Technical note

ACEPACK DRIVE assembly instructions

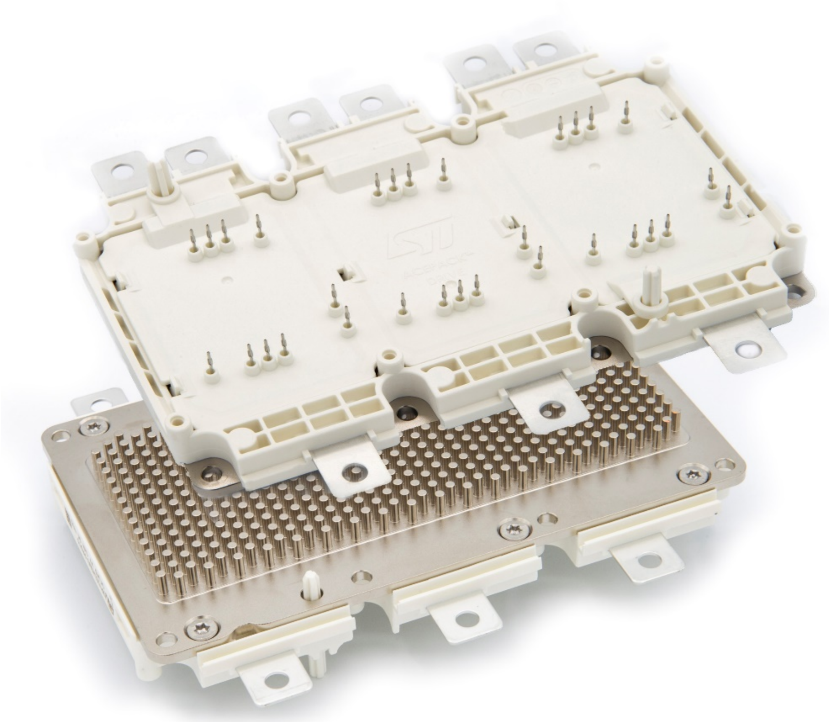
Introduction

This document describes the recommended process for mounting ACEPACK DRIVE power module: to meet the very high-quality standard requested by the automotive environment. Purpose of this document is summarize the best way to use the module that drives the most critical part in the automotive environment, which is the traction inverter.

1 General information

ACEPACK DRIVE power module, as part of ST's ACEPACK power modules, represents the state-of-art product in terms of switch and packages technologies: featuring latest innovations in terms of module assembly techniques and break-through Silicon Carbide power MOSFET. Coming out in a unique piece realizing a six-pack configuration, ACEPACK DRIVE is a fast time-to-market product suitable for high volume production providing direct liquid cooling capability and high-power density at the same time.

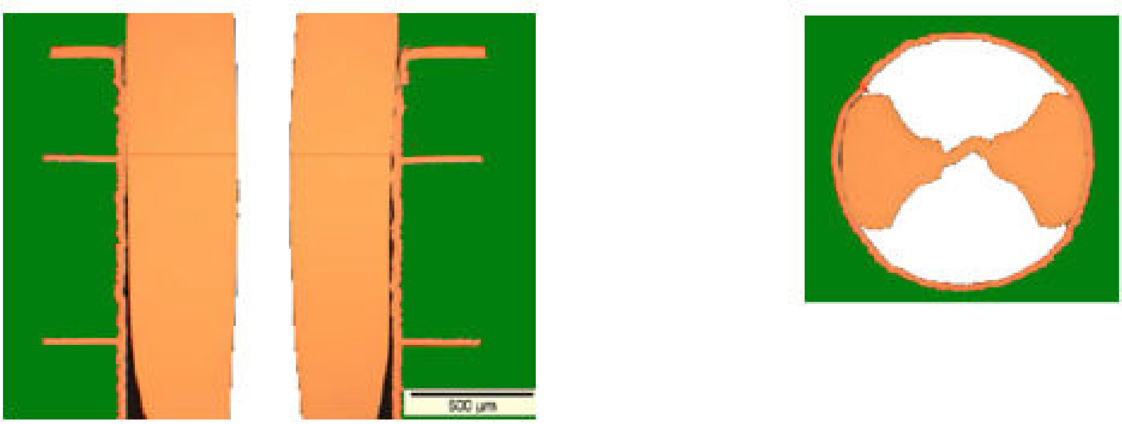
Figure 1. ACEPACK DRIVE typical appearance



In the above picture, it is possible to see the ACEPACK DRIVE typical appearance.

