VE-Trac™ Direct / Direct SiC Assembly Guide

AND9989/D

This document is intended to be a guide to correctly assemble all VE−Trac Direct family of modules. It covers the recommended tools, materials and components needed to mount the power module to the cooler and the gate driver printed circuit board to the power module.

Using the module beyond the limits and recommendation in this guide requires additional tests and verification by the user.

APPLIES TO THE FOLLOWING PARTS

NVHxxxS75LxSPx	IGBT 6pak /w Press−fit pins, pin−fin & Flat back series
NVXRxxSxxMxSPx	SiC 6pak /w Press−fit pins, pin−fin & Flat back series

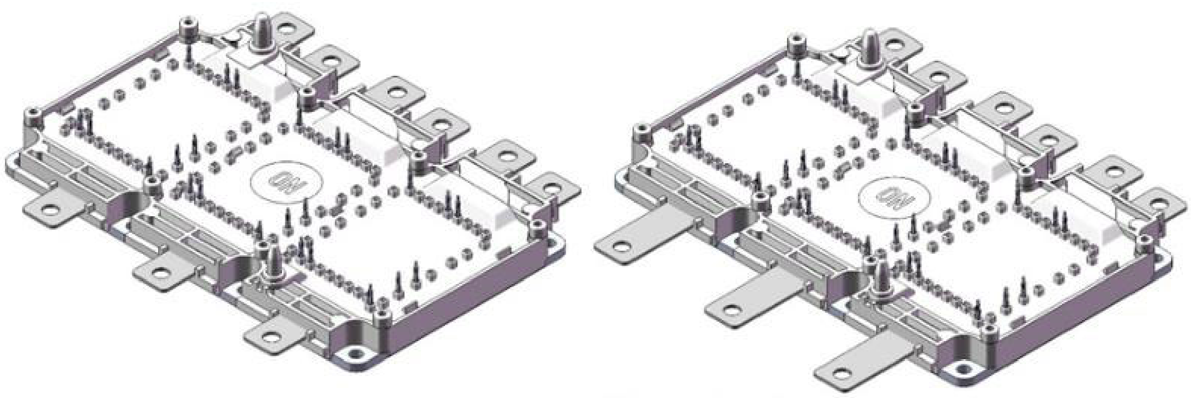


Figure 1.

INTRODUCTION

VE−Trac Direct represents a family of power modules specifically designed for Electric Vehicle (EV) traction application. This document is intended to serve as a guide for Si−IGBT and SiC MOSFET version of the product. It also includes the various terminal and heatsink variations. In order to avoid unnecessary mechanical stress on the assembly it is important to follow the recommended assembly order to correctly install the power module into the end application power converter. Be sure to follow the detailed guidelines explained in this document for each step listed.

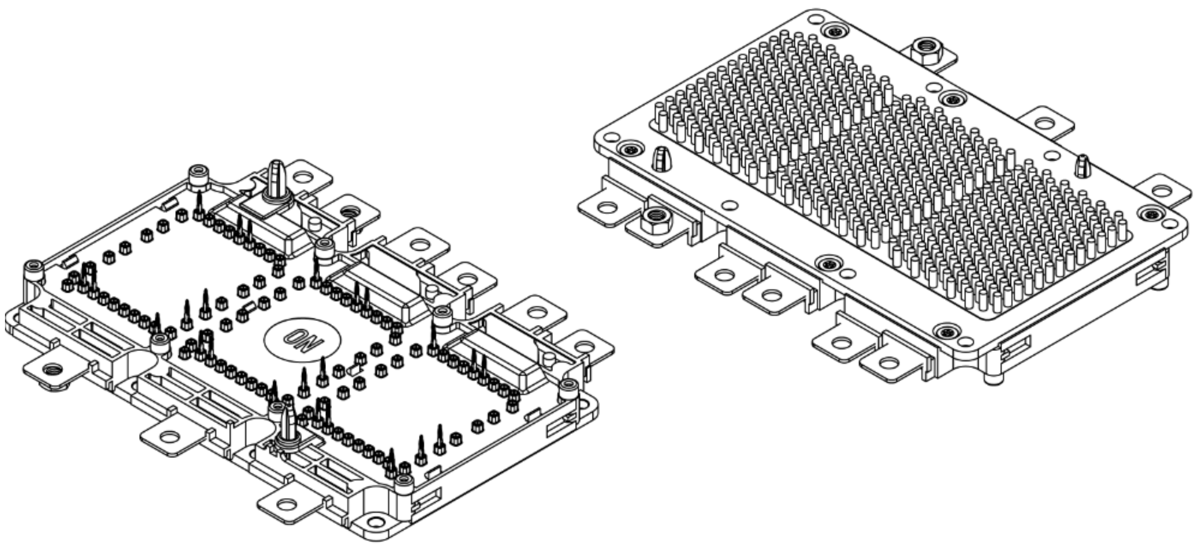


Figure 2. Example VE−Trac Direct Power Module Top View (right) Bottom View (left)

Recommended mounting order for the assembly for press−fit:

1. Align PCB to the power module.
2. Press−in the PCB to the press fit pins
3. Prepare cooler with the sealing ring
4. Attach the power module with PCB to the cooler
5. Secure the module to the cooler
6. Secure the PCB to the power module
7. Connect the module terminals to the end application power converter

Recommended mounting order for the assembly for press−fit pins with soldering:

1. Prepare cooler with the sealing ring
2. Attach the power module to the cooler
3. Align PCB to the power module and insert until resting on the case mounting domes
4. Secure the PCB to the power module
5. Solder the press−fit pins to the PCB

PRINTED CIRCUIT BOARD (PCB) ASSEMBLY

PCB Requirements for Press−fitting Only

All VE−Trac Direct power modules have a unique press−fit pin design suitable for standard FR4 printed circuit boards with tin plating. The PCB material must be compliant with IEC 60249−2−4 or IEC 60249−2−5 for double sided PCBs. For multi−layer PCBs the material must be compliant to IEC 60249−2−11 or IEC 60249−2−12. The requirements for the press−fit pin holes are summarized below for a std. 1.6 mm thick PCB and the component keep out zone around each press−fit pin hole:

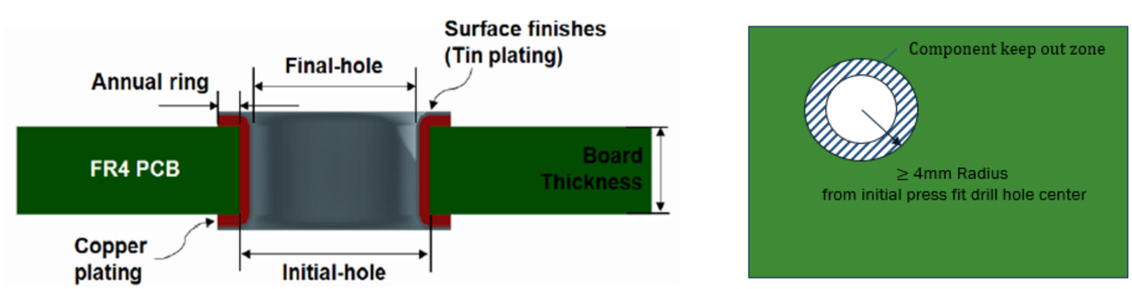


Figure 3. Press−fit Hole Definitions for PCB and Component Keep Out Zone around each Press−fit Hole

It should be noted that slotting to reduce forces on the press−fit pin is not recommended for a press−fit only interface. But if slots are being added, it is necessary to keep them out of the defined keep−out zones.

The table below summarizes the specifications for a 1.6 mm thick two layer PCB. The force required for insertion and extraction is specified in the next section.

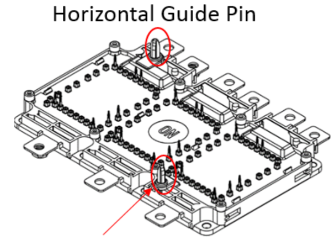
Table 1. REQUIREMENTS FOR PCB FOR PRESS−FITTING

#	Description	Min	Typ	Max
1	Initial (Drill) hole diameter (mm)		1.15	
2	Copper thickness in press−fit hole (μm)	25		50
3	Metallization (Sn) in press−fit hole (μm)	10		15
4	Final hole diameter (mm)	1	1.04	1.09
5	Annular ring (μm)	300		
6	Hole to Hole pattern tolerance			±100 μm
7	Metal type on circuit board	Tin		
8	Metal type on pin	Sn/Ni to mitigate whisker growth		

In addition to the press−fit holes, it is also necessary to have the holes in the PCB for the guide pins. The requirement for the guide pin holes are listed in the table below.

