SEMIKRON
innovation+service

Mounting Instruction SEMITOP® Classic

Revision:	04
Issue date:	2021-07-30
Prepared by:	R.Agostini
Approved by:	F.Brucchi,V.Cardi,M.Muscolino

Keyword: SEMITOP Classic, mounting instructions, one screw, no baseplate, press-fit, solder, 12mm, thermal paste, assembly, torque, washer, screw, heatsink.

Revision history

SEMIKRON reserves the right to make changes without further notice herein

Date	Revision n°	Description	Pages
10.05.2014	01	First release	13
06.06.2014	01	Improvement of contents	13
07.07.2014	01	PTH tin plating details for direct soldering to the PCB	13
08.05.2017	02	New template and general review	14
28.08.2017	03	Update of Mounting specifications for SEMITOP®Classic (Table 6) Harmonization of thermal grease thicknesses (Table 5)	14
30.07.2021	04	Update of specifications for PCB design Update of pin soldering profile Integration of mounting instructions for modules with solder pin Integration of acceptance criteria for cosmetic issues	20

1. Mounting process overview

Following figure shows possible mounting sequences to assemble SEMITOP®Classic, with Solder or Press-fit terminals, onto PCB and heatsink. SEMIKRON recommends fixing the module to the PCB first so this document follows sequence as shown under Option2.

Figure 1: Assembly sequence

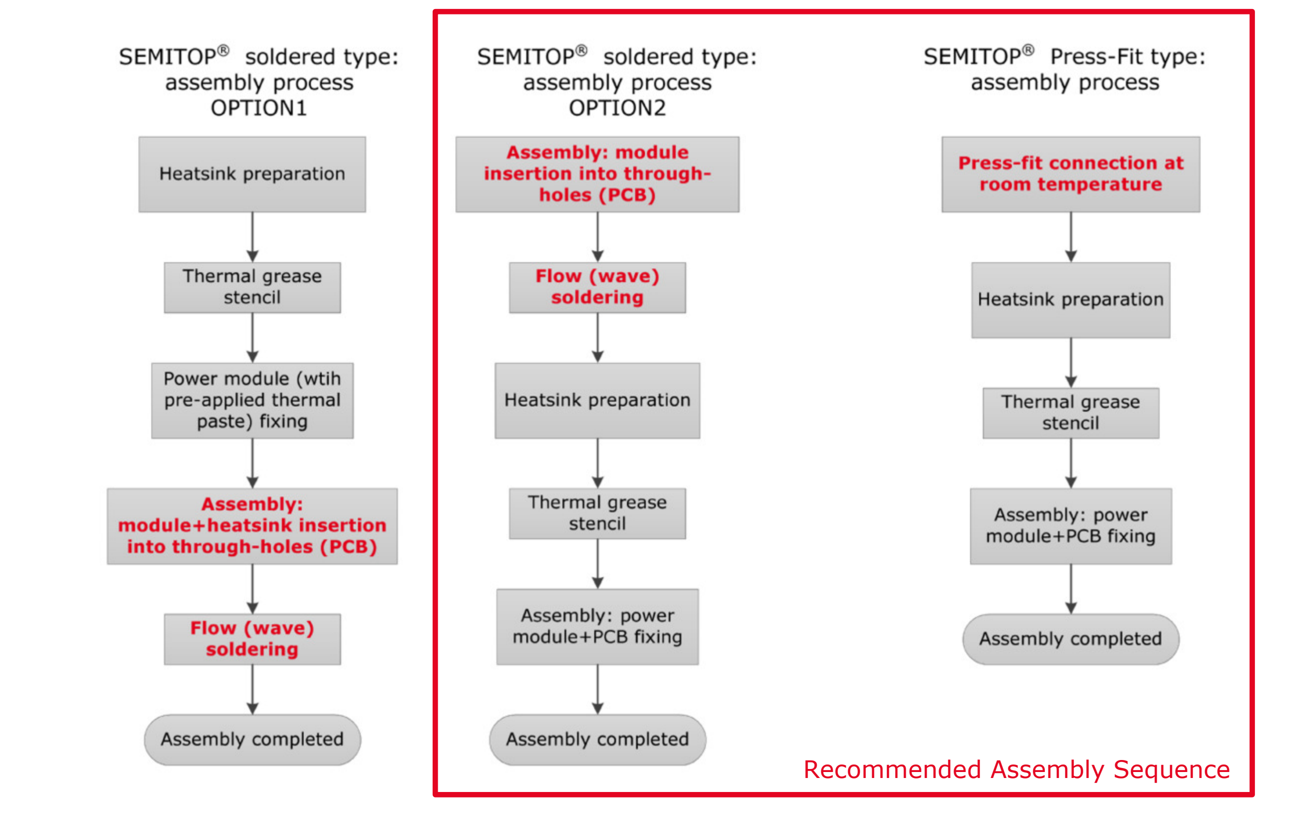


Figure 2: Possible assembly solutions (Heatsink first vs. PCB first)

Option1 - Heatsink first

Option2 - PCB first (Recommended)

2. PCB Assembly

2.1 Press-fit vs. Solder Terminals

Table 1 shows a comparison between available terminals technologies.

Table 1: Press-Fit vs. Solder Terminals

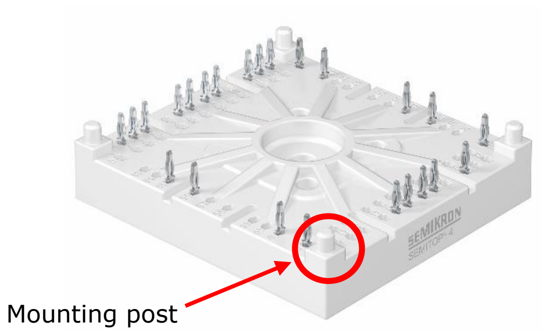
Press-Fit		Solder
+ Just press-in at room temperature	**Joining effort**	With chemicals at high temperature −
+ Lower	**Assembling time and cost**	Higher −
+ Higher	**Mechanical ruggedness in harsh environment**	Lower −
+ Easier	**Rework**	More difficult −
− Higher	**Requirements for tolerances of PCB Plated Through Hole**	Lower +
− Press-in tool	**Tools required for prototype and low volume production**	No tool +

2.2 PCB preparation

The recommended holes diameter for the mounting posts to match the SEMITOP®Classic and the PCB should be designed in accordance with the following table. Mounting posts have no holding functionality, they are needed in the first matching step to ensure PCB and module are properly aligned before they are assembled via soldering or press-in process.