For the ACEPACK DRIVE power module, the press-fit pin is the kind of connection chosen to have the most reliable contact between the module and the driving board. The electrical and thermal contacts with the circuit board are implemented by means of cold welding when press-fit pins are used. Permanent deformation takes place because of PCB insertion and this deformation is intended to accommodate the tolerance and provides the basis for the cold welding. The resulting forces during the press-fit process ensure that the welded materials onto the PCB and pin exhibit a continuously consistent and, unlike other contact technologies, very small electrical contact resistance (see Figure 2).

Figure 2. **Materials connected together in a gas-tight manner due to the press-in force**



A module that has been pressed in and then pressed out again cannot be longer pressed in again since. This is because plastic deformation of the press-fit zone does not permit further press-fit processes.

We must highlight that press-fit contact is not sensitive to oxidation and corrosion or vibration and it realize a gas-tight connection with PCB dedicated holes. Since no preconditioning or heating is needed for the assembly, the assembly process is very reliable and easy to be industrialized.

The bus bars, also called power tabs, are available in different options to suit a different fixing methods and safety features required. Long bus bars on the AC side are suitable for the use of a hall effect current sensor. The holes at the end of the bus bars can be used for screw connection or with self-clinching nuts. Bus bars without holes shall be used for welding connections.

ST's ACEPACK DRIVE is featuring state-of-art silicon carbide Power MOSFET. To get the best switching performances, considering that an ACEPACK DRIVE power module is housing several POWER MOSFET devices in parallel, a particular focus has been dedicated when designing the modules substrate. As a result of this research for best performance, the module SiC-based is featuring a symmetrical pin-out between high-side and low side-side switches. To avoid any possible mistake during the assembly phase and to speed up the process X-pin & Y-pin implementing a poka-yoke concept has been adopted in the ACEPACK DRIVE power module: the X-pin (smaller) and Y-pin (larger) shows different dimensions that allow a properly designed PCB a single possible path to the press-fits. Refer to datasheet for detailed mechanical data.

2 Recommended mounting order

ACEPACK DRIVE is a plug and play power module, capable of achieving an unequaled power capability thanks to the possibility of direct liquid cooling. Clearly, the module must be connected with the drive components and the cooling system. In order to do this, and to avoid any mechanical stress to the sensitive components, ST recommends following this sequence when assembling the power module:

1. Align driving board PCB to power module. X-pins with the poka-yoke ensure the proper alignment
2. Press-in driving board through a mechanical press and a JIG designed on the power module, whose design is shown later in this document
3. Prepare water jacket with sealing ring
4. Position and screw the preassembled power module and driving board in the water jacket
5. Screw the driving board to the power module case

3 Driving board and press-fit assembly details

3.1 Requirement for driving board PCB design

Press-fit pins used in the ACEPACK DRIVE power module design, are based on international norm IEC 60352-5 for standard FR4 PCB boards, with tin chemically plated. Driving board PCB material must be compliant with IEC 60249-2-4 or IEC 60249-2-5 for double-sided printed circuit board, and IEC 60249-2-11 or IEC 60249-2-12 for multilayer printed circuit boards.

For a proper connection between the power module press-fit and driving boards, the dimensions given in the following table must be respected. In case of different dimensions, the risk is not to realize a gas-tight connection.

Table 1. Driving board PCB requirement for press-fits

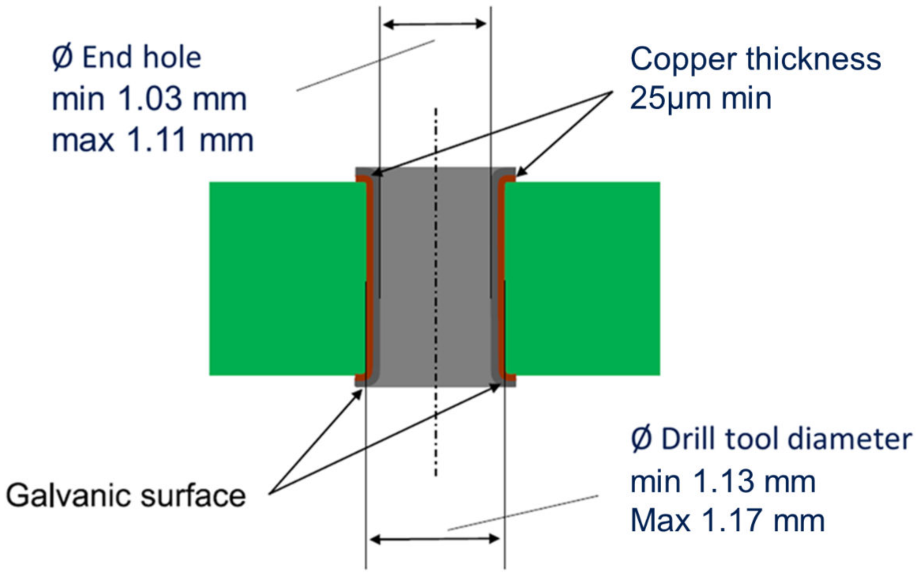
#	Description	Min.	Typ.	Max.	Unit
1	Drill tool diameter	1.13		1.17	mm
2	Copper thickness in hole	25		50	µm
3	Metallization in hole			15	µm
4	End hole diameter	1.03	1.07	1.11	mm
5	Copper thickness of conductors	35	70-105	400	µm
6	Metallization of circuit board	TIN (chemically)			
7	Metallization of pin	TIN (galvanic)			