Table 2. GUIDE PIN REQUIREMENTS

#	Description	Min	Typ	Max
1	End hole diameter of Horizontal Guide Pin	5.82 mm	5.9 mm	
2	End hole diameter of Rotational Guide Pin	4.82 mm	4.9 mm	
3	Hole to Hole dimensional tolerance			±100 μm



PCB Mounting Tool

For press−fitting option (not required if soldering press−fit pins) it is highly recommended that a tool be used to mount the PCB to the power module to ensure a proper fit without damage to the PCB or the power module. The tool itself is made of two parts – a top and bottom part (Figure 4).

The bottom part of the tool is made of plastic to avoid damaging the critical baseplate surface used for sealing. It is designed as a cradle to properly support the power module and protect the pin fins from damage during the PCB press fit mounting process. The guide pins at the bottom of the power module ensure that the module is always oriented correctly in the bottom tool.

The top tool supports the PCB around each of the press−fit pins to ensure an even delivery of force across the PCB without warping of bending the PCB during the press−in process. The tool is made of steel to withstand the required press−in forces. A hollow cylinder around each of the press−fit pin hole in the PCB ensures that the there is no mechanical interference between top tool and the other components on the PCB. Since the SiC version of the modules have a different press−fit pin layout, it is necessary to have a slight modified version of the top tool for SiC modules.

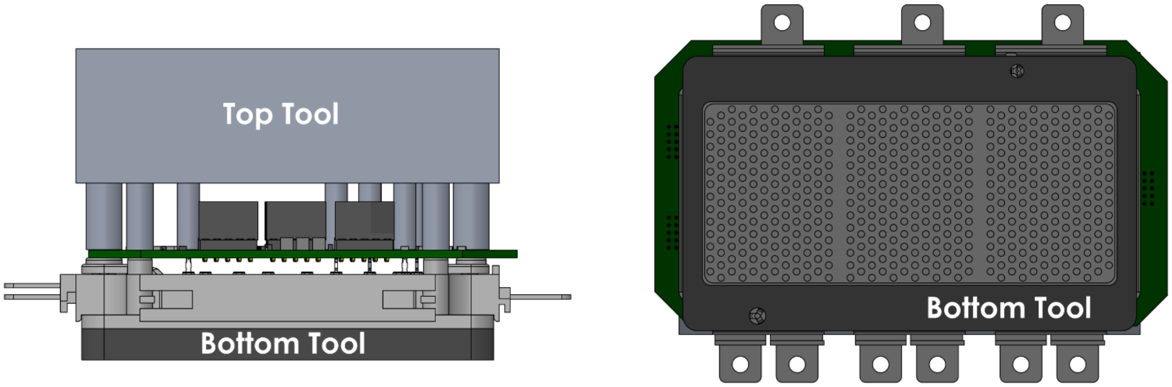


Figure 4. PCB Mounting Tool for All Si−IGBT Version of the Modules is shown

It should be noted that the height of the hollow cylinders on the top tool must such that it can clear the tallest components on the PCB. During the press−in process the top and bottom tools must be parallel to each other and a force is applied in the vertical direction to complete the press−in process to attach the PCB to the power module.

The design for a reference PCB insertion tool is provided below in Figures 5, 7 and 8. The reference tool design maybe adapted for specific customer systems provided the key concepts remain the same.