Table 2: Specification of PCB hole diameter for the mounting post

Module type	Diameter [mm]
SEMITOP®4	3.6
SEMITOP®3	2
SEMITOP®2	2
SEMITOP®1	2



2.3 SEMITOP®Classic with Solder terminals

2.3.1 PCB Specifications

Printed board material should meet requirements of IEC 61249-2-7. The maximum number of conductive layers is not limited. PCB should be covered with solder mask on both sides. Minimum distance between edge of the PCB and the center of the pin hole should be 5 mm. Minimum distance between center of the pin hole and components on the PCB should be 5 mm.

After fixing the module to the PCB, all pins must be soldered. The plated-through hole diameters on the PCB has to be designed according to the pin dimensions: Ø1.5$^{(\pm0.02)}$mm. Dimensions refer to the finished product after plating. For the directions of the soldering pads design, it is suggested to follow regulation IPC-2221A.

For the PCB specifications, it is recommended to follow the acceptability of the electronic assemblies regulation number IPC-A-610, and for the acceptability of the Printed Circuit Boards, to follow the regulation IPC-A-600. Furthermore, for the PCB design, following regulations should be considered: IPC-2221, IPC-2222, IPC-2223, IPC-2226 and IPC-A-7351.

2.3.2 Soldering on PCB

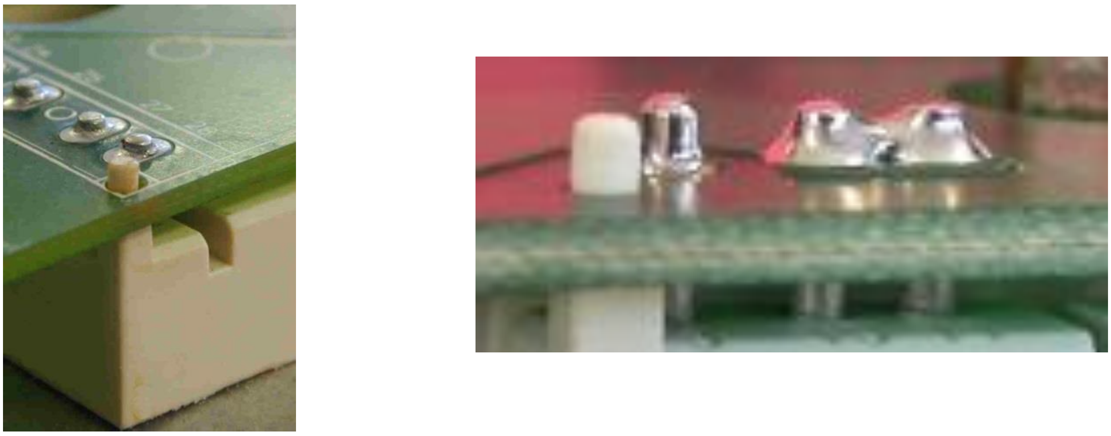
SEMITOP®CLASSICmodules can be soldered to the PCB using the most common soldering processes:

- Hand iron
- Wave soldering
- Selective soldering

Regardless of the soldering process used to fix SEMITOP®Classic modules to the PCB, SEMIKRON recommends a thorough evaluation of the solder joints to ensure an optimal electrical and thermal connection between SEMITOP®Classic and the PCB.

Figure 3 shows the profile of a good soldered joint. As a basic recommendation valid for any plated through hole (PTH) device, the terminal should present a vertical solder fill of minimum 75% of its dimension, with a fully formed meniscus on the solder side and evidence of minimum 75% wetting of the exposed terminal, barrel and pad.

Figure 3: Good solder joint profile



SEMIKRON recommends that the soldering joints should be thoroughly checked by the customer via Design Of Experiments to ensure the high quality of the solder joint itself. If necessary, different parameters should be adjusted in order to optimize the process.

Hand Soldering

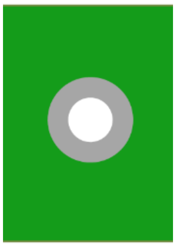
For the hand soldering process, usually performed by applying a manual solder iron, it is recommended to comply with the absolute maximum parameters as per Table 3.

Table 3: Hand soldering parameters

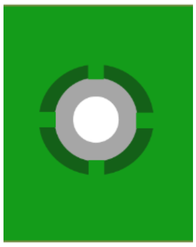
Soldering phase / Parameter	Maximum Values	Unit
Solder iron temperature	350	°C
Solder joint	260	°C
Soldering time of the terminal	10	s
Number of heat cycles	3	

SEMIKRON suggests not to exceed the **maximum temperature of 260°C** of the joint for a **maximum soldering time of 10 seconds**, especially when several pins must be soldered on large tracks or thick (>100um) copper planes (IEC-EN 60068-2-20). Furthermore, SEMIKRON recommends to provide adequate power to the iron solder machine, dimensioned according to the PCB copper planes thickness and PCB pads layout design. To reduce the effort during soldering, especially at large copper tracks or copper planes, it is recommended to provide the PCB with specific thermal relief pads (please see an example of Thermal relief pads in Figure 4b.

Figure 4: PTH standard vs. PTH with thermal relief



a) Standard PTH



b) PTH with thermal relief

Wave Soldering

For the wave soldering process, the IEC60068-2-20 it is used as reference. It is recommended to follow the wave soldering profile of Figure 5. Temperature and time restrictions listed in Table 4, must be observed.