Table 2. Driving board PCB requirement for X-pin and Y-pin

#	Description	Min.	Typ.	Max.	Unit
1	End hole diameter for X-pin (5.5 mm)	5.82	5.90	-	mm
2	End hole diameter for Y-pin (4.5 mm)	4.82	4.90	-	mm

The initial hole diameter, before plating, is important in determining the reliability of press-fit connections. As per the IEC 60352-5 specification, it should be 1.15 mm typical. The thickness of the copper plating applied to the initial hole shall be minimum 25 µm to maximum 50 µm. Then, a surface finish of about 1 µm chemical tin is applied to the hole.

Figure 3. Structure of driving board PCB final holes



3.2 General recommendation for driving board PCB Footprint

The ST ACEPACK drive with its pin-out somehow determines the positions of the driving and protection components. Despite this aspect, it is not possible for ST to suggest a recommended PCB footprint, as it depends on the devices to be used, and on the tolerance of the PFC manufacturing process for which the end customer is responsible. The following table represents only general recommendations, considering typical tolerances of the power module and driver PCB.

Table 3. Driving board PCB general recommendation

#	Description	PCB recommendation
1	Component clearance distance around press fit	General recommendation: ≥ 4 mm radius from hole center Uncritical or not safety relevant components: ≥ 3 mm radius from hole center
2	Driving board PCB to module fixing screw holes	End hole diameter: 3.60 mm Top layer copper diameter: ≥ 7.00 mm Mid layer copper diameter: ≥ 6.50 mm Bottom layer copper diameter: ≥ 6.60 mm

3.3 Press-in tools

ACEPACK DRIVE power module is featuring press-fit pins. We already described the advantages of using this pin comparing to the solderable ones. Since press-fit are not connected through the standard soldering process, but by pressing, we need to go deeper in details about this process and the step that lead to a reliable and gas-tight connection, between power module and PCB driving board.

Figure 4. Press-tool example side view

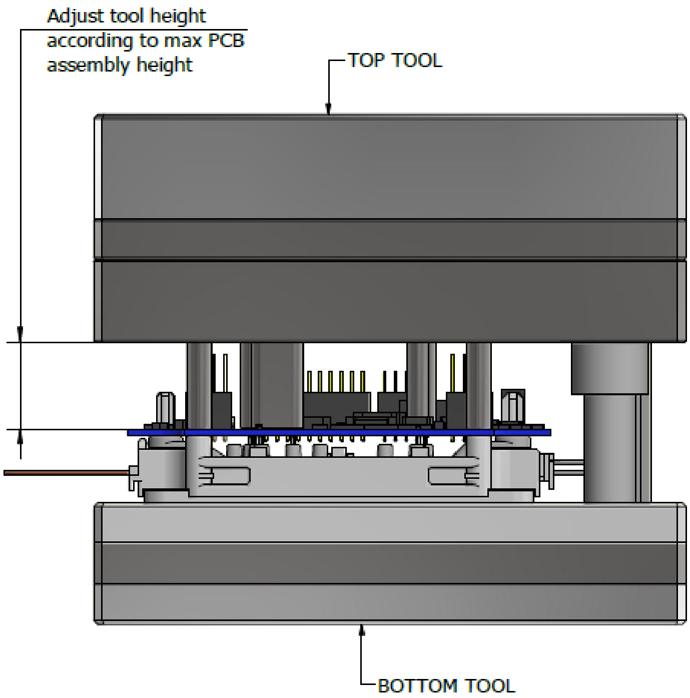
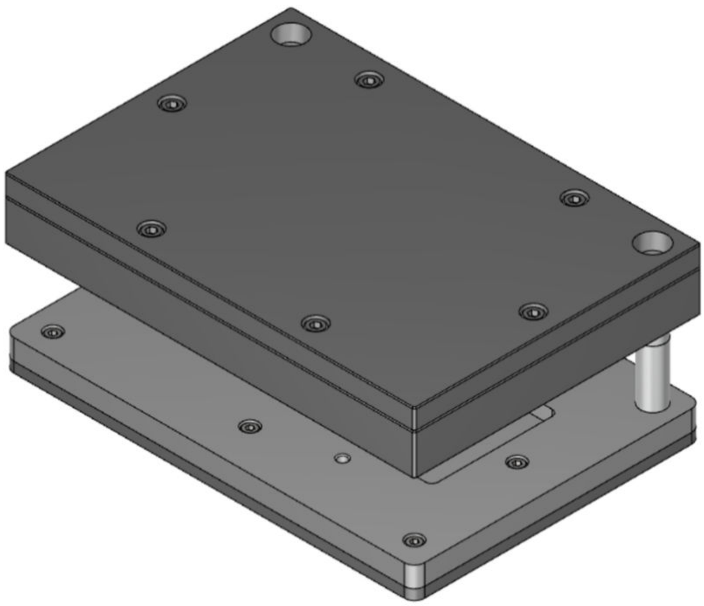