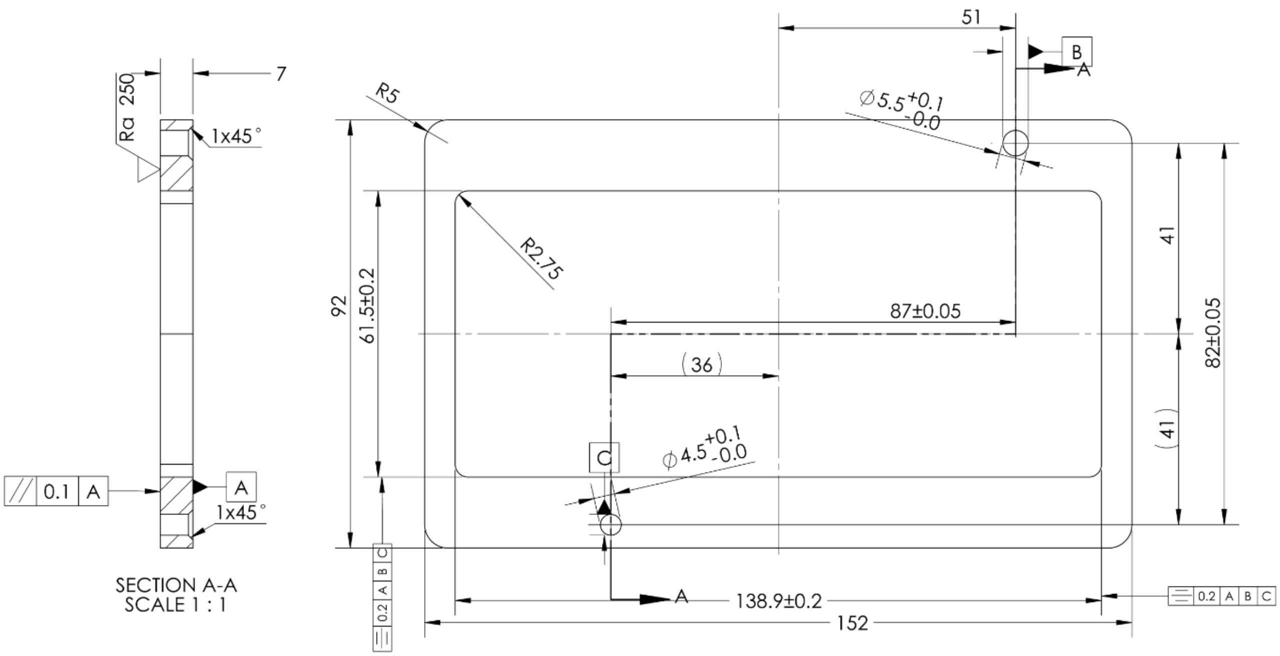


Figure 5. Bottom Tool Design

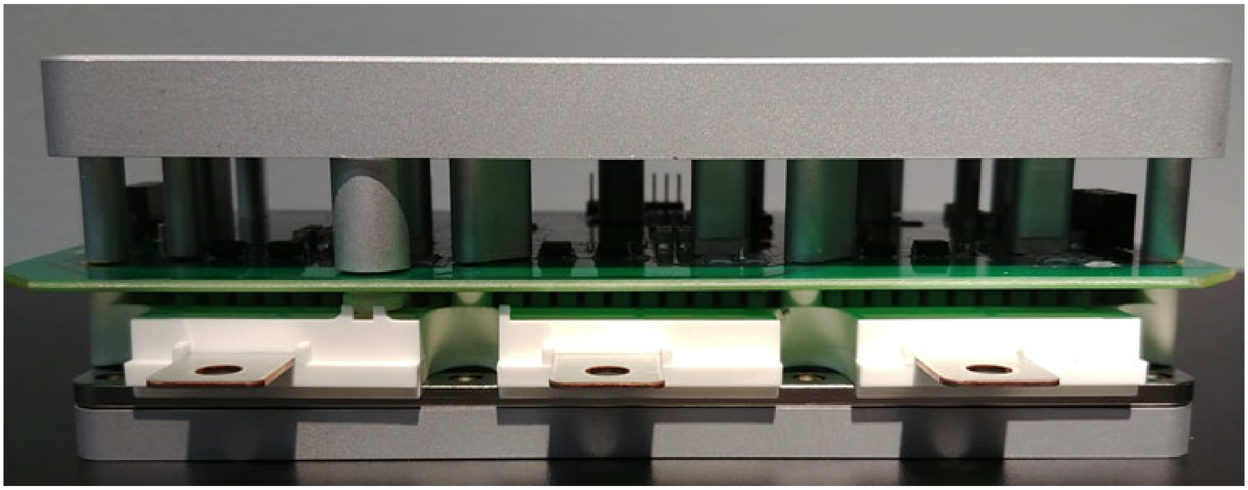


Figure 6. Example Use of the Actual PCB Mounting Tool

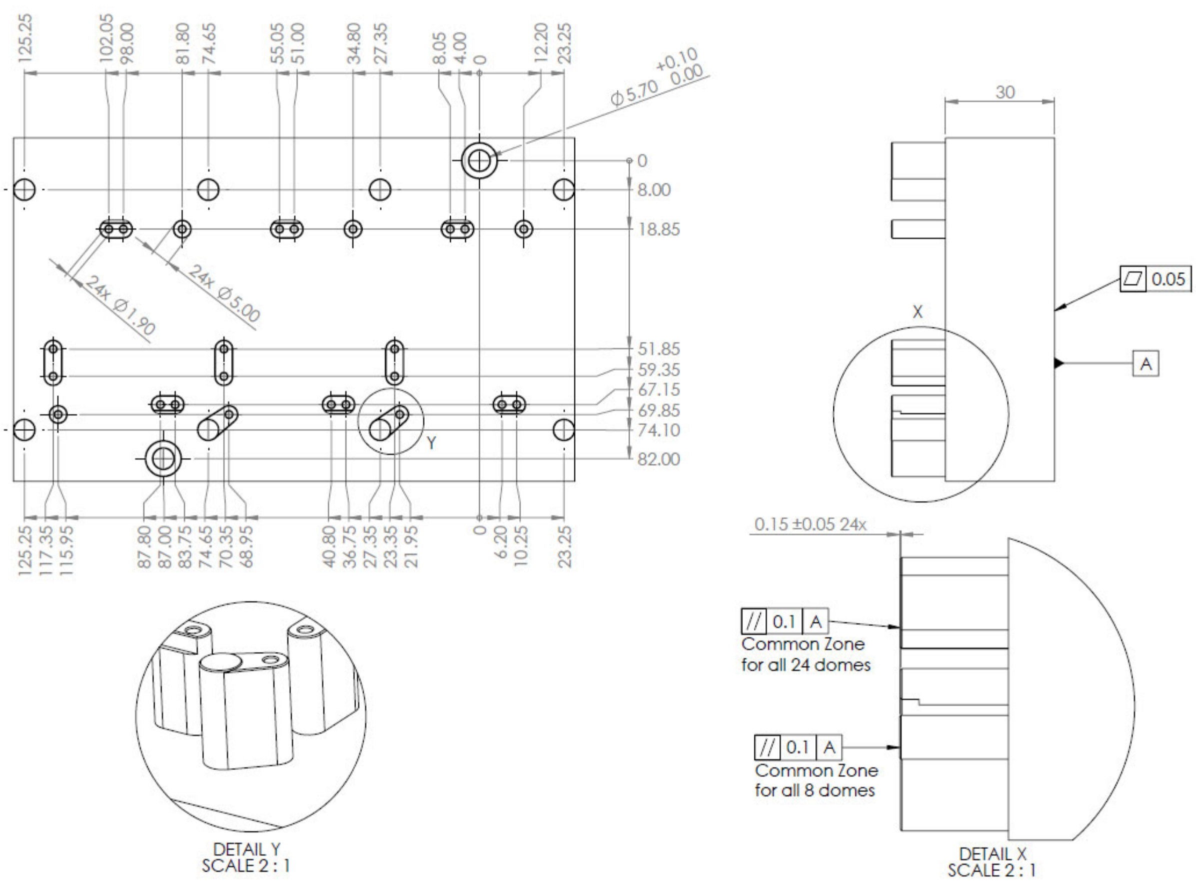


Figure 7. Top Tool Design Specifically for All Variants of Si−IGBT Modules

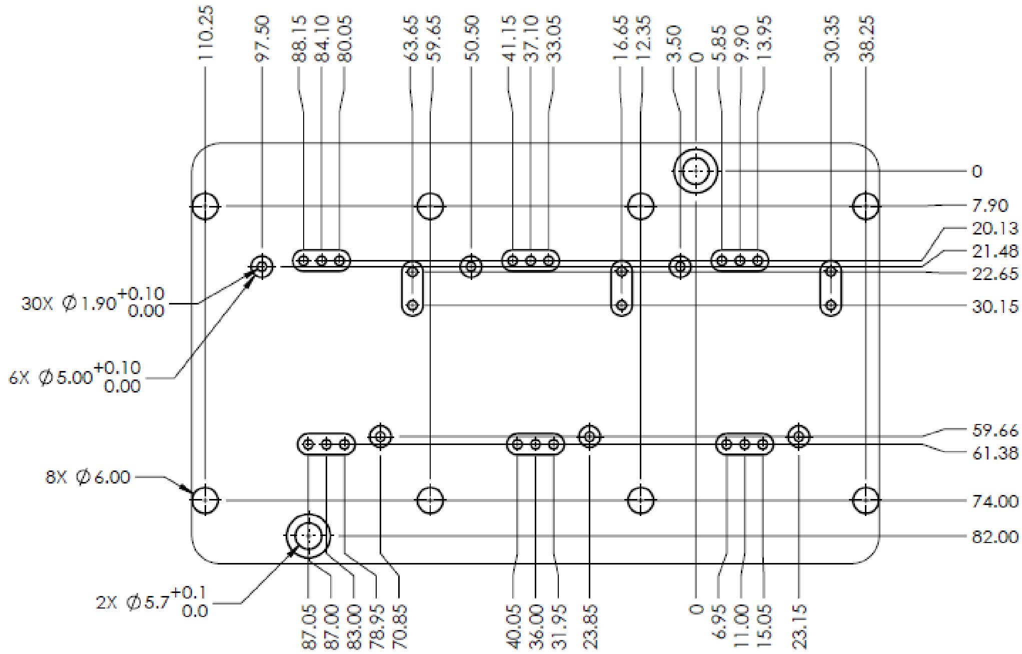


Figure 8. Top Tool for All SiC−MOSFET Variants of Module

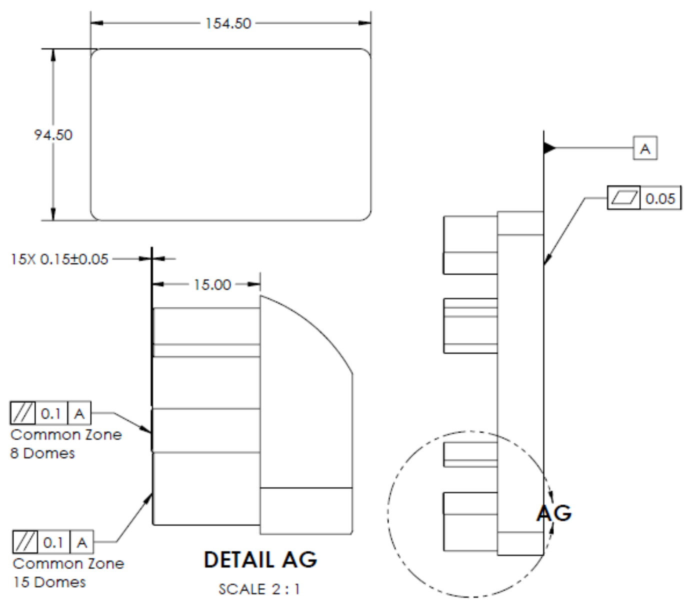


Figure 9. Detail for Top Tool for SiC Variants

Press−fit Assembly

The horizontal and rotational alignment pins on the power module ensure that the PCB is correctly oriented on the power module. This also ensure that all the press−fit pins are aligned on the press−fit holes on the PCB. Using the press−in process described in the previous section, follow the specifications for speed and force as recommended in Table 3 and Figure 10. The press−in force plot shown in Figure 10 can be split into 3 phases. In the first phase the "fish−eye" of the press−fit pin is collapsing and peaks when fully collapsed. In phase 2 the force decreases as the fish eye slides into the PCB and in phase 3 the PCB hits the mounting points on the module and any further increase in force is not beneficial and may result in damage to the PCB assembly. The lower part of the plot shows the strain on the PCB during the press−in process. The location of the strain sensors are identified and the force and strain measurements are aligned with the displacement of the PCB on the x−axis.