Figure 5: Wave soldering profile

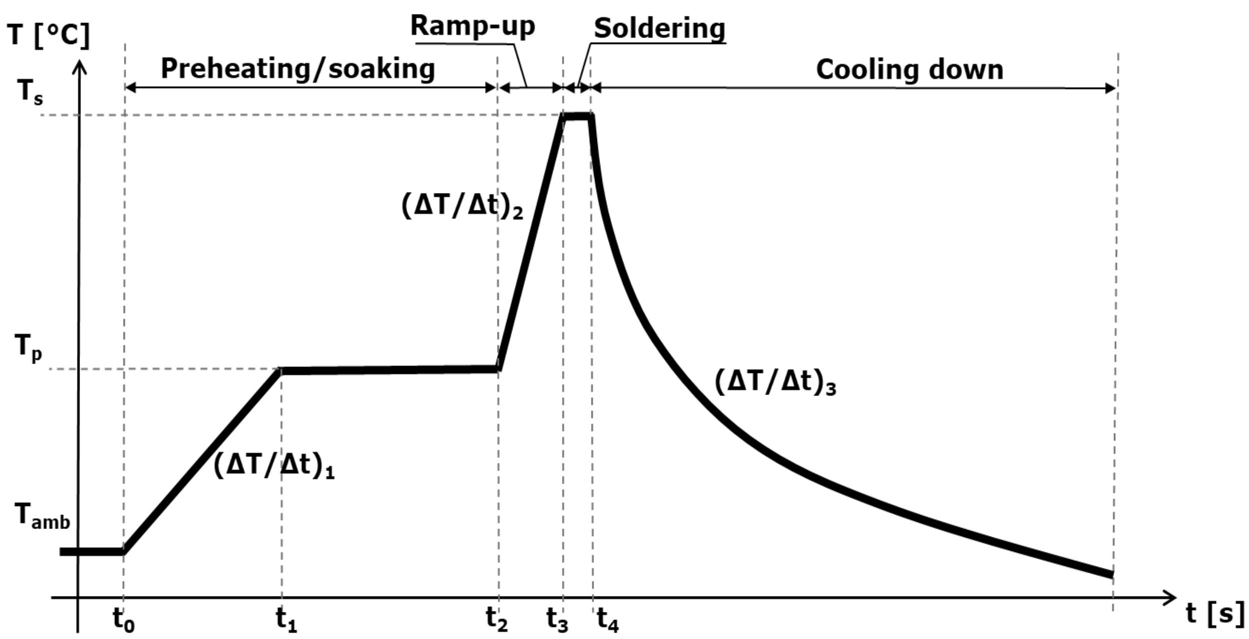
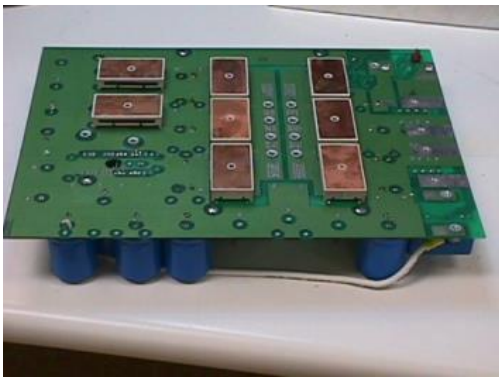


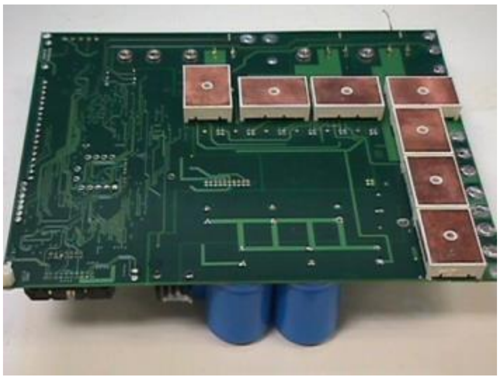
Table 4: Wave soldering parameters								
Soldering step	**Time frame**	**Temperature at solder joint**			**Temperature gradient**			**Time at max. Temp.**
		Ref. Temp.	**Typ.** [°C]	**Max.** [°C]	**Ref. gradient**	**Typ.** [°C/s]	**Max.** [°C/s]	**Max.** [s]
Preheating/ soaking	t_1 - t_0	T_{amb}	20	25	$(\Delta T/\Delta t)_1$	1	3	-
	$t_2 - t_1$	T_p	95	125	-	-	-	100
Ramp-up	$t_3 - t_2$	T_s - T_p	-	-	$(\Delta T/\Delta t)_2$	3	*	-
Soldering	$t_4 - t_3$	T_s	-	260	-	-	-	10
Cooling-down	$\geq t_4$	-	-	-	$(\Delta T/\Delta t)_3$	-4	-6	-

*) High ΔT/Δt values might endanger integrity of the ceramic substrate so maximum gradient must be defined via Design Of Experiment and verified by insulation tests.

Number of SEMITOP®Classic modules that can be assembled on the same PCB is not limited; Figure 6 shows example of application where multiple modules per PCB are assembled.

Figure 6: Multiple SEMITOP®Classic on the same PCB





2.4 SEMITOP®Classic with Press-fit terminals

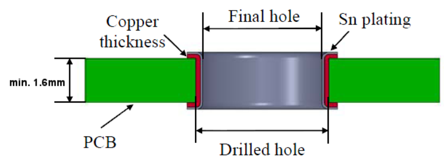
2.4.1 PCB specifications

Following requirements as regards the Plated Through Hole (PTH) of the PCB need to be fulfilled according to international standard IEC 60352-5. Printed board material should meet requirements of IEC 61249-2-7. For the PCB specifications, it is recommended to follow the acceptability of the electronic assemblies regulation number IPC-A-610, and for the acceptability of the Printed Circuit Boards, to follow the regulation IPC-A-600. Furthermore, for the PCB design, following regulations should be considered: IPC-2221, IPC-2222, IPC-2223, IPC-2226 and IPC-A-7351.

Following tables show specification of the PTH:

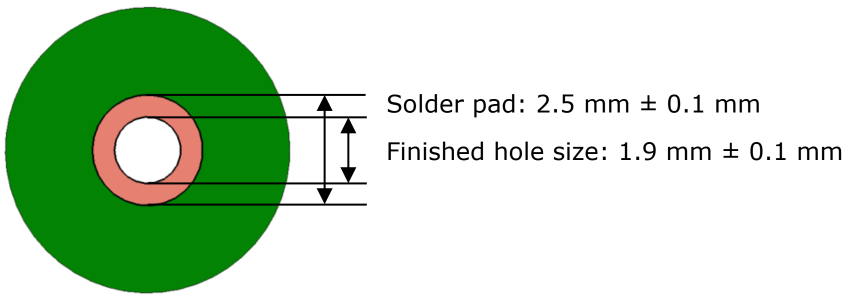
Table 5: Specification of PTH for Press-fit subject to press-in process

	Min.	Typ.	Max.
Drilled hole diameter	1.575mm	1.6mm	1.625mm
Copper thickness in via	25µm		50µm
Final hole diameter (Chemical tin)	1.47mm	1.50mm	1.54mm
Final hole diameter (HAL tin and Ni/Au)	1.39mm	1.45mm	1.54mm
Cu width of the Annular ring	100µm		
Thickness of PCB	1.6mm		



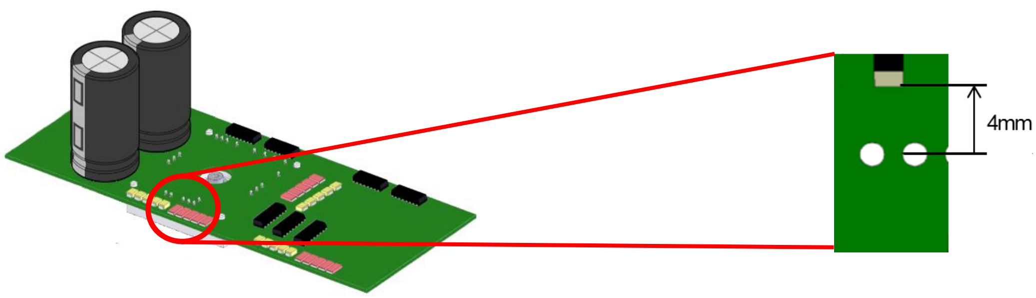
In case Press-Fit pins have to be soldered to the PCB, following specifications are given:

Figure 7: Specification of PTH for Press-fit subject to soldering process



Particular attention must be paid for those components that need to be placed close to the module pins like resistors, capacitors or diodes. A minimum distance of 4mm is required between the edge of these components and the centre of the PTH; this ensures enough space for the pressing tool.

