E17 for 1200V and 1700V combined with the dual gate drive unit 2ED300C17-S can be used.

Further details like the dedicated application note AN2007-06 [9] and more technical details regarding 2ED300C17-S as well as ordering information can be obtained from www.infineon.com.

Fig. 21 depicts the adapter board MA300E12 mounted on a PrimePack^{TM} 2 module.

Fig. 21: MA300E12 Adapter Board mounted on a PrimePACK^{TM} 2

Fig. 22: Parallel connection of 3 PrimePACK^{TM} 2 with MA300E12 adapter boards, 2ED300C17-S dual gate drive unit and 2ED300E17-SFO evaluation board

The driver board 2ED300C17-S can be used for paralleling up to 3 PrimePACK^{TM} modules with a MA300E12 or MA300E17 adapter board mounted on each module. Control boards, mounted onto the module should be evaluated regarding their maximum temperatures. More information, exemplarily for the adapter board MA300 can be found in AN2007-06 [9]. The evaluation board 2ED300E17-SFO enables the connection of the gate driver and the adapter boards as displayed in Fig. 22. The Application Note AN2007-05 [10] describes its functionality. More information regarding paralleling of IGBT modules can be found at www.infineon.com.

12 References

[1] Infineon Technologies AG: TR14 Storage of Products supplied by Infineon Technologies; Application Note; 2009

[2] Infineon Technologies AG: AN2011-05 Industrial IGBT Modules - Explanation of Technical Information, Application Note, 2013, V1.1

[3] Infineon Technologies AG: AN2010-02 Use of Power Cycling Curves for IGBT4; Application Note; 2010

[4] Infineon Technologies AG: AN2008-01 Definition and use of junction temperature values; Application Note; 2008

[5] Infineon Technologies AG: AN2006-02 Application of silk screen print templates; Application Note; 2006

[6] A. Volke, M. Hornkamp: Infineon Technologies IGBT Modules -Technologies, Driver and Applications; ISBN 978-3-00-032076-7

[7] R. Bayerer, D. Domes: Power Circuit design for clean switching; IEEE; CIPS 2010

[8] Infineon Technologies AG: AN2009-10 Using the NTC inside a power electronic module; Application Note; 2009

[9] Infineon Technologies AG: AN2007-06 MA300E12 / MA300E17 – Module Adapter Board for PrimePACK™ IGBT Modules; Application Note; 2010 V1.2

[10] Infineon Technologies AG: AN2007-05 Evaluation Board for 2ED300C17 -S/-ST IGBT driver; Application Note; 2008 V1.1

[11] Infineon Technologies AG: AN2012-07 Modules with pre-applied Thermal Interface Material; Application Note; 2012

[12] O. Schilling, M. Wölz, G. Borghoff, Th. Nübel, G. Bräker, Chr. Lübke: Properties of a New PrimePACK™ IGBT Module Concept for Optimized Electrical and Thermal Interconnection to a Modern Converter Environment; PCIM Europe; 2005

[13] S. Schlegel, S. Grosmann, H. Lobl, Technische Universität Dresden: Joint resistance of bolted copper - copper busbar joints depending on joint force at temperatures beyond 105 °C; IEEE Holm Conference; 2010