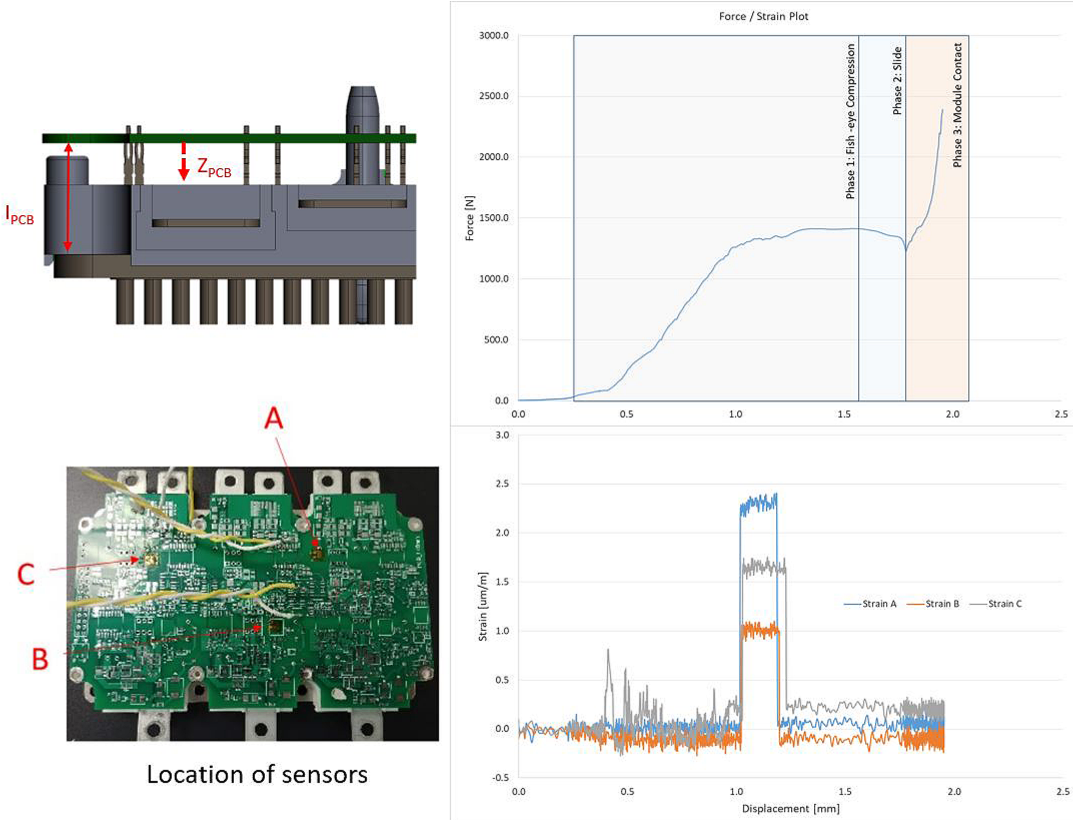


Figure 10. Press−in Definitions with Press−in Force versus Position Plot

Press−out operation and tool is presently not verified and is not recommended.

Table 3. RECOMMENDED PRESS−IN SPECIFICATIONS

#	Description	Min	Typ	Max
1	Press−in speed	25 mm/min		500 mm/min
2	Starting I_{PCB}	–	14.5 mm	–
3	Travel distance Z_{PCB}	1.7 mm		2 mm
4	Ending I_{PCB} (after securing the PCB to the module)	12.75 mm	–	–
5	Max. allowed force on module	–	–	3.5 kN

PCB Requirements for Press−fit Pins with Soldering

onsemi’s unique press−fit pin design offers one of the lowest FIT rate connectivity between a power module and PCB. This advantage primarily comes from the ability of the press−fit pin to contort or temporarily deform during insertion to form a tight yet flexible and reliable contact between the pin and the plated through hole on the PCB. Some of the flexibility is lost if the press−fit pins are soldered to the PCB after insertion and can result in an increased FIT rate. For this reason soldering press−fit pins to the PCB is NOT RECOMMENDED.

However, if there is a strong desire to solder the press−fit pins, then please follow the directions for the PCB design as stated at the start of the section for press−fit pins except for the information stated in the table below.

Table 4. PCB REQUIREMENTS FOR SOLDERING PRESS−FIT PINS

#	Description	Min.	Typ.	Max.
1	Initial (Drill) hole diameter (mm)		1.7	
2	Copper thickness in press−fit hole (μm)	20		25

Table 4. PCB REQUIREMENTS FOR SOLDERING PRESS−FIT PINS (continued)

#	Description	Min.	Typ.	Max.
3	Metallization (NiAu) in press−fit hole (μm)			7
4	Final hole diameter (mm)	1.539	1.62	1.701
5	Annular ring (μm)	650		
6	Hole to Hole pattern tolerance			±100 μm
7	Component keep out zone around the press−fit initial drill hole center on PCB	≥ 4 mm radius from center		
8	Metal type on circuit board	NiAu		
9	Metal type on pin	Sn/Ni to mitigate whisker growth		

The description of the parameters above are defined in Figure 3. Soldering the press−fit pins to the PCB makes the mechanical assembly less compliant and thus the PCB requires slotting to decouple the solder joints from shock and vibration from the mounting points on the module and eliminate any potential mechanical oscillations.

It is critical that when soldering the press−fit pins to the PCB the assembly process steps should be flowed as listed in the first section of this document.

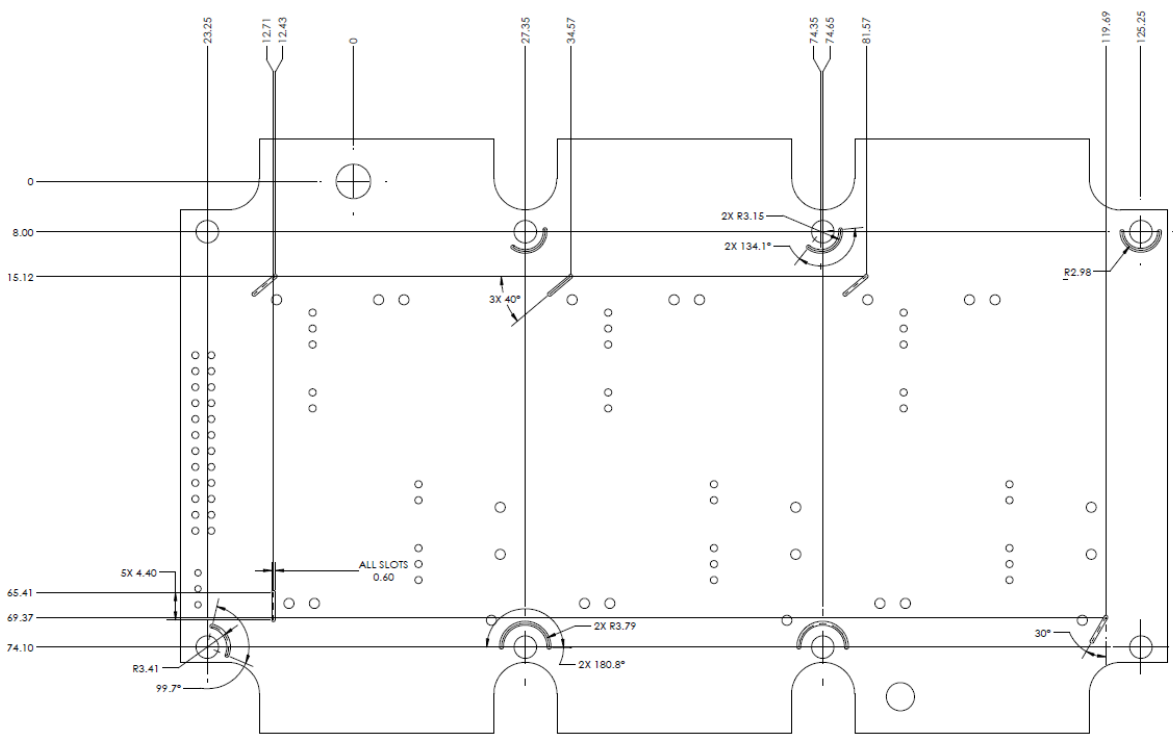


Figure 11. Recommended Slots for the PCB, used with Si IGBT Modules, to minimize the Effects of Vibration

Only hand/automated soldering with a soldering iron is recommend. For the PCB requirements as stated in Table 1, following the annular ring size recommendation for the solder option. Soldering the pins should only be attempted after the PCB is securely mounted to the module with the recommended screws. This minimizes the mechanical stress on the solder pins. According to IEC 68 section 2, the soldering time must not exceed the values shown in the table below. The power, tip size and working temperature of the iron must be adjusted such that it does not exceed the specified limits. When soldering is complete, the joint should be inspected according to IPC−A−610G for press−fit pins.

#	Description	Unit	Min.	Typ.	Max.	Comment
1	Max. solder tip temperature	°C		280	315	
2	Solder Time	s		4	7	
3	Max. module housing temperature during soldering	°C			225	
4	Module PCB mounting dome temperature during soldering	°C	100		150	

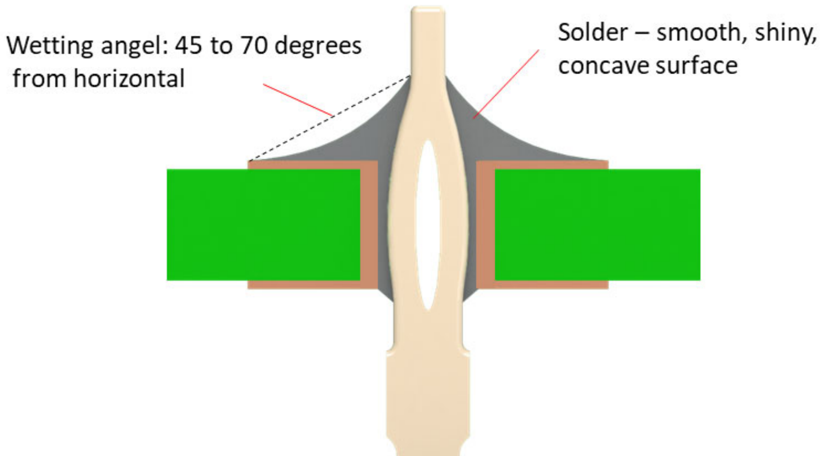


Figure 12. Example Illustration of Soldered Press−fit Pin

Attaching PCB to Power Module

The PCB should be attached to the power module with screws only after the power module is attached to the heatsink assembly. The length of the screws should be selected according to the thickness of the PCB. For a typical PCB with a thickness of 1.6 mm the following self−tapping screw type and length is recommended with recommended torque and speed shown in Table 5:

EJOT Delta PT WN5451 30x10

The length of the recommended mounting screws must be selected according to the thickness of the PCB. Using other screw types can permanently damage the mounting points on the plastic module.