Figure 5. 3D model of press-in top and bottom tool



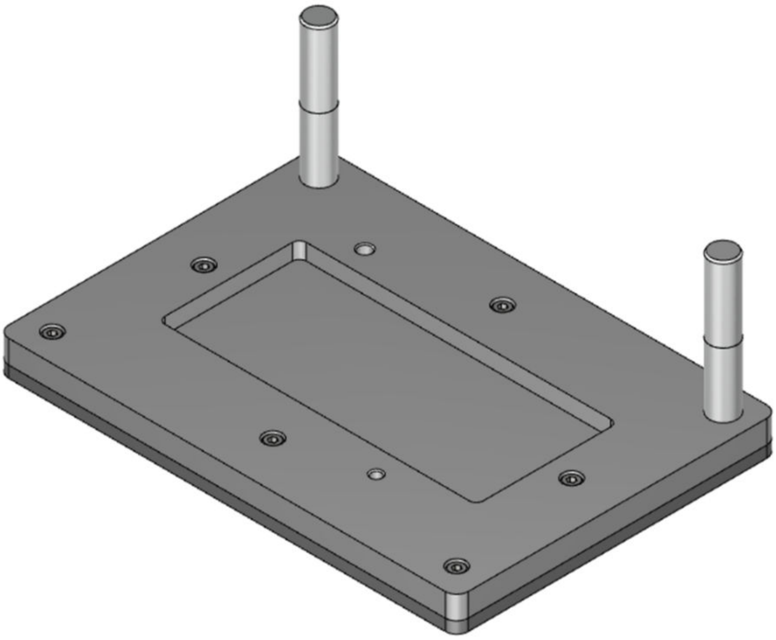


Figure 6. **Bottom tool detailed view**

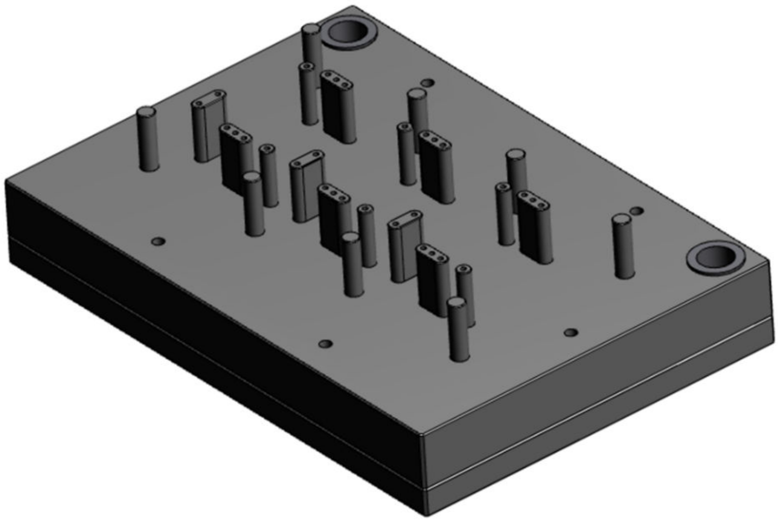
In the above figure it is possible to identify the inner box for pin-fin positioning, the two guide pillars, and X-pin and Y-pin for poka-yoke positioning, as described in Figure 4.

The Figure 6 is an example of the press-in tool that ST has designed as general indication for a safe and reliable mounting process. The press-in tool is made by two parts: a top tool and a bottom one. In the picture above it is possible to have a detailed look at the bottom tool; this part meets the power module base plate, therefore, the inner part of it must be designed to accommodate the pin fins. The parts that touch the module sustains a insertion force up to of 3.5 kN (max.), thus a plastic material shall be chosen to avoid scratches or damages in the very important sealing area.