Figure 8: Minimum distance between components and Press-fit



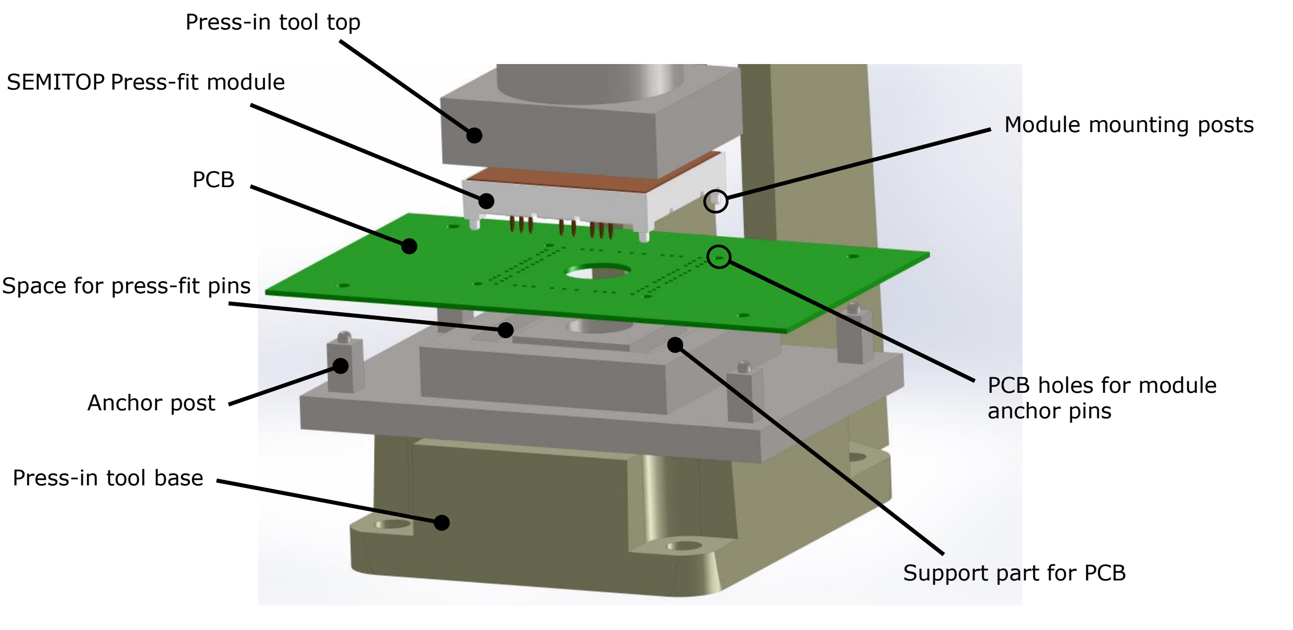
2.4.2 Press-in

For a successful press-in process with high process capability, it is recommended to use equipment that allows control of relevant process parameters like force and distance.
Following table provides an overview of the available presses and their main characteristics:

Table 6: Specification of press type			
Press type	**Control of force**	**Control of distance**	**Comments**
Manual, hydraulic and pneumatic	Low	Low	Additional visual inspection is recommended to ensure reliable press-in process
Servo electric	High	High	Accurate control of speed and position enables instant reaction to changes of press-in force

Servo electric presses are recommended to mate PCB and press-fit modules. SEMIKRON performed tests using an electric press by KISTLER. Following picture shows a concept view of the press-in equipment:

Figure 9: Schematic view of the press-in setup



The lower part of the press-in tool must be designed in order to provide free space for the components mounted on the PCB surface. Therefore shape and size of the available space for pins and components depends on size and position of the components on the PCB.
The anchor posts are needed to keep the PCB aligned during the press-in phase. The base of the anchor post should support the PCB during the press-in process and therefore has to have the same height than the support part to prevent from bending of the PCB. The support part should be fixed to the press-in tool.

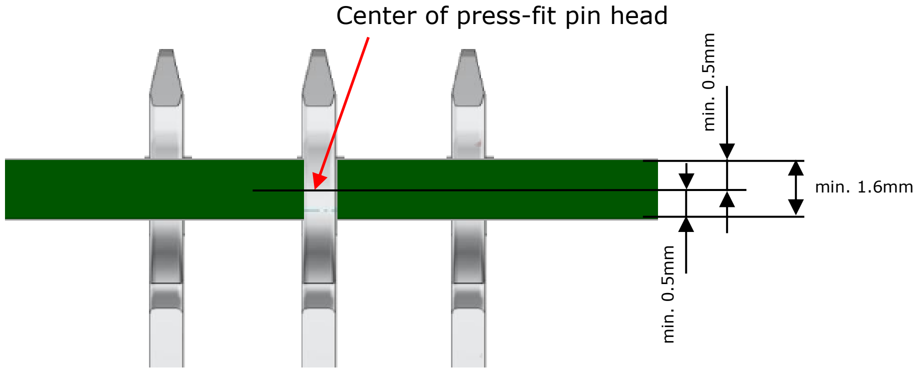
Sequence of main press-in steps is:

1. PCB placed onto support part through the anchor posts
2. Module placed onto PCB and aligned by the module mounting posts
3. Module pressed into PCB with the top of the press-in tool which has to be parallel to the support part and the press-in tool base. The bottom part of the press-in tool top side, getting in touch with module, has to be clean and free from any particles that might damage the module.

Please note! For modules with pre-applied Thermal Interface Material a special press-in tool should be used to prevent from any damage of the TIM layer. SEMIKRON provides all needed support to design such a tool according to specific module in use.

To ensure a proper press-fit contact, the centre of the press-fit pin head has to be at least 0.5mm below the top surface and at least 0.5mm above the bottom surface of the PCB (refer to the following picture).