Table 5. PCB MOUNTING SCREW SPECIFICATIONS

#	Description	Min	Typ	Max
1	Mounting torque for PCB Screw	0.45 Nm	0.5 Nm	0.55 Nm
2	Screw speed	400 rpm		600 rpm

It is necessary to follow the screw in sequence for the PCB mounting screws as shown in Figure 13.

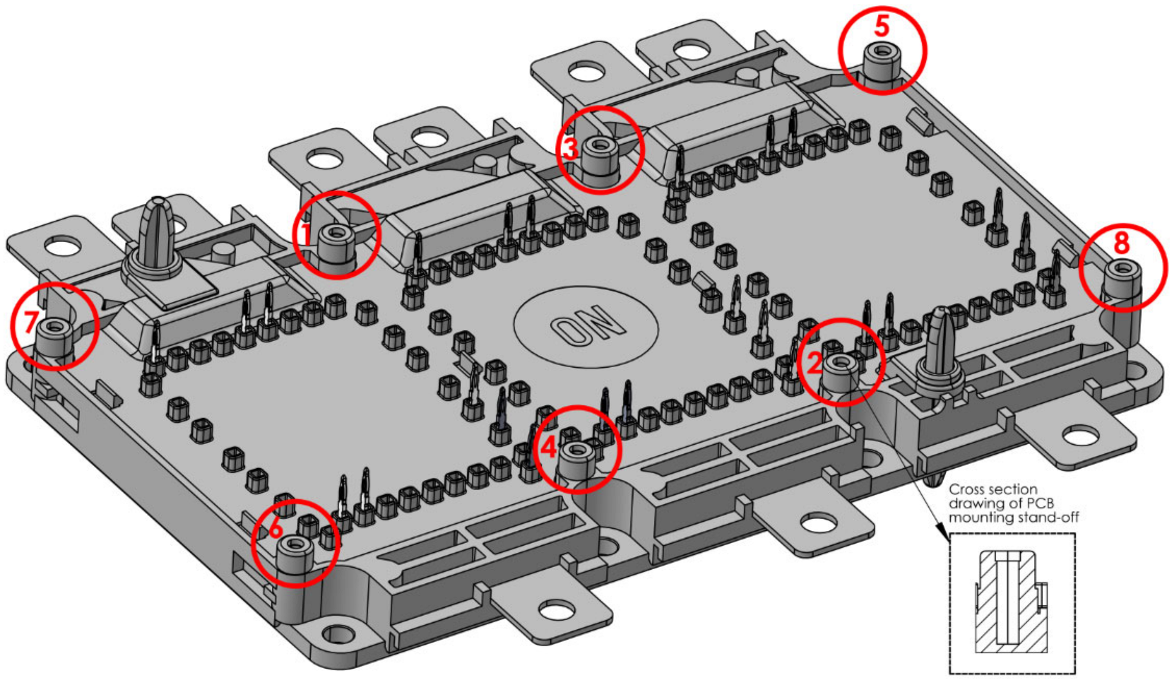


Figure 13. PCB Mounting Screw in Sequence

HEATSINK ASSEMBLY

Power dissipated in the module must be effectively removed from the module without exceeding the maximum rated operating temperature of the module as specified in its data sheet.

To do this all VE−Trac Direct modules have an array of pin−fins at the bottom of the isolated Cu base plate of the module. A cooling liquid, like a 50/50 mix of Ethylene Glycol and water is passed though the pin−fin structure to cool the module.

- The pin−fin structure allows a maximum particle size of 1.5 mm to pass through.

When mounting the module great care should be taken to not damage the Ni plating or structure of the pin−fins. Also avoid contamination, scratches or other damage to the area (Figure 14) of the base plate that will seal the module to the cooler.

Ensure that the cooling medium is compatible with the cooler material, Ni plate base plate of the power module and other parts of the cooling loop.

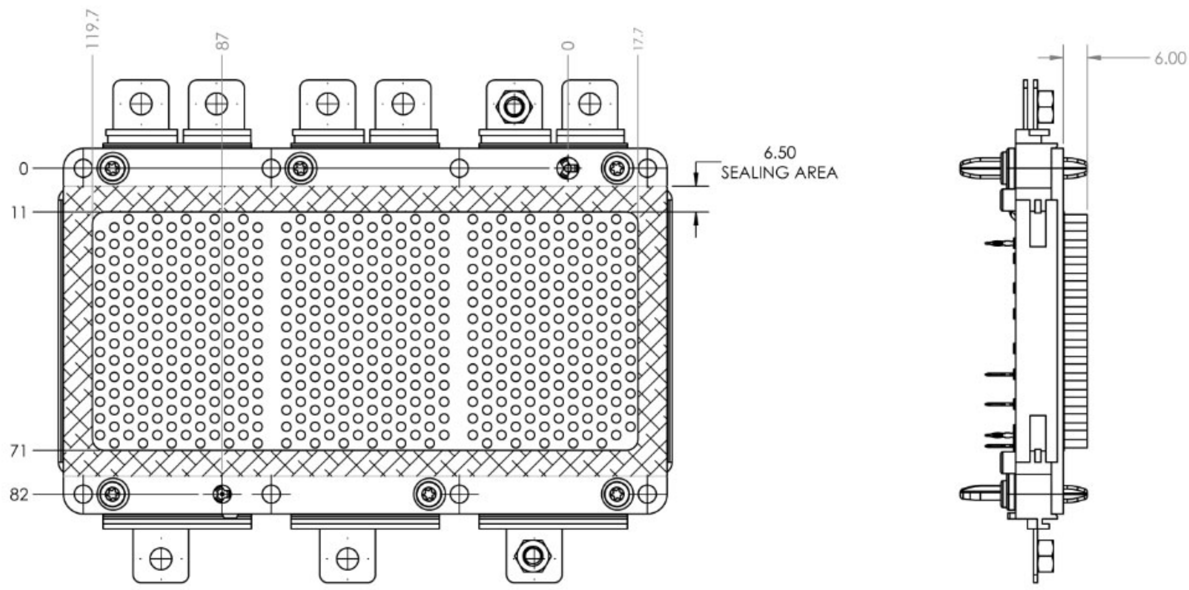


Figure 14. Bottom View of the Power Module Showing the Critical Sealing Area on the Pin−fin Baseplate

Cooling Jacket Requirements

- Roughness of the cooler sealing area as shown in Figure 14: ≤ RZ25 (DIN EN ISO 1302)
- Cooler flatness in the module sealing area: ≤ 50 μm

Not meeting the above described requirements may damage the power module or may not result in a proper seal between the module and cooler. It is recommended that the cooler material be AlMgSi0.5 or another alternative which is compatible with a Cu baseplate with Ni plating and which can meet the mechanical stress required for the application.

Sealing

A triple wiper seal with the specifications shown in Figure 14 with EPDM 50 material is recommended. The example shown is designed by **onsemi** and available from Quanzhou Shengda Rubber Products Co., Ltd. It is designed to fit in a groove, which must be designed in the cooler as shown in the reference cooler section.

There are multiple vendors suppling similar seals and also more sophisticated sealing rings with alignment and locking features that prevent the sealing ring from moving during assembly. Suggested suppliers include Dichtomatik GmbH and Fabri−tech Components Inc.

Please note that the sealing options mentioned in this section worked well in power module qualification tests. However, it is necessary to perform system qualification test by the customer to determine if it meets their specific application requirements.