X-pins and Y-pins described before in this document results here again very useful: bottom press tool must be designed considering the different dimension of the two X-pin and Y-pin leading to a poka-yoke process where it is not possible to make a mistake in module orientation inside the tool.

Other details of these bottom tools are the two guide pillars. These two structures ensure an optimal alignment between top and bottom tools and, considering large assembly volumes, can lead to a faster speed during the assembly process with consequent time saving. This is not a mandatory feature.

Figure 7. **Bottom tool details. It is possible to identify holes that respect module pin-out**



Top tool show in the above picture supports the driving board PCB and guide it to the final positions once pressed in. It is possible to see the holes at the end of the cylinders that corresponds to the pin positions. It should be noted that the height of the cylinders reported here has been designed according to the ST driving board, which is a two-level stacked board. According to the particular driving board design, cylinders height must be accommodated and some room for X-pin and Y-pin in the top tool shall be dedicated, in order to avoid any collision between the parts.

Top tool material should be made in steel or similar material to withstand press-in force.

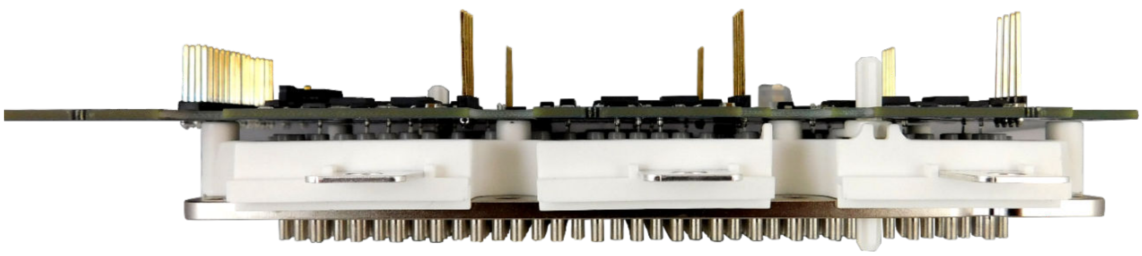
Mechanical drawings of press in tool and 3D step model are shared upon request.

Pressing the process in large volumes shall be done in a machinery that record force and travel distance. This ensures a controlled process and the best quality of final assembly.

During the pressing phase, top tool and bottom must be kept parallel one to each other. Driving board the PCB shall be fixed with a regular movement in z direction only.

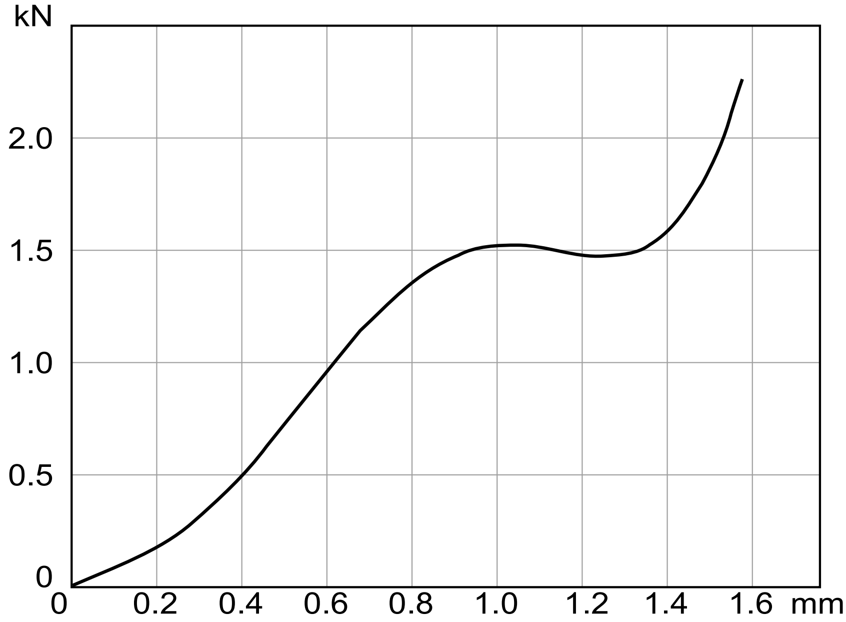
3.4 Press-in force vs displacement data

Figure 8. **ACEPACK DRIVE module with pressed driving board**



Once the driving board PCB is positioned above the module and the two press-in tools are aligned, the pressing process may start. Pressing speed can vary in a range between 25 mm/min to 500 mm/min. ST suggests staying within this limit since, lower pressing speed may result in press-fit damages, while faster speed is usually not so easy to be controlled by pressing machinery. Press-in speed is adjusted by the final customer according to the PCB type to be used and to the machinery adopted.