Figure 10: Contact between Press-Fit and PCB



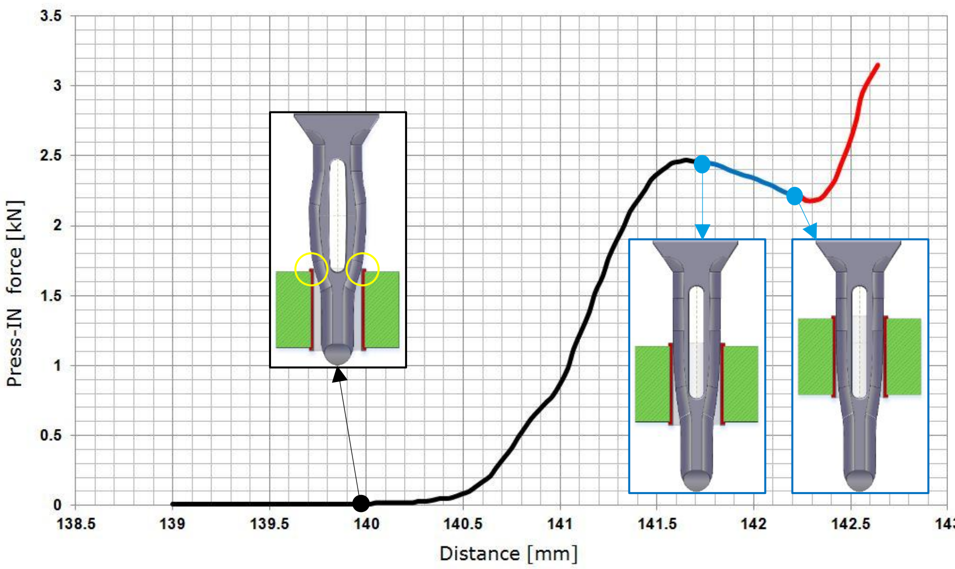
Following parameters are based on SEMIKRON press-in tool in use:

- Press-in force per terminal: 95±10N
- Press-in speed: 50-600mm/min. According to IEC 60352-5, press speed should not be lower than 25mm/min.

A typical force vs. distance profile for a press-in process is shown in the following picture. There are three main sections describing the typical press-in process (valid only for the first insertion):

- **Black** curve: The press-fit terminal slides into the holes and will be deformed to fit the holes. Here, maximum deformation of press-fit terminal occurs.
- **Blue** curve: The pin heads are fully inserted into the holes and slides to the final position
- **Red** curve: third section. Sliding of the pin is stopped. The mounting post get in contact with the PCB and they start to bend the PCB. The press-in process has to be stopped at the beginning of the red curve in order to prevent from PCB damaging.

Figure 11: Typical press-in profile for a 26 pins module

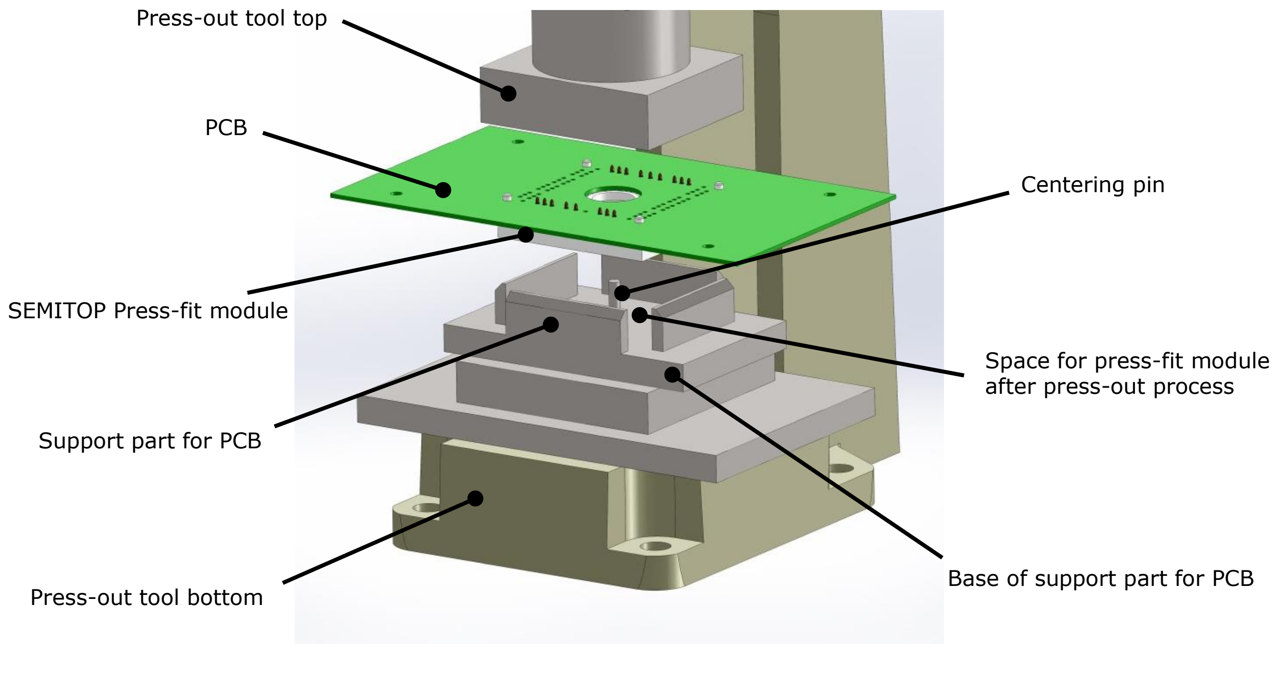


Multiple modules can be assemble onto the same PCB. In this case it is recommended to press modules all at once. Press-in tool must be designed in order to fulfil requirements given for the single module tool, and has to ensure the correct levelling of the modules and PCB to prevent from any mechanical stresses.