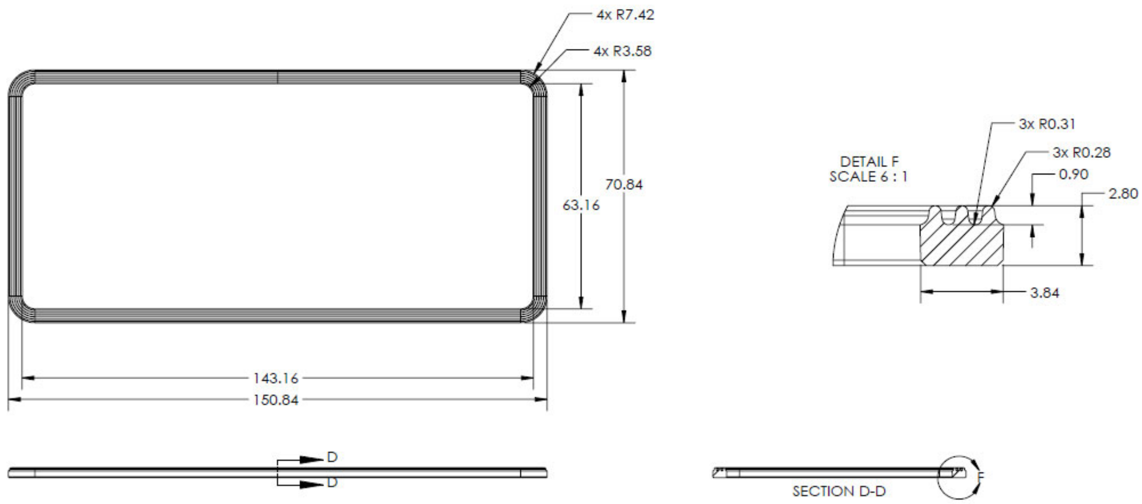


Figure 15. Recommended Drawing for the EPDM O−ring Seal and the Groove for the Cooler

We do not recommend the use of silicon gasket or any other methods to seal the module to the cooler.

Reference Cooler for Pin−fin Base Plate Modules

The reference cooler design can be used as a guide by customers to develop their own cooler designs. The thermal data shown in the data sheet for VE−Trac Direct products are all measured using this reference cooler. The cooler can be designed in different ways as long as the minimum requirements described in Cooling Jacket Requirements section are met and the proper trade−off consideration is given to the thermal resistance/impedance, pressure drop and flow rates. So, the reference design shown in Figure 16 should be considered as an example design.

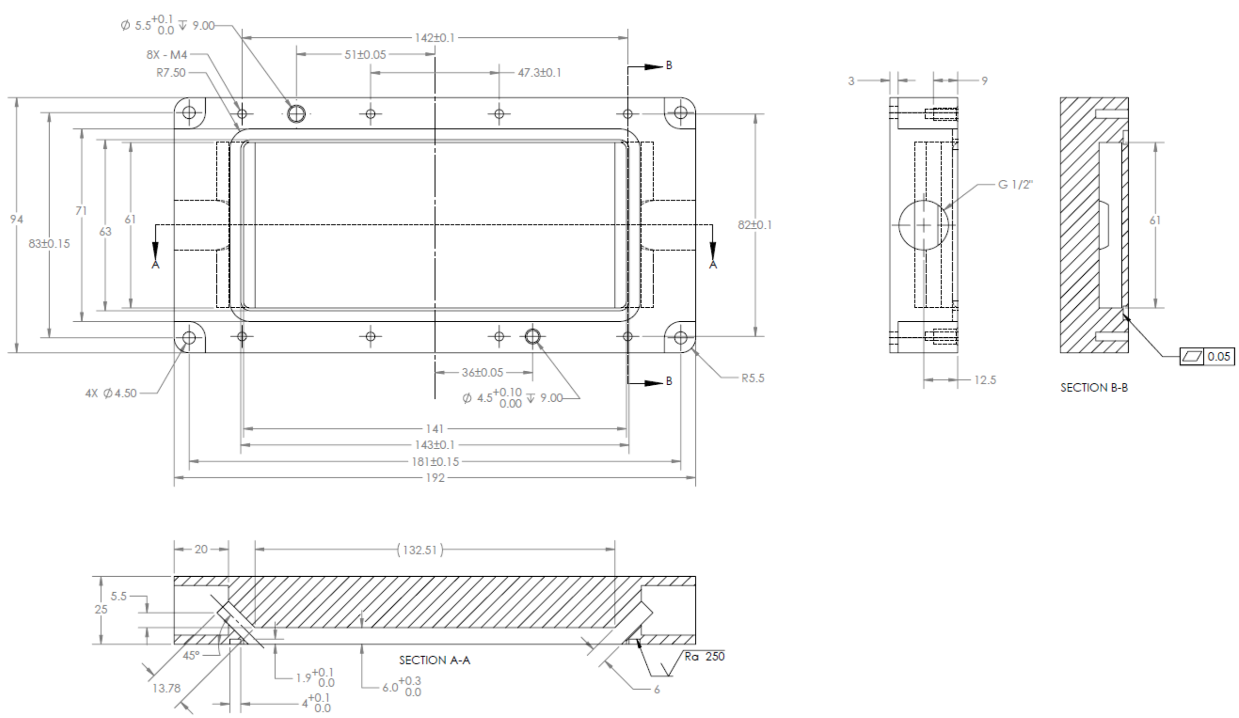


Figure 16. Reference Cooler Design for the VE−Trac Direct Family of Power Modules

Reference Cooler for Flat−back Base Plate Modules

For the flat back version of the module there is an option to use a cold plate (indirect cooling) with an interface material or a direct cooled option where the coolant is in direct contact with the module base plate (see Figure 17).

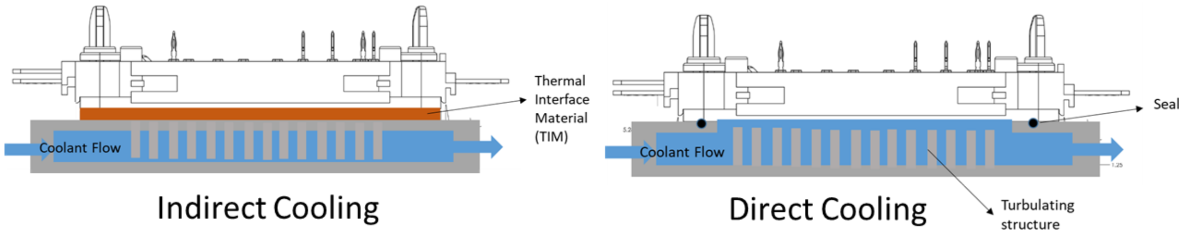


Figure 17. Indirect versus Direct Cooling for Flat Back Module

There are suppliers, Wieland Microcool for example, offering ready solutions for the indirect cooling option. However, indirect coolers do not give assembly commonality with a direct cooling approach. **onsemi** offers a reference solution for direct cooling of flat back modules. See Figure 18 for a reference cooler with diamond pin fin turbulizer structure that is designed to generate turbulence of the coolant to better cool the module with minimal presure drop. The design details of the diamond pin−fin cooler can be available upon request via **onsemi** sales.

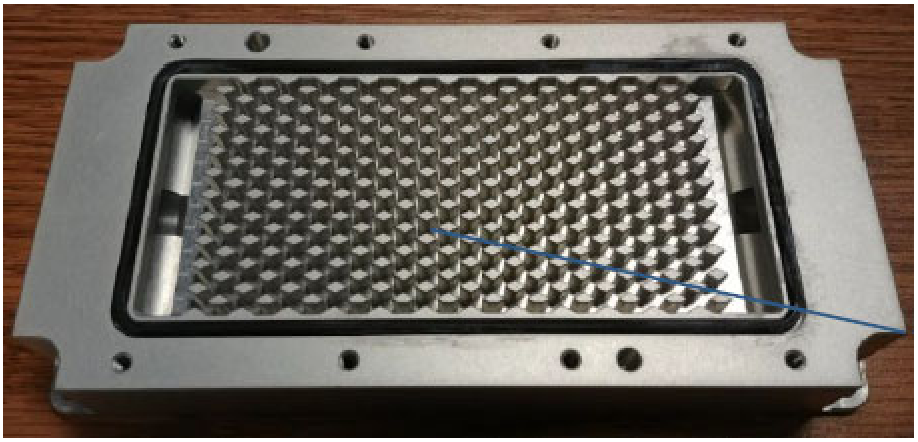


Figure 18. Diamond Pin−fin Cooler for Direct Cooling for Flat Back Modules

Table 6. PERFORMANCE COMPARISON OF CRITICAL PARAMETERS AT 10 LPM FOR DIRECT VERSUS INDIRECT COOLING

Heatsink Solution	Rth.j−f @ 10 LPM, 65C (°C/W)	ΔP (Ψ)
Indirect cooling /w Wieland Microcool solution	0.145	414
Direct cooling /w **onsemi** diamond pin−fin	0.154	122

Mounting Hardware and Method

The Power module baseplate is designed to be fixed to the cooler with M4 screws. A standard screw M4x10 ISO 4762 (DIN 912 A2) with washer M4 ISO 7090 (DIN 125 A2) may be used in combination with the following specifications:

- Mounting torque: 1.8 / 2.0 / 2.2 nm (min./typ./max.)
- Max. screw speed: 400 RPM
- Effective length of screw in cooler: 6 mm

A list of recommended screws are shown in the table below.