Figure 9. **Force vs displacement**



The Figure 9 shows an example of the ACEPACK DRIVE press-in process. The force increases while pressing down the driving board PCB because of press-fit deformation. In the case a force peak is detected instead of smooth increase, this detects a failure in the process such as PCB hole filled with soldering material or driving board PCB not in proper position.

The graph shows a slope change in correspondence of 1.5 kN (50 N per press-fit pin). The press length should be more than 0.9 mm, which ensure that press-fit are sufficiently inside PCB holes, considering a standard 1.6 mm PCB.

A maximum force should be set not to stress press-fit further than necessary; thus, it is important to set proper process control.

Table 4. **Press-in process summary table**

#	Description	Min.	Typ.	Max.	Unit	Notes
1	Press-in speed	25	-	500	mm/min	
2	Driving board PCB to module fixing screw holes		-	3.5	kN	Ideally to be stopped once slope change is detected.

4 ACEPACK DRIVE assembly to water jacket and driving board PCB screwing

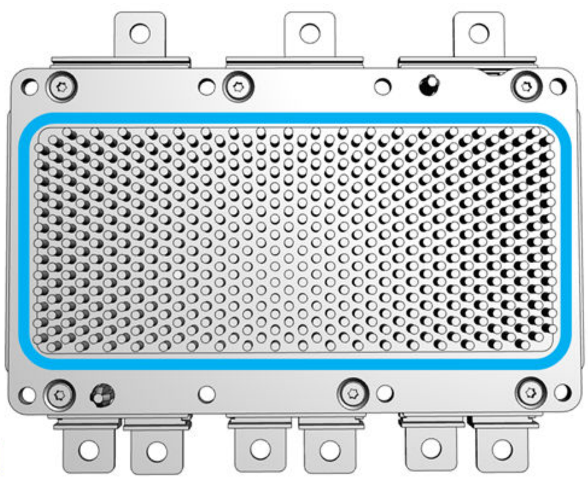
Coming back to the mounting order shown in Section 2: Recommended mounting order, now it is time to prepare the water jacket and cooling system in general: ACEPACK DRIVE power module is featuring nickel plated pin-fin structure making it ready to be used with direct cooling fluid systems. Water cooling systems ensure long lifetime power modules, as well as the possibility of reaching very high peak power for limited time.

As it may appear evident, the cooling fluid shall not meet the electronic portion of the module at all: it crucial that sealing the ring and fixing procedure do not create any possible scratch that may bring to a major failure due to cooling fluid leaks.

4.1 Recommendation for sealing ring

Power module baseplate, as shown in Section 4.6: Fixing driving board PCB to power module case, is designed to have a flat area surrounding the pin-fin area, large 6.5 mm.

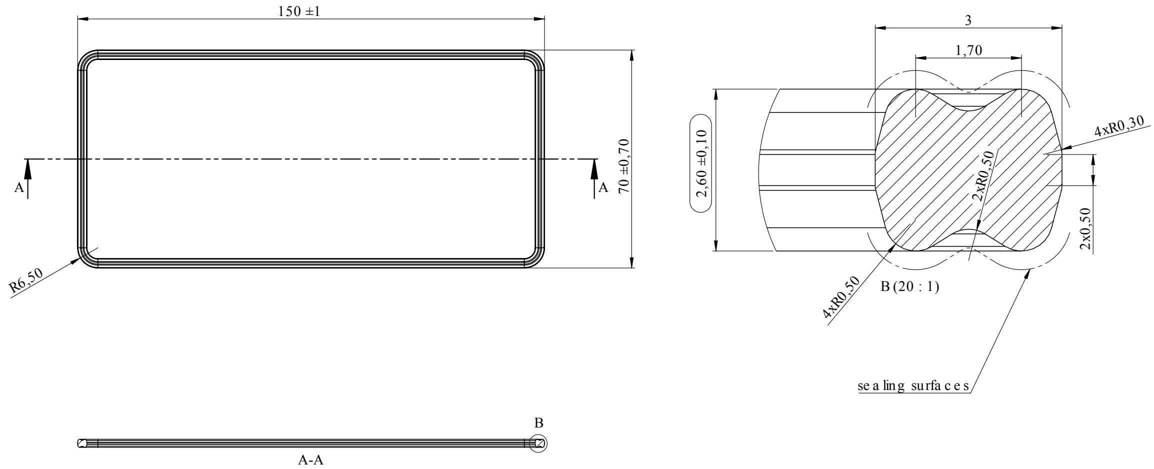
Figure 10. ACEPACK DRIVE module with highlighted sealing ring area



A generic sealing ring compatible with the HPD power module shall be adopted in the ACEPACK DRIVE module, compatible with it.