2.4.3 Press-out

Following picture shows a concept view of the press-out equipment:

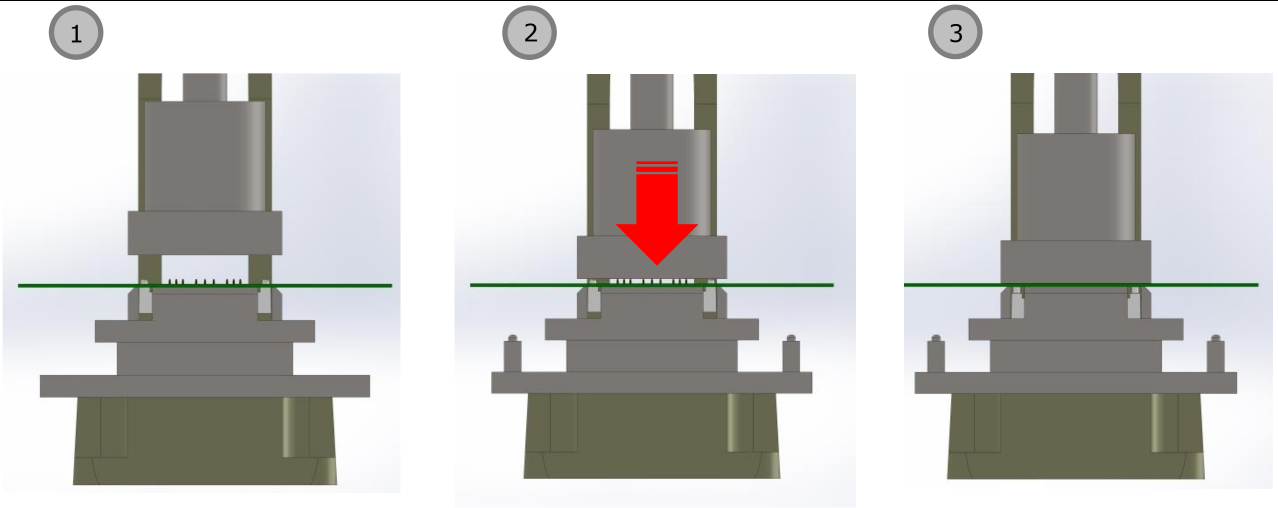
Figure 12: Schematic view of the press-out setup



Sequence of main press-in steps is shown in the following picture:

1. System "module and PCB" placed onto the support part, alignment via the centering pin.
2. Module pressed out by upper part of the tool.
3. Module drops into the space located on the base of the support part.

Figure 13: Press-out process



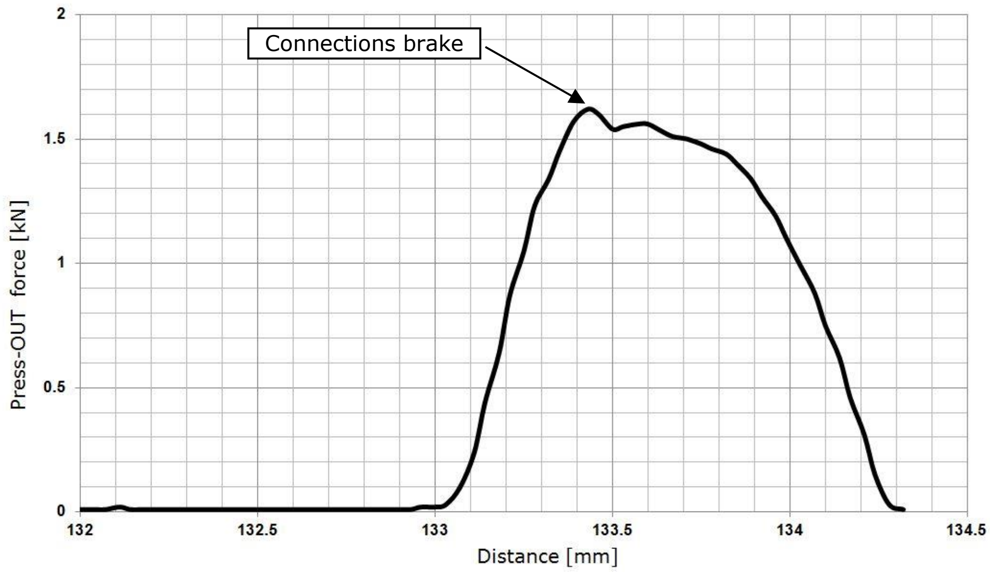
Module+PCB is placed on the support part	The press-out tool will start to go down until it will be in contact with the terminals; the terminals will slide out of the PCB	The press-out tool stops to go down when it touches the support tool. The module will be located on the base of the support part.

Following parameters are based on SEMIKRON press in use:

- Press-out force per terminal: >40N
- Press-out speed: 120-300mm/min

Typical force vs. distance profile for a press-out process is shown in the following picture. The curve exhibits a peak that indicates the breaking of the cold weld joint connection between terminal and PCB.

Figure 14: Typical press-out diagram for a module with 26 pins



2.4.4 Reworking of the assembly "module and PCB"

Each SEMITOP®Classic with Press-Fit can be used only once. In case the system "module+PCB" needs to be disassembled, following options are possible:

- **Module can be reused** by soldering the press-fit pins to the PCB. Due to the pin deformation by the initial press-in process, any additional press-in process will result in low holding forces between the terminal and the PCB hole and is therefore not recommended.

- **PCB can be reused**. The number of times depends on the plating of the via:
  - Sn > 0.5µm: PCB can be disassembled and used two additional times
  - Au 0.05 - 0.2 µm over 2.5 - 5 µm Ni: PCB cannot be reused.

3. Heatsink Assembly

Before setting up the electrical connection (including any electrical incoming test), the module must first be mounted onto the heat sink as described in this chapter.

3.1 Module specifications

3.1.1 Cosmetic defects

Due to the manufacturing process, the bottom side of the SEMITOP®Classic may exhibit cosmetic imperfections like:

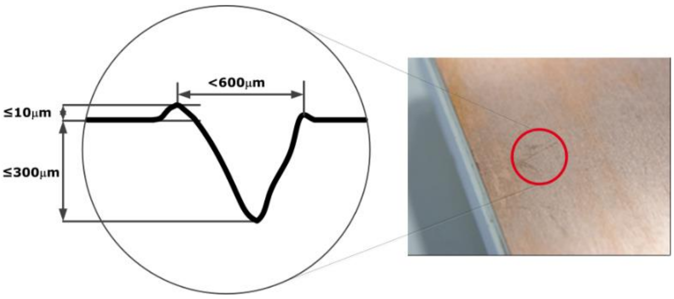
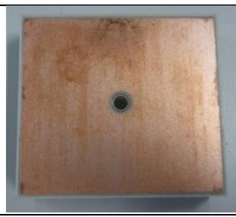
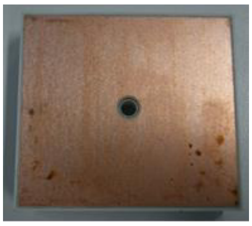
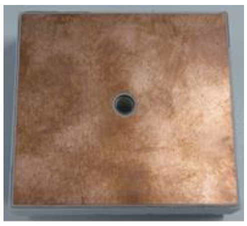
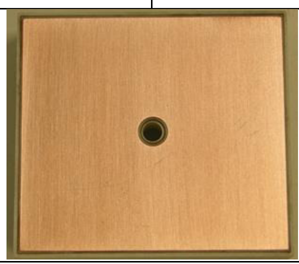
- Scratches & dents
- Etching holes
- Small marks
- Copper discoloration/oxidation