Table 7. LIST OF RECOMMENDED SCREWS TO ATTACH THE POWER MODULE TO THE COOLER

Hardware Type	Description
M4x10 ISO 4762 screw M4 ISO 7090 Washer	Standard M4 screw and separate washer
M4x10 ISO 7380−2 A2	M4 screw with integrated washer
M4x10 ISO 7380−2 A2 TX	TX20 head M4 screw with integrated washer

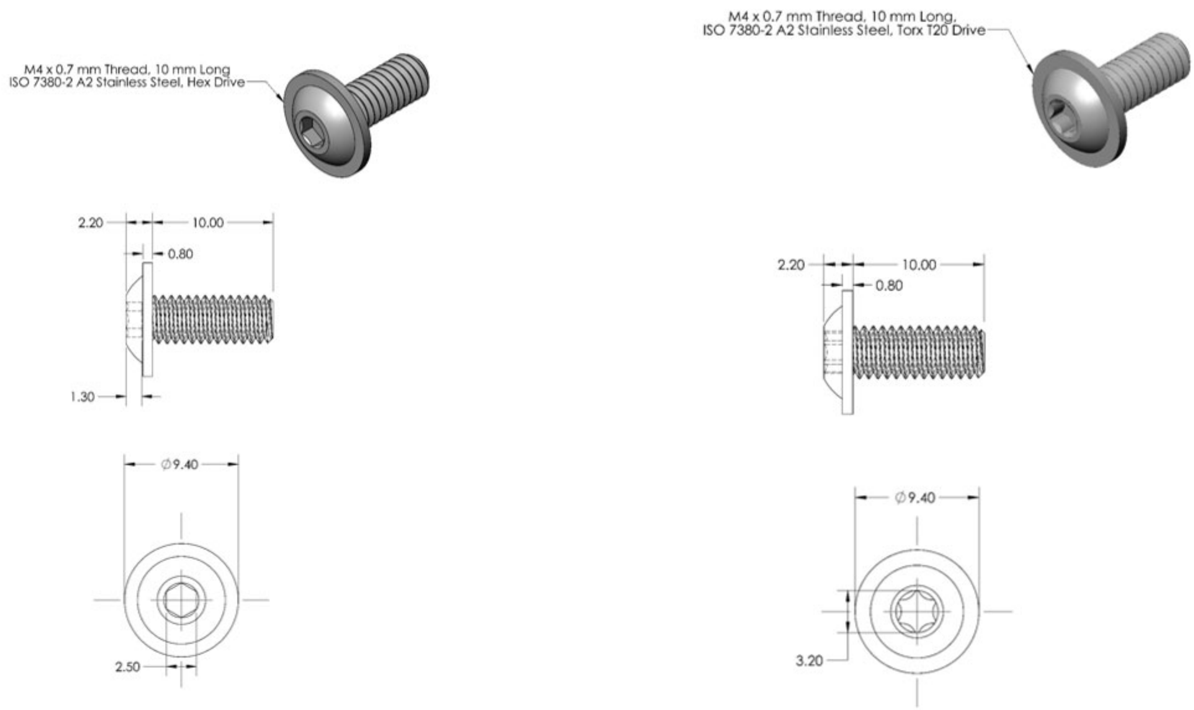


Figure 19. Recommended Screws to Secure the Power Module to the Cooler

When assembling the power module to the baseplate, it is important to follow the sequence as shown in Figure 20. This is the only recommended sequence to affix the screws.

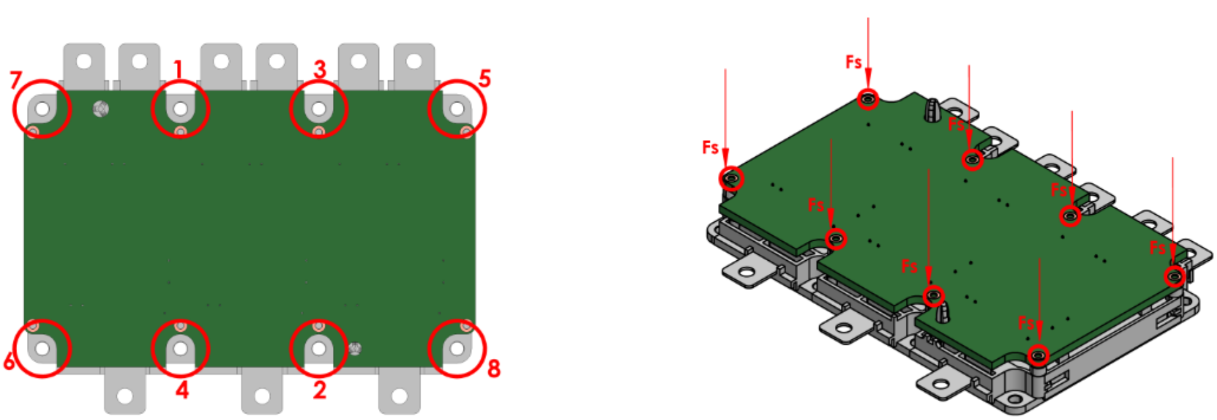


Figure 20. Screw Order and Sequence to Assemble the Power Module to the Cooler

To correctly install the power module to the cooler, it is necessary to secure the module during the mounting process to prevent the module from tilting or rotating. There are two recommended methods to secure the module:

1. Multi−step screw mounting: Screws 1 and 2 are secured to the lowest torque setting (0.4 – 0.6 Nm) to avoid tilting the module during the assembly process. Next screws are fixed to positions 3 through 8 also at the lowest torque setting. Finally, follow the sequence 1−8 again and secure the screws to its final specified torque.
2. Module Clamping Method: This method is better suited for higher volume production process. After the module with the PCB assembly is place in the cooler the module can be clamped with a total force F_S = 2 kN during the screw−in process. The clamping force can be applied in the area where the PCB mounting screw holes are located as shown in Figure 20.

POWER TERMINAL CONNECTIONS

There are several options to connect the module power terminals to bus bars. The copper power terminals are tin plated and well suited for screw type fastening including self−clinching fasteners and welding processes.

Terminal Connection Options

Different combinations of the power terminal, busbar, screw and nut are possible. Some of the acceptable stack−ups are shown in Figure 21.

Standard M4 self−clinching nuts can be used in the M5 screw holes found on the power terminals. In this case an M4 Screw is used to connect the power terminal to the busbar. Several example terminal connection options are shown below with respect to connecting the power module to bus bars. Alternatively, you can have an M5 self−clinching nut on the busbar and use an M5 screw to secure the connection. Check chart in Table 8 to determine the correct torque setting for different options.

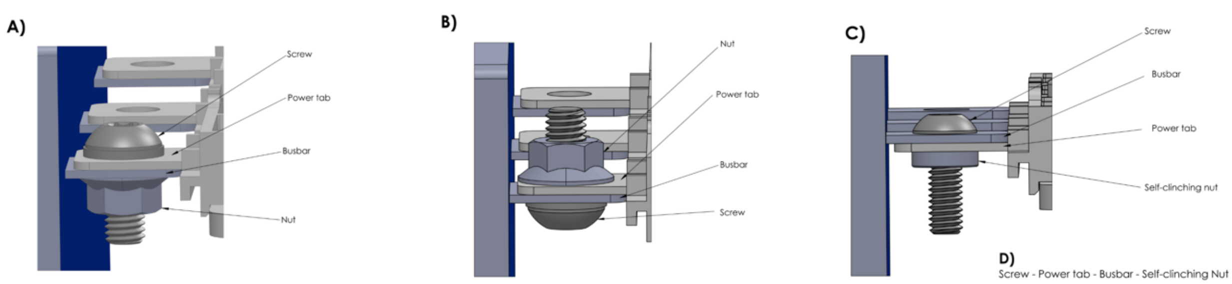


Figure 21. Different Option to Mount to the Power Converter System

Table 8. TORQUE SETTINGS FOR THE DIFFERENT MOUNTING OPTIONS

Mounting Option #	Hardware	Mounting Torque (nm)		
		Min	Typ	Max
A, B	M5 ISO 4762 Screw M5 ISO 7090 Washer M5 ISO 4032 Nut	3.6	4.0	4.4
A, B	M5 ISO 7380−2−A2 (TX) Screw M5 ISO 6923 Nut	3.6	4.0	4.4
C	M4 ISO 7380−2−A2 (TX) M4 self−clinching nut e.g. PEM S−M4−0ZI	1.8	2.0	2.2
D	M5 ISO 7380−2−A2 (TX) Screw M5 self−clinching nut	3.6	4.0	4.4
	Welding	n/a		

Limitations

The mounting process should results in a system that will limit the forces acting on the power terminals when secured to the bus bars. Figure 22 shows the maximum allowed forces at 25°C in all axis for the module power terminals and the press−fit pins.