As part of the ST evaluation kit, we suggest using the following component supplied from FREUDENBERG®. A drawing of it could be seen below:

Figure 11. **Sealing ring reference design**



All the dimensions are in mm.

4.2 Baseplate mounting screw

Screws to be used for fixing power module baseplate to water jacket are M4, in particular M4x10 ISO 7380-2 A2 with integrated screw washer shall be preferred.

Figure 12. **M4x10 ISO 7380-2 A2**

The M4x10 ISO 7380-2 A2 is the suggested screw for fixing ACEPACK DRIVE power module to water jacket. This screw is eventually available with TORX screw head.

In the next table, we summarized some recommendation to be followed while using M4x10 ISO 7380-2 A2 screws:

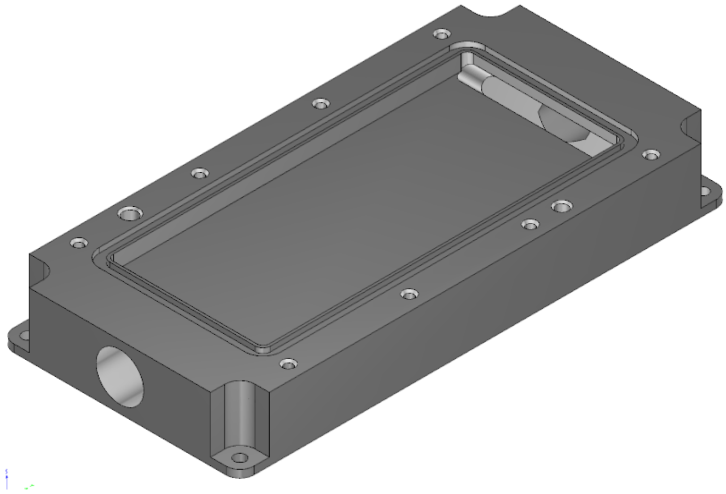
Table 5. **Recommendation to be followed using M4x10 ISO 7380-2 A2 screws**

#	Description	Min.	Typ.	Max.	Unit
1	Mounting torque	1.8	2.0	2.2	N•m
2	Mounting speed			400	rpm
3	Screw length inside water jacket	6			mm

4.3 Water jacket reference design

Water jacket and cooling system, in general, have a great impact in terms of module performance: liquid flow rate, liquid composition, water jacket design, etc., will deeply affect power module performances and lifetimes.

Figure 13. ACEPACK DRIVE cooler design reference



Different water jacked design with different water inlet position, just as the example, may lead to different performance or fluid temperature gradient across the module, which results in more efficient cooling system efficiency and overall performances in the end.

4.4 Cooling fluid

When choosing the cooling fluid, it must be considered that:

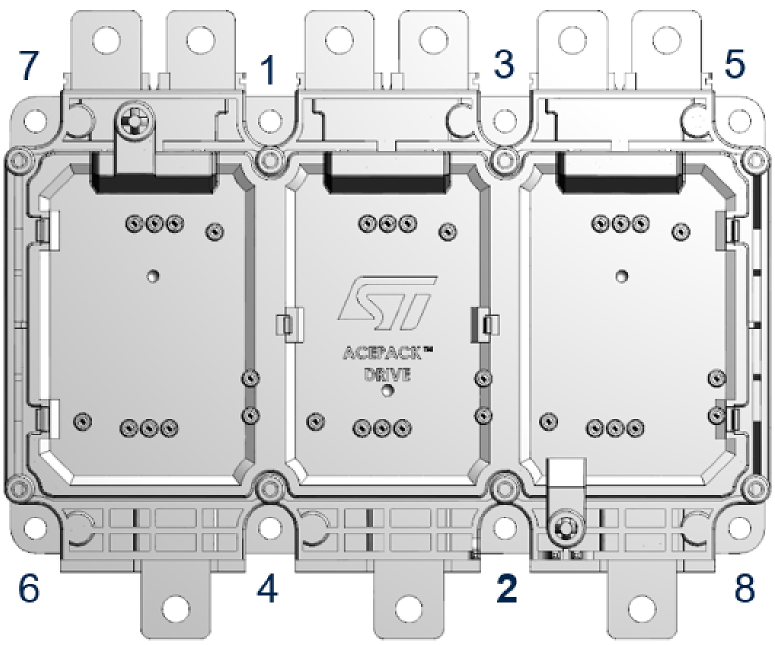
- Coolant will not corrode the nickel plating over copper base plate of the power module as well as the aluminum of water jacket
- Fluid mixture need to consider the possibility of application working range: freezing events are not allowed inside power module-cooling circuits as these may lead to deformation and leakages consequently

Just as reference, in ST side, a Glysantine G48 cooling fluid is used inside power cycling equipment and this could be evaluated in the application side as well.