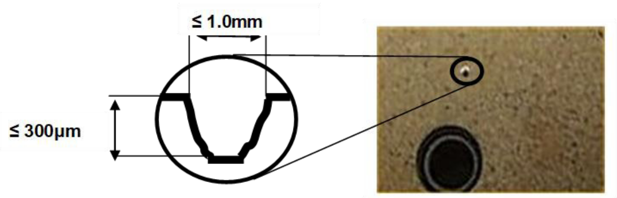
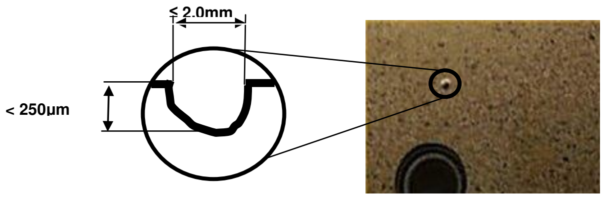
The following table describes the allowed cosmetic defects and provides the information to consider them as acceptable by incoming inspection from customer side.

The acceptance criteria are defined in order to ensure thermal behavior, reliability and mounting process are not affected. Only those modules, which fulfil acceptance criteria, are shipped.

Further information are available upon request.

Table 7: Acceptance criteria of cosmetic defects

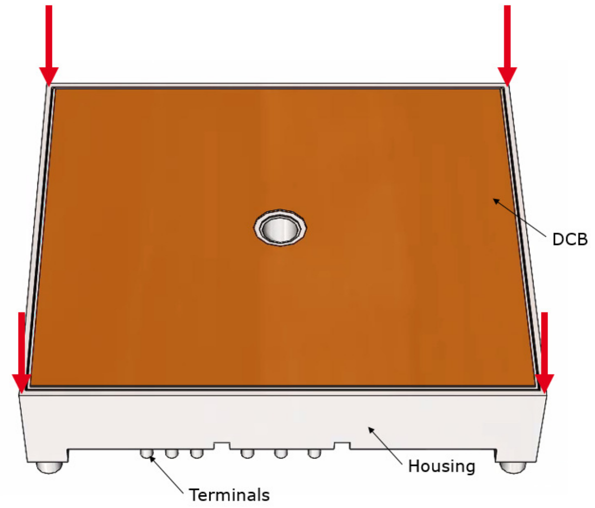
Cosmetic issue description	Picture
Dents and Scratches ➢ Depth < 300 um ➢ Width < 600 um ➢ Roughness < 10 um ➢ Number of scratches and dents is not limited ➢ Each scratch must be within the copper	
Copper Oxidation caused by: ➢ Flux used during chip soldering process ➢ Heat during pin soldering process No limitation to amount of oxidation. Oxidation observed at time of manufacturing can be very different from what observed at customer's inspection since it can be affected by environmental conditions during transportation, exposure to humidity and/or pollution and stocking of modules at customer's warehouse.	   
Copper polishing applied to remove possible residues collected during manufacturing process.	

Etching Holes Down to substrate level: ➢ Depth ≤ 300 µm ➢ Width ≤ 1 mm	
Etching Holes Down to substrate level: ➢ Depth ≤ 250 µm ➢ Width ≤ 2 mm	

3.1.2 Module Handling

SEMITOP®Classic modules are not designed to withstand forces on the module housing as shown in the Figure 15. When terminals are laid and in touch with a horizontal flat plane, possible force applied on housing, described by red arrow, turns into a push out force on the DCB.

Figure 15: Push-out force on DCB



The sealing material between plastic housing and DCB substrate has no glue function. It prevents from potential leakage of insulating gel during filling process in production. Therefore, holding strength at the interface between housing and DCB cannot be considered as a property of the power module and push out force on DCB must be avoided.

Typical press-in/out processes do not generate push out force on DCB since press-in/out forces are applied on the DCB/terminals, not on the housing.

Push out force on DCB may occur when module, without PCB, is removed from heatsink. The thermal paste provides good adhesion between the module and the heatsink, therefore pull force applied on plastic housing may turn into a push out force on the DCB.

If this step is strictly needed because of a first faulty assembly, SEMIKRON recommends following possible procedures to remove module from heatsink:

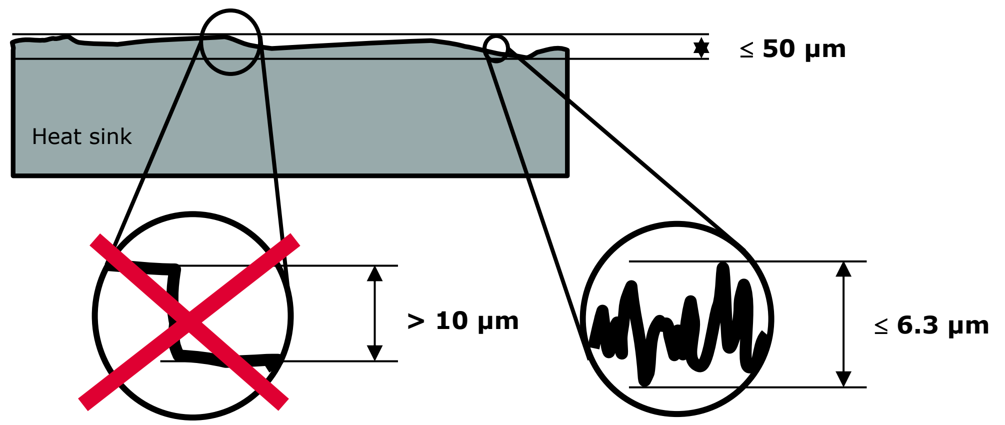
- Wait 24 hours after the screws have been loosened and then slide the module carefully from the heat sink.
- Heat up the heat sink up to 60 °C after the screws have been loosened and then slide the module carefully from the heat sink.

3.2 Heatsink preparation

To achieve a good interconnection between module and heat sink and to obtain an optimum heat transfer, the heat sink must comply with the following specification (see Figure 16).
It is recommended that the cooler is milled by a carbide indexable insert. This tooling method delivers the best result with a typical surface roughness of ~1-3µm.

- Heat sink must be free from residues, particles or dust
- Evenness ≤ 50µm on 100 mm (DIN EN ISO 1101)
- Roughness R_Z ≤ 6.3 µm (DIN EN ISO 4287)
- No steps > 10 µm

Figure 16: Heat sink surface specifications



3.3 Thermal Interface Material (TIM)

To avoid air gaps at the interface between the module and the heat sink a Thermal Interface Material (TIM) must be applied. TIM should follow the shape of the two surfaces (module and heatsink), allowing a metal-to-metal contact where it is possible, and filling the remaining gaps..