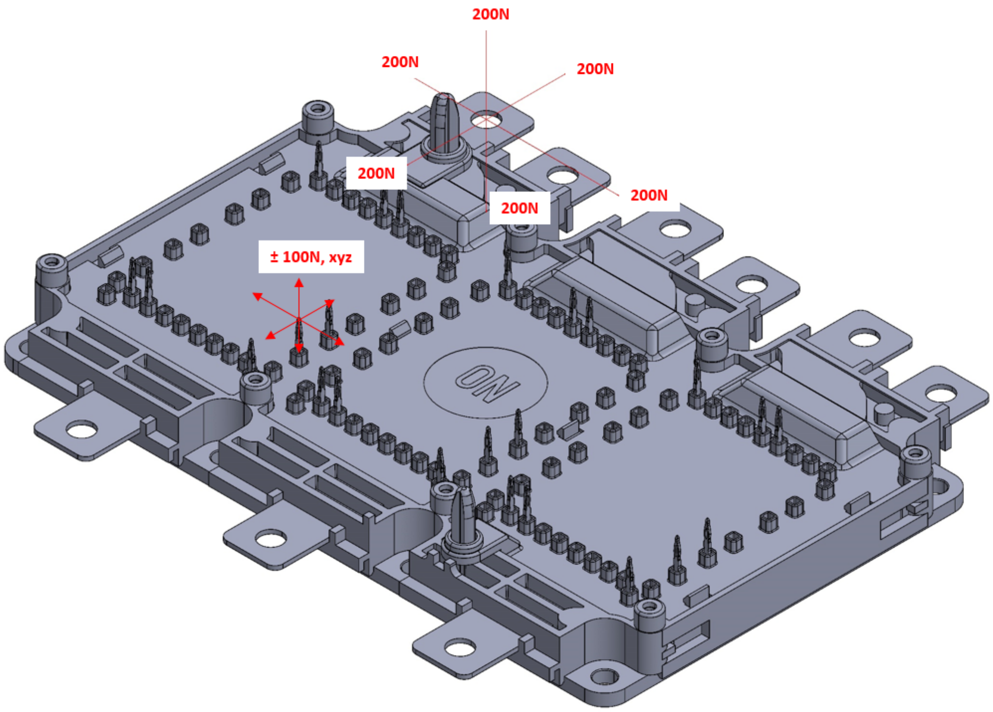


Figure 22. Allowed Forces and Direction on the Module Power Terminals

SYSTEM ASSEMBLY REQUIREMENTS

Creepage and Clearance Requirements

Care should be taken not to encroach on the creepage and clearance requirements of the module as specified in the product data sheet. Additional external components, like metal heatsinks, bus bars or fastening hardware can inadvertently reduce the creepage and clearance distances in the assembly. It is critical to check the assembly to ensure the minimum required creepage and clearance are met as shown in Figure 23.

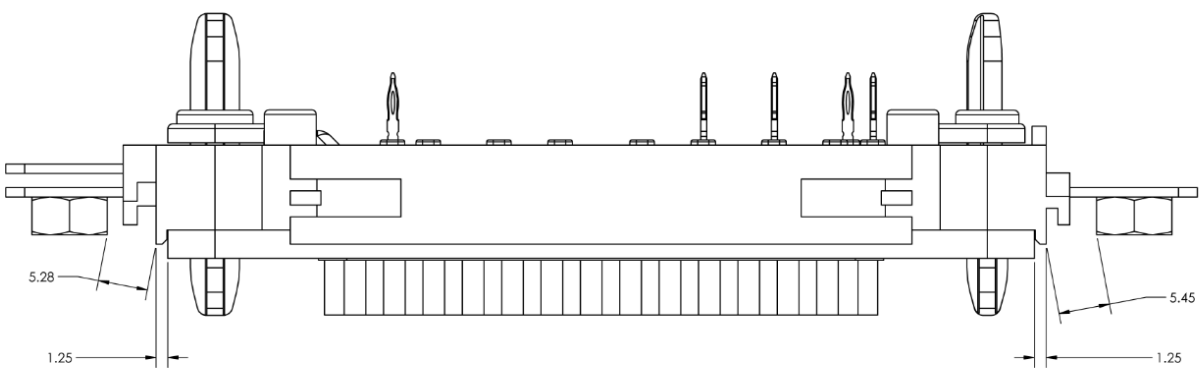


Figure 23. Minimum Required Creepage and Clearance Requirements

Current Sensor Integration

There are many options for integrating the phase current sensors with the module. Some of the most standard ready to use options are provided by LEM's HAH3DR series of current sensors. But this is not the only option. Ultimately the selection of current sensors is depended on several end application requirements and power converter package design.

VISUAL MARKINGS

Traceability and Identification

For automotive applications, proper identification of materials and traceability is an important aspect of quality.

Standard markings for the power module is shown below in Figure 24 and explained in Table 9.

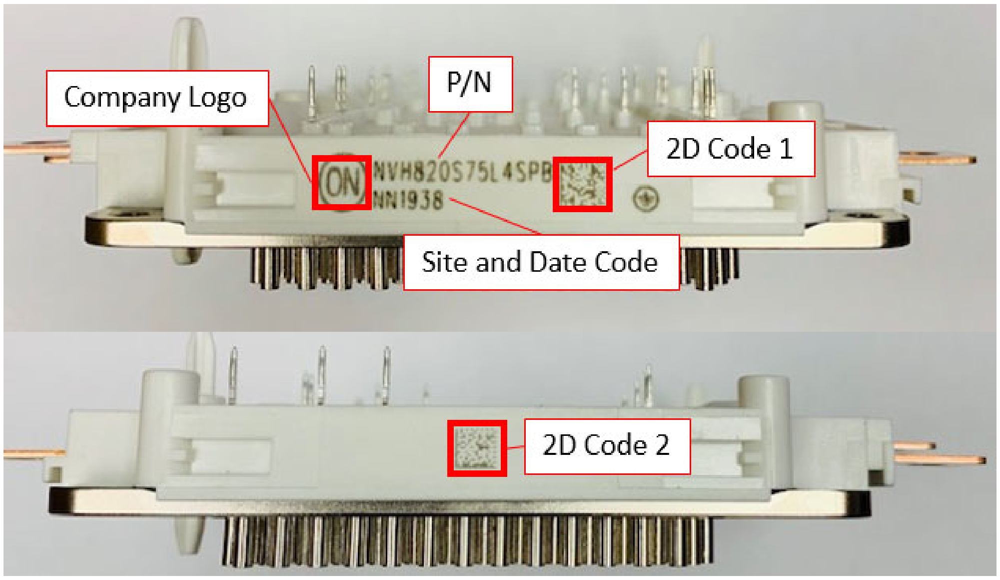


Figure 24. Module Identification Labels and Markings

The 2D Code is readable with most 2D scanners compatible with the IEC 24720 and IEC 16022 standard. Certain apps for reading QR codes on android smart phones can also read the 2D codes on the module.

Table 9. EXPLANATION OF VISUAL MARKINGS ON THE MODULE

Marker	Description
COMPANY LOGO	**onsemi** Logo
2D CODE 1	Date Code (YYWW) + Assembly Location (XX) + Assembly Lot Number + S/N
2D CODE 2	Assy. Lot Number + S/N
SITE AND DATE CODE	Assembly location (XX) and date code (YYWW)
P/N NUMBER	14 Character Product part number

Storage and Shipping

Transporting and storing the modules requires care to avoid extreme shock, vibration and environments. The recommended storage conditions for the module according to IEC 60721−3−1, class 1K2 should be followed and storage time should not exceed 2 years. Below is a summary of the recommended storage parameters:

Table 10. SUMMARY OF RECOMMENDED STORAGE CONDITIONS

Maximum air temperature	40	°C
Minimum air temperature	+5	°C
Maximum relative humidity	85	%
Minimum relative humidity	5	%
Condensation	Not Allowed	
Precipitation	Not Allowed	
Icing	Not Allowed	

ADDITIONAL INFORMATION

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