4.5 Baseplate fixing screw order

When fixing power module to water jacket, the following screwing sequence must be respected:

Figure 14. **Baseplate screwing order for ACEPACK DRIVE power module**



4.6 Fixing driving board PCB to power module case

Once the module is fixed to water jacket, the next step is to fix the driving board PCB, which was previously pressed to power the module plastic case.

Considering a standard PCB with 1.6 mm of thickness, ST recommends using "steel zinc plated PT WN5451 30 x 10" self-tapping screw. Screw length would be adjusted according to the particular PCB thickness to be adopted.

Figure 15. **PT screw (typical appearance)**

Talking about a self-tapping screw, as can be seen from the module datasheet, the holes flank are flat. Initial part of the hole is larger on purpose to be used as screw guide. Once-screwing process begin, the flat hole starts threading according to PT shape; therefore, it is important that the process will be done according to ST indications in terms of mounting speed and torque. A controlled-speed screwdriver shall be preferred to avoid and crack, or stripping, which cause the destruction of the plastic thread.

In the table below, driving board PCB screwing recommendation for assembly with steel zinc plated PT WN5451 30x10 considering a 1.6 mm PCB.

Table 6. **Recommendation for assembly driving board PCB with steel zinc plated PT WN5451 30x10**

#	Description	Min.	Typ.	Max.	Unit	Note
1	Torque to connection (M_c)	0.45		0.55	N•m	This is the torque required for screw self-tapping into the hole
2	Torque for correct assembly (M_f)		1		N•m	This is the final torque where screwing should stop. It is the results of torque to connection (M_c) plus torque to tightening (M_t).
3	Recommended mounting speed	400		600	rpm	

Screwing order to be used is the same as shown in Figure 14.

4.7 Pressure capability

A pressure capability test have been conducted, the baseplate of the ACEPACK DRIVE modules tested have been able to sustain a relative pressure of 2.5 bar in the temperature range from -40 °C to 125 °C. The pressure capability of the entire system is a function of the design of the cooling system and of the o-ring.

5 ACEPACK DRIVE power tabs connections

ACEPACK DRIVE power tabs are tin-plated and tailored for screw type connections, including self-clinching components, as well as welding process (part numbers ending with –WL).

Several different mounting options are suitable for ACEPACK DRIVE connection to DC-Link capacitor. As an example, a possible mounting order could be:

- Screw - power tab - bus bar - nut

As shown in the folloing picture, is it possible to inverter component sequence according to mounting process convenience:

Figure 16. Example of power tab connections

Table 7. Power tab mounting option and relative torque

Mounting option	Screw/nut type	Mounting torque			Unit
		Min.	Typ.	Max.	
1, 2	M5 ISO 4762 screw (M5 ISO 7090 washer) M5 ISO4032 nut	3.6	4.0	4.4	N•m
1, 2	M5 ISO 7380-2-A2-(TX) screw M5 ISO6923 nut	3.5	4.0	4.4	N•m

Revision history

Table 8. **Document revision history**

Date	Revision	Changes
18-May-2022	1	First release.
07-Apr-2025	2	Inserted Section 4.7: Pressure capability.

Contents

List of tables

List of figures

IMPORTANT NOTICE – READ CAREFULLY

STMicroelectronics NV and its subsidiaries (“ST”) reserve the right to make changes, corrections, enhancements, modifications, and improvements to ST products and/or to this document at any time without notice. Purchasers should obtain the latest relevant information on ST products before placing orders. ST products are sold pursuant to ST’s terms and conditions of sale in place at the time of order acknowledgment.

Purchasers are solely responsible for the choice, selection, and use of ST products and ST assumes no liability for application assistance or the design of purchasers’ products.

No license, express or implied, to any intellectual property right is granted by ST herein.

Resale of ST products with provisions different from the information set forth herein shall void any warranty granted by ST for such product.

ST and the ST logo are trademarks of ST. For additional information about ST trademarks, refer to www.st.com/trademarks. All other product or service names are the property of their respective owners.

Information in this document supersedes and replaces information previously supplied in any prior versions of this document.

© 2025 STMicroelectronics – All rights reserved