Further information about TIM can be found on website:
- Technical explanation of TIM [2]
- General guidelines on TIM application [3]

Wacker P12 (WP12) is the standard TIM used by SEMIKRON to perform qualification tests. SEMIKRON recommends a hard rubber roller or a screen print for an even distribution of the TIM.
Following table shows the recommended average thickness of the applied TIM layer.

Table 8: Recommended TIM thickness

Module types	General Specification	Maximum allowed thickness	Minimum allowed thickness
SEMITOP®1,2,3,4	40µm ± 25%	50µm	30µm

If there is a margin in the thermal dissipation in the specific application, and under customer approval, this thickness can be further moderated. Further evaluations have shown that even layers with thicknesses in the range of 50µm - 80µm do not cause any functional problem if an even distribution of the layer is achieved.
Nevertheless, deviations from the recommended specifications may affect reliability and/or technical performance of the modules so it is customer's responsibility to qualify his own TIM printing process.

The thickness of the applied grease can be verified by a measuring gauge from ZEHNTNER called "Wet Film Wheel" like the one shown in the picture:

Figure 17: Wet film wheel Zehntner Type ZWW2102

3.3.1 Pre-applied TIM

In order to simplify the module assembly, SEMITOP®Classic are also offered with pre-applied TIM. TIM is applied by SEMIKRON prior to delivery to the customer, thus eliminating this critical process step from the customer manufacturing process. Furthermore, TIM printing process is more efficient, reproducible and controllable.
Main advantages are:
- Optimized thickness of TIM layer
- High process reliability due to automated screen printing process

Figure 18: SEMITOP®Classic with Pre-Applied TIM

SEMITOP®2 SEMITOP®3 SEMITOP®4

SEMITOP®Classic modules are available with following pre-applied TIM:
- WP12 (Wacker P12)
- HPTP (High Performance Thermal Paste)

Further information about modules with pre-applied TIM (e.g. storage conditions) can be found on website:
- Technical explanation of TIM [2]
- Datasheet of modules with pre-applied TIM [1]

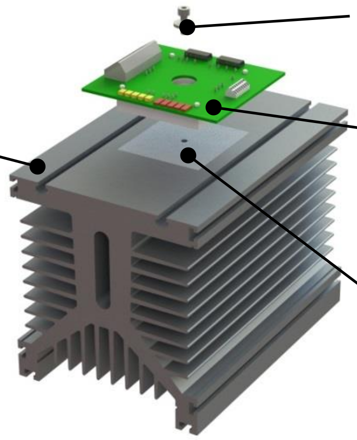
3.3.2 Add-on Service and Accessories

SEMIKRON offers additional services to customer in order to support design and industrialization phase:
- Support for stencil design (in case customer would like to apply TIM on the line via an optimized stencil process)
- Plastic cap to protect TIM from dust and contamination which may be collected on production line

3.4 Mounting Module+PCB onto heatsink

Once module is fixed into PCB (Soldered or Pressed), heatsink is properly cleaned and TIM is applied, module+PCB can be mounted onto the heatsink.

Figure 19: Mounting Module+PCB onto the heatsink



It is recommended to tighten the screws with the following mounting torque:

Table 9: Specifications for heatsink assembly

Module	Screw	Saw tooth washer (optional)	Flat washer	Mounting torque
SEMITOP®1	DIN 912-M-4x16	DIN 6798 Form A	DIN 125	1,5 Nm +0/-10%
SEMITOP®2	DIN 912-M-4x16	DIN 6798 Form A	DIN 125	2,0 Nm +0/-10%
SEMITOP®3	DIN 912-M-4x16	DIN 6798 Form A	DIN 125	2,5 Nm +0/-10%
SEMITOP®4	DIN 912-M-4x16	DIN 6798 Form A	DIN 7349	2,6 Nm +0/-5%

SEMIKRON recommends:

- a torque wrench with automatic control (see Table 10). Electric power screwdriver is recommended over a pneumatic tool. The specified screw parameters are better adjustable and especially the final torque will be reached more smoothly. A limitation to the mounting torque screw speed is recommended to allow the thermal paste to flow and distribute equally. If tightened with higher speed the ceramic may develop cracks due to the inability of the paste to flow as fast as necessary and therefore causing an uneven surface. The maximum screw speed should not exceed 250rpm if recommended Wacker P12 paste is used. A soft level out (no torque overshoot) will reduce the stress even further and is preferable
- screws and washers as shown in the above table. For different screws and/or washers, different mounting conditions might apply. In this case, SEMIKRON recommends that the mounting conditions should be thoroughly checked by the customer via Design Of Experiments to ensure high quality of the mounting process.
- tighten the screws only once. After the mounting do not re-tighten the screws to the nominal mounting torque value. Due to relaxation of the housing and flow of thermal paste, the loosening torque is lower than the mounting torque. However, the construction of the housing, the washers and the adhesion of the thermal paste still ensure sufficient thermal coupling of the module to the heat sink
- Do not exceed the mounting torque because a further increase of the maximum mounting torque will not improve the thermal contact but could damage the module

Table 10: Specification of screwdriver type			
Press type	**Torque/Angle control**	**Accurate stop control**	**Recommendation**
Manual, pneumatic	⊘	⊘	⊘
Electronic	✓	✓	✓

ESD Protection

SEMITOP®Classic modules are sensitive to electrostatic discharge. Discharge can damage or destroy IGBT/MOS structure of the gate. All SEMITOP®Classic modules are ESD protected during transport, storage and mounting process with an ESD cover. When handling and assembling the modules it is recommended that a conductive grounded wristlet is worn and a conductive grounded workplace is used. All staff should be trained suitably for correct ESD handling.

Index of figures and tables

Figures

Tables

Symbols and Terms

A detailed explanation of the terms and symbols can be found in the "Application Manual Power Semiconductors" [4].

References

[1] www.SEMIKRON.com
[2] Thermal Interface Materials (2019-09-25 - Rev-03)
[3] Thermal Paste Application (AN_18-001 / 2018-01-19 - Rev-00)
[4] A. Wintrich, U. Nicolai, W. Tursky, T. Reimann, "Application Manual Power Semiconductors", 2nd edition, ISLE Verlag 2015, ISBN 978-3-938843-83-3

IMPORTANT INFORMATION AND WARNINGS

SEMIKRON INTERNATIONAL GmbH
Sigmundstrasse 200, 90431 Nuremberg, Germany
Tel: +49 911 6559 6663, Fax: +49 911 6559 262
sales@semikron.com, www.semikron.com